(2)

Research Note 85-18

AD-A160 333

An Annotated Bibliography of the Manned Systems Measurement Literature

Joan M. Edwards, Richard F. Bloom, John F. Oates, Jr.,
Susan Sipitkowski, Paul A. Brainin,
Richard J. Eckenrode, and Peter C. Zeidler
Dunlap and Associates, East, Incorporated

ARI Field Unit at Fort Benning, Georgia
Seward Smith, Chief

Training Research Laboratory
Harold F. O'Neil, Jr., Director

U. S. Army
Research Institute for the Behavioral and Social Sciences

February 1985

Approved for public release; distribution unlimited.

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

L. NEALE COSBY
Colonel, IN
Commander

EDGAR M. JOHNSON
Technical Director

Accesion For		
NTIS CRA&I	X	
DTIC TAB	☐	
Unannounced	☐	
Justification		
By		
Distribution /		
Availability Codes		
Dist	Avail and / or Special	
A-1		

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARI Research Note 85-18	2. GOVT ACCESSION NO. AD-A160 333	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN ANNOTATED BIBLIOGRAPHY OF THE MANNED SYSTEMS MEASUREMENT LITERATURE		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER 293-6
7. AUTHOR(s) Joan M. Edwards, Richard F. Bloom, John F. Oates, Jr., Susan Sipitkowski, Paul A. Brainin, Richard J. Eckenrode and Peter C. Zeidler		8. CONTRACT OR GRANT NUMBER(s) MDA903-80-C-0345
9. PERFORMING ORGANIZATION NAME AND ADDRESS Dunlap and Associates East, Inc. One Parkland Drive Darien CT 06820		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263743A794
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria VA 22333		12. REPORT DATE February 1985
		13. NUMBER OF PAGES 524
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) --		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

--

18. SUPPLEMENTARY NOTES

Seward Smith, Contracting Officer's Representative

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Manned Systems Evaluation; Performance Measurement; Effectiveness Measurement.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A comprehensive computerized literature search was conducted on the subject of systems and measurement theory and practice. As a result of this search, 244 citations were identified as very likely relevant to the area of interest, and were abstracted for this document.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ACKNOWLEDGEMENTS

The authors depended greatly upon the assistance of many individuals during the course of this project. In particular, we wish to acknowledge the invaluable technical assistance provided by Mr. Hal C. Strasel and Ms. Dorothy L. Finley, of ARI and Drs. Marvin Grunzke and Edward Youngling of Litton/Mellonics, all at Fort Benning.

We would also like to thank the word processing department of ARI (Fort Benning) for their hard work in producing the typed copies of the abstracts.

Constant support and assistance on technical and administrative issues were generously provided by Messrs. Joseph T. Fucigna and Edward W. Bishop, the former and present Responsible Officers for this project at Dunlap and Associates, Inc.

Finally we acknowledge the help provided by the Dunlap technical assistants, namely, Cynthia Gilchrist, Susan Davies-Bloom, Karen Kolenda-Schoelch and Janet Vartuli.

SUMMARY

A comprehensive computerized literature search was conducted on the subject of systems and measurement theory and practice. As a result of this search, 244 citations were identified as very likely relevant to the area of interest, and were abstracted for this document.

TABLE OF CONTENTS

I. INTRODUCTION

This report describes one of the earliest tasks under the "Study of Effectiveness of Infantry Systems: TEA, CTEA and Human Factors in Systems Development and Fielding" (Contract No. MDA903-80-C-0345). Dunlap and Associates, Inc., is responsible for Task 3 (Systems Development and Evaluation Technology) of that contract, under subcontract (No. 05628) to the Mellonics Systems Development Division of Litton Systems, Inc. This present report is partial fulfillment of Task 3a, "Review of the Manned Systems Measurement Literature."

Published research and other literature pertinent to systems and measurement theory and practice were identified, acquired, reviewed and annotated during this task. The purpose of these activities was to obtain a clear understanding of the state-of-the-art of manned systems measurement. This would indicate the necessary direction and scope of the effort required to expand and update the Systems Taxonomy Model (STM) and the components of the Overall Conceptual Process Model (OCPM).

Task 3a was divided into two subtasks:

1. Obtain Relevant Literature

2. Review and Annotate Literature

The methods used for completing these tasks are discussed in the next sections. Appendices A and B are the bibliographies themselves, in annotated and unannotated form, respectively.

II. REVIEW OF SUBTASKS

A. Subtask 3a(1): Obtain Relevant Literature

The identification and acquisition of relevant manned systems measurement literature was built on an existing base of documentation. This base consisted of the searches conducted by ARI of the National Technical Information Service (NTIS) and Defense Documentation Center (DDC), now Defense Technical Information Center (DTIC), data bases in February 1977. The Contracting Officer's Technical Representative (COTR) provided Dunlap and Associates, Inc., with the strategy utilized in these searches and also approximately 200 documents which had been obtained in that 1977 search. Key words used in the 1977 searches were: operational test and evaluation; performance standards measurement; systems development, test and evaluation; performance measurement; systems human operators; measurement methodology; systems and methodology; measure theory; and effectiveness measurement.

Dunlap updated and extended the ARI literature file by conducting searches using the same data bases and key words to acquire new entries since the original search was performed in 1977. For the NTIS search, additional key words were selected from the candidate terms listed in Table 1. In addition to the NTIS and DTIC searches, the search was expanded to include the PASAR and COMPENDEX data bases. Complete bibliographic citations were obtained, including abstracts and printouts from the four searches.

Two of these searches (NTIS and COMPENDEX) were conducted in-house using the set of DIALOG data bases maintained by Lockheed's Palo Alto facility. The Defense Techncial Information Center conducted the DTIS search and the American Psychological Association performed the PASAR search under the direction of Dunlap staff members.

The next step was to determine the relevance of the results of the computerized search. A triage of the results was performed and abstracts were coded into one of the following three mutually exclusive categories: V for "very likely relevant," P for "possibly relevant" and L for "very likely not relevant." The triaging results for each data base are summarized in Table 2. The percentages given in the table are approximate. In the "very likely relevant" category, there is one duplication of a report and that occurs in the NTIS and DTIC lists. Since there may be duplications among the other categories as well, the actual totals may be less than the values indicated in the table.

A copy of the triage ratings was submitted to the COTR and based upon discussions with the COTR and in view of the volume of materials already available, it was decided to obtain, at the present time, only those documents classed as "very likely relevant." Approximately 50 such documents were acquired.

Table 1. Candidate Key Words for Literature Search

- System (Design, Analysis, Effectiveness, Definition, Attributes, Testing, Constraints, Performance)
- Development (Methods, Process, Models, Technology)
- System Development (Methods, Process, Models, Technology)
- Manned System Development (Methods, Process, Models, Technology)
- Mission Definition
- Measurement (Methods, Process, Models, Analysis, Techniques, Standards)
- System Measurement (Methods, Process, Models)
- Manned System Measurement (Methods, Process, Models)
- Analytic Methods
- Taxonomy (Models)
- System Taxonomy (Models)
- Evaluation (Methods, Process, Models, Technology, Criteria, Techniques)
- System Evaluation (Methods, Process, Models, Technology)
- Manned System Evaluation (Methods, Process, Models, Technology)
- Cost Benefit (Analysis, Evaluation, Methods, Measures)
- Cost Effectiveness (Analysis, Evaluation, Methods, Measures)
- Measures of Effectiveness
- Performance (Requirements, Criteria, Analysis, Measures, Assessment)
- Test (Plans, Planning, Methods, Development)
- Effectiveness (Evaluation, Testing, Measures, Criteria, Analysis, Assessment)
- Proficiency (Measures, Measurement)
- Man-Machine Systems (Evaluation, Methods, Process, Models, Technology, Assessment)
- Human Factors (Analysis, Evaluation)
- State of the Art

Table 2. Triage Results for Four Data Base Searches

Data Bases	Relevance			Total
	V	P	L	
NTIS	23	29	62	114
DTIC	19	49	32	100
PASAR	7	10	15	32
COMPENDEX	9	15	27	51
TOTAL	58	103	136	297
PERCENTAGE	20%	35%	45%	100%

B. Subtask 3a(2): Review and Annotate Literature

Following the steps described above, abstracting of the relevant material began. The format of literature annotation/abstracting conformed to the components of the overall conceptual process model. That is, an abstract was prepared for each document included in the annotated bibliography using a standard abstracting form as illustrated in Figure 1. This standard abstracting form indicates all of the conceptual process model components to which the particular document applies; the abstract itself consists primarily of separate summaries of the document's contents relevant to the indicated model components.

An annotated bibliography of the relevant literature is presented in Appendix A. The bibliography indicates all of the documents obtained as a result of the search performed in 1977 and those documents that were identified as "very likely relevant" in the new searches and obtained. A listing of documents, without abstracts, is presented in Appendix B.

APPENDIX A

ANNOTATED BIBLIOGRAPHY

AC Spark Plug Division, General Motors Corporation. Inertial guidance system 107A-2--Category II, Personnel Subsystem Test and Evaluation (PSTE) and Maintenance, Logistics, Reliability and Readiness (MLRR) test and evaluation--Objective achievement status report (AF 04 (694)-177 AFBM Exhibit 60-20A). Milwaukee, WI, 15 February 1964. (AD-829 749).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.2	This report specified the Personnel Subsystem Test and Evaluation (PSTE) objectives for the TITAN II IGS.
	2.5	Two system measures were developed: a measure of system "adequacy" and a measure of system "efficiency". The former measure subsumed the concepts of "availability" and "accuracy", while the latter measure included "expenditure per unit of output" as the primary yardstick.
	3.3	The PSTE objectives were broken down into three components that involved weapon system testing as it related to human engineering, personnel, training, and validation of technical publications: (1) Personnel Performance (2) Safety (3) Technical Data The MLRR (Maintenance, Logistics, Reliability, and Readiness) test and evaluation included the collection and data analysis items relevant to weapon system testing.
	3.4	Operationalization of this concept included the following representative items: for "maintenance", an indicator might be the determination of whether the support activities for missile and group equipment maintenance are adequate; the-

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		"logistics" concept includes spare parts consumption and compatibility requirements; "reliability" involves collection of failure data regarding all subsystems; "readiness" involves an evaluation of the interrelated effects of operations, maintenance, and reliability on the "in-commission" rate. Finally, weapon system capability is determined by the product of alert readiness reliability x launch reliability x in-flight reliability x warhead reliability.
	5.4	The main conclusion for the Personnel Subsystem section found personnel operating within tolerance limits although contributing 20% to the total downtime of the system. A morale problem was found due to the minimum level of capability required for the guidance system that underutilized personnel skills. Corrective training and reorientation were required.

Akashi, H. & Mahmood, S. Performance of human operators under various system parameters (NASA CR-6725). National Aeronautics and Space Administration, (undated)

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.1 2.2 2.3 3.1 3.2 3.3 4.3 4.4	A closed loop system, consisting of a display, control stick, an analogue computer, an operator and procedures, was used in this evaluation. The performance of operators under various system parameters was measured. Untrained operators were tested in a laboratory situation. The analogue computer compared the random input signal with operator tracking signal and computed an error signal. A performance index which is the fraction of the total time during which the error signal exceeded an arbitrarily chosen threshold was used as the measure. The objective was to measure the performance of human operators under various system parameters. A display (oscilloscope), control stick, and a controlled element (analogue computer) were used for this study. Operators were taken from 3 groups: (1) persons with both licensed flying and driving experience; (2) persons with average driving experience; (3) non-drivers. Ages: 20-40.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.3	The results show that the performance of operators can be represented in the parameter plane of time constant and gain by a hyperbolic curve, its distance from the origin showing the control ability of the operator and its general shape indicating the operator's adaptability to the variation of the two parameters.
	5.4	The effect of changing the nature of random noise, the display device and the manual control have yet to be studied.

Analytics, Inc. Measuring the performance of operational decision aids (N00014-75-C-0600, Final Rep. 1161-B). Willow Grove, PA: Analytics, Inc., April 1976. (AD-A024 795).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

1.1 The problem addressed is the development of a "methodology" for testing the acceptability of Navy operational decision aids (or systems). Resulting tests must be scientifically sound, statistically reproducible, objective and unbiased, extrapolatable to real world conditions, plausible, defensible, and evaluatable in terms of liabilities, performance and risk. The test methodology must assess the functional performance of the system and cannot be designed to match the system itself, lest the result be determined by the evaluation method.

3.1 Classes of systems were expected to be identified, such as information storage and retrieval systems. This methodological study addressed the formulation of measures of performance (MOP's) applicable to information storage and retrieval type systems. Two types of measures emerged: (1) asymptotic measure of improvement in the decision process, and (2) a time constant identifying the rate of improvement. The measures are calculable from experimental measures of reliance, irrelevance and time. The specific and tentative measures are shown to leave a common interpretation as Bayesian updated probabilities.

Anderson, R. Measures of aircraft effectiveness (AOS-TR-73-5). Kirkland AFB, NM: Office of The Assistant for Study Support (OAS), May 1973. (AD-913 306).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.5	The utility of a tactical interdiction aircraft depends upon kill potential, probability of reaching the target, probability of survival, and availability. The aircraft's worth cannot be assessed by considering these factors in isolation.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	3.2	Measures of effectiveness must be developed which quantitatively account for the interaction of these characteristic effectiveness parameters. Any valid measure of effectiveness must account for the cumulative effect of repeated sorties.
	4.1	To obtain a measure of effectiveness of an aircraft in a given scenario, it seems reasonable to keep the scenario fixed (fixed characteristic parameters) and to determine cumulative effectiveness under repeated sorties in that fixed scenario.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	5.2	The expected number of targets destroyed was expressed as a function of several probablistic variables, including kill potential, probability of reaching target and releasing weapons, probability of survival, etc. The expected number of targets destroyed was computed for the aircraft's total lifetime as well as for an arbitrary number of sorties.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	5.4	It was shown that survivability is of utmost importance since it determines the average number of sorties an aircraft can complete.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Anderson, W.H. Development of performance measures for organizational level aviation maintenance managers. NTIS Weekly Government Abstracts, October 17, 1977. (Abstract)

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.1	The assigned functions of organizational level aviation managers are the subject of this evaluation process.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	3.2	Functions are defined in terms of their objectives and "appropriate" measures are developed which reflect the effectiveness and efficiency with which these objectives are accomplished.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.3	The use of these measures is intended to provide effective feedback data for planning and controlling functions as well as for objective performance appraisal.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Andrews, L.B. Detailed Test Plan (DTP) for the Initial Operational Test and Evaluation (IOT&E) (OT-11) of the AN/IPS-59 radar set (C 0041-0-07-7). Quantico, VA: Commanding General, Marine Corps Development and Education Command, August 1977. (AD-B020 848L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.1	The radar system in question was a lightweight, long-range, three-dimensional system designed for air surveillance and ground control intercept.
	2.2	The radar was designed for a range of up to 300 nmi and 100,000 feet altitude to detect, identify, and classify targets within a defined air space to the Tactical Air Operations Center (TAOC). The purpose of the actual test was to provide data analysis on the operational effectiveness, suitability, and military utility of the Radar Set.
	3.3	The Operational Testing (OT) objectives were the verification of radar's ability to meet stated operational requirements and to estimate the radar's military utility, operational effectiveness, suitability, and any need for modifications.
	4.5	During OT, the radar was to be tested in all primary modes and in its secondary modes vis-a-vis the TAOC. Varying flight profiles will be used to assess radar detection ability and testing, itself, will be conducted under all weather conditions on a 24-hour basis.

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

Baker, J.D. Quantitative modelling of human performance in information systems. Ergonomics, 1970, 13(6), 645-664.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This paper summarizes an approach toward developing a general information system model which focuses on man and considers the computer only as a tool. The ultimate objective is to produce a simulator which will yield measures of system performance under different mixes of equipment, personnel, and procedures. In structuring the framework for this model, the assumption was made that men have five basic and critical operations to perform in an information system: screen, transform, input, assimilate, and decide. These operations, or functional areas, are interrelated along three dimensions: (1) a data flow and processing dimension; (2) a task analysis dimension for each event in the data flow sequence; and (3) a source of variation dimension, such as level of training. The model approach described has several major points of payoff. Among the immediate benefits is the potential for using the model to quantify human performance by employing system measures and the value of the model as a tested, usable tool for developing test and evaluation plans which will provide human factors data as part of the information system design verification checkout.

Basso, G. L. A methodology for measurement of vehicle parameters used in dynamic studies. Ottawa, Canada: National Aeronautical Establishment, July 1973.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.1 3.1 3.5	The system under evaluation is the highway vehicle in interactions with its occupants, the terrain and physical obstacles, during the course of ordinary operations and in the event of accidents. The parameters selected for measurement using the air-bearing device described in this study were chosen to match those in an existing mathematical simulations model, so that later comparisons could serve to validate the model. The measurement equipment, comprised of a system of air bearings, was designed to help measure vehicle parameters in a manner suitable for dynamic studies of vehicles. By providing the data needed in the mathematical model, the measurement system helps to facilitate studies involving various aspects of the vehicle occupant terrain obstacle system. The air bearing configuration of the measurement device was determined by the requirement for flexibility in the types of experiments to be conducted and by the availability of local expertise in the technology. The majority of this document describes the apparatus and its utilization.

Beau, J.F. Management of the human element in the physics of failure. Paper presented at The Third Annual Symposium on The Physics of Failure in Electronics, Chicago, IL, September 29, 1964. (AD-812 503).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.1	The human element in electronic production systems is the focus of this report.
	2.5	Reliability of human performance in factory processes is the issue of concern.
	3.1	The measurable attribute for assessing reliability and the worker's contribution is the rate of escape into the field of products with unacceptable workmanship defects.
	3.2	An audit of final products, in combination with defects found by inspection, leads to the calculation of an Estimated Outgoing Quality Level (EOQL), which is an overall performance effectiveness measure.
	3.3	The specific requirement is to maintain an overall Average Outgoing Quality Limit (AOQL). The overall AOQL is budgeted to establish contributing AOQL's for production subdivisions. These figures, in turn, are used to specify a Submitted Quality Level (SQL), for products submitted for inspection.
	3.5	The study is concerned with measuring output quality and setting acceptable limits for poor workmanship escapes and product degradation. This includes establishment of a 3-level classification scheme for defects, based on the expected impact of defects on product performance. Consistent measurement also requires the standardization of vocabulary for describing defects found during the inspection process.

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

Berson, B. L. & Crooks, W. H. Guide for obtaining and analyzing human performances data in a materiel development project (Tech Memo. 29-76). Woodland Hills, CA: Perceptronics, Inc., September 1976.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

1.3 This report contains guidelines for conducting, analyzing and reporting Human Factors Engineering (HFE) tests according to the specifications of D1-H-1334A. The requirements imposed by the specification are presented together with suggested sources of information.

4.5 A brief description of the test activities necessary to meet the requirements of D1-H-133A4 is presented below:

(1) Test administration -- Includes milestone development, manpower specification and budget preparation.

(2) Task group description -- This task requires task group identification (all operations and maintenance tasks assigned to a single personnel position); task analysis (defines in detail the behavioral requirements of the task), and performance standards identification (the identification of the specific functions that the system must program).

(3) Test planning and design -- Test planning begins with a statement of test objectives. It is felt that the more precisely the test objectives are defined the easier it is to develop the test plan. The next task is to

select and design the test equipment. The nature of this configuration depends upon the stage of system development. Test environment conditions and the need to simulate those environmental conditions likely to affect task group performances are considered. After the required environmental conditions have been specified, provisions for measurement of critical conditions must be made. For example, changing environmental conditions will necessitate more frequent measurement. It is noted that to a large extent, the validity of the HFE test results depends on selection of test personnel. Therefore, detailed guidelines are presented in the report regarding personnel selection and personnel training.

With regard to data acquisition and analysis planning, it is noted that both subjective and objective data collection techniques are required to meet the specifications of D1-H-1334A. Subjective data can be collected by such means as ratings, rankings, questionnaires and interviews.

However, it is suggested that objective measures be employed as much as possible to better provide comparison of the obtained measures and to determine the degree to which performance standards are met. In addition, errors arising from human judgment are minimized.

(4) HFE test execution -- It is recommended that a pretest be conducted and procedures are set forth for conducting such an activity.

(5) Data analyses -- Various data analysis techniques and the applicability of these techniques to the type of data collected are discussed.

(6) Summary -- A checklist of the activities associated with human factors engineering testing is included in this report.

Blanchard, R.E. & Smith, R.L. Field test of a Technique for Establishing Personnel Performance requirements. 1969 Annals of Assurance Sciences, 272-277. N.Y.: Gordon and Breach Science Publishers, July 1969.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	A technique was developed to quantify and relate human performance to the operability component of systems effectiveness. This man-machine modeling technique is titled "Technique for Establishing Personnel Performance Standards (TEPPS)," and two field tests of its application are reported here.
	4.1	A graphic mapping technique (similar to a block diagram or flow-chart) is employed to show how the system is intended to operate, how it can operate (unintended), its various required operating states, and the logic for developing a conditional probability model. Similar to the conventional reliability equation, the TEPPS mathematical model is used in derivative fashion to determine contributing probabilities of successful subsystem performance when the overall system required performance probability (reliability) is known. The model is used in integrative fashion to determine the overall probability of successful performance when the contributing subsystem probabilities are known or assumed. Due to the lack of actual human capability data, TEPPS was designed to accept relative estimates of human capability, which are obtained by subjective scaling techniques.
	6.1	The unavailability of valid human performance data seriously limits the utility of the model. Since the lack of relevant performance data is not likely to change soon, subjectively derived data continues to be given prime emphasis. In addition, there is a need to simplify, apply and test this technique so that it can be made more practical for evaluating the human component in systems.

Bloom, R.F., Pepler, R.D., Schimenz, M.V. & Lenzycki, H.P. IFV/CFV personnel selection analysis (Army Research Institute Research Note 80-41) Darien, CT: Dunlap and Assoc., Inc., July 1979.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	1.3	

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

This is the final report of an analysis to determine extranormal selection requirements for crew members of the Infantry Fighting Vehicle (IFV) and the Cavalry Fighting Vehicle (CFV).

The procedures developed to achieve the research objectives began with a clarification of objectives and assumptions. That clarification served mainly to emphasize the investigation's concern with extranormal attributes only. It was then determined from other concurrent efforts that the two vehicles (IFV and CFV) were similar enough so that a single consolidated set of five crew positions was appropriate for this analysis: Track Commander, Driver, Gunner, Firing Port Weapon Operator (IFV only) and Observer (CFV only). Next, a taxonomy of 62 personnel attributes was constructed, and a representative set of IFV/CFV mission scenarios was developed. The operator's task and subtask demands occurring during exercise of the mission scenario were analyzed to identify which of these attributes in the taxonomy were required to perform the task or subtask. Current infantry and cavalry tasks were analyzed to determine the soldier attributes required to perform the tasks. These attributes were then compared with those required to perform the IFV/CFV mission to identify those attributes that were new or unique to IFV/CFV. Six potentially extranormal attributes were identified for the Track Commander (TC) and Gunner positions, and

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		three for the Driver position, on the basis that they appear to be new to current MOS 11B or 19D personnel. Those attributes are especially needed to perform the new or unique IFV/CFV tasks, and they are not now used individually for personnel selection. Any of the attributes is considered extranormal if it must be possessed at the level of the mean or higher so that 50% or less of the personnel pool will provide the necessary level.
	4.1	Means, standard deviations, and ranges for any subset of scores were used in the analyses.

Boehm, B.W. Computer systems analysis methodology: Studies in measuring, evaluating, and simulating computer systems (R-520-NASA). Santa Monica, CA: The RAND Corporation, September 1970.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	1.1	Three modest, coordinated efforts were carried out to help in providing better techniques for the design, evaluation, and analysis of computer systems: (1) the development of design principles for languages to model and simulate computer systems, (2) the evaluation and extension of measuring and analyzing the performance of complex computer systems, and (3) the analysis of controlled experiments in man-computer problem-solving. The first effort provided a set of terms and phrases described by the author as convenient and natural while maintaining the flexibility and power of a general-purpose simulation language. The second effort was a brief review of previous studies and a description of needed further studies. The third effort reported on an experiment to test the effect of forced temporal lockout intervals on human performance in man-computer problem-solving. It concludes that the relationships involved in man-machine problem-solving are neither obvious nor simple, and further investigation is necessary.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	3.1	An appendix addresses the development of performance criteria that are discriminating and measurable. It describes a productive thought ratio (P.T.R.), based on the time spent thinking about the project in comparison to time spent thinking about programs and waiting for computer responses.

Bohdanovych, V.I., Kulyk, V.T. & Uyomov, A.I. (Development and practical application of systems analysis.) Filosofs'ka Dumka, 1973, 1, 10-16. (Arlington, VA: Joint Publications Research Service, 1973. JPRS 58935).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	In this Russian paper, there is a general discussion of the need to make broader use, in the practice, planning and management of the national economy, of novel methods, in particular systems analysis. The history of systems analysis, its essentials, and its application to the solution of problems in the concrete sciences are discussed. Presented are the general characteristics which emerge in the planning and management of the national economy in its present stage and require systems analysis application. Outlined is the perspective of the development of systems analysis into systemology, a complex science of systems. The role of Marxist-Leninist philosophy as the methodology for further improvement and development of systems analysis is also discussed.

Bond, N.A. & Rigney, J.W. Measurement of training outcomes (Tech. Rep. 66). Los Angeles, CA: University of Southern California, Behavioral Technology Laboratories, June 1970. (AD-711 302).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 1.3	The report is concerned mainly with methods of assessing the effectiveness of training programs, materials, and techniques, with special focus on Computer-Aided and Computer-Managed Instruction (CAI, CMI). Concern with "effectiveness" of training implies concern with items of information that show how well the teaching objectives are realized in the students receiving the treatment (training). The basic assessment/evaluation methodology can be outlined as follows: (1) A clear statement, in observable terms, of the expected results of the treatment, including the time span over which a specific result can be measured. (2) Development of relevant, reliable yardsticks (MOEs) which measure progress toward the stated objectives (expected results). (3) Application of the yardsticks within the time spans of the objectives. (4) Establishment of an evaluation design allowing the treatment effects to be distinguished from intervening contaminants. (5) Establishment of the kinds and sources of information required to evaluate the treatment in terms of the objectives.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(6) Specification and examination of underlying personality and situational factors which explain the identified change.
	2.6	Only relatively few indices have much practical use as criteria for evaluating learning. These include: (1) High degree of accuracy in performing the learned response. (2) Significantly shorter reaction latency than at the beginning of practice. (3) Increased rate or speed of correct response. (4) Increased amplitude of response. (5) Increased resistance to experimental extinction. (6) Increased resistance to retroactive inhibition from subsequent learning as compared to the amount occurring when learning stops short of mastery. (7) Increased positive transfer to subsequent learning in similar situations. (8) A degree of generalization to similar status events.
	3.2	General learning measurements that can be applied to practical training include the following: (1) Gain scores (difference between post-test and pre-test scores). (2) Process scores (assessment based upon application of procedures rather than overall success in problem-solving).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(3) Time to criterion (time required to complete some work or achieve some level of success). (4) Error rate. (5) Persistence measures (staying with some specific training sequence). (6) Transfer measures (generalizability of the learning to other situations). (7) Time vs. achievement measures. (8) Retention measures. The authors describe the strengths and weaknesses of these various measures, and suggest certain types of training programs for which particular measures might be most applicable.
	4.1	Evaluation designs that are considered applicable to assessment of training effectiveness include the classic Solomon four-group design; iterative adaptation to individual student progress; response surface designs; adaptive control models; decision theory models; simulation models.
	5.4	Principal conclusions are that the classic four-group design is impractical for most training evaluation; that "adaptive research for big effects" is apt to be scientifically and administratively desirable; and that current measurement of training outcomes still uses fairly simple methods.

Bovaird, R.L. & Zagor, H.I. <u>A systems approach to predicting and measuring Polaris fire control system operational availability</u> (RM 59TMP-57). Santa Barbara, CA: General Electric Company, Technical Military Planning Operation, December 1959. (AD-901 773).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

1.1 The report describes a systems approach to predicting and measuring the operational availability of a system. Operational availrability, along with the performance capability level is a major determinant of the system's operational effectiveness. A multi-moded system is operationally available whenever it is not down, i.e., whenever its performance equals or exceeds the required level.

2.1 A multi-moded system is described as a collection of functionally connected but independent subsystems. Each subsystem is a set of identical functional groups of a given type.

4.1 This viewpoint of systems and subsystems permits a simple mathematical prediction of the expected operational availability of the system at each performance level. The operational availability of i^{th} subsystem is shown to be a function of: probability that any functional group in the i^{th} subsystem is non-failed at a random point in time; number of such functional groups in the i^{th} subsystem; minimum number of non-failed functional groups required for the i^{th} subsystem to operate in the particular mode in question. The total system operational availability is the product of the subsystem availabilities.

Boycan, G.G. & Warnick, W.L. Training requirements for the armor crewman and reconnaissance specialist Advanced Individual Training programs (HumRRO-CR-D2-72-7). Alexandria, VA: Human Resources Research Organization, November 1972. (AD-759 569).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	This report summarizes the results of the initial phase of a three phase study. The study is designed to provide (a) instructional goals for each program that are stated in measurable terms and (b) corresponding performance-based Go/No Go test items suitable for evaluating trainee achievement of these goals.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The systems addressed were the armor crewman and reconnaissance specialist Advanced Individual Training programs (AIT).
	3.1	In this phase, job related tasks addressed in the AIT programs were examined and tentative proficiency levels were established.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.2	All tasks were individually reviewed and coded to reflect the estimated level of mastery required at the end of training and prior to job entry.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.5	Tasks were coded into one of four categories which represent degrees of proficiency ranging from complete qualification to basic orientation. Definitive Go/No Go performance criteria were established for those requirements considered relevant to job entry.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	5.4	Data collected during this first phase will be used as a basis for formulating performance training objectives and tests to be subsequently incorporated in new Army Subject Schedules.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentiala/Priorities 6.3 Research Planning		

Breaux, R. Training characteristics of the automated adaptive Ground Controlled Approach Radar Controller Training System (GCA-CTS) (NAVTRAEQUIPCEN-TN-52). Orlando, FL: Naval Training Device Center, July 1976.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.2	The automated adaptive controller system had, as its primary objectives, an increase in training effectiveness by application of automated performance measurement, self-paced instruction, and a type of adaptive training oriented around cognitive skills development.
	3.1	The risk or problem areas outlined in the system design included the following: (1) Performance Measurement: to evaluate trainee performance, frequency counts of errors were made in each category; error frequency counts are then combined in a linear combination and weighted to produce a single composite score. (2) Adaptive Logic: the problem here is determining the sequence of problems within the automated performance measurement system; the assumption of the arrangement of the syllabus is based on an increasingly linear difficulty of problems. (3) Adaptive Variables: the arrangement of the syllabus in terms of increasing difficulty is based on various adaptive variables such as wind factors, aircraft type, pilot response, and pilot variability. (4) Student Feedback: the trainee is given knowledge of his results at the end of each "run."

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.2	Measures were made on system output variables and on control input variables. The former referred to the simulated history of the aircraft around the glidepath and runway centerline; the latter consisted of trainee behavior measures, e.g., elapsed time between advisories. A single composite score was created by weighting a combination of these measures. The difficulty level of the next problem was then selected using this score on the adaptive logic.
	5.3 and 5.4	The laboratory feasibility model showed that the trainee must be consistent in his speaking voice before voice reference pattern data is collected. With regard to the training, the key to effective teaching was found in the order or sequence of the problems: tasks were systematically introduced in ascending order of complexity.

Brown, D. Statistical guide for CDEC experimental design (Rev. Preliminary Draft). BDM Scientific Support Laboratory, October 1976.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This document provides selected experimental descriptors which can be used to estimate sample size requirements and compare potential design schemes during the planning phase of military field tests. The data is compiled and organized under six general categories: intervisibility, detection, identification, localization/pinpoint, engagement, probability of hit/kill.
	1.2 and 3.2	Appendix B provides a listing of measures of effectiveness by the following experiment types: (1) Mounted Unit Operations. a. Mounted Unit Organization/Employment b. Antitank Weapons Fire Effect (2) Dismounted Combat Operations. a. Dismounted Unit Organization/Employment b. Small Arms Effectiveness c. Detection (3) Indirect Fire Support. a. Forward Observer and Gunner Operations

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		b. Gunnery Operations (4) Army Aircraft Operations. a. Air System-Ground Target b. Ground System-Air Target c. Air System-Air Target d. Aircraft Operations (5) Special. a. Combat Support Operations b. Night Operations c. Line of Sight/Exposure d. Two-Sided Experiments

Brown, J.D. Field evaluation of M48A5 tank product improvements. Fort Knox, KY: U.S. Armor and Engineer Board, 14 January 1977. (AD-B016 139).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

2.1 The purpose of this study was to assess the operational effectiveness of the product improved items on the M48A5 tank to include crew duties and maintenance.

The selected product improvements included a low profile commanders' cupola, externally mounted 7.62 mm machine guns and a redesigned 54-round main gun ammunition storage rack.

2.3 The tests were conducted with as much tactical realism as possible and included operation on primary, secondary, and cross-country terrain.

3.1 Reliability, availability, and maintainability data were collected on the product improved items. Personnel skills and training requirements were also identified.

4.5 The test plan utilized was the USAARENBD Test Design Plan for Field Evaluation of M48A5 Tank Product Improvements described in TRADOC Project Number 1-VC-080-M48-602, May 1975.

For each product item, detailed descriptions were presented of test procedures including objective, method, analysis, and results.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.1	There were several deviations from the test plan. These included no firing from a moving tank, the unavailability of the simulated mission firing target, and the impossibility of accurately scoring gun engagements. Conventional silhouettes were used and some of the scoring was subjective.
	5.3	It was concluded that the product improvements provided the system with increased capabilities over the present system. However, several safety and human factors engineering problems should be addressed within the current cost and time framework of the development of the system. Other corrections and improvements of a minor nature were recommended.

Buckley, E.P., Goldberg, B., Rood, R., Hamilton, H. & Champion, F. Development of a performance criterion for Enroute Air Traffic Control personnel research through air traffic control simulation: Experiment I-parallel form development (FAA-RD-75-186, Interim Rep.). Atlantic City, NJ: Federal Aviation Administration, National Aviation Facilities Experimental Center, February 1976. (AD-A023 411).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1	This report describes one of a series of experiments used in the development of a standardized performance criterion for journeyman enroute air traffic controllers. The final performance measurement system will be used in personnel research such as the evaluation of aptitude tests as to their capacity to predict suitability for entrance into training. The criterion measure being reported here will be based on the use of realistic dynamic simulation of the radar air traffic control situation. Its specific purpose is to explore one method of constructing parallel forms of a measurement system.
	2.1	This system is an Enroute Air Traffic Control system consisting of the National Aviation Facilities Experimental Center (NAFEC) dynamic air traffic control simulator and two controllers working independently.
	2.3	Two widely divergent sector structures were chosen to be examined with three traffic density levels each.
	2.4	Controllers work without assistant controllers and communicate with "pilots" over simulated radio frequencies.
	2.5	The ultimate performance requirement of the Air Traffic Control (ATC) system is the safe and expeditious movement of aircraft through the sector.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.1	The measurable attributes were as follows: Conflictions, delays, completed flights, communications, identifications, aircraft handled, physical effort of controllers.
	3.2	The attribute measures for this experiment were as follows: (1) Number of conflictions. (2) Number of delays. (3) Cumulative delay time. (4) Number of completed flights. (5) Number of air/ground contacts. (6) Cumulative air/ground communication time. (7) Number of aircraft handled. (8) Number of identifications requested. (9) Number of aircraft in sample. (10) Number of completable flights. (11) Number of conflictions/number of aircraft handled. (12) Number of conflictions/number of delays. (13) Number of delays/number of aircraft in sample. (14) Cumulative delay time/number of aircraft in sample. (15) Number of completed flights/number of completable flights. (16) Number of contacts/number of aircraft handled.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

(17) Communication time/number of contacts.

(18) Number of aircraft handled/number of aircraft in sample.

(19) Correlation hold-delay transformation.

(20) Number of identifications requested minus number of aircraft in sample.

(21) Controller heart rate.

3.5 All performance measures were recorded, and ratios computed, by the simulator computer. Heart rates were recorded continuously throughout the experiment and compared to a resting rate.

4.1 Six subjects worked the traffic control problem in each of two sectors at three traffic levels. The traffic was generated by a large-scale digital simulator and directed by simulator operators who represented pilots in the real ATC system. The computer recorded all aircraft events and printed the performance measure scores at the end of one hour.

4.2 The test parameters that were controlled were as follows:

(1) Sector 1 or 2.

(2) Traffic density of 40, 50, 60 aircraft per hour.

4.3 The test apparatus was the National Aviation Facilities Experimental Center dynamic air traffic control simulator.

4.4 Six qualified enroute air traffic controllers from the NAFEC evaluation group served as subjects.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.2	The basic data for each subject were produced in histogram form for each of the performance measures. A three-factor analysis of variance was performed involving the variables of subjects (6), sectors (2), and traffic densities (3).
	5.3	The results indicated that the hypothesis of interaction between sector and density in affecting performance was not sustained. There was little difference shown in the measures between sectors. Great difference was shown between the three levels of traffic density.
	5.4	There are wide differences among air traffic controllers in their ability to handle identical traffic. It is possible to measure these differences in a completely objective manner. The sample of subjects was small and the data points few, thus the results of this experiment are only indicative. Future experiments must consider the problem of minimal optimal traffic sample length; one hour is not enough.

Burgin, G.H. and Fogel, L.J. Air-to-air combat tactics synthesis and analysis program based on an adaptive maneuvering logic. Journal of Cybernetics, 1972, 2(4), 60-68.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	Two digital computer programs synthesizing optimal maneuvers in one-on-one air-to-air combat situations are described. The method develops intelligently interactive maneuvers without relying on human pilot experience. One program drives one of the interacting aircraft, thus replacing one of the human pilots on the NASA Langley Research Center's Differential Maneuvering Simulator, this in real time. The other program operates in a normal batch processing mode. Both programs use the same technique which maps the physical situation of the two aircraft into a quantized, abstract situation space. The outcome in this situation space is predicted for several trial maneuvers, a value is associated with the outcome of each trial maneuver, and finally, the maneuver with the highest predicted value is executed. These programs, operating with six degrees of freedom and realistic aerodynamic representation for both aircraft, provide a means for objective evaluation of weapons systems and pilot performance.

Burington, R.S. Concerning the reliability and effectiveness of weapon systems and their measurement (R-14-6). Washington, DC: Bureau of Naval Weapons, Office of Chief Mathematician, April 1961.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	In discussing the effectiveness, reliability or readiness of a weapon system, the following items must be considered: (1) General characteristics of the system. (2) Operational, tactical and strategic situation for which the system is envisioned: its missions. (3) Importance of the system relative to other systems. (4) The effectiveness of the system against various target types, under various operational situations. (5) Opportunity for using the system. (6) Comparative effectiveness with other existing or possible competitive systems. (7) Cost. (8) Suitability of system for use on ships, planes, etc. (9) Types of ships, planes, etc. on which the system must be used. (10) Ease of operation and maintenance. (11) Reliability and operability.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(12) Susceptibility to countermeasures.
		(13) Susceptibility to interference by or with other systems on the same o· neighboring vehicle.
		(14) Mobility and flexibility.
	3.1	Analysis of potential effectiveness of a typical weapon system is concerned with such factors as:
		(1) Ability to detect target.
		(2) Ability to locate and identify target.
		(3) Ability to designate target.
		(4) Ability to track target for fire control purposes.
		(5) Ability to bring the vehicle bearing the weapon into the neighborhood of the target soon enough to permit use of the weapon.
		(6) Ability to bring the weapon to bear against the target soon enough to be effective, once in range.
		(7) Ability of weapon system to place the missile within the desired damaging radius of the target.
		(8) Ability to detonate the warhead at the proper place, in the proper manner at the proper time.
		(9) Ability of warhead to inflict the quality of damage desired.
		(10) Ability to fire repeatedly with the necessary degree of rapidity.
		(11) Number of targets that may be engaged simultaneously within a given interval of time.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.2	To each of these factors one can define suitable measures of merit. In general each such factor must be taken into account in estimating or evaluating the worth of a weapon system. One of the common measues of worth of a weapon system is the probability that one burst of a missile will inflict "Kill."

Campbell, S.C., Feddern, J. & Graham, G. A-6E Systems Approach to Training: Phase I (NAVTRAEQUIPCEN-75-C-0099-1). Bethpage, NY: Grumman Aerospace Corp., February 1977. (AD-A037 468).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	This report describes the efforts and results of the application of a Systems Approach to Training (SAT).
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The system addressed was the A-6E Pilot and Bombardier (B/N) training program. The A-6E tram aircraft is a two man-subsonic, mid-wing attack aircraft. It is manned by a pilot and bombardier/navigator.
	2.2	The mission of the system is to perform high and low altitude all-weather attacks. It can provide close air support for ground forces or can conduct long or short range interdiction raids. It is capable of delivering a large selection of conventional and nuclear weapons.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	The analysis encompassed the identification of all the pilot and bombardier/navigator job performance requirements. In all, over 700 tasks were identified. Task criticality, frequency of occurrence, inherent difficulty, changes in knowledge and skills required were also identified.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.2	A Taxonomy of Training Objectives was specifically developed for this program. Criterion objectives were determined and criterion referenced tests were developed.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Chaikin, G. STINGER human factors engineering final report (Tech. Memo. 25-76). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory, July 1976 (AD-B014 866).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.3 3.1	This report summarizes design-influencing human factors engineering requirements applied to the development of the STINGER weapon system. The system, its use, and operating procedures are provided as background for the human factors engineering components of program planning, analysis, design, and test parts of the program. The following characteristics of the total system were discussed and operationalized: (1) Program Planning (2) General System Description (3) Function Allocation (4) Critical Tasks (5) Weapon System Weight and Size (6) Launch-Induced Environment (7) Launcher Controls (8) Human Engineering Handling Tests (9) System-Handling Performance (10) Training Equipment

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.2	Under program planning, the established goal involved the design and development of equipment, facilities, and procedures which would provide a work environment conducive to effective work patterns and personnel safety, minimize discomfort, distraction, etc., and downgrade human performance and/or increase error. A second part of the program planning involved the "test efforts" with an eye toward securing data-relevant selected work cycles, tests in which human participation is critical (speed, accuracy), use of personnel representative of the military population, collection of task performance data, identification of discrepancies between required and obtained tasks performance, and establishment of criteria for acceptable performance of tests. (Further sections of this document concentrate on narrow, technical aspects of the STINGER weapon system, and are not relevant to the objectives of this review.

Chaney, F.B. & Thresh, J.L. Diagnosis and correction of quality problems: A human factors approach. Paper presented at the ASQC Seminar on Product Quality Audit, Milwaukee, WI, April 19-20, 1968. (AD-855 919).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 3.2 5.4	Effective quality auditing requires consideration of human factors at each phase of the process from initial concept and engineering design through manufacturing, inspection and testing operations. The purpose of this paper is to describe human factors techniques used to obtain better understanding of basic quality problems. The first requirement for improving inspection accuracy was development of a standard procedure for measuring inspection effectiveness. Job sample performance tests were developed by selecting representative hardware items with a number of known defects. These measurements provided basic data for pinpointing problem areas and evaluating potential effectiveness of various methods for improving inspection accuracy. Research has indicated that low inspection accuracy may be due to a number of specific factors, such as: (1) Product factors. (a) Equipment complexity (b) Defect rate (2) Job (inspection) factors. (a) Procedures (b) Tools (c) Visuals

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(3) Human factors.
		(a) Selection of inspection personnel
		(b) Training of inspection personnel
		(c) Motivation of inspection personnel

Chapanis, A. Relevance of physiological and psychological criteria to man-machine systems: The present state of the art. Ergonomics, 1970, 13, 337-346. (AD-751 344).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	As shown by content analyses of symposia papers and journal articles, significant differences exist between the related disciplines of "Ergonomics" (European) and "Human Factors Engineering" (American). Ergonomics appears to be more physiologically--oriented, Human Factors more psychologically-focused. In America there has been more concern with integration of man into large machine systems. In Europe there has been more concern with the welfare of the individual worker.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	1.3	The difference in orientation, in essence, is a methodological problem. Ergonomists (and human factors engineers) are more concerned with methodological problems than are physical scientists and engineers, because precise answers about the behavior of man are hard to find in any handbook or textbook. Much work is taken up with studies in which methodology is of such great importance.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures		The methods, techniques, apparatus, and variables used by psychologists tend to be different from those used by physiologists. Trying to decide which experimental methods are appropriate to any practical problem is a very complex question.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	2.6	The value or worth of a system is normally judged by several criteria, not necessarily all compatible. Criteria vary greatly from system to system, and many criteria are specific to particular systems. Typical man machine system criteria include:
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(1) Anticipated system lifetime. (2) Appearance. (3) Comfort. (4) Convenience. (5) Ease of operation. (6) Familiarity. (7) Initial cost. (8) Maintainability. (9) Manpower requirements. (10) Operating cost. (11) Reliability. (12) Safety. (13) Training requirements.
	3.1	Common ergonomic and human factors research dependent measures used to assess system performance include: . Accuracy . Cardiovascular response . Critical flicker fusion . EEG . Energy expenditure . Muscle tension . Psychophysical thresholds . Ratings (of comfort, annoyance, etc.) . Reaction time . Respiratory responses . Spare mental capacity . Speed . Trials to learn

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.3	One of the most important methodological questions with which one has to come to grips is how can measures like these be matched to the system criteria? One needs to concentrate on finding combinations of experimental variables, and proper weights to assign to them, to arrive at an overall index of what is relevant and important.

Chasteen, C.L. IOT&E of an AWADS radar imagery recorder (MAC Project 74C-110U). Eglin AFB, FL: Military Airlift Command, Operating Location F, May 1975. (AD B003 562).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	This report addresses the evaluation of a radar imagery recorder.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The equipment evaluated was an adverse weather aerial delivery system radar imagery recorder installed in a C-130 aircraft.
	2.2	The primary purpose of the evaluation was to determine the operational effectiveness and suitability of the prototype recorder system for use in navigator ground training, radar prediction, and reconnaissance/intelligence gathering.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	Specific objectives were to determine whether the system provides imagery of such quality that radar returns are readily identifiable, whether the system can be installed in the aircraft without hindering operations, and the operational suitability of the navigator-operated controls. Additional objectives were to determine whether the system can record all range marks, leading marks, and cursors; whether the system is capable of operating at altitudes up to and including 25,000 feet above mean sea level with the aircraft pressurized and unpressurized.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	4.3	An aircraft simulator was designed and used by the engineers to exercise the prototype system. The system was installed in a field training detachment Adverse Weather Aerial Delivery System (AWADS) simulator to check compatibility with the AWADS. The C-130 AWADS equipped aircraft was used as a test bed for the prototype system.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.4	Ten navigators, three of whom were qualified weapons and tactics officers, participated in the study.
	4.5	Six missions of eleven sorties were flown under controlled test conditions; known checkpoints and offset aiming points were used by the navigators to provide independent evaluation of the system. Each sortie was flown at preselected altitudes ranging from 500 feet Above Ground Level (AGL) to 25,000 feet Mean Sea Level (MSL). Routes were preselected and enroute position coordinates were recorded on data forms along with intensity/gain used. A camera/periscope assembly recorded the radar display and auxiliary data throughout the mission. Debriefing meetings, attended by various specialists, included review and analysis of the recorded imagery; comments and recommendations were solicited from the attendee relative to his area of expertise. Questionnaires were also completed by the navigators who participated in the study.
	5.4	It was concluded that the prototype system is operationally effective and suitable for use in navigator training and radar prediction and has limited capability as a reconnaissance/intelligence gathering device. Specific recommendations for improvement of the system were made.

Chop, A. Capability measures for system effectiveness (RADC-TR-72-26, Final Tech. Rep). Sunnyvale, CA: Lockheed Missiles and Space Co., February 1972. (AD-892 863).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	System effectiveness is based on a quantitative measure of the extent to which the system is expected to meet its assigned role in a specific mission. The measure is dependent upon system parameters of availability, dependability and capability. The capability parameter measure the ability of a system to achieve specific mission objectives, given that the system is in a particular operating condition.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.2	A system's required overall capability is directly related to its set of defined mission objectives.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.5	System capability is a focal parameter in that it is the top performance parameter of a system against which all other parameters are funneled, evaluated, cross-traded and optimized. It provides the linkup of system performance with mission objectives.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.2	The most practical and realistic frame of reference for categorization of capability measures is by specific and discrete types of major missions assigned to Air Force squadrons, wings, or unit equipment. A logical initial refinement of that broad categorization is to drop down and recast the measures by force type. The final refinement is to group the forces by common force missions and stratify the resultant force missions by discrete types of major missions.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		The report presents a compendium of capability measures for each of the different types of stratified force missions. Fourteen (14) stratified missions are listed, for which a total of forty (40) capability measures are defined.
	5.2	Because overall performance response of the system with time will inherently fluctuate, the capability measures require use of statistical methods based on probability distribution laws or use of empirical methods for their evaluation.

Churchman, C.W. Systems analysis and organization theory: A critique (Internal Working Paper No. 3). Berkeley, CA: University of California, Space Sciences Laboratory, June 1971.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This paper describes, in five basic points, the normative technique approach to the study of organizations. (1) Organizations are goal oriented and the goal structure can be translated into a "measure of performance" such as profitability, benefit minus cost, social utility, etc. (2) Organizations can be subdivided into components which themselves have sub-goals. However, these sub-goals must necessarily be in partial conflict. (3) In order to be feasible, it is necessary to set boundaries of the system so that analysis can proceed in an orderly fashion. The boundaries are set by identifying a decision maker. (4) The systems analyst's task is to identify one or more important problems of the decision maker and to formulate the problems so that they can be expressed in terms of a model. The model must be rich enough to lay out the alternatives available to the decision maker and to enable the systems analyst to estimate optional solutions. (5) The systems analyst should have an active role in implementing his "solutions."

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.1	A system is defined as that which a decision maker can control and change.
	2.3	The environment of a system is the set of things which the decision maker cannot control but which nevertheless affect the performance of the system.

6 W

City of Reading. Systems analysis completion report, Vol. 2: Systems analysis methodology (USAC-RPAO-005). Reading. PA: City of Reading, September 1971. (PB-208 500-2).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 2.5	This volume of the study describes the system methodology employed by the City of Reading, Pennsylvania for urban information systems. The objectives of the system are: (1) A system design that is transferable to other Municipalities. (2) Production of fact and methodology for rationalizing the information flow of the Municipality. (3) Definition of horizontal loops. (4) Developing a regional environment for sharing system operation. (5) Laying groundwork for improvement. (6) Consideration of future linking with the state-wide information system. (7) Utilization of other on-going Federal projects. (8) Taking advantage of existing information system technology. (9) Viewing the city as a "natural information system" with inputs, processes, and outputs.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(10) Scheduling to utilize project funds appropriately.
	3.5	The system analysis process was divided into eight phases: (1) Organization of project. (2) Research - literature, field trip/technology, studies, workshops. (3) Survey and data collection. (4) Synthesis and coarse analysis. (5) Data conversion. (6) Detailed analysis. (7) Report preparation. (8) Reanalysis.
	4.1	The methods associated with the above phases used the following: (1) Technology studies. (2) Policy guidelines, application inventories. (3) Annual reports from departments, summaries of codes and ordnances. (4) Flow charts of current systems. (5) Reading analysis technique/event matrices, decision flow charts. (6) Statistical tables.

Clovis, E.R. & Muller, T.H. Development of procedures for evaluating unit performance (TRA-75/009, Final Rep. Vol. 1). Monterey, CA: Litton Mellonics Defense Sciences Laboratories, March 1975.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	A Unit Performance Assessment Model (UPAM) was designed to evaluate simulated 2-sided actions.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The systems addressed are rifle squads, rifle platoons, and tank platoons.
	2.2	The missions are selected kinds of engagements (e.g., attacking, defending) with the enemy for each system.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.5	The ultimate requirement is to destroy the enemy's ability to wage war.
	3.1	The effectiveness measures include capturing, immobilizing or defending an objective in a given time and at a given cost. In the study example, 20 cost and achievement measures were selected by military experts who rated a larger number of objective, quantitative, face-valid measures.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.4	Performance criteria are established by having experts rate the significance of the various cost and achievement measures, calculating and applying weights to those measures, and combining the set into a single performance criterion. An appendix provides a step by step procedure for setting these criteria.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	3.5	Measurements are made through the use of simulated engagements and expert estimates.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.1	Weighted variables are developed by having experts rank each measure, and performing a statistical regression on the set of rankings. Another multiple regression procedure is used to combine these measures into a single index of performance for comparison with pre-set criteria. An appendix (K) provides a step by step procedure for calculating actual achievement and cost scores, and computing the performance index.
	6.1	To deal with the limitations of this study, a cross validation effort is recommended to test the efficiency of the regression equations used in calculating the index of performance. Also situational exercises should be used to validate the UPAM, and to provide practical application guidelines.

Coburn, R. Human engineering guide to ship system development (NELC Tech. Doc. 278). San Diego, CA: Naval Electronics Laboratory Center, October 1973. (AD-772 535).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This document was prepared to assist Navy and contractor personnel in planning, managing and carrying out human engineering programs to support development of ship systems. Very little attention is devoted to issues concerning measurement of system performance or effectiveness. Human engineering services and end products relating to assessment of system performance include: (1) Man-Machine Concept Analyses -- Prediction of man-related aspects of system performance for candidate or selected system configurations. (2) Man-Machine System Design -- Establishment of performance specifications which set bounds on man-machine system performance and define what the system must do in operational terms.

Cogan, E.A. If it exists, it can be measured - but how? In E.A. Cogan & J.D. Lyons, <u>Frameworks for measurement and quality control</u> (HumRRO-PP-16-72). Papers presented at New York University First National Annual Training in Business and Industry Conference, New York City, March 1972. (AD-748 081).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	1.1	

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

In selecting or devising a measurement, it is essential to decide or determine the purpose of the measurement. In industry the purpose translates to decisions that management or personnel people must make.

The second element in defining measurement concerns what is to be measured. In job performance evaluation there are several categories of tests available, each measuring different things:

(1) Natural observation.

(2) Job sample tests.

(3) Analytic tests.

(4) Indirect tests.

(5) Rating scales.

Measurement effectiveness or validity is best described by what one should consider in dealing with it. These considerations are in the form of the following questions:

(1) Accuracy - What are the tolerances of the emerging numbers?

(2) Stability - If one retested later, how similar would the measurement numbers be to the first set?

(3) Pay-off - How much better are the decisions reached using measurement than those reached without such information?

Companion, M. A. and Corso, G. M. Task taxonomy: Two ignored issues. In A. S. Neal & R. F. Palasek (Eds.), Proceedings of the Human Factors Society 21st Annual Meeting. San Francisco, October 17-20, 1977.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1 1.2	One of the problems encountered in the definition of a task can be linked to the problems associated with the system level to which the taxonomy is being applied. Another problem frequently encountered in defining a task is deciding who should define the task, the investigator or the operator: what the scientist says a person is doing may or may not conform to what the person thinks he is doing. Two issues often ignored when developing a task taxonomy are (1) a set of criteria, i.e., rules on which a judgment can be based for the evaluation of how well a task taxonomy accomplishes the goals underlying its development and (2) the relation between taxonomic structure and empirical data, i.e., laboratory and field data. An effective task taxonomy should include the following criteria: (1) The taxonomy must simplify the description of tasks in the system because the goal of any taxonomic scheme is to make the subject matter more manageable. (2) The taxonomy should be generalizable. If the taxonomy is system specific, the effort necessary to develop it might outweigh the benefit derived.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Also, generalizability is congruent with the necessary assumption that activities have some common basis.
		(3) The taxonomy must be compatible with the terms used by others. Unless the taxonomy is in a form that is meaningful to those who will use it, its application will be inefficient and often ignored.
		(4) The taxonomy must be complete and internally consistent, i.e., it must deal with all aspects of human performance in the system without logical error.
		(5) The taxonomy must be compatible with the theory or system to which it will be applied.
		(6) The taxonomy should help to predict operator performance. This is necessary to evaluate and compare performance between operators on different as well as identical tasks.
		(7) The taxonomy must have some utility, either practical or theoretical.
		(8) The taxonomy must be cost effective. It is possible that in many situations the time and money required to develop and implement a task taxonomy may add to the overall cost of the system and provide little increase in operating efficiency.
		(9) The taxonomy must provide a framework around which all relevant data can be integrated. Without this the taxonomy is merely a verbal device with no ties to reality and, therefore, no applicability.

Companion, M. & Teichner, W. H. <u>Application of task theory to task analysis: Evaluation of validity and reliability using simple tasks</u> (AFOSR-TR-77-1008). Las Cruces, NM: New Mexico State University, Human Performance Laboratory, January 1977. (AD-A043 243).

Topics Relevant to System Development and Evaluation Technology

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

Topic No.	ABSTRACT
1.3	The purpose of this study was to determine whether inexperienced people can be trained to apply Teichner's Theoretical Task Concepts.
2.1	This research was intended to provide a first evaluation of the reliability and validity of a task analysis performed with respect to Teichner's Theoretical Task Taxonomy and instructional procedures for training individuals to perform the analysis.
4.5	Problems performed on desk and pocket calculators were developed so as to represent theoretical tasks. Ten subjects were instructed in the theoretical concepts, and were then provided a partial operational analysis of the task problem. They were then required to complete the operational task analysis and to transform it into a theoretical task analysis.
5.2	Using the built-in operational and theoretical steps as references, the validity of the subject's procedures was evaluated in terms of how closely the analysis agreed with the references.
5.3	It appears that, with very little training, people can comprehend the concepts and be at least as proficient in the theoretical analysis as they are at describing actual operations. Considering that, and the general level of performance, it is concluded that the practicality of the

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		approach is supported, i.e., operational task descriptions or task analysis, can be translated correctly into the tasks of the theory by minimally trained observers.
	6.2	It is suggested that this approach should be extended to the evaluation of more complex tasks.

Connelly, E.M., Bourne, F.J., Loental, D.G. & Knoop, P.A. Computer-aided techniques for providing operator performance measures (AFHRL-TR-74-87). McLean, VA: Quest Research Corp., December 1974. (AD-A014 330).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The problem was to develop and implement standardized techniques for deriving and validating measures of operator performance. Traditional techniques involve hand-selecting measures which appear to have content validity, then testing the measures against other validation criteria using operator performance data. This usually results in a resource-consuming iterative research process that is often unsuccessful, because: (1) It is never known at the onset whether or not the most useful measures have been overlooked. (2) The number and potential validity of measures investigated are limited by and vary with the researcher's ingenuity and the time available for the study. (3) The research process and all associated manual effort must be repeated for each new measurement task.
	1.3	The approach was to develop and implement computer-aided techniques for deriving and validating operator performance measures. A "universal" set of potential measures was defined which possesses characteristics encompassing many traditionally selected measures. The set also inherently contains a myriad of other measures whose characteristics render them reasonable candidates. Vectors were then identified which constitute generators for the set of measures (i.e., the vectors span the defined measure space). Computational

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		algorithms were developed which generate and operate on the constituent vectors using multiple regression techniques. Several empirical validation methods were developed for testing candidate measures thereby generated. All techniques were implemented in a computer-aided measurement processor which: (1) accepts sample performance data and various user inputs, and (2) generates and tests candidate measures, computes statistics for assessing their validity likelihood, and prints results for user analysis.
	2.1	The sample system used for measurement was a T-37B aircraft in flight maneuvers.
	2.2	Five specific flight maneuvers were flown: (1) Cloverleaf. (2) Split S. (3) Lazy 8. (4) Normal Landing. (5) Barrel Roll.
	3.1	Measurable attributes for the flight maneuver sample were pitch, roll, heading, maneuver sector, airspeed.
	3.2	The measures were in degrees for pitch, roll and heading.
	4.1	Regression analysis was used to generate reference functions which are representative of excellent performance.
	4.3	The test apparatus consisted of an instrumented T-37B aircraft.
	4.4	Test subjects were instructor pilots who purposely demonstrated both good and bad maneuver performances.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.2	The developed measurement processor was successfully implemented on a Sigma 5 computer. Demonstrations of the operation of the software were performed using a limited amount of pilot performance data recorded on a T-37B aircraft. The processor performed necessary data smoothing, automatically segmented the flight maneuvers for measurement, and developed criterion functions from the skilled operator data provided. Actual generation and validation of measures was not demonstrable due to nonavailability of originally anticipated data. However, correct software performance of all parts of the processor was verified.
	5.4	The theoretical concepts and computational techniques underlying the developed measurement processor are unique and have great potential for operator performance measurement research. The applied concept of developing a set of vectors which span a conceived measure space and operating on it with regression techniques to generate candidate measures is itself suggestive of a new and extremely powerful measurement tool. The processor operation can be largely independent of user intervention; however, it is also capable of accepting user inputs reflecting his knowledge about specific measurement problems. It represents a truly interactive research system wherein user tasks as distinguished from processor tasks are logically defined, and the outcomes of each are integrated.
		Evaluation of the adequacy of the spanned measure set, the generating vectors, and the computational mechanics for generating and testing measures could not be performed as originally planned due to non-technical problems which prevented the collection of required data. This was extremely detrimental to the study because: (1) many of the techniques could not even receive preliminary test prior to their

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		incorporation in the processor, and (2) the contributions made by this study to the general technology can only be suggested instead of exemplified.
	6.1	Follow-up research should include derivation of the basis of the defined measure set using the implemented processor as an aid to empirical studies. This is, in essence, the real crux of the operator performance measurement problem.

Connelly, E.M., Bourne, F.J., Loental, D.G., Migliaccio, J.S., Burchick, D.A. & Knoop, P.A. Candidate T-3̄ pilot performance measures for five contact maneuvers (AFHRL-TR-74-88). McLean, VA: Quest Research Corp., December 1974. (AD-A014 331).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.1 2.2 3.1 3.2 4.1	The purpose of this study was to develop candidate T-37 pilot performance measures, for ultimate use in an advanced simulator. Five undergraduate pilot training contact maneuvers were selected for this development: lazy 8, barrel roll, split S, cloverleaf and landing. The first step of the approach was to analyze each maneuver, using techniques from function and task analyses, in order to identify candidate measures. Several algorithmic measures were defined which, collectively, support performance assessment over all maneuver segments. Content validity was then assured, and the user specified measures were then computed using specially developed software. Empirical testing was to be conducted next to establish criterion-related validity. However, non-technical problems prevented the data collection phase from being completed. Specific measurement formula combines the various measure types such as: continuous difference error measures (used to identify the deviation from a trajectory), threshold error measures (used to identify violation of a threshold), differential difference error measures (used for time dependent

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		changes during a maneuver), discrete task error measures (used to identify the accomplishment of a discrete event), sample error measures (used in relation to a series of measures during a specific maneuver), and miscellaneous error measures.
	4.3	Computer programs were developed to: (1) Smooth, print out, and plot data recorded on-board a T-37B aircraft. (2) Automatically detect task segment boundaries. (3) Compute criterion functions from skilled performer's data. (4) Compute measures specified at run-time by the user. (5) Perform and print results of several empirical validation tests of the candidate measures for subsequent researcher analysis.

Connelly, E.M., Schuler, A.R. & Knoop, P.A. Study of adaptive mathematical models for deriving automated pilot performance measurement techniques (AFHRL-TR-69-7, Vol. 1: Model Development). Falls Church, VA: Melpar, October 1969. (AD-704 597).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

1.3 Present methods of (trainee performance) measurement consist almost exclusively of ratings or judgments made by skilled pilot instructors/examiners. Automatic performance measurement requires measures and criteria in precise, quantitative terms in lieu of the more qualitative terms familiar to human evaluators.

The approach used in this study is quite different (from most performance measurement research). Instead of first deriving measures and criteria explicity and molding them into an evaluation system, the authors try first to derive a reliable performance evaluation system and then analyze the system to determine performance measures and criteria required for valid and reliable performance measurement.

The evaluation system is derived by developing and using adaptive mathematical and computer models operating on representative performance data corresponding to known skill levels. The models automatically adjust themselves and their methods of data analysis until capable of independently evaluating performance. Development of this system of adaptive models is the subject of this report.

2.3 Automated performance evaluation is basic to the concept of adaptive training. The problem is to develop valid and reliable pilot performance measures and criteria for use in automatically and objectively evaluating trainee performance (on a flight simulator).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.4	The characteristics of the adaptive modeling problem are as follows: (1) The requirement is to simulate/automate the results or effect the trainee performance assessment process, not necessarily to faithfully simulate the way in which a human would execute the process. (2) The performance assessment process, as performed by a human, is not sufficiently well defined or understood to allow its direct implementation on a computer. (3) Information does exist about the data required by a human in order for <u>him</u> to perform the process. (4) Some skilled humans perform the process very well.
	2.5	The approach described in the report involves development of an adaptively - programmed computer model which performs the following functions iteratively: (1) The program examines actual data, consisting of pilot performance data on some flight maneuver or task; many sets of representative data are needed. (2) The program hypothesizes/approximates the required "process-effect," i.e., a score or rating for the pilot whose data has just been examined; this requires a method of predicting a score from actual flight data. The study developed three computational methods for doing this, each of which attempts to predict score or a portion thereof in a unique way.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

(3) The program compares its own derived score with the "true" pilot score or rating that had been produced for the set of data by skilled human judgment.

(4) As necessary, the program adapts itself and its methods of data analysis to improve its previous approximation.

(5) As long as the program's derived ratings do not correlate sufficiently closely with the experts' ratings, the program repeats the preceding steps with a new set of data and continues to adapt itself. But, once a sufficiently close correlation is achieved, the program shifts to a "testing" mode, wherein it ceases adaptation and produces scores for new sets of data for purposes of evaluation.

3.2 The three computational methods used by the program to produce pilot scores/ratings are:

(1) The state transfer technique.

(2) The relative technique.

(3) Absolute techniques.

State transfer technique is based on the assumption that performance skill may be partly predictable by examining trends in the performance data. Relative technique assumes that performance skill may be partly predictable by examining relationships among separate variables in the performance data. Absolute technique assumes performance skill may be partly predictable by examining specific characteristics of performance as compared with some absolute reference-performance.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.1	The results produced by each of the computational methods consist of components of the performance evaluation. These components are routed through an "adaptive-mix," program which computes a single composite performance score.
	5.4	A preliminary demonstration and evaluation of this adaptive modeling system produced encouraging results.

Connolly, E. M. & Sloan, N. A. Manned system design using operator measures and criteria. In A. S. Neal & R. F. Palasek (Eds.), Proceedings of the Human Factors Society 21st Annual Meeting. San Francisco, October 17-20, 1977.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 3.4 4.3 4.5	The designer of a man-machine system typically performs his design task with knowledge of system objectives, human factors principles, and display and control requirements. However, it is the human operator who adapts his control rule (his input/output control characteristics) so that the overall system responses satisfied (to the degree possible) his performance criteria. The performance that is actually achieved will be obtained in cooperation with a system that has a good system design - and in spite of a system having a poor design. The above argument suggests that the designer should have available as a design tool a means for estimating the operator's performance criteria and his control actions. The designer would like to know which design features support performance and which features degrade performance. The distance between the intial and final positions is approximately 30 miles and the time allotted for the transit is 90 minutes. The equipment used in the present investigation included a surface ship bridge console system and a CRT. In this study, subjects acting as Officers of the Deck (OOD) controlled a simulated ship in a simulated environment. Their task was to divert a ship transit from the initial point to the terminal point within a pre-specified time interval while avoiding simulated contacts along the way.

Connelly, E.M., Zeskind, R.M., and Chubb, G.P. Development of a Continuous Performance Measure for manual control (AMRL-TR-76-24). Vienna, VA: Omnemii, Inc., April 1977. (AD-A041 676).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.3 2.2 3.1	Past performance measurement of manual control systems has used a single summary measure to indicate performance of the total control problem. While summary measures give the total picture, they do not indicate problems that arise during the control problems. If performance is monitored continuously throughout the control problem, each control action, discrete or continuous, can be individually evaluated. The Continuous Performance Measure (CPM) could be used to increase the efficiency of experiments, training, and design of manual control systems. This report documented research that deals with development of CPM for flight control systems. The desired CPM will provide the correct motion indication of the aircraft at each point of the mission segment, thus providing a flight standard against which actual flight performance can be compared. Moreover, motion errors can be evaluated in terms of their significance with respect to the summary performance measure in question. Optimal control theory can determine each aircraft state in the mission segment and the optimal control and solution trajectories. The term "optimal solution trajectories" is equivalent to the aircraft motion trajectories that minimize the performance measure selected for that particular mission segment. The term "aircraft state" comprises those state

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		variables that describe the values for all aircraft variables involving position and rotation, including velocity.
	3.2	Several model components were constructed in order to determine what is "optimal": (1) A representation of the current task objectives and weights to determine their importance (2) A system representation of what is to be controlled, and (3) A representation of limiting or constraining factors on the system and its controls.
	3.3	A mission can be segmented so that flight variables may be specified for each segment. The total mission can be regarded as a series of segments where the end-flight conditions of one segment are the beginning conditions for the following segment. A Segmented Mission Model can thus be constructed if mission segment specifications are converted to a summary measure, including flight constraints.
	3.4	In order to convert mission specifications into a summary measure, a cost index function, or "penalty function," was constructed which identifies: (1) Deviation from the desired end state, and (2) Variable rates of change, control actions, and deviations from reference trajectories occurring along the solution path.
	4.2	The particular mission, in fact, identified the parameter of an aircraft operating in a Close Air Support Night Attack mode.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.4	This look into CPM showed that summary measures developed from mission segment specifications can be converted into performance measures, this was done by using optimal control theory to either linearize the aircraft equations, or solving the optimal control for the non-linear aircraft equations.

Connelly, M.N. & Willis, J.E. The development of a Human Effectiveness Function Allocation Methodology (HEFAM) (Research Memo. SRM 70-11). San Diego, CA: Navy Personnel and Training Research Laboratory, October 1969. (AD-699 173).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This report describes an effort to develop a workable cost/effectiveness methodology for man/machine function allocation. The project consisted primarily of a literature review and interviews with numerous technical personnel working in the areas of human factors and personnel research. The Human Effectiveness Function Allocation Methodology (HEFAM) was conceived as an automated data storage and processing system to be used many times during the development cycle of new weapon and support systems. The research on HEFAM was directed toward three major areas of system development: (1) Initial Data Collection. (a) Development of data source. (b) Development of data collection techniques. (2) Effectiveness Quantification. (a) Development of conceptual basis for human effectiveness quantification. (b) Development of formulae for human effectiveness quantification. (c) Development of preliminary methodology for human effectiveness prediction.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

(3) Overall Conceptualization of the HEFAM System.

(a) Data bank system.

(b) HEFAM - user interface.

(c) Relationships between th HEFAM and other data banks.

5.3 The findings of the study are as follows:

(1) There has been much effort devoted to the problem of improving human reliability and collecting human reliability data, however, there has been very little conceptualization of the overall problem of quantifying human effectiveness, especially in the area of human effectiveness prediction.

(2) There is a lack of development of the state-of-the-art of quantifying human performance effectiveness.

(3) Mathematical models for HEFAM were determined, computer storage capacity estimated and data collection methods proposed.

(4) The type of data required and the manner in which it is to be stored were stated.

5.4 The study's conclusions are as follows:

(1) Much more work effort and time will be needed to develop the HEFAM system.

(2) The HEFAM system will consist of a methodology, computational formulae, and an automated data processing system.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(3) More sources of data are needed in order to provide a large enough sample of human performance to form a data base for effectiveness predictions. (4) Simpler methods of data collection than the Operational Sequence Diagram (OSD) method are needed in order to collect human performance data in a timely manner. (5) Computational and predictive formulae for HEFAM must be developed further in order to be used for actual computation or prediction. The following recommendations are made: (1) It is recommended that the HEFAM system be developed as rapidly as possible. This will require more effort than is currently being expended. (2) The future development of HEFAM should include: the further development of the conceptual bases of human effectiveness quantification; the further development of the HEFAM data processing system; the collection and utilization of human performance data; the development of better data collection methods; the further development and testing of computational and prediction formulae; and the development of the HEFAM prediction methodology.

Cunningham, J.B. A systems-resource approach for evaluating organizational effectiveness. Human Relations, 1978, 31(7), 631-656.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.2 2.1	The basic systems-model, which is applied by the author to evaluate organizational effectiveness, deals primarily with sub-system interrelationships. Basic to the systems model is an analysis of environmental inputs, methods by which the inputs are transformed (throughputs), and the end-products of this transformation (outputs). Characteristics of the systems-model are physical and chemical laws that are applicable to social organizations as follows: (1) Every system uses energy in a cyclical way: the environmental product or output becomes the energy source for the subsequent activity cycle. (2) Systems are separated from their environments by boundaries; since events are structured in a systematic way in an organization, the boundaries of the system are between events. (3) Equifinality in open systems: a final or specific end state can be reached by a diversity of inputs and varying environmental and internal activities. (4) Entropy: in nature, all organized systems "wind down" or move toward disorganization and/or death - this is the second law of thermodynamics; in open systems, however, negative entropy allows the system to

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		temporarily circumvent entropy by importing more environmental energy than it expends.
		(5) Equilibrium, or dynamic homeostasis: systems adapt to change and attempt to maintain a balance in their status quo; the system will also attempt to acquire a margin of safety in inputs above and beyond what it needs for mere survival.
		(6) Feedback: an information input into the system resulting from previous outputs and their effect on the system's environment.
	2.2	The primary goal of the application of the systems model was to apply it to real-world modeling of organizational effectiveness: specifically, seven local organizations (city and county governments) in southern California were evaluated.
		The effectiveness of these organizations was studied in terms of several factors:
		(1) The organization's ability to respond to its external environment.
		(2) The organization's ability to utilize resources in producing outputs and maintenance/restoration of the system.
		(3) The organization's ability to bargain and optimize its use of resources in an environment with multiple decision-makers, each with different goals.
	3.3	With regard to the first factor (responding to the external environment), four different computer simulation problems were designed - - an airplane crash, an earthquake, a flood, and ordinary day-to-day problems - - which provided a means to assess the adequacy of various organizational resources for coping with

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		these disasters of various magnitudes (including variations in population density, residential structures, and knowledge-levels).
		The specific requirement of the first factor evaluation was to measure the organization's ability to achieve the highest resource allocation for various levels of damage.
		The organization's response to its internal environment - - its efficiency and bargaining power were measured in experimental simulations of each of the seven local government organizations.
		In terms of the third factor, a specific allocation of resources was needed for a given organizational resolution of a problem; the decision to allocate X was made on the basis of a probable payoff Y. Since a decision-maker should logically allocate resources to problems of the highest payoff first, each problem was measured in terms of its demand for X amount of resources.
	3.4	The actual measurement of resource availability for each environmental possibility was computed by dividing the total cost of damage by each subsystem's reserve of resources.
		This factor was measured by the following: each problem is assessed in terms of time, location, cost, and amount of information given to the decision-makers. Each of three organizational resources - vehicles, equipment, and personnel - were then given a value or a cost as an indication of its value to the organization. The resource value needed for the resolution of a given problem could then be calculated.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

The value of resources theoretically necessary to respond to problem j is:

$$sop_j = \sum_k (p_{jk} * rr_k)$$

P_{jk} is the number of resources of type k which are the standard operational response to problem j.

rr_k is the value of resource k.

SOP is the Standard Operational Response.

4.1 The data for the above were collected through:

(1) Use of a panel of experts to predict problems and events occurring with an organization's external environment.

(2) Prediction of possible environments by computer simulations.

(3) Accounting of resource availability for each local governmental department.

(4) Use of a gaming simulation experiment measuring the decision-maker's efficiency and bargaining capability.

5.2 The decision-maker's ability to correctly interpret the external environment was calculated through the use of F ratios indicating the degree of difference among the resource ratios (resource available/possible damage levels) of the various organizational subsystems. These analytic techniques were also repeated for factors 2 and 3 (organizational efficiency and bargaining capability).

5.3 Private organizations were found to respond at a much higher level than the governmental organizations studied; this,

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		however, does not necessarily indicate greater efficiency: private organizations over-responded as a public relations gambit, not just in response to the "problem". There was also greater variation among private organization efficiencies than there were in the public sector.

Cunningham, R.P., Sheldon, M.S. & Zagorski, H.J. Project NORM: Pilot study report (TM-2232/000/00). Santa Monica, CA: System Development Corp., February 1965. (AD-458 341).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.2	Historically, there has been much controversy concerning the measures used to assess performance, some of which purport to evaluate functional units of the system, while others deal with subsystems and still others attempt to assess the behavior of the total system. Little is known about the relationship among the various measurements or their relevance as criteria for making adequate judgments regarding training operations. Frequently, it has been asserted that single performance measures are inadequate for making overall evaluations of system effectiveness, presumably because multiple factors are involved in the determination of mission success or failure. Combining measures into overall indices has, so far, not seemed to help much, probably because the relationship between them is not clearly understood. Thus, lumping them together does not necessarily improve the quality of system evaluation.
	2.2	Project NORM (Normative Operations Reporting Method) was a pilot study for a subsequent comprehensive research effort aimed at obtaining a better understanding of air defense mission evaluation and analysis.
	3.1	A mission problem containing 37 fakers was tested. A computer printout was obtained and data relevant to 41 situational, subsystem and system performance variables were extracted. Those variables actually considered in the study were:

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(1) Detection latency. (2) Total track off time. (3) Commitment latency. (4) Distance interceptor - faker at first pairing. (5) Faker target life. (6) Faker distance travelled. (7) Faker distance to nearest ground target.
	4.1	Statistical treatment of the data was made with the aim of demonstrating how prior knowledge of the mission situation can be used to predict expected performance for the purpose of gauging crew progress.
	5.4	This pilot study clearly demonstrated the feasibility of addressing the criterion development problem in a quantitative and scientific fashion.

Defense Science Board. Report of task force on test and evaluation. Washington, DC: Office of the Director of Defense Research and Engineering, April 1974.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	This report provides guidance on test and evaluation (T&E) at two distinct levels. At the most general level, this report discusses a number of issues which are appropriate for all weapon system acquisition programs. In addition, a general checklist of items is presented which is organized for a rapid overall review of T&E aspects, generally applicable to all systems development and deployment. A sample of the recommendations is included in this abstract.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.3	Demonstration and acceptance tests, as well as tests intended to evaluate performance under operational conditions, should always be conducted under conditions as close to those anticipated in practice as possible. On the other hand, test conditions during development should be determined by the primary objectives of that test, rather than by more general considerations of realism, etc. Whenever a non-tactical, non-operational configuration is dictated by test requirements, the results of the tests should not be challenged by the fact that that configuration was not tactical or operational.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures		
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	2.6	By the end of the systems definition phase, it should be made certain that test criteria are established so that there is no question as to what constitutes a test and what performance is to be obtained. A relationship between the identified performance parameters and the test results should be established prior to the conduct of the test. Further, the set of objectives for each of the tests should be clearly related to the program objective.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Ddevelopment and Evaluation Technology	Topic No.	ABSTRACT
		Each performance characteristics specified should be measurable through bench and laboratory or proving ground testing. The test design and the number of tests should be adequate to provide results with confidence limits compatible with the statements of desired characteristics. Testing in advanced development should be planned to explore performance characteristics over a broad range of environments so as to provide insight into system performance over the expected operational range and not just at a single point.
	3.5	A good test program makes provisions for feedback of test results, during conduct of the testing, so as to influence: (1) Course of the T&E program (test director, program manager). (2) Tradeoff decisions between modifying the system design and relaxing the operational requirements (program manager, operating/supporting commands, HQ). (3) Missions, employment doctrine, tactics and constraints, tactical organization, etc. (operating command, operational units). (4) Parts provisioning. When developing, testing and evaluating the various subsystems (and systems) of non-expendable weapon systems, each component of the systems should be numbered and a performance history kept which allows an analysis of that component's performance with respect to reliability, maintainability, availability, etc. An analysis of failure modes should be made in advance so as to relate test results to the operational capability of the system when in a degraded condition.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Techniques and system range instrumentation should be developed tc provide the type of data in the proper form to allow econimic, analytical, and mechanical simulation for alternate scenarios and combinations.
	4.3	If there are government furnished equipment (GFE) and other government commitments in the proposed contract, be concerned about the following: (1) Can the gear with required performance be available when required? (2) Can government supported facilities provide the assistance required at the time needed? If not, is it reasonable to construct the required facilities (test range, instrumentation, building, etc.)? If not, what alternatives are available?
		Whenever possible the initial phase of operational test and evaluation (IOT&E) of a weapon system should be planned to include other systems which must have a technical interface with the new system. Thus, missiles should be tested on most of the platforms for which they are programmed. Interfaces between system should receive special attention.
		The manner in which T&E instrumentation is used can be extremely important in determining the realism possible in the OT&E phases. The instrumentation package should be fixed early in the design phase of the development; it is difficult and costly to change thereafter. For this reason, instrumentation requirements must be specified early in the program and operational factors must be incorporated early.
		The applicability of existing test ranges and the adequacy of facilities and instrumentation should be verified.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.4	Testers, evaluators and operators have quite different backgrounds and needs which affect the T&E of the weapon system. Each has a different approach which has merit and utility at almost all points in the T&E program. A mix of these types is needed throughout the program. Early in the program, the lead emphasis should be from the tester, shifting to the evaluator and finally the operator, but at all times all parties and their needs should be coordinated.

Training plans and certification plans for test personnel should be established early in the Full-Scale Engineering Development Phase. Errors by test personnel are usually expensive and often cloud the reason for test failures.

It is imperative that the Independent Test Agency participate in all of the T&E phases to ensure that the user needs are represented in the development of the system concept and hardware. Initially, the Independent Test Agency should play an advisor role during the feasibility and engineering testing, and gradually take over leadership in the conduct of the testing program as it becomes more and more operational. This should facilitate the necessary communication and interaction between developing and user commands.

The test director and/or key members of the test planning group within the project office should have significant T&E experience. If the requisite experience does not exist at the appropriate levels within the project office, test plans may be based on too shallow or too naive a conception of the role and potential utility of the T&E process. All too often, key test personnel are assigned to T&E slots with little prior exposure to T&E or its management, and with inadequately experienced support as well. The test planning group should have personnel experienced in engineering testing, development testing and

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		and operational testing. This experience should be available very early and all efforts should be made to encourage these people to remain with the weapon system project office through the T&E phases of the program.
		The planners and evaluators for the OT&E of the production equipment can do a better job if they are initially involved in planning and conduct the IOT&E.
		In the initial conduct of OT&E, the participants should be given a period of time to dry run the scenarios and to shake-down the instrumentation and the overall operation before key resources are expended in tests for record. In a properly planned OT&E program, the people will have completed proper individual training on the new system but the operational organization will not be able to conduct full unit training until the hardware, software, and support equipment are on hand. After the period when the unit is qualified as being operationally ready, it would be ready for assignment to OT&E testing.
		Test conduct can be influenced by the actions of the observers and umpires. These people can provide important clues to the participants of operational suitability testing and in that way lesson the validity of the test. For example, in situations where air/ground duels are to be conducted, briefed observers who look in the direction of the aircraft, might inadvertently tip-off the direction of approach to the ground party in the duel. Similarly, concentrations of observers at a certain location may clue the aircrews where to search first for the ground targets.
	4.5	Every test plan should include clear statements of: (1) The overall purpose of the test. (2) Critical issues with respect to operational requirements.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

(3) The major test objectives.

(4) The schedule of test milestones.

(5) The major resources required:

(a) Test environment, facilities and instrumentation.

(b) Operational environment

(6) The organizations which will conduct the test program.

(7) The analysis and evaluation approach.

Tests should:

(1) Have specific objectives.

(2) List in advance actions to be taken as a consequence of the test results.

(3) Be instrumented to permit diagnosis of the causes of lack of performance.

(4) Not be repeated if failures occur, without detailed analysis of the failure.

(5) Be rehearsed for each new phase of testing.

The test schedule should:

(1) Allow for a sufficient time between the planned end of demonstration testing and major procurement decisions so that there is a flexibility for modification of plans which may be required during the test phases of the program:

(a) The number of test items available and the schedule interface with other systems needed in the tests, such as aircraft, electronics, missiles, etc.

(b) Support required to assist in the preparation, conduct of the tests, and the analysis of test results.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(2) Be adjusted to minimize the so-called T&E gap caused by a lack of hardware. Specifically, a test gap can result if funds are not applied until the results of IOT&E are known because of the required lead time for production planning, production facilities, and tool and production hardware. Budgeting documents should be regularly reviewed to ensure that there are adequate identified funds for testing, relative to development and fabrication funds. Budgeting documents need careful scrutiny to ensure that there are adequate contingency funds to cover correction of difficulties at a level which matches the Industry/Government experience on such contracts. (Testing for difficulty without sufficient funding for proper correction results in band aid approaches which ultimately require correction at a later and more expensive time period.) The constraints to be placed on the test because of the range and instrumentation are of prime importance. As previously stated, the test facilities and instrumentation requirements to conduct operational tests should be identified, along with a tentative schedule of test activities. The applicability of existing test ranges and the adequacy of current facilities and instrumentation should be verified. Insofar as possible, alternative approaches (different ranges, etc.) and instrumentation improvements needed should be specified. If range and instrumentation factors are found to cast significant doubt on the meaningfulness of the test data because of a lack of operational realism, the steps necessary to assure meaningful data should be previously identified and planned. The primary basis for the test sample size is usually based on one or more of the following: (1) Analysis of test objectives.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(2) Statistical significance of test results at some specified confidence level. (3) Availability of test vehicles, items, etc. (4) Support resources or facilities available. (5) Time available for the test program.

Dieterly, D.L. The evaluation of training with specific emphasis on criteria (AU-AFIT-SL-9-73). Wright-Patterson AFB, OH: Air Force Institute of Technology, School of Systems and Logistics, October 1973. (AD-771 009).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentiala/ Priorities 6.3 Research Planning	1.1	The purpose of this paper is to present a descriptive model of the evaluative process that has been synthesized from the concepts presented in numerous papers. In addition emphasis was placed on the criterion problem. Evaluation of training should be considered in the initial developmental stages of program design. The evaluation process consists primarily of translating the program objectives into quantifiable measures which can be used to feed back into the program to indicate needed modifications or as the final information used in making the decision as to whether the program should continue or not. The major problem in training evaluation is the translation of objectives into criteria. The criterion is a measurable variable which represents the dimension of interest in the research study. In industrial psychology the criterion is usually predicted from knowledge of the predictor variable measure. The greater the ability of the predictor variable to predict or capture the criterion variable the higher the validity of the predictors. Three criterion concepts are presented: (1) Ultimate, intermediate, immediate. (2) External, internal.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(3) Summative, formative. Each type in each concept is defined as follows: (1) Ultimate criteria are usually stated in broad conceptual terms and represent the total goal of a particular action. (2) Immediate criteria are some variable measures which are obtainable and are logically felt to represent the ultimate criteria. (3) Intermediate criteria are some measurable variables that are logically felt to be related to the immediate variables and which are obtainable prior to attaining the immediate criteria. (4) Internal criteria are considered outcome measures linked directly to the training content which are assessments made during or immediately after the learning experience. (5) External criteria are designed to assess behavioral changes in the organizational role of the individual. (6) Formative criteria are those used to evaluate segments of the training program to make changes within the program prior to its culmination. (7) Summative criteria are concerned with the final evaluation of the total program. Three dimensions of criteria are discussed: (1) The static dimension which is the usual type of criteria of production or job performance behavior.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(2) The dynamic dimension which is the change over time of job performance. (3) The individual difference dimension which measures the change in the individual over time. In selecting the criterion measure to be used in a research design there are four basic considerations upon which to evaluate the criterion: (1) Relevance. (2) Reliability. (3) Discrimination. (4) Practicality. Criteria measures used in evaluation usually fall into one of these categories: (1) A test (2) A rating (3) A production measure (4) Some archival record data For training evaluation all internal criteria measures are some form of test with the objective of indicating the increase in knowledge resulting from training. Rating scales are used to measure total job performance but are not too valid. Productive measures increase validity but introduce social dynamics of the job situation. Archival records offer some of the most interesting possibilities for unusual criteria but result in a high degree of chaotic error and systematic bias.

DiGialleonardo, F.R. & Barefoot, D.B. An approach for measuring benefit and cost in management and information systems (TR 75-21). San Diego, CA: Navy Personnel Research and Development Center, October 1974. (AD-A014 209).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The objective of this study was to support the Manpower Requirements and Resources Control System (MARRCS) by providing an effective means of assessing benefits and costs in management and information systems. The primary focus is on measuring benefit of the information rather than cost. The cost and benefit indices obtained through this approach are being used to identify development opportunities and priorities and to permit comparisons between present and proposed systems for manpower planning in terms of possible increase in effectiveness. Scales that are based on this information benefit model presented below make up part of a larger instrument that is the primary vehicle for MARRCS Phase I data collection. That instrument, the Manpower Personnel Planning Questionnaire, is included in the report as Appendix A. The benefit model developed in this study is as follows: Realized Value (Benefit) = P x R x U where, P, the Potential Contribution, is a value attached to the information on the basis of some predetermined set of specifications that the information should meet; R, the Received Value, is the portion of potential contribution that is normally received by users of the information; U, the Utilization Value, is the portion of the received value that users are normally able to actually apply in performing their functions.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Values for P, R, and U are developed through the questionnaire administered to both producers and users of the information. P is estimated on a scale of 0 to 4 while R and U are estimated percentages. Although producer and user estimates usually have some bias in them, the two perspectives are complementary and the technique gains much of its strength from having both perspectives. Preliminary analyses were performed using a total of 145 observations that were obtained by applying the data gathering instrument in limited parts of the Navy's manpower planning system. Because of data constraints conventional independence assumptions of statistical techniques such as regression and analysis of variance were not satisfied. However, the basic objective of this preliminary analysis was to obtain an indication of how helpful the hypothesized benefit factors might be. Indications are that of the three factors, Potential Contribution (P) is most strongly related to overall benefit. The Received Value (R) factor showed the next highest regression coefficient with Utilization Value (U) being least related. It was concluded that the approach presented in this report is viewed as a significant advancement in dealing with the problem of benefit measurement and analysis in humanistic systems. It is recommended that a programmatic approach to this problem area, using the benefit factors developed in this preliminary study be employed.

DiGialleonardo, F.R., Barefoot, D.B., Blanco, T.A. Technique for Interactive Systems Analysis (TISA) (NPRDC-TR-75-22). San Diego, CA: Navy Personnel Research and Development Center, 1974. (AD-A013 223).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 1.3	The field of systems analysis has traditionally been devoted to obtaining the necessary basis for design or redesign of hardware systems. While this analytic capability is no less desirable for soft systems, applications in that area have been hampered by data deficiencies, difficulties in system definition and the specification of desired performance, measurement problems, and the like. As a result, many attempts to perform systems analyses on organizations, for example, have resulted in lengthy verbal products too inescapably static to have a real-time impact on system design. In response to particular problems in the field of system analysis, a Technique for Interactive Systems Analysis (TISA) was developed. TISA is a computerized technique for conducting systems analysis in a conversational mode from interactive terminals. It uses networking algorithms to access and structure system descriptive data from computer files. Specifically, TISA was developed in order to perform the systems analysis necessary to: (1) Assess the state of the current system at the onset of a major development effort (i.e., establish a baseline). (2) Reveal deficiencies in the Manpower System and probable candidates for further R & D.

(3) Provide a convenient and effective means for assessing the progress of the development program at any point in its evaluation.

3.3 TISA was designed to meet certain requirements of data manipulation. These requirements included the following:

(1) The ability to structure the data in a network flow context.

(2) The ability to structure the data in an organizational context.

(3) Versatility of data access for direct and selective analysis with a variety of routines in an interactive mode.

(4) Speed, lucidity, and reliability in the graphical depiction of any system of communications as specified by a selected data set.

5.4 The following recommendations are made for TISA:

(1) The development of TISA into a standard initial analysis approach for soft system development programs.

(2) The use of TISA as a methodological device in more basic areas of research such as organizational behavior, information processing, and human factors.

Duning, K.E., Hickok, C.W. Emerson, K.C. & Clement, W.F. Control-display testing requirements study (AFFDL-TR-72-122). Cedar Rapids, IA: Collins Radio Co., December 1972. (AD-759 539).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	The following steps represent the blocks in a procedural block diagram culminating in system and pilot-centered evaluation criteria: (1) Describe vehicle operational profile. (2) Select outcomes of interest. (3) Specify outcomes and pilot acceptance in terms of critical limits of pertinent variables in numerical terms. (4) Determine system error and state variable performance response to inputs. (5) Determine outcome probabilities and pilot acceptance probabilities. (6) Define safety, operational capability and pilot acceptance design qualities. (7) Determine procedural variables. (8) Determine task variables. (9) Determine environmental variables. (10) Define normal/degraded feed back arrangements and control-display mechanizations to perform functions. Allocate functions to manual and/or automatic systems.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(11) Identify system performance-centered variables and physical characteristics.
		(12) Identify human operator-centered variables.
	2.1	The system used to develop control-display testing requirements is a Microwave Landing System (MLS). The MLS provides increased senior capability to support terminal area approach and landing operations. Its potential includes zero visibility landings, maximum runway utilization, noise abatement, ground fire avoidance and reduced separation standards.
	2.2	The mission to be evaluated is aircraft approach and landing using MLS.
	2.5	The ultimate performance requirement of the MLS is to insure successful aircraft landing.
	2.6	The ultimate criteria of the MLS system is that the aircraft must be within a successful landing window defined by dispersions at decision height and reference position at touchdown.
	3.1 and 3.2	Quantitative and qualitative performance measures and evaluation criteria are as follows:
		(1) System Performance (Evaluation criteria are commensurate with metrics and absolute in value).
		(a) At Approach Window
		• Location in state space with respect to window boundaries
		• Probability of approach success

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

(b) At Touchdown

- Longitudinal and lateral touchdown location with respect to runway
- Sink rate
- Sideslip
- Heading
- Pitch, and roll attitudes
- Airspeed error

(c) Composite Measures

(2) Safety Measures

(a) Probabilities (Evaluation criteria are commensurate)

- Successful landing
- Successful missed approach
- Accident or incident
- Margin (stall, performance, etc.)

(b) Qualitative Asssments (Evaluation criteria are relative and subjective; the graceful degradation hypothesis provides a guide).

- Missed approach procedures
- Failure detection procedures
- Emergency takeover procedures

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(3) Pilot Performance and Acceptance Measures (a) Pilot Dynamic Behavior (Evaluation criteria are relative) • Describing functions (loops closed and equalization demanded; control display associations and residual cross-coupling; sensitivity of stability, disturbance regulation, and command-following performance to variations in gain, time delay, and equalization; the adaptive feed back selection hypothesis and successive organization of perception hypothesis provide guides). • Scanning activity distributions (incoherence in system performance caused by scanning remnant; system status monitoring threshold for confidence and decision-making; the display arrangement hypothesis provides a guide). • Opinion ratings (psychometric scales). • Workload and operability assessment (excess control capacity; auxiliary task scores and loads; psychophysiological measurements; there is no guide to evaluation other than sensitivity and relative differences. (b) Pilot Acceptance of System Performance

- Attitude, attitude rate, and load factors variances from trimmed values (Evaluation criteria are commensurate and absolute, e.g., probabilities of exceeding acceptable levels from trimmed values).

- Control displacement and rate variances from trimmed values (Evaluation criteria are commensurate and absolute, e.g., probabilities of exceeding maximum authorities).

- Response compatibility and motion harmony-automatic and flight director versus manual control (Evaluation criteria are relative to the response and motion attributes under manual control).

- Command consistency-flight director versus Manual control Evaluation criteria are based on the consonance between the spectral distribution of status variables in the director command and the displayed status variables themselves).

- Qualitative assessments-pilot commentary (Evaluation criteria are subjective and relative).

4.1 The control-display design validation process will be conducted in three phases:

(1) Theoretical analysis

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(2) Simulation
		(3) Flight test
	4.3	During actual flight tests, phototheodolites may be used for tracking simulated IFR approaches, but radar must be used under actual IFR. Special flight control systems will be required to allow pilot performance measurement.
	4.5	Flight test plans must define specific tasks and responses as well as complex sequences of tasks designed to provide information on pilot understanding, workload, tracking, monitoring, and decision-making abilities. In the area of tracking performance, specific acquisition, approach, and missed approach paths need to be defined, and data on aircraft displacement and attitude accumulated through the beam capture, approach, and landing phases. Data from flights will be used to form statistical performance distribution curves for comparative analyses. To help evaluate one aspect of pilot workload, these same flights can be used to obtain similar distribution curves for wheel motion, command nulling error, pilot's eye-point-of-regard, and subjective ratings. When combined with pilot interview data, these data will form an analytical basis for control-display system evaluation. In addition to verifying beam capture, approach, and landing, special emphasis will be required to exercise the new capabilities of MLS coverage for guiding and monitoring segmented and curved approach paths and missed approaches. Deliberate disturbances to test control responses, distracting influences to test pilot error sensitivity, deliberate failures to test pilot reaction, and extensive use of the real environment will

be made to determine display capabilities.

If the TIFS aircraft can be made available, simulated weather would be a possibility to provide one-to-one correspondence of vehicle and simulation. Further, multiple vehicles can be simulated with the TIFS vehicles. This would provide a very flexible platform, requiring only one set of instrumentation.

Use of the digital computer and flexible displays may be strong contributors to the hardware flexibility requirements. This would allow study of data rate problems but, more significantly, would provide a capability of readily changing control-display parameters over a very wide range. Such tools should certainly be considered for curved path studies. Controlled inputs allowing for correlation studies in the air should be considered with the flexibility provided by this advanced equipment to measure pilot behavior.

Automatic data logging can be valuable as a flight test technique. Failure information, data discrepancies, and complex path geometries can be introduced and pilot responses noted with experimental certainty. Extensive use will be made of the monitor pilot, voice recording, strip chart recording, magnetic tape recording, and controlled test stimuli.

5.4 A program plan for control-display testing requirements for the new Microwave Landing System can expeditiously and effectively be implemented within the 5-year period. A great deal of directly relevant, applied research on landing systems has been conducted by many agencies. Perhaps the most notable example is the Air Force PIFAX program. For well over a decade this and corollary efforts have addressed key control-display, instrumentation, operational, and pilot factor problems in

118

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		approach and landing operations. The result is a large reservoir of experimentally demonstrated concepts, principles, and prototype instrumentation. Also, the existence of various ILS-based systems for almost three decades has developed a broad appreciation for desirable operational characteristics among users. It remains to condense, coalesce, and apply these inputs into a meaningful and comprehensive program plan. In this section, an attempt was made to show how theoretical analysis, simulation, and flight test can be coordinated so that, when all levels of analysis are completed, the resulting control-display system design will be validated as "best."

Dunlap, J.W. & Affinito, F.J. Development of methodology for measuring effects of personal clothing and equipment on combat effectiveness of individual soldiers (Final Rep.of Phase 3). Darien, CT: Dunlap and Assoc., Inc., December 1967. (AD-836 904).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

2.1 An Integrated Test Facility was designed and constructed combining the individual test courses developed in a previous phase of this study. Requirements were developed for an instrumentation system to measure automatically the performance of test participants and requirements and specifications were developed for a centralized, computerized, data logging system to record, process and statistically analyze performance data collected by the system.

2.2 A field methodology was developed for measuring the effects of experimental clothing and equipment on the combat effectiveness of individual infantrymen.

2.3 The Integrated Test Facility, located at Camp Picket, Va, consisted of eight test situations, five of which were developed and tested in a previous phase of this study.

3.2 Performance data were collected by various types of electromechanical sensor devices located on the various performance courses of the Integrated Test Facility.

3.3 Sensors were activated by the activities of the subjects causing input signals to be sent to a centrally located data logging facility.

4.1 The Integrated Test Facility consisted of eight distinct courses representative of important combat tasks. Estimates of the

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		performance scores which each course generated were collected as well as estimates of the time required to complete each course.
	5.4	The tryout and evaluation which was necessary to meet the last objective of this phase, could not be accomplished due to procurement difficulties in acquiring the Data Logging System. The evaluation and final refinement will be conducted upon acquiring this system.

Dunlap and Associates, Inc. Performance measures for human factors engineering evaluation of EARL equipment (SSD-332-618). Darien, CT: Dunlap and Assoc., Inc., June 1966. (AD-653 627).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

2.1 The system evaluated was a 105 mm howitzer battery consisting of six sections, each with one howitzer and an eight-man team.

2.2 The tactical activity was an RSOP (Reconnaissance, Selection and Occupation of Position): 105 mm howitzer sections conducting modified planned occupation of an area. The occupation was preceded by a recon party in order to determine firing positions, installation sites, routes of march, defensive plans, etc. Each section was to complete four major actions: uncoupling the howitzer, preparing for actions, firing and march order.

2.3 Each team member was equipped with the following: fatigue uniform, field jacket, helmet with liner, M56 harness with ammo pockets, canteen, entrenching tool, poncho, M16 rifle and M17 field mask.

2.4 The field test had the following conditions:

(1) Moderately unpracticed teams in actual training.

(2) Emplacement at an actual field site on the firing range.

(3) Full tactical uniform, equipment and live ammo.

(4) Complete emplacement, live firing and march order sequence.

(5) Field training SOP.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.1	The characteristics to be measured were:

(1) Sequence of team subtasks.

(2) Number of visual, oral and manual team coordination cues.

(3) Quality of performance.

(4) Time to perform.

(5) Density of team's activity.

(6) Number of critical incidents.

(7) Subjective rating of performance.

(8) Tactical accuracy.

(9) Total time of team performance.

(10) Comparative indications of physiological energy expenditure.

3.2 The units of measurement were as follows:

(1) Number of scheduled and unscheduled oral communications.

(2) Number of scheduled and unscheduled visual communications.

(3) Number of errors by team and individual.

(4) Number of unsafe conditions.

(5) Time data in minutes and seconds.

(6) Quality data was "good," "fair," or "poor," based on the subjective judgment of an experienced battery officer.

(7) Heart rate of certain team members.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.5	Measurement was accomplished using a series of methods: (1) Visual recording by film and TV camera. (2) Oral recording by taping and pick-up technicians. (3) Observers for visual and oral interactivity and team events.
	4.1	The data analysis methods employed were: (1) Means (2) Standard deviations (3) t ratios (4) Regression analysis (5) Sequence effects analysis (6) After-task questionnaires
	4.3	The test apparatus included film and TV camera, tape recorders, still cameras, telemetry charts (heart rate).
	4.4	Forty-eight test subjects were used (six teams of eight men each). The chief of section was either an E-5 or E-6. All others were E-2 or E-3's.
	5.2	The resulting analysis pointed out variables relevant to small-group interaction and performance which were able to discriminate differences between performance of teams with and without the M-17 protective mask.
	5.4	The conclusions of this study can be summarized as follows:

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(1) A simple measurement design is inadequate for field testing of teams. Observations must be structured to detect separate patterns of performance across multiple variables, individual team members, and various sub-tasks. (2) Human observers at the field site cannot alone record this wide range of data at the pace of team performance. Data recording equipment, particularly video-recorders, assure a more adequate and objective data collection. (3) Performance of certain team tasks, generally those requiring individual initiative in coordinating activity, may be significantly altered by the wearing of protective masks. Other tasks of a repetitive drill nature may be much less affected. Even very meticulous testing during field training activity may fail (because of the "slack time" and indirect motivations inherent in the practice environment) to reflect validly potential decrements in a tactical environment. (4) For 105 mm howitzer crews specifically, there will probably be no consistently critical performance problems while wearing protective masks, although the team's normal pattern of oral intercommunication is definitely disrupted.
	6.2	The results of this effort offer three promising directions for further study in the areas of field collection equipment, team data analysis, and standard performance testing.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

(1) A system of team data reduction and analysis in depth should be sophisticated, so that large quantities of data from mul'iple trials over time could be methodically built into a data base for each variable, team member, and sub-task of a standard test. Application of automatic data processing and mathematical modeling should be investigated, and weak spots in the initial design, such as the quality and density of activity variables, should be strengthened through quality control and systems analysis techniques.

(2) The generalizability of objective field-monitoring techniques, such as video-recording, should be explored in detail. Any field performance that is broadly repeatable could become a standard test, in effect, by visually recording each trial and redirecting the structuring control from the participants to the observation procedure: standardly structured camera coverage, videotape editing and playback, observer training, and video viewing schedules by separate variables and sub-tasks.

(3) Routine team testing should be conducted using the improved data collection devices and data analysis techniques perfected in the study described above. The current study emphasized the detection of pattern changes, not the significance or tactical validity of all such changes. In its field observations, this objective was achieved. The promising trends in variables from this small number of trials should now be pursued in a much larger "n" to provide the data base for probable statistical significance in several categories. These extended performance tests, if

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		done with chemical protective equipment, could then possibly establish reliable patterns of difference valuable in improving design of the equipment and in predicting masked team behavior under valid tactical conditions.

Egbert, J.J. & Rau, J.G. Techniques for bounding and estimating measures of effectiveness. Newport Beach, CA: Ultrasystems, Inc., July 1973. (AD-772 550).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition	3.1	This study describes methods for the formulation of measures of effectiveness (MOE's) used in studies where variables are not readily (if at all) measurable in the real world. Within this report is a survey (and listing) of both algebraic and statistical techniques which are useful in bounding and estimating MOE's. Bounding in this context means confidence limits or intervals.
2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific	3.2	The results of the survey are intended to be illustrative, rather than exhaustive of some of the types of MOE's in use. For example, an MOE for Airborne Antisubmarine Warfare (ASW) is the probability of submarine detection by helicopter. These MOE's are chosen from a spectrum of naval warfare areas with particular emphasis placed on antisubmarine warfare.
3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	3.5	For each MOE the measurement techniques are provided to determine the bounds of the MOE values. These techniques are of various forms such as linear-exponential product, sum of exponentials, sum of products etc.

Ellis, R.H. Task Analysis Reduction Technique (TART) for the quantification of human performance (Research Memo. SRM 71-7). San Diego, CA: Naval Personnel and Training Research Laboratory, September 1970. (AD-711 807).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This document describes a procedure for collecting performance data and examining man/machine interaction. This procedure, called a Task Analysis Reduction Technique (TART), allows for facilitation of human performance quantification, clarification of analysis and improved useability of the data.
	3.1	The TART focuses on the interface at the task level of complexity. Analysis at the task level is advantageous because one can, according to one's needs, break the task down into movements and actions for detailed analysis or one can combine tasks and analyze different configurations at a higher functional level.
	3.2	The example provided demonstrates the use of TART by deriving measures for the air detector/tracker (ADT) position on the Antisubmarine Warfare Tactical Data System (ASWTDS).
	3.3	The TART, in general, can produce the following types of data: (1) Frequency -- the absolute and relative frequency for each of the tasks for given periods of time under any type of loading condition for any type of operator. (2) Time -- mean and relative times for each task, under conditions of varying loads and operators.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(3) Frequency/time comparisons -- comparisons between the absolute and relative occurrence of each.
		(4) Sequential properties -- the nature of strategies employed by the various operators in performing their various functions.
		(5) Error analysis -- number and type of deviations from expected procedures and the effects of innovative actions.
	3.4	Specific performance measures are presented in the ASWTDS example.
	3.5	The TART consists of a three-part procedure:
		(1) Task analysis Operational Sequence Diagrams (OSDs) are developed for the tasks observed.
		(2) A video recording of the action and feedback channels of the machine is obtained.
		(3) The video-recording of that activity is reduced to a time-line sequence of basic tasks, and an analysis of the frequency, time and sequential properties of that time-line is performed.
	5.4	Using the techniques described in this report, it is possible to collect and quantify useful human performance data. It can be used to analyze a realistic man/machine interface. An automated form of the task analysis OSD is useful for developing base-line performance expectations, and the basic form of the data collected can be useful types of analyses.
		It is recommended the TART system be continued and onboard ship programs begun. It was also suggested that this technique be included in the repertoire of those considering man/machine interface analysis, and a data bank of empirical personnel performance data begun.

Engel, J.D. An approach to standardizing human performance assessment (Professional Paper 26-70). Presentation at the Planning Conference of Standardization of Tasks and Measures for Human Factors Research, Texas Technological University, Lubbock, Texas, March 1970. (AD-717 258).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 Syster Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The purpose of this paper is to consider data concerning the relationship of a task taxonomy and performance measurement taxonomy. A task classification scheme was used as follows: (1) Learning identifications. (2) Perceptual discriminations. (3) Principles and relationships comprehension. (4) Procedural sequencing. (5) Decision making. (6) Perceptual motor skills. The performance measurement classification system is categorized on the basis of remoteness from actual job performance. The four major segments along this continuum are: (1) On-the-job measures. (2) Work sample measures. (3) Simulated-job measures. (4) Correlated-job measures.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.1	The system studied was that of the general vehicle mechanic for wheeled and tracked army vehicles.
	4.1	A four-day proficiency test consisting of 33 sample exercises was used. The test included a diagnostic scoring procedure for use in scoring men on quality of performance. In addition a questionnaire was used to obtain supplemental information regarding the mechanic's experience. A second phase of research dealt with a comparision of two job correlated measures with the work sample via a paper and pencil evaluation test.
	4.4	The test subjects were 38 organizational mechanics drawn from all organizational maintenance units at Fort Knox. The exercises were individually scored by experienced mechanics trained in test administration procedures.
	5.2	The results indicated that the total test appears to have a high degree of reliability, indicating it should permit a high degree of accuracy measurement when used as a criterion in evaluating other measurement techniques. The second phase written test had a low degree of validity when correlated with the work sample and as a result should not be used in group or individual measurement.
	5.4	Further research should be conducted along two parallel lines: (1) Development and refinement of an interim task classification system. (2) Development and refinement of a interim classification system for human performance measures.

Eppler, W.G. Analytical design of manned control systems (SUDAAR No. 280). Stanford, CA: Stanford University, Center for Systems Research, May 1966.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This dissertation treats the problem of designing high-performance, closed-loop control systems which include a human operator. In particular it describes research conducted to answer the following rather general questions: (1) How should the state of the system be displayed to the operator and how should his responses to the display be processed before they are input to the system? (2) In what way does the operator's dynamic response limit the performance of the overall system, and how does this limitation depend on which of his several possible outputs is used for controlling the system? The results presented are applicable to the design of a wide variety of manned control systems.

Erickson, R.A. Field evaluation of a visual detection model. In G. W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus OH: North American Aviation, November 1968. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	4.5	The report describes a 1962 field experiment conducted to validate a mathematical model of the visual detection process. All observations were made by pilots flying A-4 aircraft above a bulldozed strip in the desert. Ground targets were a Sherman tank and a radar van without the radar dish/antenna. Thus, the visual search was in one dimension only; the model was not capable of handling 2-dimensional search. Flights were conducted at altitudes of 1000, 2500, and 4000 feet, at indicated airspeeds of 275, 270, and 265 knots, respectively.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	5.3	Data showed that the model's predictions of detection range are quite accurate, but the prediction of recognition range is in error by substantial amounts.

Farina, A.J. & Wheaton, G.R. Development of a taxonomy of human performance: The task characteristic approach to performance prediction (Tech. Rep. 7). Pittsburg, PA: American Institutes for Research, February 1971. (AD-736 191).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

1.2 The present research described a series of studies conducted to develop an instrument in terms of which the stimulus, procedural and response characteristics of tasks could be described.

2.5 The basic steps in this research were to: (a) develop descriptive characteristics of tasks; (b) assess the reliability of rating scales derived to measure these characteristics; and (c) determine if these characteristics represented correlations of performance.

3.1 Major components of a task were identified and treated as categories within which to devise task characteristics or descriptions. Each characteristic was cast into a rating scale format which presented a definition of the characteristic and provided a seven-point scale with defined anchor and mid-points, along with examples for each point.

3.2 Nineteen scales were developed and evaluated in a series of three reliability studies. The following are the task components and related characteristics (for which the 19 scales were formed):

Component	Task Characteristics
Goal	Number of output units
	Duration for which an output unit is maintained
	Number of elements per output unit
	Work load imposed by task goal
	Difficulty of goal attainment
Response	Precision
	Rate
	Simultaneity of responses
	Amount of muscular effort involved
Procedures	Number of steps
	Dependency among procedural steps
	Adherence to procedures
	Procedural complexity
Stimulus	Variability
	Duration
	Regularity of stimulus occurrence
Stimulus-responses	Degree of operator control
	Reaction time/feedback lag relationship
	Decision making

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.1	The paradigm used to determine whether the task characteristics were correlates of performance upon which predictive relationships might be established was that of "post-diction".
	4.2	Post-diction referred to the situation in which performance measures were abstracted from studies already existing in the literature.
	4.5	Subjects were supposed to rate descriptions of the tasks used in these studies on task characteristics scales and then these ratings were to be subjected to multiple regression analysis to establish the extent to which they were related to the performance in question.
	5.1	Two such post-diction studies were conducted.
	5.2	In general, it was found that a subset of scales having adequate reliability consistently emerged in all three reliability studies. The results of the two post-diction studies were encouraging in that significant multiple correlations of .82 and .73 were obtained between task characteristic ratings and the performance measures.
	5.3	It does appear possible to describe tasks in terms of task-characteristic language which is relatively free of the subjective and indirect descriptions found in other systems. Further, task characteristics may represent correlates of performance.

Featherstone, C.L. & Scaglione, R.J. A feasibility study for determining a small arms measure of effectiveness for handling characteristics (Master's Thesis). Monterey, CA: Naval Postgraduate School, September 1975. (AD-B008 586L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	The results of a feasibility study for determining a small arms measure of effectiveness for handling characteristics were presented in this report.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The system being measured was the small arms user, and .45 and .38 caliber pistols.
	2.2	The handling characteristics of these weapons were selected for evaluation.
	2.3	The tests were conducted on a typical pistol range common to most Army installations.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.5	The ultimate performance requirement is that the small arms user survives in a combat or other situation and that his weapons are utilized effectively.
	2.6	The ability to shift a weapon rapidly and accurately from one target to another is a critical factor in the use of small arms weapons.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.1	The primary purpose of this study was to measure an individual's performance while he was accomplishing a series of movement and firing tasks and determine whether the resulting MOE's could discriminate between the two systems.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.2	The time it took for an individual to accomplish these tasks without error was recorded. In addition, an index of difficulty for the performance of shooting tasks was developed using information theory.
	4.1	Analytic methods were used to determine if there is a statistically significant difference between the mean times it takes an individual to complete a set of prearranged movement tasks with two differently handling weapon systems.
	4.3	The weapons used in this experiment were the M1911A1 .45 caliber automatic pistol and the Smith and Wesson Model 10-38 caliber revolver and appropriate ammunition. Targets, timing devices, and record sheets were utilized in this experiment.
	4.4	The subjects were selected from the population of military personnel who, at a minimum, would be required as part of their combat equipment, to carry and be prepared to use a sidearm. All participants were volunteers, ages 28-37, all were officers, time in military service ranged from 7-16 years. Range of experience with weapons in question varied.
	4.5	The weapon, task sequence, and subject factor levels were set prior to conduct of experiment. Four task sequences were selected. Subjects were briefed prior to the experiment and received written instructions. Practice on both types of weapons was permitted followed by actual firing in the task sequence assigned. At the end of the firing the subject filled out an information sheet giving personal data and weapon evaluation.
	5.3	The conclusions were as follows: (a) There was no statistical difference between weapons used. (b) Three of the four task

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		sequences were different. Sequences 1 and 2 tested as having no significant difference. (c) The average information processing rates for each weapon were different but were not tested for statistical significance. The index of difficulty measurement of the tasks was shown to have a high correlation to the time required by each weapon to perform the tasks that had one or more movements specifically designed into the tasks.

Fineberg, M.L., Meister, D., and Farrell, J.P. An assessment of the navigation performance of Army aviation under Nap-of-the-Earth conditions (Research Rep. 1195). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD-A060 563).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	1.1	The basic objective for this series of studies was to obtain empirical data on how the Nap-of-the-Earth (NOE) navigational skill level of Army aviators is affected by pilot experience and two levels of training. Other objectives were to define a baseline on pilot navigation proficiency and to develop a field research methodology to measure pilot performance in NOE flight.
	2.6	The dependent measures were measures of navigational performance.
	3.1 and 3.2	Two measures of mission success were used. These were: (1) A subjective mission success score - the instructor pilot rated the subject's navigational effectiveness in terms of three categories: complete failure, partial success, and complete success. (2) An objective mission success score - this measure was constructed to serve as a component metric representative of the subject's scores on four individual measures: number of initial points (beginning of a route) missed, number of landing zones missed, number of 250 meter excursions from the course line, and number of 1,000 meter excursions.

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.3	Two UH-1H helicopters were employed in the study over a test range near Troy, Alabama.
	4.4	The subjects in the study were 35 Army helicopter pilots who were currently proficient with the test copters and had some exposure to NOE flight at either entry or unit level. Four Army navigators conducted the tests, two being highly qualified NOE instructor pilots.
	4.5	The navigators were assigned missions in which designated landing zones had to be found for simulated medical evacuations or supply deliveries. All 35 aviators navigated at least six NOE routes ranging from 23 to 25 kilometers (km) in length. Twenty-eight of the aviators were also tested on aircraft control and the performance of various NOE maneuvers.
	5.3	NOE navigation is a trainable skill. Experienced aviators with training performed better than experienced aviators without training. In addition, recent graduates with 15 hours of NOE training performed better than experienced aviators without training.
		Specialized training in NOE navigation is valuable. The instructor pilots indicated that experience is more important in aircraft control than in navigation. The group, with an average of 1,380 flight hours, controlled their aircraft better than the group with 200 hours but this difference in experience appeared to have no effect on the navigation.
		The field research measures and techniques developed for these experiments seem well-suited for NOE navigation research. The Objective Mission Success Score (OMSS), a composite performance measure indicating the probability that the mission would be successfully completed, proved useful and has a .75 correlation with subjective

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		ratings by expert NOE instructor pilots. As expected, it was shown that NOE navigation is an extremely difficult and complex task. The OMSS' show that NOE missions flown over the Fort Rucker terrain resulted in an overall probability of success of .63.

Finley, D.L. & Muckler, F.A. Human factors research and the development of a manned systems applications science: The system sampling problem and a solution. Northridge, CA: Manned Systems Sciences, Inc., July 1976. (AD-029 4'7)

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.2 2.1 5.3	This report points out: the need to identify and incorporate systems design and operation parameters into research programs; the nature of systems research and the dimensional problem, and presents a model to support the systems dimensionalization process, i.e., a systems taxonomy model. This study addresses the manned system and the need to develop a body of knowledge on the dimension of a system, as opposed to such components as an individual operator or a piece of equipment. The beginnings of a systems taxonomy model are presented. It consists of three major levels: (a) system objectives; (b) system functional purpose and (c) system characteristics (structural operator/equipment, operating and support requirements). These three levels are further defined by their relationship to the nominal versus relative levels of measurement. Information is presented on how to use this model and of the model level implications and importance.

Finley, D.L., Muckler, F.A., Gainer, C.A. & Obermayer, R.W. An analysis and evaluation methodology for command and control: Final technical report. Northridge, CA: Manned Systems Sciences, Inc., November 1975. (AD-A023 871).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.2	The systems taxonomy model abstracted documented from this article is shown on the following page:

	MEASUREMENT LEVELS	SYSTEM TAXONOMIC LEVELS	EXAMPLES OF POSSIBLE TAXONOMIC CATEGORIES & DIMENSIONS
LEVEL ONE	Nominal Measurement	SYSTEM OBJECTIVES	• Production • Supply • Navigation • Air Traffic Control • Health & Welfare • Transportation • Maintenance • Weapons • Surveillance • Etc.
LEVEL TWO	Nominal ⇑ - - - - - - - - ⇓ Relative	SYSTEM FUNCTIONAL PURPOSES	Nominal • Indirect command/control/guidance operations • Relatively direct control/navigation operations • Maintenance operations • Data or materials processing - - - - - - - - Relative • Command • Control • Information • Data
LEVEL THREE	Relative Measurement (Ordinal, Interval and Ratio)	STRUCTURAL CHARACTERISTICS	• Organization and layout • Size • Level of automation • Implementation capabilities
		OPERATOR/EQUIPMENT CHARACTERISTICS	• Human skills, equipment conditions • Human abilities & IQs, equipment capabilities • Values • Needs
		OPERATING CHARACTERISTICS	• Inputs to operator • Operator processing • Operator outputs • Units being dealt with by system • Environment • Feedback
		SUPPORT REQUIREMENTS CHARACTERISTICS	• Materials (including people) • Maintenance (including people)

From: Finley et al. (1975)

Systems Taxonomy Model

Finley, D.L., Obermayer, R.W., Bertone, C.M., Meister, D., and Muckler, F.A. Human performance prediction in man-machine systems-Volume I-A technical review (NASA CR-1614). Canoga Park, CA: The Bunker-Ramo Corporation, August 1970.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	Over the pas three decades there has been an increasing demand for quantitative techniques of human performance prediction in man-machine system tasks. A somewhat bewildering variety of methods has evolved to satisfy this need, ranging from specific task simulation to classical tests of fundamental human abilities.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	1.2	From the existing literature, 75 behavioral dimensions were defined and incorporated into a Performance-Descriptor X Physical-and-Interactional-Categories Matrix. This is shown in Figure 1. Implicit in the adoption of the dimensional approach to human performance prediction was the assumption that it would be possible to denote a set of specific procedures which would define a comparatively objective mapping process wherein the accuracy of the mapper would be more a function of available knowledge than of the goodness of his intuition. (Mapping, as used here, refers to the a priori selection of those socio-psychological dimensions which would be required to perform an operational task.)
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	The basic objective of this program was to critically review tests and test techniques for human performance prediction. Such a review, however, is best facilitated by conceptual and methodological criteria. At a very basic level, four fundamental questions were asked: (1) To predict what?

SYSTEM CATEGORY	INPUT		PROCESSING		OUTPUT		
BODY CATEGORY / GENERAL DESCRIPTOR	RECEPTOR MECHANISMS	PERCEPTION	THINKING, CONCEPTUALIZATION, MEMORY, KNOWLEDGES	OUTPUT SELECTION	GROSS BODY MOVEMENT	PSYCHO-MOTOR	INTERACTION
DISCRIMINATION BALANCE	(47) DISCRIMINATION ABILITIES KINESTHETIC AUDITORY VISUAL: PERIPHERAL ACUITY DYNAMIC ACUITY STATIC ACUITY DYNAMIC DEPTH PERCEPTION STATIC DEPTH PERCEPTION COLOR BRIGHTNESS NIGHT VISION (52) AUDITORY RHYTHM PERCEPTION	73 EMOTIONALITY SENSITIVITY OF REACTION			12. GROSS BODY EQUILIBRIUM	31 ARM-HAND STEADINESS	
MANIPULATION		55. SPATIAL VISUALIZATION	27 SYMBOL MANIPULATION				64 LEADERSHIP
SPEED		40 PERCEPTUAL SPEED SPATIAL SCANNING 50 SPEED OF CLOSURE 53 AUDITORY PERCEPTUAL SPEED	21a NUMERICAL ABILITY 22 CONCEPT FLUENCY 20 WORD FLUENCY		13 SPEED OF LIMB MOVEMENT ARMS 15 SPEED OF LIMB MOVEMENT LEGS	45 REACTION 30 SPEED OF ARM MOVEMENT 32 WRIST FINGER SPEED	
SELECTION (DECISION-MAKING)		49 TIME SHARING 54 SPATIAL ORIENTATION 72 SUBJECTIVITY OBJECTIVITY REACTION		36 RESPONSE ORIENTATION 69 CONFORMITY AND OR CONTROL REACTION 71. SELF CONTROL REACTION 74 DESIRED LEVEL OF OUTPUT 75 DESIRED VALUE OF OUTPUT			
FLEXIBILITY		51 FLEXIBILITY OF CLOSURE 70 FLEXIBILITY RIGIDITY REACTION	26 FLEXIBILITY		10 EXTENT FLEXIBILITY 11 DYNAMIC FLEXIBILITY	46 MIRROR TRACING	
KNOWLEDGES			19 VERBAL KNOWLEDGE 21c NUMERICAL ABILITY MECHANICAL KNOWLEDGE				
MEMORY		60 VISUAL MEMORY AUDITORY MEMORY	56 ASSOCIATE MEMORY ROTE MEMORY 57 ASSOCIATE MEMORY MEANINGFUL MEMORY 58 MEMORY SPAN IMMEDIATE MEMORY 59 MEMORY SPAN (INTEGRATION) 18 MEANINGFUL MEMORY ABILITY				
GENERAL REASONING			28 GENERAL REASONING 38 INTELLIGENCE				
DEDUCTION, ANALYSIS			78 LOGICAL EVALUATION 25 SEEING IMPLICATIONS AND CONSEQUENCES (FORESIGHT) 29 PRACTICAL JUDGMENT 81 MOVEMENT ANALYSIS				
COORDINATION INTEGRATION			23 DISCOVERY OF PRINCIPLES		16 GROSS BODY COORDINATION	39 MULTILIMB COORDINATION 34 MANUAL DEXTERITY 33 FINGER DEXTERITY	
PREDICTION			42 MOVEMENT PREDICTION			43 RATE CONTROL 35 POSITION ESTIMATION	
VISUAL FEEDBACK USAGE				12 BALANCE VISUAL CUES		AIMING 27 CONTROL PRECISION	
STRENGTH					1 EXPLOSIVE STRENGTH GENERAL 2 EXPLOSIVE STRENGTH LEG EMPHASIS 3 EXPLOSIVE STRENGTH ARM-SHOULDER EMPHASIS 4 STATIC STRENGTH ARM-HAND SHOULDER EMPHASIS 5 STATIC STRENGTH TRUNK LEG EMPHASIS 6 DYNAMIC STRENGTH ARMS FLEXOR EMPHASIS 7. DYNAMIC STRENGTH ARMS-EXTENSOR EMPHASIS 8. DYNAMIC STRENGTH LEGS 9 TRUNK STRENGTH		
STAMINA					17 STAMINA CARDIO-VASCULAR ENDURANCE		
POSITION REPRODUCTION						48 POSITION REPRODUCTION	
AGGRESSION REACTION							68 AGGRESSION REACTION
INTERACTION SOCIAL							65 CLOSENESS OF INTERATIONS 66. AMOUNT OF INTERATION 67. STRENGTH OF INTERACTION

Figure 1. The Performance-Descriptor X Physical-and-Interactional-Categories Matrix (presented as a human-task mapping guide).

(2) Upon what dimensions and measures?

(3) With what tools?

(4) For what purposes?

Human performance prediction in man-machine systems must be concerned with three levels of measurement analysis:

(1) System requirements and appropriate system performance measurement.

(2) Human operator task analysis and the performance measures related to that level.

(3) Basic behavioral dimensions involved in human task performance.

Further, the precise interrelationships between these levels should be quantified. Tests must be related to human performance dimensions found in human operator tasks which are executed to help achieve system performance criteria. For tests to be meaningful in man-machine systems, quantitative transformations must be possible between levels. This required mapping operation turns out to be a formidable technical challenge.

Both the questions and levels of analysis can be combined into a single conceptual structure, as shown in Figure 2. The question of purpose is external to this matrix, but each of the first three questions can be asked at each of the three levels. The addition of an analytic requirement to interrelate these levels results in a Generalized Methodological Model which can be (1) used to evaluate the existing literature and (2) form a framework of requirements for future test development. To be general, one must at least postulate a hierarchical system structure consisting of many levels of embedded functional units, e.g., total system, subsystems/modules/etc...components, action elements. It may be uncommon to find a

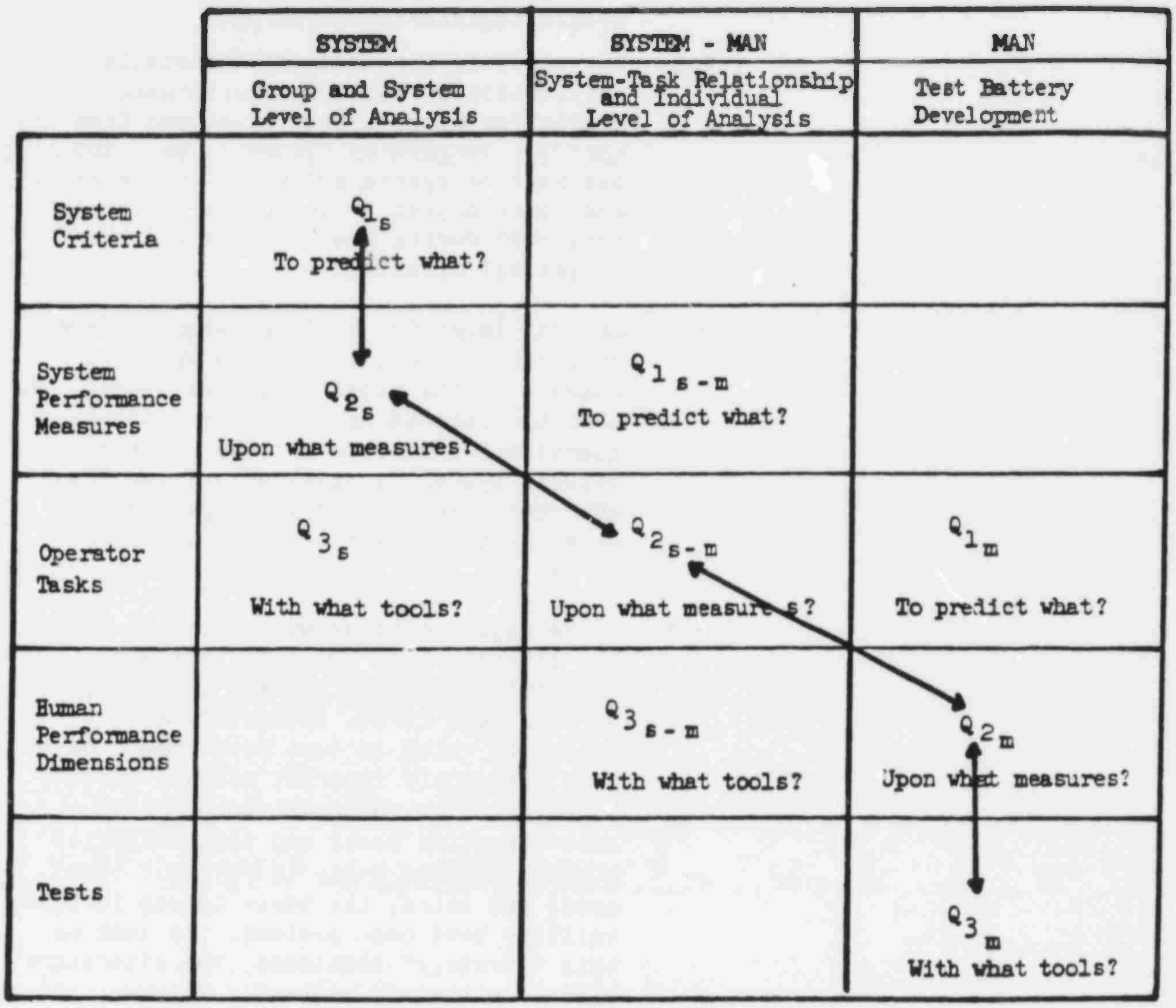

Figure 2. A generalized methodological model for human performance prediction.

complex system with such a clear-cut hierarchical structure; many system functional units may depend upon, or influence, many others. Consequently, the system organization may require a complex block diagram to display, but such a block diagram will also be required for other system engineering purposes.

2.2 The analysis was used in the detailed application of the human performance prediction methodology (developed from the approach implied by Figure 1) to a specific man-machine system activity: the celestial and space-object radiometry experiments conducted during the Gemini V and the Gemini VII missions.

4.1 Several intensive analyses were performed at several levels to provide specific answers to the above basic questions. The analytic outputs were in terms capable of quantitative measure and the relationships between system, system-man and the human operator levels of critical performance were identified with respect to these terms.

6.1 Three major problems were found to dominate the literature on human performance prediction tests in man-machine system performance; first, elementary and essential rules in test development have been frequently ignored; second, modern techniques for the development of cost-effective tests and test batteries through utility analysis have not been used; and third, the basic issues in test validity have been avoided. So long as this "strategy" continues, the literature will be extremely suspect. However, all of these difficulties can be resolved.

Many methods of task analysis exist within the literature, but a very thorough review of these methods failed to reveal any particular method of direct usefulness, showed the lack of standardization in the field, and suggested that a new attempt at a basic taxonomy was in order.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		As a result of trying out three different behavioral taxonomies, it was found that the effectiveness and usefulness of a taxonomy is a function of the following factors: (1) How appropriate the level of detail is to the purpose of the taxonomy. (2) How cleanly separated and appropriate the categories are. (3) How objectively and thoroughly the categories are defined. (4) In the case of the analytic behavioral categories, how completely the taxonomy covers the behavioral domain.

157

Fischl, M.A., Siegel, A.I., & Wolf, J.J. Application of a multiple task interactive model: Simulation of human performance in sonar maintenance. In G. W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	The paper describes an application of a digital computer simulation model aimed at predicting maintenance task performance in a sonar system under development. The model provides for simulation of one or two operators in a man-equipment interface situation.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The application described involved a simulation of the coordinated activities of a sonar technician and sonar supervisor in performing two representative maintenance tasks. The simulation examined the impact of different skill levels and time constraints on task performance.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	4.2	To employ the model, the task to be simulated must be broken down into subtasks (e.g., "depress pushbutton," "set toggle switch," etc.). Input parameters define time constraints, probability of successful execution, subtask sequence, and a variety of other actions.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	5.3	A number of recommendations for the sonar system under development were made based on the findings of the model application.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Foley, J.P., Jr. Criterion referenced measures of technical proficiency in maintenance activities (Final Rep.). Wright-Patterson, AFB, OH: Air Force Human Resources Laboratory, Advanced Systems Division, October 1975. (AD-A016 420).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.1	This study addressed the performance of maintenance personnel.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.2	The maintenance man's mission in a man-machine system is to ensure that the machine subsystem is in prime operating condition when the mission is started.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	A model battery of 48 criterion referenced Job Task Performance Tests (JTPT) were used in this study.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.2	A scoring scheme for the measurement of the task performance ability of maintenance personnel was developed.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	3.3	The following classes of job activities were considered: equipment checkout, alignment/calibration, removal/replacement, soldering, use of test equipment, and troubleshooting.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	3.4	After considering product, process and time as to their appropriateness for scoring results for each activity, it was decided that a test subject had not reached criterion until he had produced a complete, satisfactory product.
	3.5	Many factors were considered including the identification and clarification of tasks to be measured, the hierarchical relationship of maintenance tasks, the most effective order of measurement and the ease of test administration.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.1	The battery of tests included 48 tests, 81 problems and 133 scorable products. A profile for displaying the results of these tasks which attaches meaningful information to these numbers was developed. This profile contained information regarding a test subject's success on the full range of tests including a subject's job abilities, strengths, and weaknesses.
	5.3	Due to the unavailability of test subjects, the tryout was not as extensive as planned. The tryout did indicate that the tests as developed are administratively feasible. It is felt that their use would result in further modifications and improvements.

Foley, J.P., Jr. Performance measurement of maintenance. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, 1977. (AD-A053 475).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 6.2	This paper discusses the status of performance measurement for maintenance and describes how formal Job Task Performance Tests (JTPTs) have been replaced by paper and pencil theory and job knowledge tests. The paper states that research has indicated that these latter methods have proved unsuccessful in terms of measuring the ability to perform maintenance tasks. The author describes the Air Force Human Resources Laboratory (AFHRL) efforts to give consideration to the man-machine interface in performance measurement. One result of this effort has been the articulation of a structure for handling maintenance functions and their complex relationships in a systematic manner. Several problems concerning the research, development, and implementation of performance measurement were discussed and the paper ended with a proposal for future research and development efforts based on what has been accomplished. Five general areas of consideration were recommended: (1) Refinement of Model JTPT Battery (Electronic Maintenance). (2) Refinement of Symbolic Substitutes (Electronic Maintenance). (3) Development of Model JTPT Battery (Mechanical Maintenance). (4) Development of Symbolic Substitutes (Mechanical Maintenance). (5) Job Aptitude Test Research based on results of JPPT.

Ford, J.P., Harris, J.H. & Rondiac, P.F. Performance measures for AIT armor crewman (HumRRO-CR-D2-74-2). Alexandria, VA: Human Resources Research Organization, April 1974. (AD-A019 375).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	This report summarizes the procedures followed in developing performance measures for AIT (Advanced Individual Training) Armor Crewmen. The objective of the study was to establish definitive performance measures for those requirements considered relevant to job entry and to present these measures in the training objective format.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	3.1	The performance measures to support revisions in the Armor Crewmen AIT program were developed in three phases. (1) Development of a tasklist. (2) Written objectives and tests. (3) Selected tasks for training.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures		In the first phase a working committee (representatives from the Training Center, HumRRO and the Armor School) developed a task inventory. Following this activity each task was coded to reflect level of mastery that a man should achieve prior to entering an Armor unit. In phase 2 training objectives were developed. The goal of these objectives was to define entry level mastery for each task. The objectives included conditions for task performance and standards to evaluate proficiency of task performance. The third phase was to identify those tasks that were appropriate and feasible for AIT.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		In instances where time standards were not available in published doctrine, they were recommended by subject matter experts. When selecting the tests to be used for training, they were submitted to expert reviewers to assure accuracy of checkpoints, appropriateness of time limits and feasibility of administering tests.
	3.2	The majority of the tasks involved an observable procedure and most of the standards are tests of the process in performing the tasks. A time limit is included on the assumption that time to perform a task is an integral component of mastery.

Geddie, J.C. Profiling the characteristics of the developmental test participant (Tech. Memo. 31-76). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory, October 1976. (AD-A031 563).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 1.3	This report discusses methods to control the variance contributed by the human operator which influence the total system performance. It is proposed that human operators of the system which is being evaluated be selected according to criterion which eliminates personnel who fall at extreme ends of the distribution of values of relevant characteristics. Selection criteria should include: (1) Military Occupational Specialty (MOS), complete with skill level suffix. (2) Physical dimensions. (3) Sensory acuity. When selection has taken place, a more detailed description of his/her characteristics should be obtained as follows: (1) Actual value for the participant on each of the selection criterion measurements. (2) Scores from aptitude and MOS tests. (3) Experience (in months) in the relevant MOS. (4) Total service time. (5) Other related training, results of tests, level of performance attained.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(6) Education. It is noted that this procedure is not a radical change from current procedures. It suggests that some consistency be imposed in the selection process.
	5.4	It is felt that a long-run benefit from the proposed approach would be the development of performance based selection criteria. If a data base is built, it should be possible to develop a profile of levels of the characteristics which are required by similar tasks in other systems.

Geer, C.W. Navy manager's guide for the test and evaluation sections of MIL-H-46855 (D194-10006-2). Seattle, WA: Boeing Aerospace Company, Logistics Support and Services, June 30, 1977. (AD-A045 098).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.1	Two general types of test and evaluation methodologies were considered: (1) Development Test and Evaluation (DT&E) and (2) Operational Test and Evaluation (OT&E). A third category, Production Acceptance Test and Evaluation (PAT&E) consisted of testing production items to demonstrate that contract requirements of the system were met.
	2.2	HFE T&E (Human Factors Engineering - Test and Evaluation) existed to (1) Demonstrate system, equipment, and facility design conformance, to human engineering design criteria. (2) Determine man's contribution to performance requirements. (3) Quantify man-machine interactive measures of system. (4) Detect undesirable design on procedural features of system. Through these steps, this guide was designed to match particular techniques to particular applications, and describes how to utilize the techniques.
	3.1	The "real world" requirements that the HFE needs to verify in order to optimize the man-machine interface were technical

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		requirements of human performance, design criteria, safety, training, personnel skill/quantity, technical publications, and life support criteria; decision-making structures, data inputs, timing, level of detail, applications.
	4.1	T&E techniques consisted of direct manual, system measurement, indirect manual, automatic recording, physiological, and simulation.

Geer, C.W. User's guide for the test and evaluation sections of MIL-H-46855 (D194-1006-1). Seattle, WA: Boeing Aerospace Company, Logistics Support and Services, June 30, 1977. (AD-A045 097).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process		See abstract of similar document: Geer, C.W. Navy manager's guide for the test and evaluation sections of MIL-H-46855 (D194-10006-2). Seattle, Washington: Boeing Aerospace Company, Logistics Support and Services, June 30, 1977.
1.1 General System Measurements		
1.2 System Taxonomy Model (STM)		
1.3 Overall Conceptual Process Model (CPM)		
2. Contextual Components of the Process		
2.1 System Definition		
2.2 Mission Definition		
2.3 Environment Definition		
2.4 General Constraints		
2.5 Performance Requirements, Ultimate		
2.6 Performance Criteria, Ultimate		
3. Analytic Components of the Process		
3.1 Practical Measurable Attributes		
3.2 Practical Attribute Measures		
3.3 Performance Requirements, Specific		
3.4 Performance Criteria, Specific		
3.5 Measurement Procedures		
4. Planning Components of the Process		
4.1 Analytic Methods		
4.2 Parameter Determinations		
4.3 Apparatus for Testing		
4.4 Personnel for Testing		
4.5 Test Plans		
5. Application Components of the Process		
5.1 Test Execution		
5.2 Data Analysis		
5.3 Findings Interpretation		
5.4 Conclusions and Recommendations		
6. Further Research Areas		
6.1 Measurement System Limitations		
6.2 Research Potentials/Priorities		
6.3 Research Planning		

George, C.E. & Dudek, R.A. Performance, recovery and man-machine effectiveness: Final report on a basic research program under project THEMIS (Tech. Memo. 9-74). Lubbock, TX: Texas Tech University, April 1974. (AD-777 797).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This report is a final summary of many individual and interdisciplinary group studies conducted as a part of the total project. Each study had the goal of the project, performance and recovery of man within a work system, as a basic direction. In many work oriented groups it is required that missions be fulfilled while in, or just after being in, environments such as noise, vibration, or unfavorable climatic conditions. All of those factors affect human performance drastically. Other variables which affect human performance include task demands, motivational level, type of organization, and nutritional status, as well as others. It was the purpose of this research program to generate basic data concerning human performance and recovery under the conditions mentioned above. Experiments were conducted to study the effects of these variables singly and in combination on human performance and recovery. All experimentation was conducted within the framework of a task model as follows: (1) Items Measured (Dependent Variables): a. Performance Responses - Latency, accuracy, length of time, increments and decrements, etc.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		b. Physiological Responses - Oxygen consumption, GSR heart rate, skin and/or core temperature, urine analysis, etc. c. Training Responses - Subjective states or moods, attitude, learning, etc. (2) Measurement Conditions (Independent Variables): a. Task Demands - Amount of work, complexity, difficulty, work-rest cycles (duration), and ambiguity. b. Level of Motivation - Interpersonal response traits, drive state, reinforcement value, amount of deprivation, instructional set, etc. c. Nutritional History - Meal spacing, intake, social class, ethnic group membership. d. Environments - Effective temperature, vibration, normal, lighting conditions, etc. e. Work Systems Setting - Individual, team, crew. (3) Tasks Included: a. Man as a Machine b. Man as a Machine User c. Man as a Machine Controller d. Man as a Machine Servant e. Man as a Social Interactor In addition to the task model, research was guided by the military interest in continuous operations. The research team emphasized experimentation with relatively long-term repeated measurement designs.

Gephart, L.S. & Balachandran, V. A stochastic system effectiveness simulation model (Tech. Rep. UDRI-TR-70-12). Dayton, OH: University of Dayton-Research Institute, June 1969. (AD-865 449).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (OCPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The worth of any system is directly relatable to the confidence the user has in its ability to perform its designated tasks. Systems effectiveness and its fiscal corollary, cost effectiveness, consititute the most important area of concern to research and development management. As a result the Weapon System Effectiveness Industry Advisory Committee (WSEIAC) was established to develop a technique to apprise management of current and predicted system effectiveness at all phases of system life. The technique known as the WSEIAC model was developed for this purpose. This report augments the basis WSEIAC model development in three areas. One of these areas is the partitioning of system capability into hardware and personnel adequacy. System effectiveness may be defined as the probability that the man-machine complex system will successfully meet an operational demand and fulfill the predetermined mission objective within a given mission time when operated under stated conditions.

Gex, R.C. Personnel subsystem testing and evaluation for missiles and space systems: An annotated bibliography (SB-61-21). Sunnyvale, CA: Lockheed Aircraft Corp., Missiles and Space Division, April 1961.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	In the face of radical restrictions to traditional psychometric approaches, progress has been made in personnel measurement programs in connection with weapon systems developed by all three major branches of the military. It was felt that this program could not be found in single sources and therefore this literature search was designed to provide an annotated bibliography in four major areas: (1) Performance evaluation and unit proficiency. (2) Personnel requirements. (3) Training and training equipment. (4) Human engineering.
	5.4	Although many of the reports are concerned with equipment design, training development, and generation of personnel requirements information, it is very likely that the rationales and criteria adopted for such activities can provide guidelines for the subsequent test and evaluation. It is believed that this bibliography will be useful to personnel subsystem specialists in particular.

Goldbeck, R.A., Wright, K.A. & Fowler, R.L. Operator performance and panel layout for discontinuous tasks (AMRL-TR-70-137). Palo Alto, CA: Philco-Ford Corp., WLD Division - Human Engineering Section, March 1971. (AD-727 791).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	This is a follow-on to a previous investigation of panel layout. The purpose of this study is to determine whether or not previous findings generalize to discontinuous action sequences.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The system under study is a panel layout, controls, display hardware and operators.
	2.2	The arrangement or layout of controls and display should optimize operator performance.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	4.1	Analyses of variance were conducted on the two major dependent variables, total operating time per trial, and total errors of omission and commission per trial.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	4.3	The basic apparatus consisted of four major components: a subject's console; an experimenter's console; a diode matrix; recording and auxiliary equipment.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	4.4	Subjects were 200 male college students between the ages of 18 and 26 years, who met certain physical and scholastic criteria. All subjects were paid for their participation.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.5	The experimental design was formed by combining factorially three experimental task operations with four principles to produce 12 panels or groups of 10 subjects each. The principles applied were: Sequencing (SEQ), Functional Grouping (FG), Location by Frequency (FREQ) or Location by Importance (IMP). The action sequence was made discontinuous by dividing the dominant action path of the continuous study into twelve coherent segments with each segment beginning with a display and ending with a control action followed by a delay period.
	5.3	The major finding of this study is that the overall superiority of the Sequencing Principle has been confirmed using a discontinuous presentation of the operator's task. It is concluded that the most powerful tool available to the control panel designer is optimum application of the Sequencing Technique.

Greening, C.P. Unfinished business in the utility of visual detection models. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	1.3	The paper describes a visual detection model that has been subjected to a rather thorough validation study. The model provides estimates of target acquisition probability as a function of range. These estimates are used as a major input to an overall system effectiveness model. The visual detection model is a "glimpse model", i.e., the cumulative probability of target acquisition is obtained as the product of a series of single glimpse probabilities.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.5	Validation of the model was obtained by comparing the model's predictions for 34 selected targets with the results obtained in an experiment in which a number of observers viewed a motion picture presentation of a flight over those targets. The overall product-moment correlation between predicted and experimental median ranges was +.53.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	4.2	Certain "unfinished business" problems remain with each of the parameters involved in the model. These parameters are: (1) The probability of looking at the target. (2) Sensor resolution. (3) Inherent object/background contrast. (4) Sky/ground luminance ratio.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(5) Aircraft altitude above the target. (6) "Visibility" or meteorological range. (7) Threshold contrast. (8) Target dimensions. (9) Number of required resolution elements.
	6.1	A number of parameters currently are "missing" from the model, including: (1) Level of confidence [of the observer]. (2) Briefing and reference materials. (3) Search techniques. At present it is not known how these parameters should be handled.

Grunzke, P.M. Evaluation of the Automated Adaptive Flight Training System's air-to-air intercept performance measurement (AFHRL-TR-78-23). Williams AFB, AZ: Flying Training Division, July 1978. (AD-A060 320).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	The objectives of this study were to assess the effectiveness of a performance measurement package and to evaluate the efficiency of operational test and evaluation procedures developed as a data gathering tool for performance measurement. An operational test and evaluation was conducted on the capabilities of the Automated Adaptive Flight Training System (AAFTS) system prior to this study. The data gathered during the course of that effort provided the data source for this evaluation.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The AAFTS was installed on the F-4E #15 Weapon System Training Set (WSTS). The subject of this evaluation was the aircrew skills in Air-to-Air Intercepts (AAI).
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.2	The AAI program is broken into nine modes: (1) Single turn attacks (2) Increasing/decreasing aspect attacks (3) Stern conversion attacks (4) Stern conversion ID passes (5) Snap-ups (6) Single turn attacks with stern conversion reattacks (7) No lock-on attacks (8) No Ground Control Intercept (GCI) attacks
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(9) Tactical intercepts Each of the above modes has a number of steps within it. The steps were designed to present progressively more difficult intercepts as a function of the values of certain variables.
	3.1	In the AAI environment, variables often measured the geometry of attack, missile launch parameters, and other variables deemed important to an intercept. The AAFTS device used a scoring system of this nature. A set of 28 dependent variables were determined by the Operational Training Development Team (OTDT). These variables included measures of how closely the crews stayed to assigned airspeed; altitudes and headings; how accurately the crew launched missiles; whether or not correct missile launching control procedures were followed/accomplished; and other variables specific to particular types of AAIs.
	3.2	All variables had acceptable bandwidths of performance that the crew had to maintain in order to accumulate scoring points. While the AAFTS has a 28 variable standard format, only these variables relevant to the particular engagement underway were scored by the AAFTS system.
	4.1	T-statistics were used to test differences between the total scores (a summation of all the variables measured for each engagement completed) achieved by the crews for each mode. They were also used to test differences between two types of crews and on a variable-by-variable basis across modes wherever the particular variable was measured. The AAFTS device had specific point values assigned to performance error tolerance limits for each variable. An equal interval scoring technique was also employed to more accurately satisfy assumptions on which the statistic is based (i.e., a variable with scored values of 10, 8, 6, 3, 0 was arbitrarily rescaled to 4,

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		3, 2, 1, 0) and then between-groups differences were examined by mode and by variable.
	4.3	The AAFTS was a parasitic computer-based instructional device interfaced with the F-4E WSTS #15. The system can automatically score advancing aircrews through various programs including a 116-step AAI program.
	4.4	Seven operationally qualified crews and five student crews participated in the study.
	4.5	Training received by both crews was constrained by Tactical Air Command training requirements and OT&E limitations. The operational crews received experience in flying the F-4B WSTS #15 and the student crews were instructed using the AAFTS training device. Crews flew and were scored on nine different types of air-to-air intercepts that were programmed into the AAFTS device. The crews flew the simulator under different conditions--the operational crews were adaptively scheduled by the AAFTS as often as possible while the student crews flew what was dictated by the instructor.
	5.3	The data revealed significant differences favoring the operational crews in two types of attacks, single turns and stern conversions. On a variable-by-variable basis, there were three significant differences between operational and student crews, two of which indicated superior performance by student crews.
	5.4	The data warranted the following conclusions: (1) The AAFTS as an instructional tool has the potential to provide standardized and objectively scored training/ evaluation scenerios for aircrews.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(2) The performance measurement package performed adequately as an informational feedback tool but requires more research to select and validate variables that discriminate better between aircrew skill levels. Failure to discriminate could have occurred because the variables and their weights were based on the opinions of subject matter experts and not on empirical evidence. (3) Use of the OT&E procedures was minimally effective for a performance measurement but served well as a means for acquiring aircrew subjective impressions on the systems' overall training/evaluation potential.

Gustafson, H.W. The measurement of proficiency of Air Force maintenance personnel (ATPTRC SM 7-1957) Denver, CO: Air Force Personnel and Training Research Center, Air Research and Development Command, Lowry AFB, 29 July 1967. (AD-841 711).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	The purpose of this paper is to describe some of the deficiencies in Air Force proficiency assessment and to indicate broadly how these deficiencies can be corrected. In addition, suggestions are given for promising immediate research and development efforts.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	Air Force maintenance personnel and their training was the system addressed.
	2.2	The training must accomplish the job of making the maximum number of personnel adequately proficient during the training period.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.4	The Air Force competes with industry for the services of trained personnel and is not usually able to retain its personnel longer than a four-year tour. There is a need to train the maintenance personnel at a great variety of tasks, some of which require high levels of skill in a short period of time without further education, cross-training, or re-training.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	2.5	The researchers showed that there are no suitable over-all objective measures of performance and there was no ultimate criteria against which training standards and intermediate measures of achievement can be evaluated.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	5.4	It was concluded that the many deficiencies in current proficiency measurement of maintenance personnel can be corrected through a vigorous program of development
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		and implementation. However, such a program must have, as an integral aspect, the definition of training and job performance standards for each Air Force maintenance position. Only when performance is assessed against such standards can all of the requirements for proficiency measurement be met.
		It is recommended that the definition of training and job performance standards for selected critical maintenance positions be undertaken in association with the development of performance measures in order to serve as a model which can be applied to other Air Force maintenance positions.
	6.2	Recommendations were made for future research. They included:
		(1) Research to refine principles and techniques for assessing individual performance in troubleshooting and other complex tasks.
		(2) Research be sustained on improving maintenance records and supervisers' ratings as criteria of performance on the job.
		(3) A practical, procedural handbook be developed which can be followed in assessing performance capabilities.
		(4) That the preceding efforts be aimed at specifications for the development of proficiency measures for inclusion in weapon system development contracts.

Haight, F.A. Indirect methods for measuring exposure factors as related to the incidence of motor vehicle traffic accidents (DOT-HS-800-601). State College, PA: Pennsylvania State University, September 1971. (PB-205 031).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	This article dealt with exposure of categories of driver-vehicles to motor vehicle traffic (exposure in the narrow sense) or to all external hazards (exposure in the wide sense).
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	3.5	A number of different models for the measurement of exposure were considered.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	5.3	The Koornstra method showed sufficient agreement with real data to justify further exploration.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	5.4	The next step would be validation through use of other categorization, other time periods and other locations than used.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Hakansan, N.H. An adaptive method of test selection in system development (RM-5238-PR). Santa Monica, CA: The RAND Corporation, April 1967. (AD-653 942).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	In this report an adaptive model of the development process in weapons systems is presented which enables decision-makers to determine which tests, if any, should be performed at a given stage and what corrective actions, if any, should be taken when test results are known. The final checkout phase of the system is considered first. A model developed for the purpose of determining the optimal troubleshooting procedure when an operating system fails is an appropriate abstraction of this phase. The model is then generalized to include the case in which the object tested is destroyed. In addition, sufficient conditions for the optimality of the test procedures are given. Next, the problem of test selection in early stages of development is superimposed on the final checkout phase. A dynamic programming formulation is given which enables one to determine which test, if any, should be performed at any given stage and what corrective action, if any, should be taken. As a by-product, means for determining net benefits of a given test at a given stage is obtained. The situation in which there is serial dependence among certain test information messages is examined. Finally, it is shown that a model of parallel research and development efforts may be viewed as a special case of the model developed in this paper.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.4	While this model is presented in terms of relatively simple systems and tests, it is capable of handling systems and tests of a highly complex nature.

Hall, D.H. Confidence limits for measures of effectiveness in weapon system analysis (NWC TP 5437). China Lake, CA: Naval Weapons Center, May 1973. (AD-762 401).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	1.3	This report justifies the use of established statistical methods to obtain confidence intervals for measures of weapon system effectiveness.
	2.1	These methods apply to effectiveness measures that are generated by sampling mathematically simulated weapon/target encounters.
	4.1	There are two general sources of unreliability in computer simulations. (1) the computer program does not model the real world as closely as it should and (2) the number of encounters simulated is insufficient to yield statistically significant conclusions. The first sources of unreliability can be revealed and remedied by a model validation procedure. The second source of unreliability can be reduced by standard statistical methods by determining the proper sample size.
		It is demonstrated in this report that relatively straightforward statistical techniques can be used to generate confidence limits. Methods applicable for use with continuously distributed functions and with zero-or-one measures of effectiveness are briefly described with detailed illustrative examples.

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

Hammell, T.J., Gasteyer, C.E. & Pesch, A.J. Advanced officer tactics training device needs and performance measurement technique (NAVTRAEQUIPCEN72-C-0053-1, Vol. 1). Groton, CT: General Dynamics/Electric Boat Division, November 1973. (AD-922 929L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	This study was conducted to determine the advanced tactics training device needs for submarine officers and to develop a technique for measurement of tactical training performance.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.5	The determination of the requirements for the training and devices was made through the use of operational task analysis data, direct observation and discussions with qualified Navy personnel concerning the existing tactics training program and devices.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.5	Recommended tactical team trainer modification consisted of a diagnostic feedback display, a sophisticated instructor's console, a knowledgeable opponent capability, automatic performance measures, a standard training computer, and a trainee performance library.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	4.1	A performance measurement technique was based on a mathematical weapons system effectiveness model to measure trainee tactical performance.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	5.1	Application of the measurement technique to applied tactical scenario examples demonstrated its potential for performance evaluation.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Hanifan, D.T. & Knowles, W.B. Human performance in system effectiveness modeling: Issues, approaches and critique. La Jolla, CA: Dunlap and Assoc., Inc., December 1968.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This report is concerned with human factors engineering methodologies. It is particularly concerned with quantitative methods applicable to system engineering efforts. The role of human factors engineering in each phase of system development is summarized. The methods used by human factors personnel in performing the activities are largely heuristic. They include both quantitative and non-quantitative techniques. The variety of non-quantitative techniques is illustrated in the following table. Quantitative techniques come from both the physical and behavioral sciences.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

Illustrative Non-Quantitative Techniques in Human Factors Engineering

NAPRATIVE	TABULAR	GRAPHIC
Position Description	Task Equipment Analysis	Operational Sequence Diagram
Job Description	Task Analysis of Procedures	Maintenance Sequence Diagram
Task Analysis	Position-Equipment-Task Summary	Time Line Charts
	Task Analysis Worksheet	System Analysis and Integration Technique
LISTS AND RATING SCALES		
Equipment Evaluation Guide	System Requirements and Capability Analysis	Integration Task Index
Human Engineering Checklist	Maintenance and Handling Analysis	Mission Profiles
Physical Demands Form	Operational and Support Data Collection Sheet	Link Analysis
Job Psychograph	Performance Observation Record Form	Function Flow Diagram
Work Characteristic Form	Performance Factor Form	Multiple Process Chart Man-Machine Chart
	Task Analysis for Error Identification	Information-Decision-Action Chart

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		In defining an approach to the problems of incorporating human factors into system effectiveness modeling three basic issues should be considered: (1) The ways in which models are used (2) The kinds of human engineering data that are available, (3) The ways in which people are used in systems. A representative sample of some of the more important types of models are discussed. These include: (1) On-line simulations. (2) Control theory models. (3) Process models. (4) Task analysis models. (5) Human reliability models. (6) Operability index. (7) Technique for human-error rate prediction (THERP). (8) Technique for establishing personnel performance standards (TEPPS). (9) "Logical man". (10) Special models.

Hansen, D.N., Johnson, B.F., Fagan, R.L., Tam, P.L., & Dick, W. Computer-based adaptive testing models for the Air Force technical training environment Phase I: Development of a computerized measurement system for Air Force technical training (AFHRL-TR-74-43). Tallahassee, FL: Florida State University, July 1974. (AD-785 142).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	The purpose of this study was to explore the utility, from a psychometric and cost effectiveness standpoint, of a computerized adaptive measurement system in the Air Force technical training environment. This phase of the study was designed to produce an operational system ready to test technical training students adaptively.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	3.1	For the two blocks of instruction, a task analysis was performed and appropriate measurement items selected.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.2	A review of the literature indicated that two testing techniques showed promise: flexilevel testing and hierarchical testing. These procedures were modified by adopting a two-stage approach whereby a student would be branded into the testing net according to a regression estimate of his predicted score.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.5	Two courses were selected to implement these procedures: one was selected for implementation of the hierarchical testing and the other for flexilevel testing.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	4.1	The selected measurement items were incorporated into a computer program for adaptive testing. The testing procedures were programed in the TUTOR language supported by the PLATO system at the University of Illinois.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.4	Preliminary conclusions indicated that adaptive testing offers the potential for time savings up to 50%. It was found that a feasible computer system to drive the adaptive testing strategies could be relatively easily developed. The file handling and report generating capabilities of the PLATO system were found to require considerable ingenuity in programming.
	6.2	Three studies were designed to evaluate the adaptive testing approach: (a) a study to test and validate flexilevel testing, (b) a study to test and evaluate hierarchical testing, and (c) a study to explore testing of the examinee in the criterion zone.

Hansen, D.N., Ross, S. & Harris, D.A. Flexilevel adaptive testing paradigm: Validation in technical training (AFHRL-TR-77-35-1-). Memphis, TN: Memphis State University, July 1977.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	In this report, means to empirically assess a computerized adaptive testing model in an ongoing technical training system were presented.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The system studied was an Inventory Management/Materiel Facilities Training Course for Air Force personnel.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	The achievements of students in one section of the course were measured.
	3.2	An adaptive testing model was utilized. This model was a modification of Lord's (1971) flexilevel paradigm and consisted of (a) the sequencing of test items in a difficulty hierarchy, (b) adaptive entry into the test by students at a difficulty level appropriate to their predicted score, and (c) systematic movements of students up and down the hierarchy based upon their performance on preceding items.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	4.4	Four hundred and forty four airmen participated in this study. The student population selected was considered fairly homogeneous in characteristics pertaining to age, educational background, career goals, and military experience. The typical student was male (759 m, 259 f) an average age of 20, high school graduate with less than one year Air Force experience.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.5	Preparation activities included meetings with course instructors for briefings. Students were administered reading aptitude tests to provide predictor performance scores. Test items were administered separately with rate of presentation determined by the student.
	5.3	The results of this testing procedure revealed a high positive part-whole correlation between flexilevel and total test scores. Internal consistency indices were essentially equivalent. The flexilevel test required nine fewer items than the entire test, yielding a length reduction of 39.5% and time savings of over 18%. The interpretation of findings stresses the potential benefits of adaptive testing in terms of significant time reductions and maintenance of high standards of test validity.

Harrison, W.L. A theoretical basis for the concept of effectiveness (Master's Thesis). Monterey, CA: Naval Post Graduate School, October 1966. (AD-807 386).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The effectiveness of a system depends on its mission. With a narrow system and mission definition it is possible to measure the system's ability to achieve that mission directly through analytical models or experimental testing. A broader definition reduces the problem of sub-optimization created by the narrow definitions; however, valid analytical expression is now threatened. Therefore, the basic consideration in a system definition is "optimization" of the measurability - sub-optimization relationship.
	1.2	The lowest level of measurable characteristics are those numerous and distinct attributes of a system contributing to its effectiveness, for example, speed and burntime. The second level set of characteristics represents a manner of describing the system's effectiveness through a smaller and more general set of parameters. The elements of this higher level are combinations of basic attributes that describe a slightly more general system characteristic, for example, the range of the missile (as a function of the above two lower level attributes).
	1.3	From the definition of a system to a quantitative criterion of its value, the following steps are identified:

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(1) Define the mission as broadly as possible, being consistent with some concept of how its ability to achieve the former can be expressed quantitatively.
		(2) The system designed to accomplish the mission should be explicitly defined to some "boundary." The latter must separate the system from its environment; contributions from other elements or systems are incidental.
		(3) A criterion for judging the value of a system must be formulated and/or,
		(4) A method of optimizing the design or choice of system devised.
		(5) Based on the method of optimization chosen, certain types of measurements must be obtained for a complete set of characteristics at the highest level possible.
		(6) A method of expressing the effectiveness of a system as a function of the elements in a set must be designed, or if this measure can't be obtained with the desired confidence of correctness then,
		(7) The mission should be redefined such that effectiveness can be more confidently expressed.

Harry, H.P. RANN utilization experience. Case study number 10. Effectiveness measurement methods (NSF-RA-G-75-038). Washington, D.C.: Urban Institute, 1975. (PB-247 254).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	This project was designed to provide substantive information on the effects of government services in the community.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	Nine service areas were chosen for measurement. These were crime control, recreation, library, fire protection, transportation, solid waste, water supply, waste water, and citizens' complaints.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	For each of the above service areas, the project staff developed 15 to 20 new effectiveness measures.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.2	Examples of these effectiveness measures were: the clearance rate of arrests through court system, the percentage of individuals, by age groups, using a city recreation facility, circulation per capita of library materials, number and rate of injuries and deaths due to fire, and subjective measurements of passenger comfort on local transportation. Other measures included inspection results and response times. No procedures are described for deriving these effectiveness measures.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	5.1	Two cities (St. Petersburg, FL and Nashville, TN) were chosen as the experimental sites for this study. Data were collected by appropriately designed surveys of the user or providers of these services. A computer program for organizing and analyzing the data was developed.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.4	It was concluded that this study provided the tools and an implementation system that would afford local officials significantly improved information on their services. Specifically, the measures were intended to help identify current problem areas, indicate trends, inequities in service areas, and provide a data base for use in comparison research between cities. Cities throughout the nation are adopting the techniques derived from this project and the techniques are readily modifiable for almost any local government.

Helm, W.R. Human engineering design deficiencies: A comparative analysis of the P-3 and S-3 aircraft (NATC-SY-41R-76). Patuxent River, MD: Naval Air Test Center, March 1976. (AD-B010 940).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3 3.1 3.2 4.1 5.3	Engineering design deficiencies of two aircraft were examined to determine deficiencies of a human engineering nature. The following human engineering deficiencies were reported: erroneous, ill-placed, inaccessible, inconsistent, incompatible, missing, too complex, unclear, unneeded, and unreadable. In order to classify these deficiencies in terms of system hardware components, the following categories were adopted: display, control, workspace, lighting, life support, escape egress, seats, parachutes, canopy, and weapons system. The human engineering was considered deficient when it specifically violated the large list of display design principles, or the list of control design principles, which might lead to display or control induced operator errors. The critical incident technique was used to catalogue, describe and analyze the human engineering design deficiencies. The results indicate that there were substantial numbers of human engineering design deficiencies in relation to total engineering deficiencies. The results suggest that, although the airframes of the two aircraft are dissimilar, there was a basic similarity in the number and types of human engineering design deficiencies.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.4	Since display and control deficiencies accounted for approximately three quarters of the human engineering design deficiencies, it could be advantageous to both the design and evaluation personnel to concentrate more of their efforts in these two areas.

Helm, W.R. Human factors test and evaluation, Functional Description Inventory as a test and evaluation tool, development and initial validation study (NATC-SY-77R-75- Vol. 1). Patuxent River, MD: Naval Air Test Center, September 1975. (AD-B007 463L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	The purpose of this report is to describe and present a new method developed to evaluate the operational functions performed by crewmembers.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	This study addressed the human factors aspects of aircraft man-machine systems, in particular the S-3A aircraft and crew.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	A series of investigations were conducted analyzing the operational functions of crewmembers. Roles, duties and tasks performed by each crewmember were determined. Crewmember judgments were compiled to establish relative importance to mission success of these roles, duties and tasks, in addition to the frequency of performance on a typical mission, the training necessary to insure effective performance, and how effective the system was in accomplishing these operational functions.
	3.2	The technique described above results in a Functional Description Inventory (FDI). The FDI has the potential as a tool for providing quantitative assessment of the human factors aspects of aircraft man-machine systems.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	5.4	It is recommended that the development of the FDI technique be validated with fleet training crews, etc., through comparative analysis of Board of Inspection Survey (BIS) Yellow Sheet deficiencies.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

190

Henderson, R.L. & Burg, A. The role of vision and audition in truck and bus driving (Final Rep). Santa Monica, CA: System Development Corp., December 1973. (PB-230 776).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.1	This study addressed the commercial carrier driver, the accident record, and the driving task.
	2.5	The safe operation of buses and trucks was the ultimate performance requirement.
	2.6	The performance of the system in terms of safety could be determined by the number of accidents in which a driver is involved compared to test scores.
	3.1	The objective of the study was to identify, through analytic techniques, the basic visual and auditory requirements of the commercial carrier driver. A review of the literature was conducted, and a detailed, systematic examination of the driving task was undertaken, including interviews with drivers and direct observation of the driving task. Inputs from these sources determined the importance of each visual function, and determined the auditory standards to be tested.
	3.2	A device was designed and constructed that provided the capability of testing performance on visual performance parameters. Basic hearing loss data was obtained by means of a standard audiometric technique.
	4.1	Tests were administered to a sample of commercial carrier drivers whose performance on the various tests was compared against past accident history. Multiple regression analyses and a graphical analysis technique were used in data analysis.

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constrainta
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Componenta of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.4	236 subjects were recruited from a large trucking firm and two large bus companies also participated in this study.
	4.5	To evaluate experimentally both the results of the analytical effort and the test device, the entire battery of visual and auditory tests were administered to the subjects along with a questionnaire to derive biographical and driving pattern data. Driving record information was obtained from company files for each driver tested, including total number of accidents on file, number of "responsible" accidents on file, number of months covered by the files and total number of accidents and "responsible" accidents for the last 36 months.
	5.3	The new measures of visual performance were shown experimentally to relate to past driving records. However the limited size of the sample prevents generalization to the entire population. It is recommended that additional data be collected to increase sample size. If findings can be verified the probability is high that new visual qualification standards can be generated, resulting in a more valid screening procedure. The results of the analysis of auditory data are not so positive. Assuming the results are not antifactual, hearing loss standards presently allowed are not related to accident involvement. The question of whether standards are too strict cannot be answered experimentally.

Hicks, J.A. A methodology for conducting human factors evaluations of vehicles in operational field tests (Draft). Fort Hood, TX: U.S. Army Research Institute for the Behavioral and Social Sciences, Fort Hood Field Unit, June 1977.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	The purpose of this research was to develop a standardized methodology for conducting human factors evaluation of trucks and similar vehicles in operational field tests.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The system is composed of trucks and similar vehicles within the context of operational field tests.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	Eighty-five human factor characteristics relevant to vehicle design and evaluation were selected for measurement and they were organized into six principal categories: Driver compartment, visibility, control and control operations, instruments, handling characteristics, and ride characteristics.
	3.2	The method for measurement of these characteristics focused on the assessment of users' judgements of the vehicles being evaluated.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.5	The methodology used was the Human Factor's Vehicle Evaluation Instrument (HFVEI). Upon completion of the test drive, the driver was interviewed and used a six point rating scale - extremely acceptable to extremely unacceptable. In addition, the drivers were required to rate the relative importance (weight) of each of the 85 characteristics.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	4.1	The data were analyzed using Analysis of Variance (ANOVA) and post-hoc multiple comparison techniques.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.2	Test parameters included the elimination of those drivers who could not meet minimum performance standards; the training of interviewers, the familiarization of drivers to procedure; the establishment of a test course with a variety of representational tasks over terrain appropriate for vehicles. The order of driving the course was counterbalanced and the driver interviewed while still in the driving seat.
	4.3	This evaluation compared a non-standard 3-1/2-ton cargo truck with both a standard U.S. Army 2-1/2-ton truck and a 5-ton cargo truck. The test took place around a four-mile test course.
	4.4	Twenty-nine licensed U.S. Army truck drivers were trained to drive all three types of vehicles.
	5.3	The data analyses revealed that the drivers judged the 3-1/2 ton and 5-ton vehicles to be significantly better than the 2-1/2-ton vehicle from a human factor's standpoint. There were no significant differences between the 3-1/2-ton and 5-ton trucks.
	5.4	The evaluation methodology should be of use to all agencies conducting user tests of trucks and similar vehicles.

Highsmith, R.C. Proposed measure of effectiveness for human resource availability periods and their impact upon unit operational readiness. Monterey, CA: Naval Postgraduate School, December 1976. (AD-A036 028).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.1	The following aspects of commands were measured: (1) Command Climate: Communication Flow, Decision-Making, Motivation, Human Resource Emphasis, Lower Level Influence. (2) Supervisory Leadership: Support, Teamwork, Goal Emphasis, Work Facilitation. (3) Peer Leadership: Support, Teamwork, Work Facilitation, Problem Solving. (4) Work Group Processes: Work Group Coordination, Work Group Readiness, Work Group Discipline. (5) Satisfaction (6) Integration of Men and Mission (7) Training (8) General (9) Equal Opportunity (10) Drug Abuse (11) Alcoholism Prevention (12) Community Interrelationships

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.3	The purpose of this study was to develop a methodology for evaluating the impact of the Human Resource Management Support System (HRMSS) in those commands where it is utilized. Its primary mission was to assist those commands with trained specialists in order to provide assistance in increasing the overall performance of its personnel toward goal attainment and quality performance.
	2.4	Several limitations characterized this study: (1) Data samples used to test the two hypotheses were necessarily smaller than those required for rigorous statistical analysis. (2) Data used to test both hypotheses were from different units (test sites).
	3.1	This study centered around two hypotheses: (1) There will be no significant difference in response between the Human Resources Management (HRM) specialists and the commanding officers regarding how well the various Human Resources Availability (HRAV) activities were accomplished. (2) Comparison of units participating in an HRAV with control units will statistically differ in a significant manner.
	3.2	Two questionnaires were designed to test the first hypothesis. One tapped HRM specialists regarding their assessment of their own performance; also, the commanding officer of the unit receiving the services was asked the same set of questions. AB513 The second hypothesis would lead one to expect some degree of positive change in unit performance as measured by recognized

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		performance criteria. This was measured by comparison of unit performance in the area of interest with the HRAV being the independent variable.
	4.1	A Likert-type scale was administered to relevant respondents and data were analyzed through the use of chi-square tests of significance and regression equations.
	5.3	It was concluded that the various HRAV activities had merit to the commanding officers and that the HRM Support Team perform those activities at an acceptable level of effectiveness.

Hill, J.W. & Eddowes, E.E. <u>Further development of automated GAT-1 performance measures</u> (AFHRL-TR-73-72). Menlo Park, CA: Stanford Research Institute, May 1974. (AD-783 240).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	1.3	This report describes a systematic, statistically-directed search for automated flight measurements that correlate with pilot proficiency.
	3.1	In experiment 1, four different flight tasks of about 10 minutes long were measured. In experiment 2, six additional tasks were measured.
	3.3	Pilots' performance during various simulated flight tasks was required for this evaluation.
	3.5	Three hundred and twenty six measurements over the four task series in the first experiment and 2436 measurements in the 2nd experiment were made. Many measurements had the same name but were measured in different tasks. A numbering system was used to identify each of them.
	4.1	Tables of more than 400 important measurements were developed with group means and standard deviations and further cross-tabulations showing which tasks and families of measurements best discriminate among pilots. Three different statistical methods were used to select a set of measurements from experiment 1 and combine them into two canonical variables, each a linear weighted combination of the measurements in the set, to discriminate optimally among the three groups of subjects. Applying the canonical variables to the repeated measurements of Experiment 2 allowed several deductions about the best selection procedures to be made.

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.3	This approach utilized a GAT-1 trainer, a Line-8 computer system and pilots.
	4.4	Subjects (30 in each experiment) were selected on the basis of their flying experience. One group had less than 10 hours experience, the second group had 25-50 hours, and the third group had more than 100 hours of experience. The majority had had some experience in the GAT-1 trainer. Some subjects volunteered, others were paid.
	4.5	Before each subject was asked to perform the series of maneuvers, a warm-up period was allowed to familiarize pilots with the GAT-1 and its flight characteristics. The warm-up period varied depending on the skills of the pilots. In experiment 1 the major tasks were: (1) Roll and pitch tracking. (2) Roll and pitch tracking with power changes. (3) Flight profile. (4) ILS landing approach. In Experiment 2, the following tasks were added: (1) Roll tracking. (2) Roll, pitch and yaw tracking. (3) Reduced bandwidth roll tracking. (4) Reduced competence roll tracking. (5) Ground reference turning maneuver. (6) Altitude position tracking.
	5.4	The results show that there is little difficulty in obtaining measurements that correlate significantly with experience.

Holshouser, E.L. Guide to human factors engineering General Purpose Test Planning (GPTP) (TP-77-14). Point Mugu, CA: Pacific Missile Test Center, June 1977 (AD B022 013L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1 and 2.2	The purpose of this document was to provide the Navy with a generalizable Test and Evaluation (T&E) planning scheme which can be more easily reviewed and evaluated in addition to providing a basis for implementation monitoring and systematic data analysis. In brief, the generalized T&E plan describes the details that the Human Factors Engineer (HFE) should consider when preparing or implementing a plan for a specific weapon system. The essential elements of this system covered planning, conducting, reporting, and correcting; the system becomes more detailed as the tasks and sub-tasks become smaller in scope.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	3.1	The characteristics of the system consisted of the following: review of test plan requirements; review general and/or detailed specifications; review previous test data; prepare general test plan; detail the test plan; negotiate and/or revise test plan; commence testing within given constraints; document human factors deficiencies; prepare the human factors input to project office T&E final report; prepare separate report for the Feedback Loop Action Generation (FLAG) information system; negotiate for follow-on human factors effort; participate in product improvement and deficiency correcting programs.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.2	Examples of how the above system components were quantified are given in detail. Examples of these sub-routines, in respective order, are as follows:

(1) Determination of phase and scope of T&E, determination of scheduling.

(2) Budget constraints, and manpower requirements.

(3) Review of weapon system documents for relevance to human factors.

(4) Review analytical efforts, simulations, modeling, etc., conducted during concept validation.

(5) List areas to be investigated.
(6) Determine safety factors to be incorporated into the aircraft/weapon system.

Possible areas to be investigated may consist of such factors as crew station geometry, anthropometrics, and controls/displays; moreover, questionaire checklist tests must be specified and instrumentation requirements listed. Project office personnel should be consulted regarding test parameters and data collection methods; finally, the report itself follows a standard format which meets the requirements of the FLAG system.

House, E.R. Assumptions underlying evaluation models. Educational Researcher, 1978, 7(3), 4-12.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The basic theme of this paper is that all the evaluation models are based on variations in assumptions of liberal ideology, the conceptions of liberal democracy. The models differ from one another as the basic assumptions vary. The paper describes some evaluation models and explains their premises. It is part of a larger work which attempts to present a comprehensive analysis of evaluation.

Hyatt, C.S. & DeBerg, O.H. A scoring system for the quantitative evaluation of pilot performance during Microwave Landing System (MLS) approaches (ASD-TR-17). Wright-Patterson AFB, OH: Aeronautical Systems Division (AFSC), August 1975. (AD-A025 782).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Furtner Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.1 2.2 2.4 2.5 3.1 3.2 4.1	This evaluation addressed the Microwave Landing System (MLS) including aircraft and pilots. A number of landing approach patterns with multiple aircraft were selected for this study. It was noted that aircraft using the same airspace are likely to have a wide spectrum of interpretative capabilities. The constraints for use of this equipment are weight, space, capital and maintenance costs. The ultimate requirement is that the system provide accurate information regarding an aircraft's position during a landing approach. Deviation in position and speed from planned glide path were measured. Errors across track, along track, above and below glide path and speed along path were determined. The descent rates were compared with the criteria and the difference was defined as error. Error values were modified to relate to their size and significance. The modified error value was weighted for each parameter to reflect its true influence relative to other parameters. The modified and weighted error values were combined into score(s).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.2	A limited number of typical approaches and rates of descent were selected for this analysis.
	5.4	This scoring system works and is being used for other MLS systems.

Hunter, B. Report on the final acceptance test for CTS (Computerized Training System). Alexandria, VA: Human Resources Research Organization, August 1976. (AD-A033 400).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	The Phase III Computerized Training System (CTS) Final Acceptance Test Plan was conducted in five levels that corresponded to five test objectives: Level I: Verification of Phase II Software Tests. Level II: Reliability. Level III: Verification of Phase II Class I Language Tests. Level IV: Response Time. Level V: Full Operational Load.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The CTS, a full 128-terminal system, was under investigation in the present study.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.3	The primary objectives of the test were to determine whether the full 128-terminal system will operate under operational live user conditions and meet contract requirements for reliability and response time.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.4	As regards reliability the system must achieve a minimum of 95% under specified conditions. Up-time refers to the capability of the hardware and software to perform basic tasks of system initiation, program compilation and execution, job and file management, and program library maintenance.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Regarding response time, performance specifications for the 128-system state that there shall be a 90% probability that the response time will be 2 seconds or less.
	5.4	Since the system did not meet reliability objectives (plus had an insufficient number of response time recordings for a representative sample), it is recommended that the system not be accepted in its present state. Following debugging of the present problems, further retesting of the system for overall performance is recommended.

Hutchins, C.W. A Computer Aided Function Allocation and Evaluation System (CAFES). Proceedings of the Human Factors Society Annual Meeting, Huntsville, AL, October 15-17, 1974.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

1.3 The Computer Aided Function Allocation and Evaluation System (CAFES) is a support tool for Human Factor Engineers (HFE) conducting man-machine research, requirements analysis, design, test, and training and maintenance systems development. The CAFES program's principle objective is to facilitate application of essential elements of human factors technology in systems development using automatic data processing techniques in order to analyze and evaluate crew subsystem performance as it affects total systems effectiveness.

2.1 The CAFES was being developed to provide the HFE with an integrated system of computer models which progress from early concept formulation phase through crew station design to the final test and evaluation of the completed system.

2.2 The CAFES objective was to allow the HFE to treat in a comprehensive way all parameters to be considered in the designing of a man-machine interface of advanced Navy systems.

3.1 The CAFES models were, in fact, composed of six integrated sub-models:

(1) A Data Management System (DMS) which provides baseline data for all the models.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

(2) A Function Allocation Model (FAM), which is a collection of computerized algorithms that helps derive and process various alternatives for allocating functions to operator(s) and machines.

(3) A Workload Assessment Model (WAM) which considers the human performance aspect of man-machine function allocation schemes on a time and cumulative tasks basis to determine if man can perform all of the tasks derived from the functions that compose one or more missions. The model also determines those periods when man is overloaded in terms of time availability versus time required to do all tasks.

(4) A Computer-Aided Design (CAD) which will furnish aids to the designer in producing crew station configurations that are consistent with mission requirements.

(5) A Crew Station Geometry Evaluation (CGE) which evaluates the physical geometry of a crew station.

(6) A Human Operator Simulator (HOS) which provides a generalized model of a seated human being in a task environment with limitations on time and goals.

3.3 The specific performance requirements of the above models were as follows:

(1) DMS: its major functions are data input and storage, file modification, CAFES Executive, error diagnostics, report generation.

(2) FAM: predicts overall system effectiveness and generates crew operational procedures for detailed evaluation of promising allocation

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		candidates. (3) WAM: crew workload is analyzed on the basis of how workload varies in each performance "channel" (vision, hands, feet, etc.). (4) CAD: assists in crew station geometry development, design analysis, and design drawings. (5) CGE: functions includes man-model simulation (computes body configurations approximating human movements during task taxonomy), conducts interference analysis (identifies visual or physical interference for various crew members executing a task sequence), evaluates military standard and specification compliance. (6) HOS: serves to simulate human operator performance in aircraft systems, interfaces directly with the hardware simulator, provides simulated human performance output, and re-examines human performance workload and task duration in an operating environment.
	5.4	Computer techniques can only assist the HFE, not substitute for his judgment. The computer can assist the engineer in design and analysis tasks by recalling/processing data and performing simple logic operations. The responsibility of the HFE remains with interpretation of effects from system requirements, performance criteria, and trade study results in defining system specifications.

Irish, P.A., Grunzke, P.M., Gray, T.H. & Waters, B.K. The effects of system and environmental factors upon experienced pilot performance in the Advanced Simulator for Pilot Training (AFHRL-TR-77-13). Williams AFB, AZ: Air Force Human Resources Laboratory, Flying Training Division, April 1977.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

2.1 The system being studied was the Advanced Simulator for Pilot Training (ASPT) configured as the T-37 aircraft.

2.2 The mission included five specific flight maneuvers: takeoff, GCA, 360 degree overhead patterns, aileron rolls, and slow flights.

2.3 The environmental conditions in this study included three levels of wind, three levels of turbulence, and two levels of ceiling/visibility.

2.4 The constraints on the system were those of the ASPT which include six degrees of freedom motion platforms providing approximately three feet of vertical travel and four feet of horizontal travel. Displacement capabilities included: pitch - 20 degrees to + 30 degrees; roll ± 22 degrees; yaw ± 32 degrees. The pneumatic G-seat provided more continuous cues than the motion platform in response to requirements for each particular maneuver. The visual system was comprised of seven 36-inch monochromatic CRT's giving the pilot 110 degrees to -40 degrees vertical cuing and ± 150 degrees horizontal.

3.1 and 3.2 The dependent variables used in this study were derived from the ASPT Automated Performance Measurement System which is a criterion-referenced approach to measurement. Because most skillful piloting involves the attempt to maintain or change to specified flight parameters criteria, deviations from these desired parameters provides the method of quantitative objective performance measurement. Some examples of the dependent variables (measures) reported in this study include:

(1) Deviations from prescribed flight parameters.

(2) Power applied to control surfaces.

(3) Scores formulated from multiple factors.

3.5 Each subject flew one profile 72 times and the other 27 times during the course of the study. The profiles were randomly ordered for all subjects. Each session was begun with instructions provided by a computer driven word generator. Each maneuver was begun on command and completed when selected criteria were satisfied. At the completion of each maneuver within the profile, the console operator entered comments on any system malfunction or errors experienced during the maneuver. All other data values were recorded by the ASPT computer at an iteration rate of 3.75 to 15 times per second.

4.1 A multivariate analysis of variance was used for data analyses. The statistic used in determining significant effects was the Wilks Lambda.

4.2 The independent variables of the test were as follows:

(1) Wind (0, 12, 24 knots from 60^{o})

(2) Turbulence (none, light, moderate)

(3) Ceiling/visibility (clear and minimum (200 ft/1/2 mile)).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.3	The primary test apparatus was the six-degree-of-freedom Advanced Simulator for Pilot T-aining configured as a T-37 aircraft cockpit.
	4.4	The test subjects were three T-37 instructor pilots whose flying time ranged from 550 to 900 hours.
	4.5	Two separate experimental designs were used. The first was structured to evaluate main, first-order interaction, and second-order interaction effects of all six independent variables. The second design was a partially compounded factorial which used four independent variables, each with three levels.
	5.1	Subjects were scheduled on a day-to-day basis depending on ASPT system availability.
	5.4	In this study, each of the system configuration variables produced significant effects. The dependent variables used to measure performance in this study showed that manipulation of the three environmental variable combinations produced changes in system-oriented dependent variables. Similarly, changes in the pilot input variable were concomitant with simulator configuration changes.

Jahns, D.W. A concept of operator workload in manual vehicle operations. Meckenheim, BRD: Forschungsinstitut für Anthropotechnik, December 1973.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This report represents an initial attempt to scope, through a literature review, the complexity of developing a conceptual structure (model) of operator workload. The ultimate goal is to develop a quantitative index of operator performance for any point in time during a given vehicle operation. The operator's role is basically that of a data transmission and processing link between displays and controls of any vehicle. The operator's basic functions are sensing, identifying, and interpreting. Workload is the extent to which an operator is occupied by a task. It can be divided into three functionally relatable attributes: input load, operator effort, and work result. Four categories of workload research were identified during the literature review: (1) Time-and-motion studies. (2) Information processing status. (3) Operator activation-level studies. (4) Equipment design - implicit studies. The report describes each in detail and presents their advantages and disadvantages.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		The report concludes from the literature survey that, in general, the approach to workload research has been either too molecular or too molar to provide the broad spectrum of data required during various phases of crew system design and evaluation. A number of potentially useful techniques are available to partially provide meaningful, quantitative answers on many parameters influencing operator effort. These techniques need to be systematically evaluated and integrated in the specific context of design requirements. Because of the complexity of factors affecting human behavior and our limited knowledge regarding operator capabilities and limitations, no absolute measure of workload exists.

Jahns, D.W. & Katz, R. Preliminary concepts for Computer Aided Function Allocation Evaluation System (CAFES) (NADC-72106-CS). Seattle, WA: The Boeing Company, Aerospace Group, May 1972. (AD-902 670L)

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

Topic No.: 1.3

This study describes a comprehensive crew system development tool called CAFES (Computer Aided Function Allocation and Evaluation System). The CAFES concept is a set of submodels working in conjunction with a data/information management system. Each submodel may be used individually or in combination with one or more of the others depending upon the data requirements (and system definition). The modular nature of CAFES provides flexibility for integrating the parameter in the definition and evaluation of the human role in naval aircraft systems. The mission of CAFES is a reduction in performance time and increased quantification for the following human factor tasks:

(1) Perform and evaluate man-machine function allocations.

(2) Develop design concepts/requirements for each crew work station.

(3) Identify potential human factors engineering risks.

The following are descriptions of the various submodels which make up CAFES:

(1) The Functional Allocation Model (FAM) is a collection of computerized algorithms that will, in conjunction with the Data Management System (DMS) and crew system designer, derive and process various alternatives for allocating functions to operator(s) and machines. The FAM will identify and organize system function to an

allocable level, identify and rank order function allocation schemes, and will provide detailed communication with the available system definition at any point in the development cycle.

(2) The Workload Assessement Model (WAM) considers the human performance aspects of man-machine function allocation schemes to determine whether man can perform all of the tasks derived from the allocable functions that make up one or more missions. The submodel uses a timeline of mission duration and determines those periods when man is overloaded, necessitating either a reallocation of that function to machine or additional crew or a modification of the system requirement.

(3) The Computer-Aided Design (CAD) furnishes aids with which the designer can develop crewstation configuraticns compatible with the men who will work in them, consistent with the missions to be performed, and constrained by military design standards and specifications as well as technical and cost considerations.

(4) The Crewstation Geometry Evaluation (CGE) program is a standardized method for evaluating the physical geometry of a crewstation. It evaluates the physical compatibility of a seated crewmember of any size with any crewstation as soon as a design concept is available.

(5) The Human Operator Simulator (HOS) is a generalized model of a seated human being in a time-based, goal-oriented, task-processing environment. It is used in parallel with the CGE submodel in the CAFES system to evaluate the

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		function allocation as well as the adequacy of the crewstation design. It determines operator workload as well as procedure (task) duration, movement distance, and sequence statistics going from one control to the next.
		(6) The Tradeoff Analysis Routine (TAR) is used after the CGE and HOS models have been run and modification to the weapon system are necessary from a geometric or workload point of view. The crew systems designer must decide whether it would be most effective to modify the design to eliminate the problem or to reallocate one or more functions to eliminate the problem.

James, L.R. Criterion models and construct validity for criteria (72-32). San Diego, CA: Navy Medical Neuropsychiatric Research Unit, August 1972. (AD-770 412).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	Methods pertaining to the measurement of criteria and ascertaining underlying criterion constructs were reviewed. Three criterion measurement models, i.e., the ultimate criterion model, the multiple criterion model, and a "general" criterion model for the determinants of managerial effectiveness, were examined and attempts made toward integration. The three models were compared to a formal construct validation model, and strengths and weaknesses in both the constructs provided by each of the criterion models and construct validation procedures were discussed. An integrated multiple and general criterion model and construct validation procedures more extensive than the multitrait-multimethod matrix were recommended for future criterion research.

Jaschen, D.G. Mechanized Infantry Combat Vehicle, XM723, system operational climatic test (TDP-OT-67A). Falls Church, VA: U.S. Army Operational Test and Evaluation Agency, Test Design Division, 1975. (AD- B008 212L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		
	1.1	This report describes a plan for testing the Mechanized Infantry Combat Vehicle (MICV).
	2.1	The MICV system is a companion to the main battle tank and is composed of four parts: the vehicle itself, the primary armament, the secondary armament, and the supplementary armament.
	2.2	The vehicle's ultimate functions are as follows: mounted fighting capability for one mechanized infantry squad; swim and cross-country mobility; full protection of the infantry squad from small arms; etc.
	2.4	The MICV system is to be tested under certain climate conditions mainly characterized by "winter thaw."
	2.5	The primary role of the MICV lies in its offensive weapons capability.
	2.6	In this role, the MICV is expected to improve mobility, protection, firepower, survivability, reliability, crew comfort, etc.
	3.1	Characteristics of the system which will be measured include: mission performance, survivability, availability, training, and logistics.
	3.2	Measurement of the above may be performed by measuring the speed, range, and maneuverability degradations caused by snow, mud, and frozen ruts (for "mission performance"); ability of MICV to be

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		effectively camouflaged (for survivability); ability of crew to perform maintenance and service of the MICV (for availability); techniques of vehicle operation (for training), etc.
	4.2	Test parameters include day and night conditions and live fire conditions. Organization, doctrine, training, and limited logistical support will be factors held constant; terrain and weather will be uncontrolled.
	4.1	Data collected will be analyzed and reported in relative terms (not quantitative). RAM data will be qualitative; reliability will be limited to a consolidation of data regarding malfunctions which occur, impact of malfunctions, and maintenance problems associated with them. Availability will be measured through records on uptime and downtime of system. Maintainability will be observed under winter thaw conditions and will be established through observations of the test experience.
	4.4	Participants will perform mechanized infantry squad and scout team tactics as prescribed.

Johnson, E.M. & Baker, J.D. Field testing: The delicate compromise. Human Factors, 1974, 16(3), 203-214.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1	This paper selectively compares human factors field testing with laboratory experimentation. The basic steps of research design provide a point of departure to illustrate the differences between laboratory and field research. Differences in problem recognition are described. It is noted that the laboratory researcher often uncovers a research problem by exhaustive examination of the literature. In contrast, a problem for the field researcher typically originates with questions from a sponsor/user group. A table is presented which charts the stages of a system's life and ties these stages to the associated events that aid problem recognition. It is evident that the precision of the evaluation data is a direct function of the stage of life at which the problem is identified.
	4.1	Problem recognition is only the first link in the chain of thought necessary for planning a successful research study. The next step of the experimental method should follow in a standard order. The differences between laboratory and field testing in the basic steps of a research design are presented on the following page.
	5.4	While it can be noted that there are great similarities between laboratory experimentation and field research, many subtle, but critical, differences exist in the substance. Field testing is not a simple extension of the laboratory into an operational setting.

Major Differences in Hypotheses

Characteristic	Type of Study	
	Laboratory	Field
Sources	Literature search Theory/prior data	Colleagues and institutional reports System model
Derivation	Deductive	Inductive
Definition	Precise	Vague
Number	Few	Many
Type of Test	Null hypothesis	Positive hypothesis
Purpose	Develop further research/theory	Answer a question

Major Differences in Independent Variables

Characteristic	Type of Study	
	Laboratory	Field
Selection	Ad hoc; experimenter determined	Post hoc; system determined
Number	Few	Many
Relationship Between	Orthogonal	Nonorthogonal
Definition	Precise	Vague (easily confused with dependent variables)
Durability	High	Low-obsolescent

Major Differences in Dependent Variables

Characteristic	Type of Study	
	Laboratory	Field
Selection	Ad hoc; experimenter determined	Post hoc; system determined
Measures	Human performance	Human performance/system performance
Definition	Precise	Vague (easily confused with independent variables)
Number	Few	Many
Relationship Between	Independent	Unknown intercorrelation
Type of Measure	Quantitative	Often qualitative
Sensitivity	Linked to independent variable	Linked to system performance
Desirable Sensitivity	Statistical	Practical

Major Differences in Control

Characteristic	Type of Study	
	Laboratory	Field
Experimental Error	Replications	"One trial"
Experimental Controls	Matched groups/control groups	Usually one group
Protocols	Well defined	Vague
Intrusive Factors	"Controlled"	Uncontrolled
Physical Environment	Controlled	Natural
Time	Broken into short segments (trials)	Continuous-mission/scenario shift time
Scale (Logistics)	Small	Large
Variables Driven By	Experimenter	System

Major Differences in Subjects

Characteristic	Type of Study	
	Laboratory	Field
Source	"College Sophomore"	User Population
Motivation	Implicit	Explicit
Attitude	Positive	Neutral (or negative)

Major Differences in Output/Reports

Characteristic	Type of Study	
	Laboratory	Field
Frequency of Report	Low--determined by quality	High--determined by cost
Audience	One--professional community	Many: user/sponsor; management; professional community
Dissemination	Wide--professional journal	Narrow--institutional report
Ethics	Individual	Organizational
Result	"Publish or perish"	"Publish and perish"

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Techniques, procedures and research strategies differ. However, a technology is evolving to bridge the gap between the two research domains. Recognizing the problem and describing its dimensions does not solve it. There are few reports of attempts to validate laboratory findings in the field. Some indicate success, others indicate failure.
	6.1	Limitations in the methods and data of human factors tend to prevent the accurate prediction of human performance in operational settings. What still is required is an approach to research design which will, in fact, coordinate the laboratory and the field.

Kagerer, R.L. & Weiss, E.C. Development of a checklist and guidebook for human factors evaluation of general equipment (Final Rep.). Alexandria, VA: The Matrix Corporation, January 1968. (AD-827 808).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This report describes the development of two documents: "Human Factors Evaluation Data for General Equipment" (HEDGE) and "Guidebook Supplement." These products were designed to provide test engineers with a human factors evaluation guide to potential human factors problems for the various types of equipment tested and a methodology for conducting these evaluations. These documents were designed specifically for use by personnel with engineering qualifications who have had little or no exposure to human factors evaluation techniques. The work was conducted in three phases. Phase I consisted of defining requirements for human factors testing and analyzing current test and evaluation practices. A classification system for test items and test functions and an exhaustive listing of the requirements and constraints for the contents and format of the human factors guide were developed. Phase II developed the format and content of the guide. The HEDGE document consists of four major sections: (1) how to use HEDGE, (2) an index and associated definitions, (3) detailed data sheets, and (4) appendix. The detailed data sheets are the heart of the strategy proposed. Since the major emphasis in human factors evaluation is the nature of the interaction between man

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		and the item, these sheets attempt to detail the man/item tasks that must be performed on all (or most) items in a given subclass for a specific test function. The second part of these data sheets is a detailed design consideration sheet. These pages contain the critical human factors considerations in the test and evaluation of the class of items for which they were prepared. Phase III of this project was devoted to the evaluation and revision of the products. This evaluation involved on-site use and evaluation by test engineers and the conduct of field tests. Based on these user trials it was determined that these documents are appropriate and adequate for human engineering evaluations of general military equipment.

Kaplan, J.D., Crooks, W.H., Boylan, R.J. & Sanders, M.S. Human Resources Test and Evaluation System (HRTES) (PDR-1057-78-11). Woodland Hills, CA: Perceptronics, November 1978.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 1.2 1.3	The Human Resources Test and Evaluation System (HRTES) is a systematic and integrative approach to planning and conducting evaluations of human contributions to system performance. It encompasses a set of procedures which will assure that human resources (1) are properly included in a system design, and (2) are adequately assessed and evaluated during Operational Test and Evaluation (OT & E). The HRTES philosophy is that understanding of missions is basic to the measurement of systems in operational tests. There must be a logical link between the missions to be performed and the selected measures of performance. The first step in the HRTES procedure to accomplish this linking is to define systems according to their generic class(es). Each generic class is defined by general functional and hardware similarities. Systems belonging to the same generic class have certain missions in common while having other missions specific to themselves individually. The generic classification or indexing of the system is the first step in the HRTES process. The subsequent steps can be listed as follows: (2) assignment of missions, (3) specification of system performance issues, (4) identification of human performance functions and human performance measures, (5) identification of test conditions, (6) specification of human resources issues and human resources measures, (7) operational testing, (8) evaluation of OT results, and (9) diagnosis of performance inadequacies.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.1	The prototype HRTES handbook lists eleven (11) generic classes of Army Systems, VIZ, Armored Vehicles; Anti-Armor Weapons; Tube Artillery; Missile Artillery; Aviation; Air Defense Systems; Point Target Weapons; Area Weapons; Electronic Warfare Systems; Electronics Associated with Other Systems; Engineering Systems.
	2.2	Following generic classification of the system, the analyst using the HRTES procedure identifies and assesses the relative importance of the various missions of the system. Knowledge of the missions allows the analyst to specify the system performance issues of interest.
	2.4	Specific test conditions (or constraints) that may affect or further define the system performance issues must be identified.
	3.1	Human performance functions that derive from the system performance issues and human resource issues that contribute to human performance constitute the measurable attributes of concern to the HRTES procedure.

Karush, A.D. Benchmark analysis of time-sharing systems (SP-3347). Santa Monica, CA: System Development Corporation, June 1969. (AD-689 781)

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.2	A benchmark is a routine which is run on a number of different computer configurations to obtain comparative throughput performance figures regarding the abilities of the various configurations to handle some specific application. A benchmark problem is a selected portion of an entire job that should be representative of that job.
	2.3	The benchmark programs measured system performance under the following environmental conditions: (1) Stand-alone - only one object program makes demands upon a system's resources. (2) Benchmark - the seven programs are considered users, and run simultaneously as a simulation of a typical user population to assess system changes in a real-world environment. (3) Real-world - one benchmark program is run as a pseudo-user when the system is operating near its rated capacity under conditions of the real-world.
	2.4	Planning and estimating the system's workload was difficult due to a variety of demands and the random user times. Establishing equivalent environments within the computer systems being evaluated was the major constraint of benchmarks.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.1	Because of the factors stated above, the behavior of certain functional variables of a system was measured; a functional variable included software, hardware, and user components that support a particular activity. The particular variables measured were:

- swap activity
- compute activity
- interactive activity
- I/O activity
- page activity
- resource allocation
- user population

3.2 The following were measures of the stimuli:

For compute activity, the number of loops is the measure of the amount of CPU time allocated to the program by the scheduling algorithm. The interactive activity used the average number of messages printed per minute as its measurement. I/O activity used the average number of records read from the disc per minute as its measurement. No direct measure of swap activity was made. Instead, the obtained results from the small and large versions of the same program were compared with the measurement of the increase in system overhead due to the increase in swap times. The metric used in evaluating the effect of page management schemes was the compute activity and interactive activity measures. An increase in these values implied a more effective page management scheme. For resource allocation activity, a measure of the overall effect of the resource management algorithms may be determined by running an environment consisting of only the benchmark programs. The effect of different algorithms can be determined by changes in the measures printed by each benchmark program.

The measurement of compute activity was the maximum throughput that any compute-bound job could obtain. The measurement of response time was the minimum (best) time that any terminal bound job could attain.

Karush, A.D. Two approaches for measuring the performance of time-sharing systems (SP-3364). Santa Monica, CA: System Development Corporation, May 1969. (AD-691 366).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The paper discusses two significantly different approaches for measuring the performance of time-sharing systems. The "analytical" approach involves the insertion of probes into the system to allow measurement and recording of the system's most subtle behavior. In the "stimulus" approach the system is conceptualized as a "black box" containing a limited number of known functions. This measurement technique involves applying a controlled set of stimuli to the black box in order to activate its function and then observing the results.
	3.1 and 3.2	The analytical approach can have several applications. In program and hardware analysis, the stochastic behavior exhibited by the system and its interpretation in terms of the executive or supervisor function may be elucidated. In system analysis the degree and manner in which the man-machine software complex has affected its environment in terms of costs, efficiency and security can be determined. There are two paths that can be followed in system research: (1) modeling or simulation; and (2) controlled experimentation upon the time-sharing itself. The stimulus approach can be applied to several applications. It can be used to indicate the degree of throughput and response time degradation under varying system loads; it can indicate the degree to which the system load varies; it can "take a reading" of the system with respect to the volume of service being requested from it; it can be an

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		experimental test bed for examining the effects of different scheduling algorithms; and it can examine the effects of changes to functional variables.
	3.5	The analytical approach has several practical measurement options: (a) sampling measurement - this technique can provide a frequency distribution which describes the activity of the program; (b) trace measurement - here the interest is often focused upon the sequential behavior of some portion of the system; (c) accounting measurement - this is a frequently required measure of a time-sharing system. It is a summary of resource utilization such as volume of file storage, size of programs, etc.; (d) logical measurement - the purpose of which is to select for further evaluation a subset of a data base as a function of the content, description, or environment of that data base; (e) playback measurement - involves recording all the input to the system or subsystem together with time lags, and then rerunning the component of interest with the recorded input substituted for the real input.
		The stimulus approach also has several practical measurement options depending upon the environment in which the system runs: (a) stand-alone environment - the system is viewed as a batch processor with a benchmark program as the only program running which provides the best measure of throughput and response time; (b) benchmark environment - in this situation all benchmark programs are run simultaneously simulating a "typical" user population; (c) real world environment - this technique involves loading the system with an almost full complement of users and running a benchmark program simulating a user who has a constant and known demand for service. Several runs are needed to establish norms.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.1	Both the "analytic" and "stimulus" approaches were used in SDC's ADEPT time sharing system.
	5.3	The development costs for the stimulus technique were much lower. The analytical technique provided data on the more subtle behavior and complex interactions and provided measures of performance on any portion of the system. The stimulus approach produced gross data on the behavior of the system in terms of throughput and response time. The analytic measurement required extensive offline reduction and analysis before the data were meaningful. The measurements for the stimulus techniques were simple and immediately obtainable.
	5.4	A number of areas for further development for both approaches were mentioned.

Kelley, C.R. Human operator models for manual control. In G. W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3 2.6	Models are constructed for various purposes and with various goals in mind. Four general functions of models are: (1) To formalize scientific theory. (2) To improve man-machine theory. (3) To improve automatic devices. (4) To measure "hidden" processes. Some models are built solely to replace man in specific tasks, and should be judged solely on how well they perform these tasks, regardless of whether they perform them like the man does. But the more common purpose of the model is to help understand human performance. In that case, four criteria for judging the worth of a model are proposed: (1) Accuracy--Does the model's performance of a task produce a response record closely resembling that of a human operator? (2) Verifiability--Are the processes that underlie the model's performance similar to those that underlie human performance? (3) Generality--Is the model applicable to a large range of tasks, or only to a few?

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(4) Parsimony--Is the model unnecessarily complex?
	3.5	The author reviews five classes of human operator models in more or less historical sequence: (1) Continuous transfer and describing function models. (2) Operator intermittency: Sampled data models. (3) Operator non-linearities: Some partial models. (4) Computer analogs. (5) Predicted and preview models.
	6.1	The point is made that human performance is not linear, and may be poorly represented by linear control-theory models, except for certain fairly simple or restricted tasks. Also, human control is exercised not on the basis of present error, but rather on the basis of predicted future error.

Kerner, H. and Beyerle, W. A PMS level language for performance evaluation modeling (V-PMS). Vienna: Institut fuer Digitale Anlagen Technical University.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	A comparison of Register Transfer (RT) level modeling and V-PMS is quite indicative. While RT-modeling approaches a restricted goal, viz. a hardware structure capable of performing a few hundred algorithms, a V-PMS level model has a complete computer system as its target, i.e. a composite of hardware structures of the RT-level complexity cooperating under the control of an operating system in the execution of a load. In order to construct a language suitable for describing the hardware as part of a total PMS-level model for performance evaluation, the original form of PMS was substantially changed by providing an expanded set of building blocks with corresponding definitions. This language, with its clearly defined functions and performance data, its unambiguous communication blocks and rules for interconnections, provides a human reader with a clear understanding of the performance of components and of their internal communication within the computer system, and links the hardware part to a model of an operating system (to be supplied at a later time). For computer readable system specification a syntax for connecting the above symbolic components is proposed. A description of the CDC Cyber 74/CDC 6600 system examplifies the use of the proposed language and its merits for building performance evaluation models.

Kiraly, R.J., Babinsky, A.D. & Powell, J.D. <u>Aircrew oxygen system development: Man-in-the-loop test report</u> (NASA CR-73395). Cleveland, Ohio, TRW, Inc., July 1970.

Topics Relevant to System Development and Evaluation Technology

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

Topic No.	ABSTRACT
1.1	This report discusses the test of a "man-in-the-loop" program conducted with an aircrew oxygen system.
2.1	The system was the NAOS Flight Breadboard System which uses electrochemical generator and carbon dioxide removal. Human and animal test subjects participated in this study.
2.2	The mission of this system was to provide aircrews with a safe, reliable, and compact oxygen system.
2.3	Two experiments, one involving animals and one involving human test subjects, were conducted in a laboratory situation.
2.5	The ultimate performance requirement of this system was that aircrews receive the life support necessary during flight.
2.6	The object of the study was to provide a safe, reliable, compact system which would replace present systems minimizing the need for ground support facilities and reduced time and effort for servicing.
3.1	Two experiments were conducted in this study. The first experiment was conducted to measure the effects of oxygen generated by the Flight Breadboard System on lung tissue of small animals. The second experiment involving human test subjects concerned the physiological effects and comfort of the equipment.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.3	The specific performance requirement of this system was that the system meet safety and comfort limits.
	3.4	Subjective judgments of comfort were obtained when evaluating different masks and suspension systems. Determination of the physiological aspects were obtained by physical examination of the test subjects and based on expert judgments.
	4.3	The animal tests were conducted in a plexiglass enclosure through which rebreather gases were calculated. Human tests utilized aviation oxygen masks and the Flight Breadboard System.
	4.4	Hamsters and mice participated in the animal experiment. Four members of the project team volunteered for the human tests.
	4.5	The animals received a single acute exposure of 3.5 hours duration and a chronic exposure of 5.5 hours/day for ten consecutive days of rebreather gases. The animals were sacrificed and lab examinations conducted on lung tissue.
		In the human tests, two series were conducted. In the first test, subjects experienced the system operated with and without safety presssure to determine comfort levels and possible physiological damage to respiratory systems. The second test was to determine relative comfort of alternative equipment. In both tests carbon dioxide levels and oxygen levels were monitored. Mask leakage measurements were also made in relation to the employment of safety pressure and comfort levels.
	5.4	The system operated successfully in most areas of expected performance. However, mask leakage problems must be solved if the full advantage of closed-loop oxygen systems is to be realized. It is recommended that future testing make provisions for a higher oxygen rate to be used.

Klein R. Integrated operational test and analysis procedures for small arms weapon systems evaluation. Manuscript in preparation. (Undated)

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	This report addresses the integrated operational test and analysis procedures for small arms weapon system evaluation.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The system was composed of infantrymen, their weapons, and equipment.
	2.2	The mission was the use of small arms in combat situations by infantrymen.
	2.3	Simulated combat conditions were utilized in this study.
	2.4	The ability to duplicate combat actions and tasks in a test facility affected the validity of test results.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.5	The ultimate performance requirement of this system is mission accomplishment in which the mission is to close with and defeat the enemy.
	2.6	One of the primary measures of success of a combat mission was described as the number of enemy casualties.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.1	The performance of infantrymen using small arms weapons was evaluated. The criteria used were accuracy, sustainability, responsiveness, and reliability.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	3.2	The number of hits was the measure of effectiveness of this system.
	3.4	The criteria for the evaluation of weapon system performance fell into four categories:
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(1) Accuracy (number of hits), hit probability, first round hit probability, engagement hit probability, distribution of near misses.
		(2) Sustainability (number of hits per round and hits per basic load).
		(3) Responsiveness (time to fire first round, time to first hit, time betwe rounds, time to shift fire).
		(4) Reliability (number of malfunctions, numbers of rounds between malfunctions, and time to clear malfunctions).
	3.5	For the purpose of this study, the missio accomplishment measure was equal to the number of target hits.
	4.1	Sample size should be based on the specif test criteria and selection of the approp ate MOE. The technique for performing th primary analysis is a 3x2x2 factorial exp iment. The factors were facilities, weap- ons and modes of fire. A linear model ca be developed and an analysis of variance can be performed.
	4.2	The sample of test soldiers should be representative of the infantry as a whole in terms of age, rank, experience and physical attributes. Weapon should be assigned on the basis of a performance measure. Training was found to be a substantial source of bias. An accelerat training class was held to familiarize th subject with new weapons. Results showed bias favoring a standard weapon but time limitation prevented elimination of this bias. A balanced experimental design was implemented. The test facility was designed to duplicate as closely as possible the "real-world" combat-situatio

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.4	Ninety-six infantrymen/in 96 rifle systems participated in this experiment.
	4.5	The components of the test plan were: selection of subjects, determination of sample size, weapon assignment, training of subjects, scheduling, test facility determinants, test implementation, and data analysis.

Klein, R. D. & Thomas, C. B. <u>The development of combat related measures for small arms evaluation</u>. Fort Benning, GA: US Army Infantry Board, June 1969. (AD-713 552).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

1.1 This paper discusses the development of combat related measures for small arms evaluation.

2.1 The system studied included the infantry soldier, his weapons, and equipment.

2.2 The mission of the system was the most effective use of men, equipment, and weapons in a combat situation.

2.6 The specific requirements of the system was the achievement of a "hit" during a quick-fire engagement in the shortest period of time.

3.1 A list of 26 separate combat-actions was prepared. Secondly, a list of tasks normally accomplished by the infantryman when executing the combat actions was developed. It was determined that three basic tactical situations (attack, quickfire, and defense) would accommodate all these actions and tasks.

3.2 Twenty-six measures of effectiveness were developed. These included time to first round, time between trigger pulls, distribution of near misses, time to shift fire, and hits per pound expressed as a percent of a soldier's basic load.

3.5 Several measurement procedures were used: the time to fire first round measures, the time it takes for a soldier carrying his rifle at ready position to engage a surprise target, and the time between trigger pulls which is defined as an

		indicator of the soldier's ability to absorb the recoil, acquire the target, obtain a new sight-picture, point the weapon and squeeze the trigger. An effectiveness scale of five levels was developed.
	4.1	The firing engagements were categorized according to the degrees of effectiveness as defined by whether or not the firer achieved a hit. Those engagements which required multiple trigger pulls and failed to achieve a hit were defined as least effective. Those which resulted in a hit, whether single or multiple trigger pulls were required, were designated as the most effective. Time-of-first round, target range, time between bursts, time between trigger pulls, number of rounds to first hit, burst size, and burst hit probability were presented graphically, and provided a comparison between the weapons being tested.
	4.3	The test equipment were two different automatic rifles, tested in a simulated combat-firing facility.
	5.3	It was determined that the potential of one weapon was greater than the other being tested. Two findings were considered important: (1) the service test must determine the weapons systems optimum operating mode to yield complete information on weapon potential and (2) training procedures are related directly to weapon performance and therefore should not be considered separate entities.
	5.4	It is felt that this technique of equating a specific measure to real world effectiveness represents an advance in military test procedures, but is limited in that the "real world" is still a simulated combat firing facility. However, with these limitations the facility is a dynamic test environment and brings into play many of the influencing variables common to the

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		combat environment and provides an improvement in operational testing. The ultimate value to be realized from this methodology is how well these statistical measures can be weighed in this "real-world" atmosphere.

Kleinman, D.L., & Baron, S. Manned vehicles systems analysis by means of modern control theory (NASA CR-1753). Cambridge, MA: Bolt, Beranek and Newman, Inc., June 1971.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	Optimal control and estimation theory may be used to develop a model of human response in manual tracking tasks. The tasks considered were those in which the controlled element was linear and the system was disturbed by a white noise input. The model included representations of human limitations and a cascade combination of a Kalman filter, a least-mean-squared predictor, and a set of optimal feedback gains as compensating elements. An "optimal scanning mechanism" was also added to the model to account for situations where the human operator must visually scan several instruments in order to achieve his control objectives. The use of the model in predicting task performance, controller describing functions, and power spectra was demonstrated. The model was then validated by comparing model results with experimental data from three simple, but classical, manual control tasks. Sensitivity studies of simple manual control tasks (i.e., single input, single display indicator) were conducted. The measures examined incuded: (1) Neuromotor time constant. (2) Time delays. (3) Observation noise. (4) Motor noise.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		A prediction of pilot performance in a hovering task was also attempted. Agreement between measured and predicted quantities was obtained, demonstrating the value and potential of the optimization approach to manned-vehicle systems analysis.

Knoop, P. A. Survey of human operator modeling techniques for measurement applications (AFHRL-TR-78-35). Wright-Patterson AFB, OH: Air Force Human Resources Laboratory, Advanced Systems Division, July 1978.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1	The purpose of this study was to review existing human modeling techniques and evaluate their potential utility for performance measurement applications. It appeared that existing performance measurement techniques do not have the capability to support the type of flight simulation research that entails accounting for the perception and utilization of various cues. Since model validity is particularly important in the case of the envisioned measurement applications, the first task was to identify the major human operator characteristics that ought to be accounted for. A review of work dating from 1944 was conducted and this material was categorized into six types: (1) describing functions, (2) optimal control model, (3) discrete and finite state methods, (4) adaptive techniques, (5) preview models, (6) other nonlinear approaches. A survey of models in each category was made by reviewing the literature and summarizing various modeling studies. Models in each category were evaluated based on the extent to which they represented the identified human operator characteristics as well as other aspects of their general validity for performance measurement applications.
	5.4	Results show that none of the models implemented more than a few of the operator characteristics; many are based on assumptions which are unacceptable for

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		measurement applications and others have not been developed far enough to justify their use as a po_nt of departure for measuremen_s. It is concluded that existing models are not sufficiently representative of known characteristics to be useful for general applications in performance measurements.

Knowles, W.B., Burger, W.J., Mitchell, M.B., Hanifan, D.T. & Wulfeck, J.W. Models, measures, and judgments in system design. Human Factors, 1969, 11, 577-590

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1 6.3	Current practice of system design commonly requires the use of analytical models. While such tools are finding increasingly wide application and acceptance, their use is often limited by the lack of data in forms suitable for modeling effects. Overall, there can be little doubt that the design of systems would be greatly facilitated if tasks and equipment could be treated within the same conceptual scheme. Unfortunately, techniques originally developed to describe and predict human performance for that purpose have fallen short of the goals. The following approach is suggested for studying system design: (1) Identify a practical situation where suitable populations of expert judges and tasks can be obtained, and where estimates and actual measures of task performance can be obtained. (2) Conduct a study to identify the relevant dimensions along which to categorize tasks and judges, and to obtain correlations between estimated and actual performance. (3) Develop means for structuring the presentation of stimulus materials, i.e., task descriptions, so that the relevant aspects of the tasks are suitably displayed.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(4) Develop means for classifying judges and for selecting "valid" individual judges.
		(5) Conduct a study to revalidate the estimates obtained with the improved methods.
		(6) Develop category scaling procedures to be used generally in evaluating equipment-oriented tasks, and develop a set of standard stimulus materials to be used in differentiating among prospective judges.

Kreifeldt, J. Analysis of predictor model. Unpublished Preliminary Data, Massachusetts Institute of Technology, 1954.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This memorandum discusses an analysis of a predictor model which realistically accounts for inputs which have spatial as well as time dependence. An analysis is presented which attempts to abstract the real world to some degree. In this outline a model of a human operator controlling a vehicle was analyzed. The model attempts to account for the fact that in many situations (i.e., driving) the operator has an input which is not a single point in time but an input which has spatial as well as time features, that is, he can look at the road ahead. The sampling theorem in spatial coordinates was invoked in order to treat the time-space input as k discrete inputs to the operator simultaneously available. The model then states that the operator runs some sort of thought experiment in which position is extrapolated and future error is computed if the same control signal is maintained. This computed and weighted predicted error forms the basis for the operator's control action. The model performs the thought experiment by computing from vehicle initial conditions and command signal what the errors will be at the previewed points. These individual errors are simultaneously

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		computed and weighted in a length of time requiring π seconds. The transformed impulse response for this model was derived and composed of discrete and continuous elements. This impulse response was specifically evaluated for a first-order vehicle and two input points. It was seen that if stable, it eventually reaches a reference step height input.

Kurke, M.I. Operational concept analysis and sources of field data. Human Factors, 1965, (7), 537-544.

Topics Relevant to System Development and Evaluation Technology

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

Topic No.	ABSTRACT
1.1	The human factors approach to an operational analysis should be commensurate with that of the operations research approach. One approach to this methodology is described in this paper. A hypothetical example (i.e., a rock) is given in which the essential elements of analysis are presented in order to determine whether an item of materiel should be included in an Army inventory.
2.1	The five major functions described are: firepower, mobility. combat service support, intelligence and reconnaissance, command, control and communications.
2.2	The functions are analyzed into subfunctions which are relevant until a level of description is reached that can be measured operationally. For example, firepower can be a measure of hit probability as a function of range. In addition, if is determined from an analysis of the subfunction, mobility, that the ability to throw the hypothetical weapon (i.e., the rock) while running is a very important operational capability, then this ability would be an attribute measured in terms of accuracy when using protective equipment versus not using protective equipment.
3.1	The essential elements of the analysis include: effectiveness in attaining objectives, effectiveness when chemical agent protective equipment is being used, training requirements, and operating costs.
4.1	The field data collected for military OR studies come from three sources: field exercises, troop tests, and field experiments.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

The characteristics of these three sources of field data for operational concept and evaluation have been compared with the field data sources for systems analysis and evaluation.

The three sources of field data are defined as follows:

(1) Field Exercise--an exercise conducted in the field, under simulated war conditions, in which troops and armaments of one side are actually present, while the other side may be imaginary or in outline.

(2) Field Experiment--an investigation to experiment with or evaluate new or revised doctrine and organizations, and new, modified or current materiel in order to develop combat capabilities

(3) Combat Development Troop Tests--a field investigation designed to test the ability of a prototype organizational structure to follow a specific doctrine using specific equipment to complete a specific mission and/or to test the concept of operations as limited by the structure and functions of a prototype organization.

A table is presented which compares the three sources of army field data in terms of methods, kinds of analyses, reliability of data and types and usefulness of results. In a study of 32 tests and experiments published in 1963, it was noted that only the field experiments and troop tests provided systematic data.

The field experiments tended to gather base data, compare systems and collect information about specific variables. However, although more than half of the conclusions in these experiments were drawn from objective data, the balance supplemented their results with subjective data.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Some troop tests were developed to collect base data about a system but only one out of eight compared systems. Generally, in these reports, test objectives were not clearly stated. Few of these tests investigated specific variables although all investigated the total system. All troop test conclusions were based on subjective data. More than half of these troop tests were uncontrolled both statistically and experimentally and none presented anything more sophisticated than a measure of control tendency.
	4.5	The test plan for functional analysis would include:

(1) Development of a frame of reference for operations.

(2) Determination of the functions or subfunctions relevant to describing effectiveness. In this analysis, some screening or weighting of functions in terms of their relative importance may be performed.

(3) Development of operational criteria based on the determination of relevant functions.

(4) Refinement of the essential elements of the analysis in terms of specific performance criteria.

(5) Determination of the appropriate operational criteria, their measures and the correct mode of collecting the information.

(5) Determination of appropriate data collection techniques, i.e., field experiment supplemented y computer simulations.

Kvalseth, T.O. A decision-theoretic model of the sampling behavior of the human process monitor. IEEE Transactions on Systems, Man, and Cybernetics, November 1977 SMC-7(11).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

1.3

The present document presents a theoretical model for the characterization of the sampling behavior of an optimal process monitor. The dynamic decision model was based on the proposition that an ideal monitor adopts a sampling strategy that, at any point, maximizes some expected value (worth or utility) for the monitoring of a single signal with a fixed cost of sampling and of the signal exceeding certain threshold units. The present model was shown to lead to the strategy that sampling should occur when the conditional probability of the signal going beyond the threshold units exceeds the ratio of the sampling cost to the threshold cost.

Labor/Management Task Force on Rail Transportation. Terminal performance measurement systems. (DOT-FR-4-3003). Washington, DC, May 1975. (PB-252 225).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Mod... ..PM) 2. Contextual Compone.. s of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Rese..rch Potentials/ Priorities 6.3 Research Planning	2.1 2.2	The St. Louis [Railroad] Terminal Project is an experimental program seeking ultimately to produce a more saleable transportation service and greater profit to the railroads. The experimental procedure places heavy emphasis on quantitative measurement of the impact of operational changes. To determine the best method for measuring performance of the terminal as a whole, a seminar on terminal performance measurement systems was conducted by the St. Louis Project Team. Current terminal performance measurement systems were found to be designed to support one or more of the following functions: (1) Evaluate performance and trigger the planning process to develop changes that will produce improved performance. (2) Evaluate experimental changes in operations to determine the actual improvement in performance. (3) Monitor the operations to provide information that results in corrective action to prevent a deterioration in performance. (4) Assess the performance of the managers responsible for the operations.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.1	Observations of the various terminal performance measurement systems indicated that: (1) All measurements systems use car movement data collected by real-time [automated] systems, with no additional burden placed on clerical forces. (2) Speed of car movements is measured by the time cars spend under a terminal superintendent's responsibility. (3) Reliability of car movements is measured by comparing elapsed time with a standard. (4) Most systems measure the car time costs of car movements. (5) The systems currently in use do not measure all of the variables with which terminal management must deal.

Larson, O.A., Sander, S.I. & Steinemann, J.H. Survey of unit performance effectiveness measures (TR74-11). San Diego, CA: Navy Personnel Research and Development Center, January 1974. (AD-774 919).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1 5.4	A survey to determine the state of the art of performance assessment systems and methodologies was conducted to support a Marine Corps requirement for improved measures of performance effectiveness to be used in conjunction with the Tactical Warfare Analysis and Evaluation System (TWAES). In addition to a literature search, researchers observed field exercises and examined related U.S. Army systems. A number of areas were identified as needing support efforts including timely reporting and assessment of events by umpire personnel. It was concluded that the literature does not contain substantive research studies defining human performance assessment methods and criteria suitable for direct application to TWAES. Studies were found, however, that will be of use in initiating and structuring the research in this area. Organizational, situational and evaluative factors all hold promise as potential sources of performance effectiveness measures along with the use of Delphi-type approaches for the development of interim methods and criteria.

Lawrence, D.H. The evaluation of training and transfer programs in terms of efficiency measures. The Journal of Psychology, 1954, 36, 367-382. (AD-87 172).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This paper discusses the decision making involved in designing training programs. It is noted that programs are designed to produce the desired level of proficiency with the minimum outlay of time, energy and cost. However, it is theorized here that the implications of such a principle are not explicitly formulated as they bear on the efficacy of the decisions or on the research needed as a basis for such decision. This paper attempts to remedy part of this deficiency by means of a preliminary, simplified simulation of the training and transfer problem in terms of the principle of minimization of expenditure. Simplified assumptions are made about cost functions and learning curves involved in training to permit a clear expression of the methodology involved. Any use of this methodology in other specific training situations may involve a different set of assumptions. A mathematical formula is presented which demonstrates a relationship between the cost and the stage of training. This states that, in general cost is universally related to the level of proficiency achieved at any given time. Factors influencing the cost of training an individual are considered as well as the average cost for group training. The paper discusses ways in which training costs can be reduced by means of improved

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		training techniques, selection of individuals to be trained, and by the utilization of the transfer of training procedures. It is pointed out that standardized training programs which bring all individuals to a level of proficiency can result in overtraining for some. Cost benefits of considering individual differences by modifying training programs are discussed. The final section of this paper deals with the employment of transfer of training situations as a means of reducing training costs. The assumption underlying the transfer paradigm is that an individual can be trained to a desired level of performance easier and with less cost if he is first trained on a preliminary task.

Levy, G.W. Criteria for selection and application of models. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 19?8. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3 3.2 4.2	This paper presents some thoughts on considerations for selecting and applying man-machine system models. The author classifies these considerations as: (1) Those relating to the model itself, i.e., its output, input, and form. (2) Those relating to the precision and validity of the model predictions. Concerning the model's output, consideration should be given to whether the model predicts human performance or system performance. System performance measures involve parameters of both human and machine and even their interaction. Such measures imply a system effectiveness mode of thought, a concern with overall system performance rather than human performance per se. However, it becomes necessary to separate man and machine performance explicitly and to develop human performance submodels that include system-oriented human performance measures. Examples of these may include mean time to repair, slant range at target identification, etc. As regards model input, an initial consideration should be the number of variables involved. Often, too many variables are specified, either because an attempt is made to achieve an unrealistic predictive precision, or because it isn't possible to separate meaningful variables

from the great number of possible variables. On the other hand, meaningful variables sometimes are overlooked because they haven't been studied empirically. Operator motivation is an example of a variable that most models disregard. A second consideration related to input is the existence of the necessary data. Thirdly, model parameters may also be treated as needed input for application of the model: the significant consideration is whether these parameters are fixed beforehand or estimated from the data.

Concerning the form of the model, the first issue is whether it is an empirical or a theoretical model. Theoretical models are obtained by a hypothetical-deductive procedure, empirical model equations are obtained by curve fitting. Theoretical models provide a guide to research and a programmaticity which empirical models lack, but theoretical models involve assumptions which may or may not have been tested. Another issue concerning form is "what kind of man is being modeled." Is it an individual with individualistic parameters or is it the famous average man? Is he trained or untrained? Few models handle the problems of individual differences and training.

5.3 Concerning the precision or accuracy required of a model, this is generally regarded to be a function of the stage of the system life cycle in which the model is being used. However, it is believed that the same levels of precision are required in the initital stages of design as in later applications. In order to be truly useful, applied models must consider the relevant interactions of design parameters with difficulty of conditions and must possess a sufficient degree of accuracy. Unfortunately, the criterion of how much accuracy has never been spelled out.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	6.1	Turning to validity, it is noted that the vast majority of man-machine system models have never been validated. It is suggested that a research design termed the "field laboratory validation design" is very useful in developing and validating applied models. This design calls for collection of performance data and input data in field situations, with the input data recorded for use in laboratory studies aimed at model development. The models in turn are validated by comparing their outputs with the pre-collected field performance data.

Lindsey, M.B. A human performance investigation in a NAVORD weapon system - Part 2 (Report 27-349). Annapolis, MD: Naval Ship Research and Development Center, Propulsion and Auxiliary Systems Dept., March 1974. (AD-918 202L)

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This study is part II of an investigation regarding integration of ordnance systems personnel functions and the design of man-made interfaces. A specific modification of a methodology was developed to yield quantitative data for the purpose of determining the performance levels of maintainers/operators in ASROC (Antisubmarine Rocket) launching groups.
	1.3	If "performance" means demonstrable operational capability, then a system's performance is taken as the total behavior of its man and machine module components interacting over a specified period of time in the environment for which it was designed; its reliability is the probability of performance.
	3.1	Previous researchers have categorized the major variables that affect system performance as: (1) Personnel (2) Equipment (3) Procedure (4) Environment (5) Administration (6) Interaction
	4.1	The statistical methods used to determine the performance levels were calculations of

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		the mean (including the grand mean), the standard deviation, and the range.
	4.3	A job performance questionnaire was developed for the job activities as a cross-section of ASROC; the work done by Siegel on multidimensional scaling was found to be applicable with only minor revisions made (definitions appropriate to ASROC were adjusted accordingly.)

LTV Aerospace Corporation. Shuttle active thermal control system. Vol. 3: Modular radiator system test data correlation with thermal model (Rep. No. T169-28, NASA CR-M0269). Dallas, TX: LTV Aerospace Corp., Vought Systems Division, December 1973.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	Accurate predictions of the space shuttle radiator system performance is of prime importance in the design and development of the heat rejection system. Due to the large size of the radiator system it is impractical to determine the optimum radiator system by test. An accurate model is needed to study parametrically all design variables and insure optimum radiator performance. This volume presents results of an analysis to correlate the system thermal model with test data.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The modular radiator system submitted to testing consisted of modular test panels, each made up of 12 tubes arranged in a "U" shaped pattern. The innermost tube is the prime tube. The other 11 tubes comprise the main system. Heat rejection is regulated by controlling the flow split through the main system and the prime tube. At high heat loads, approximately 99% of the flow is routed to the main tubes; minimum heat rejection occurs when approximately 99% of the flow is routed to the prime tube.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures		
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	2.4	The multi-panel configuration proposed for use on the shuttle requires that the model predict interaction between the panels; thus, dictating a separate model for each panel.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.1	The primary objective of the thermal model is to provide a tool for performance predictions of the radiator system under the design conditions of maximum and minimum heat rejection. A single tube is used to model the bank of 11 main tubes. The resulting model thus consists of two separate models - one for the mair system for maximum heat rejection conditions, one for the prime system for minimum heat rejection. There are no thermal connections between the two systems.
	5.2	Comparisons were made between test results and (model) predictions for selected test points. The model predictions agreed well with the test data. Excellent agreement was achieved for the high heat load conditions. Good performance predictions also were produced under minimum load design conditions, although these correlations generally were not as good as were those for high load.
		In summary, a thermal model of the proposed space shuttle modular radiator system has been developed and verified by comparison to thermal vacuum test data. Application of the test panel modeling techniques to the (actual) flight panel should provide an accurate model for the radiator system performance evaluation.

Lyons, J.D. Measuring effectiveness: Quality control of training. In E.A. Cogan & J.D. Lyons Frameworks for measurement and quality control. (HumRRO-PP-16-72). Papers presented at New York University First National Annual Training in Business and Industry Conference, New York City, March 1972. (AD-748 081).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The process of developing the raw material of human potential deserves a system of quality control at least as carefully developed as that applied to the manufacturing process. The quality control system must accomplish four major objectives: (1) Quality assurance. (2) Control of student progress. (3) Training program improvement. (4) Training system diagnosis and change. Quality assurance requires that specifications be delineated in terms of operational requirements and these requirements be reflected in end-of-course proficiency measures. Control of student progress is accomplished by developing a means of selecting and organizing the learning experiences to facilitate achievement of objectives. This can sometimes be achieved by dividing the training program into modules each with its sub-objectives. A systematic quality control process must identify weaknesses and strengths in the program by assessing and diagnosing the performance of the trainee.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		The essential elements of a training quality control system are: (1) Training objectives (performance requirements). (2) Proficiency and diagnostic measures. (3) Data reduction and analyses. (4) Procedures for decision and corrective actions. (5) Communication procedures. (6) Managerial support.

Markel, G.A. Toward a general methodology for systems evaluation (352-R-13). State College, PA: HRB-Singer, Inc., July 1965. (AD-619 373).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1	This report considers some of the issues involved in a general theory of systems evaluation. It suggests an organized and comprehensive framework for approaching any systems evaluation. Definitions of systems are considered and characterized as an assembly of interrelated elements acting as an integral ensemble in performing some functional objective. The report examines some of the issues involved in realization of practical evaluations. It discusses the need to define the problem -- why is the evaluation being performed, which parts of systems concepts are involved, etc. It is felt that breaking down the problem into smaller, more tractable problems facilitates a workable approach to any evaluation. Fundamental considerations such as criteria selection are discussed. The report stresses the need to select the criteria with great care. The underlying substance of the evaluation process is measurement and the key to successful measurement and evaluation is to be found in criteria selection. It is suggested that the development of general theory of systems evaluation can be approached by identifying and defining these elements which can provide a basis for the overall evaluation of any system. These elements may be described in three

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		broad areas of primary concern for systems in general: (1) Systems structure. (2) Systems operations. (3) Systems performance. It is felt that a valid approach is to employ a modular concept of systems evaluation addressing each basic factor as a separate module. Each application uses only the modules most appropriate to that system and the results obtained from the various modules are integrated subjectively. Different modeling concepts are discussed in the last section of this report. It is felt that network models are best suited for structural aspects, hierarchical tree models are best for studying aggregation of operational aspects, and black box models provide the best perspective for overall performance appraisal.

Mason, A.K. & Rigney, J.W. Toward a general characterization of electronic troubleshooting. In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	Several factors underly the desire to formulate a troubleshooting processor model accommodating a broad spectrum of possible specific procedures: (1) such a model would unify the alternative ways of characterizing and explaining human technician troubleshooting behavior; (2) it would serve as a vehicle for formulating the cost effectivneess structure associated with troubleshooting electronic equipment.
	3.2	Ideally, a characterization of the electronic troubleshooting process would be sensitive to the degree of automation in the troubleshooting tasks. Thus, measures of effectiveness for particular equipment could be generated across the spectrum of alternative troubleshooting processors (from the automated to the manual), and improve the sensitivity of the "maintainability" component of cost effectiveness models.

Matheny, W.G., Patterson, G.W. & Evans, G.I. Human factors in field testing (LS-FR-71-1). Hurst, TX: Life Sciences, Inc., December 1971. (AD-741 216).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	The aim of this study was the development and test of methods for evaluating operator performance during field test of complex man-machine systems.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	Several Navy aircraft systems were examined in detail/and two systems were selected for detailed study -- the A-7A and the P-3C anti-submarine warfare systems. The major portion of the work was carried out using the P-3C.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	Tests were conducted to determine the feasibility of identifying operator performance measurement points within the system. Both an Operational Sequence Diagram (OSD) and a Mission Time Line (MTL) were developed for the Tactical Coordination station within the context of a standard Evaluation Mission.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.2	The appropriate scales of measurement for various task types are as follows: (1) Absolute deviation from standard percent of time out of design limits (continuous control tasks). (2) Percent of incorrect responses (discrete control tasks). (3) Percent settings not on design setting or percent outside design limits (pointer/symbol positioning tasks). (4) Percent of decisions agreeing with judges' established decisions (technical decision tasks).
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentiala/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.5	The Mission Time Line (MTL) was used to test the feasibility of obtaining estimates of Tactical Coordinates Workload in the early stages of work with the P-3C. The feasibility of the method is demonstrated in this report, but the procedures utilized are not since the estimate of workload from the MTL is more properly a part of the system development phase.
	5.4	Recommendations are made with regard to the need for assigning personnel with authority and means for accomplishing human factors requirements. (1) Detailed listing of operator tasks and OSD's should be developed and kept current throughout the development and tests of the systems. Manual performances and tactical decision points should be identified early along with scales of measurement and performance criteria. (2) The evaluator must be oriented toward obtaining reliable measures under test conditions. The evaluator should strive towards the most representative conditions possible while maintaining good test procedure. (3) Reliable performance data must be obtained by which the criterion requirement for successful performance can be compared in order to reach an evaluative judgement as to the adequacy of design. (4) The determination of whether an operator can successfully accomplish a sequence of tasks in the time available in the actual mission must be made under conditions as nearly representative of the operational minimum as possible.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(5) It is important that the evaluator set-up observational and report procedures to determine the degree to which deviations from design procedures occur through use of earlier learned habits.

Matthews, E.P. A visual target acquisition model. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	The paper describes a particular visual target acquisition model originally developed for a particular air-to-ground application, but subsequently extended to other air-to-ground and air-to-air applications. The basic building block of this model (and all other visual acquisition models) is the capability of the human eye. Separate modifying branches are added to this basic block to increase the model's versatility.
	3.1	The model treats acquisition data as a function of slant range to target. Four types of sequential acquisition events are included in the model: (1) Detection--When the observer becomes aware of something in the field of view. (2) Orientation--Enough of the target's outline is seen to distinguish between its longest and shortest dimensions. (3) Recognition--The outline is seen with sufficient clarity to establish the general classification of the target, e.g., tank, truck, parked aircraft, etc. (4) Identification--Sufficient detail to establish the particular kind of tank, truck, or whatever.
	5.3	Verification of this model using actual test data have been very good.

McCalpin, J.P. Development of a methodology for obtaining human performance reliability data for a machine gun system (Tech Memo. 6-74). Baltimore, MD: AAI Corporation, February 1974 (AD-777 020).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.2	The purpose of this study was the development of the general procedures necessary to obtain human performance data which will satisfy a prior model that includes human performance data in models of infantry weapon system reliability.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	3.1	The following procedures were followed in order to implement the study: (a) development of a taxonomy for weapon-system tasks performed by the operator; (b) selection of an infantry weapon system for study; (c) analysis of maintanence tasks to insure said tasks were consistent with taxonomic terms; (d) development of categories for human performance errors that relate to hardware failures; (e) propose a study to collect objective data on human performance.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	4.1	The following methods were used to implement the study. (1) A behavioral taxonomy was developed which divided behavior into process, activities, and specific behavior. Process referred to groups of behavior associated with perception, judgment, communication and muscular activities; the activities column classified each of these processes; the "specific behavior" column showed the system-oriented behavior associated with each category of each process.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(2) The task taxonomy was developed from the behavior taxonomy. Hardware elements that comprise most gun systems were identified; row headings representing the hardware elements were matched with column headings representing the terms in the behavior taxonomy; the cell entries represent performance criteria.
		(3) Human performance requirements and human error categories were developed and correlated such that the criticality of human performance error was established in terms of its probable effect on the weapon.
		5.4 It was concluded that human performance data can be incorporated into the models currently available that seek to input human engineering factors into system reliability models.

McDonnell Douglas Astronautics Company, Eastern Division, Optimized cost/performance design methodology, Vol. 3-Concept analysis and model development, Book 1-Concept Analysis (MDC-E0005). September 1969.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	The overall purpose of this study was to provide a method of using cost as a basic design parameter in identifying and defining more economical space transportation systems. This volume reports on Task 6 which sought to determine economically optimum design and operational philosophies.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	Using alternatives defined in previous tasks, systems for resupply of an orbiting space station were synthesized. These systems included both ballistic and lifting entry vehicles with reuse concepts.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	4.1	These systems were analyzed using the Economic Optimization Model to determine the effect of various system parameters on total program cost for a fixed program size.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	4.2	Cargo weight per launch and certain operational modes were optimized. Sensitivity of program cost to other operational modes, crew size, cargo density, number of launches, subsystem elements/return time/orbit inclination, and number of landing sites were also evaluated.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

McDonnell Douglas Astronautics Company, Eastern Division, Optimized cost/performance design methodology, Vol. 3-Concept analysis and model development, Bo›k 2-Model Formulation (MDC-E0005). September 1969.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	1.1	This report presents a model for relating various operating and design parameters to cost and by using search and optimization techniques, finds the least cost system for the specified parameters. This model was developed for two types of spacecraft - ballistic and those with bodies having low lift-drag ratios. There are three major modules to this model. The first is the main module which is the executive control logic, the second is the size module which translates performance and operational requirements into a vehicle description and weight statement. The third module is the cost module which develops the total program costs from the data supplied by the other two modules.

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

McGrath, J.E., Nordlie, P.G. & Vaughan, W.S. A systematic framework for comparison of system research methods (HRS-TN-59/7-SM). Arlington, VA: Human Sciences Research, Inc., November 1959. (AD-229 923).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	System research has four stages or purposes with three kinds of research functions. The four stages are: delineation of system requirements, delineation of design consequences of requirements, system development and integration, and system evaluation. The three types or research functions are: development of models, collection of research information, and synthesis of information. Two general types of models were distinguished: design and research models. Successive cycles of development of models, and collection of information and synthesis of information serve to reduce uncertainty in the formulation of research problems and to delimit a reduced matrix of potential design solutions from which an optimal design is to be selected. The information gathering and synthesis function includes: determination of relevant variables, determination of the range of values of these variables, and the determination of the interaction of the variables. The information gathering and synthesis methods differ to the extent to which they permit, require or prohibit the occurrence of values of relevant variables; and, thus, the amount of information which potentially can be obtained from them. The efficiency of a given system research method can be assessed in terms of the total amount of accountable information about the system research problem which its application can provide for a given level of research effort.

McKendry, J.M. & Harrison, P.C. Assessing human factors requirements in the test and evaluation stage of systems development, Volume II (ND64-68). State College, PA: HRB-Singer Inc., June 1964. (AD-603 304).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	1.1	A project officer's primary responsibility is to determine whether or not the system undergoing an operational test can accomplish its assigned mission under realistic fleet conditions. An important aspect of system performance to be considered is the field of human factors, that is, human performance in relation to system performance. An Operational Evaluation (OPEVAL) is the test and analysis of a weapon system, support system, component, or equipment conducted by the Operational Test and Evaluation Force, under service operation conditions insofar as practicable, to determine the ability of a system, component, or equipment to meet specified operational performance requirements and/or to establish suitability for service use. When appropriate, an operational evaluation may be ordered solely for the development of basic tactical doctrine, training procedures, and requirements for training aids and/or countermeasures.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Reaearch Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	The OPEVAL has five major phases: (1) Preparation and initial planning. (2) Devising and writing the test plan. (3) Conducting the test. (4) Evaluation of data from the test.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(5) Derivation of conclusions and preparation of the final report.
	2.4	The following were identified as OPEVAL considerations in human factors testing: (1) While human factors are important, they are only one of a number of important factors that need to be considered by the project officer. (2) It is unreasonable to ask that the project officer become a skilled human factors specialist. He cannot trace all of the implications of what he observes, nor should he be expected to comprehensively examine exactly how some of the important human effects he notes can be brought under control. (3) Most test environments do not have a large enough sample of men for the project officer to get a clear indication of how all of the human factors problems arise. He cannot duplicate the fleet personnel problem on a single ship. (4) Many human factors tests are extremely time-consuming and expensive to run because all of the situational conditions must be repeated exactly, with different men working within the system. (5) Practical aborts can be expected which will complicate and sometimes negate the project officer's attempts to complete a test of anything, including human factors. (6) The most efficient use of the project officer's time would be to concentrate on the most important human factors effects and to gather data on these effects. Additional associated

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		problems must, by necessity, remain the province of the human factors specialist who can assemble large amounts of data, carefully study the personnel situation in general, and draw needed conclusions.
	4.3	The instruments used to record human performance data included an operations events recorder (the model in this study was a 20 pen Esterline Angus), recycling timers, tape recorders, counters (both manual and automatic), and function recorders.

McRuer, D., Jex, H.R., Clement, W.F. & Graham, D. A systems analysis theory for displays in manual control (STI Tech Rep. 163-1). Hawthorne, CA: Systems Technology, Inc., June 1968. (AD-675 983).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	This report presents the basic structure of a comprehensive theory for the development of control displays for pilots of manually controlled vehicles. This theoretical framework provides a paradigm for control display development, a rational basis for experimental programs, a theoretical foundation for analyzing the comparative merits or problems of new operational display systems, and for the generation of new display concepts. The theory combines several manual control developments in its structure: (1) The vehicle dynamics, environmental disturbances, command structure, and mission criteria derived in terms of meaningful servo analysis parameters. (2) The "best" or "alternative best" feedbacks for the pilot are derived using the "multiloop feedback selection hypothesis," which includes the human operator's describing functions, remnant, and subjective preferences. (3) Quantitative evaluation of the system performance measures, information bandwidths, and stability margins made by systems analysis techniques. (4) The required display resolution, scaling, scanning pattern and rates, and workload margins are derived, based on pilot monitoring and scanning

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		models in terms of meaningingful sampling analysis parameters. (5) Preferential display arrangements are predicted from scanning pattern and workload measures. (6) Progression and regression of the level of pilot behavior (e.g., during training, transfer, stress, or equipment failure) are treated by the successive organization of perception theory of manual control skill development. The theory can be utilized for the following: (1) Exposure of potential problem areas and directions for improvement at an early enough stage to minimize detail design risks and costs. (2) Prediction of the best display scaling, filtering, and equalization parameters (e.g., "quickening"). (3) Analysis of display/pilot/vehicle system instability under instrument flight conditions (e.g., flight path oscillations under Instrument Landing System (ILS) guidance). (4) Selection of optimum feedbacks and their gains for integrated displays. (5) Specification of display instrument dynamic range, bandwidth, and tolerable dynamic lags. (6) Estimation of functional limitations on existing instruments as applied to new missions, vehicles, and tasks.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(7) Optimization of the location of related instruments for specific mission phases. (8) Rapid post-mortem investigation of anomalies in measured display system performance. (9) Analytical evolution of relevant parameters and their interactions, as a guide to the experimental design of display simulations and flight tests. (10) Correlation and unification of the results of numerous ad hoc display tests performed in the past. (11) Exposure and prediction of solutions to new problem areas in integrated displays, terrain-following displays, etc. (12) Evolution of display simulator functional requirements (e.g., instrument servo lags, cathode ray tube capabilities). (13) Interpretation of experimental findings in an analytical manner to permit their extrapolation to actual flight and future problems. (14) Establishment of a rational basis for cardinal elements on contact analog displays. (15) Evolution of displays to resist disorientation and to achieve optimum head-up display arrangements. (16) Synthesis of improved blind-landing and terrain-following displays. (17) Specification of the best training and utilization procedures to enhance learning and skill transfer. An example is presented of the application of the theory to the manually controlled ILS approach of a large jet aircraft.

Meister, D. A pragmatic approach to the prediction of operational performance. In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	1.3	The pragmatic approach to predicting operational performance has the following characteristics: (1) a conscious attempt to avoid mathematical models and theoretical processes and, instead, to extrapolate predictive indices directly from empirical data; (2) an emphasis on data, not theory; (3) a focus on certain parameters that are assumed to be important to operator performance. Logically and heuristically, it can be assumed that a restricted number of parameters account for the greatest part of the operator's performance; if human performance were affected equally by all possible factors, it would be infinitely variable and unpredictable. The important parameters tend to be task oriented or at least related to operational system requirements. The parameters selected for predicting operational performance obviously define what data are needed.
	2.4	In predicting performance, it is also necessary to account for the fact that more than one task may be performed concurrently by the same operator. Each of two concurrent tasks has its own important parameters, for predicting the task's individual performance; the concurrency of the two tasks is another important parameter for predicting the total performance.
	3.1	The parameters considered to be important, in general, are the following:

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

(1) The number, organization, and utilization sequence of controls and displays involved in the task.

(2) The display exposure time.

(3) Display visibility.

(4) The nature of the stimulus displayed (i.e., structured or unstructured).

(5) The number of visual stimuli.

(6) The operator function (i.e., the type of response required of the operator: e.g., discrete control response, continuous control response, simple monitoring, detection, discrimination, tracking, stimulus identification, information extraction, decision-making, etc.)

(7) Stimulus movement.

(8) The characteristics of the control-display coordination.

(9) The amount of information the operator must handle.

(10) The feedback (type, amount) provided to the operator following his actions.

3.3 Other important parameters that relate to task requirements include:

(1) The performance accuracy required of the operator.

(2) The operator loading (pacing, or time constraints).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.2	Theoretically, data on these parameters can be obtained under either experimental conditions or the actual operational environment. The author doubts that experimental work will be able to supply the necessary information, given the poor record of human factors research in supplying relevant data stores, and given the focus of most research on operationally meaningless, artificial, unrealistic tasks. The difficulty of data collection in the operational environment is one of setting up conditions which isolate the parameters of interest: the parameters usually exist only in interaction under operational conditions. The solution is to identify operational conditions which display combinations of parameters of interest. By locating and measuring different parameter combinations, comparing results, and ascribing differences to variations in the parameters between the two combinations, the individual parameter effects can be isolated.

Meister, D. Assumptions underlying test and evaluation strategies. San Diego, CA: Navy Personnel Research and Development Center. (Speech, undated).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	Five assumptions are discussed at length. They are summarized below: (1) Human performance can be measured in a system work context. (2) Since human performance occurs as part of system operations, it must be measured in a system-related way. (3) Maximum simulation fidelity produces more valid tests and evaluations than lesser amounts of simulation fidelity to the operational system and environment in which the system being tested will perform. (4) Test and Evaluation (TE) is important only during a specific period of system development. (5) It is possible to conduct TE without specifying in advance human performance criterion values. The primary question asked in any TE situation is: Is personnel performance satisfying overall system requirements? It should be noted that assumptions 3 to 5 are either elaborated on and/or refuted by the author.
	2.1	Test and evaluation, as the author described it, is termed OST (Operational System Testing) in which the new system is a prototype placed in a functional setting that is or resembles the environment it will ultimately be exposed to.

Meister, D. Assumptions underlying the human reliability model. In G. W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69F-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1 2.4	The author points out that any measurements of system reliability or system effectiveness which do not include indices of human performance must necessarily produce an erroneous estimate of that system's reliability or effectiveness. The goal of the human reliability methodology is to quantify human performance in a man-machine context. The author notes that these procedures derive by analogy from an equipment reliability orientation; the human component is viewed as a "black box", and human performance is conceptualized in terms of a single probabilistic measure, i.e., task completion or task failure. This concept also implicitly assumes that each stimulus condition presented to the subject increases the potential for error and reduces the probability of successful task completion. Another assumption of the model is that the individual probabilities of performance for the behavioral units summate mutiplicatively; however, when combining task probabilities to derive higher function probabilities, it is unreasonable to assume independence of those tasks implicit in multiplicative summation. The model also makes the overly simplistic assumption that error is equivalent to failure to complete the task; however, it is perfectly obvious that a task might be completed successfully even if several

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		errors are made during its performance because the human operator often can correct his errors.
		The model also has the inadequacy of dealing only with individual operator behavior; it forms predictions of group performance through the straight miltiplicative process, and this is manifestly inappropriate.
		The model also assumes no change in the behavioral unit probabilities as a function of repeated performance, and takes no account of individual variations in skill.
	3.5	The major steps in the application of the human reliability model are as follows:
		(1) Analyze system operations into discrete units of behavior to which predictive data can be applied.
		(2) Determine the parameters affecting each task behavioral unit.
		(3) Assign probability values based on historical data to each behavioral unit.
		(4) Combine the individual unit probabilities together to form task probabilities, function probabilities, etc.
	5.4	In the summary, it is noted that many of the assumptions in this model are consciously incorrect, and therefore it is questioned whether this knowingly inadequate model still has value. The answer is yes, and that it has two types of values: First, it stimulates conceptual activity by the investigators and raises scientifically important questions which might not have been raised without the model. Second, it has heuristic value, in

that is reduces the amount of uncertainty that we have.

6.1 The paper discusses the human reliability model primarily as a means of illustrating certain characteristics of behavioral models in general and certain characteristics of model-makers themselves. The author's personal view is that a model is effective to the extent that it helps either to gather data and/or to explain those data. As a corollary, he states that any behavioral model which is not concerned with real-world data (as opposed to laboratory data) is not useful. However, he observes that behavioral models characteristically have employed laboratory data and ignored or been unable to handle natural event data. Models thus are painfully data limited - - their characteristics and their basic assumptions often are determined by the limitations of the data input to them. These data limitations often result from the way in which we scientists have been taught to perform our studies and by the biases we knowingly or unknowingly insert into these studies.

The human reliability model is cited as a case in point. The author asserts that this model's assumptions derive from the unsystematic manner in which the model's input data were secured, and he points out that at least in part, these assumptions demonstrably are not in accord with empirical reality.

Meister, D. A systematic approach to human factors measurement. San Diego, CA: Navy Personnel Research and Development Center, October 1978.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1	The concept of "system" is the foundation of human factors studies which seek to measure factors that affect personnel performance in manned systems. In measuring any system, one must keep in mind certain universal properties of all systems: they are organized hierarchically, have a purpose, are interdependent, and contain their own standards for measurement, evaluation, and feedback since a purposive system establishes, ipso facto, its own standards.
	1.3	Looking at operational manned systems in general, one can list several aspects of the measurement process that are common to any analysis: (1) Assessment of the impact of system parameters on personnel performance. (2) Assessment of the impact of human factors on system outputs. (3) Specification of the "mission scenario" of the system (initial stimulus to end-point). (4) Replication (validation) of the research study under identical or simulated conditions.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		All system-relevant factors must be included in any measurement situation to ensure that those variables chosen represent the operational system. There are two factors involved: (1) all variables that would be expected to affect system output in the operational environment must be included; (2) all interactions in the system representation must also be included.
	2.1	The type of measurement system focused on here was called PSM or Personnel Subsystem Measurement: measurement of personnel performing a task or job within the actual work, or system, environment.
	2.2	PSM's purpose was to determine the feasibility of a research approach; choose an optimal alternative; determine performance capability; resolve personnel subsystem dysfunctions; contribute needed research.
	2.5	A comprehensive use of PSM has the potential to answer the following questions pertaining to four separate stages: system development, training program development, system operation, and system maintenance. (1) System Development: a. Do personnel have the capability to perform certain tasks at a specified level? b. Is there an optimally efficient interface between system design and personnel? c. Regarding personnel performance, two or more system configurations is most effective?

d. Does the prototype or developmental system fulfill system requirements from the personnel perspective?

e. How does one develop a system by using human factors inputs? What relationship exists between system characteristics and operator performance?

(2) Training:

a. Has training been adequate?

b. Is there transfer of performance from the simulated learning environment to the real, operational environment?

c. Does training in one mode compare with training using another mode?

d. How closely must the training environment match the operational one?

(3) System Operations:

a. Do system personnel perform according to requirements?

b. Is the system ready to operate as required?

c. How can system verification problems be solved?

d. How do new and old system configurations compare?

(4) System Maintenance:

a. How do technicians perform and resolve equipment malfunctions, i.e., "diagnostic maintenance"?

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		b. How efficient is that maintenance?
	3.1	In using measures to evaluate system performance, PSM's approach is to measure the individual, team, subsystem, and system levels where appropriate. PSM emphasizes normative data, which are primarily descriptive. Two types of normative data were used in PSM evaluation: (1) Data describing systems and their interelationships. (2) Data describing personnel task performance.
	4.1	Data are analyzed by correlational analysis in PSM under operational conditions; in a laboratory experiment, testing the significance of differences is the most common technique.
	4.2	The parameters of a given PSM evaluation involved system and personnel specification. With regard to personnel parameters, the following must be defined: characteristics of equipment, job, individual aptitude, skill, experience, and motivation.

Meister, D. Human factors in operational system testing: A manual of procedures (NPRDC SR 78-8). San Diego, CA: Navy Personnel Research and Development Center, April 1978.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	This handbook has been developed to enable Marine Corps test personnel to evaluate a new system for its human factors adequacy. The term "human factors" refers to the entire complex of elements that affect personnel performance. This handbook provides information on the Personnel Performance Test Plan, including its purpose, a step-by-step description of its various sections and requirements for completing those sections, a model for illustrating the material to be included in such a plan and a procedure for developing quantitative personnel performance criteria. The next section covers the selection and development of measures and measurement methods followed by a human engineering checklist of procedures. The handbook also describe "Self Report Rating Scales" and interview questions. Test procedures are covered and there is also an introduction to statistical methodology. The last sections contain a "Personnel Performance Test Planner's Checklist" and a Personnel Performance Test Report. The final section gives references which might be useful to the user of this handbook.

Meister, D. & Rabideau, G.F. Human factors evaluation in system development. New York: John Wiley & Sons, 1965.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The practice of human factors in the relationship between the capabilities and limitations of men and the characteristics of machines involves the following: (1) Performance of a functional analysis of system requirements. (2) Development of personnel selection and training criteria. (3) Design and evaluation of manually operated control and crew personal equipment. (4) Study of the environmental factors affecting human performance. (5) Participation in system performance tests. (6) Surveillance of production facilities and applied research. Whenever there are design alternatives, human factors evaluation is essential to eliminate the systems' susceptibility to human error.
	1.2	It is difficult to compare the man-machine behavior of one system with that of another because the terms of that behavior are not yet operationally definable.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		A crucial characteristic of the system is its purposiveness (goal-directed behavior). Goals can be divided into two groups: primary (mission-oriented) and secondary (supporting). Primary goals seek to accomplish the system mission and direct the performance of all mission-related system activities. Secondary goals seek to maintain the integrity of the system until the mission has been accomplished.
	2.2	The mission described the man-machine activities performed to accomplish the primary system goals. Unless it is framed in terms of mission goals, system behavior becomes extremely difficult to explain or understand because purpose is the single factor which unifies a great variety of disparate system behavior.

Melching, W.H. A concept of the role of man in automated systems (Professional Paper 14-68). Presented at the Southwestern Psychological Association Annual Meeting, New Orleans, LA, April 1968 (AD-671 128).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	A problem to systems designers is the allocation of functions between man and machine. This paper reports an attempt to isolate and identify factors pertinent to making allocation decisions. In an analysis of the functions and missions of several automated systems, the following factors were shown to be highly relevant to allocation decisions: (1) State of the art. (2) Cost of automation. (3) Space and weight constraints. (4) Lead time. (5) Difficulty to program. (6) Man's role in automated systems. The designer of an automated system needs a clear-cut conception of the general role of man in such systems. In effect, the designer needs a conception of what man's role <u>should</u> be before he can decide what it <u>will</u> be.

Meyer, R.P., Laveson, J.I. & Pape, G.L. Development and application of a task taxonomy for tactical flying (AFHRL-TP-78-42, Vol. 1). St. Louis, MO: Design Plus, September 1978 (AD-061 387).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.1	The primary purpose of this document is the development of a "surface task analysis" based on a sample of sixteen tactical maneuvers found in tactical flying (seven air-to-ground maneuvers and nine air-to-air).
	2.3	The authors chose the F-4E aircraft as a representative tactical craft, and based their analyses on pilot performance in the F-4E.
	2.5	Ultimately, the use of a surface task analysis will allow a complete description of a flying task or maneuver, step-by-step.
	2.6	By focusing on the pilot's aircraft control behavior, this study offers a data system from which improved flying training concepts and methods can be derived. Using this system (surface task analysis), training developers can determine and substantiate the content of training programs. Training programs can also be identified and alternative solutions formulated using this system.
	3.1	The surface analysis technique, by definition, measures the following: (a) cues, or inputs which the pilot received from his flying environment to perform a certain task; (b) mental action, which processed the cues, and (c) motor actions, or outputs in the form of movements of the aircraft flight controls.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.2	The cues were divided into four categories: visual, aural, control, and motion cues. Visual cues included outside or environment-generated cues, such as the horizon or cloud formation; inside, or aircraft-generated cues, includes information obtained from flight instrumentation or radar. Aural cues include such items as communication, weapons tones, slipstream, etc. Control cues involved aircraft flight controls, which were either (a) dynamic tactual, e.g., aileron, stabilizer, rudder, throttle, or (b) discrete tactual, e.g., toggle and rotary switches, etc. Finally, motion cues consisted of stimuli which were sensed by body receptors such as + or - G-force, vibration, etc.
	3.3	Rules and procedures were developed for the specific application of the cues categories in performing a surface task analysis. Generally speaking, each surface analysis must identify the following: (a) the aircraft type involved; (b) the maneuver(s) involved and weapons delivery; (c) whether the maneuver environment is a range- or tactically-oriented one; (d) the flight path(s) of the aircraft; (e) the starting situation of the aircraft and the specified task goal. A diagram of the maneuver is then prepared, and for each element of the flight sequence, a chart is filled in with information on cues, mental action, and motor action.
	4.1	The data base for the entire taxonomy classification consisted of interviews with pilots regarding sixteen representative tasks, both air-to-ground and air-to-air. There are, therefore, sixteen separate surface task analyses. Detailed analyses, or classifications of flight maneuvers were given to complete Volume I of the study. Volume II details the rationale and methods used to formulate a taxonomic structure for tactical flying tasks.

Meyer, R.P., Laveson, J.I. & Pape, G.L. Development and application of a task taxonomy for tactical flying (AFHRL-TR-78-42. Vol 2). St. Louis, MO: Design Plus, September 1978. (AD-061 388).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	A taxonomy of tactical flying skills was developed as a user-oriented skill-task analysis system for practical application in solving Tactical Air Command (TAC) continuation training problems and for a behavioral data base for skill maintenance and reacquisition training research and development. Sixteen representative tactical air-to-air and air-to-surface maneuvers were analyzed and classified within the system with provision for later expansion. A classification system was developed to accommodate the complexities of tactical flying. A data system was organized with sufficient flexibility to objectively address many areas of tactical flying. The taxonomy system also included methodology for addressing on-going training problems and requirements.

Meyer, R.P., Laveson, J.I. & Pape, G.L. Development and application of a task taxonomy for tactical flying (AFHRL-TR-78-42, Vol. 3). St. Louis, MO: Design Plus, September 1978. (AD-A061 478).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.2	A taxonomy of tactical flying skills was developed as a user oriented skill-task analyses system for practical application in solving Tactical Air Command (TAC) continuation training problems and for a behavioral data base for skill maintenance and reacquisition training research and development. Sixteen representative tactical air-to-air and air-to-surface maneuvers were analyzed and classified within the system with provisions for later expansion.

Miles, J.L. Some recent trends in human factors testing (Tech. Memo. 22-76). Abeerdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. June 1976. (AD-B012 110).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 3.1	The cost-effectiveness of human factors (HF) testing in any material development project depends in large part, on the uses to which the test data will be put. Whereas the human engineer contributes data in terms of human performance or effects of specific variables, the systems analyst wants the question "So what" explained in numbers. AMSAA (Army Material Systems Analysis Activity) has stated that the "soldier is part of the system" and human factors data should be analyzed "not as a separate additional activity, but as an integral part of our evaluation of each system". The HF data therefore, need to fit into five categories of interest to the systems analyst: effectiveness, reliability, availability, maintainability, and training. The normal performance measures used to determine figures for the above five categories were time and error.

Miller, J.G. Living systems. New York: McGraw-Hill, 1978.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.2	The author examines all biological and social systems and divides them into seven hierarchical levels: cells; organs (composed of cells); organisms (independent life forms); groups (families, committees, etc.); organizations (communities, universities); societies or nations; and supranational systems. Each of these levels carries on both matter-energy and information-processing functions for a total of 19 critical subsystems. The author defines 13 distinct concepts which must be understood in analyzing any living system at any level: (1) Space and Time: all concrete systems, living and non-living, exist in physical space; this latter space acts in various ways to partially constrain and determine the system under consideration. For example, residents of a neighborhood who are physically closer in space to each other will interact with a greater rate of frequency; alternatively, the number of nucleotide bases - which are configurations in space - that a DNA molecule contains will determine the amount of information (bits) that it can contain. Examples of conceptual space which can be found in all living and nonliving systems include: (1) Lewin's "life space," which is the perceived environment that immediately surrounds an individual; and (2) Warner's "social-space" which separates, say, an upper-lower class person from a lower-middle class person.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

The concept of time has been acceptably quantified through everyday use of seconds, minutes, etc., to measure durations, speeds, accelerations, etc. However, the general theory of relativity makes it clear that for large systems, e.g., astronomical systems, time cannot be measured on any absolute scale.

(2) Matter and Energy: Matter, defined as anything which has mass and occupies physical space may have several forms of energy, defined in physics as the ability to do work: (a) Kinetic energy, when mass is moving and creates a force on other matter; (b) potential energy, referring to a mass' position in a gravitational field, and (c) rest mass energy, which results from the conversion of matter into energy. Matter and energy are equivalent ($E=MC^2$); all living systems require specific types of matter-energy.

(3) Information: here defined as ". . . the degrees of freedom that exist in a given situation to choose among signals, symbols, messages, or patterns to be transmitted." The term "marker" is used to denote an observable unit or change of matter-energy whose patterns indicate informational symbols (e.g., cuneiform writing, punched cards, pulses on a telegraph wire); due to advances in technology, the matter-energy costs of storing and transmitting these markers has decreased, while information-processing efficiency has increased by decreasing the mass of these markers: cuneiform tables carried 10^{-2} bits of information per gram; paper with typed messages 10^3 bits per gram; electronic magnetic tape storage carries 10^6 bits per gram. The point to be made for

systems analysis is that there are significant matter-energy constraints upon information-processing of all living systems as a result of the composition of their "markers."

(4) System: the most general definition is " . . . a set of interacting units with relationships among them." Systems may be open (boundaries may be crossed by information or matter-energy transmissions), closed, nonliving, living, totipotential (can carry out all critical subsystem processes necessary for life), partipotential, fully functioning, or partially functioning. Each type of system responds to varying types of measurement.

(5) Structure: ". . . the arrangement of its subsystems and components in three-dimensional space at a given moment in time."

(6) Process: changes in the matter-energy or information in a system is called a process. A process is reversible if it remains the same regardless of the time dimension. Process includes the function of a system and its history.

(7) Type: refers to similar characteristics among a number of living systems.

(8) Level: level refers to the particular position of a system within a hierarchy, e.g., groups are composed of organisms, organizations are composed of groups, etc.

(9) Echelon: this refers to the various levels of components in a system or subsystem. Certain decisions are made by one component of a subsystem and others by another, the two components being either at the same or different

echelons of the subsystem.

(10) Suprasystem: this refers to the next highe· system in which the system in question is a subcomponent or part. The immediate environment of a system should be distinguished from the suprasystem: the latter will affect both the system's environment and the system itself.

(11) Subsystem and component: subsystems are distinct structures which carry out distinct processes within a system. The distinct, structural units themselves are called the components. Within the level of organizations, the concept of role would be a component; however, not only will the role affect the organization, but the nature of the individual who fills that role will have an impact as well.

(12) Transmissions in Concrete Systems: Transmissions may be of matter, energy, or information, and can be analytically distinguished in terms of (a) inputs across system boundaries, (b) internal processes within a system, and (c) system outputs. The "template" of a system is its original genetic or information input that programs the system's structure and process.

(13) Steady State: all living systems maintain steady states (homeostasis) among their variables, keeping a balance not only with intra-system variables, but with their environments and suprasystems as well. The "LeChaterlier principle" is particularly apropos to the steady state concept, and states that a stable system under stress will move in that direction which minimizes the effect of stress (a compensatory force

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		will be exerted to oppose the stress, usually accompanied by changes in related system variables that are not directly affectrd by the stress). Cybernetics, the study of methods of feedback control, is an important part of steady state theory.

Miller, J.R. Assessing alternative transportation systems (RM-5865-DOT). Santa Monica, CA: The RAND Corporation, April 1969. (PB-185 167).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	This paper addresses the problems of assessing worth among alternative transportation systems. It assumes that a decision context has been specified and that a fixed set of discrete alternatives has been produced.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.5	The performance requirements are that the criteria are complete, mutually exclusive, of major significance and free of worth interdependence.
	2.6	The first step of the assessment procedure is to define explicitly what is desired in the way of performance for each alternative.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.3	Having established a list of overall objectives, the second step is to generate a hierarchial structure of successively more specific performance criteria. This involves breaking down or subdividing higher level criteria into one or more lower-level criteria alleged to be included within the meaning thereof.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.4	The third step is to select a physical performance measure for each lowest-level criterion. Performance measures describe what an alternative can deliver, while performance criteria state what the decision-maker desires. The purpose of selecting performance measures is to establish concrete connections between desires and deliverable performance from real alternatives.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	3.5	In the fourth step specific worth relationships are mapped out between each

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		lowest-level criterion and its related performance measure. This is implemented by defining scoring functions which assign a unique numerical worth score to every possible value of a performance measure. The worth scores are then combined to arrive at an overall index of each alternative's worth. This is accomplished by defining a weighting function. An additive function with constant trade-off weights can be adopted for this purpose. The sixth step is to validate both the scoring functions and the weighting functions against whatever alternatives have been produced. This means computing an overall worth index for each alternative and judging the results for reasonableness. Results generated during early passes through the procedure are usually unreasonable in some respect. Selective revisions by use of the following might be needed: adding criteria, further defining or subdividing existing criteria, re-calibrating scoring functions and re-adjusting weights.
	4.1	The final process is to assess each alternative by trading off each's overall worth by the following considerations: risk, required resource expenditures, temporal changes in objectives, aspiration levels and tastes, and different and possibly conflicting points of view among diverse interest groups.
	5.1	An experimental test of the procedure was included in the report.

Mills, R.G. & Hatfield, S.A. Sequential task performance: Task module relationships, reliabilities, and times (AMRL-TR-72-56). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory, 1974. (AD-787 322).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

1.3 Attempts to quantify human performance in man-made systems are generally of a system reduction form; reductionism means that a system is analyzed into modular task elements. Following this analysis, an estimate of HPR (Human Performance Reliability) and the performance time associated with each module is obtained with their mathematical synthesis provided as an estimate of the complete system's performance.

The problems underlying this procedure include assumptions of normal distributions, of a single distribution underlying task-module performance time, and of interactions among task modules.

4.1 The statistical methods used to analyze the data included calculation of the mean, median, standard deviation, t-tests, and Duncan's Multiple Range Test.

4.3 The apparatus for this study included a display/control device, two books of Z tables and a device for displaying single lines of a computer print-out on a trial-by-trial basis.

The Z-values were obtained by assessing the tables using the displayed X and Y values as table coordinates. The display/control device consisted of five analog meters and five digital read-out modules; one meter was designated the "Primary Meter," the remaining four meters displayed extraneous information, while three of the five

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		digital modules were collectively labeled "y".
	5.3	The following results were indicated: (1) the normality assumption for distribution of task time is inappropriate; (2) the rules for combining task times are satisfactory if the underlying distribution of task times is known; (3) HPR is affected severely by combining tasks; and (4) any model for estimating HPR will require parameters to account for task combining and difficulty.

Mitchell, M.B. & Blanchard, R.E. The allocation of System Effectiveness Requirements for man-machine effectiveness analysis. In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 2.1	Allocation of System Effctiveness Requirements (SER's) is the process of determining how the total system's effectiveness requirements distribute among the system's constituent man-machine functional units/states. To develop a procedure for effectiveness requirements allocation, guidelines must be generated for: (1) Specifying the system effectiveness requirement along all its dimensions. (2) Partitioning the system into segments and states. (3) Characterizing and specifying input data. (4) Relating the SER to system segments consistent with the input data. The concept of requirements allocation implies a multiplicity of contributors to the meeting of those requirements. "Contributors" generally fall into one of two categories of verbal description: (1) activities, or (2) system states. The author found that analysts who are activity-oriented tend to be more stimulus-bound and less free from pre-conceived notions than those who are state-oriented. Specification of system states tends less to imply transitionary methods for achieving those states and

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		tends to lead to a creative, open-minded approach to analysis-both for new designs and for evaluation of existing systems.
	2.2	It is necessary that valid system effectiveness requirements exist and are derived from mission analyses, and that the system is partitioned into manageable units for evaluation of their contribution to system performance. There still remains the need for relevant data and procedural rules for systematically applying those data to enable allocation of the given SERs among the component units.
	2.5	A stipulated value for the SER is established to define an acceptable level of performance with respect to system objectives. Effectiveness requirements may take the form of a single value, several values or an interval. These values represent levels of effectiveness which are acceptable under specified operating or environmental conditions. When more than one effectiveness dimension is needed to reflect the system objective adequately, the SER may be represented as an index resulting from the mathematical combination of values on several effectiveness dimensions.
		For allocation of SERs, mission analyses must have been directed toward defining requirements appropriate for effectiveness analyses. Values along all relevant dimensions must emerge as an end product. Currently such end products are sorely lacking due to the intuitive approach to design for meeting imprecisely defined system objectives. SERs are rarely specified, either because (1) they had not been considered, or (2) the researchers don't wish to face the fact that serious objectives may not always be reached, or (3) they are unwilling to record fallibility.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.1	Quantification of effectiveness requires identification of one or more measurement dimensions. Most frequently used measurement dimensions are accuracy, time, quantity, and rate, constrained by cost limitations. Effectiveness dimensions must be related as directly as possible to stated system objectives.
	5.3	The allocation of SERs must provide a set of performance requirements or standards at a level sufficiently elemental to facilitate: (1) Trade-off studies. (2) Relative appraisal of various system design concepts. (3) Absolute evaluation of given design concepts. (4) Absolute evaluation of a given design against the SERs established for the system.

Mitchell, M.B., Smith, R.L. & Blanchard, R.E. Test application of TEPPS on a Navy CIC subsystem. Santa Monica, CA: Dunlap and Assoc., Inc., August 1967. (AD-821 573).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The Technique for Establishing Personnel Performance Standards (TEPPS) provides for establishing performance standards that are defined as criterion measures along such effectiveness dimensions as probability of accomplishment and time to perform definable man-involved operations. The technique involves analysis of a system into describable and useful units of personnel behavior. Once that has been accomplished, system effectiveness requirements are allocated along the units, and the resulting standards can be used to evaluate the efficacy and efficiency of a particular system design relative to stated system effectiveness requirements. To achieve those objectives, application of TEPPS involves the following general procedures: (1) Collect and organize pertinent data. (2) Construct the Graphic State Sequence Model (GSSM) relating system required states to one another and to man-machine activities. (3) Relate probability and time to achieve system output to probability and times to accomplish defined man-machine activities: OR (1) Employ TEPPS computer program for deriving standards by allocating

effectiveness requirements to man-machine activities:

(2) Compare performance standards with human capability values.

(3) Evaluate differences and determine optimal corrective action.

2.1 A field test of the TEPPS was performed on a simulated, conventional radar detection and record-keeping subsystem of an anti-air warfare system.

3.1 Data was collected by observation, documentation and interviews at a training center, and a GSSM was developed.

3.2 Since the program required human capability estimates, subjective data were collected from 16 expert judges on 29 unique activities identified in the GSSM.

3.4 Indices of probability of accomplishment and performance time estimates were derived from those data and were included as part of the input to TEPPS computer program, along with the coded GSSM and the imposed effectiveness requirements. TEPPS computer program was run and probability and time standards were established under all modes of system operation.

Montgomery, D.C., Callahan, L.G. & Wadsworth, H.M. Application of decision/risk analysis in operational tests and evaluation. Atlanta, GA: Georgia Institute of Technology, The School of Industrial and Systems Engineering, September 1975. (AD-A024 205).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

1.1 The objectives of the project were to develop a methodology with a set of procedures for applying decision/risk analysis to the design of operational tests and the analysis of operational test results. An operational test was defined as that test and evaluation conducted to estimate the prospective system's utility, operational effectiveness, and operational suitability. One of the objectives of operational testing is an independent evaluation of competing systems resulting in some statement of relative attributes and preference.

3.5 The project contains a review of four analytical procedures for risk assessment. Risk analysis can be viewed as the process of combining the risk assessment with alternative courses of action in an iterative cycle.

(1) "An application of Multivariate Discriminant Analysis and Classification Procedures to Risk Assessment in Operational Testing." This research developed a methodology for determining an index useful in the assessment of risk in operational testing. The risk assessment problem examined is that of preference statements regarding systems. To evalute the competing systems, multivariate distributions of each system and the overlap of these distributions is used to determine the index of risk. The index of risk is a

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		measure of similiarity of the competing systems. (2) "An Application of Simulation Networking Techniques in Operational Test Design and Evaluation." Operational tests contain several activities, subtests, or subprograms. Each of these activities or subtests has related functional values. These values may be deterministic, stochastic, or some mathematical transformation of a value computed in an earlier activity. These activities lead to milestones or events and the outcome of the operational test can be represented by a set of successful and a set of unsuccessful events. This set of conditions describes a stochastic network. Of the network analysis tools, network simulation affords the greatest versatility and flexibility in modeling this set of conditions. Of the family of network simulation programs two programs have evolved as useful analysis tools to assess risk, SOLVNET and VERT. The objective of this research is to investigate the use of these network simulation programs in the design of operational tests and the analysis of operational test data. (3) "An Application of Bayesian Analysis in Determining Appropriate Sample Sizes for Use in U.S. Army Operational Tests." The research was devoted to modifying the Bayesian Techniques associated with determining the minimum sample size required to construct interval estimates of the true mean of an experimental or sampling process which is modeled by a normal distribution with unknown parameters. The procedure considers only the case where the prior information can be represented by a

normal distribution with known mean and known variance.

(4) "Finding a Minimum Risk Path through a Network Using Resource Allocation Techhiques." The objective of this research was to develop an optimization method for network risk analysis where a resource constraint is present. (This thesis was unfinished and only the methodology outline was presented.)

Mumford, J. & Smith, J.P. The development of performance criteria for turret mechanics (HumRRO Research Memo.). Alexandria, VA: Human Resource Research Organization, July 1961. (AD-477 647).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.1	The armor turret mechanic and his equipment in the training environment was the subject of this study.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	3.4	This study attempts to develop performance criteria for turret mechanics.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	4.5	The first step is to collect information on the task at the organizational level. This was accomplished by studying job descriptions and interviewing consultants knowledgeable in the field. Tasks selected, in a large measure, reflected judgment of personnel consulted. Exercises and tests were developed and administered to subjects. A scoring system was developed which enabled the tests to distinguish degrees of adequacy or inadequacy of performance. On the basis of this testing, the exercises were revised and a new draft prepared.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Nelson, R.T. A research methodology for studying complex service systems (Working Paper No. 139). Los Angeles, CA: University of California, Western Management Science Institute, July 1968. (AD-673 233).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The purpose of this study is to propose a research methodology which considers the physical, environmental, and decision-making aspects of complex service systems as a total system and to present a methodology in generalized concepts and terminology to emphasize the potential application to all systems. A schematic diagram is presented to structure the author's view of the physical service system, intra-system decision making and the environment. An illustration of the methodology proposed is also presented in this report. The example given is a simple production/inspection system producing a single product to inventory. The outline and description of the proposed research methodology is presented below: METHODOLOGY OUTLINE (1) Identification and Modeling a. Modeling of the physical system. b. Characterization of the system decision process. c. Modeling of the system criterion function. d. Modeling of the environmental response process.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(2) Experimentation a. Input-output analysis. b. Equilibrium analysis. c. System performance evaluation. d. Variation of system-environment decision variables. e. Variation of system control variables. f. Variation of system design variables. (3) Implementation An illustration of the process is presented which includes continuing observation of the operating system and its environment, and modification of the system model as well as continuing experimentation of the decision algorithm. It is expected that field studies may present far more of a challenge because of the identification, modeling and data requirements which will arise in actual situations. The methodological plan proposed here focuses attention on these requirements as an integral part of systems analysis.

Obermayer, R.W. & Vreuls, D. Combat-ready crew performance measurement system: Phase I measurement requirements (AFHRL-TR-74-108-II). Northridge, CA: Manned Systems Sciences, Inc., December 1974. (AD-B005 518L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	In an effort to improve training performance information, this study is directed towards a systematic definition of performance and development of methods for measurement. The primary goal is to provide usable measurement tools for attacking problems related to combat-crew training. This report covers the first phase - - definition of requirements for information based on data collection surveys to six selected combat-crew training sites.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The systems addressed were the A-7, B-52, C-130, C-141, F-4, and F-106 weapon systems, their crews, and their training.
	2.6	The performance of trainees during and at the end of training is the measure by which these training programs can be judged.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	Instructional system development requires that performance standards are identified so that the most efficient approach is used to train for the needed skills and knowledge to the desired level of performance. The first phase of the study consisted of three tasks: (1) Data collection; (2) Analysis of common measurement requirements; (3) Dimensions of measurement modularity.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT - -

(1) Data Collection - - All existing subjective and objective methods of measuring performance during and at the end of training were examined. Researchers attempted to:

(a) Properly consider measurements in the context of combat-crew training.

(b) Assess the measurements already included as well as potential measurement.

(c) Assess the constraints placed by the combat-crew training environment on feasible usable measurement systems.

(2) Training Measurement - - At each site, information was collected with respect to:

(a) The training sequence.

(b) Points where measurement exists.

(c) Measurement possibilities.

(d) Feasibility of research measurement.

(e) Specific new measurement development.

Six quite different aircraft were included in the sample for measurement analysis and an attempt was made to determine whether a simple practical measurement system for all applications is possible.

(3) Prototype Measurement - - As a natural extension of the considerations of measurement commonality, examples of the information required for training were developed. These measurement requirements are extensive and

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		complex. However, this detail is probably needed to support the training process.
	5.4	This study is continued in Phases II and III.

Obermayer, R.W. & Vreuls, D. Combat-ready crew performance measurement system: Phase II measurement system requirement (AFHRL-TR-74-108-III). Northridge, CA: Manned Systems Sciences, Inc., December 1974. (AD-B005 519).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3 3.2	This report describes the second phase of a study directed towards a systematic definition of performance and development of methods for measurement in an effort to improve training performance information. This phase deals with the requirements for a measurement system to process the measurement which has been dictated by the previous reports. Research procedures were developed to indicate the operation in which a measurement system is to serve as a tool in achieving research goals, and methods of measurement processing were determined to investigate the nature of data processing associated with training research measurement. In addition, system criteria to guide design tradeoffs were addressed and preliminary systems analyses conducted to establish measurement system requirements which follow rather directly from the system criteria. In the latter effort, measurement parameters were identified and the approximate number of measurement parameters for each flight phase were presented.

Obermayer, R.W. & Vreuls, D. Combat-ready crew performance measurement system: Phase IIIA crew performance measurement (AFHRL-TR-74-108-IV). Northridge, CA: Manned Systems Sciences, Inc., December 1974. (AD-B005 520L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3 2.1 2.4	This report describes Phase IIIA of an effort to improve training performance information. This study is directed towards a systematic definition of performance and development of methods for measurement. The primary goal of the study is to provide usable measurement tools for attacking problems related to combat-crew training. In accordance with the initial definition of this study, emphasis was placed on pilot performance, but it was soon recognized that avoiding the contribution of other crew members and the interaction between crew members, had serious consequences. Therefore, additional tasks were undertaken. The systems addressed in this phase are the F4E and the C141A weapon systems and their combat crew training units. After the requirements for pilot proficiency measurements were established, time was given to the consideration of the variety of possible systems and to the constraints imposed. A conceptual design had been formulated, consisting of feasible alternatives, to indicate the type of information possible, the places where such information would be useful, and the possible ways such information could be collected. It was concluded that measurement of crew/system performance (as opposed to pilot only) was important to a thorough description of performance for certain tasks and missions. Consequently, the additional task of defining crew

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		proficiency measurement requirements was undertaken and these requirements will be incorporated into the conceptual design.
	4.5	This phase addressed the problem of crew performance as opposed to pilot performance. A survey was conducted to thoroughly define requirements in the measurement-system to sense crew interaction. The survey was conducted at nine sites, two of which were visited specifically for the collection of information on crew performance.
	5.4	One of the main difficulties in performing detailed analyses of crew interaction is the lack of specificity in stating requirements for crew relationships. Since crew interaction techniques are non-standard, and specific techniques are non-trained, measurement of crew interaction cannot be explicitly defined in most cases. A further difficulty is the degree to which the performance of each crew member is dependent upon the performance of others. It was concluded in this phase of the study that better methods of crew interaction must be discovered and developed.

Obermayer, R.W., Vreuls, D. & Conway, E.J. Combat-ready crew performance measurement system: Phase IIIC design studies (AFHRL-TR-74-108-VI). Northridge, CA: Manned Systems Sciences, Inc., December 1974. (AD-B005 521L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	This report covers a further phase in the research for the improvement of combat-crew training. This effort deals with design studies to determine desirable system features to meet the research needs documented in the earlier reports of this sequence.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate		An analysis of factors to be considered in training measurement system design is presented and the nature of tradeoffs for each system criterion established are indicated.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	A number of analyses were performed in this program to guide design decisions. Eight primary analytic steps were: (1) Determine Measurement Needs (2) Identify Physical Parameters for Measurement (3) Develop Automated Measure Descriptions (4) Develop Manual Measure Descriptions (5) Determine Where to Obtain Information (6) Determine Data Processing Needs (7) Determine if Visual Information is Sufficiently Accurate (8) Determine Cost Tradeoff Data
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		A measurement example was produced as a product of visits to combat-crew training units to attempt to express the main items of information relevant to training. Using this as a stimulus, preliminary measurement definitions were made along with assumed techniques for computation, leading to identification of a required set of parameters for measurement generation. These analyses were begun in earlier program phases, and subsequently were revised and extended. Continuing from the basic analyses, specific computational algorithms were chosen for both automatic and manual modes of measurement, forming an initial software specification. The next steps in the sequence attempt to determine best methods for sensing the needed information and the nature of appropriate data processing equipment. As video or photographic means of sensing information must be considered, it follows that a minimum resolution for such devices must be specified to ensure that the desired data are sufficiently legible. Lastly, data are collected relating to cost and personnel requirements to permit tradeoff analyses between alternative measurement system candidates. The design analyses resulted in tradeoff comparisons at two levels: (1) comparison of competing data sources, i.e., audio, X-Y, video/photo, and instrumentation (digital recording), and (2) comparison of systems built around only video/photo sensors and only digital recording. Tradeoff comparisons at the first level reveal the rule of alternative data sources, while second-level comparisons establish cost-effective system combinations.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.4	A clear uncomplicated choice is not possible between video/photo and digital recording approaches to measurement system design, but if such a choice must be made, video/photo recording will be chosen for cost, information provided, flexibility and ease of use. However, a hybrid system, combining the advantages of both, is preferable to either type of recording alone. Due primarily to cost, the bulk of measurement parameters would be derived from a video/photo system, and the remainder with a small digital recording capability. It would be desirable for the major components of a hybrid system to have a stand-alone capability of modest means and power for all combat-crew training measurement when used together. Auditory data recording should be incorporated together with the option for merging data with that from ground-tracking radar. All data recording must include provision for synchronization with other data sources.

131

Obermayer, R.W., Vruels, D., Muckler, F.A. & Conway, E.J. Combat-ready crew performance measurement system: Phase IIID specifications and implementation plan. (AFHRL-TR-74-108-VII). Northridge, CA: Manned Systems Sciences, Inc., December 1974. (AD-B005 522L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	Phase IIID of this study, designed to improve training performance information, presents specifications and an implementation plan for the performance measurement system recommended as a result of this program. The report covers the acquisition and processing of data personnel and facilities required, and describes the implementation plan.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	4.3	The appendix of this report provided a tentative survey and specification of equipment and instrumentation required for the implementation of the performance measurement program. There are three major sections to this appendix. Section one addresses the monitoring and data collection equipment anticipated for installation on the test aircraft(s). The second section discusses the post-flight ground debriefing facilities and associated equipment. The last section describes the data processing facilities and equipment requirements anticipated for detailed analysis and evaluation of collected data.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures		
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	4.4	An analysis of personnel requirements was conducted in Phase IIIC of this study. Further clarification is presented here with a reassessment of the total personnel requirements of the performance measurement system.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.5	The implementation plan recommended was based on Air Force Systems Command Manual AFSCM 375-5. There are five major steps required to implement this plan: (1) Selection of a system integration contractor. (2) Completion of preliminary detail system and subsystem design. (3) Selection of the final system design with appropriate testing. (4) Procurement of system hardware and system integration. (5) Completion of final system tests resulting in system turnover to the Air Force.

O'Connor, M.F. & Buede, D.M. The application of decision analytic techniques to the test and evaluation phase of the acquisition of a major air system (TR-77-3). McLean, VA: Decisions and Designs, Inc., April 1977. (AD-A040 691).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Mensures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 1.2	Currently the procedure for evaluating the suitability of the air system from a human engineering standpoint consists of test pilot inspections of the air system. The deficiencies are noted, the report is written, and the defect put into one of three categories. However, time is important and so a method is needed to communicate the information quicker with a prioritization of corrections as well. The answer to the questions of time and prioritization is a computerized system containing the test and evaluation information appropriately prioritized. One task to this goal is the development of a hierarchical evaluation structure which relates all the test and evaluation information to the missions of the F18 (the aircraft system under consideration). A diagram of that hierarchy is presented in the report.

Pew, R.W., Baron, S., Feehrer, C.E. & Miller, D.C. Critical review and analysis of performance models applicable to man-machine systems evaluation (BBN Rep. No. 3446). Cambridge, MA: Bolt Beranek and Newman, Inc., March 1977. (AD-A038 597).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.3 6.1	The present document deals with the attempt to design a guidebook for the evaluation of man-machine systems. The researchers feel that advocating the rise of the information processing data and modeling literature as a base presupposes that models will be developed with the most elemental components of performance and building from there. The limitations of models that were derived by human information processing specialists are: (1) The models tend to be compartmentalized by the very fact that most of them deal with particular stages of information processing rather than being integrative of human performance in general. (2) For the most part, human information processing models deal with the average performance of well-motivated, highly practiced individuals, under relatively ideal conditions. There are many hypotheses but few data and virtually no models in the information processing literature on how human performance capacities change under stress, under reduced motivation, before practice has stabilized performance, when interacting in groups or on the range, or characteristics of individual differences.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	6.2	Recommendations for further research and development of large scale systems modelling efforts include the following: (1) Development of a test bed to evaluate alternative model formulations of common task environments and to conduct empirical validation studies to compare model predictions with actual human peformance. (2) Methodological research on: a. Implications of combining sub-task or information processing component models on system performance in the aggregate. b. Validation of large scale simulation models. c. Development of guidelines for the acceptable number of free parameters in useful predictive models. (3) Further model development in topical areas of high priority for representation of command and control systems. (4) Advancing to state-of-the-art with respect to the specific modeling approaches discussed in the body of the report.

Phatak, A.V. Improvement in weapon system effectiveness by application of identification methods for determining human operator performance decrements under stress conditions (AMRL-TR-73-38). Palo Alto, CA: Systems Control, Inc., December 1973. (AD-773 856).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	The problem studied in this report is the development of realistic models for weapon system controllers that can be used to predict the effectiveness of manned weapon systems under stress conditions.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The system chosen for this study was the pilot of a high performance aircraft.
	2.2	The aircraft missions were engagements in either precision weapon delivery or air-to-air combat.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	The task chosen for this experiment was a single axis stable tracking task whose dynamics were representative of a high performance aircraft pitch axis control system. However, two other compensatory tracking tasks were also employed, but only the task described above is considered in this report.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	4.1	Two types of models were considered: (1) the input-output stochastic linear state-variable models (equivalent to describing function models when process noise $\equiv$ 0), and (2) the optimal control model developed by Kleinman, et al. The maximum liklihood identification technique was used in estimating model parameters from input-output data.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.5	The subjects performed the tasks at sea level followed by the same task at a simulated altitude of either 12,000 or 20,000 feet. Each run of this experiment consisted of two tracking periods. Each period was preceded by one minute of pre-breathing at the indicated altitude followed by one minute of tracking. The order of presentation of the simulated altitudes and tasks was randomized in order to minimize the effects of learning and anticipation of experimental factors.
	5.3	Results showed that the identification algorithm was highly successful in identifying the parameters of the stochastic state variable models. However, difficulties were encountered in applying the technique to identifying parameters of the optimal control model. It appears that the unsatisfactory identification results with the optimal control model are due, first, to the over parameterization of the model structure and second, because of the finite data and specific input-output data. Inferences regarding performance decrements due to stress were precluded because of insufficient data base for this study.

Phatak, A., Weinert, H. & Segall, I. Identification of the optimal control model for the human operator (AMRL-TR-74-79). Palo Alto, CA: Systems Control, Inc., May 1975. (AD-A009 956)

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	In this report, the optimal control model is analyzed from the system identification point of view to determine which parameters can be identified. As a result, a procedure for the identification of the optimal control model parameters from measured experimental data has been developed. This procedure is validated by application to experimental human operator data provided by Aerospace Medical Research Laboratory. In addition, a systematic approach is presented towards the development of a metric for measuring and ranking system difficulty as experienced by human operators in terms of system properties such as the degree of controllability and the degree of observability.

Philco-Ford Corporation Human engineering design check list (WDL-TR 1968A). Palo Alto, CA: Philco-Ford Corporation, May 1964. (AD-829 426).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	This report presents a checklist to be used for human engineering acceptance testing and design verification. It is also to be used as a human engineering guide. This checklist is a device by which human engineering design criteria and standards, as set forth in MIL STD-803A-1, can be verified during acceptance testing and checkout. The human engineering design is verified (a) in plant during equipment acceptance testing and (b) in-the-field during subsystem and system checkout. Plant acceptance testing is composed of two parts - - visual inspection and functional test. Field (on-site) checkout has five parts: completion of checks to verify compliance with MIL-STD-803A-1 on equipment acceptance-tested in-plant; inspection and test of all control/display equipment; monitoring of subsystem functional tests; monitoring of system functional tests during fly-bys and during system checkout with the checkout-subsystem; analysis, evaluation, and documentation of verification results.

Polak, W.T., Robertson, J.C. & Yuan, L.S. Systems Effectiveness Analyzer (AMRL-TR-73-113). Sudbury, MA: Raytheon Company, Simulation and Surveillance Systems, February 1974. (AD-781 124).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	The System Effectiveness Analyzer (SEA) is a weapon system measuring system which is based primarily upon the utilization of existing equipment (controllers and peripherals) supplemented by the additional software required to enhance existing capabilities to evaluate simulated weapon systems.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The SEA System has two major functions: (1) to checkout, control, monitor, and perform statistical analyses associated with tracking simulators; (2) to provide an estimation of weapon system effectiveness.
	2.5	There were several design features that were considered imperative to the development of the SEA measurement system: input flexibility, operator input options, simulator interface, turn-around-time minimization, and expansion.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.5	The weapons system includes the human tracker as its principal sensor of target motion. The metrics used to evaluate weapon system performance were the weapon's round-by-round probability of kill and the resulting target's probability of survival. Angular error statistics are used to evaluate tracker performance. One SEA simulation has been implemented. The simulated weapon system is an AAA battery using manned optical sights. The target being engaged is an aircraft deploying optical countermeasures. The SEA commands the tracking simulator's display of the sights picture, both with regard to target
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		position and countermeasure stress level. Outputs from the simulator include the subject's control movements and the gun trigger state. These outputs are used by the SEA, in conjunction with the target trajectory, to update the sights picture, to accumulate the statistical measures of the tracker's performance, and to compile the data on which to base the effectiveness analysis of the AAA system. The collected data are essentially that which would have been determined from an actual AAA system. The Lead Angle Computer directs the gun to the predicted position of the aircraft. The mean miss distance of each shell fired is estimated and error sources appropriate to the gun system are used to find the distribution of shot relative to the target aircraft. Weapon lethality and target vulnerability data are then used in conjunction with the shell mean miss distance and scatter area to determine the kill probability of each shell. The probability that the aircraft survives the mission is derived after each round is fired.

Popham, W.J. & Husek, T.R. Implications of criterion-referenced measurement. Journal of Educational Measurement, 1969, 6 (1), 1-9.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	For several years, measurement and instructional specialists have been drawing distinctions between norm-referenced and criterion-referenced approaches to measurement. A norm-referenced test identifes an individual's performance in regards to the performance of others; a criterion-referenced test identifies performance in regard to an established standard of performance. This report examines the implications of these two approaches to measurement, particularly criterion-referenced measurement, with respect to variability, item construction, reliability, validity, item analysis, reporting and interpretation.

Potempa, K.W. A catalog of human-factors techniques for testing new systems (AFHRL-TR-68-15). Wright-Patterson AFB, OH: Air Force Human Resources Laboratory, February 1969. (AD-854 482).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1	This report contains 16 human factors testing techniques contributed by a number of Air Force and contractor personnel. While limited in number, it covers a broad segment of the human factors testing spectrum. This catalog was developed as a prototype to determine its usefulness to human factors personnel as a reference source for human factors testing devices and techniques. The following information is generally provided on each technique. (1) Purpose (2) Author (3) Published references (4) Description of technique, including how it is utilized, at what phase in the system it is most useful, and what kind of equipment is needed (5) The advantages and disadvantages of the technique (6) The limitations, validity and reliability of the technique The human factors techniques included in this report and a description of their purpose are presented below. (1) Miniature Simulation To determine the maintainability of an aircraft by evaluating the design of the aircraft and its associated aerospace ground equipment through the use of a miniature scale model.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(2) Automated Readability Index To determine reading difficulty level derived from ratios representing word difficulty and sentence difficulty.
		(3) Flight Simulator and Associated Simulation Complex To provide engineering data in the area of guidance and control, navigation, human factors, target acquisition, trajectory error analysis, sensor and display development, and flying qualities.
		(4) Terrain Visibility Definition To determine the in-flight vertical and horizontal visual angles. This data can then be used to determine the visual area available to aircrews with the aircraft in the horizontal flight attitude.
		(5) Definition of Functional Eye Position To determine the eye position of pilots seated in a cockpit in their normal flight posture. This technique can be used to generate a three-dimensional eye ellipse with subjects seated either in a cockpit mockup or in an actual aircraft.
		(6) Definition of Dynamic Body Positions To locate various body components while a man is riding a captive ejection seat.
		(7) Personnel Activity Analysis Radio System (PAARS) To collect job activity information, via radio, on a number of operational or maintenance personnel while they are working dispersed over a wide area.
		(8) Work Station Analyzer To determine the viewing angles and distances of display panels.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(9) Secondary Task Monitoring To determine performance decrement under dynamic conditions on a flight simulator. (10) Operator Analysis in Command and Control Systems To analyze those operator performance sequences which are judged to be the most difficult to perform without error. (11) Human Factors Test Planning To describe the development of a test plan for field evaluation. It includes the development of test objectives and determination of data requirements to plan a test program which gives a well balanced coverage of the areas of interest. (12) Induced Error Technique for Evaluating Command and Control Systems To determine the criticality of various problems that may arise under operational conditions. Time to correct errors and number of times the operator fails to correct errors are determined. (13) System Load Mission Plan To determine efficiency of human and system performance under heavy load conditions and to determine if the combination of operators and equipment specified can successfully handle the maximum system load specified by the operational requirements. An extensive list of the performance measures utilized in each of the operational analyses is presented in this report.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	(14)	Programmed System-Performance Measuring Equipment To provide an objective means of evaluating performance on simulators and avionics equipment. The equipment used was the Digital System Synthesizer, a punched paper tape recorder, a computer and necessary software.
	(15)	DACOLS To describe an automated method of recording large amounts of time and event data in a format which can be readily reduced and analyzed by computer processing.
	(16)	Open-Ended Maintenance Questionnaire To present a questionnaire designed to collect information on maintenance activities performed during the test of new systems. The questionnaire is of the open-ended type and was compiled by taking those questions judged to be the best from a large number which have been previously used in system evaluation. Subjective judgment was the only criteria used in selecting these questions and the questionnaire has not been valided in a system test situation. However, it is hoped that it may prove useful in reducing duplication of effort.

Pritsker, A.A., Wortman, D.B., Seum, C.S., Chubb, G.P. & Seifert, D.J. SAINT: Vol. 1. Systems Analysis of Integrated Networks of Tasks (AMRL-TR-73-126). West Lafayette, IN: Purdue University, School of Industrial Engineering, April 1974. (AD-A014 843).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	SAINT (Systems Analysis of Integrated Networks of Tasks) provides a graphic symbol set for diagramming event sequences. SAINT is a combination of a set of network symbols (modeling vehicle) and simulation (analysis technique). A topdown analysis is employed such that the system is defined in terms of missions with the output of SAINT consisting of task and mission performance estimates.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.2	A mission was defined as a network of tasks performed by a crew of operators having a complement of equipment in the face of environmental factors.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.3	Workload stress is the time pressure imposed on an operator by a discrepancy between the amount of work to be done and the time remaining for doing it. The effects of this stress are reflected in the operator's task duration and task success.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.1	The set of problems focuses on task allocation, operator workload, and environmental stressors. It is conjectured that network concepts and symbols can be developed that will permit the modeling of one or more operators performing an assigned set of tasks within the context of a specific mission and the operating environment for a mission. Once the network concepts and symbols are designed, a simulation program can be developed for analyzing mission performance as a function of operator and environmental variables.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	6.2	The following points are proposed: (1) Verification of the factors and relations included in the characterization of task performance. (2) Development of new concepts in order to model tasks that require continuous monitoring, queuing and resource allocation. (3) Extend the treatment of task type and the method by which operators are assigned to tasks.

Quinn, J.L. Research and development appraisal and evaluation (SLTR5-70). Wright-Patterson AFB, OH: Air University, School of Systems and Logistics, November 1970. (AD-876 006).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The particular method or combination of methods employed in an evaluation must be fitted to the given situation in light of such variables as the level of research and the stage of the development-cycle being evaluated, along with a host of other situational factors. By using qualitative means to assist in formulating quantitative judgments, management-decision makers can predict, measure, and evaluate research and development efforts and results. Methods of evaluating research potential, performance, and effectiveness may be quantitative, qualitative, or combinations of both. Quantitative methods employ mathematical equations or models that are coupled with dollar evaluation to arrive at a figure of the research's effectiveness. Quantitative methods evaluate the research via the profits created and the improved or cost-reduced products, techniques, processes, and materials. Qualitative evaluation is subjective judgment, that is, the composite judgment of qualified and responsible management and research personnel arrived at through logical, not mathematical, procedures and devices. Qualitative methods are applied to the quality of research results, the degree of research efficiency, the results of long-range research, and the intangible products of research such as publications.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	1.2	A basic criterion for categorizing the level of research effort is the degree of uncertainty of research results. The four classifictions of research are pure, basic, applied, and developmental with pure research at one end of the spectrum of uncertainty and developmental research at the other. The principal implication of the spectrum of uncertainty on the evaluation of research effort is that the result of research at the less uncertain end of the spectrum may be predicted and measured with some degree of confidence whereas those at the upper end are more difficult to predict and measure.

Ramsay, J.O. Some statistical considerations in multidimensional scaling (RB-66-26). Princeton, NJ: Educational Testing Service, June 1966. (AD-489 591).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	Like most statistical methods, multidimensional scaling is merely a procedure for converting the numerical data resulting from an experiment into a more interpretable form. As with most statistical methods, it is the hope of the experimenter that not too much of the information available in the sample will be lost during the course of analyses. The problem of minimizing the loss of information, therefore, is really two problems - one of estimation and the other of a scaling procedure. The second problem has received considerable attention, while the first has received virtually none. The purpose of this study is to show the importance of the estimation problem and to make some appropriate comments.

Rankin, G.L. An application of fault tree analysis to operational testing (Master's Thesis). Georgia Institute of Technology, 1975.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1 3.5	The purpose of this study is to determine the use of fault tree analysis in operational test planning for military systems. The research attempted to demonstrate how the logic of fault trees could be used in an area other than safety and reliability. In this case it was in test design. A detailed discussion was given as to the procedures used in fault tree analysis: fault tree terminology and symbology, system definition, fault tree construction and qualitative analysis, the identification and ranking of components and subsystems through fault tree analysis permits direction of tests towards the weak links in the system. System weakness and the causes of important failures can be explored in testing. Fault tree analysis increases system understanding. It provides a vehicle to explore system alternatives. Structural analysis frees the method from reliability data which may not be available due to the nature of the system or the equipment state of the art. Fault tree analysis is a binary modeling scheme which ignores partial failures. It is also situation specific, that is, each tree is constructed only about the failure of interest. Hence, it can explore only one critical issue for each model developed. An example was directed toward the operational testing of automated command and control systems for use in the U.S. Army division.

351

Rankine, R.R. The effects of aircraft dynamics and pilot performance on tactical weapon delivery accuracy (UCLA-ENG-7085). Los Angeles, CA: University of California, School of Engineering and Applied Science, November 1970. (AD-728 324).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This report presents a model of piloted weapon delivery through the application of mathematical models of the human operator's performance characteristics to the dynamic description of the combined control-display-vehicle system. By doing this an understanding of the interaction and relative importance of the various elements of the system were obtained. A statistical model of the propagation of these pilot-induced errors into impact error is then developed by considering each of the pilot inputs to be a random variable. A method for including the effect of pilot compensation for an observed error in one of the variables with an intentional deviation in another is also introduced. An analytical model of the human pilot is used to estimate the tracking error from the controlled-element dynamics and the turbulence environment. Typical pilot performance in controlling the other task variables is estimated empirically from piloted simulation results. Once the system is modeled in this manner, the effect of display, computational, and dynamic changes on weapon delivery accuracy can be readily determined. A reiterative design approach is used to improve the system using impact point accuracy as a figure of merit; thus, the effects of changes in displayed information, of computational aids provided to the pilot, and of varying degrees of control system augmentation can all be compared on a common scale.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		The approach is applied to a gun-firing pass of a typical tactical fighter aircraft equipped with a conventional fixed optical sight. A sequence of design improvements is proposed which are predicted analytically to improve impact accuracy. The proposed changes are then tested in a complete, six-degree-of-freedom, piloted simulation in order to validate the modeling technique and determine the extent to which predicted improvements materialize. The simulation discloses that tracking error is the principal contributor to strafing inaccuracy and that poor tracking capability in either the longitudinal or lateral axis will degrade the accuracy in both axes. A five-fold increase in single shot/pass hit probability is demonstrated which can be primarily attributed to a 55% reduction in lateral tracking error. The mathematical model of the air-to-ground gun-firing pass is revised to incorporate this coupling effect and other effects noted in the piloted simulation.

Rasch, W. H., Jr. Guidelines for making tradeoffs: The special role of Technical Performance Measurement. Ft. Belvoir, VA: Defense Systems Management College. 1973. (AD-A045 256).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	Generally speaking, this document describes the trade-offs made during the various phases of acquisition (e.g., of naval vessels), explains TPM (Technical Performance Measurement), and provides guidelines for using the TPM outputs in trade-off analyses.
	2.1	The purpose of this system for making trade-offs was to specify those performance measurement factors relevant to ship acquisition and to specify standards for using TPM outputs to make the necessary trade-offs for ship design decisions. The system allowed for the determination of which trade-offs were possible during each phase of ship acquisition and gave a "user's guide" for the process of TPM.
	2.2	The primary goal of the trade-off TPM system was the specification of the performance/schedule/cost parameters that eventually determine the system's effectiveness and/or the success probability of the mission.
	3.1	The trade-off problem was attacked through several stages of analysis: (1) The Validation Stage, or System Contract Design (i.e., do individual systems fulfill requirements?) (2) Detail Design and Construction: factors such as cost and delay, legal approval, ongoing modification, etc.,

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

must be considered during the blueprinting of the ship design.

(3) Deployment and Disposal: technological and "threat" changes should be considered in an evaluation of the ship's optimum capability; the ship itself, as a total system, has a much longer life than its subsystems.

3.3 Specifically, TPM was used to predict the degree of actual or potential achievement of certain technical objectives of a system or subsystem, and causally analyzes the variance between achievement and goals.

3.4 To quantify technical performance, the following steps must be taken:

(1) Identify performance variables (inputs) crucial for success and relate them, by means of equations, to design variables or outputs.

(2) Through questioning of design personnel, subjective probability distributions can be made for the design variables.

(3) To estimate the probability of obtaining desired performance or meeting certain technical objectives, appropriate techniques, e.g., simulation, can be used.

(4) Changes in the probability of achieving target goals in performance should be monitored.

4.5 In order to implement the TPM program, the following elements play a determining role: Parameter Selection and Documentation of Detail; Construction of TPM models; Profiling Parameters; Planning the TPM; Assessing Organizational Participation; Preparation of Reports and Formats; Data Analysis and Predictions.

Rau, J.G. Measures of effectiveness handbook. Irvine, CA: Ultrasystems, Inc., August 1974. (AD-A021 461).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3 2.1 2.2 3.1 3.4 6.1	This document presents a summary of measures of effectiveness used by the Navy's Operational Test and Evaluation Force (OPTEVFOR). Several platforms, systems and subsystems were considered. The minimal operational situation was described for each system or subsystem discussed. A reference source was provided based on a review of OPTEVFOR reports, of measures of effectiveness used in Naval warfare and previous OPTEVFOR projects. The specific criterion performance requirements were presented followed by specific measures of effectiveness for each system. The scope of this handbook is limited to effectiveness measures only. Material reliability and human factors measures are not included. The handbook is for guidance only and the coverage is not intended to be complete.

Ray, E.C., Hiltz, H.A. & Spurway, D.T. Test design plan for Defense Satellite Communications System III (DSCS III) initial Operational Test and Evaluation (IOT&E). U.S. Army Operational Test and Evaluation Agency, Test Design Division, 1979. (AD-B041 308L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.1	The Defense Satellite Communications System Phase III (DSCS III) consisted of four operational satellites that were synchronized with the earth's movements, and two spare satellites, positioned equidistant at equal intervals from the earth's equator. Several types of "Earth Terminals" (ETs) also comprised the system at various locations around the world, with four to eight SCCE facilities (Satellite Configuration Control Elements).
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.2	The primary "mission" of the DSCS was an increased communications capability, particularly an improved ability to operate in an Electronic Warfare (EW) environment.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.5	The ultimate performance requirement of the test design plan was the collection and analysis of data regarding operational effectiveness, vulnerability of the system in an EW environment, assessment of the operational, maintenance, and logistic support concepts of the system, RAM data (reliability, availability, and maintainability).
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.1	Operational issues included the areas of mission performance, vulnerability, training, organization, RAM, and safety/human factors engineering.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	3.2	These will be measured through such indices as Bit Error Rate (BER), Test Tone-to-Noise Ratio (TTNR), and carrier-power-to-noise spectral density ratio. These measurements
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		are used to determine if a link (circuits) will pass data traffic.
	4.2	Test factors were identified which would probably influence the operational effectiveness of DSCS III; examples of those factors which are varied included communications access, user community, antenna coverage, satellite configuration, etc.
	4.1	There are four test conditions which required action from the satellite control system: a "normal" mode, "degraded" mode, "hostile" electronic warfare environmental mode, and subnetwork control mode.

General data collection involved information on performance of the system with regard to:

(1) Reception of telecommunications service order from Defense Communication Agency Operation Center.

(2) Performance of network analysis using resource allocation software in network computer.

(3) Instruction of satellite controller to command necessary communications payload change.

(4) Instruction of earth terminal operators to establish link with parameters as specified.

Repperger, D.W., Smiles, K.A., Neff, J.A. & Summers, W.C. A feature selection approach in evaluation of parameter changes on the human operator under thermal stress. Ergonomics, 1978, 21(1), 35-48.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	A feature selection approach to define changes in parameters of the human operator is used in this study.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The human operator was involved in a closed-loop tracking task simulating a flight in a very unstable aircraft or a very stable aircraft.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.3	The experiment was conducted in a laboratory situation under thermal stress conditions. The subjects were exposed to an environment of 50° C dry bulb and 30° C wet bulb to simulate a pilot forced to sit prior to take off in a heat-soaked aircraft.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	4.1	By choosing a class of features which characterize the general shape of the human operator's transfer function, significant changes in these characteristics were found to occur under thermal stress conditions. An F-Ratio Test was used with an analysis of variance to test the significance of the change in those features which describe the input/output characteristics of the human.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	4.2	The human's parameters are assumed to be characterized by second-order transfer functions, and features of the transfer function are chosen which describe its general shape.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	4.4	Four healthy and highly trained male subjects were used in this experiment.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.5	These subjects were exposed for 1 hour to a simulated heat-soaked aircraft environment. They performed a single dimension compensatory tracking task for 5 minutes duration, separated by 5 minutes of rest. The tasks represented flying a very unstable aircraft or a very stable aircraft under vertical wind buffet. Each subject participated in six experimental conditions, three control runs and three exposures to the heat-loading environment. During the experiment the subject maintained one of three conditions of water-electrolyte balance. He either drank nothing or replaced weight losses with water or NaCl solution. The subject urinated and blood samples were drawn periodically. Mean skin temperature, rectal temperature, weight loss, heart rate, air temperature, water temperatures, and humidity were recorded along with tracking performance parameters.
	5.3	The results of the experiment indicated that the effects of thermal stress (and the type of electrolyte used in the recovery period) will significantly change the input/output characteristics of the human operator.

Rhoads, D.W. In-flight evaluation of your cockpit controller configurations in a variable stability airplane (AFFDL-TR-70-95). Buffalo, NY: Cornell Aer›nautical Laboratory, Inc., September 1970. (AD-876 589).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.1	This report described an in-flight evaluation of four cockpit-controller configurations in a variable stability airplane with pilot.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.2	Evaluation was based on three tasks: up and away cruise condition maneuvers, low level terrain following simulated altitude, approach landing, and take-off.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.3	Each task was performed under conditions of different simulated static and dynamic characteristics of a B-1 type airplane.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.1	Qualitative and quantitative data were obtained consisting of pilot inflight comments and pilot ratings of handling characteristics and tracking error.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	3.5	The pilot inflight comments were responses to a prepared comment guide and the last Cooper-Harper handling rating scale was utilized.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	4.1	Much use of simple average numerical rating data were used in pilot rating analysis; average of replication, average of pilots, etc. In the tracking tasks, raw data were oscillograph recorded. A limited amount of raw data were reduced to a variance spectral density form. This form indicates variance as a function of frequency and shows the variance present in any frequency bandwidth throughout the spectrum (and hence a frequency bandwidth for maximum variance) and the overall variance for the paramenters of the maneuvers.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.3	A conventional wheel and column and three new concepts: a circumferential wheel and column; a circumferential wheel and column with hand controller; and a duel side arm configuration were evaluated using a CAL B-26 variable stability airplane of the B-1 type.
	4.4	Four pilots - - two USAF and two CAL participated in these tests.
	4.5	The pilots flew all four controller configurations four times each through each of the three tasks.
	5.3	Results of the analysis indicated that all three new concepts would be accepted by pilots of large airplanes with only a nominal associated learning period and that all three new concepts are preferable to the conventional equipment. Despite some detailed design deficiencies, the dual side arm configuration was most preferred.

Rigby, L.V. The Sandia Human Error Rate Bank (SHERB). In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Topics Relevant to System Development and Evaluation Technology

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

Topic No.	ABSTRACT
1.1	The Sandia Human Error Rate Bank (SHERB) is an evolving file of Human Error Rates (HER) on specific tasks associated with component assembly, equipment installation, system operation, and maintenance. It is intended to serve as a data base to allow analysts to estimate the probability of human error and its impact on system performance.
3.1	If human error is defined as any variant of human performance that reduces the probability of system or mission success, then failures due to human error can be treated very similarly to component failures, i.e., human errors can be predicted as a probabilistic function of the variables determining or influencing that human performance related to system performance.
6.1	Development of an accurate data base of human error rates is impeded by the following factors: (1) Accidents and mission failures resulting from human error are not reported with the same regularity and accuracy as equipment failures; there is a lack of good feedback data. (2) The data that are available vary widely in terminology, manner of development, and level of reporting; there is a lack of standardization.

Rouse, W.B. Estimation and control theory: Application to modeling human behavior. Human Factors, 1977, 19(4), 315-329.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The methodology of estimation and control theory is considered in terms of response, stability, estimation, and control of linear dynamic systems. Within the context of discrete time systems, multi-input, multi-output, nth-order linear systems are discussed, and general results for optimal estimation, optimal control, and other topics are presented. The application of these results to modeling human behavior is considered with special emphasis on man-machine system models.

Sauer, D.W., Campbell, W.B., Potter, N.R. & Askren, W.B. Human resource factors and performance relationships in nuclear missile handling tasks (AFHRL-TR-76-85, AFWL-TR-76-301). Dayton, OH: Systems Research Laboratories, Inc., 1977. (AD-A042 604).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.2	The primary goal of this study was to assess, through quantification, the relationships between human resource factors and nuclear system safety, and to use these data to simulate nuclear system maintainance operations.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	3.1	Thirteen factors considered relevant to nuclear safety maintenance operations were identified: motivation, group cohesiveness, behavioral/emotional stability, fatigue, leadership, organizational structure, task complexity, written manuals, job skill proficiency aptitude, training, work experience, and environmental conditions.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.2	Each of these thirteen factors were quantified for computer simulation use; measures of quantification included psychological tests, supervisor ratings, and biographic data. These were consolidated into one questionnaire and administered to each missile technician.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	4.1	Data were analyzed through a computer simulation model. The Short-Range Attack Missile (SRAM) network was fed into the computer with each task assigned four descriptors: time, crew type, hazard value, and maintenance task category. Equations describing functions between the human resource factors, time, and hazard were correlated by the System Analysis of Integrated Networks of Tasks (SAINT) computer simulation model and cycled about
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		500 times to approximate how a crew possessing given characteristics of motivation, work experience, fatigue, and training under given environmental conditions would perform.
	4.2 and 4.3	Test parameters were described by the maintenance and ground handling tasks involving the SRAM system. Tasks were described by time required for completion, career field involved in the task, degree of hazard inherent in the task, and task classification by either transport, checkout, or assemble/disassemble.
	5.3	Results of supervisor rankings of technicians indicated that those technicians who had more experience, higher aptitude levels, were more stable emotionally, had less fatigue, and greater morale were more satisfied with their jobs. The above factors were also positively correlated with accuracy and task performance.

Schaeffer, K.H., Fink, J.B., Rappaport, M., Wainstein, L. & Erickson, C.J. The knowledgeable analyst: An approach to structuring man-machine systems (SRI No. IMU-3546). Menlo Park, CA: Stanford Research Institute, February 1963. (AD-297 432).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The objectives of systems analysis are to analyze specific systems in order to solve predesignated problems. These objectives are at variance with those of the empirical sciences, which attempt to discover general laws. Since the two objectives differ, the method of systems analysis differs from the method of science. In an attempt to evolve a general method for systems analysis, the matrix-network approach for the analysis of complex man-machine systems is presented. This approach consists of seven steps which show how a system can be structured and how mathematical models of systems aspects can be incorporated into the over-all analysis. However, some of these steps involve, besides formal rules, the judgment of a knowledgeable analyst. To delve deeper into this judgment function, various logical, methodological, and psychological aspects concerning this function are discussed by different authors. On the basis of these discussions the principal author develops requirements which must be met by successful approaches to the structuring of complex systems.

Self, H.C. Performance measures, observer selection, and reconnaissance/strike effectiveness (AMRL-TR-72-86). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory, November 1972. (AD-770 647).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	In a reconnaissance strike or reconnaissance/strike system there is a complex of equipment and men. One would assume that maximum effectiveness of the man-machine system would be obtained by utilizing the best men and the best machines; this reasoning, however, conflicts with problems of expenses, unavailability, and the inability to determine the best men for the job.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate		Characteristics of the men, the equipment, and the mission interact such that variations in equipment and/or situation will have an effect on the men in the system. In other words, a system approach is essential when dealing with a system.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	The performance measures in this study were percent detection, accuracy, and reaction time or slant range at detection.
	3.3	The ideal observer would detect all of the targets (%D = 100%), mistake no targets (accuracy = 100%), and would detect and recognize targets the instant that their images appeared on the display (reaction time = 0 seconds).
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.4	Mission-relevant performance criteria included the following:
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		(1) The number and percentage of targets that are detected. An ideal observer would detect all targets that were displayed with some minimum image quality.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentiala/Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(2) An ideal observer would make no mistakes in designating targets as such.
		(3) Targets should be adequately recognizable at long slant range.

Shapero, A. & Bates, C., Jr. A method for performing human engineering analysis of weapon systems (WADC Tech. Rep. 59-784). Wright-Patterson AFB, OH: Wright Air Development Center, Aerospace Medical Laboratory, September 1959.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3 2.1	A weapon System Analysis and Integration Model (SAIM) has been developed that includes the system's human elements and that can be employed as an aid in the analysis, synthesis, evaluation, planning, and management control of weapon systems. A diagrammatic matrix is used to structure the model. The system components (subsystems) are represented in the same way as the system. The matrix can be described as a two-dimensional square. The headings of the rows and columns are symmetrical and consist of the system elements. The orientation of the matrix is such that the elements appearing as headings of rows are considered as affecting those appearing as headings of columns. The matrix includes system determinants, system and subsystem components, and system integration. SAIM is designed to indicate interactions and to provide a means for describing the interactions at a given time. The effects of developmental changes that occur can be taken into account by updating the matrix. (2.1) The SAIM is a descriptive matrix model that classifies the elements of a weapon system into those determining the nature and form of the system, those comprising the parts of the system, and those integrating the parts of the system. The approach used in SAIM predicates that any system and any of its subsystems have the same kinds of conceptual elements and SAIM employs a scheme for classifying these elements that is applicable to any system or any level.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		In SAIM, system components are described in terms of mechanism modules, human operator modules and facility modules. This modular treatment affords flexibility since it allows each subsystem to be handled in a building-block fashion, thus making it easy to describe complex functions that combine many items, and to extend or to modify the model as the system itself is modified or extended. System integrators are the elements that link the system's components in a "nonhardware" or abstract way.
	2.2	In this model, the mission statement is always framed in general terms, enabling it to remain unchanged while permitting the incorporation of changes in performance requirements as imposed by technical, budget or other changes in the weapon system.
	2.4	Limits on the system are imposed by the state-of-the-art, by nature, and by the agencies that have cognizance over the system. The constraints imposed by nature or society relate to the physical environment and/or human and material resources. Constraints imposed by cognizant agencies include those that relate to funds and developmental time.
	2.5	The performance requirements detail the system's mission into a set of goals, standards and objectives. Performance requirements are usually categorized into operational and support requirements. Operational requirements might include such factors as kill probability, range, speed, etc. Support requirements could include readiness, maintenance and servicing, and handling.

Sheldon, M.S. & Zagorski, H.J. Man-machine system evaluation - The Normative Operations Reporting Method. In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

1.1 It is increasingly evident that man-machine system evaluation needs techniques that are radically different from traditional methods. The authors call this work area systemetrics. The overall purpose of the systemetric model is to develop a methodology permitting evaluation of man-machine performance to be based on a series of flexible standards reflecting the difficulty of the mission, in direct contradistinction to the absolute standards approach. The systemetric approach requires intimate familiarity with the system.

1.3 One example of the kind of work that can be done is the Normative Operations Reporting Method (NORM). This method includes no exotic breakthrough; its creativity lies in its unique combination and application of assessment techniques that are well known. The NORM methodology features a set of flexible standards that are adjusted according to the relative difficulty of the mission.

2.1 NORM was applied for field evaluation of the Semi-Automatic Ground Environment (SAGE) system. In dealing with any man-machine system, one must ask, "What is the system trying to accomplish?" and "What available data will adequately reflect system performance?" Answers to these questions will lead to development of suitable criterion measures. The quality of the criteria is the single most important element in determining the

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		meaningfulness of the evaluation. The overall objective of the SAGE system was stated as "neutralize as many invaders as possible a: quickly as possible as far out as possible."
	2.2	Once the criterion measures have been defined, the developers of the systemetric model must try to account for the portion of performance variance that is attributable to mission difficulty. To do this, one must determine the mission characteristics that are most likely to contribute to mission difficulty. For the SAGE system, the pertinent groups of mission difficulty variables were found to be (1) radar variables, (2) invader variables, and (3) operational environment variables.
	3.2	The SAGE system overall objective was translated into three quantifiable criterion measures: (1) percentage fakers killed, (2) faker life time in system's air space, (3) depth of penetration. The above three measures were supplemented by other measures concerning explicit system functions, including (1) detection latency, (2) unassociated time non-conformance of display symbology and raw video, (3) interception time, and (4) tactical action latency.
	4.1	To develop more comprehensive criteria of effectiveness, the performance measues are factor-analyzed using the principal components methods. The first two factors that emerge are termed "Weapon Performance" (defined by the measures: Tactical Action Latency; Interception Time; Depth of Penetration) and "Air Surveillance Performance" (defined by five different measures of air surveillance). These two factors account for about 76% of the observed variation in performance. They are more reliable than any of the individual measures, and they have intrinsic face validity.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.1	The performance measures are collected from simulated air defense missions performed at SAGE direction centers. The data are obtained from operational recording tapes containing a history of all relevant activities taking place during a mission.
	5.2	Initial statistical procedures in NORM focus on basic correlations between each criterion measure and each mission difficulty variable, and on the relative independence of the candidate predictor variables. Following this, multiple regressions are run for each measure using selected sets of mission difficulty variables as independent variables. Overall, about 50% of the variance of criterion performance is accounted by the presently available mission difficulty variables.
	5.3	The criterion research in SAGE has resulted in relevant, quantifiable measures of system and functional performance. The creation of these measures has led to a meaningful procedure for evaluating man-machine performance at the direction center level.

Siegel, A.I. Human performance reliability--Its measurement and impact on system reliability. ASME Publication, 78-DE-17, New York: The American Society of Mechanical Engineers, 1978.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1	This paper discusses methods for measuring human performance reliability and methods for integrating human performance reliability with equipment reliability to derive a measure of total system reliability. Emphasis was placed on a computer simulation model. The data presented show the model to possess validity and utility. The model in its current form is basically a sequential processor which incorporates human, equipment, and environmental factors. Three categories of independent variables are considered: (1) Personnel (quantity, category types, goals, physical properties, performance attributes). (2) Mission (composition, duration, environment, elements/tasks). (3) Equipment (quantity, capability, performance/status). The dependent variables are the Output Measurements (mission effectiveness, time utilization, personnel, and report frequency).

Siegel, A.I., and Federman, P.J. Development of performance evaluative measures: Investigation into and application of a fleet post training performance evaluation system. (Rep. No. 7071-2). Wayne, PA: Applied Psychological Service, Inc., September, 1970. (AD-713 192).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	The purpose of this study was to develop and demonstrate an economical and practical method for measuring technical proficiency.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	Of particular interest was the readiness of Naval electronically-oriented technical personnel (reserve and regular) for completing their assigned mission.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	The study attempted to answer such questions as: What is the current level of effectiveness of maintenance personnel in a given rating, ship or squadron; why is it low or high; what specific job skills need improvement? Also, an attempt was made to determine the need for additional training and to compare the effectiveness levels between various ratings, ships, and squadrons.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.2	The method relied largely on a personnel reliability index modeled after an equipment reliability index. Specifically, the personnel reliability index was based on the compounding of probability of successful performance values for each of eight factorially derived electronic job dimensions. A second instrument was also administered. This instrument was based on a Guttman-scaled checklist and yields an absolute measure of performance.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.4	It was held that the methods and techniques employed a series of psychometric and measurement criteria. Statistically significant differences were evidenced among the derived indices for the Naval ratings and job factors involved but not among the ships and squadrons sampled.
	6.2	The results and experience of the study were interpreted as indicating that the methods and data treatment techniques employed possess sufficient merit for their purpose to warrant trial use on a larger scale.

Siegel, A.I., Pfeiffer, M.G. & Worms, T.M. Development and evaluation of a content analytic approach in Army field system data organization (ARI Tech. Rep. TR-77-A11). Wayne, PA: Applied Psychological Services, Inc., August 1977. (AD-A042 075).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.2	The logic, methods, and results of a study into the derivation of a content analytic approach to Army field system data organization are described. The first steps of the program involved a linguistic analysis of a set of battlefield messages and multidimensional scaling analysis of a sample of messages representing all information classes yielded by the linguistic analysis. Four multidimensional scaling analyses were completed. Each was based on the linguistic similarity perceptions of one of four experienced battlefield analysts. High agreement was found among the factorial structures yielded by the data of each battlefield analyst. Accordingly, an overall analysis was completed and 15 factors were identified as representing the perceptual substrate of the Army field information linguistic system. On the basis of the derived factors, a battlefield language taxonomy was developed. The taxonomy was tested in two separate field oriented experiments. The results of these experiments indicated that intelligence analysts can classify messages reliably within the taxonomy and that they can reliably use the taxonomy for inquiry purposes. Moreover, adequate subjective confidence was expressed by the analysts in the use of the system. Finally, a computer system for automatic classification of battlefield messages is presented.

Siegel, A.I., Platzer, H.L. & Lanterman, R.S. Techniques for evaluating operator loading in man-machine systems. Wayne, PA: Applied Psychological Services, Inc., March 1967. (AD-810 787).

Topics Relevant to System Development and Evaluation Technology

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

Topic No.	ABSTRACT
1.1	This study investigated the utility of the human transfer function as an indicator of operator status. An analysis of previously acquired data from an experiment into the human transfer function was conducted. In that experiment, three subjects performed a sequence of tasks, including a compensatory tracking task, that kept them occupied overnight. The results of the study were not in accordance with the pre-experimental hypothesis, in that the two indicators derived were not found to decrease uniformly as the period of sleep deprivation increased. The present set of studies expanded on these previous data by presenting a reanalysis of the previous data and by describing the rationale, method, and results of a new study into the effects of operator overload on the transfer functions.
2.1	The study addressed operator loading in man-machine systems.
3.1	Measurements of tracking records were obtained.
3.2	These measurements were made to the nearest quarter millimeter.
4.1	Data for three minutes of each selected hourly sample were transcribed at 0.10 second intervals. This yielded 1800 data points for each input and 1800 for each output position signal sample. The first, second, fourth and sixth hours of tracking

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		performance were selected for analysis. Frequency analysis was employed in data analysis.
	4.3	An oscilloscope display and a tracking-control were used in this experiment. Programming and recording equipment were also utilized.
	4.4	Four male college students were subjects in this study. They were paid for their participation.
	4.5	The experimental subjects tracked continuously for eight hours between 8 am and 4 pm. No breaks were allowed. Samples of their performance were recorded for the last five minutes of each hour. The subjects were unaware how much, if any of their performance was being recorded. Transcription of the data involved measuring the displacement of the input and output signals as recorded on the ink writing oscillograph.
	5.3	The results of this study were interpreted to suggest that the spectral analytic technique possesses considerable potential as an objective, behavioral, diagnostic method for on-line assessment of operator status in man-machine systems involving perceptual motor behavior.

Siegel, A.I., Schultz, D.G. & Federman, P. Post-training performance criterion development and application: A matrix method for the evaluation of training. Wayne, PA: Applied Psychological Services, Inc., January 1961. (AD-251 082).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	This report describes a matrix method for the evaluation of training.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	Training programs in general were the object of the evaluation.
	2.2	The mission of the training program was described as the preparation of students for the jobs performed after training.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	"Suitability" for the job was used as a basis for training evaluation. "Suitability" was defined as the training graduates' ability to do the tasks involved in the job.
	3.2	Matrix solutions were described which yield three indices, each reflecting a different aspect of the comparison between the skills of the trained man and the job's requirements.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.3	The training program is deemed effective if the graduate carries out the duties of his job proficiently.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	3.4	Specific measures of job performance can indicate the effectiveness of a training program.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.5	In this study a specific evaluative scheme was developed for summarizing suitability and the application of the scheme to data previously collected on technicians in four Naval ratings. The method for accomplishing these tasks is the Technical Behavior Checklist (TBCL). These checklists are comprehensive detailed compilations of the tasks performed.
	4.1	Various responses to the TBCL by the supervisor indicating the level of proficiency of the ratee were assigned different score values. The average proficiency level of each task was computed - - determined by the mean of these scores. An index of importance of each task was developed from the TBCL and the supervisor. These importance ratings were weighted and the task's importance for classification in the matrix was a combination of its frequency of performance and its criticality to the mission. From this information three indices were developed. (1) The training index; (2) an "overtraining" index; (3) an "undertraining" index. The training index reflects how closely the average graduate fits the model of high proficiency on relatively important tasks and low proficiency on relatively unimportant tasks. The overtraining index indicated the extent to which graduates were highly proficient even on unimportant tasks. Important tasks that technicians performed with relatively low proficiency constituted the undertraining index.
	4.4	The subjects of this study were: (1) Aviation Machinist Mates (Turbo Jet) (2) Air Controlman (Tower) (3) Parachute Rigger (Survivalman) (4) Aviation Electronics Technician (Radar)

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.5	In a previous study a Technical Behavior Checklist was developed for four naval ratings. This checklist was a detailed comprehensive checklist of the tasks performed in that rating. For this study a supervisor was asked to indicate the proficiency level of the man he was rating in terms of how much supervision and the number of checkouts required.
	5.3	The technicians in the four ratings studied were found generally to be suitably trained.
	5.4	The matrix method is feasible and simple to use provided task proficiency measures and an index of task importance are available. The use of this method provides meaningful results. Its use should provide an increased understanding of the effects of training and is one basis for changing training emphasis.

Siegel, A.I. & Wolf, J. J. Computer simulation: Savior, sanctuary, or silliness? In G. W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	The paper discusses advantages and disadvantages of stochastically oriented digital computer simulation models and their applications to predicting the effects of the human on the output of complex systems. The advantages of simulation modeling are given as follows: (1) It necessitates a rigorous, insight-providing analysis of the human and machine elements and their interactions. (2) It provides a means of representing the complex human organism to a degreee of realism not available through deterministic mathematical formulations. (3) It can cost less than either physical simulation or laboratory experimentation. (4) It allows the testing of hypothetical systems and of hypothetical operating procedures. (5) It can show the effects of interactions on system function, e.g., the interaction between operator skill and workday length. (6) It can be useful in establishing training requirements and areas for training emphasis.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(7) It enables us to deal with a complexity that cannot be managed by other techniques. It is also pointed out that there are adverse aspects to digital simulation which could serve to limit its potential. These include: (1) There is a tendency to confuse the model on which the simulation is based with a theory, and hence to employ inappropriate standards and criteria to judge the model and the simulation. (2) Digital modeling depends on the data and methods of a number of disciplines, and this can lead to complexity and confusion. (3) The necessary data may be unavailable or of poor quality (garbage in, garbage out). (4) There are equally damaging but opposite points of view that impede serious research by computer simulation; one is that attempts to simulate man via a computer are antireligious or at least degrading; the other is that a computer's results are automatically sacred and of unquestionable precision. (5) The argument exists that behavioral science does not possess powerful enough theory for model building.
	5.4	It is concluded that digital simulation is an emergency tool for the behavioral sciences.

Siegel, A.I., Wolf, J.J. & Lanterman, M.R. A model for predicting integrated man-machine system reliability: Model logic and description. Wayne, PA: Applied Psychological Services, Inc., November 1974. (AD-A009 814).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	The integration of Human Reliability (HR) and Equipment Reliability (ER) data into a single comprehensive model for predicting System Reliability (SR) has been one of the major concerns of Navy system planners.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	1.3	The present study attempted to: (1) Extend and strengthen a previously developed model for simulating the acts and behaviors of the operators of an intermediate size system to include a greater number of options to the model user. (2) Evolve the model into one which produces reliability oriented metrics for both humans and equipment on both an event and overall system level. (3) Conduct an initial series of sensitivity tests relating the new variables and parameters to those already present in the model.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	The variables selected for measurement in the present document included: (1) Physical capability - working pace (2) Competence - level of aspiration (3) Fatigue - psychological stress (4) Physical incompatibility - confidence
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	4.1	Data were analyzed, in part, via the mean and standard deviation.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Simon, C.W. Advanced methodologies study program (Final Rep.). Culver City, CA: Hughes Aircraft Company, June 1975. (AD-A021 099).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	Many of the problems associated with the low productivity and high costs of human factors engineering research could be resolved if more variables were studied in a single experiment, particularly if these variables were the ones having the greatest effect on the performance of the task under investigation. Acceptance of this conclusion resulted in a formulation of a two-stage approach to experimentation: first, to identify the most important variables and second, to relate them functionally to performance. A suitable screening methodology is selected for this process with blocking techniques useful both as a means of economizing when collecting data and of reducing scores of irrelevant variance that cause shift in performance as a function of time.

Simon, D.E. et al. Standard procedures for Air Force Operational Test and Evaluation (RADC-TR-74-270, Final Rep., Vol. 1). Albuquerque, NM: Braddock, Dunn & McDonald, Inc., October 1974. (AD-B000 365).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	The report provides an overall skeletal structure of the Operational Test and Evaluation (OT&E) process. From the structure, a step-by-step procedure is derived. Steps can be summarized as follows: (1) Review of documentation. (2) Formulation of test objectives. (3) Selection of applicable test concept. (4) Measures of effectiveness (MOE). (5) Test design. (6) Simulations. (7) Data. (8) Range instrumentation. (9) Test plan. (10) Conduct of test. (11) Data analysis. (12) Conclusions and recommendations. (13) Test report.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.1	Review of documentation relevant to a given system to be tested is important because the test managers need to have a clear understanding of the critical issues, data requirements, and test objectives, and need to be familiar with the system, how it operates and its history in previous tests.
	2.4	Selection of a test concept is a trade-off between the magnitude and depth of testing and the available resources. Factors affecting the trade-off may include: (1) Time. (2) Availability of the (test) range. (3) Availability of personnel. (4) Availability of equipment. (5) Risk of overrunning time due to test complexity. (6) Data quality and quantity. (7) Cost.
	3.1	OT&E objectives are formulated to answer critical questions and to provide a basis for making decisions affecting development, production, support, employment of a system. Typical OT&E objectives are: (1) To observe the degradation. (2) To collect data on... (3) To evaluate ability to meet the requirement...
	3.2	Measure of effectiveness of an item is a parameter which evalates the extent of the adequacy of the item to accomplish an intended mission under specific conditions. An MOE is a function of Availability (A),

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Dependability (D), and Capability (C). MOE's are expressed as probabilities since A, D, C are probabilities. Good MOE's: (1) Should be sensitive to all variables affecting the item. (2) Should be precisely defined. (3) Should not be overly broad. (4) Should be mutually exclusive. (5) Should have exhaustive inputs. (6) Should be relevant to the mission. (7) Should have inputs relevant to the design issues. (8) Should be expressed in terms meaningful to the decision maker. (9) Should have inputs that are measurable. (10) And its inputs should be quantifiable if at all possible.

Sjogren, D.D. Measurement techniques in evaluation. Review of Educational Research, (undated), 40(2), 301-320.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This article deals with educational evaluation and the implementation of an input-process-outcome evaluation plan. For many years evaluation has been concerned with determining whether specified objectives were attained but current evaluation models focus on a larger number of phenomena. Therefore evaluation theorists indicate that evaluation should attend to outcomes other than specified objectives, to inputs or antecedent conditions, and to processes or transactions.

Smith, R.L., Westland, R.A. & Blanchard, R.E. Technique for Establishing Personnel Performance Standards-TEPPS (PTB-70-5, Vol. 1). Santa Monica, CA: Integrated Sciences Corp., December 1969. (AD-704 103).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	1.1	The cost and complexity of modern military systems have given rise to the development of a technology that is referred to as system and cost effectiveness analysis. Until recently, however, only limited effort has been directed toward the specification of the contribution made by system personnel as well as human error in a system's overall effectiveness. TEPPS (Technique for Establishing Personnel Performance Standards) was designed to meet two primary objectives: (1) To derive specific personnel performance standards with definable relations to system effectiveness requirements. (2) To determine the influence on system effectiveness of performance levels that deviate from established performance standards.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.1	A system was a set of personnel-equipment functional units whose collective purpose is to achieve a particular goal. Differentiating between systems and subsystems is arbitrarily based since most systems can be defined as subsystems when referenced to larger overall systems of which they are a part. What is important is the relationship of a given system's goals with respect to those of another. Thus, the effectiveness of a given system should be evaluated with respect to the parent system. A system can be assumed to have been 100% effective if it performed up to its maximum capability, regardless of

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		whether or not it was subsequently destroyed. Thus capability is an important factor contributing to establishing system effectiveness requirements and the evaluation of system effectiveness.

Smith, R.L., Westland, R.A. & Blanchard, R.E. Technique for Establishing Personnel Performance Standards-TEPPS (PTB-70-5, Vol 2). Santa Monica, CA: Integrated Sciences Corp., December 1969. (AD-704 104).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 1.3 2.1	Through the years, technological advances have provided military systems with increased capability. Planners have subsequently devised techniques or tools to resolve problems more quickly; however, many such tools are individualistic in that they have been independently developed and employed by individuals through their own unique experiences. For that reason TEPPS (Technique for Establishing Personnel Performance Standards) was developed. Overall, TEPPS is a set of procedures for gathering information about a system and for developing a qualitative and/or quantitative model of that system. The utility and accuracy of TEPPS depends on such information as system descriptive data, operational requirements data, and human capability data. A graphic representation of the major steps in applying TEPPS is presented in Figure 1. The system employed was an Anti-Air Warfare Combat Information Center (CIC) typically employed on a picket ship involved in fleet defense. The CIC system is composed of three functions: (1) The gathering and display of target information. (2) Actions of the command officer (evaluator) on that information. (3) The Air Intercept Controller's (AIC) vectoring of a Combat Air Patrol (CAP) fighter.

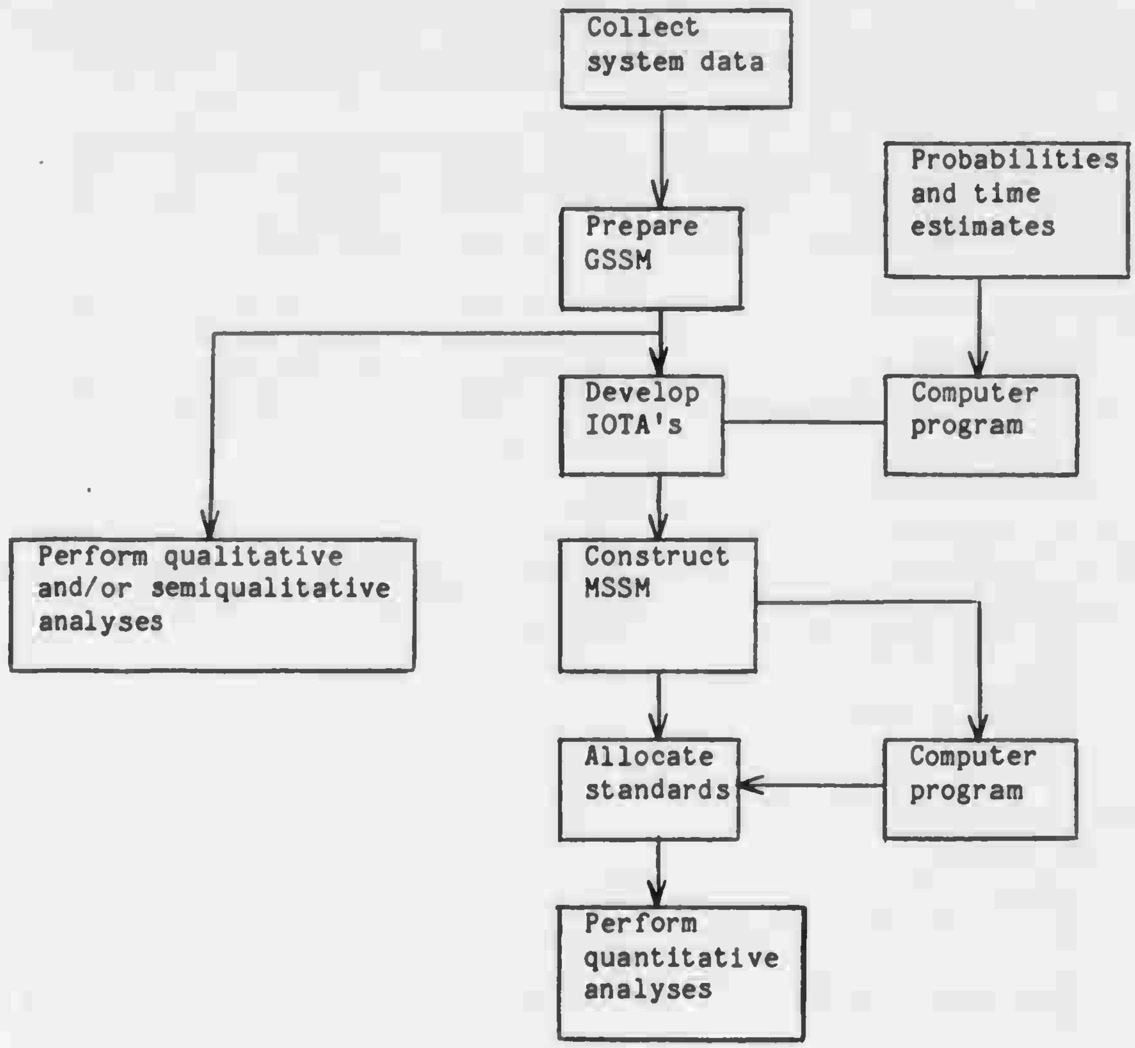

Figure 1. Representation of Major Steps in Applying TEPPS

Smode, A.E., Gruber, A. & Ely, J.H. The measurement of advanced flight vehicle crew proficiency in synthetic ground environments (Tech. Rep. MRL-TDR-62-2). Darien, CT: Dunlap and Associates, Inc., February 1962.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	The purpose of this report is to present a systematic treatment of the major considerations in the measurement of advanced flight vehicle crew proficiency in synthetic ground environments. Measurement in the training context serves two main functions. One is prediction of how well an individual or team can be expected to perform under some specified conditions anticipated in the future. The second is measurement of present knowledge or level of proficiency in some area or task.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.2	It is always a difficult problem to define mission purpose. Recognizing that a precise definition will seldom or ever be spelled out, some statement of mission purpose must nevertheless be available. Such a statement represents a starting point insofar as determining the criteria for measurement and for suggesting what specific tasks are most critical.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.6	Seldom can one obtain direct measures of the ultimate criteria for a system. It is usually necessary to select some actual criterion which in practice is an approximation of the ultimate one. In general, a good criterion is one that is both reliable and relevant. Reliability implies that proficient or successful performance will not vary widely because of chance factors. Relevancy refers to the validity of the actual criteria. The actual criterion is relevant to the extent that it approximates the ultimate criterion.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans		
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		The multidimensional nature of proficient performance will often require that several criteria, all of which are relevant for a particular activity, be used. In such cases, it may be desirable to combine these several criteria into a single comprehensive one. Combining subcriteria into a single composite will usually involve assigning relative weights to the individual criterion. These weights must often be determined on the basis of expert opinion since it is seldom possible to determine statistically the intercorrelation or overlap between subcriteria. A measured relationship between the actual and ultimate criteria is even more rare. Subcriteria should be weighted according to their relevance, and those which overlap factors in another subcriteria should receive a low weight. Subcriteria which are more reliable should be weighted more than those subject to error.
	3.2	Both overall and diagnostic measures of performance are required in any systematic effort. Overall measures refer to global indices of behavior associated with large aspects of performance such as occur in mission segments and complete missions. Diagnostic measures are quite specific, identifying certain aspects or elements of a job or performance in specific skill areas. In any extensive evaluation effort, subjective and objective measures might well be used. Generally, objective measures permit measurement relatively independent of the observer and with a high degree of reliability. However, insistence on complete objectivity tends to result in omission of a variety of critical job components because of the inability to measure them objectively. Subjective techniques also have limitations. The evaluation, generally, is dependent upon the characteristics of the observer and agreement between independent observers is not high. The use of such observers can introduce a set of biases into the observations.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Much of what is stated about combining criteria also applies to combining performance measures. However, in the latter case it is usually possible to determine the interrelationship between each measure and the criterion. Such information is important in developing a single combined proficiency score.
		A single overall proficiency score has the desirable characteristic of providing one overall proficiency index. However, a point to consider in determining whether or not to combine several performance measures is that a single index will no longer reflect performance of the individual measures. Where at least a minimum amount of proficiency with respect to a particular measure is critical to an overall activity, it may be more appropriate to treat the several measures in terms of a profile. This will preserve the individual measures while allowing for a simultaneous viewing of the measured results.
	3.5	It is most important that any system for structuring measurement of proficiency requires as an integral part a systematic classification of behavior which can be present within the system. Underlying the development of this report is the assumption that behavior can be analyzed in terms of basic components, that these components can be conceptually identified in a way that is convenient and agreeable to people and that there are specific measurement techniques which appropriately go with various behavioral components. The behavior classification is operationally defined and structured in a way meaningful for measurement. Four levels of job analysis are presented under which can be subsumed the varieties of operational events and behaviors predicted for the system. The scheme is able to accommodate both diagnostic measures relating to elemental tasks as well as to more global measurements relating to overall system performance. The classes are as follows:

Topics Relevant To System Development and Evaluation Technology	Topic No.	ABSTRACT
		Level I Elemental tasks Level II Complex tasks irvolving composite learning activities Level III Mission segments Level IV Combined mission segments The classification begins with the simplest level of analysis and proceeds to the most complex and is so structured that each succeeding level of complexity is made up of recognizable behavioral units of the proceeding level. A sequence of logical steps is presented concerned with setting up, obtaining and reporting proficiency measures of individuals and crews. With these procedures, the user is provided guidance for the design of a measurement system. Step 1 - Conduct a system and job analysis Step 2 - Identify important and critical tasks Step 3 - Determine performance requirements for important tasks Step 4 - Select and obtain measurements appropriate for the behavior to be evaluated Step 5 - Make decisions on recording the measurement data and combining the results

Spencer, G. Man-machine simulation - the PIMO application. In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 2.1 4.1	PIMO is an acronym for a project entitled Presentation of Information for Maintenance and Operation. The purpose of the project is to develop a new, improved approach for presenting the technical data used by Air Force maintenance technicians. For test purposes, the project focused on maintenance operations for the C-141A jet cargo aircraft. The staff realized that improvements in maintenance information presentation had to be expressed in terms of the object system, i.e., the C-141A. The value of changes in performance at the support level must be evaluated in terms of object system performance and/or cost. Some means had to be devised which would relate changes in maintenance performance to changes in C-141A effectiveness. The means employed was the Aircraft Maintenance and Effectiveness Simulation model (AMES). The AMES model was constructed to include measures of functional reliability and alternative personnel utilization, and was used to establish payoffs in terms of increased aircraft utilization and cost savings which could be compared to the cost of maintenance information system improvements.

Spyker, D.A., Stackhouse, S.P., Khalafalla, A.S. & McLane, R.C. Development of techniques for measuring pilot workload (NASA CR-1888). Roseville, MN: Honeywell, Inc., November 1971.

Topics Relevant to System Development and Evaluation Technology

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

Topic No.	ABSTRACT
1.3	The goal of this study was to provide objective, quantitative methods of measuring pilot workload.
2.1	The system being measured was a pilot and a simulated tracking task.
2.3	The experiment took place in a laboratory situation and physical, psychological, and environmental conditions were kept as constant as possible.
3.1	The attributes measured were physiological and performance dimensions over a range of visual motor tracking tasks, and the subject's reserve capacity.
3.2	Electrophysiological measurements were made and a sensitive, nonloading measure of reserve capacity was determined.
3.5	A Measured Workload Index (MWI) and a Physiological Workload Index (PWI) were extracted. A workload index based on the pilot's physiological response to a simulated tracking task was evolved. Important steps in this approach included: (1) Validation of a sensitive, nonloading secondary task. (2) Collection of physiological and performance data over a range (easy to land) visual motor tracking tasks. (3) Extraction of any potentially meaningful features from the analog physiological data.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(4) Normalization of the features. (5) Selection of the "best" subset of these features. (6) Simultaneous computation of the workload index and the best linear predictor from the subset of features. (7) Validation of this predictor. The entire study was structured to provide: (1) A sensitive, non-loading measure of reserve capacity. (2) An unencumbering reliable measure of the psychological state. An important measure of the success of this study was the degree to which the MWI and the PWI agreed across the randomly presented 243 - four-minute trials. Three direct measures of reserve capacity were provided: (1) Miss Rate - - % of error in responding to secondary task. (2) Response time - - average time from secondary task stimulus onset to response. (3) Subjective Rating - - pilots' evaluation of task difficulty. AB137.
	5.4	The salient features of this study include: (1) A simple, sensitive, nonloading secondary task. (2) A subjective rating which agrees with other secondary task measures but with less intersubject variance. (3) A multichannel physiological monitoring and recording system.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(4) Automatic feature extraction software which transforms the analog data base into meaningful features.
		(5) Very good separation results using a pattern recognition system, assuming the data to represent a two-class problem.
		(6) Use of simultaneous least-squares prediction to arrive at statistically significant, validated, workload index and the physiological features which best predict it.

40 |

Swink, J.R., Butler, E.A., Lankford, H.E., Miller, R.M., Watkins, H. & Waag, W.L. Definition of requirements for a performance measurement system for C-5 aircrew members (AFHRL-TR-78-54). San Diego, CA: Logicon Inc., October 1978.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	This study identifies and defines C-5 aircrew tasks and performance.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	The system addressed was the C-5 aircraft and aircrew.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.2	The mission definition was the effective operation of the aircraft on a typical mission.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.1	Aircrew performance was selected for measurement.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	3.2	A candidate set of performance measures was developed to assess aircrew proficiency. This was accomplished (1) Determination and segmentation of a representative mission profile. (2) The determination of aircrew activities within each segment. (3) The determination of mission-essential/critical aircrew tasks and duties amongst these aircrew activities.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	3.5	The C-5 inflight performance measurement can be obtained through several methods. It appears that the C-5 MADAR system which routinely monitors approximately 19 parameters and has the ability to interrogate a number of key switch positions will provide a feasible basis for interfacing the inflight measurement system with the C-5 components.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.3	A C-5 simulater was used in this study.
	4.5	In Phase I candidate performance measures were developed. The source of this information included documentation, interviews, and dialogue with operationally qualified aircrews. A special purpose evaluation sortie for the C-3 simulater was developed. In Phase II efforts were developed toward the definition of several alternative configurations to meet the performance measure requirements and provide MAC with capabilities of conducting the evaluation. A review of existing system, documentation, and interviewing techniques accomplished this task. In Phase III, the functional and engineering requirements for the C-5 performance measurement system were described.

Taylor, E.N. & Tillman, B. Human factors engineering study of two ball port designs for IFV. Unpublished manuscript, October 1977.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	This study was undertaken to compare two ball port designs.
	2.1	The current firing port weapon (XM231)/ball port design for the Infantry Fighting Vehicle (IFV) was compared to a new design.
	2.2	Data were collected on the removal and installation of the firing port weapons.
	2.6	Critical to acceptance of the proposed design was its effect on the time required to dismount as part of rapid egress from the vehicle. In addition, the weapon retention characteristics were considered.
	3.2	Time required for removal and installation of the firing port weapon was measured.
	4.4	Five subjects and one test coordinator participated in the experiment.
	4.5	Each subject was trained to install and remove the weapon on each configuration. The seat chosen for the experiment was at the worst possible angle for the tasks. Each subject performed six trials in removing and installing the weapon in each design configuration. Time measurements were obtained by means of a stopwatch.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	5.4	Average time for removal of the firing port weapon was 1.4 seconds for the current design-used snap ring, 3.5 seconds for the current design-new snap ring, and 3.4 seconds for the proposed design. While the current design-used snap ring is approximately 2 seconds faster for weapon removal than either of the other two configurations, its condition (state of fatigue of the snap-ring) was probably unsafe. Average times for installation of the firing port weapon were 8.4 seconds, 6.2 seconds, and 3.8 seconds with the current design-used snap ring, current design-new snap ring and the proposed design, respectively. While installation time is less critical than removal time it is clear that the proposed design provides an advantage for ingress and rapid firing of the weapons mounted in the ramp.

The Bunker-Ramo Corp. Proposal for a study of human factors field performance measurement methodology (Proposal No. 5655-022-5U1). Canoga Park, CA: The Bunker-Ramo Corp., Defense Systems Division, June 1965.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planni·: Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This proposal describes a study to investigate and develop a methodology for human factors evaluation of equipment using field performance measures at the small-group level. The theoretical framework around which this proposed study is oriented involves the determination of relationships among subtasks and between subtask outputs and the terminal task output. It is conceptualized that measurement criteria should be developed for those subtasks and outputs which are most highly correlated with the terminal task output. Additional inputs to the measurement should involve consideration of the stress imposed on task performance by various operational conditions. Equipment operability would be defined in terms of resistance to the performance degradation caused by these stress conditions.
	1.3	The proposed process for the development of valid field performance measures is as follows: (1) Select tasks which manifest a range of behaviors from complex to simple; which are related in the performance of some total system function; which are exposed normally to a variety of operational conditions. (2) Analyze tasks to describe the task hierarchy and show interrelationships among tasks; to describe the behavioral functions which implement performance; to determine the points at which load conditions arise for

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		personnel; to indicate contingent events which may affect task performance; to indicate the probable effect on task performance of introducing chemical agent protective equipment; to describe the nature of stimulus inputs, terminal outputs and potential methods of task measurement.
		(3) Develop and administer a task performance characteristics scaling test which would depend on the experience of skilled military personnel to discriminate between the correlated factors involved in selected task performance.
		(4) Develop predictive criteria from the test data to be validated in field exercises.
		(5) Conduct the field exercises; record and analyze the field data to determine the correlation between test and field measurements.

Tien, J.M. Toward a systematic approach to program evaluation design. IEEE Transactions on Systems, Man, and Cybernetics, September 1979, SMC-9(9), 494-515.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.2	In this paper, the broad field of program evaluation, specifically evaluation of programs in the public sector, is reviewed. Attempts are made to synthesize and systematize the steps necessary to develop valid and comprehensive evaluation designs. First, a design framework is identified which links program characteristics to design elements through an expanded set of threats to validity. Second, the various design elements are grouped into five systematically convenient components, including test hypothesis, selection scheme, measures framework, measurement methods, and analytic techniques. Third, it is proposed that the different types of evaluation can be contained in an evaluation taxonomy composed of eight measures-related classifications. It is noted that there were many ways of classifying a program evaluation effort: by subject matter of the evaluation; by the purpose of the evaluation; by the methodology employed in the evaluation; or by some other criterion. A number of the most commonly used evaluation categorizations is listed in terms of the subject matter or purpose of the evaluation. The authors state that this paper should be regarded as only an initial step towards a systematic approach to program evaluation design while a basis for further discussion is provided.

Timson, S.F. Measurement of technical performance in weapon system development programs: A subjective probability approach (RM-5207-ARPA). Santa Monica, CA: The RAND Corporation, December 1968. (AD-681 771).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 1.3	There is an effort underway to develop the framework of a procedure for the collection and analyses of data on uncertainty and progress regarding technical performance in weapon systems development. The data collected are concerned with uncertainty about the characteristics of the component parts of the total system. These data are combined using systems design relationships to determine the uncertainty about the performance of the total system. The steps undertaken to determine the uncertainty of a total system's performance are: (1) Find design equations that relate the subsystem properties to the total system performance. (2) Determine the subjective probabilities for the subsystem and the component properties that influence the total system performance. (3) Utilize the Monte Carlo procedures to generate probability distributions for the system performance characteristics. (4) Compute the statistical measures of the system performance probability distribution. (5) Compare the statistical measures for the different time periods to obtain indications of progress.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.1	The performance characteristics critical to the aircraft's mission capability are speed, altitude, range, and endurance.
	4.1	The computational methods used to analyze the data were the measures of central tendency (mean, median, mode) and the measures of dispersion (range, standard deviation, variance).

Topmiller, D.A. Mathematical models of human performance in man-machine systems (AMRL-TR-68-22). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratories, May 1968. (AD-673 348).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	This report describes three research approaches to the problem of mathematically representing human performance parameters in weapon, maintenance, and command and control systems. In the first approach, twenty operations research analyses and models of military systems were examined to determine if the models included human factors parameters and to what extent they were sensitive to variations in these parameters. Although many of the functions of the systems modeled were performed by humans, human performance parameters were not, in general, sufficiently defined to permit mathematical or empirical manipulation within a man-machine simulation framework. In the second approach, an attempt was made to establish predictive relationships, based on regression and factor analysis techniques, between human engineering design parameters and those criteria of systems effectiveness, such as maintenance task time, that can be transformed into a more molar index - system downtime. The human engineering predictor-parameters accounted for 50% of the criterion variance. In the third approach, a series of experiments involving real-time simulation of a command and control system was conducted to determine if, and how, a computer might aid diagnostic performance (in tactical decision making) in threat evaluations. The system output or criterion of effectiveness was the degree to which the system assesses the true state of threat. With computer aiding, correct decisions increased by 13%.

Topmiller, D. A. The role of applied man-machine models. In G. W. Levy, (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 1.3	Three stages can be identified in the evolution of human engineering: (1) Operationally-oriented design criteria development (or the "knobs-and-dials" stage). (2) Design criteria formalization (publication of Human Engineering (HE) specifications, standards, handbooks, etc.). (3) Systems effectiveness modeling (or "systems-oriented human engineering"). Systems effectiveness modeling is concerned with quantifying the impact that HE design has on systems parameters. It faces the question: if one maximizes performance for a particular man-machine interface, what impact will this have on overall system performance? Three major categories of man-machine models are identified: (1) Behavioristic Models. (2) Adaptations of Engineering Models. (3) Systems Economic Models. Behavioristic models derive from or parallel the stimulus - organismic - response (S-O-R) paradigm of experimental psychology. These models include:

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(1) A "sensing or "input" portion. (2) A "processing" portion. (3) An "output portion." Adaptations of engineering models basically form two classes: Servotheoretic Models and Information Theoretic Models. Systems Economic Models are divided into two classes: Operations Research Models and Systems Effectiveness Models.
	2.6	The major parameters of system effectiveness have been defined as availability, capability and dependability. Availability is equivalent to the system's readiness to perform its mission. Dependability is equivalent to a measure of system condition at points during the mission. Capability is a measure of the system's ability to achieve the mission objectives. These parameters are criteria of system performance which require measurement and prediction. A paradigm or quantifiable framework is required which permits assessment of man's performance and contribution to these criteria - parameters.
	3.5	The following are goals of applied man-machine models. Such models should: (1) Describe and quantify the functions of both man and machine. (2) Allocate functions for most efficient utilization of man's capabilities and machine's capabilities. (3) Offer design alternatives with functional tradeoffs between design parameters and human performance. (4) Predict influence and variations in functional considerations on systems criteria.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(5) Be capable of sensitivity analysis. (6) Be capable of assimilating new human performance data. (7) Be appropriate to the level of systems description. (8) Human performance measurement should be standardized as equivalent to engineering parameter measures.

Tranby, E.D. Advanced surface ship weapon systems test and evaluation (NSWSES-TP-60). Port Hueneme, CA: Naval Ship Weapon Systems Engineering Station, January 1976. (AD-390 826).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	The purpose of this study was to produce a test and evaluation guide for an advance surface ship weapon system. This guide is intended to be used by personnel well qualified operationally and technically, but who have limited test and evaluation experience. The guide provides an overall skeletal structure of events that take place in T and E from the issuance of project assignment to composition of the final report. This structure provides a step-by-step procedure that aids in organizing the total effort. Standardized formats with instructions provide guidance in key steps such as writing the test plan and producing final test report. Checklists of important actions are presented and reference lists have been provided. The structure of the document is heavily influenced by the process the test team experiences. Numerous examples are used to illustrate the collection, verification, reduction, and control of data. A standardized test plan format is presented with instructions for use and follow-up. A standardized format for test procedures is also supplied. The use of simulators for physical testing and as a diagnostic tool is discussed. The processes of analysis are set down in a step-by-step procedure. A standardized test report format is presented and a glossary is provided.

Turner, C.R. & Bard, J.F. Tactical AWACS measures of effectiveness (ESD-TR-72-142). Bedford, MA: The MITRE Corp., April 1972. (AD-742 233).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.1	This report discussed the Airborne Warning and Control System (AWACS).
	2.2	The utility of AWACS when employed as an element of the Tactical Air Control System (TACS) was examined and nine generic tactical air missions were selected for this evaluation.
	2.5	The ultimate requirement of the AWACS was to kill hostiles and destroy targets.
	3.1	AWACS' MOE's were divided into five distinct categories: (1) Reaction (receive a mission, request a message, process data, communicate response); (2) Surveillance (detect, identify and track aircraft); (3) Command (allocation of available resources); (4) Control (the control of friendly aircraft) and (5) Communications (on-board communications capability).
	3.2	Reaction is measured in units of time and surveillance ability in terms of numbers of friendly/hostile aircraft detected, identified, tracked, etc., per unit of time. Command is measured by the ability of AWACS to allocate resources in terms of number and percent of sorties scrambled, immediate response requests accomodated, and sorties diverted. Control reflects the number and percent of friendly aircraft under control per unit of time per sortie. No MOE was assigned to the Communication category - - this function is implicit in all the reaction time and command MOE's and in all but one of the control MOE's.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.3	The AWACS' contribution in terms of surveillance, command, control, and communications capabilities was the specific area of interest.
	3.5	A methodology and criteria were established for assessing the system's capability using system-level measures of effectiveness. A set of MOE's was established for both levels (the AWACS system and the tactical mission). To obtain a standard for comparison the scenerio under consideration was analyzed both with and without AWACS. The incremental differences in tactical mission MOE's combined with AWACS system MOE's provided the insight into the effectiveness of AWACS.
	5.4	It was felt that by following the methodology developed in this report, the specific contributions of the AWACS will be clearly measured and established. Subsequent application of the tactical mission level MOE's will yield additional insight into the operational significance of the AWACS' contribution to the success of the tactical mission.
		It is stated, however, that no single unique MOE can be generated to measure either AWACS' effectiveness or tactical mission success.

Uhlaner, J.E. Human performance, jobs, and systems psychology-the systems measurement bed (Tech. Rep. S-2). Arlington, VA: Behavior and Systems Research Laboratory, October 1970. (AD-716 346).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	1.1	The systems measurement bed is a means of focusing step-by-step on the human performance aspects of the system to be enhanced and identifying the interrelationships of the human factor system variables in order to determine productivity under varying conditions. The job of leader must take into consideration the influence of the situation and styles of behavior on job performance. How a leader goes about carrying out the mission objective is directed, in part, by his particular style of behavior, value system, and the situation.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods	1.2	A taxonomy of jobs containing cognitive variance (responses more objectively characterized as right or wrong) and noncognitive variance (responses less objectively characterized as desirable or undesirable) were determined from this study. The system measurement bed assists the researcher in dealing with the different measurement characteristics of the two classes of jobs.
4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	The establishment of a systems measurement bed calls for a great deal of subject expertise: situations have to be designed, scenarios written, measurement strategies devised, and computer programs prepared. Appropriate experienced personnel must be identified to serve as subjects. Lastly, all these concepts, materials, and procedures have to be built into a logistically feasible space where relevant factors and criteria can be incorporated.

Uhlaner, J.E. & Drucker, A.J. Military research on performance criteria: A change of emphasis. Human Factors, 1980, 22(2), 131-139.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This paper discusses trends in the development and use of performance measures. It is noted that Army research to develop and to predict criteria of human performance has attempted to achieve greater relevance between performance measures and job tasks. The paper discusses the various performance criteria utilized in the past to predict individual effectiveness; these criteria include grades, ratings, and performance tests. It describes the more recently developed measures of unit effectiveness and measures dealing with human factors problems encountered in systems analysis. Some of the measures mentioned are the "Skill Qualification Test" (SQT), devised as a performance - based measure in one of the Army's new tactical training systems. This method provides two-sided free play exercises under simulated battlefield conditions and includes a specific set of operations for observing and recording actions that operational personnel have agreed upon as relevant to mission success. Other Army measurement systems described include the Organizational Effectiveness (OE) program, using a Work Environmental Questionnaire (WEQ) for diagnostic purposes, and a field method for evaluating the performance of Army helicopter pilots. The paper goes on to describe the System Measurement Bed (SMB) research approach associated with the concept of how section

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		training and work environment interact to influence the performance of the individual on the job. The paper concludes by noting that there are exciting possibilities in the future of human performance systems research and that analytic techniques in this area have the potential to impact a wide range of areas beyond the man-machine systems in the Army.

Ultrasystems, Inc. A study of measures of effectiveness used in naval analysis studies (Vol. 1 Summary). Newport Beach, CA: Ultrasystems, Inc., October 1972. (AD-912 443).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	1.3	This study is concerned with the collection and comparison of measures of effectiveness (MOE's) used in naval studies and analyses. Volume I is the final report of the study and includes the results of examining 213 Navy studies of system effectiveness covering virtually all aspects of naval warfare. The results of this study are presented in several different forms. First, a data base, utilizing two types of formats - - Study Review Summary or MOE Review, was established to present in summary form the effectiveness profile of each study examined. This profile presents an outline of the military situation addressed, variables and qualitative factors considered, and the special assumptions and limitations in MOE formulation and development. In addition, a general summary of measures of effectiveness used in naval warfare is presented.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	2.1	Of the studies examined, the ASW area accounted for 37%, the attack area accounted for 23%, and the anti-air warfare area accounted for 9% of the warfare areas considered. The remaining 31% consisted of mining and mine countermeasures, surveillance, strategic systems, electronic warfare, amphibious assault, communications, command and control, navigation, special warfare, reconnaissance/intelligence, logistics, and ship support.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.1	Analysis was conducted on the types of variables used in mathematical formulation and development. The results showed that nearly 45% of all independent variables considered were associated with the particular interests of the author. Only 19% of all independent variables related to the threat or target, and slightly less than 3% related to the physical environment. In Appendix E of this report an index of the measures of effectiveness used in these studies was presented. The index described the system and its function, the situation and the criterion for success, and lists the measures of effectiveness considered.
	6.1	Several limitations on system measurement in these studies were noted. Briefly stated they are: (1) The criterion for success is seldom explicitly stated. (2) There exists more than one way of quantifying how well the criterion for success is met. (3) For each possible mission title there is more than one way of defining the mission. (4) The rationale for MOE selection is not always presented. (5) Physical environment aspects appear to be generally ignored or casually treated in effectiveness studies. (6) It appears that there are cases where the variables selected for model formulation are not readily (if at all) measureable in the real world. (7) In general, the MOE's used are those that are readily obtained via model development.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(8) Very seldom, when more than one MOE is identified, is a ranking of importance performed or combined measure developed and used. (9) Expected value type MOE's are most prevalent in force level studies whereas probability type MOE's are most prevalent in subsystem level studies. (10) On the average, over twice as many independent variables occur in the friendly force category than in the threat and target categories combined. (11) As the study level increases, from subsystem to system to force level, the percentage of independent variables in the friendly force category decreases and the percentage of independent variables in the friendly force interaction with threat or target category increases. (12) It is not easy to compare similar effectiveness studies.

Ultrasystems, Inc. A study of measures of effectiveness used in naval analysis studies (Vol. 2 Study Review, Summaries, Part 1). Newport Beach, CA: Ultrasystems, Inc., October 1972. (AD-912 444).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 2.2	This document contains annotated bibliographies. The following is a list of the 10 specific categories or headings plus the number of bibliographies each contains: (1) Airborne ASW 17 (2) Airborne AAW 4 (3) Airborne Attack 14 (4) Environmental Systems 1 (5) Mining 2 (6) Mine Counter Measures 3 (7) Ocean Surveillance 3 (8) Submarine ASW 18 (9) Submarine Attack 4 (10) Surface ASW 15 The following is a representative sample of missions: (1) Submarine search (2) Sonobuoy barrier patrol (3) Barrier placement/patrol (4) Surface ship defense (5) Air strike (6) Close air support (7) Surveillance of ocean area (8) Bathythermograph maneuver (9) Mine clearance (10) Contact prosecution (11) Search and destroy (12) Submarine attack on convoy (13) Escort/screen

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

3.2 The following is a representative sample of practical attribute measures:

(1) Probability of submarine detection, localization, and kill.

(2) Ratio of the incremental improvement in accomplishing the mission to the incremental monetary cost of such an improvement.

(3) Detection range of raid relative to the vital area center (CVA) for a given intercept range.

(4) Expected number of targets destroyed in a given period of time.

(5) Difference in fuel consumption due to the bathythermograph maneuver.

(6) Total force level required to clear a given area in a given time.

(7) Expected number of ships hit.

(8) Elapsed time to target detection.

(9) Maximum exposure time of the submarine.

3.3 The following is a representative sample of the criteria for success:

(1) Detection of submarine.

(2) Suppression of submarine activity.

(3) Destruction of target.

(4) Successful attack capability.

(5) Low cost measurement of the vertical ocean temperature profile.

(6) Survival of aircraft and planting of mines.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(7) Clearance of minefield (8) Surveillance and establishment of the track of ships at sea. (9) Preparation for attack in the least possible time without being counter-detected. (10) Insurance of the safe passage of convoys, strike groups, and amphibious forces in the presence of hostile submarines.

Ultrasystems, Inc. A study of measures of effectiveness used in naval analysis studies (Vol. 3 Study Review Summaries, Part 2). Newport Beach, CA: Ultrasystems, Inc., October 1972. (AD-912 445).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process		See Ultrasystems, Inc. A study of measures of effectiveness used in naval analysis studies (Vol 1 Summary). Newport Beach, CA: Ultrasystems, Inc., October 1972. (AD-912- 443)
1.1 General System Measurements		
1.2 System Taxonomy Model (STM)		
1.3 Overall Conceptual Process Model (CPM)		
2. Contextual Components of the Process		
2.1 System Definition		
2.2 Mission Definition		
2.3 Environment Definition		
2.4 General Constraints		
2.5 Performance Requirements, Ultimate		
2.6 Performance Criteria, Ultimate		
3. Analytic Components of the Process		
3.1 Practical Measurable Attributes		
3.2 Practical Attribute Measures		
3.3 Performance Requirements, Specific		
3.4 Performance Criteria, Specific		
3.5 Measurement Procedures		
4. Planning Components of the Process		
4.1 Analytic Methods		
4.2 Parameter Determinations		
4.3 Apparatus for Testing		
4.4 Personnel for Testing		
4.5 Test Plans		
5. Application Components of the Process		
5.1 Test Execution		
5.2 Data Analysis		
5.3 Findings Interpretation		
5.4 Conclusions and Recommendations		
6. Further Research Areas		
6.1 Measurement System Limitations		
6.2 Research Potentials/ Priorities		
6.3 Research Planning		

Ultrasystems, Inc. A study of measures of effectiveness used in naval analysis studies (Vol. 4 MOE Reviews). Newport Beach, CA: Ultrasystems, Inc., October 1972. (AD-912 446).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Re[illegible]w of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		See Ultrasystems, Inc. A study of measures of effectiveness used in naval analysis studies (Vol 1 Summary). Newport Beach, CA: Ultrasystems, Inc., October 1972. (AD-912- 443)

U.S. Army Armor School. Tank platoon: Organization for combat and techniques of movement (TC 17-15-3). Fort Knox, KY: U.S. Army Armor School, April 1975 (Pamphlet).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The U.S. Army must learn to fight outnumbered and win. The priorities to these goals include the following: (1) Suppressive fires against enemy air defense systems, especially radar-directed systems, to permit scout and attack helicopters to operate more effectively. (2) Attack and counterattack on reverse slopes to protect attacking forces from long range enemy observation and fire. (3) Operating in darkness or other conditions of reduced visibility to reduce range and accuracy of enemy observation and fire. (4) Precision, discipline, speed, and security in the directing and reporting of the battle in order to win the battle quickly, unimpeded by enemy countermeasures. (5) Adequacy of stowed loads of ammunition and fuel; speed, responsiveness, and security of resupply systems to reduce the need to resupply, but to ensure prompt resupply when it is needed. (6) Detection and identification of the enemy at maximum possible distances from the friendly main body to prevent engagement of the main body under adverse conditions--when it is

unwarned, poorly deployed, not poised to fight.

(7) Firing fast first in a tank-antitank battle, especially at targets that can shoot back. In a tank duel, accuracy is important--firing first is more important.

(8) Control and distribution of tank anti-tank fires to kill targets rapidly and save ammunition for engaging the next attacking echelon.

(9) Battlefield movement only along covered avenues-making maximum use of terrain to evade enemy long range observation and fire.

(10) Suppressive fires delivered from overwatching positions to reduce the chance that maneuvering friendly forces can be seen and engaged by the enemy.

2.3 The assault takes place from the last available cover and carries onto the objective. The assault is normally initiated from a wedge; however, terrain and individual tank actions will govern the actual alignment.

U.S. Army, Army Materiel Command. Engineering design handbook: Recoilless rifle weapon systems. Alexandria, VA, 15 January 1976. (AD-A023 513).

Topics Relevant to System Development and Evaluation Technology

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

Topic No.	ABSTRACT
2.1	This handbook was an exposition of proven methods and materials for the engineering design of the recoilless rifle weapon systems.
2.2	The purpose of this handbook was to guide the engineer, the mature practitioner as well as the novice, directly to project goals. It provided a comprehensive summary of the available relevant technology and the system engineering rationale.
3.1	The basic input requirement to the weapon system was the kill probability for a particular target and specified range.
	The kill probability, in turn, places requirements on the hit probability and fire power of the weapon being designed. As these requirements are traced further through the system, it is found that all components of the rifle are affected. The result of this interaction is a system weight for a given terminal ballistic requirement.
3.2	Kill probability was defined as the product of hit probability of a kill given a hit. From the definition of target vulnerable area, conditional kill probability can be expressed as the ratio of the vulnerable area to the presented area.
	Hit probability was defined as the probability of a hit or hits on a target occurring out of a given number of rounds fired at a target. For a specified target and weapon system, the hit probability depends only on the overall weapon dispersion. The principal sources of these dispersions or firing errors are range estimation aiming, muzzle velocity variation, system jump and cant, crosswind and the fire control equipment.

U.S. Army Combat Developments Command. Communications-electronics-75 (CE-75) phase 1-field Army (No. 6492, Vol. 9). Fort Monmouth, NJ: U.S. Army Combat Developments Command, Communications-Electronics Agency, September 1968. (AD-883 611).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3 2.1	In the CE-75 man-machine interface investigation, the following procedures were undertaken: (1) Creation of a data base (2) Analysis of systems concepts (3) Expansion of a data base (4) Examination of suitable mode s (5) Review of the personnel subsystem (6) Critical incident analysis (7) Measurement of man's contribution to system effectiveness A system definition is a conceptual framework for attacking problems. In its broadest terms a system was comprised of hardware, facilities, logistic support, and the trained manpower required for operation in a particular environment. For CE-75, the MMI system included the entire collection of men, facilities, and equipment in the CE-75 Field Army Tactical Communications System. This system also included the area and command systems.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.2	In a broad sense, the mission of the CE-75 communications system was to provide a means for the timely transfer of meaningful and significant information from action officer to action officer. In a more specific sense, what was considered were the estimates of how much time can be allowed for the information transfer process, message priorities, and a delineation of the organization to be served. Additional elements of the mission were: (1) How much information and of what kind need be transferred between individuals? (2) What mode should be used for transmission of this information?
	2.4	A man-machine interface is the boundary at which a man and a machine interface in order to achieve a system objective. The extent of this boundary was constrained by three factors: (1) Tasks required of both the man and the machine to attain the system objective. (2) Capabilities and limitations of the machine. (3) System objectives as affected by environment, personnel policies, and equipment use.

U.S. Army Human Engineering Laboratories. Standardization of tasks and measures for human factors research. Proceedings of a Conference at Texas Tech University, Lubbock, TX, 18-19 March 1970. (AD-714 669).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

Topic No.: 1.1

This conference provided a forum for discussion of the question: "Is standardization necessary in human factors?" The papers presented, although they did not completely answer this question, did give some guidance to research groups regarding the necessity for insuring that human factors research is mission oriented and relevant to the needs of its sponsors.

There was considerable discussion with regard to a proposal that a data bank be established for use by human factors researchers. It was pointed out that a data bank could supply copies of specific tables, figures and formulae directly to the requester which would reduce the amount of duplicated effort presently expended by researchers. Some expressed the fear that such a system would seduce the user into weighting poorly collected, unreliable data equally with carefully generated reliable data. The rebuttal to this point was that experienced investigators could generally evaluate a set of data in terms of its "reasonableness" and source. It was the consensus that the data bank concept could be of great value although there was some concern for the potential misuse of such a system.

It was noted that the value of a data retrieval system would be enhanced if one could query the system about performance on specified tasks under specified conditions. However, there was some reservation with regard to the practicality of standardizing tasks and/or variables. The comment was made that tasks might be defined in terms of human functioning compartmentalized by the muscle groups involved rather than apparatus used.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Another point of view was presented to the effect that standardization of tasks may be less important than specification of conditions under which the performance data is collected. The major concern throughout the discussion was for end-goal, or mission completion, requirements in research. This was considered by most participants to be more important than standardization. There was lengthy discussion of work measurement problems and considerable dissatisfaction was expressed with currently available measures of human work. There was also discussion of field experimentation versus laboratory experimentation and the need for research on mission-oriented tasks. It was stressed that the operational environment must be kept in mind when planning human factors experiments. The need for a systems approach which would include the study of social and physical environments in mission-oriented situations was also noted.

U.S. Army Infantry Board. Infantry weapons test methodology study. Vol. 1: Small arms test methodology (USAIB-3319-F-Vol. 1). Fort Benning, GA: U.S. Army Infantry Board, November 1971. (AD-890 998L).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.3	This volume summarizes progress made in the area of small arms weapon system test methodology.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.1	In this phase of the study test facilities were constructed for the evaluation of small arms weapons utilized by the infantry.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.3	The object of the study was to simulate as nearly as possible actual combat conditions.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.1	Several categories of MOE's were established: accuracy, responsiveness, sustainability, reliability, portability, and compatibility, and signature effects. These characteristics are measured under attack and quickfire and defense modes.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	3.2	Quantitative data were used to answer questions concerning the weapons system performance.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	3.5	Instrumentation was developed and data processing and computer equipment installed at the test facilities. The goal was to use more than one test soldier at a time and yet be able to measure individual performance.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.1	Multivariate analysis is used to measure more than one measure of effectiveness, and takes into consideration the variability of sample size and the interrelationships among the various measures. It permits the observation of statistical weighting factors and is considered the key to the operational weighting of factors which influence the combat environment. Regression analysis using miss distance data was used for comparison of different types of rifles.
	4.5	Three facilities are operational: attack, defense, and quickfire. In this report, no specific test plans were presented.
	5.3	This report discusses in general terms the operational capabilities of the test facilities. Data are presented in various appendices (not in our files).

U.S. Army, Materiel Testing Directorate. U.S. Army test and evaluation command development test II (EP)--System test operations procedure "Test, Measurement, and Diagnostic Equipment (system peculiar)." Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory, 7 May 1974. (AD-781 94[illegible]).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	This report describes a methodology for evaluating system peculiar Test, Measurement, and Diagnostic Equipment (TMDE), including physical and operational characteristics. Procedures are provided for initial inspection, physical characteristics, safety, performance, extreme environments, r-f interference, reliability, maintenance, and human factors. Supplementary instructions are provided for identifying the test item, documenting test criteria, developing performance tests, environmental tests, test plan organization, and maintenance evaluation of the TMDE.

U.S. Army Operational Test and Evaluation Agency. Mechanized Infantry Combat Vehicle (MICV), XM723, operational climatic test/force, development test and experimentation (Draft). Falls Church, VA: U.S. Army Operational Test and Evaluation Agency, March 1976.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	2.1	The MICV (Mechanized Infantry Combat Vehicle) was a lightly armored vehicle designed to provide rapid cross-country mobility, large volumes of fire power from organic weapons, armored protection to a fully equipped rifle squad, and communications between all elements of the unit. It was designed to enable the rifle squad to fight effectively in both mounted and dismounted roles in offensive, defensive, or retrograde formations.
	2.3	The tests on the MICV were performed under climatic conditions best described as European winter thaw.
	2.4	During a specific phase (i.e., fording, in which is measured vehicle egress and ingress ability at water crossings), time constraints did not permit waiting for the desired winter conditions. The intent was to specifically address wetness effect on system functions under winter thaw conditions.
	4.4	People who participated in the present study included six scout drivers, six tract commanders, nine tank drivers, and nine tank commanders. Infantry players received both individual and squad training in their duties in the MICV. The gunner training developed the gunners to perform at a predetermined safe level of proficiency, though not at the level to perform combat duty.

U.S. Army Test and Evaluation Command. Materiel test procedure 3-3-521. Fort Benning, GA: U.S. Army Infantry Board, May 1970. (AD-871 788).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.1	Human factors engineering (HFE) is the application of scientific principles concerning human physical and psychological characteristics to the design of equipment, thereby increasing speed and precision of operations providing maximum maintenance efficiency, reducing fatigue, and simplifying operations. HFE requires the consideration of human characteristics such as separate anthropometrics, intellectual abilities, sensory capacities, mobility, muscle strength, basic skills, and the capacity to learn new skills.
	2.3	The study was conducted under a simulated battle environment with the physical and environmental conditions duplicating those to be found in the equipment's future use.
	3.1	Battlefield Mobility - - Within the limitations imposed by the nature of the equipment, physical design should provide integral features and/or special provisions to facilitate lifting and carrying by the individual soldier with minimum loss of efficiency. During conduct of common MTP 3-3-502, battlefield mobility, measurements and observations will be made to determine HFE design characteristics which enhance or unduly limit the man-portability and man-transportability of the equipment. Some subjects for HFE consideration are listed below. These will be explored as appropriate for the particular test item:

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/ Priorities
   - 6.3 Research Planning

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(1) Weight, dimensions, and configurations with respect to anthropometric characteristics of representative test soldiers. (2) Method of carry and means to secure during marches. (3) Location, design, and texture of gripping areas and carrying handles. (4) Location, configuration, and surface texture of areas which, although not specifically intended for the purpose, may be used for lifting and carrying heavy items. (5) Mutual interference with individual equipment and clothing. (6) Human limitations to endure strain, fatigue, and discomfort while carrying. (7) Effect on combat readiness of the soldier. (8) Handling characteristics during combat movements which require the soldier to run, jump, hit the ground rapidly, roll, and assume various firing positions. (9) Capabilities and limitations for carrying over all types of terrain. (10) Ease of carry and freedom from interference while carrying in air and ground vehicles. (11) Ease of carry and delivery by individual parachutists. (12) Human capabilities and limitations with respect to distance of carry. (13) Weight, configuration, center of balance, and load distribution of items which are transported by two or more men.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(14) Compatibility of design for use with standard individual load carrying equipment.
		(15) Packaging, protection, or other preparation required to ready the item for field transport.
	4.3	Photographs, motion pictures, videotapes, and fast frame photographs were used as aids evaluating human engineering aspects of the service test.

U.S. Army Test and Evaluation Command. Materiel test procedure 6-2-502. (Electronics Proving Ground). Fort Benning, GA: U.S. Army Infantry Board, August 1969. (AD-720 976).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 1.3	Human engineering is defined as the design of equpment, man-machine systems, and human tasks for the most effective human accomplishment of the job. Such engineering requires consideration of human characteristics such as anthropometrics, intellectual abilities, sensory capacities, mobility, muscle strength, basic skills, and the capacity for learning new skills. In military human factors engineering, the designer must consider human limitations imposed by the environmental conditions typical of military situations of use where the operator is often working under stress and fatigue. The subtests given in this Materiel Test Procedure (MTP) are performed on a selective basis as required for a specific item of equipment. The eight subtests and their objectives are as follows: (1) Control-Display Relationships - The objective of this subtest is to determine the degree to which the test item design contributes to ease of operation through incorporation of preferred display and associated control location relative to each other and to operational characteristics. (2) Visual Displays - The objective of this subtest is to determine the suitability of visual displays relative to type, size, location, readability, consistency, and operational characteristics.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(3) Auditory Warning Devices - The objective of this subtest is to determine the suitability of auditory warning devices relative to human factors aspects and operational characteristics.
		(4) Controls - The objective of this subtest is to determine the suitability of controls relative to type, size, application, location, coding, consistency, and operational characteristics.
		(5) Labeling - The objective of this subtest is to determine the suitability, readability, and consistency of labeling used for critical markings, identification, and instructions.
		(6) Workspace Design and Layout - The objective of this subtest is to determine the suitability of workspace relative to location, size, accessibility, and configuration.
		(7) Operator Comfort and Lack of Interference - The objective of this subtest is to determine if operator comfort and lack of interference aspects are satisfactory.
		(8) Special Observational Tests - The objective of this subtest is to determine the cause of special human factors engineering problem areas noted during some phase of equipment operations or testing.

U.S. Army Test and Evaluation Command. Materiel test procedure 10-2-505 (General equipment test activity). Fort Benning, GA: U.S. Army Infantry Board, September 1971. (AD-729 855).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	1.1	Experience has shown that the incorporation of human engineering design criteria, principles, and practices has improved mission success through the integration of the human into the system, subsystem, equipment, or facility. Furthermore, the cost effectiveness ratio has generally improved as a result of the application of optimum man-item design through increased simplicity, improved safety of operations, and reduced training and maintenance requirements.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	3.1	The attributes that were measured in this study were noise, visibility, thermal considerations, pressure considerations, ventilation, vibration, and radiation.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	4.3	The equipment that was required in this study is as follows: (1) Linear measuring devices, tape measures, rules, etc. (2) Scales, balances, and/or other weighing devices. (3) Temperature sensors. (4) Pressure Sensors. (5) Octave-band filter set. (6) General purpose sound level meters. (7) Light meters. (8) Vibrometer.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(9) Radiation measuring equipment (as applicable). (10) Photographic equipiment. (11) Gas sample set. (12) Accoustical chamber with sound pressure apparatus.

U.S. Department of the Army. Army training and evaluation program for mechanized infantry battalion and combined arms task force (ARTEP 7-45). Washington, DC: Headquarters, Dept. of the Army, September 1975.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This ARTEP serves as a basis for developing a mechanized infantry battalion's training and evaluation program. The program is designed: (1) To evaluate the ability of the battalion to serve as the nucleus of a combined arms task force performing specified missions under simulated combat conditions. (2) To provide a guide of training objectives by specifying minimum standards of performance for combat-critical missions and tasks. (3) To evaluate the efficiency and effectiveness of past training of all echelons of the battalion from crew/squad through battalion/task force. (4) To provide an assessment of future training needs.

U.S. Department of the Army. Skill Qualification Test notice for MOS 11B SQT 3 infantryman (No. 7-11B3-N). Washington, DC: Headquarters, Dept. of the Army, June 1976. (Pamphlet).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 3.1	The Skill Qualification Test (SQT) tests a soldier's ability to do those tasks in his Military Occupational Specialty (MOS) that are most important to his survival in combat, to the accomplishment of his job, and to his unit's mission. The SQT may contain up to three parts: the written component, the hands-on component, and the performance certification component. A soldier's ability to perform a task is measured by the SQT.

U.S. Department of the Army. Tank gunnery (Field Manual 17-12). Washington, DC: Headquarters, Dept. of the Army, March 1977.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.1	The system under discussion in this manual is tank gunnery and includes task descriptions for all crew members--drivers, loaders, gunners, and tank commanders.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.2	The mission of this system was to score a first-round target hit in the minimum possible time.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	3.1	Individual tasks for crew members were presented. These tasks apply to nearly all series and models of tanks.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.2	Crew standards were presented for each series and model of tank. Performance standards included: time to fire, range, degrees off-target for daylight hours and darkness under artificial illumination. Skill tests and scoring sheets for performance tests are included in this manual.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Pricrities 6.3 Research Planning		

U.S. Department of the Army, Office of the Chief of Staff, Tank Forces Management Group. Tank weapon system management. Washington, D.C.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	2.1 3.2	The various factors that go into the optimization of tank weaponry effectiveness were broken down into subsystems and analyzed regarding the impact of each subsystem - and subsystem integration - on the combat capability of the total tank weapons system. Subsystems were defined into personnel, logistics, training, development, and management components and are examined in turn. 3.1 The characteristics of each subsystem to be measured were as follows: (1) Personnel Management System, consisting of training, distribution, sustainment, separation, and management components. (2) Logistics System, consisting of fixing, arming, fueling, and managing. (3) Training, consisting of entry-level individual training, collective and combined arms training, reserve component, training management, tank distribution/procurement requirements, and organization/doctrine. (4) Tank Forces Management System, including science and technology base, tank system development, and resource allocation. Units of measurement, of course, differ between subsystems. The personnel subsystem consisted of processes directed toward the procurement, training, utilization, separation, development, and motivation of military personnel. The training requirements of the personnel

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		management system are separated into basic combat training, advanced individual training, and one-station unit training. The distribution aspect involving the proper mix of personnel to fill field requirements was assessed by: (1) Properly identified and timely submitted requirements by units. (2) Accurate authorizations and personnel inventory data bases. (3) Support at all command levels through the reduction of diversions. The sustainment component of the Personnel Management System (to develop and maintain the career force to best meet the readiness requirement) was assessed through the Enlisted Force Management Plan (EFMP), which provides both qualitative and quantitative goals for the Army for the period FY 73 - FY 82. The logistics subsystem, which seeks to optimize the interaction of functional equipment, trained personnel, and responsive support, was assessed through the: (1) Fixing or supply and maintenance system (wholesale and retail logistics doctrine and procedures). (2) Arming requirements for the tank force, e.g., ammunition resupply rates, transportation requirements for bulk cargo from entry points to ultimate user. (3) Fueling supply, e.g., what organizations at what level fulfill this function and what report/request procedures exist to support it.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Assessment of the training subsystem is made through evaluation of the Army's service schools and training centers, training materials and extension courses, operational unit-field training, and simulated combat training.
		Finally, the tank forces management system is based on an analysis of system characteristics, levels of decision, material acquisition analysis, and operational and development testing.
	5.3	The findings of this analytical report have direct relevance for the primary mission of the Army Tank Development Program: equipping armor units with the best available tank in sufficient numbers to counter the threat:
		(1) There currently exists no viable tank development/procurement strategy in the Army.
		(2) There is no single coordinating agency within the U.S. Army Material Readiness and Development Command (DARCOM) in charge of integrating all tank related science and technology-based programs.
		(3) Documents in current use do not identify user tank development priorities.
		(4) Control of tank programs is fragmented.
		(5) Tank project managers fail to initiate early planning in the development cycle.
		(6) Responsible Army staff agencies are not reviewing logistic plans prior to program milestones.

Van Acker, A. & Wohl, J.G. Modeling the sonar operator's detection process: A progress report. In G. W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.3 2.4	To assist in developing sonar operator performance standards, models representing different aspects of an operator's activities are being developed and implemented as computer programs. This paper discusses the search and detection performance model. The overall simulation model includes three submodels: (1) The geometric submodel (which controls movement of the target submarine). (2) The physical world submodel (controlling sonar signals, reverberations, noise, etc.). (3) The decision-maker submodel (which simulates the operator's search and detection processes and procedures). The decision-maker submodel involves certain basic assumptions: (1) The operator fixates on the CRT at a series of points in consecutive sequence, and a target can be seen only when fixating. (2) A specified scanning policy is followed in regard to fixation. (3) Only targets (not noise) will cause interruption of the scan policy.

Y17

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(4) Probability of glimpsing a target is a function of retinal position and brightness contrast ratio.
		(5) Probability of glimpsing a target also is a function of an internal criterion used by the operator (which depends on his conservatism, short-term memory, data handling capacity, the noise level on the PPI, as well as some psychophysical limitations).
		(6) The decision maker decides that a target is present if his last glimpse of the target is foveal <u>and</u> if he has glimpsed it a specified number of times out of the last group of pings (called the detection announcement factor).
	4.2	As variable inputs, the decision-maker submodel has the following: (1) A scanning policy. (2) Fixation time. (3) Glimpse criterion factor (the operator's internal criterion). (4) Detection announcement factor.
	5.3	Early results with the submodel indicated that fixation time is not a highly critical factor to detection range, and that various regular search patterns produced little statistical differences. However, the sonar performance was extremely sensitive to the operator's internal glimpse criterion, and also to the detection announcement factor.
	6.1	The basic detection model involves only the video sonar scan and applies only to a small proportion of the situations encountered in practice (viz., isothermal water and non-maneuvering targets). Work is underway to extend the model and remove these constraints.

Von Winterfeldt, D. An overview, integration and evaluation of utility theory for decision analysis (SSR1 Research Rep. 75-9). Los Angeles, CA: University of Southern California, Special Science Research Institute, August 1975. (AD-A021 497).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

2.1 Utility theory is a division of measurement theory that assigns numbers to objects by indexing them to a decision-maker's values. Utility theory, however, unlike measurement theory in general - differs by measuring objects of cost or value, relates objects by means of preferences, while operations involving these objects are either missing or are made through surrogate objects.

2.2 The goal of this analysis of utility theory is in its application to certain decision situations that may be classified according to the following factors:

(1) Static versus dynamic decision environment.

(2) Single decision maker versus multiple decision makers.

(3) Single aspect choice entity versus multiple aspect choice entity.

3.1 Specifically, five model classes of utility theory are discussed: "weak orders", "difference measurement", "bisymmetric measurement", "conjoint measurement", and "expected utility measurement".

3.2 The weak order measurement model is applied in cases of multiple affected individuals and assumes transitivity of preferences.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Difference models compare the relative differences of the strength of preference between pairs of choice entities, and uses "operational surrogates". The idea behind bisymmetric measurement is to find an element "c" that bisects "a" and "b", i.e., the objective is that "c" has the average utility of "a" and "b" numerically speaking. Conjoint measurement models are used for measuring utilities over several choice entities that take on different value configurations. Expected utility theory makes three common assumptions about preferences among risky choice entities: (1) Risky alternatives can be ordered transitively. (2) If events have common outcomes, then preferences among risky alternatives should be independent of those events. (3) There are equivalents for all possible uncertain entities.
	5.4	Decision analysts may improve their model-building by using utility theory to define problem structure, model forms and possible errors in models. However, utility theory is not appropriate for scale construction.

Vreuls, D., Wooldridge, A.L., Obermayer, R.W., Johnson, R.M. & Norman, D.A. Development and evaluation of trainee performance measures in an automated instrument flight maneuvers trainer (NAVTRAEQUIPCEN 74-C-0063-1). Westlake Village, CA: Canyon Research Group, Inc., October 1975. (AD-A024 517).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.1	This system is an automated flight training system consisting of an instrument flight maneuvers flight simulator modified to operate with three measurement systems.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.2	The system was configured as a high performance fighter aircraft (F-4E) capable of four instrument flight maneuvers. The flight conditions selected are straight and level flight, standard rate climbs and descents, level turns and climbing and descending turns.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.4	The system consists of an F-4E cockpit mounted on a four-degree of freedom motion platform. It contains all controls and displays of the jet fighter cockpit except radio navigation, communications and weapons control.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	3.1 and 3.2	The following characteristics and units of measure were used in this study:
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations		
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning		

PARAMETER	UNITS
(1) System Clock Count	
(2) Elevator Stick Force	Pounds
(3) Elevator Stick Displacement	Inches
(4) Angle of Attack	Units

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

(5)	Pitch Attitude	Degrees
(6)	Climb/Descent Rate	Feet per Min
(7)	Altitude	Feet
(8)	Right Throttle Displacement	Degrees
(9)	Airspeed	Knots
(10)	Aileron Stick Force	Pounds
(11)	Aileron Stick Displacement	Inches
(12)	Roll Attitude	Degrees
(13)	Turn Rate	Degrees per Second
(14)	Heading	Degrees
(15)	Rudder Pedal Force	Pounds
(16)	Rudder Pedal Displacement	Inches
(17)	Sideslip	Degrees
(18)	Turbulent Air Intensity	Arbitrary Units

Initially, 16 of these measures were selected for use. Correlation analysis of redundant information reduced the 16 to 12. Multiple discriminant analysis produced nine measures which could be weighted and summed into a single score.

3.5 All data were recorded on magnetic tape at the rate of five times-per-second in real time for each full training run.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.1	Correlation and multiple discriminant analyses were used on the collected measurement data.
	4.2	The controlled test parameters were air turbulence set at "light" for this test, aircraft weight was either light or heavy and a center-of-gravity shift of 29.0 to 30.2 percent mean aerodynamic chord.
	4.3	The test equipment was the Training Device Computer System (TRADEC) located at the Naval Training Equipment Center, Orlando, Florida. It was configured as a fixed wing aircraft (F-4E) on a four-degree of freedom motion platform.
	4.4	The test subjects were twelve low-time civilian student and private pilots.
	5.4	The major conclusion and recommendation of the study was that the discriminant model should be applied to the problem of specifying measures for future flight training systems. In addition, a series of individual conclusions and recommendations were presented.

Waag, W.L., Eddowes, E.E., Fuller, J.H. & Fuller, R.R. ASUPT automated objective performance measurement system (AFHRL-TR-75-3). Williams AFB, AZ: Air Force Human Resources Laboratory, Flying Training Division, March 1975. (AD-A014 799).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	The implementation of the measurement system requires: (1) Definition of criterion objectives in terms of a candidate set of simulated parameters. (2) Evaluation of the proposed set of measures for the purpose of validation and simplification. (3) Specification of criterion performance by requiring experienced instructor pilots to fly the particular maneuver. (4) Collection of normative data using students as they progress through the training program.
	2.1	The Advanced Simulation in Undergraduate Pilot Training (ASUPT) facility is designed to be a research device capable of providing answers regarding the hardware design and effective use of flight simulators.
	2.4	A criterion referenced approach to measurement system development was pursued under the following constraints: (1) Measures will assess the degree to which the criterion objectives are met.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(2) Measures will reflect only the most salient characteristics of performance.
		(3) Measures will be meaningful and interpretable to the user -- the student and instructor pilot.
		(4) Measures will be generated on a real-time basis so that feedback is immediate.
	3.1	Those attributes measured in this study were: Altitude, Airspeed, Heading, Stick movement, Throttle movement, Elevator stick force, Pitch rate, Pitch acceleration, Roll rate, Roll acceleration, Vertical velocity, Vertical acceleration
	4.1	The statistics in this study were calculations of the mean, mean root square, and the standard deviation.

Weapon System Effectiveness Industry Advisory Committee. Final report of task group II. Vol. 1 Prediction-measurement: Summary, conclusions and recommendations (AFSC-TR-65-2). 1965. (AD-458 454).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1 1.3	The purpose of the Weapon System Effectiveness Industry Advisory Committee was to provide technical guidance and assistance to Air Force System Command in the development of a technique to apprise management of current and predicted weapon system effectiveness at all phases of weapon system life. It was noted that system effectiveness evaluation/prediction can be reduced to an ordered set of tasks as follows: (1) Mission Definition a. Functional description of purpose b. Quantitative requirements (2) System Description a. General configuration b. Block diagram c. Time line analysis (3) Specification of Figures of Merit (4) Identification of Accountable Factors a. Level of accountability b. Personnel characteristics c. Procedure characteristics

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		d. Hardware characteristics e. Logistics f. Data constraints (5) Model Construction a. Assumptions b. Delineation of possible mission outcome c. Delineation of significant system states (6) Data Acquisition a. Specification of data elements b. Specification of test methodology c. Specification of data reporting system (7) Parameter Estimation (8) Model Exercise a. Numerical evaluation of effectiveness and its factors b. Comparative system analysis c. Parameter variation study The examples of Volumes II and III adhere rather closely to this analysis of the steps required to achieve a system effectiveness evaluation/prediction.
	2.1	The life cycle of a system was divided into the conceptual, definition, acquisition, and operational phases.
	3.1	System effectiveness was defined as the function of a system's availability, dependability, and capability.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		Availability was a measure of the system condition at the start of the mission. It was a function of the relationships among hardware, personnel and procedures. Dependability was a measure of the system condition at one or more points during the mission given the system condition(s) at the start of said mission. Capability was a measure of the ability of the system to achieve the mission objectives, given the system condition(s) during the mission. Capability accounts for the performance spectrum of a system.
	4.1	No specific statistics were given. However, the procedure went as follows: effectiveness was the product of availability, dependability and capability. To provide for the treament of the various conditions, these three variables were expressed as a vector or matrix. In highly complex systems, when matrices were impractical, an analog or digital computer simulation was employed.

Weapon System Effectiveness Industry Advisory Committee. Final report of task group II. Vol. 2 Prediction-measurement: Concepts, task analysis, principles of model construction (AFSC-TR-65-2), 1965. (AD-458 455).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3	This document is part of the final report of the Weapon System Effectiveness Industry Advisory Committee (WSEIAC). The purpose of the Weapon System Effectiveness Industry Advisory Committee was to provide technical guidance and assistance to air force system command in the development of a technique to apprise management of current predicted weapon system effectiveness at all phases of weapon system life. Four systems were illustrated including an airborne avionics system, an intercontinental ballistic missile system, a long range radar surveillance system, and a spacecraft system. The four phases of system life (conceptual, definition, acquisition, operation) were discussed as well as the eight tasks used to evaluate system effectiveness. (1) Mission definition (2) System description (3) Specification of figure(s) of merit (4) Identification of accountable factors (5) Model construction (6) Data acquisition (7) Parameter estimation (8) Model exercise

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.1	The long range radar surveillance system consisted of two transmitters in parallel, an antenna, a receiver, a display and synchronizer, and an operator.
	3.3	The system should detect target aircraft above the horizon line of sight at ranges up to 200 miles and, while the target is within this maximum range, track it in range and azimuth within admissible error.

Weapon System Effectiveness Industry Advisory Committee. Final report of task group II. Vol. 3 Prediction-measurement: Technical supplement (AFSC-TR-65-2). 1965. (AD-458 456).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentiala/Priorities 6.3 Research Planning	1.1	The purpose of the Weapon System Effectiveness Industry Advisory Committee was to provide technical guidance and assistance to air force system command in the development of a technique to apprise management of current and predicted weapon system effectiveness at all phases of weapon system life. The objective of Task Group II was to review existing documents and recommend uniform methods and procedures to be applied in predicting and measuring systems effectiveness during all phases of a weapon system program. 2.1 This report is concerned primarily with four examples of effectiveness evaluation, involving the following systems: (1) Avionics system in a tactical fighter - bomber. (2) Squadron of ICBMs. (3) Fixed radar surveillance and threat evaluation system. (4) A spacecraft system. Each system is evaluated at a different phase of development.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	3.1	The specific basic analytical model proposed by Task Group II is, symbolically, E = A[D]C Where E = system effectiveness A = Availability [D] = Dependability C = Capability The basic model is not restrictive; variations on the basic model are illustrated in four examples.

Weinstock, G.D., Douglas, M. & Blom, B. Development of criteria and measures of effectiveness for U.S. Army tactical communications systems (Tech. Rep. ECOM-5012-1). Paramus, N.J.: Communications Systems, Inc., May 1969. (AD-881 145).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.1	This study addressed competing communications systems.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.2	The purpose of these systems is to transfer information between two separate locations.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.5	The requirement is that the information is received and that the information reaches its destination.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	2.6	The ultimate criteria are that the information is understood within "acceptable boundaries of quality or error rate" and that it reaches its destination in a timely fashion.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	3.1	The measure of benefit has two dimensions -- information and time.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	3.2	Information flow and information capacity can be measured mathematically.
	3.3	Specific performance requirements of this system include: transportability, mobility, capacity, quality of service, survivability, vulnerability.
	4.1	An integrated system effectiveness model was developed in this study which is capable of providing a single explicit measure of system effectiveness when evaluating competing communication systems. This model is based on statistical analysis and the probability of successful communications derived from queuing relationships.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.4	The approach was broken down into four tasks: (1) Development of a comprehensive listing of criteria and associated performance factors. (2) Establishment of the format for three matrices: (a) assignment of mission to conflict intensity by frequency of occurrence and relating allocation of resources to conflict intensity; (b) identification of tactical functions; and (c) relating quantitative communications requirements by communication nets to tactical functions. (3) Development of quantitative relationships between the criteria and measures of effectiveness. (4) Use of the above items to show the procedure for measuring effectiveness of the proposed system.
	5.4	The conclusion of this report states that it is desirable at this time to test the model and evaluation concept by means of a not too complex test problem. It is believed that a test problem will establish confidence in the model and provide insights into the model's operation.

Weisz, J.D. System analysis: Manpower resources/system design integration methodology (Tech. Note 9-68). Aberdeen Proving Ground, MD: Human Engineering Laboratories, August 1968. (AD-675 481).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	General methodology is introduced which, when used appropriately by decision makers, may assist them in deciding which system concepts among several to approve for further development. This technical note attempts to establish a general framework around which manpower factors can be effectively introduced into system analyses studies. It is stated that with expert inputs from specialists in training, selection and utilization of personnel, and human performance, a human factors team should be able to provide an estimate of which concept from the human factors viewpoint will best fulfill system performance requirements at least total cost. It is suggested that to successfully complete the manpower factors part of the systems analysis, a constantly updated data bank of manpower resources should be available. The data bank would include training time and cost data on all past fielded systems, and a skill-level breakout of the present Army performance data in the areas of vision, tasks, etc. Experts in the area of training and job analysis should, with this information, be able to estimate the skills required for each concept being considered. If the estimates are detailed enough, sufficient sensitivity should exist to differentiate among the concepts being considered.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		In addition, appropriate data in the data bank would enable estimates to be performed as to whether a person can or cannot perform the functions required in each concept. Following the initial system-concept comparison, trade-off studies could be conducted. The human factors team could assist in deriving these data in various forms: cost, estimated amount of down time, system performance change and personnel skill-requirements change.

Wellman, L.N. & Neill, W.H. The development of performance measurement standards for the USAF base level supply system (SLSR-12-72B, Master's Thesis). Wright-Patterson AFB, OH: Air Force Institute of Technology, September 1972. (AD-750)12).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM)	2.1	The system addressed in this thesis is the Standard Base Supply System and its associated personnel.
2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate	2.2	The Base Supply System provides support to aircraft maintenance.
3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures	2.5	The ultimate performance requirement of this system is that the base supply be controlled in the most cost-effective manner to ensure that resources are used efficiently and effectively.
4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans	2.6	The current system has no set of standard measurement areas to indicate how well the system is supporting its objectives.
5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations	3.1	In order to determine which attributes should be measured, an open-ended questionnaire, accompanied by a letter of explanation of the research project, was sent to the selected "experts." The response from this questionnaire resulted in the development of a "follow-on" questionnaire. From this information a consensus of opinion on the measurable attributes of importance was obtained.
6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	3.5	The measurement tool utilized in this study was the Delphi technique. To determine a consensus, the mode response was chosen as it is the response which occurs most often.

X-1

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	4.1	The Delphi technique was utilized to induce opinion convergence through a sequence of questionnaires using controlled feedback to the participants.
	4.4	It was determined that an appropriate sample size for the study would be 35. Two groups were selected composed of supply experts and experts from the maintenance career field. The following criteria were used as a basis for selection: a. Stature of the individual in his career area. b. Breadth of his experience. c. Degree of varied assignments with different major commands. d. Level of assignment from base, major commands and Air Force levels.
	5.4	A consensus was obtained on seventeen measured areas from the panel of experts. This initial research indicates that the Delphi technique can be effectively used for design of some elements of a management control system, but there are limitations which should be considered.

Wherry, R.J. The development of sophisticated models of man-machine system performance. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/Priorities 6.3 Research Planning	1.1	This paper is concerned with the development of models which will aid in the design, development, test and evaluation of military systems, equipment, and facilities. Too often, design approaches that are taken seem to be based on "clinical" or intuitive judgments without formally stated assumptions. Whenever assumptions are not formally stated there is an increased chance that erroneous assumptions will not be recognized as such. There is a need, as model builders, to formalize assumptions to be sure that they are not inconsistent.
	1.3	This paper examines the feasibility of far more sophisticated digital computer programs [models] than currently exist. It is possible to distinguish several classes of models which would be extremely useful if they (a) existed and (b) worked. These include: (1) Instrument design/evaluation programs. (2) Human operator simulator programs. (3) Optimization programs. (4) Training requirements programs.
	3.1	Major subsections of human operator simulators are identified:

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(1) Individual Differences--The model should have the option of reading in a profile of abilities so that a system could be tested to determine its sensitivity to various operator states.
		(2) Procedures---Procedures for the simulated operator must be oriented to the "perceptual" level and stated in terms of desires rather than imperatives. The model can never positively require [or guarantee] that the operator will absorb any particular information or make any particular control manipulation. The locus for decisions to actions resides in the operator, not in external commands or procedures.
	4.3	The use of a Human Operator Procedures (HOPROC) language for Human Operator Simulator Programs is discussed.

Williams, G.S. A methodology to establish the criticality of attributes in operational tests (Master's Thesis). Georgia Institute of Technology, 1975. (AD-A024 199).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	This thesis addresses a method which provides a basis for the selection of critical attributes which best discriminate between acceptable and unacceptable systems in order to facilitate the selection of measures of effectiveness. The author states that current test structure in operational testing is not amenable to the standard application of multivariate statistics. The methodology developed in this thesis encompasses a means to combine results from past tests with subjective information to determine, the relationship, in terms of covariances between two attributes. This information is incorporated with subjectively obtained acceptable and unacceptable mean vectors in stepwise discriminant analysis. It is concluded that multivariate techniques may be a valuable aid in determining which attributes contribute more in distinguishing between successful and unsuccessful systems. It is also concluded that current test design for operational testing can be modified to facilitate a broader use of multivariate statistical analysis techniques. This modification should permit the correlation among attributes to be objectively determined and the marginal normality of observations for each attribute to be validated.

Williams, H.L. Dependent models for estimating human performance reliability. In R.E. Blanchard, & D.H. Harris, (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 5.3 Research Planning	1.1	Tasks performed by human operators, technicians, and ground crews in assembly, test, and handling frequently have a significant effect on the efficiency of a weapon system. In assessing system and design feasibility. one must also determine the reliability of human performance.
	1.3	Methods developed for estimating human performance reliability require that the human task be divided into discrete steps, and that a probability model be fitted to the task. Probability values of successful performance are estimated for each step in the model, and the success probability for the total task is then computed. If the task's discrete steps are independent, human performance reliability can be estimated without undue difficulty. Data stores exist which provide marginal probabilities for independent task steps (e.g., American Institute for Research data store). One finds that the great majority of operational procedures tasks encountered break down into dependent steps. The combination of dependent relationships usually is unique and the analyst finds that neither data nor procedures for estimating the dependent probabilities are available to him. One must conclude that the conditional probabilities of a model composed of dependent events will not be found in a data store.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	6.2	The problem of estimating conditional probabilities of dependent task steps can only be solved by developing transition models that make the transition from the marginal probabilities of the data store to the conditional probabilities of the dependent relationships. Although much work remains to be done, one can determine the general form of the transition models by using the techniques of experimental design and analysis. Two major problems that must be solved before there will be significant progress in developing transition models are (1) factors responsible for dependent relationships among task steps must be fully identified, and (2) effects of dependent relationships must be determined.

Williams, R.L., Long, T.W. & Windholz, W.M. A standardized munitions effectiveness methodology (K-75-57 R). Colorado Springs, CO: Kaman Sciences Corporation, July 1975. (AD-B009 483).

Topics Relevant to System Development and Evaluation Technology

1. State of the Art Review of the Process
   - 1.1 General System Measurements
   - 1.2 System Taxonomy Model (STM)
   - 1.3 Overall Conceptual Process Model (CPM)
2. Contextual Components of the Process
   - 2.1 System Definition
   - 2.2 Mission Definition
   - 2.3 Environment Definition
   - 2.4 General Constraints
   - 2.5 Performance Requirements, Ultimate
   - 2.6 Performance Criteria, Ultimate
3. Analytic Components of the Process
   - 3.1 Practical Measurable Attributes
   - 3.2 Practical Attribute Measures
   - 3.3 Performance Requirements, Specific
   - 3.4 Performance Criteria, Specific
   - 3.5 Measurement Procedures
4. Planning Components of the Process
   - 4.1 Analytic Methods
   - 4.2 Parameter Determinations
   - 4.3 Apparatus for Testing
   - 4.4 Personnel for Testing
   - 4.5 Test Plans
5. Application Components of the Process
   - 5.1 Test Execution
   - 5.2 Data Analysis
   - 5.3 Findings Interpretation
   - 5.4 Conclusions and Recommendations
6. Further Research Areas
   - 6.1 Measurement System Limitations
   - 6.2 Research Potentials/Priorities
   - 6.3 Research Planning

Topic No.	ABSTRACT
2.1	This report develops a practical munitions effectiveness methodology relevant to five types of munitions: artillery, tank ammunition, rockets, mortars and mines. Since no formalized procedure exists for making comparative munition effectiveness analyses, the authors here attempt to standardize the effectiveness evaluation procedure.
2.2	The ultimate goal here is development of a standardized formula applicable to munitions effectiveness analyses in general, based on three general components: definition of weapon purpose, identification and measurement of performance and "pain" (costs of achieving a given level of performance), and determination of the exchange relationships among quantities represented by the above concepts.
2.4	The effectiveness methodology developed is applicable to the five classes of weapons mentioned above, applies in all types of weather and in all terrains.
2.5	The ultimate requirement of this munitions effectiveness model is the determination of the expected fraction of the target destroyed, which is the formal definition of munitions effectiveness (E).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
	2.6	For a single round, munitions effectiveness is defined by the equation E = ARE(c), where A = Availability R = Reliability and E(c) = Effective coverage AB158
	3.1 and 3.2	Attributes of the munitions effectiveness concept and their operationalization, where quantifiable, are as follows: (1) Safety: concerned with personnel safety and the possibility of premature detonations. (2) Reliability: assessment of constituent elements of the munition in terms of performance, both human and weapon; also includes concepts of success and failure. (3) Availability: includes logistic integrity of personnel - weapons system; manufacture, availability of raw materials, availability of plant capacity, shipping, storage, and transport to the unit of utilization, and ability of weapon to survive troop handling; also includes concepts of dependability, durability, ease of use and training. (4) Lethality: capability, arming and delivery accuracy, kill mechanisms of overpressure, shock, penetration or fragmentation, etc. (5) Range: treated by assessing overall effectiveness as a summation of effectiveness at specific targets at different ranges weighted by the probability of frequency of occurrence. (6) Flexibility: the degree to which a design can be modified for utilization in different procedures.

(7) Countermeasures: enemy tactics which affect target definition. Examples include armor plating, reenforced bunkers, etc.

(8) Utilization Rate: rate of fire.

(9) Weight: of weapon.

(10) Firing Doctrine and Tactics: effectiveness of individual subcomponents of man-weapon system.

(11) Complexity: simplicity and ease of use are adversely affected by complexity.

(12) Training and Documentation: the likelihood of successful performance of necessary tasks, degree of training, etc., i.e., the human element.

(13) Cost: referred to as the "pain."

4.1 A sample effectiveness evaluation for the Lightweight Company Mortar System is given: the specific steps involved in the evaluation are as follows:

(1) Step 1: Define Munition Purpose. 158

(2) Step 2: Define the Mission: general description, functional examination (success criteria) for each component/module/assembly.

(3) Step 3: Create the Availability/Reliability Event Sequence and General Organizational chart.

(4) Step 4: Determine Numerical Estimates for Events/Components (Reliability Allocation and Prediction).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		(5) Step 5: Calculate Availability/Reliability Estimates.
		(6) Step 6: Obtain Target and Lethality Data.
		(7) Step 7: Exercise Effectiveness Computer Model.

Willis, J.E. Feasibility of the development and utilization of personnel performance effectiveness measures for man/machine function allocation decision (Research Memo. SRM 68-7). San Diego, CA: U.S. Naval Personnel Research Activity, October 1967. (AD-660 003).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.1	The general goal of this study is to provide a methodology which will enable cognizant persons to obtain quantitative information on personnel effectiveness and relative costs.
	2.1	The system under discussion in this report is the human component of a system who performs operator or maintenance functions.
	2.2	The mission of the human component in this system is that his/her function is performed adequately and in such a way that it will always lead towards mission accomplishment.
	4.1	As there exists no body of quantitative evidence about the performance effectiveness of personnel in present systems, it is suggested that as a first step it would be appropriate to collect data to be used as a basis for predictions. Samples should be selected which will generalize to entire classes of populations.
	4.2	It is suggested that the following parameters should be used to describe the operating conditions for which task accomplishment must be predicted: (1) Number (2) Sequence (3) Response pacing (operator pacing)

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT

(4) Feedback

(5) Required Accuracy

(6) Display exposure time

(7) Display visibility

(8) Type of stimulus in a display

(9) The number of stimulus dimensions

(10) The number of visual stimuli displayed

(11) Operator function

(12) Stimulus movement

(13) Requirements for control - display coordination.

4.5 The plan suggested for research is:

(1) Select parameters and start observation on simulated system.

a. Contact system designers regarding useful content and format of data and reported PPE indices.

b. Utilize the automated OSD.

(2) Test and refine parameters.

(3) Contacts to determine how methodology might be implemented.

(4) Develop automated system for handling data.

6.2 It is recommended that the program for development of a Navy PPE prediction methodology be implemented and that a "boot strap" operation be started to begin the development of a data bank on personnel performance.

Wortman, D.B., Hixson, A.F. & Jorgensen, C.C. A SAINT model of the AN/TSQ-73 guided missile air defense system (Research Memo. 79). W. Lafayette, IN: Pritsker and Assoc., Inc., January 1979.

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	2.1	The AN/TSQ-73 Missile Minder was a lightweight mobile automatic data processing command and coordination system for NIKE-Hercules and Hawk Army Air Defense units. The AN/TSQ-73 integrates radar and identification of friend or foe (IFF) data from vocal and remote radars for console display. The SAINT model of the AN/TSQ-73 system was designed to simulate the tasks performed by a single operator/repairman involved in monitoring and operating the AN/TSQ-73 display console during a simulated mission. The SAINT model was comprised of four submodels: operator control, aircraft control, fire unit control, and systems control. These four submodels operated relatively independently of each other.

Wortman, D.B., Sigal, C.E., Pritsker, A.A. & Seifert, D.J. New SAINT concepts and the SAINT II simulation program (AMRL-TR-74-119). W. Lafayette, IN: Pritsker and Assoc., Inc., April 1975. (AD-A014 814).

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
1. State of the Art Review of the Process 1.1 General System Measurements 1.2 System Taxonomy Model (STM) 1.3 Overall Conceptual Process Model (CPM) 2. Contextual Components of the Process 2.1 System Definition 2.2 Mission Definition 2.3 Environment Definition 2.4 General Constraints 2.5 Performance Requirements, Ultimate 2.6 Performance Criteria, Ultimate 3. Analytic Components of the Process 3.1 Practical Measurable Attributes 3.2 Practical Attribute Measures 3.3 Performance Requirements, Specific 3.4 Performance Criteria, Specific 3.5 Measurement Procedures 4. Planning Components of the Process 4.1 Analytic Methods 4.2 Parameter Determinations 4.3 Apparatus for Testing 4.4 Personnel for Testing 4.5 Test Plans 5. Application Components of the Process 5.1 Test Execution 5.2 Data Analysis 5.3 Findings Interpretation 5.4 Conclusions and Recommendations 6. Further Research Areas 6.1 Measurement System Limitations 6.2 Research Potentials/ Priorities 6.3 Research Planning	1.3 2.5	This report details the development of an integrated package of computer routines designed to aid the system design engineer in determining the impact of the human operator on system performance. The objective of SAINT is to provide the necessary tools and conceptual framework to develop simulation of complex man-machine systems. SAINT enables the designer to imput a description of the activities which the human operator must perform in the course of a mission. These activities are represented in a task network framework in which task performance descriptions as well as precedence relations among tasks are defined. SAINT performs an analysis of the task sequence and provides information concerning operator workload, task completion times and other performance measures. The SAINT II package (an expansion of SAINT I) has techniques which enable the user to model continuously changing variables such as aircraft position in space, engine temperature, fuel consumption, etc. Additional refinements have been devoted to the incorporation of the capability to modify operator and system characteristics as a function of mission contingencies and external events. Each operator involved in a mission simulation with SAINT II has certain attributes which must be assigned to him. Using input data, the program sets seven operator attributes into a packet, although

Topics Relevant to System Development and Evaluation Technology	Topic No.	ABSTRACT
		additional attributes can be included. The seven standard attributes are: (1) Speed factor. (2) Accuracy factor. (3) Stress threshold. (4) Goal gradient. (5) Time available to complete mission. (6) The next intermediate stress tasks. (7) Time available to reach the next intermediate stress task.
	5.1	A test simulation of aircraft refueling was presented as an example. In the example, the receiver and tanker are initially flying at the same velocities. Perturbations of the tanker's velocity are incorporated in the model and represent environmental disturbances (turbulence). The objective of this simulation was to determine how well the receiver pilot is able to maintain his refueling position in the face of these disturbances and the prescribed control strategy.

APPENDIX B

BIBLIOGRAPHY

(without annotations)

AC Spark Plug Division, General Motors Corporation. Inertial guidance system 107A-2—Category II, Personnel Subsystem Test and Evaluation (PSTE) and Maintenance, Logistics, Reliability and Readiness (MLRR) test and evauation—Objective achievement status report (AF 04 (694)-177 AFBM Exhibit 60-20A). Milwaukee, WI, 15 February 1964. (AD-829 749).

Akashi, H. & Mahmood, S. Performance of human operators under various system parameters (NASA CR-6725). National Aeronautics and Space Administration, (undated).

Analytics, Inc. Measuring the performance of operational decision aids (N00014-75-C-0600, Final Rep. 1161-B). Willow Grove, PA: Analytics, Inc., April 1976. (AD-A024 795).

Anderson, R. Measures of aircraft effectiveness (AOS-TR-73-5). Kirkland AFB, NM: Office of the Assistant for Study Support (OAS), May 1973. (AD-913 306).

Anderson, W.H. Development of performance measures for organizational level aviation maintenance managers. NTIS Weekly Government Abstracts, October 17, 1977. (Abstract).

Andrews, L.B. Detailed Test Plan (DTP) for the Initial Operational Test and Evaluation (IOT&E) (OT-II) of the AN/TPS-59 radar set (C 0041-0-07-1). Quantico, VA: Commanding General, Marine Corps Development and Education Command, August 1977. (AD-B020 848L).

Baker, J.D. Quantitative modelling of human performance in information systems. Ergonomics, 1970, 13(6), 645-664.

Basso, G.L. A methodology for measurement of vehicle parameters used in dynamic studies. Ottawa, Canada: National Aeronautical Establishment, July 1973.

Beau, J.F. Management of the human element in the physics of failure. Paper presented at The Third Annual Symposium on The Physics of Failure in Electronics, Chicago, IL, September 29, 1964. (AD-812 593).

Berson, B.L. & Crooks, W.H. Guide for obtaining and analyzing human performance data in a materiel development project (Tech. Memo. 29-76). Woodlands Hills, CA: Perceptronics, Inc., September 1976.

Blanchard, R.E. & Smith R.L. Field test of a Technique for Establishing Personnel Performance requirements. 1969 Annals of Assurance Sciences, 271-272. New York: Gordon and Breach Science Publishers, July 1969.

Bloom, R.F., Pepler, R.D., Schimenz, M.V. & Lenzycki, H.P. IFV/CFV personnel selection analysis (Army Research Institute Research Note 80-41). Darien, CT: Dunlap and Associates, Inc., July 1979.

Boehm, B.W. Computer systems analysis methodology: Studies in measuring, evaluating, and simulating computer systems (R-520-NASA). Santa Monica, CA: The RAND Corporation, September 1970.

Bohdanovych, V.I., Kulyk, V.T. & Uyemov, A.I. (Development and practical applications of systems analysis.) Filosofs'ka Dumka, 1973, 1, 10-16. (Arlington, VA: Joint Publications Research Service, 1973. JPRS 58935).

Bond, N.A. & Rigney, J.W. Measurement of training outcomes (Tech. Rep. 66). Los Angeles, CA: University of Southern California, Behavioral Technology Laboratories, June 1970. (AD-711 302).

Bovaird, R.L. & Zagor, H.I. A systems approach to predicting and measuring Polaris fire control system operational availability (RM 59TMP-57). Santa Barbara, CA: General Electric Company, Technical Military Planning Operation, December 1959. (AD-901 773).

Boycan, G.G. & Warnick, W.L. Training requirements for the armor crewman and reconnaissance specialist Advanced Individual Training programs (HumRRO-CR-D2-72-7). Alexandria, VA: Human Resources Research Organization, November 1972. (AD-759 569).

Breaux, R. Training characteristics of the automated adaptive Ground Controlled Approach Radar Controller Training System (GCA-CTS) (NAVTRAEQUIPCEN-TN-52). Orlando, FL: Naval Training Device Center, July 1976.

Brown, D. Statistical guide for CDEC experimental design (Rev. Preliminary Draft). BDM Scientific Support Laboratory, October 1976.

Brown, J.D. Field evaluation of M48A5 tank product improvements. Fort Knox, KY: U.S. Armor and Engineer Board, 14 January 1977. (AD-B016 139).

Buckley, E.P., Goldberg, B., Rood, R., Hamilton, H. & Champion F. Development of a performance criterion for Enroute Air Traffic Control personnel research through air traffic control simulation: Experiment I—parallel form development (FAA-RD-75-186. Interim Rep.). Atlantic City, NJ: Federal Aviation Administration, National Aviation Facilities Experimental Center, February 1976. (AD-A023 411).

Burgin, G.H. & Fogel, L.J. Air-to-air combat tactics synthesis and analysis program based on an adaptive maneuvering logic. Journal of Cybernetics, 1972, 2(4), 60-68.

Burington, R.S. Concerning the reliability and effectiveness of weapon systems and their measurement (R-14-6). Washington, DC: Bureau of Naval Weapons, Office of Chief Mathematician, April 1961.

Campbell, S.C., Feddern, J. & Graham, G. A-6E Systems Approach to Training: Phase I (NAVTRAEQUIPCEN-75-C-0099-1). Bethpage, NY: Grumman Aerospace Corporation, February 1977. (AD-A037 468).

Cheikin, G. STINGER human factors engineering final report (Tech. Memo. 25-76). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory, July 1976. (AD-B014 866).

Chaney, F.B. & Thresh, J.L. Diagnosis and correction of quality problems: A human factors approach. Paper presented at the ASQC Seminar on Product Quality Audit, Milwaukee, WI, April 19-20, 1968. (AD-855 919).

Chapanis, A. Relevance of physiological and psychological criteria to man-machine systems: The present state of the art. Ergonomics, 1970, 13, 337-346. (AD-751 344).

Chasteen, C.L. IOT&E of an AWADS radar imagery recorder (MAC Project 74C-110U). Eglin AFB, FL: Military Airlift Command, Operating Location F, May 1975. (AD-B003 562).

Chop, A. Capability measures for system effectiveness (RADC-TR-72-26, Final Tech. Rep.). Sunnyvale, CA: Lockheed Missiles and Space Company, February 1972. (AD-892 863).

Churchman, C.W. Systems analysis and organization theory: A critique (Internal Working Paper No. 3). Berkeley, CA: University of California, Space Sciences Laboratory, June 1971.

City of Reading. Systems analysis completion report, Vol. 2: Systems analysis methodology (USAC-RPAO-005). Reading, PA: City of Reading, September 1971. (PB-208 500-2).

Clovis, E.R. & Muller, T.H. Development of procedures for evaluating unit performance (TRA-75/009, Final Rep., Vol. 1). Monterey, CA: Litton Mellonics Defense Sciences Laboratories, March 1975.

Coburn, R. Human engineering guide to ship system development (NELC Tech. Doc. 278). San Diego, CA: Naval Electronics Laboratory Center, October 1973. (AD-772 535).

Cogan, E.A. If it exists, it can be measured—but how? In E.A. Cogan & J.D. Lyons, Frameworks for measurement and quality control (HumRRO-PP-16-72). Papers presented at New York University First National Annual Training in Business and Industry Conference, New York City, March 1972. (AD-748 081).

Companion, M.A. & Corso, M. Task taxonomy: Two ignored issues. In A.S. Neal & R.F. Palasek (Eds.), Proceedings of the Human Factors Society 21st Annual Meeting, San Francisco, October 17-20, 1977.

Companion, M. & Teichner, W.H. Application of task theory to task analysis: Evaluation of validity and reliability using simple tasks (AFOSR-TR-77-1008). Las Cruces, NM: New Mexico State University, Human Performance Laboratory, January 1977. (AD-043 243).

Connelly, E.M., Bourne, F.J., Loental, D.G. & Knoop, P.A. Computer-aided techniques for providing operator performance measures (AFHRL-TR-74-87). McLean, VA: Quest Research Corporation, December 1974. (AD-A014 330).

Connelly, E.M., Bourne, F.J., Loental, D.G., Migliaccio, J.S., Burchick, D.A. & Knoop, P.A. Candidate T-37 pilot performance measures for five contact maneuvers (AFHRL-TR-74-88). McLean, VA: Quest Research Corporation, December 1974. (AD-014 331).

Connelly, E.M., Schuler, A.R. & Knoop, P.A. Study of adaptive mathematical models for deriving automated pilot performance measurement techniques (AFHRL-TR-69-7), Vol. 1: Model Development). Falls Church, VA: Melpar, October 1969. (AD-704 597).

Connelly, E.M. & Sloan, N.A. Manned system design using operator measures and criteria. In A.S. Neal & R.F. Palasek (Eds.), Proceedings of the Human Factors Society 21stAnnual Meeting. San Francisco, October 17-20, 1977.

Connelly, E.M., Zeskind, R.M. & Chubb, G.P. Development of a Continuous Performance Measure for manual control (AMRL-TR-76-24). Vienna, VA: Omnemii, Inc., April 1977. (AD-A041 676).

Connelly, M.N. & Willis, J.E. The development of a Human Effectiveness Function Allocation Methodology (HEFAM) (Research Memo. SRM 70-11). San Diego, CA: Navy Personnel and Training Research Laboratory, October 1969. (AD-699 173).

Cunningham, J.B. A systems-resource approach for evaluating organizational effectiveness. Human Relations, 1978, 31(7), 631-656.

Cunningham, R.P., Sheldon, M.S. & Zagorski, H.J. Project NORM: Pilot study report (TM-2232/000/00). Santa Monica, CA: System Development Corporation, February 1965. (AD-458 341).

Defense Science Board. Report of task force on test and evaluation. Washington, DC: Office of the Director of Defense Research and Engineering, April 1974.

Dieterly, D.L. The evaluation of training with specific emphasis on criteria (AU-AFIT-SL-9-73). Wright-Patterson AFB, OH: Air Force Institute of Technology, School of Systems and Logistics, October 1973. (AD-771 009).

DiGialleonardo, F.R. & Barefoot, D.B. An approach for measuring benefit and cost in management and information systems (TR 75-21). San Diego, CA: Navy Personnel Research and Development Center, October 1974. (AD-A014 209).

DiGialleonardo, F.R., Barefoot, D.G. & Blanco, T.A. Technique for Interactive Systems Analysis (TISA) (NPRDC-TR-75-22). San Diego, CA: Navy Personnel Research and Development Center, 1974. (AD-A013 223).

Duning, K.E. Hickok, C.W., Emerson, K.C. & Clement, W.F. Control-display testing requirements study (AFFDL-TR-72-122). Cedar Rapids, IA: Collins Radio Company, December 1972. (AD-759 539).

Dunlap, J.W. & Affinito, F.J. Development of methodology for measuring effects of personal clothing and equipment on combat effectiveness of individual soldiers (Final Rep. of Phase 3). Darien, CT: Dunlap and Associates, Inc., December 1967. (AD-836 904).

Dunlap and Associates, Inc. Performance measures for human factors engineering of EARL equipment (SSD-332-618). Darien, CT: Dunlap and Associates, Inc., June 1966. (AD-653 627).

Egbert, J.J. & Rau, J.G. Techniques for bounding and estimating measures of effectiveness. Newport Beach, CA: Ultrasystems, Inc., July 1973. (AD-772 550).

Ellis, R.H. Task Analysis Reduction Technique (TART) for the quantification of human performance (Research Memo. SRM 71-7). San Diego, CA: Naval Personnel and Training Research Laboratory, September 1970. (AD-711 807).

Engel, J.D. An approach to standardizing human performance assessment (Professional Paper 26-70). Presentation at the Planning Conference of Standardization of Tasks and Measures for Human Factors Research. Texas Technological University, Lubbock TX: March 1970. (AD-717 258).

Eppler, W.G. Analytical design of manned control systems (SUDAAR No. 280). Stanford, CA: Stanford University, Center for Systems Research, May 1966.

Erickson, R.A. Field evaluation of a visual detection model. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Farina, A.J. & Wheaton, G.R. Development of a taxonomy of human performance: The task characteristics approach to performance prediction (Tech. Rep. 7). Pittsburgh, PA: American Institutes for Research, February 1971. (AD-736 191).

Featherstone, C.L. & Scaglione, R.J. A feasibility study for determining a small arms measure of effectiveness for handling characteristics (Master's Thesis). Monterey, CA: Naval Postgraduate School, September 1975. (AD-B008 586L).

Fineberg, M.L., Meister, D. & Farrell, J.P. An assessment of the navigation performance of Army aviation under Nap-of-the-Earth conditions (Research Rep. 1195). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD-A060 563).

Finley, D.L. & Muckler, F.A. Human factors research and the development of a manned systems applications science: The system sampling problem and a solution. Northridge, CA: Manned Systems Sciences, Inc., July 1976. (AD-029 417).

Finley, D.L., Muckler, F.A., Gainer, C.A. & Obermayer, R.W. An analysis and evaluation methodology for command and control: Final technical report. Northridge, CA: Manned Systems Sciences, Inc., November 1975. (AD-A023 871).

Finley, D.L., Obermayer, R.W., Bertone, C.M., Meister, D. & Muckler, F.A. Human performance prediction in man-machine systems—Volume 1—A technical review (N70-21907; NASA CR-1614). Canoga Park, CA: The Bunker-Ramo Corporation, August 1970.

Fischl, M.A., Siegel. A.I. & Wolf, J.J. Application of a multiple task interactive model: Simulation of human performance in sonar maintenance. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Foley, J.P., Jr. Criterion referenced measures of technical proficiency in maintenance activities (Final Rep.). Wright-Patterson AFB, OH: Air Force Human Resources Laboratory, Advanced Systems Division, October 1975. (AD-A016 420).

Foley, J.P., Jr. Performance measurement of maintenance. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, 1977. (AD-A053 475).

Ford, J.P., Harris, J.H. & Rondiac, P.F. Performance measures for AIT armor crewman (HumRRO-CR-D2-74-2). Alexandria, VA: Human Resources Research Organization, April 1974. (AD-A019 375).

Geddie, J.C. Profiling the characteristics of the developmental test participant (Tech. Memo. 31-76). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory, October 1976. (AD-A031 563).

Geer, C.W. Navy manager's guide for the test and evaluation sections of MIL-H-46855 (D194-10006-2). Seattle, WA: Boeing Aerospace Company, Logistics Support and Services, June 30, 1977. (AD-A045 098).

Geer, C.W. User's guide for the test and evaluation sections of MIL-H-46855 (D194-10006-1). Seattle, WA: Boeing Aerospace Company, Logistics Support and Services, June 30, 1977. (AD-A045 097).

George, C.E. & Dudek, R.A. Performance, recovery and man-machine effectiveness: Final report on a basic research program under project THEMIS (Tech. Memo. 9-74). Lubbock, TX: Texas Technical University, April 1974. (AD-777 797).

Gephart, L.S. & Balachandran, V. A stochastic system effectiveness simulation model (Tech. Rep. UDRI-TR-70-12). Dayton, OH: University of Dayton-Research Institute, June 1969. (AD-865 449).

Gex, R.C. Personnel subsystem testing and evaluation for missiles and space systems: An annotated bibliography (SB-61-21). Sunnyvale, CA: Lockheed Aircraft Corporation, Missiles and Space Division, April 1961.

Goldbeck, R.A., Wright, K.A. & Fowler, R.L. Operator performance and panel layout for discontinuous tasks (AMRL-TR-70-137). Palo Alto, CA: Philco-Ford Corporation, WLD Division - Human Engineering Section, March 1971. (AD-727 791).

Greening, C.P. Unfinished business in the utility of visual detection models. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Grunzke, P. M. Evaluation of the automated adaptive flight training system's air-to-air intercept performance measurement (AFHRL-TR-78-23). Williams AFB, AZ: Flying Training Division, July 1978. (AD-A060 320).

Gustafson, H.W. The measurement of proficiency of Air Force maintenance personnel (ATPTRC SM 7-1957). Denver, CO: Air Force Personnel and Training Research Center, Air Research and Development Command, Lowry AFB, 29 July 1967. (AD-841 711).

Haight, F.A. Indirect methods for measuring exposure factors as related to the incidence of motor vehicle traffic accidents (DOT-HS-800-601). State College, PA: Pennsylvania State University, September 1971. (PB-205 031).

Hakanson, N.H. An adaptive method of test selection in system development (RM-5238-PR). Santa Monica, CA: The RAND Corporation, April 1967. (AD-653-942).

Hall, D.H. Confidence limits for measures of effectiveness in weapon system analysis (NWC TP 5437). China Lake, CA: Naval Weapons Center, May 1973. (AD-762 401).

Hammell, T.J., Gasteyer, C.E. & Pesch, A.J. Advanced officer tactics training device needs and performance measurement technique (NAVTRAEQUIPCEN 72-C-0053-1, Vol. 1). Groton, CT: General Dynamics/Electric Boat Division, November 1973. (AD-922 929L).

Hanifan, D.T. & Knowles, W.B. Human performance in system effectiveness modeling: Issues, approaches and critique. LaJolla, CA: Dunlap and Associates, Inc., December 1968.

Hansen, D.N., Johnson, B.F., Fagan, R.L., Tam P. & Dick, W. Computer-based adaptive testing models for the Air Force technical training environment Phase 1: Development of a computerized measurement system for Air Force technical training (AFHRL-TR-74-48). Tallahassee, FL: Florida State University, July 1974. (AD-785 142).

Hansen, D.N., Ross, S. & Harris, D.A. Flexilevel adaptive testing paradigm: Validation in technical training (AFHRL-TR-77-35-1). Memphis, TN: Memphis State University, July 1977.

Harrison, W.L. A theoretical basis for the concept of effectiveness (Master's Thesis). Monterey, CA: Naval Post Graduate School, October 1966. (AD-807-386).

Harry, H.P. RANN utilization experience. Case study number 10. Effectiveness measurement methods (NSF-RA-G-75-038). Washington, DC: Urban Institute, 1975. (PB-247 254).

Helm, W.R. Human engineering design deficiencies: A comparative analysis of the P-3 and S-3 aircraft (NATC-SY-41R-76). Patuxent River, MD: Naval Air Test Center, March 1976. (AD-B010 940).

Helm, W.R. Human factors test and evaluation, Functional Description Inventory as a test and evaluation tool, development and initial validation study (NATC-SY-77R-75, Vol. 1). Patuxent River, MD: Naval Air Test Center, September 1975. (AD-B007 463L).

Henderson, R.L. & Burg, A. The role of vision and audition in truck and bus driving (Final Rep.). Santa Monica, CA: System Development Corporation, December 1973. (PB-230 776).

Hicks, J.A. A methodology for conducting human factors evaluations of vehicles in operational field tests (Draft). Fort Hood, TX: U.S. Army Research Institute for the Behavioral and Social Sciences, Fort Hood Field Unit, June 1977.

Highsmith, R.C. Proposed measure of effectiveness for human resource availability periods and their impact upon unit operational readiness. Monterey, CA: Naval Post Graduate School, December 1976. (AD-A036 028).

Hill, J.W. & Eddowes, E.E. Further development of automated GAT-1 performance measures (AFHRL-TR-73-72). Menlo Park, CA: Stanford Research Institute, May 1974. (AD-783 240).

Holshouser, E.L. Guide to human factors engineering General Purpose Test Planning GPTP) (TP-77-14). Point Mugu, CA: Pacific Missile Test Center, June 1977. (AD-B022 013L).

House, E.R. Assumptions underlying evaluation models. Educational Researcher, 1978, 7(3), 4-12.

Hyatt, C.J. & DeBerg, O.H. A scoring system for the quantitative evaluation of pilot performance during Microwave Landing System (MLS) approaches ASD-TR-17). Wright-Patterson AFB, OH: Aeronautical Systems Division (AFSC), August 1975. (AD-A025 782).

Hunter, B. Report on the final acceptance test for CTS (Computerized Training System). Alexandria, VA: Human Resources Research Organization, August 1976. (AD-A033 400).

Hutchins, C.W. A Computer Aided Function Allocation and Evaluation System (CAFES). Proceedings of the Human Factors Society Annual Meeting, Huntsville, AL: October 15-17, 1974.

Irish, P.A., Grunzke, P.M., Gray, T.H. & Waters, B.K. The effects of system and environmental factors upon experienced pilot performance in the Advanced Simulator for Pilot Training (AFHRL-TR-77-13). Williams AFB. AZ: Air Force Human Resources Laboratory, Flying Training Division, April 1977.

Jahns, D.W. A concept of operator workload in manual vehicle operations. Meckenheim, BRD: Forschungsinstitut für Anthropotechnik, December 1973.

Jahns, D.W. & Katz, R. Preliminary concepts for Computer Aided Function Allocation Evaluation System (CAFES) (NADC-72106-CS). Seattle, WA: The Boeing Company, Aerospace Group, May 1972. (AD-902 670L).

James, L.R. Criterion models and construct validity for criteria (72-32). San Diego, CA: Navy Medical Neuropsychiatric Research Unit, August 1972. (AD-770 412).

Jaschen, D.G. Mechanized Infantry Combat Vehicle, XM723, system operational climatic test (TDP-OT-67A). Falls Church, VA: U.S. Army Operational Test and Evaluation Agency, Test Design Division, 1975. (AD-B008 212L).

Johnson, E.M. & Baker, J.D. Field testing: The delicate compromise. Human Factors, 1974, 16(3), 203-214.

Kagerer, R.L. & Weiss, E.C. Development of a checklist and guidebook for human factors evaluation of general equipment (Final Rep.). Alexandria, VA: The Matrix Corporation, January 1968. (AD-827 808).

Kaplan, J.D., Crooks, W.H., Boylan, R.J. & Sanders, M.S. Human Resources Test and Evaluation System (HRTES) (PDR-1057-78-111). Woodland Hills, CA: Perceptronics, November 1978.

Karush, A.D. Benchmark analysis of time-sharing systems (SP-3347). Santa Monica, CA: System Development Corporation, June 1969. (AD-689 781).

Karush, A.D. Two approaches for measuring the performance of time-sharing systems (SP-3364). Santa Monica, CA: System Development Corporation, May 1969. (AD-691 366).

Kelley, C.R. Human operator models for manual control. In G.W. Levy (Ed.). Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Kerner, H. and Beyerle, W. A PMS level language for performance evaluation modelling (V-PMS). Vienna: Institut fuer Digitale Anlagen Technical University.

Kiraly, R.J., Babinsky, A.D. & Powell, J.D. Aircrew oxygen system development: Man-in-the-loop test report (NASA CR-73395). Cleveland, OH: TRW, Inc., July 1970.

Klein, R. Integrated operational test and analysis procedures for small arms weapon systems evaluation. Manuscript in preparation (undated).

Klein, R.D. & Thomas, C.B. The development of combat related measures for small arms evaluation. Fort Benning, GA: U.S. Army Infantry Board, June 1969. (AD-713 552).

Kleinman, D.L. & Baron, S. Manned vehicle systems analysis by means of modern control theory (NASA CR-1753). Cambridge, MA: Bolt, Beranek and Newman, Inc., June 1971.

Knoop, P.A. Survey of human operator modeling techniques for measurement applications (AFHRL-TR-78-35). Wright-Patterson AFB, OH: Air Force Human Resources Laboratory, Advanced Systems Division, July 1978.

Knowles, W.B., Burger, W.J., Mitchell, M.B., Hanifan, D.T. & Wulfeck, J.W. Models, measures, and judgments in system design. Human Factors, 1969, 11, 577-590.

Kreifeldt, J. Analysis of predictor model. Unpublished Preliminary Data, Massachusetts Institute of Technology, 1964.

Kurke, M.I. Operational concept analysis and sources of field data. Human Factors, 1965, 1, 537-544. (AD-474 358).

Kvalseth, T.O. A decision-theoretic model of the sampling behavior of the human process monitor. IEEE Transactions on Systems, Man, and Cybernetics, November 1977, SMC-7(11).

Labor/Management Task Force on Rail Transportation. Terminal performance measurement systems (DOT-FR-4-3003). Washington, DC, May 1975. (PB-252 225).

Larson, O.A., Sander, S.I. & Steinemann, J.H. Survey of unit performance effectiveness measures (TR74-11). San Diego, CA: Navy Personnel Research and Development Center, January 1974. (AD-774 919).

Lawrence, D.H. The evaluation of training and transfer programs in terms of efficiency measures. The Journal of Psychology, 1954, 36, 367-382. (AD-87 172).

Levy, G.W. Criteria for selection and application of models. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697-939).

Lindsey, M.B. A human performance investigation in a NAVORD weapon system—Part 2 (Rep. 27-349). Annapolis, MD: Naval Ship Research and Development Center, Propulsion and Auxiliary Systems Department, March 1974. (AD-918 202L).

LTV Aerospace Corporation. Shuttle active thermal control system. Vol. 3: Modular radiator system test data correlation with thermal model (Rep. No. T169-28, NASA CR-M0269). Dallas, TX: LTV Aerospace Corporation, Vought Systems Division, December 1973.

Lyons, J.D. Measuring effectiveness: Quality control of training. In E.A Cogan &. J.D. Lyons, Frameworks for measurement and quality control. (HumRRO-PP-16-72). Papers presented at New York University First National Annual Training in Business and Industry Conference, New York City, March 1972. (AD-748 081).

Markel, G.A. Toward a general methodology for systems evaluation (352-R-13). State College, PA: HRB-Singer, Inc., July 1965. (AD-619 373).

Mason, A.K. & Rigney, J.W. Toward a general characterization of electronic troubleshooting. In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Matheny, W.G., Patterson, G.W. & Evans, G.I. Human factors in field testing (LS-FR-71-1). Hurst, TX: Life Sciences, Inc., December 1971. (AD-741 216).

Matthews, E.P. A visual target acquisition model. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

McCalpin, J.P. Development of a methodology for obtaining human performance reliability data for a machine gun system (Tech. Memo. 6-74). Baltimore, MD: AAI Corporation, February 1974. (AD-777 020).

McDonnell Douglas Astronautics Company, Eastern Division. Optimized cost/performance design methodology, Vol. 3--Concept analysis and model development, Book 1--Concept analysis (MDC-E0005). September 1969.

McDonnell Douglas Astronautics Company, Eastern Division. Optimized cost/performance design methodology, Vol. 3--Concept analysis and model development, Book 2--Model Formulation (MDC-E0005). September 1969.

McGrath, J.E., Nordlie, P.G. & Vaughan, W.S. A systematic framework for comparison of system research methods (HRS-TN-59/7-SM). Arlington, VA: Human Sciences Research, Inc., November 1959. (AD-229 923).

McKendry, J.M. & Harrison, P.C. Assessing human factors requirements in the test and evaluation stage of systems development, Volume II (ND64-68). State College, PA: HRB-Singer, Inc., June 1964. (AD-603 304).

McRuer, D., Jex, H.R., Clement, W.F. & Graham, D. A systems analysis theory for displays in manual control (STI Tech. Rep. 163-1). Hawthorne, CA: Systems Technology, Inc., June 1968. (AD-675 983).

Meister, D.A. A pragmatic approach to the prediction of operational performance. In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Meister, D. Assumptions underlying test and evaluation strategies. San Diego, CA: Navy Personnel Research and Development Center. (Speech, undated).

Meister, D. Assumptions underlying the human reliability model. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Meister, D. A systematic approach to human factors measurement. San Diego, CA: Navy Personnel Research and Development Center, October 1978.

Meister, D. Human factors in operational system testing: A manual of procedures (NPRDC SR 78-8). San Diego, CA: Navy Personnel Research and Development Center, April 1978.

Meister, D. & Rabideau, G.F. Human factors evaluation in system development. New York: John Wiley & Sons, 1965.

Melching, W.H. A concept of the role of man in automated systems (Professional Paper 14-68). Presented at the Southwestern Psychological Association Annual Meeting, New Orleans, LA, April 1968. (AD-671 128).

Meyer, R.P., Laveson, J.I. & Pape, G.L. Development and application of a task taxonomy for tactical flying (AFHRL-TR-78-42, Vol. 1). St. Louis, MO: Design Plus, September 1978. (AD-061 387).

Meyer, R.P., Laveson, J.I & Pape, G.L. Development and application of a task taxonomy for tactical flying (AFHRL-TR-78-42, Vol. 2). St. Louis, MO: Design Plus, September 1978. (AD-061 388).

Meyer, R.P., Laveson, J.I. & Pape, G.L. Development and application of a task taxonomy for tactical flying (AFHRL-TR-78-42, Vol. 3). St. Louis, MO: Design Plus, September 1978. (AD-A061 478).

Miles, J.L. Some recent trends in human factors testing (Tech. Memo. 22-76). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory, June 1976. (AD-B012 110).

Miller, J.G. Living systems. New York: McGraw-Hill, 1978.

Miller, J.R. Assessing alternative transportation systems (RM-5865-DOT). Santa Monica, CA: The RAND Corporation, April 1969. (PB-185 167).

Mills, R.G. & Hatfield, S.A. Sequential task performance: Task module relationships, reliabilities, and times (AMRL-TR-72-56). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory, 1974. (AD-787 322).

Mitchell, M.B. & Blanchard, R.E. The allocation of System Effectiveness Requirements for man-machine effectiveness analysis. In R.E. Blanchard & D.H. Harris (Eds.). Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Mitchell, M.B., Smith, R.L. & Blanchard, R.E. Test application of TEPPS on a Navy CIC subsystem. Santa Monica, CA: Dunlap and Associates, Inc., August 1967. (AD-821 573).

Montgomery, D.C., Callahan, L.G. & Wadsworth, H.M. Application of decision/risk analysis in operational tests and evaluation. Atlanta, GA: Georgia Institute of Technology, The School of Industrial and Systems Engineering, September 1975. (AD-A024 205).

Mumford, J. & Smith J.P. The development of performance criteria for turret mechanics (HumRRO Research Memo.). Alexandria, VA: Human Resources Research Organization, July 1961. (AD-477 647).

Nelson, R.T. A research methodology for studying complex service systems (Working Paper No. 139). Los Angeles, CA: University of California, Western Management Science Institute, July 1968. (AD-673 233).

Obermayer, R.W. & Vreuls, D. Combat-ready crew performance measurement system: Phase I measurement requirements (AFHRL-TR-74-108-II). Northridge, CA: Manned Systems Sciences, Inc., December 1974. (AD-B005 518L).

Obermayer, R.W. & Vreuls, D. Combat-ready crew performance measurement system: Phase II measurement system requirement (AFHRL-TR-74-108-III). Northridge, CA: Manned Systems Sciences, Inc., December 1974. (AD-B005 519).

Obermayer, R.W. & Vreuls, D. Combat-ready crew performance measurement system: Phase IIIA crew performance measurement (AFHRL-TR-740108-IV). Northridge, CA: Manned Systems Sciences, Inc., December 1974. (AD-B005 520L).

Obermayer, R.W. Vreuls, D. & Conway, E.J. Combat-ready crew performance measurement system: Phase IIIC design studies (AFHRL-TR-74-108-VI). Northridge, CA: Manned Systems Sciences, Inc., December 1974. (AD-B005 521L).

Obermayer, R.W., Vreuls, D., Muckler, F.A. & Conway, E.J. Combat-ready crew performance measurement system: Phase IIID specifications and implementation plan (AFHRL-TR-74-108-VII). Northridge, CA: Manned Systems Sciences, Inc., December 1974. (AD-B005 522L).

O'Connor, M.F. & Buede, D.M. The application of decision analytic techniques to the test and evaluation phase of the acquisition of a major air system (TR-77-3). McLean, VA: Decisions and Designs, Inc., April 1977. (AD-A040 691).

Pew, R.W., Baron, S., Feehrer, C.E. & Miller, D.C. Critical review and analysis of performance models applicable to man-machine systems evaluation (BBN Rep. No. 3446). Cambridge, MA: Bolt Beranek and Newman, Inc., March 1977. (AD-A038 597).

Phatak, A.V. Improvement in weapon system effectiveness by application of identification methods for determining human operator performance decrements under stress conditions (AMRL-TR-73-38). Palo Alto, CA: Systems Control, Inc., December 1973. (AD-773 856).

Phatak, A., Weinert, H. & Segall, I. Identification of the optimal control model for the human operator (AMRL-TR-74-79). Palo Alto, CA: Systems Control, Inc., May 1975. (AD-A009 956).

Philco-Ford Corporation. Human engineering design check list (WDL-TR 1968A). Palo Alto, CA: Philco-Ford Corporation, May 1964. (AD-829 426).

Polak, W.T., Robertson, J.C. & Yuan, L.S. Systems Effectiveness Analyzer (AMRL-TR-73-113). Sudbury, MA: Raytheon Company, Simulation and Surveillance Systems, February 1974. (AD-781 124).

Popham, W.J. & Husek, T.R. Implications of criterion-reference measurement. Journal of Educational Measurement, 1969, 6(1), 1-9.

Potempa, K.W. A catalog of human-factors techniques for testing new systems (AFHRL-TR-68-15). Wright-Patterson AFB, OH: Air Force Human Resources Laboratory, February 1969. (AD-854 482).

Pritsker, A.A., Wortman, D.B., Seum, C.S., Chubb, G.P. & Seifert, D.J. SAINT: Vol. 1. Systems Analysis of Integrated Network of Tasks (AMRL-TR-73-126). West Lafayette, IN: Purdue University, School of Industrial Engineering, April 1974. (AD-A014 843).

Quinn, J.L. Research and development appraisal and evaluation (SLTR5-70). Wright-Patterson AFB, OH: Air University, School of Systems and Logistics, November 1970. (AD-876 006).

Ramsay, J.O. Some statistical considerations in multidimensional scaling (RB-66-26). Princeton, NJ: Educational Testing Service, June 1966. (AD-489 591).

Rankin, G.L. An application of fault free analysis to operational testing (Master's Thesis). Georgia Institute of Technology, 1975.

Rankine, R.R. The effects of aircraft dynamics and pilot performance on tactical weapon delivery accuracy (UCLA-ENG-7085). Los Angeles, CA: University of California, School of Engineering and Applied Science, November 1970. (AD-728 324).

Rasch, W.H., Jr. Guidelines for making tradeoffs: The special role of Technial Performance Measurement. Fort Belvoir, VA: Defense Systems Management College, 1973. (AD-A045 256).

Rau, J.G. Measures of effectivess handbook. Irvine, CA: Ultrasystems, Inc. August 1974. (AD-A021 461).

Ray, E.G., Hiltz, H.A. & Spurway, D.T. Test design plan for Defense Satellite Communications System III (DSCS III) Initial Operational Test and Evaluation (IOT&E). U.S. Army Operational Test and Evaluation Agency, Test Design Division, 1979. (AD-B041 308L).

Repperger, D.W., Smiles, K.A., Neff, J.A. & Summers, W.C. A feature selection approach in evaluation of parameter changes on the human operator under thermal stress. Ergonomics, 1978, 21(1), 35-48.

Rhoads, D.W. Inflight evaluation of four cockpit controller configurations in a variable stability airplane (AFFDL-TR-70-95). Buffalo, NY: Cornell Aeronautical Laboratory, Inc., September 1970. (AD-876 589).

Rigby, L.V. The Sandia Human Error Rate Bank (SHERB). In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Rouse, W.B. Estimation and control theory. Application to modeling human behavior. Human Factors, 1977, 19(4), 315-329.

Sauer, D.W., Campbell, W.B., Potter, N.R. & Askren, W.B. Human resource factors and performance relationships in nuclear missile handling tasks. (AFHRL-TR-76-85, AFWL-TR-76-301). Dayton, OH: Systems Research Laboratories, Inc., 1977. (AD-A042 604).

Schaeffer, K.H., Fink, J.B., Rappaport, M., Wainstein, L. & Erickson, C.J. The knowledgeable analyst: An approach to structuring man-machine systems (SRI No. IMU-3546). Menlo Park, CA: Stanford Research Institute, February 1963. (AD-297 432).

Self, H.C. Performance measures, observer selection, and reconnaissance/strike effectiveness (AMRL-TR-72-86). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory, November 1972. (AD-770 647).

Shapero, A. & Bates, C., Jr. A method for performing human engineering analysis of weapon systems (WADC Tech. Rep. 59-784). Wright-Patterson AFB, OH: Wright Air Development Center, Aerospace Medical Laboratory, September 1959. (AD-255 920).

Sheldon, M.S. & Zagorski, H.J. Man-machine system evaluation—The Normative Operations Reporting Method. In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of Cali nia at Los Angeles, June 15, 1967. (AD-735 718).

Siegel, A.I. Human performance reliability—Its measurement and impact on system reliability. ASME Publication, 78-DE-17, New York: The American Society of Mechanical Engineers, 1978.

Siegel, A.I & Federman, P.J. Development of performance evaluative measures: Investigation into and application of a fleet post-training performance evaluation system (Rep. No. 7071-2). Wayne, PA: Applied Psychological Services, Inc., September 1970. (AD-713 192).

Siegel, A.I., Pfeiffer, M.G. & Worms, T.M. Development and evaluation of a content analytic approach in Army field system data organization (ARI Tech. Rep. TR-77-A11). Wayne, PA: Applied Psychological Services, Inc., August 1977. (AD-A042 075).

Siegel, A.I., Platzer, H.L. & Lanterman, R.S. Techniques for evaluating operator loading in man-machine systems. Wayne, PA: Applied Psychological Services, Inc., March 1967. (AD-810 787).

Siegel, A.I., Schultz, D.G. & Federman, P. Post-training performance criterion development and application: A matrix method for the evaluation of training. Wayne, PA: Applied Psychological Services, Inc., January 1961. (AD-251 082).

Siegel, A.I. & Wolf, J.J. Computer simulation: Savior, sanctuary or silliness? In G.W. Levy (Ed.). Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Siegel, A.I., Wolf, J.J. & Lanterman, M.R. A model for predicting integrated man-machine system reliability: Model logic and description. Wayne, PA: Applied Psychological Services, Inc., November 1974. (AD-A009 814).

Simon, C.W. Advanced methodologies study program (Final Rep.). Culver City, CA: Hughes Aircraft Company, June 1975. (AD-A021 099).

Simon, D.E. et al. Standard procedures for Air Force Operational Test and Evaluation (RADC-TR-74-270), Final Rep. Vol. 1). Albuquerque, NM: Braddock, Dunn & McDonald, Inc., October 1974. (AD-B000 365).

Sjogren, D.D. Measurement techniques in evaluation. Review of Educational Research, (undated), 40(2), 301-320.

Smith, R.L., Westland, R.A. & Blanchard, R.E. Technique for Establishing Personnel Performance Standards—TEPPS (PTB-70-5, Vol. 1). Santa Monica, CA: Integrated Sciences Corporation, December 1969. (AD-704 103).

Smith, R.L., Westland, R.A. & Blanchard, R.E. Technique for Establishing Personnel Performance Standards—TEPPS (PTB-70-5, Vol. 2). Santa Monica, CA. Integrated Sciences Corporation, December 1969. (AD-704 104).

Smode, A.E., Gruber, A. & Ely, J.H. The measurement of advanced flight vehicle crew proficiency in synthetic ground environments (Tech. Rep. MRL-TDR-62-2). Darien, CT: Dunlap and Associates, Inc., February 1962.

Spencer, G. Man-machine simulation—the PIMO application. In R.E. Blanchard & D.H. Harris (Eds.), Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Spyker, D.A., Stackhouse, S.P., Khalafalla, A.S. & McLane, R.C. Development of techniques for measuring pilot workload (NASA CR-1888). Roseville, MN: Honeywell, Inc., November 1971.

Swink, J.R., Butler, E.A., Lankford, H.E., Miller, R.M., Watkins, H. & Waag, W.L. Definition of requirements for a performance measurement system for C-5 aircrew members (AFHRL-TR-78-54). San Diego, CA: Logicon, Inc., October 1978.

Taylor, E.N. & Tillman, B. Human factors engineering study of two ball port designs for IFV. Unpublished manuscript, October 1977.

The Bunker-Ramo Corporation. Proposal for a study of human factors field permance measurement methodology (Proposal No. 5655-022-5U1). Canoga Park, CA: The Bunker-Ramo Corporation, Defense Systems Division, June 1965.

Tien, J.M. Toward a systematic approach to program evaluation design. IEEE Transactions on Systems, Man, and Cybernetics, September 1979, SMC-9(9), 494-515.

Timson, S.F. Measurement of technical performance in weapon system development programs: A subjective probability approach (RM-5207-ARPA). Santa Monica, CA: The RAND Corporation, December 1968. (AD-681 771).

Topmiller, D.A. Mathematical models of human performance in man-machine systems (AMRL-TR-68-22). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratories, May 1968. (AD-673 348).

Topmiller, D.A. The role of applied man-machine models. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Tranby, E.D. Advanced surface ship weapon systems test and evaluation (NSWSES-TP-60). Port Hueneme, CA: Naval Ship Weapon Systems Engineering Station, January 1976. (AD-390 826).

Turner, C.R. & Bard, J.F. Tactical AWACS measures of effectiveness (ESD-TR-72-142). Bedford, MA: The MITRE Corporation, April 1972. (AD-742 233).

Uhlaner, J.E. Human performance, jobs, and systems psychology—the systems measurement bed (Tech. Rep. S-2). Arlington, VA: Behavior and Systems Research Laboratory, October 1970. (AD-716 346).

Uhlaner, J.E. & Drucker, A.J. Military research on performance criteria: A change of emphasis. Human Factors, 1980, 22(2), 131-139.

Ultrasystems, Inc. A study of measures of effectiveness used in naval analysis studies (Vol. 1 Summary). Newport Beach, CA: Ultrasystems, Inc., October 1972. (AD-912 443).

Ultrasystems, Inc. A study of measures of effectiveness used in naval analysis studies (Vol. 2 Study Review Summaries, Part 1). Newport Beach, CA: Ultrasystems, Inc., October 1972. (AD-912 444).

Ultrasystems, Inc., A study of measures of effectiveness used in naval analysis studies (Vol. 3 Study Review Summaries, Part 2). Newport Beach, CA: Ultrasystems, Inc., October 1972. (AD-912 445).

Ultrasystems, Inc. A study of measures of effectiveness used in naval analysis studies (Vol. 4 MOE Reviews). Newport Beach, CA: Ultrasystems, Inc., October 1972. (AD-912 446).

U.S. Army Armor School. Tank platoon: Organization for combat and techniques of movement (TC 17-15-3). Fort Knox, KY: U. S. Army Armor School, April 1975. (Pamphlet).

U.S. Army, Army Materiel Command. Engineering design handbook: Recoilless rifle weapon systems. Alexandria, VA, 15 January 1976. (AD-A023 513).

U.S. Army Combat Developments Command. Communications-electronics-75 (CE-75) phase 1-field Army (No. 6492, Vol. 9). Fort Monmouth, NJ: U.S. Army Combat Developments Command, Communications-Electronics Agency, September 1968. (AD-883 611).

U.S. Army Human Engineering Laboratories. Standardization of tasks and measures for human factors research. Proceedings of a Conference at Texas Tech University, Lubbock, TX, 18-19 March 1970. (AD-714 669).

U.S. Army Infantry Board. Infantry weapons test methodology study. Vol. 1: Small arms test methodology (USAIB-3319-F-Vol. 1). Fort Benning, GA: U.S. Army Infantry Board, November 1971. (AD-890 998L).

U.S. Army, Materiel Testing Directorate. U.S. Army test and evaluation command development test II (EP)—System test operations procedure "Test, Measurement, and Diagnostic Equipment (system peculiar)." Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory, 7 May 1974. (AD-781 946).

U.S. Army Operational Test and Evaluation Agency. Mechanized Infantry Combat Vehicle (MICV), XM723, operational climatic test/force, development test and experimentation (Draft). Falls Church, VA: U.S. Army Operational Test and Evaluation Agency, March 1976.

U.S. Army Test and Evaluation Command. Materiel test procedure 3-3-521. Fort Benning, GA: U.S. Army Infantry Board, May 1970. (AD-871 788).

U.S. Army Test and Evaluation Command. Materiel test procedure 6-2-502. (Electronics Proving Ground). Fort Benning, GA: U.S. Army Infantry Board, August 1969. (AD-720 976).

U.S. Army Test and Evaluation Command. Materiel test procedure 10-2-505. (General Equipment Test Activity). Fort Benning, Ga. U.S. Army Infantry Board, September 1971. (AD-729 855).

U.S. Department of the Army. Army training and evaluation program for mechanized infantry battalion and combined arms task force (ARTEP 7-45). Washington, DC: Headquarters, Department of the Army, September 1975.

U.S. Department of the Army. Skill Qualification Test notice for MOS 11B SQT 3 infantryman (No. 7-11B3-N). Washington, DC: Headquarters, Department of the Army, June 1976. (Pamphlet).

U.S. Department of the Army. Tank gunnery (Field Manual 17-12). Washington, DC: Headquarters, Department of the Army, March 1977.

U.S. Department of the Army, Office of the Chief of Staff, Tank Forces Management Group. Tank weapon system management. Washington, D.C.

Van Acker, A. & Wohl, J.G. Modeling the sonar operator's detection process: A progress report. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

von Winterfeldt, D. An overview, integration, and evaluation of utility theory for decision analysis (SSRI Research Rep. 75-9). Los Angeles, CA: University of Southern California, Special Science Research Institute, August 1975. (AD-A021 497).

Vreuls, D., Wooldridge, A.L., Obermayer, R.W., Johnson, R.M. & Norman, D.A. Development and evaluation of trainee performance measures in an automated instrument flight maneuvers trainer (NAVTRAEQUIPCEN 74-C-0063-1). Westlake Village, CA: Canyon Research Group, Inc., October 1975. (AD-A024 517).

Waag, W.L., Eddowes, E.E., Fuller, J.H. & Fuller, R.R. ASUPT automated objective performance measurement system (AFHRL-TR-75-3). Williams AFB, AZ: Air Force Human Resources Laboratory, Flying Training Division, March 1975. (AD-A014 799).

Weapon System Effectiveness Industry Advisory Committee. Final report of task group II. Vol. 1 Prediction-measurement: Summary, conclusions and recommendations (AFSC-TR-65-2). 1965. (AD-458 454).

Weapon System Effectiveness Industry Advisory Committee. Final report of task group II. Vol. 2 Prediction-measurement: Concepts, task analysis, principles of model construction (AFSC-TR-65-2). 1965. (AD-458 455).

Weapon System Effectiveness Industry Advisory Committee. Final report of task group II. Vol. 3 Prediction-measurement: Technical supplement (AFSC-TR-65-2). 1965. (AD-458 456).

Weinstock, G.D., Douglas, M. & Blom, B. Development of criteria and measures of effectiveness for U.S. Army tactical communications sytems (Tech. Rep. ECOM-5012-1). Paramus, NJ: Communications Systems, Inc., May 1969. (AD-881 145).

Weisz, J.D. System analysis: Manpower resources/system design integration methodology (Tech. Note 9-68). Aberdeen Proving Ground, MD: Human Engineering Laboratories, August 1968. (AD-675 481).

Wellman, L.N. & Neill, W.H. The development of performance measurement standards for the USAF base level supply system (SLSR-12-72B, Master's Thesis). Wright-Patterson AFB, OH: Air Force Institute of Technology, September 1972. (AD-750 912).

Wherry, R.J. The development of sophisticated models of man-machine system performance. In G.W. Levy (Ed.), Symposium on applied model of man-machine systems performance (NR69H-591). Columbus, OH: North American Aviation, November 1968. (AD-697 939).

Williams, G.S. A methodology to establish the criticality of attributes in operational tests (Master's Thesis). Georgia Institute of Technology, 1975. (AD-A024 199).

Williams, H.L. Dependent models for estimating human performance reliability In R.E. Blanchard & D.H. Harris (Eds.). Man-machine effectiveness analysis. Papers presented at The Human Factors Symposium, University of California at Los Angeles, June 15, 1967. (AD-735 718).

Williams, R.L., Long, T.W. & Windholz, W.M. A standardized munitions effectiveness methodology (K-75-57 R). Colorado Springs, CO: Kaman Sciences Corporation, July 1975. (AD-B009 483).

Willis, J.E. Feasibility of the development and utilization of personnel performance effectiveness measures for man/machine function allocation decisions (Research Memo. SRM 68-7). San Diego, CA: U.S. Naval Personnel Research Activity, October 1967. (AD-660 003).

Wortman, D.B., Hixson, A.F. & Jorgensen, C.C. A SAINT model of the AN/TSQ-73 guided missile air defense system (Research Memo. 79). W. Lafayette, IN: Pritsker and Associates, Inc., January 1979.

Wortman, D.B., Sigal, C.E., Pritsker, A.S. & Seifert, D.J. New SAINT concepts and the SAINT II simulation program (AMRL-TR-74-119). W. Lafayette, IN: Pritsker and Associates, Inc., April 1975. (AD-A014 814).