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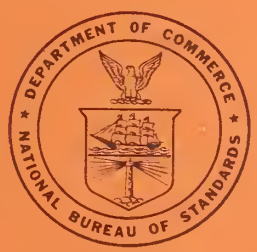
Operations Research

Proceedings of a Conference
For Washington Area Government Agencies
April 20, 1966



United States Department of Commerce
National Bureau of Standards
Miscellaneous Publication 294

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D. C., 20234.

[2] Located at Boulder, Colorado, 80302.

[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

UNITED STATES DEPARTMENT OF COMMERCE • Alexander B. Trowbridge, *Secretary*
NATIONAL BUREAU OF STANDARDS • A. V. Astin, *Director*

Operations Research

Proceedings of a Conference for Washington Area Government Agencies April 20, 1966 Held at Museum of Natural History, Smithsonian Institution, Washington, D. C.

Editor: J. A. Joseph
Technical Analysis Division
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

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Preface

On April 20, 1966, the National Bureau of Standards sponsored a one-day symposium whose purpose was to convene operations research practitioners and users in the agencies of the Federal Government so that they might exchange information on topics of mutual concern.

The following considerations underlay the planning of the conference, and our hopes for future related activities:

(1) There does not exist, but there should exist, a reference inventory of completed and on-going operations research/systems analysis/multidisciplinary research/scientific planning activities in the Federal Government, so that a technical exchange of methods, techniques, benefit measures, cost methods, etc. could be facilitated.

(a) There are methods to be applied that are not unique to one agency, e.g., tests of organizational effectiveness.

(b) There are suggestive analogies among problem types from agency to agency, e.g., a network of highways and a network of post offices.

(c) There are interaction situations, e.g., the full program benefit to one agency may be incompletely calculated due to excluding benefits arising to other Federal missions.

(2) The growth in opportunity to test the usefulness of systems analysis in new non-defense contexts underscores the importance of making sure that any initial study has the fullest possible measure of success at an early date, and this might exclude repeating exploratory work others have done. No reasurring encyclopedic memory bank exists.

(3) Each of us knows of a dozen or two other studies or groups, but the creation of new groups is making it more difficult and time-consuming to keep up to date. We need a new one-time updating.

(4) The introduction of the new Bureau of the Budget Planning, Programming, and Budgeting System (Circular 66-3) places an explicit requirement on agencies to provide systems analysis, benefit-cost studies, and supporting documentation. Some agency chiefs have asked OR groups, "Tell me what you can do to help;" the OR groups need to meet with the PPB originators on a technical basis for a fuller understanding of the substantive requirements and desires so that they can help their parent agency to respond adequately to this new system.

(5) The problem of identifying measures of effectiveness for agencies is a common one; some have made good progress in this area, and others are searching for ways to make a good start. Furthermore, many agencies have missions whose ultimate measures of effectiveness can be partly stated in common terms, e.g., stimulate the economy, improve the standard of living, etc. Aside from the recent Brookings Institution publications, Roland McKean's earlier book, the BOB bibliography of benefit-cost studies, and a few other attempts of a more nebulous nature, the best information on measures of benefit is scattered among our individual heads and in individual files.

(6) The changing semantics and connotative nuances placed on the terms, "operations research," "systems analysis," "multidisciplinary problem-solving teams," and "planning systems," are further confused by actual practice. For example, OR is frequently defined to be identical with what the statistics group does, or with the problems that are sent to the computing lab, or with the management analysis program of an agency, or with just plain horse sense. Accordingly, there does not seem to be a good common dictionary of what to include, or what to exclude from a conference such as this. Each agency has one or more groups with something significant to contribute or gain; these groups are all talking, with greater or lesser degree of specialization, to a common problem—that of providing a rational scheme for identifying and comparing alternatives in terms of their expected payoff and resource requirements. Similar differences exist in the dimension that starts with pure methods research and ends somewhere with "the back of the envelope calculation" or "the horseback guess." We thought it better to invite all these audiences in the first round, and let the agency decide whether the conference was relevant enough to participate.

(7) With non-defense OR getting a stronger impetus, there is an obvious need to profit from the lessons learned in the Defense business. There is also the need to make sure that when defense readiness is a relevant measure of effectiveness of civilian programs, it is included; the reverse is also true. Furthermore, because of the scarcity of professional personnel at the present time, it is important that the growth of non-Defense OR not compromise Defense requirements.

(8) Procedural and institutional problems related to starting and effectively using OR groups probably have a large degree of similarity from agency to agency. The lone systems analyst who has been instructed to prepare a plan to start a viable activity in the agency should have access to plans that have a good chance of succeeding.

(9) There are agency officials who would like to get OR started, and would like some impartial advice, but who aren't quite sure how to get it. Furthermore, they would like to see at first hand what the nature of the projects suitable for such a group might be.

(10) The agency OR groups need to have an inventory of external resources available to help him in his problem solving: universities that want graduate thesis topics and support, professors who want a sabbatical, colleges that are willing to carry out a class project on a systems problem for an agency, etc.; contractors and their strong points and experience; expert personnel resources; data sources that could be relevant and could be used; etc. We recently compiled a list of contracting agencies with a Washington office and which advertised OR or systems analysis as a specialty, and ended up with 40 on the first trial. RFP lists should be complete and relevant, and there is no good way of being reason-

ably sure of this at present. It is not common knowledge how much or on what basis one agency can call on another (e.g., Bureau of the Budget or Bureau of the Census) for substantive help or data exchange.

(11) Currently employed methods of quality control on OR studies could be improved if experts in other agencies were known and could be asked to participate in project design or review.

(12) There is a need for an experimentation laboratory in systems analysis in addition to the specific agency opportunities. Field experimentation has always been part of a complete analysis, yet for most purposes, a truly experimental opportunity does not exist.

(13) There will soon be a need for some analytic scheme to tackle the inter-agency program balance problem, be it a system of rebuttal and debate with common reference terms, or a government management game, or an inter-agency analysis group, or some other method.

(14) There is a need for an OR textbook suitable for Government agency use.

(15) There may be a need for an explicit mechanism to rotate OR personnel among agencies, to universities and back, etc.

(16) There is a need for a census of resources including hardware, software, programs, computers, etc.

The recent rapid growth in operations research/systems analysis/multi-disciplinary problem-solving teams in the non-defense agencies of the Federal Government has opened a challenge of unusual proportions to the O.R. community.

At issue are questions concerning the development of analytic methods, test methods, data systems, and means of drawing inferences in studies whose purpose is to improve the operations of the non-defense agencies of government. Questions related to the definition, the criteria, the measures, and the means of measuring the effectiveness of non-defense programs are but the beginnings of the work ahead. There is the problem of determining the best program mix within an agency whose missions are stated in many different ways and which sometimes appear irreducible to a single common scalar purpose. There is the question of how to determine the effectiveness of a Federal program when it is designed to assist in improving individuals, communities, states, and regions, especially since the instruments of bringing about that improvement are in the hands of many sources of power in the democratic system of rebuttal and debate that characterizes the American society.

Accordingly, operations research in the non-defense agencies is confronted with the unavoidable task of discussing issues that are at the heart of our democratic society. It is important that analytical, methodological, and substantive discoveries made in one agency that are suitable for use by another agency be made a portion of the Government memory bank as easily and quickly as possible.

One of the aftermaths of the O.R. Conference was an expressed need, as articulated by many groups, for the following two kinds of activity as a minimum.

(1) The convening of small informal *ad hoc* discussion sessions by agencies of the Government to which the O.R. people from other agencies are invited.

(2) The maintenance by some agency of an up-to-date mailing list of all those government agencies O.R. groups, universities, and contractors, who should be informed of relevant items, including an up-to-date inventory of on-going O.R. projects and people finders in Government.

It appeared that each agency might want to take its own initiative in convening informal group meetings of interest to itself. The Technical Analysis Division of the National Bureau of Standards volunteered to perform the second function insofar as it was able to do so. In the course of preparing for the symposium, we had already circulated questionnaires inquiring as to O.R. activities in various agencies. The wide variations in respondents' interpretations of "operations research" precluded the replies' being sufficiently consistent to warrant inclusion in these Proceedings, but the experience gained should prove valuable to us in designing a more carefully phrased survey.

Prior to the Conference, a number of agencies mailed us summary statements about the contents of their operations research programs. These were posted at the entrance to the auditorium at the time of the meeting. These forms appear to be a good starting point for the creation of an informal and frequently updated notebook of agency O.R. work that might be circulated widely, both among the agencies and to external institutions such as consulting firms and universities which might assist in solving agency problems. Our current plan is to issue that first set of reports as a separate document, and then to undertake the administrative chore of issuing updated versions of it.

We deeply appreciate your participation in this conference and sincerely hope that this volume will serve a continuing useful purpose for you. We hope that it will be but the first of a long series.

W. E. CUSHEN, *Chief*
Technical Analysis Division

PROGRAM

Wednesday, April 20, 1966

CHAIRMAN: Dr. Walter E. Cushen
Technical Analysis Division
National Bureau of Standards

Morning

ADDRESS OF WELCOME
Dr. Allen V. Astin
Director
National Bureau of Standards

O.R. IN THE CIVILIAN SECTOR OF THE GOVERNMENT
Professor Merrill M. Flood
Visiting Prof. Mgt. (MIT), and
Professor, University of Michigan

GENERAL DISCUSSION
The Improvement of Communications Among O.R. Government Agencies in the Civilian Sector

PPB AND ITS RELATION TO SYSTEMS ANALYSIS
Dr. John Haldi
Office of the Director
Bureau of the Budget

GUIDELINES FOR THE AFTERNOON PANELS
The Chairman

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GROUP SESSION
Chairman: Mr. John Moss
Social Security Administration

OPERATIONS RESEARCH RESEARCH
Dr. Alan J. Goldman
Operations Research Section
National Bureau of Standards

REPORTS OF THE PANEL CHAIRMEN

CONCLUDING REMARKS
Dr. Walter E. Cushen

Opening Remarks Dr. Allen V. Astin

Director

National Bureau of Standards

Washington, D. C. 20234

The National Bureau of Standards has a statutory responsibility to provide scientific and technical advice and assistance to other Federal Government agencies. It is in this capacity that the National Bureau of Standards has sought to apply operations research to the solution of a variety of technical problems of the Federal Government and has served as the sponsor for this conference. In seeking to develop techniques and opportunities for the wider application of operations research in the Federal Government, we wish to pay tribute to the Department of Defense for the leadership it has taken in this area for more than two decades. Essentially we are seeking to achieve throughout the Government establishment the type of benefits whose possibility has already been demonstrated by the Defense Agencies.

The National Bureau of Standards has still another interest in the development and extension of operations research. The central concern of the NBS is in advancing and utilizing the science of physical measurement. We believe, as did Lord Kelvin, that when you can measure what you are talking about and express it in numbers your knowledge is much more useful than when you cannot measure it. In operations research we are seeking to extend the measurement process into areas where subjective judgment rather than measurement has been traditionally used. Our interest in operations research goes back many years. The Operations Research Society of America grew out of a symposium held at NBS under the auspices of our Applied Mathematics Division. Several years ago we established in that Division a section for operations research, and a year and a half ago we established a Technical Analysis Division to serve as a center for the application of operations analysis to the evaluation of problems within the Department of Commerce and in other interested Government agencies.

With this background information you will readily understand my pleasure in welcoming you to this symposium. I trust it will prove fruitful in advancing both practical and methodological aspects of the application of operations research to the many pressing and difficult problems confronting Government agencies today.

Operations Research in the Civilian Sector of the Government

Professor Merrill M. Flood
University of Michigan
Ann Arbor, Michigan 481004

It is a rare privilege for me to meet with you on this occasion, and to have an opportunity to express some of my views regarding the great opportunities for the future of operations research in the civilian sector of the government. Although I speak often, and freely, about operations research opportunities with respect to major national problems, and especially in connection with those not directly related to national defense, it is rare that I have an opportunity to discuss such matters with those of you actually responsible for the work in the federal government.

I believe, quite sincerely, that you have an unparalleled opportunity and one unique during our time for any nation in the world, to demonstrate that the approach of the scientist, the engineer, the mathematician, the economist, the behavioral scientist, and others knowledgeable about the scientific method, and adept in its use, can indeed contribute substantially in the future to the solution of some of our most important problems at the national level.

I would not wish to take the time, nor is it at all necessary with this distinguished group of operations researchers and systems analysts, to attempt one more definition of "Operations Research," or to offer one more listing of currently relevant techniques, or to give one more cataloging of the important tools used in our trade. Suffice it to say that I share with all of you the belief that our kit of techniques and tools gets better each year, and that our shared experiences in their use makes us increasingly skillful and therefore more successful as the years go by.

Nevertheless, I also feel sure that you will all agree that we have had very modest success indeed, in comparison with our expectations for the future; or as judged objectively by ourselves and others as we assess past accomplishments, both inside the federal government and elsewhere. I hasten to add that this is not in any way intended to minimize the very substantial progress already made with respect to national defense—in this case even at the highest policy levels. There has certainly also been progress outside the Federal government, but as yet primarily at lower operating levels. I am sure that we are all vastly impressed with the successes of Secretary McNamara, Mr. Hitch, Dr. Enthoven, and their colleagues, in introducing systems analysis and other management and planning methods into the Defense Department so effectively during recent years. I am sure that we all share the feeling that President Johnson has given this approach a tremendous boost by his endorsement with respect to other departments of the Federal government; I look forward to hearing more about this from Mr. Haldi, your next speaker.

You may or may not be disappointed to learn that I do not intend here to suggest openings for future effective application of OR skills, primarily because my time is too limited for this. Instead I shall concentrate upon one important national and world development that I feel is particularly significant for the immediate future, in the context of the discussions in this conference.

My remarks will concentrate upon opportunities for communication among all of you who are concerned with the application of O.R. skills, for I believe that the civilian sector of the Federal government has a special characteristic that makes this opportunity exceptionally attractive in comparison with similar work for national defense or in competitive industry. I refer to the fact that the detailed results of investigations can normally be passed freely among all workers both during the progress of the studies and when they are completed—and perhaps even more important, after there is an opportunity to gauge the degree of success, or lack of success.

You are all familiar with the considerable difficulty encountered in communicating about studies connected with defense problems. In spite of the many efforts made to bring defense operations researchers together, often under the barrier of security classification, there has been relatively little communication—at least in the sense of free and open publication and discussion of the type that has seemed to be so vital for progress in the world community of scientists. This conference is an example of the kind of interchange that is possible, and should be encouraged and promoted increasingly in the future.

However, I am stressing quite another type of communication, or of information exchange as I should perhaps call it, that I believe will be increasingly important and especially significant for O.R. work such as yours. We seem to be on the threshold, finally, of the next great

advance in our system for storing and communicating information of all kinds. I refer, of course, to all those kinds of things that we would bring into this conversation if we were talking about computerized information nets, automated libraries, electronic data centers, and so forth. And, of course, I include in this development ordinary communications as represented by publication, both in the traditional sense and, in the future, in new ways through the information transmission net. These developments may even affect the nature of our conferences and meetings in the future, if and when we can afford to interact frequently and effectively over a communications system and without need to gather together physically for such interchanges.

I shall narrow my remarks even further, to a very special aspect of this newly developing national and international information network. I refer to the storage and transmission of raw data, or summaries of data, or formal models that represent large bodies of data compactly, and all other "facts" that can be stored and made accessible quickly and efficiently through such information network facilities.

Important among these many forms of stored models are the increasingly powerful computer programs that we can all share in use while profiting from the systematic synthesis they provide, often as a result of the work of a quite small group of persons.

More specifically, I propose as well worth your careful consideration, the possibility that all operations researchers throughout the federal government can look toward the development of great information files that will be accessible for all who have a real need. This constitutes a very important new form of communication, since the information stored by one group need be made available to others only after they recognize a real need for it, and then in a form where it has been precisely described and is easily used.

Some may say that my proposal is equally applicable to many other kinds of persons and activities. Although this is true to some extent, and is certainly true very importantly in some instances, I am arguing that the analysts throughout the government are in the best position to develop these information stores so that they are indeed reliable and can indeed be used easily. Nor do I mean to limit this to relatively simple tasks such as the standardization of accounting data, or programming and budgeting data, important as these are; rather, the intent is to include as data such things as a highly perfected and validated simulation of a major agency or operation within the government. I hasten to remark for the benefit of any who may feel that I am far too optimistic about such hopes, that I would expect this to be a gradual development but will be very surprised if it is not clearly significant within ten or fifteen years from now.

Let us consider the proposal from a rather different point of view, stressing the importance of working toward a systematic understanding through modelling, of larger and larger portions of the Federal government. It is probably impractical currently to construct a valid mathematical model, or useful computer simulation, of the entire Department of State or Department of Justice, or even of major subordinate bureaus or agencies. But I would not consider it naive, or undesirable, to begin the attempt immediately.

I am reminded of the story about President Jefferson when he was impatient with his gardener about planting a tree and immediately responded, when reminded that the tree would not reach maturity for 20 or 30 years, that this made it all the more imperative to plant it that same day. It is in this spirit that I urge the importance of keeping this larger goal in mind over the coming years, as you all meet with success in analyzing and understanding larger and larger segments of Federal governmental activities.

For example, and from a purely practical standpoint, I would think it not too soon now to begin the development of models that might eventually enable us to evaluate tradeoffs between such major activities as education and justice. More specifically, it should be very instructive and helpful to make a study that attempts to evaluate the tradeoffs between another million dollars for the FBI in contrast to another million dollars for educational research, or for care of the aged, or for foreign aid, or for any one of the other major national programs that surely are all directed toward the same set of national goals. This is not at all to say that such work will be easy, or yield immediate results, but it will happen sooner and better if an early attempt is made to develop the study activities in a way that will increase the likelihood of eventual success.

How might some relative simple steps be taken now to promote progress of the kind I have proposed? Obviously there are many present activities that are substantial and already making contributions in this sense. In particular, the activity that Mr. Haldi represents, will surely yield very important ingredients indeed for just such tradeoff evaluations.

My primary suggestion is that an explicit attempt be organized and made to accelerate this advance by cooperation among all of you in the development of a computerized information network that will store such information and make it much more readily accessible throughout the Federal government for use by

operations researchers, and for others having need for such a resource.

As J.C.R. Licklider often puts it, you can create your own online intellectual community.

My own first association with an operations research type of effort within the Federal government was a little over 30 years ago when I worked with a distinguished panel of technical experts on an advisory task for Attorney General Homer Cummings. Our panel was part of a broad study under Dean Wayne Morse, now Senator Wayne Morse, that was intended to bring expert advice to the Attorney General in connection with his broad responsibility for parole and release procedures. This panel was chaired by the late Professor Samuel Stouffer, eminent sociologist, and included among others, Samuel Wilks and Frederick Stephan, both distinguished statisticians. The panel also included criminologists, economists, psychologists, mathematicians, and lawyers and was supported by a strong staff group.

We could barely discuss basic questions such as the negative social value of a released murderer, or other criminal, as compared with the social value of keeping him in custody or under parole supervision. It was my impression then, at a time when I was engaged in studies of this kind in New Jersey, that we knew essentially nothing about major social questions of this type, nor did we have the talents or the trained personnel to tackle them. From what little I know at present about this field, I suspect that we remain pretty much in that same position today, except for the fact that we certainly have new talents and much more expert personnel who could tackle such problems—perhaps with considerable success.

The newly established National Commission on Crime, and similar commissions that have been established recently in some of our states, reflect a growing public awareness of the importance of dealing with major social problems more systematically and more effectively.

My most recent operations research kind of service for the federal government was a study that I completed this past September for the National Commission on Technology, Automation and Economic Progress. My assignment was a study of the national information network development, or the "computer utility" as it is sometimes called at MIT by Professor Fano and others. My report is just now being published by the National Commission, but Dr. Cushen has asked me to comment regarding some of its conclusions — I am, of course, pleased to have this chance to do so.

Briefly, I am impressed by the great opportunity afforded our nation in terms of the rapidly developing information network, which is a good and exciting prospect indeed, but I am disappointed by the slow pace at which this will all move unless steps are taken by the Federal government and industry to anticipate and correct some of the glaring deficiencies in our communications system and in our laws and administrative practices. I suppose that none of the difficulties I foresee has already been observed and discussed somewhere within government or industry, but I concluded on the basis of my study that a great deal could be done to improve the situation.

For example, the common communications carriers, such as the American Telephone & Telegraph Company and the Western Union Telegraph Company, are moving very vigorously to develop and construct a national communications network that will permit the speedy and efficient transmission of data as well as voice messages. However, it is generally agreed by experts on communications systems, who are also knowledgeable about data transmission systems, that this must be a "store and forward" system, rather than a system which merely provides an exclusive line connecting two users for some period of use. In other words, data will originate at many individual nodes on the network, then be transmitted to intermediate nodes where it will in turn be sorted and re-routed, perhaps after temporary storage, and eventually reach "terminal" nodes, where it will often be processed and sent back through the nodes of the system, often through quite complex paths.

All of this requires new kinds of electronic switching centers, computerized to handle, store and forward activity of this type, and industry is moving ahead to provide this type of service. Unfortunately, data transmission demand will surely exceed transmission capacity in the very near future. The need is to take steps soon which will minimize this disparity between capacity and demand in future years; my report suggests a few moves that might be made toward this goal.

For example, there seems now to be no single Federal agency that is clearly and obviously charged with responsibility for insuring that this important development does take place within our nation at the proper pace.

Another example, and a lesson learned from experience with some of our major time-shared computing systems, such as one at MIT and another at the System Development Corporation, is the importance of bringing the future users into the system early to help ensure that its developing direction is a good one.

Toward these ends, the report proposes that at least one major national information network be sponsored by the Federal government in the near future and that several major systems be made available in the immediate future for use by individual citizens, as students, or housewives or merchants, and so on. The report

also stresses a number of social problems that require changes in legislation, or in regulations, or in administration, if we are not to suffer from too leisurely development of the national information network facility. The report also urges that the Federal government look very carefully at its own internal operations to ensure that this type of network capability is made available and used appropriately soon by Federal agencies.

It is in this spirit, within the Federal government, that I believe there is an unusual opportunity for analysts to cooperate in specifying the nature of such a system in order that it meet their needs later. Meanwhile, there will be many opportunities for all of you to exert your influence through usual channels as this developing information network progresses within the government, and for your agencies.

It may strike you as strange that I have devoted most of my time to a proposal that rests so heavily upon recent technological developments in information networks within the Federal government and elsewhere. I have done this partly because of my recent experiences with such activities, but primarily because I have been deeply interested in these developments for I feel that they are so centrally important for the future of scientific and analytical efforts to improve operations and management within the Federal government and elsewhere.

I close by repeating my opening remark, that the special opportunity that seems to me to be available to all of you working within the Federal government on problems primarily within the civilian sector is the relative openness of this system and the opportunity you have to communicate with each other regarding your work both while it is in progress and after it is completed. Furthermore, I see the developing information networks providing you with a truly advanced method of communications, or information transfer, since you can in the future share your experiences and your data by storing them in the information network and taking advantage of that store as you each proceed with your own work.

If the information network facility will be with us in the near future, then I predict that you will be sorely pressed to develop good methods in time for preparing your experiences for storage in that system, so that they can in fact be useful and be used by others working on similar problems. Just as President Jefferson remarked with respect to his tree, since it will take so long to finish, you should begin immediately.

The Planning-Programming-Budgeting System

Dr. John Haldi

Program Evaluation Staff
Bureau of the Budget
Washington, D. C. 20234

I welcome this opportunity to discuss the Planning-Programming-Budgeting (PPB) system with you. Historically, suggestions for Federal program budgeting date from 1912, when a Commission reporting to President Taft proposed that a "budget bureau" be established and that Government agencies present their budgets along program lines. More recently, two Hoover Commissions have recommended the improvement of Federal management through the adoption of program budgeting. Before Mr. McNamara came to the Department of Defense, many agencies already had some form of this type of budgeting. Many facets of PPB are in use in certain Government agencies.

It is probably the combination of Planning, Programming, and Budgeting into an integrated system which is most new to all Government agencies. The system, which most economists view as a straightforward application of common sense, has a few fundamental concepts. All agencies are being required to: (1) define their activities *by objective* within what is called a program structure, (2) prepare a multi-year program and financial plan, (3) translate program decisions into the conventional appropriation format, and (4) provide for periodic reappraisals of their major programs and objectives.

The first step in the installation of a PPB system is definition of outputs and drawing up program structures or outlines grounded on those outputs. For the last several months all major agencies have been developing program structures focused on what the agency produces, whether for the benefit of the public or of other Government agencies. The program structures include categories, subcategories, and program elements. Program elements are the smallest units in the program structure of an agency.

The major purpose of the program structure is to serve as a tool for top management review. We hope that it will lead managers to ask the "right questions"—as President Johnson has said, to reexamine the programs to see if we are really doing the right thing, or to see whether we are actually funding obsolete programs. The primary focus of this exercise is to make sure that we are selecting the right alternative among plausible policies, and directing resources to their best use. A program structure, intended primarily for consideration by the Secretary, the Director of the Budget Bureau, and the President, must be aggregated into a few meaningful program categories. Here are illustrations of program categories.

Example 1: A program category in the Department of Defense is "Strategic Retaliatory Forces." This program consumes billions of dollars. Subcategories within it are "Offensive Forces" and "Defensive Forces," and Offensive Forces are broken down into sub-subcategories, such as "Manned Bomber Systems" and "Missile Systems." Program elements in the Defense structure are B-52's and Polar Missiles. In the Defense Department structure, the element "Polaris Missile System" is the lowest level of detail shown. Yet this element has a budget which is bigger than many total agency budgets. Included in the Polaris Missile System element are not only the missiles, but also the submarines needed to keep these missiles on station, the men that man the submarines, and the tenders and other supply facilities necessary to keep these submarines operating. Thus the program element is an aggregate of many things. This illustrates the total system concept. It enables management to see at a glance how much of its resources are devoted to this specific element. The program element indicates the purpose for which these resources are brought together, and it provides a focus for the measure of performance. Management's attention is thus focused on the performance of the entire weapons system and not on the performance of support items.

Example 2: In many instances, Government agencies do not produce tangible products. The Department of Justice, for example, produces no hardware. Yet here, again, program budgeting means deciding what the money should be spent *for*. That is, the purposes for which the program is engaged, and what the program accomplishes. The Department of Justice program structure would include programs dealing with anti-trust declaratory policy, investigations and prosecutions under O.R. relating to other laws which are the direct responsibility

of Justice, investigations for other Government agencies, etc.

Example 3: The program structure for the Forest Service includes such major categories as timber production, wildlife, grazing, and recreation. Within the Department of Agriculture also, there are services directly providing outdoor recreation facilities, and also two more services indirectly providing recreation through conversion of crop land. This year, for the first time in Federal budgeting, the Department of Agriculture has pulled together all its efforts on recreation and reviewed and analyzed them at the Secretary level. This review is one immediate benefit of program budgeting.

This Recreation example shows how program budgeting can shed light on Government programs. For example, the Recreational Advisory Council produced a study which showed that about 80 percent of all Government expenditures on recreational activities are made west of the Mississippi whereas about 75 percent of the people live east of the Mississippi. Because of PPB, we have now changed the emphasis to providing more recreation facilities in the East.

Example 4: Some agencies, like those just discussed, use a mission-oriented program structure. The Post Office Department, on the other hand, has a program structure oriented toward function, because that seems more appropriate for their needs. The four most important categories in the Post Office program structure are: (1) Getting Mail into the System, which consists of two primary subcategories—window operations and mail collection services; (2) Processing the Mail; (3) Transporting the Mail; and (4) Delivering the Mail. In addition, there is the catch-all "General Support" category for overhead.

"Processing the Mail" is an intermediate operation which might appear to be merely part of a broader system. Why was it made a major category? The reasons are:

—Over $2 billion is spent to process the mail and
—Mail processing involves many interesting "trade-off" possibilities—alternatives which merit investigation and analysis.

The dollars involved raise technical discussions all the way to the Postmaster General, and mail processing decisions are often made at that level. Even though mail processing is an intermediate output, there are sound, pragmatic reasons for considering it a program.

Although some agencies have outputs which cannot be measured in physical terms, almost all programs should be output-oriented. This method shows what is to be *accomplished,* not merely the old accounting of object classes, or inputs (personnel, buildings, vehicles, etc.)

Setting up a structure requires rigorous conceptualization, but not many man-months. Once the structure is set up, an enormous amount of work goes into the Programming task. This involves taking the existing budget and converting input categories into new output format. It produces what is called the "crosswalk," and this is essential since the traditional categories are used for submissions to Congress. Since much top management time is devoted to budget review, and since top management wants to think in terms of programs, it is important that agency resources be structured in this way. Programmers speak the planners' language, and they are expert at checking and translating costs. Through programming we ensure that work of the budget people and the planning people corresponds even though the conventional budget structure is used with the planning structure.

Once the structure is set up, the agency begins developing a multi-year *Program and Financial Plan* (PFP), which specifies the outputs and cost estimates for each program element. The PFP time span can be as short as five years beyond the current Fiscal Year and the next Fiscal Year, or as long as ten years for the Corps of Engineers' water projects, or even 80-100 years for the Forest Service planting program. In the PFP the agencies are asked to reflect a comprehensive plan, corresponding to the program structure. The PFP is the integrated financial document for the agency. Three sets of tables make up the PFP: Part I sets forth outputs for each year by program element; Part II shows dollar costs associated with each program element; Part III shows whatever other information the agency determines is relevant and necessary, including alternative measures of outputs. Agencies that have not been obtaining such data all along may soon be making somewhat greater demands on field personnel than in the past.

Analysis is the cornerstone of the PPB system. We are giving this major emphasis—forming planning and analytic staffs at the Secretary level where they do not exist, and improving those which already exist. Without much better analysis than we have previously had, this whole effort would fail.

This year the budget submission for the spring preview will consist solely of the Program and Financial Plan (PFP) and Program Memoranda (PM) in support of the PFP. The Program Memoranda are to be hard analytic documents which deal with the issues confronting the agency and which propose *alternatives* for study during the year, *before* critical decisions are made. I stress the word *"alterna-*

tives." This is fundamental to the PPB system. Without alternatives, the analyst is likely to become the decision maker. If a study is presented with costs, details, and recommendations—but no alternatives—then the agency head's choice is either to accept the study, stick with the status quo, or perhaps, suffer a budget cut. The reason a study is usually commissioned in the first place is that the agency head (or perhaps the President) has already decided that the status quo must be changed.

PPB does not envision all-powerful analytic staffs. It is envisioned that these staffs will come up with alternatives, will study their pros and cons, quantify their implications and present them to the agency head. Under PPB the agency head may become much more involved in decision-making in the future than previously.

The Budget Bureau is interested in seeing how well alternatives have been studied. A good review of alternatives is fundamental to justification of major expenditures. The Bureau of the Budget does not and will not make the agency's decisions. It may make recommendations regarding programs, and it may send proposals back for further study. The Bureau does not anticipate doing studies for the agencies, and it does not intend to develop a vested position in special analysis. The analysis will be done in the agencies.

In the near-term, we hope to improve major decision-making. In addition, we hope to see improvement in daily management. If we can develop better measures of agency output, in the long run we can use these measures as primary means of management control. This will also affect the budget making process. In the long run, perhaps in the 1980's or later, I anticipate that PPB will not only give us better program planning, but also help us achieve more rational control of the day-to-day functions.

Appendix

In accordance with the instructions in the now well-known Bureau of the Budget Bulletin 66–3 and its Supplement, Government agencies are busily engaged in developing their Planning-Programming-Budgeting (PPB) systems. The Program Evaluation Staff, which I represent, has been deeply involved in the Budget Bureau's recent task of overseeing the establishment of the PPB system, in offering guidance, and in arranging for training opportunities for the agency staffs. In this paper, I will emphasize the "analysis" and "planning" aspects of the documentation and conclude with some implications of the advent of PPB.

PROGRAM STRUCTURES. Agencies have been defining their activities in a systematic, formal manner through categories, subcategories, and program elements which describe what the agency does. For this year's spring preview, that job is now finished.

In some instances, however, the existing structures still contain obvious shortcomings. A good program structure should define agency outputs in a way that will be of *most use to agency top management,* and some structures can be considerably improved in this regard. Future refinements must, therefore, seek to accomplish this.

A second problem with some program structures is the *lack of uniformity* among agencies engaged in similar programs. For example, at least three major agencies are involved in providing outdoor recreational opportunities: Agriculture, Interior, and the Corps of Engineers. All three agencies now show the recreational opportunity they provide by geographic region, but the regions don't coincide. If each of these agencies reported the recreational opportunities they offer along similar geographic lines, it would then be very easy to construct a total Federal recreational budget which would show exactly (by area) what the total program amounts to. In many such areas interagency uniformity of this type is desirable. This year, though, there simply has not been enough time for any of this to be accomplished.

PROGRAMMING. This system formally establishes the base five-year plan in detail, dictates how program change proposals will be processed, and determines when and how the base-year plan will be extended.

A better grasp of what programming is about can easily be obtained by considering some of the questions which programming staffs have been grappling with recently. For example: What information should be requested from submitting bureaus or agencies? How much detail should the initial plan contain? How much detail should the plan ultimately contain? What forms should be used? To what extent do Department of Defense forms and procedures apply to an agency, and to what extent is DOD experience not applicable?

The programming system must provide for a "crosswalk" which will convert the budget in the new program structure into the present

appropriation structure. But how much accuracy and detail are needed in this conversion? To what extent is accounting precision necessary, and to what extent are statistical cost-finding procedures acceptable? Should we try to allocate any joint costs? Which joint costs? What allocation procedure should be used? Or should all joint costs be put in a "general support" category? In passing, let me note that there are no pat answers to these questions. Good programming systems must be individually tailored to the particular needs and circumstances of each agency, and good programming systems therefore demand a lot of hard work.

Definition of the "costs," to be shown in the PFP, has been something of a problem. Some financial people have interpreted "cost" with much preciseness. However, the Supplement to Bulletin 66–3 was written chiefly by economists who were thinking of costs in an analytic sense —that is, the cost of the resources that go into the plan. Now it so happens that one of our BOB Circulars contains a precise, accrued-accounting definition of costs which includes depreciation, changes in inventories, accrued annual leave not taken, etc. In application, many have interpreted costs as used in the Supplement to Bulletin 66–3 in terms of this formal definition, while it was our intention to interpret costs variously for different agencies in whatever way makes the most sense from an economic point of view. For this year, we must live with whatever confusion we have generated. In the future, these multi-year program and financial plans should be tailored to suit the needs and the requirements of the individual programs.

One comment about costs which I feel can be made with some degree of assurance is that in future years the multi-year plan will show investment and operating costs separately for each program element. Many of the problems that we are now trying to solve will then be a lot easier to handle.

MULTI-YEAR PROGRAM AND FINANCIAL PLAN. Probably the two most important parts of the whole PPB effort are output data and analyses. These are covered in two basic documents: the multi-year *Program and Financial Plan* and the *Program Memoranda.*

The Program and Financial Plan (PFP) will consist of three parts—all tables. Part I will be a table of outputs, showing measures for each program element expressed as physical units of what an agency is building, producing, or encouraging, year by year. Part II will show the financial implications of Part I; e.g., how much the units of the building plan are going to cost each year. Part III will contain relevant supplementary tables.

Submission of a multi-year Program and Financial Plan to the Bureau of the Budget will be new to all agencies. The degree of additional planning required will vary considerably among agencies since some have been planning ahead only on a year-to-year basis.

The PFP *is not* intended to be an analytic document and it should not be interpreted as a refined cost-benefit analysis. We are *not* going to be able to take the cost in Part II, divide it by unit outputs in Part I, and automatically come up with something that says this is the "cost per unit of output" or that the reverse shows "benefits per dollar."

The PFP *is* a summary planning document. As a quantified expression of an agency's plans, it becomes a valuable document for dialog among the bureau chief, the head of the agency, the Director of the Budget Bureau, and the President.

PROGRAM MEMORANDA. This is the analytic document. It should state the basis and objectives of the analysis, describe the concepts and assumptions that were used, and contain all the narrative associated with the budget submission. Just as the PFP states *what* is planned, the Program Memoranda explains *why.*

This year, of course, we do not expect to receive a thorough analysis of all programs. But we do feel there is time to (1) formulate reasonably clear and precise program objectives, (2) define the major issues, and (3) at least mention some of the principal alternatives which were weighed against the selections reflected in the FY 1968 budget. Our plan at BOB is to give each agency a critique on its PM's and have them reworked during the summer and resubmitted in the fall. The final version of this year's PM's will be the springboard of those to be written for the following spring preview. Through this process, we hope to inject a note of continuity to the budget review process.

Let me elaborate for a moment on the subject of alternatives and their role in the budget review process. Past agency submittals to the Budget Bureau rarely suggested program alternatives (except for Defense, which now makes this a regular habit). The fact that the Budget Bureau is now asking for alternatives to be discussed explicitly has caused many people to ask me whether BOB intends to start "running the agency" or "making major agency decisions." The answer to such questions is decidedly NO! If you will reread the instructions carefully, you will note that they do *not* ask the agency to submit alternatives to us for a decision. Budget submissions should continue to reflect decisions made by the agency head. However, when significant sums of money are involved, decisions should reflect the agency's

judgment of what constitutes the best choice *among* the most imaginative alternatives possible. That is, *major decisions with large spending implications should be the consequence of a systematic search process.* (NOTE: The Airlift/Sealift memo contained in the Supplement to Bulletin 66–3 illustrates a proper procedure for handling alternatives in budget submittals.) A tenet of program budgeting is that until the best and most efficient means of achieving a stated goal has been thoroughly and systematically searched for and analyzed, major program spending decisions *are not justified.* I repeat: the Budget Bureau is *not* asking any agency to abdicate its decision-making responsibility. The Budget Bureau *is* asking each agency to justify its decisions by showing that it has diligently searched for the best and most efficient means of achieving stated goals and objectives. In the past, justification *of this nature* has been, by and large, noticeable by its absence. The old form of "justification," which rarely contained the rational basis for any justification whatsoever, is no longer considered acceptable.

ROLE OF THE ANALYST IN PPB. Let me distinguish between decision-makers and analysts in the PPB system. They may, in rare cases, be the same individuals, but there is a conceptual difference between the two roles which is worth noting.

PPB assumes that the decision-makers are agency heads and their principal assistants. Analysts are people trained to dissect problems, to look at them different ways, *to develop alternatives,* to employ quantitative analysis where practicable, and to make suggestions for the decision-maker's consideration.

The phrase "develop alternatives" is really the key to the distinction between decision-makers and analysts. All too frequently a proposal submitted to the decision-maker describes but one course of action. The only choice the decision-maker then has is to accept it or reject it. This procedure is neither logical, necessary, nor desirable. It *de facto* turns the analyst into the decision-maker. Program budgeting strives to separate the two functions by having analysts develop and present choices between meaningful and imaginative alternatives.

Operations Research Research and Government O.R.[1]

Dr. Alan J. Goldman[2]

National Bureau of Standards

1. Introduction

I'd like to lead up to my "message for today" with a little analogy. It concerns, on the *one* hand, the typical relationship between the manager and the operations researcher—and, on the *other* hand, that between everyman and his physician. What I have in mind is that, unfortunately, most of us don't visit a doctor unless and until we're already feeling uncomfortably ill—and when we do arrive, what we long for is that famous "fast, fast relief." Similarly, an operations analyst's introduction to a new task is all too often in terms like these: "We have this problem. It's hurting us badly, *very* badly. Please give us a guaranteed optimal solution by yesterday."

Under these circumstances, it's pretty clear what will happen. Perhaps, by rare good fortune, the problem will happen to fall neatly into one of those areas in which both theory and practice are especially well developed. But most of the time, the "solution" obtained will necessarily be of the "quick and dirty" variety.

Such a solution may (quite properly) be accepted and acted upon as "best available." However, it may *in fact* be so crude as to lead to really unsatisfactory results—we all know that even our best efforts can't *ensure* the soundness of an O.R. study's conclusions. *Or,* the quick and dirty solution may be technically satisfactory, but considerably more expensive to implement than some alternative that was missed. The proposed solution may even be fairly acceptable on *all* counts, but the manager will never know how much better an answer *might* have been forthcoming if only a little more time or effort could have been spared—*or,* and this is the possibility I want to stress—if only the state of the art had been a *little* more advanced.

This brings me close to my message. If most government practitioners of operations research are feverishly racing the clock in attempts to solve pressing practical problems, then just who *is* going to advance the state of the art? There is a quite obvious need for the analog of medical research—for groups whose dominant concern is not the rapid resolution of specific agency problems, but rather the systematic improvement, extension and creation of the *methods* of operations research. This is what I like to call *"operations research research,"* i.e., research into the techniques and tactics of operations research. Abbreviation: O.R.R.

A natural reaction is that O.R.R. activities are properly the province of the universities. And so they are *largely,* but certainly not *exclusively.* It's easy to see why:

(a) We're concerned here with research which is applied rather than basic,[3] i.e., takes its main stimulus from present and anticipated real-world problems rather than the general urge to advance human knowledge.

(b) More specifically, *we're* concerned with methods of operations research needed in *government* O.R. studies. Appraisal of these needs requires extensive exposure *to* such government studies; bringing the new methods into effective use quickly also requires close contact with the broad stream of government O.R. activity. I suggest that any *university* group which finds itself in such a position needs to do some earnest soul-searching about the primary functions of a university.

(c) Any university outfit will (and often should) be deeply concerned with issues distinctly peripheral to the needs of governmental O.R. A not infrequent occurrence is the tendency to slide the research toward some area which is sufficiently fashionable academically as to permit the guiding professors to publish rather than perish, and the guided graduate students to achieve acceptable theses.[4]

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[1] Revised text of a presentation to the Operations Research Conference for Non-Defense Washington Area Government Agencies, 4/20/66. Includes sections omitted from the delivered address for the sake of brevity. I am indebted to J. R. Rosenblatt and J. M. Cameron for helpful comments.

[2] Chief, Operations Research Section, Applied Mathematics Division, Institute for Basic Standards, National Bureau of Standards, Washington, D. C. 20234. The text is an expression of the author's views on the subjects treated, rather than an "official pronouncement" of any sort.

[3] This rather fuzzy distinction is inappropriate in many of the contexts in which it appears, but seems genuinely relevant here.

[4] The phrase "not infrequent" was carefully chosen; "typical" would have been unjust.

2. Government O.R.R.: Demand and Supply

For the reasons just given, there's a clear necessity for operations research research groups *within* the government, located at focal points for a *number* of Federal O.R. studies. Let me spell out this necessity more clearly. Among the effective resources of the operations research practitioner, I do not count all that has been discovered, or even all that has been published, but rather only those items which have been so clearly written up and so appropriately implemented (e.g., in a computer program) as to be truly "available" for application or adaptation within the time and resource limits of a particular O.R. study. On this basis, as a direct or consultative participator in a number of government studies, I can say flatly (and with no doubt that many of you have had similar experience) that the state of the O.R. art is all too often a recognizably *critical* limiting factor on the quality of what can be achieved within an assigned deadline or budget ceiling. And instances of this kind go unrecognized in many more cases, since we naturally tend (without conscious decision) to *formulate* problems only in terms which correspond to an available "solution" method.

What makes this even more frustrating is the presence of "observed regularities," i.e., the recognition of essentially the *same* gap in methodology or implementation as arising in project after project, although no one sponsor has the time or resources to permit attacking the beast head-on. So we end up *ad-hoc*cing our way through, in more or less makeshift fashion, on each individual occasion. The efficient approach to these recurrent problems often involves looking at a version general enough to refer not only to Agency X's problem in 1966, but also to what *will* be the problems of umpteen other agencies (but perhaps *not* Agency X) by 1976. As we know, to support such research out of Agency X's 1966 budget is typically unthinkable. Work of this sort naturally constitutes the role of an independently supported operations research research group with the *specific mission* of ascertaining and responding to these general needs of governmental O.R.

With the "demand" side of the picture for government operations research research thus indicated, let's turn to the "supply" side. First, the *military* O.R. sector. Here one thinks at once of the outstanding achievements of the RAND Corporation, then of the many contributions of ORO/RAC, OEG/CNA, WSEG/IDA, etc. (Note, though, that none of these are exactly *within* government.)

Now for the *civilian* side. To exclude the other "giant" as well, I'll call it the non-military *terrestrial* sector, comprising government activities concerned with such minor items as the education and international dealings. Despite nation's economy, natural resources, health, some notable individual efforts, if one compares the available resources for government O.R.R. in this sector with:

(a) the difficulty and number of the problems involved, and

(b) the resources for analogous functions in the military sector, then it seems very hard to arrive at a rating significantly different from *zero*.

The gist of my "message" is that this *just won't do*. It is a platitude that yesterday's O.R. methods will fall short of adequacy for today's problems—they fell short for yesterday's, and today's are certainly no easier. Moreover, I can see a clear and present danger that techniques developed for military O.R. studies will be stretched well past the validity point to cover the kinds of objective functions injected into non-military analyses by public interest considerations.

The contention here is that lack of appreciation for the need for adequate civilian terrestrial government O.R.R. has hurt us in the past, and is hurting now. Without remedial action, the pain will rise to the *agony* level as PPB and its offspring make ever-increasing demands on the O.R. capabilities of all government agencies, and thus on the O.R. art itself. And these are needs which can't be met "on the cheap," in dedication or time or dollars.

Who should bell this cat? Despite the government tradition that questions of organization generally take priority over questions of substance, I have no considered views to present. In the long run, it seems quite likely that each Executive Department (and several of the major independent agencies) will require at least one O.R.R. facility attuned to the peculiarities of its own needs.[5] In the short term, it seems apparent from my prejudiced viewpoint that *one* natural locus for such work will be the National Bureau of Standards, with its tradition of O.R.-type services to other agencies, and its special assigned responsibilities regarding both (i) cost-benefit analyses and (ii) helping to achieve increasingly efficient government use of that very valuable O.R. tool, the digital computer. But my personal acquaintance with many talented government O.R. professionals just doesn't amount to the kind of knowledge, of agency structures and traditions, that would permit me to identify the other natural loci or nuclei which must surely exist.

[5] Such facilities would still need access to specialized consultants expert in the more esoteric spells.

3. Data, Dissemination, Documentation

Before becoming a little more specific about promising areas for operations research research, I want to remind you of some other aspects of government O.R. (or operations research in general) which have their own unpleasant features to add to the difficulties arising from inadequate methods.

One such aspect is the typical quality of the *data* with which we must deal. It is depressing to recall that to the scientist, "data" are carefully defined numbers derived from precise measurement.[5a] It is even more depressing to observe that according to the Latin, "data" means "things which are *given*," i.e., are lying at hand and freely available. In contrast, the numerical material of most O.R. studies seem to fall into four categories:

(a) Predictions or extrapolations into the future. My only comment here is the recommendation that anyone who applies the word "data" to any glimpse into any crystal ball should be shot as soon as possible (within constraints of time and budget, of course).

(b) "Data" which, though essential to your purpose, were so far from "freely available" that acquiring them has left you too exhausted and broke to go on and use them. In the military O.R. field, it has not been uncommon for inter-service rivalries to force data-gathering to take forms just short of espionage. I hope this won't recur in the civilian sector.

(c) "Data," so-called, which started out as reasonably honest numbers. But they've been aggregated and re-aggregated and disaggregated and interpolated and scaled and adjusted —in short, subjected to so many operations, each somewhat open to question, that the ratio of fact to artifact is slim indeed. You don't *want* any decision significant for our nation to lean on numbers like these, put together with pipe cleaners and chewing gum. You wouldn't even want the fate of Northwest Saratoga Falls to depend on them. *But*—they're what you've got.

(d) My final category consists of those numbers which are indeed "freely available," but simply aren't to be believed—they have perhaps been prepared to bias the analysis you're attempting, or else with no axe to grind but in total ignorance of proper sampling technique, or may reflect drastically different usage of certain key words by you and by your informant.

This list of horrors reminds us that O.R. studies often involve conceptually complex processing of their input data; knowing how far we can go (and in what directions) requires a rather sophisticated understanding of just what the numbers mean and how they were arrived at. It requires recognizing that the "data" as received are generally not raw strings of digits, but rather have had a *structure* implicitly imposed on them by the methods (accounting rules, consistency criteria, formulas based on economic or social or demographic theories) used in checking and "adjusting" them. Hopefully our models will be compatible with this structure, perhaps even incorporating some of its elements. Achieving the kind of understanding yearned for here, would certainly be facilitated by close association with the planning and evolution of the coming generation of Federal reporting systems.

So much for data. On *dissemination*, I simply call to your attention how much high-quality operations research work, which could provide essential starting points for efforts by other agencies, is either never written up properly, or written up only years and years after the fact, or is written up well and on time only to be buried in the deepest dungeon of "administrative classification" by the agency involved.

This leads to a third striking aspect of the government O.R. scene—the scandalously low average quality of documentation of (in-house and contracted) operations analyses. Let me describe the standards used in that appraisal. In looking at a piece of O.R. documentation—from the viewpoint of the analyst, not necessarily that of the manager for whom the study was made—what *is* one justified in expecting?

To permit concentration on the intellectual content, the text must be written in clear and reasonably smooth style, without side expeditions to drag in and display clusters of whatever terms (e.g., "system") are believed to be in current fashion. Turning to substance, we note that the *motivation* for reading the document is presumably a hope of employing its results as partial basis for some decision or as inputs to some further analysis, or perhaps of adapting its *methods* for use in some new study. None of these purposes is well-served unless the serious reader can without undue effort track down what assumptions and approximations were made (and with what justification), what particular meanings were attached to significant but somewhat ambiguous terms, and so on. Getting at this sort of information is hard enough today, when the principal author is perhaps only as far away as the other side of the Federal Triangle. And *if* the present quality of documentation remains typical, and *if* Professor Flood's predictions are realized and one will typically be applying X's model to Y's data after picking both up "blind" through computer tie-in with points 1000 miles distant—

[5a] The contrast being drawn is too sharp to be blunted by the qualifications needed to make this over-simplification respectable.

then the odds against producing anything but garbage seem intolerably high.

But there is still another class of readers to consider, those anxious to find what the course of progress of the documented study has to teach us in operations research. They would need to know what *alternatives* to the approach actually chosen were considered, and why they were rejected. What was the institutional framework in which the work was done, and the backgrounds of those with whom and for whom the work was done, and how did these factors influence the conduct of the study? If a predictive model was developed, what provision was made for follow-up observation to permit adaptive corrections, and (hopefully in a follow-up volume) how successful were the predictions and what are the implications for the predictive technique used?

Some of the reasons for the present average level of O.R. documentation lie fairly near the surface. In the first place, the kinds of material demanded above are really extremely *hard* to exposit, and can easily run into agency clearance problems. (Perhaps this explains why the mathematicians—whose contributions are particularly easy to write up and to present abstractly without reference to the controversial issues of a particular study—are now nearly monopolizing the O.R. journals, thus reinforcing the widespread impression that operations research is basically a collection of esoteric mathematical magics. As an operations research mathematician, I certainly appreciate having my colleague's mathematical contributions to O.R. readily available to me in print, but I long for a professional literature which would provide me with more useful insights on the all too many facets of operations research in which my technical training *doesn't* leave me fairly capable of fending for myself.)

Second, project budgets almost invariably underestimate, quite substantially, the drain on time and dollars and manpower needed to do such recording *right*. This in part reflects the fact that much of the quality described above is not strictly necessary for the short-term interests of the agency funding the study. It also reflects the lack of a *tradition*, like that in the sciences, of documentation of a sort directed at the professional community. This lack is not surprising, since so much operations research is carried out in areas where considerations of military security or industrial "proprietary" reticence are appropriate. But these constraints should *not* apply to the civilian government O.R. sector!

For the agency sponsoring an O.R. study which has been documented in the usual slovenly style, the consequence is that if the manager for whom the study was done leaves—and he will—or if the study team breaks up—and *it* will—then the future potential return from the resources invested in the project becomes essentially nil. The benefits thus jeopardized, to the agency and to other agencies with related problems, can be quite substantial.

For the O.R. community, the prevalence of inadequate documentation means systematic deprivation of precious opportunities to learn from each other's insights and aberrations. Some of what isn't written down does ultimately get communicated to a few colleagues by word of mouth, but this is the *prehistoric* mode of information transfer, scarcely one to rely on for efficiently promoting the advance of the state of the art in operations research.

I suspect that studies exceeding a certain (what?) level of effort should routinely include a project historian—even though this may rule out a type of doctoral thesis (The Story of Project Q: "What Fools We Mortals Be") otherwise likely to be quite popular in the next decade. I hope to see an increasing stream of solid case histories published in our journals; the forthcoming "applications" issue of the O.R. Journal should either set the necessary precedent, or provide keener insight into the difficulties involved, or do some of both. But most strongly of all, I want to urge that in allocating resources and energies among the various phases of our work, we remember that in the documentation phase we are not writing exclusively for this decision-maker and this year, but also for our present and future colleagues, and have a heavy obligation to contribute what we can to our profession.

4. Communication, Organization, and Strategy

In this and the following section, I want to mention a few potentially important areas for operations research research. The list is of course quite an individual matter, reflecting my own reactions to those difficulties encountered during the particular O.R. studies in which I've happened to participate. Some of you would likely have selected a totally disjoint list for special mention, but there would probably be substantial agreement that the subjects sketched below *do* rank high in significance and promise for O.R.R.[6]

The first topic is that of communication—with the manager or decision-maker for whom the O.R. study is carried out. It's often said that the success of an O.R. project should be judged

[6] In restrospect, the questions relating to the proper selection of measures of effectiveness or benefits (i.e., "objective functions"), and to the related foundational field of utility theory, seem so central as to make their absence from this Section and the next somewhat embarrassing.

by the extent to which its recommendations are implemented. I believe that's a gross exaggeration—I *have* to believe it, since otherwise I'd have become so discouraged as to leave the field long ago. What *is* essential is that the framework, the model underlying the study, has been communicated to the manager clearly enough, and is sufficiently convincing and illuminating to him, as to substantially help him in reaching a decision. If for example his ultimate selection over-rides whatever recommendations the O.R. report contains, then at least he will have a good idea of what has been sacrificed, and will have been compelled to think through (and will therefore be prepared to explain to others) what additional considerations compel this sacrifice.

But how often do we achieve this degree of communication? What can we do during the study to increase its likelihood? At what points, at which levels, and how frequently should the manager and his staff be brought into the study? A number of articles have offered sage (and sometimes snide) counsel on such topics, but I think the time is ripe for carefully designed experiments, and for informed empirical observations, that could shed substantial light on these important questions.

Besides communication with the sponsor, there is also the matter of communications within the O.R. team itself. How much information should junior staff be given—with the risk on the one hand of distracting them from their assignments, and on the other hand of missing their potentially valuable suggestions and failing to give them a full sense of participation? What degree of consensus should be required for significant strategy decisions in the study—e.g., does one want to receive unanimous consent by task leaders, or perhaps adopt a policy of "O.K. if no-one objects in writing?" What's to be done about the fact that the participants in a 5-person meeting will go off with *at least* 5 different impressions of what's been decided?

I have found these questions to be sadly significant, to the point of wondering whether each 10 or so staff members don't normally need another man to provide mere *coordination*, as distinguished from technical direction. Here again the adage "know thyself" seems applicable to O.R.—simulation and experimental studies on these questions of O.R. project organization seem well worth pursuing.

There are also some more basic questions of project strategy. It takes mighty steady nerves to "keep you cool," to sit tight while systematically working out a program of activities, to do preliminary explorations of several alternative approaches, to wait for clarifying data or "customer" resolution of ambiguities—all this while deadline time ticks closer and closer. There is the compulsion to *do* something—to get *cracking*—to get *something* going which can be reported as *progress* to the customer, and most of all to oneself. Yet my own experience, at least, indicates that a deliberate planning phase is essential for substantial projects, that 15-20% of the allotted study period is probably even scanty for this phase, and that shortchanging it leads to premature commitments which require agonizing and basically unsatisfactory patching up toward the end of the job. Do we know enough, in operations research, to be able to study this sort of decision process? I would certainly like to think so. Are they *worth* studying? I have no doubt they are.

5. Mathematical Methods and Models

The topic of this section is the one closest to my own heart. I am a bit reluctant to display my enthusiasm, however, for fear of reinforcing a widely held image of the mathematician in operations research as infatuated with his favorite abstruse technique to the point of unconcern with the actual needs of the problem at hand. This image is in some cases all too well deserved, but I suspect that in many instances it arises from a somewhat oversimplified view of quantitative models:

To be at all manageable, a model must omit the overwhelming preponderance of the bloomin' buzzin' confusion that is reality. Since complete realism is out of the question, it follows that there is no one "right" model for a given situation, just more or less *suitable* models. A certain fidelity to the main features of the actual situation is obviously necessary if *relevant* answers are to be obtained. But to yield any answers at *all*, the model must be tractable to whatever "solution" or "manipulation" operations are required. And so a "best fit" to the desired degree of realism must be chosen from among those models for which solution procedures do exist, not because use of these procedures is an end in itself, but simply because there's nothing else to be done.

The role of mathematical O.R.R. is to enlarge this area of choice, of "solvable" mathematical models, so as to permit a *better* fit. In cases where *no* decent fit was previously available and one is now provided, we find sudden recognition that instances of model M are really numerous and important—how could they have been overlooked for so long? *Solutions make problems* as well as *vice versa*, i.e., it is the existence of an efficient solution method for a

certain model which creates the incentive to investigate whether a situation under study can't be subsumed under that model without unacceptable distortion.

There are two areas of mathematical operations research in which the last few years have seen especially notable progress,[7] with every prospect of even greater successes in the years to come. One is the field of *combinatorial optimization*, largely but not exclusively concerned with *network* problems (routing, scheduling, partitioning, etc.). Here the "exponential explosion"—the fact that the number of alternatives to be chosen among increases exponentially (or worse!) with problem size—is being coped with successfully in more and more cases. The second field is that of *nonlinear programming*, i.e., the maximization or minimization of a (not necessarily linear) function of many variables, perhaps subject to a number of (not necessarily linear) side conditions.

Mathematical O.R.R. ought to increase its efforts in these fields, so as to exploit promptly the present and anticipated breakthroughs. Furthermore the results have to be turned into reliable tools, readily available for use during O.R. studies which require them. This calls for efficient well-documented computer codes, as well as systematic computational experiments to compare alternative methods and learn which among them are best suited to particular types of problems.

Of course many of the problems we will want to solve will still turn out to be mathematically intractable with the tools available. I would hope to see more emphasis in O.R.R. on developing and disseminating rigorous sophisticated procedures for approximating intractable models by simpler ones, in particular for "surrounding" the original situation with a number of tractable ones, each deliberately biased in a known way.

It is natural to wonder whether *civilian* government O.R. will have some distinctive demands to make on mathematics. One speculative notion is that there will be an increasing need to determine appropriate sorts of *equilibria* rather than optima, that it may be less fruitful to seek a solution which is "best" in some sense than to aim at striking a proper balance between conflicting public interests.

I must confess to a general uneasiness about the basic appropriateness, for much of operations research, of traditional mathematics. Mathematics originated in connection with human activities—surveying, accounting, navigation—characterized by rather precisely quantifiable "data," and a requirement for rather precise numerical results. The further development of mathematics occurred in connection with the sciences and engineering, again fields where "hard numbers" prevail. It seems unlikely that techniques developed in such contexts would be generically suitable for situations involving "data" scarcely deserving of the name, and requiring not the precise evaluation of various courses of action but rather only their *ranking* according to quite fuzzy criteria, or even just the determination of the top one or two or three among them. There may well be a need for some *new kinds* of mathematical concepts and operations, or at least a greater application in O.R. of the notions of "modern mathematics" with its stress on structures and relationships rather than numbers.

6. Summary

Operations research has been described as an art which "gives bad answers to problems which otherwise would receive even worse answers." This art is being and is going to be applied, by the non-military sector of our government, to problems so important, so difficult and so numerous as to require every effort to minimize the "badness" of our answers.

We can make *some* progress toward this goal by raising the quality of our documentation from its present abysmally low level, so that we can make better use of each other's work and thus free resources for resolving those difficulties unique to the problem at hand. We can delve more deeply into the reliability of the "data" entering our work, and adjust our methods and conclusions accordingly. But even with all this done, we would be faced with substantial gaps between our needs and the O.R. methods available to us. Our work will frequently call for knowledge and methods which don't yet exist, or which exist in theory but not in practically usable form—perhaps for material there was no real incentive to develop in the climate of military or industrial O.R. A substantial in-house capability to advance the art of operations research for civilian terrestrial branches of government is needed, but practically none is not present. In the present paper I have tried to indicate the reasoning behind these assertions, and to identify some of the areas on which a proper O.R.R. effort should focus.

[7] It would be inappropriate, in a non-technical paper such as this, to cite the specific publications involved.

Reports of Panel Meetings

Editor's Note: As noted in the agenda, three panel sessions were held in the afternoon: Panel I, Special Problems of OR in Several Agencies of Government; Panel II, Management Views in OR/SA to Fulfill PPB Requirements; Panel III, Broadening the OR Competence of Mid-Careerists. The panel chairmen were asked to prepare a set of notes on the activities of their panels. Notes on Panel I and Panel III were received and are published herein.

Panel I

"Special Problems of Operations Research in Civil Agencies of Government"

Chairman: Mr. Ezra Glaser
Health, Education, and Welfare

This panel was to review communication problems among technical operations researchers and to attempt to specify those factors which limit the quality and extent of operations research practice in the civil agencies.

The conference proceeded by asking those in attendance to express agreement with a number of propositions, each of which postulated an important limiting factor for the quality and extent of operations research practice. Four classes of problems and/or limiting factors were identified as "severe," for the quality or extent of operations research practice:

1. Difficulties in dealing with the upper echelon of the organization. The prevalence of preconceived problems and preconceived answers were symptomatic of these difficulties. Lack of understanding by the upper echelon of what operations research is and how it might usefully be employed in solving the problems of the organization.
2. The training and quality of operations analysts.
3. The difficulty of developing measures of effectiveness in civilian agencies. While there has been some success in constructing measures of effectiveness in business organizations and military agencies, there is very often great difficulty in finding means of measuring the effectiveness of civilian programs. The problem is how to be quantitative without by-passing the principal reasons for the existence of the program.
4. Communications among operations researchers. This applies both to the techniques employed and to results obtained.

There was little support for the proposition that inadequacy of financial resources was a serious limiting condition. The group indicated a belief that sufficient funds were generally forthcoming in situations where there was some satisfactory way of handling the problems noted above.

Relatively little weight was given to the inadequacies in the technical literature, which might impede teaching or the upgrading of quality of operations researchers.

Each of the four principal obstacles will be discussed in turn.

1. *Relation to Upper Echelon of the Organization*

One principal and frequent problem is the indirectness of the O.R. staff's organizational relationship to the head of the agency. This means that the staff is often not in a position to watch the development and identification of major problems from the viewpoint of the agency head, and therefore not in a position to prepare in advance for studies aimed at assisting in reaching important decisions. Experience shows that such operations research studies require substantial lead time for high-quality results, but in practice this time is generally unavailable. The likely result is a hasty and ill-considered effort which can take but little advantage of the potentialities and resources of O.R. techniques.

2. *The Training and Quality of O.R. Personnel*

It was pointed out that technical courses in O.R. that might prepare analysts for government applications leave much to be desired.

It was suggested that an interdepartmental and consortium approach be utilized to offer enough kinds of courses, for different clienteles and describing different techniques and focussing on different problem applications to fill out the field in some systematic manner. While no single institution could collect enough students or assign enough specialized faculty for such a program, it seems likely that a group of educational institutions could arrange just such a spectrum of courses.

Another problem area is the recruitment of college personnel for operations research work. Generally the Government is not competitive with private enterprise. Competitiveness requires sending out technical recruiters who are able to discuss the technical opportunities in language meaningful to recent graduates of

technical courses. Moreover, recruiters for private enterprise can make a commitment on the spot whereas the Federal recruiter can only point to the long and tortuous path of examinations, ratings, etc., which might eventually lead to some type of promotion. While these constraints are consistent with Civil Service philosophy and practice, they should be recognized as placing the Federal establishment at a serious disadvantage in competing with private organizations for superior students.

The group recommended more emphasis on sending rusty students back to school, renewing their technical abilities and extending these into operations research studies. There is also need for a series of shorter courses, especially those directed at technique in the modelling process, with use of "live" exhibits of real problems used to the maximum extent possible.

3. *Measures of Effectiveness*

This is one of the most difficult problems in the useful application of operations research to the programs of civilian agencies. One cannot measure the benefits from various program elements or administrative alternatives by their effects on "profits." Nor are there well defined military type objectives. The difficulty is serious enough as regards provision of current services (health, occupational retraining, vocational rehabilitation, etc.) but is an order of magnitude more severe in dealing with those programs whose benefits lie in the improvement of *future* services (improvements in elementary school education, biomedical research).

There is almost a total absence of training materials suitable for most of the civilian agencies of the Government, which communicates the few hard-won currently known approaches to the problems of constructing measures of effectiveness.

In practice this problem tends to be linked with the relation of the operations research group to the top man in the organization—in the absence of opportunity for this group to formulate and inject any more objective measure of effectiveness, the evaluation necessarily turns out to be an expression of his personal preferences.

4. *Communication Among Operations Researchers*

The key notion here seems to be the existence of "natural aggregates" in Government programs. For example, the interests of the Federal Government in transportation are scattered over many agencies, many programs, and many objectives. It would seem desirable for operations researchers who are working on the many aspects of transportation program to be in communication with others working within the same aggregate.

A yet broader combination can be obtained by grouping the interests of transportation and communication, since these two are interchangeable or substitutable in some situations.

The Planning-Programming-Budgeting System will probably provide an organizational entry into these natural groupings by the requirements of PPB that common objectives be identified and put into some rational programming framework.

For operations researchers whose activities fall into some natural aggregate (not quite as strictly interpreted as Derek Price's *Invisible Colleges*), it would seem desirable to program a certain number of technical colloquia and seminars. These are not envisaged as meetings to compile lists of proposed projects or ongoing research, but rather as solid discussions in considerable depth of technical problems, attempts to use various techniques, obstacles met, tentative results achieved, and so forth.

One question that arises in the reconstruction of budget decision making categories is the way in which the Bureau of the Budget itself would adapt to such natural aggregates as are not now expressed in its own organization, and what part they might play in any colloquia which are organized in behalf of some substantial common interests among the Federal agencies and programs.

Panel II

The Summary of Proceedings for Panel II is not available.

Panel III

Broadening the O.R. Competence of Mid-Careerists

Chairman: Mr. Joseph Lowell, Jr.
Civil Service Commission

Panel III was attended by 13 participants, almost all of whom are actively engaged in Operations Research.

Perhaps the most significant result of Panel III's discussion was the refinement of the panel topic. Participants agreed that the topic was too broad, including at least two sub-problems worthy of quite separate treatment.

The first problem involves the identification, recruiting and training of those persons presently in non-O.R. positions who have the potential to be made over into O.R. practitioners.

The second problem involves the assistance and/or training which non-technical people need in order to understand enough about O.R. to know when and where to turn to O.R. practitioners for help.

(A third problem, raised but not extensively discussed, involved the education of O.R. practitioners in the art of communicating their profession and its techniques in lay terms.)

It was generally agreed that each of the above mentioned problems merited serious and separate discussion. Recommendations were made that they be treated individually at any follow-up sessions. There was general agreement that participants in such discussions should be pre-registered and pre-selected to avoid the situation of one group discussing the problems of another, unrepresented, group; e.g., O.R. people deciding independently what non-O.R. people need to know, or vice versa.

List of Attendees

Name	Agency
ALEXANDER, Mark A.	Atomic Energy Commission
ASTIN, Allen V.	National Bureau of Standards
AZE, Albert Y.	Internal Revenue Service
BERSHAD, Max A.	Bureau of Census
BLACK, Guy	Council of Economic Advisors
BOULAND, Heber D.	National Bureau of Standards
BREZINA, Dennis W.	Science Policy Research Division
CANNON, Edward W.	National Bureau of Standards
CASE, C. Marston	Office of Education
COFFEY, Matthew B.	The White House Office
CONNOR, Lawrence W.	Post Office Department
CONWAY, Paul T.	Office of the Chief of Naval Operations
CRUMLISH, Joseph D.	National Bureau of Standards
CURTIS, Donald W.	Treasury Department
DAVIS, Charles J.	Department of the Army
DE RAAT, Jacob H.	National Bureau of Standards
DONAHUE, Gilbert E.	Department of Labor
DORFMAN, William	Environmental Science Services Administration
DOUTY, Harry M.	Department of Labor
FAZAR, Willard	Bureau of the Budget
FLORY, John A.	Economic Development Administration
FLYNN, John C.	Economic Development Administration
GILES, J. K.	Post Office Department
GLASER, Ezra	National Institutes of Health
GLEASON, Jacqueline	Office of Education
GLEASON, Maynard G.	Maritime Administration
GOLDMAN, Alan J.	National Bureau of Standards
GOLDMAN, Morris R.	Office of Business Economics
GOLUBIN, Nicholas M.	Defense Supply Agency
GORDON, Virginia B.	Economic Development Administration
GREEN, John C.	Office of Emergency Planning
GREENHOUSE, Samuel M.	Veterans Administration
GREENWOOD, Joseph A.	Food and Drug Administration
GROSSE, Robert N.	Health, Education and Welfare
HAHN, Walter A.	Environmental Science Services Administration
HALDI, John	Bureau of the Budget
HALL, Glenn O.	Economic Development Administration
HANNA, C. R.	Department of Agriculture
HARTEL, Robert J.	Interstate Commerce Commission
HATRY, Harry	OSD—Systems Analysis
HEARN, Saul D.	Social Security Administration
HENIG, Seymour	National Bureau of Standards
HEYL, Arnold A.	Health, Education and Welfare
HIPP, Fred C.	National Bureau of Standards
HOBBAH, Reginald V.	National Bureau of Standards
HOOPER, William L.	Health, Education and Welfare
HOPKINS, Cleveland	National Bureau of Standards
HOWE, E. Eugene	HQ USA CDC
JENKINSON, Ernest H.	Department of Agriculture
KAITZ, Hyman	Business and Defense Services Administration
KIT, Boris	National Bureau of Standards
KLINE, Robert C., Jr.	Interstate Commerce Commission
LANDIS, Rex	Post Office Department
LANKA, George	Federal Aviation Agency
LAVELL, Robert J.	Department of the Interior
LEARY, Thomas J.	Internal Revenue Service
LINER, C. D.	Office of the Secretary of Defense
LOMBARD, Edward E.	Small Business Administration
LOWELL, Joseph W., Jr.	Civil Service Commission
McMANUS, Frank	National Bureau of Standards
MAHONEY, Edward J.	General Accounting Office
MEGLES, Richard C.	Department of Labor
MENDENHALL, O. H.	Federal Aviation Agency
MICHELSON, Aaron	Veterans Administration
MILILLO, Frank A.	Naval Command Systems Support ACT
MILLER, Robert F.	Post Office Department
MILLIE, Harold R.	National Bureau of Standards
MORROW, James C.	U.S. Coast Guard
MOSS, John	Social Security Administration
NASSETTA, F. C.	Naval Command Systems Support ACT
O'BRIEN, James L.	Census Bureau
PAIGE, Harvey C.	National Academy of Sciences
PANZER, Fred	The White House
PARKER, Walter W.	Patent Office

PICCIRELLI, Robert	National Bureau of Standards
PICKERING, Harlan	Environmental Science Services Administration
PINCUS, Saul	Department of Defense
POCINKI, Leon	Environmental Science Services Administration
RAUCHSCHWALBE, Otto	National Park Service
REIFMAN, Lucille	National Institutes of Health
RIEKERT, F. M.	Small Business Administration
ROOT, James G.	National Bureau of Standards
ROSENBLATT, David	National Bureau of Standards
ROTHMAN, Abe	Department of Labor
SAMORDIC, Michael	Office of Economic Analysis
SAUNDERS, Edward R., Jr.	Executive Office of the President
SCHEIG, Sue	Civil Service Commission
SCHWALB, Louis	Department of the Army
SIMPSON, J. R.	Department of the Navy
SINGER, Burton O.	Civil Aeronautics Board
SIROTA, Milton	Federal Aviation Agency
SLAUGHTER, Lawrence A.	Department of State
SOLOMON, David	Bureau of Public Roads
SPENCER, Richard A.	Patent Office
STERNBERGER, Jesse L., Jr.	Federal Aviation Agency
STEVENS, John T.	Navy Department
SUSZYNSKI, N.	Smithsonian Institution
SUTHERLAND, Henry C.	Patent Office
SUZUKI, George	National Bureau of Standards
THAYER, T. C.	Office of Assistant Secretary of Defense
TREIRES, James J.	Economic Development Administration
TRIPLETT, Robert S.	National Civil Defense
TYNER, Richard	State Department
URBAN, Bernard	Bureau of the Budget
VAN TRAIN, W. A.	Office of Naval Warfare Analyses
VERNIER, Claire M.	Veterans Administration
VINCENT, Alvin R.	Atomic Energy Commission
WAGNER, Lloyd	Veterans Administration
WALTERS, Stanley S.	U.S. Arms Control and Disarmament Agency
WEIL, Lisa	National Bureau of Standards
WEINGARTEN, Harry	Bureau of Public Roads
WIGLER, Ken	Department of Agriculture
WILKES, John D.	Agency for International Development
WILLIAMS, Jacob A.	Social Security Administration
WILLOUGHBY, John E.	Veterans Administration
WILSON, Dale W.	DSAH-LSO Cameron Station
YUROW, Jerome A.	National Bureau of Standards
ZABROWSKI, Edward J.	Office of Education
ZIMMERER, Robert W.	National Bureau of Standards
ZWINSCHER, Walter H.	Federal Aviation Agency

Acknowledgment

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