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1978 NASA AUTHORIZATION

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HEARINGS
BEFORE THE
SUBCOMMITTEE ON
TRANSPORTATION, AVIATION AND WEATHER
OF THE
COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
NINETY-FIFTH CONGRESS
FIRST SESSION
ON
H.R. 2221
(Superseded by H.R. 4088)

FEBRUARY 16 AND 17, 1977

[No. 1]

VOLUME II
Part 2

Printed for the use of the
Committee on Science and Technology

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U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1977

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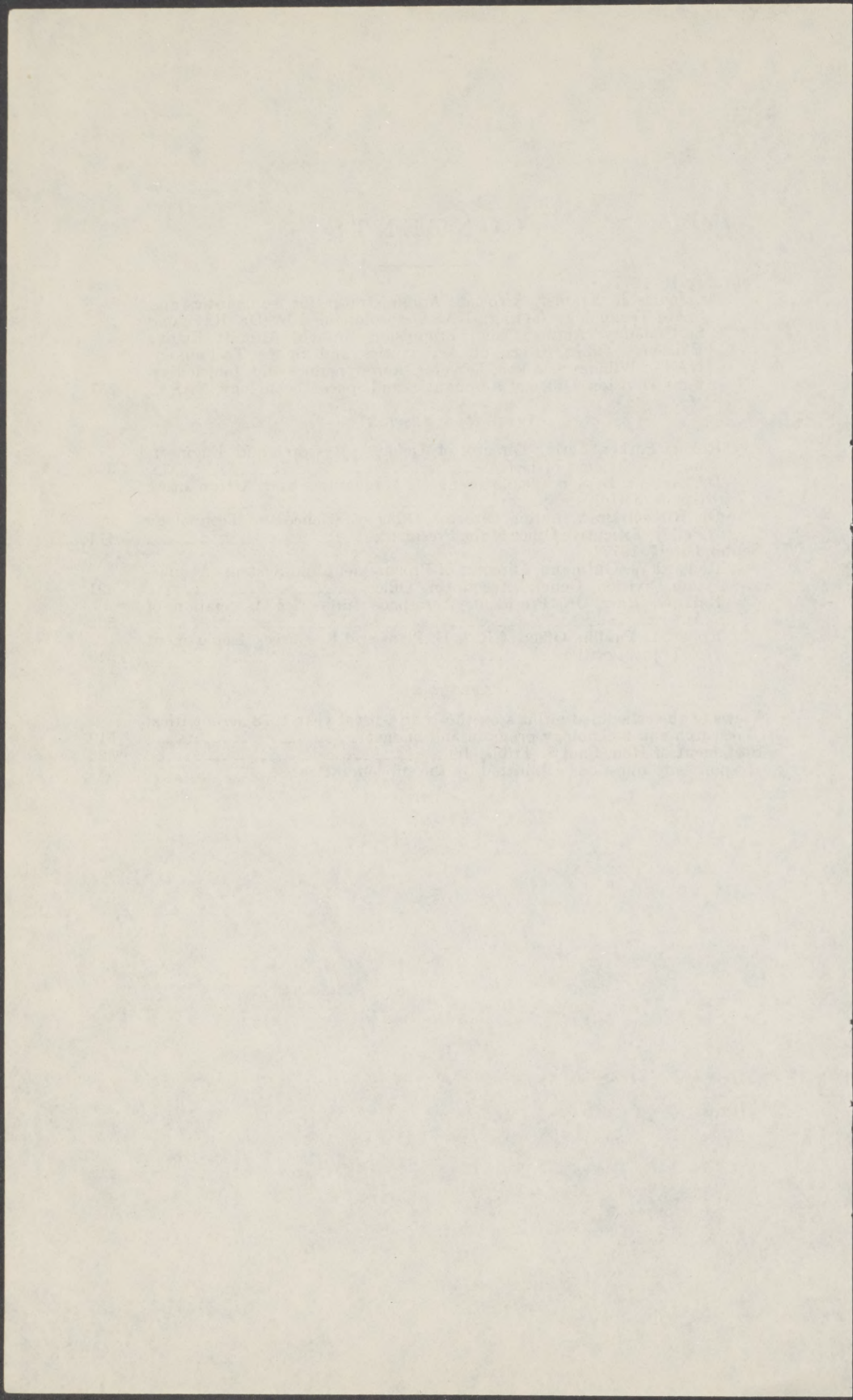
Dr. James J. Kramer, Associate Administrator for Aeronautics and Space Technology (acting), NASA, accompanied by Dr. Raymond S. Colladay, Acting Chief, Propulsion Branch, Aircraft Engine Efficiency Office, Office of Aeronautics and Space Technology, NASA; William S. Aiken, Director, Aerodynamics and Vehicle Systems Division, Office of Aeronautics and Space Technology, NASA	Page 257
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1978 NASA AUTHORIZATION

WEDNESDAY, FEBRUARY 16, 1977

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND WEATHER,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:30 a.m., in room 2325, Rayburn House Office Building, Hon. Dale Milford, chairman, presiding.

Present: Representatives Milford and Wydler.

Mr. MILFORD. The subcommittee will come to order.

Today the Subcommittee on Transportation, Aviation and Weather will start the second phase of our annual review and authorization of the NASA fiscal year 1978 aeronautics program.

The first phase, which was completed last fall, consisted of program review hearings in Washington along with visits to several NASA field installations and many of our major industrial facilities.

The information gathered at these meetings provided a useful background for the budget review which we are starting today, and which will lead to markup of the fiscal year 1978 NASA authorization for aeronautics.

Before we begin, I want to remind the members that the 5-minute rule for questioning will be closely enforced.

Our first witness is Dr. James Kramer, who is the Acting Associate Administrator for Aeronautics and Space Technology at NASA.

Dr. Kramer, we welcome you to the subcommittee.

I am sorry that some of our other members are not in this morning. We had a shift in plans at the last minute in the House schedule, and as a result, many have to take care of other business.

STATEMENT OF DR. JAMES J. KRAMER, ASSOCIATE ADMINISTRATOR FOR AERONAUTICS AND SPACE TECHNOLOGY (ACTING). NASA, ACCOMPANIED BY DR. RAYMOND S. COLLADAY, ACTING CHIEF, PROPULSION BRANCH, AIRCRAFT ENERGY EFFICIENCY OFFICE, OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY, NASA; WILLIAM S. AIKEN, DIRECTOR, AERODYNAMICS AND VEHICLE SYSTEMS DIVISION, OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY, NASA

Dr. KRAMER. Thank you, Mr. Chairman.

It is a pleasure to be here.

Since we last spoke to you in September, we have had some changes in the management structure of OAST. I am now acting as the Asso-

ciate Administrator, replacing Ed Smylie, who was the Acting Associate Administrator the last time we spoke to you. Mr. Paul Holloway on my left, whose normal activity is Director for Space at the Langley Research Center, is serving as my deputy temporarily. On my right is Mr. Aiken, Director of our Aerodynamics and Vehicle Systems Division. He will testify shortly on our supersonic cruise aircraft research program.

We have, as you know, prepared fairly extensive written statements, and we would appreciate it if those statements would be made a part of the record.

Mr. MILFORD. Your entire statement will become a part of the record at this point, and you are welcome to either read it or summarize it, or present it in any fashion you care to.

Dr. KRAMER. Thank you, Mr. Chairman.

[The prepared statement of Dr. Kramer follows:]

HOLD FOR RELEASE UNTIL
PRESENTED BY WITNESS
FEBRUARY 16, 1977

NASA AERONAUTICS FY 1978 AUTHORIZATION REQUEST

Statement of

Dr. James J. Kramer
Acting Associate Administrator
Office of Aeronautics and Space Technology
National Aeronautics and Space Administration

Before the

Subcommittee on Transportation, Aviation and Weather
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

In preparing NASA's proposed FY 1978 aeronautics program, we have had the benefit of several sources of guidance not ordinarily available as part of the normal planning process. One of the primary inputs has been the October 1976 report of this subcommittee on its review of The Future of Aviation. I think it is safe to predict that the future of aviation, and the important contributions which aviation makes to our transportation and economic well-being, will be materially improved by this report and the changes it will bring about.

In some instances, the recommendations in the subcommittee report address issues much broader than the specific research and technology aspects which are NASA's primary or exclusive concerns. A thorough response to the recommendations will require actions by NASA, by other executive agencies, and probably by the Congress -- and cannot be achieved during the next few months. Nevertheless, these recommendations have influenced our FY 1978 planning, and they form a frame of reference for your authorization considerations. I therefore propose to introduce the budget discussion by expressing NASA's position on those recommendations which relate directly to the research and technology activity covered in our authorization request. I will not repeat the individual recommendations verbatim, but the references to specific recommendations are underlined in the written text for convenient identification.

First, we agree completely that preeminence in aeronautics is absolutely vital to the national interest,

and that this point should be accepted as national policy. We believe further that preeminence depends critically upon research and technology, and that government aeronautical R&T must therefore be vigorous, effective, and constantly tuned to apparent and anticipated national needs. Creation of a National Civil Aviation R&D Policy is certainly a worthy objective; so is the related recommendation concerning expansion and independent pursuit of federally-sponsored civil aeronautical research, development, and demonstration (R, D, and D) efforts to compensate for reduced military fall-out. In connection with both of these recommendations, however, NASA's experience in providing the technical foundations for both civil and military development has shown that, even when the developments diverge -- as they do for specialized combat aircraft -- the research and technology in the aeronautical disciplines are usually commonly applicable. The ability to take full advantage of this important R&T commonality, assuring the necessary military and civil technology advancement with minimal duplication of effort and facilities, is a public benefit which should be preserved carefully when measures are defined to strengthen the civil-oriented activity. The civil/military research and technology commonality must also be given serious consideration in regard to the recommendation that the responsibility for coordination of all government-sponsored aeronautical R&D be assigned to a centralized authority with jurisdiction over federal agencies dealing with civil aviation. Under the present arrangement, our R&T programs fulfill both civil and military needs. Both DOD and DOT/FAA are represented in NASA's advisory committee structure, and we hold routine formal coordination meetings with both agencies as well as frequent exchanges on specific issues.

With regard to the recommended restructuring of R, D, and D programs for better coordination with other modes of transportation and for expansion of R&T into other areas of development beyond the capacity of private enterprise, some comments appear in order. Far more than other established modes of transportation, aviation is highly dependent on advanced technology -- for civil transportation, military superiority, and aeronautical exports. Cross-modal coordination of research and technology can strengthen both the transportation system and the national posture -- but it must be based on actual needs. Coordination must not be permitted to retard progress in aeronautics or in any other mode by arbitrary pressures for equality among modes. Pending definition of the better coordination mechanism, NASA

will continue to base its aeronautical R&T planning on the combined consideration of air transportation and military aviation needs, and international aeronautical competition.

NASA also supports the view that government activity should go beyond traditional research and technology bounds and should extend to the point where results can be readily applied by industry. For the past several years we have been increasing our efforts on technology demonstration to facilitate the application of research results by industry -- as illustrated by the composite structures and active controls flight demonstrations included in our Aircraft Energy Efficiency program. These technology demonstration programs, in which we work closely with the FAA, go well beyond previous traditional R&T bounds and facilitate certification as well as design implementation of new technology advances. We do not, however, view NASA's role as encompassing larger scale demonstrations such as prototypes or transportation system demonstrations.

One additional point should be made relative to the recommended restructuring and reorientation of R, D, and D programs: As the subcommittee report points out, new-generation air transport products require years of development and long-term financial commitments. The research and technology to make such development possible, however, may require even more years, and must be initiated long before general agreement can be reached as to which developments will actually or even probably be undertaken. The establishment of long-term stabilized goals, and the corresponding identification of required Federal resources must, therefore, include substantial allowance for the conduct of R&T which provides options for important potential developments, and not simply R&T which supports firmly committed programs.

Several of the subcommittee recommendations address the increased threat of government-subsidized foreign competition and the related issues of technology export and multinational joint ventures. These are complex issues involving numerous factors other than technology. Because the technology is a primary consideration and a clear NASA responsibility, however, we have initiated studies which we hope will provide clarification and guidance. In one study, we are reviewing the competitive state of the art in the technology areas considered critical to international competition for civil aircraft markets; we are also examining our procedures for periodic updating of such assessments and for expediting the

dissemination of critical NASA research results to U.S. industry. In another study we hope to define the specific technology transfers likely in various types of multinational joint ventures, and to assess at least qualitatively the benefits and costs of the technology transfer in relation to the other positive and negative attributes of joint ventures. Although these modest study efforts are not intended to cover the full range of questions raised by the subcommittee, they should provide valuable insights from the technology standpoint.

NASA endorses the recommendation that the Department of Transportation provide a focus for civil aviation R&D by addressing the role of aviation within the national transportation system, and the markets best served by air. We believe NASA can best contribute to this endeavor by continuing to identify desirable alternatives offered by air transportation, and opportunities for improved air transportation derived from available or anticipated technology advances. We will also continue to coordinate with the DOT in our own transportation systems studies, which we conduct to evaluate various technology alternatives and to explore potential options as a guide to early planning of long-lead-time research.

With respect to the recommendation on accelerating the technology availability date for an environmentally acceptable, fuel efficient and economically viable supersonic air transport aircraft, we are proposing this year to augment our Supersonic Cruise Aircraft Research (SCAR) program by advancing from the small-scale component level to the large-scale subsystem testing level in our work on the technology for the variable cycle engine (VCE) which is crucial to accomplishment of these more advanced supersonic flight objectives.

Consistent with the recommendation relative to expansion of the Aircraft Energy Efficiency (ACEE) program, the FY 1978 request features a considerable expansion of the ACEE program, with emphasis on expediting the technology readiness for practical application of results by industry.

Finally, in regard to the recommendations concerning technology and standards for noise and emission suppression, NASA's R&T programs continue to emphasize work directed at these vital environmental concerns. Our objective is to provide advanced technology results as quickly as possible to the regulatory agencies as a basis for rational regulatory standards, and to the industry as a basis for design and production of

equipment meeting the standards. As a research agency, we are free to pursue potential technical advances without the pressures of regulatory or operational responsibilities. Nevertheless, we recognize the obligation to provide with this technology the assurance that the results have been adequately proven and that the data are sufficiently complete to permit accurate determination of the economics of implementation. I believe our programs are fully responsive to these needs.

The intent of this introductory discussion has been to place our aeronautical research and technology authorization request for FY 1978 in perspective relative to the subcommittee's stated positions on aviation research and development policy and to present NASA's views on resulting issues.

The Aeronautics research and technology budget request is \$231 million (Figure 1), an increase of 22 percent relative to FY 1977. The increase is made up of an \$8.5 million increment to the R&T Base, which generates advances in the primary technical disciplines and thus provides the foundation for both ongoing and future programs, and a \$32.4 million buildup in Systems Technology and Experimental Programs, in which technology advances are carried toward the point where they can be applied in actual development. While responsive to the need for constraints on government expenditures, this budget is designed to assure continued progress in FY 1978 in each of the program areas selected for emphasis, and in the continued R&T Base preparation for more advanced programs in the future.

In presenting the FY 1978 program, I believe I can best convey to you the direction and emphasis of our activity by highlighting the Systems Technology and Experimental Programs being conducted in the major areas identified in our planning activities (Figure 2). I will also review, under the headings of Generic Technology and R&T Base some other important systems technology activities and some significant research which is more basic and not specifically directed toward particular applications. I will also call on Mr. Aiken and Dr. Colladay to discuss in greater detail the proposed major efforts in Variable Cycle Engine-Supersonic Cruise Aircraft Research and Aircraft Energy Efficiency technology.

In Helicopter/VTOL technology we are reaching the important flight testing phase in two major joint Army/NASA research programs. October 1976 saw both the

first flight of the Rotor Systems Research Aircraft (RSRA) (Figure 3) and the roll-out of the first Tilt Rotor Research Aircraft (TRRA) (Figure 4).

We have, as you know, made the Ames Research Center our lead center for helicopter technology activities in order to improve the effectiveness of our helicopter research. Research objectives are aimed at continuing advancement in helicopter performance, vibration and dynamics, noise, and flying qualities.

The RSRA will be utilized in advanced rotor research (Figure 5) as a flight research facility which is the culmination of the research activities carried on in ground laboratory facilities and in preliminary flight experiments. Small-scale tests in wind tunnels (upper left, Figure 5) will evaluate rotor aerodynamics and advanced hub concepts; large-scale or full-scale tunnel tests (lower left) will follow for rotor concepts which show promise in the small-scale tests; flight tests of advanced rotor airfoils on the AH-1G "Cobra" Research Helicopter (lower right) will be completed in FY 1977. RSRA flight tests (upper right) will continue into FY 1978. They will be conducted with the initial rotors and in both the basic helicopter configuration shown and a compound configuration with wings and jet engines. Objectives include vehicle flight envelope expansion and investigations of handling qualities and other flight characteristics -- some of which are possible only with a flight research facility such as the RSRA which permits us to isolate the rotor for research measurement and to operate over a broad range of rotor loadings by transferring load from the rotor to the wings. Future flight research on the RSRA will evaluate advanced rotors and control concepts now being explored in the R&T Base program. The two RSRA vehicles are scheduled to be delivered to the Ames Research Center in late FY 1978 following their contractor flightworthiness testing.

In the rotorcraft technology area, we will be emphasizing technology for helicopter transmissions. The objective is to bring several advanced transmission components, which have reached individual technology readiness, into a state of integrated system technology readiness. The program goal is to establish a high level of confidence in the use of advanced mechanical components in civil and military helicopter transmissions and similar applications so that major reductions in maintenance can be realized (Figure 6). The program goal is 2,500 hours between overhauls, compared with about 700 hours today.

In FY 1978 transmission system designs will be started, accompanied by some component testing -- primarily bearings and gearing. Greater durability is sought in the bearings, and higher load capacity for a given size is expected in the gearing. Also being evaluated is a traction drive speed reduction system which could exceed the capability of conventional gearing in terms of speed reduction, low noise and long life.

In the Tilt Rotor research program flight tests will get under way with a pair of research vehicles (Figure 4). Proof-of-concept flight tests will start in FY 1978, following full-scale tests in the Ames 40-by-80 foot wind tunnel. The objectives of the flight tests will be to explore the vehicles' operating envelope and to evaluate their performance, dynamic stability, handling qualities and terminal operations. By being able to operate the rotors both in this vertical-lift position (Figure 4) and in a forward-thrust, propeller-like position in flight, a tilt rotor aircraft attains the hovering characteristics of a conventional helicopter with about twice the cruise speed.

The technology of higher performance VTOL aircraft will be advanced through continuation of the aerodynamic and flight dynamic R&T Base activities. Both low- and high-speed wind-tunnel tests will be conducted with powered models. The Ames flight simulators and advanced analytical programs will also be used to improve the prediction of performance and flying qualities. NASA activities in VTOL technology will be closely coordinated with Navy needs and R&D programs.

Another type of VTOL flight system receiving attention is the heavy-lift airship (Figure 7). Buoyant and rotor lift are combined in a hybrid vehicle predicted to be capable of precision vertical lift and placement of heavy, outsized loads. Potential military uses include ship off-loading, as in an emergency when port facilities are damaged or inadequate. Civil uses include transportation of power plant or reactor components, placement of assembled oil-rig or transmission towers, and short-haul cargo movement in regions with inadequate ground transportation. Availability of this postulated heavy-lift capability could lead to significant changes in several major industries and their design and fabrication processes. After several years of study, and in cooperation with the U.S. Navy and Army, NASA expects to initiate basic technology activities in FY 1978 in areas such as stability and control, aerodynamics and structures.

The next FY 1978 highlight area is General Aviation. This broadly based R&T program, which has been strengthened with the subcommittee's encouragement and support, is now showing visible results in production aircraft (Figure 8). Activities continue in crashworthiness, noise and emission reduction, drag reduction, interior noise reduction, and integrated avionics systems. The FY 1978 program (Figure 9) will highlight: airfoil development with emphasis on medium-speed (300-500 mph) applications on high-performance, single- and twin-engine turboprop aircraft; stall-spin research, in which the effort will be accelerated and expanded to include full-scale testing with high-wing, low-wing and twin-engine aircraft; low-cost avionics, particularly in navigation equipment and cockpit displays; and propulsion, including component testing and assembly of the Quiet, Clean General Aviation Turbofan (QCGAT) experimental engines and the advancement of propeller technology using new materials; airfoil sections and controls.

A closely related technology area which has received considerable recent attention is that of aerial applications, or agricultural aviation. This is a difficult area to assess because of the diversity of operations and multitude of manufacturers and users. Extensive NASA contacts with people and organizations in this field, including three NASA-sponsored workshops, have pointed to critical needs and high potential benefits. Program definition is under way in FY 1977 by means of system studies and preliminary experimental evaluations. The objective is to aid NASA management in its determination of a proper NASA role and level of involvement. During FY 1978 we expect to investigate four principal technology areas (Figure 10): improved aircraft characteristics, flow field modification, integrated dispersal equipment, and specialized measurement systems. We are identifying the major requirements and limiting factors in aerial applications and will then develop the technology to apply the materials, liquid or dry, precisely where they are needed and in controlled quantities. These efforts thus far, and complementary programs by EPA, USDA and FAA, show that significant improvements can be achieved.

In response to recommendations by the GAO as a result of its review of the federal activity on short-haul STOL aircraft, we reassessed the technical content, scale, and pace of NASA's STOL technology program. The reassessment included reviews in depth with the DOT, the FAA, and the DOD, and emphasized the relationship between

NASA's activities and those of other interested agencies. Recognizing that NASA's concern is the long-lead technology which is required to provide options for advanced short-haul systems in the future, and recognizing also that the propulsive-lift technology has potential application to conventional as well as STOL aircraft, it was generally agreed that the program is appropriate, necessary, and timely. We will continue to coordinate and evaluate our program with these agencies and with industry in the context of evolving civil and military plans for applying STOL technology.

The current program to advance the technology of short-haul transports, with emphasis on quiet propulsive lift for short-takeoff-and-landing (STOL) aircraft, is chiefly comprised of the Quiet Short-Haul Research Aircraft (QSRA) project, NASA participation in the USAF flight tests of the Advanced Medium STOL Transport (AMST) prototype aircraft, the Quiet, Clean Short-Haul Experimental Engine (QCSEE) Program, and the STOL Operating Systems Experiments Program. Flight research on QSRA (Figure 11) is scheduled to begin in FY 1978. A C-8A Buffalo aircraft is currently undergoing modifications (see insert, Figure 11) to receive the new wing and engines, and will be out of the Boeing shop in about a year.

The QSRA is a research aircraft designed to permit flight investigations over a range of conditions beyond the capabilities of an AMST which, as a military pre-production prototype, is necessarily a point design. The QSRA is also designed to allow flight research specifically addressed to future civil applications, including broad and flexible exploration of operational boundaries, safety margins, and noise characteristics of a high propulsive-lift configuration. Such data are necessary for civil certification of STOL transports. Wind-tunnel tests of one-sixth and one-half scale models have been completed, showing satisfactory flap/nozzle flow turning and providing essential design data on flow interactions, aerodynamic performance, air loads, and stability and control coefficients.

While an AMST (Figure 12) is less versatile as a flight research facility, it provides a very useful adjunct to the QSRA with the advantage of earlier flight availability. NASA's participation in the USAF's AMST flight test program is an opportunity to obtain necessary STOL data and correlate flight, simulator and wind-tunnel test data. Although NASA's part in the prototype test and evaluation program was on a limited, noninterference

basis, valuable research data have been obtained. In FY 1978, during the AMST development phase, NASA will have additional opportunity to measure research data relative to a wide variety of STOL aircraft characteristics throughout the range of operating conditions. These flight data will be used to correlate theory, wind-tunnel model data and test-rig data to improve our understanding of propulsive-lift STOL transport aircraft.

NASA's Quiet, Clean Short-Haul Experimental Engine (QCSEE) Program (Figure 13) is designed to provide advanced propulsion system technology applicable to future STOL transport aircraft. QCSEE objectives include major noise reduction and the demonstration of several advanced technology propulsion innovations, such as the acoustically-designed, all-composite, structurally-integrated nacelle. The noise goal is a 90 EPNdB footprint area of under one square mile (compared to 4-5 square miles for the YC-14 AMST). Test results through CY 1976 from inlet/nozzle-model and initial full-scale engine tests (Figure 13) give us high confidence that program objectives will be met. The QCSEE program is scheduled to be completed in FY 1978.

In addition to these highlight theme areas, in which our aeronautical technology activities are focused on specific aviation needs and systems, a substantial portion of our FY 1978 technology activity will be generic or related to other potential applications or broad problem areas. One such activity is that of configuration research aimed at the improvement of military combat aircraft (Figure 14). Using wind tunnels, remotely-piloted research vehicles (RPRV) and full-scale military aircraft, NASA is carrying out a coordinated program of configuration research. The objectives include maneuverability enhancement through the use of canards, strakes, blowing and thrust vectoring as well as improved propulsion integration with two-dimensional nozzles. Proof-of-concept flight tests follow for the most promising technologies. The HiMAT program (Figure 15) will provide a remotely-piloted flight research facility for safe and economical integration and demonstration of advanced configuration features, serving to verify wind-tunnel and analytical data, and making the combined use of these research tools more effective. These methods, used in a unique interactive fashion, have resulted in a configuration which should provide a 100 percent increase in aerodynamic efficiency at high lift. That is, compared to current and emerging maneuverable aircraft, the HiMAT vehicle should be

capable of twice the 'g' loads. In FY 1978, fabrication of the HiMAT research vehicle will be completed and the flight research program will begin.

Looking further into the future, long-lead technology is being pursued for potential use in advanced aeronautical concepts. Included are very large, long-range cargo aircraft -- possibly several times the capacity of the B-747F, some concepts having the load carried inside the wing. Hydrogen fuel for aircraft also continues to be a possible future option because of the potential improvement in petroleum consumption and environmental impact. Low-level programs of studies and critical disciplinary experiments will be continued in FY 1978 in these and similar advanced concept technologies, providing the basis for future decisions regarding the elevation of such programs to major emphasis status.

In the area of Aircraft Operating Systems Technology, NASA will identify aircraft system and flight management technology of benefit to CTOL, STOL and VTOL terminal-area operations. Research is being conducted in cooperation with the FAA that will support improvements in terminal-area capacity and efficiency, approach and landing capability in adverse weather, noise impact, and fuel conservation. As an aid in realizing these objectives, NASA's Terminal Configured Vehicles (TCV) program (Figure 16) uses a representative CTOL airplane (a B-737, upper left in Figure 16) which has been equipped with a second (aft) flight deck and an array of computers and instrumentation in the passenger cabin. The display, navigation and flight control systems in the TCV research airplane are the first application of all-digital systems to a conventional transport. The aircraft is designed to be flown from the forward flight deck (lower left) with conventional flight controls and from the aft flight deck (upper right) using a fly-by-wire, triply-redundant digital computer system. Advanced electronic displays (lower right) and pilot-selectable navigation, guidance and control functions are combined during our research into operations such as fully automatic landings. Such landings were demonstrated with the Microwave Landing System (MLS) at the FAA National Aviation Facility Experimental Center (NAFEC) in May 1976 for ICAO representatives. In FY 1978 the TCV program will conduct flight experiments to expand our data base and flight experience with advanced digital systems and displays, utilizing techniques previously evaluated in ground simulation facilities.

In a coordinated effort with the FAA, we are undertaking an evaluation of head-up displays. During FY 1978 the evaluation will be extended to full mission simulation studies to determine the advantages and disadvantages of the device in conditions as close to operational realism as possible. Investigations in the flight management area are continuing to assess factors affecting human performance in the cockpit. This human factors research investigates the complex interactions among crew members, aircraft, and the air traffic system, using flight simulation to represent operational conditions. Specific emphasis is on developing means to enhance crew coordination.

Another broadly applicable systems technology project is IPAD (Figure 17), which stands for Integrated Programs for Aerospace Vehicle Design and is the development of a computerized system to support the design process for complex aerospace vehicles. The objective is to reduce significantly the cost and time required for vehicle design; the program goals are reductions of 25 percent in cost and 50 percent in time. As illustrated, a design team would operate with interactive facilities, each member having a specific responsibility but working together in real time through the computer. Console displays and controls would permit ready modification of technical and management information in graphical and textual format, interactive communication among users, and on-line manipulation of codes, data and other design information. The first release of IPAD for evaluation purposes is scheduled for June 1978. Feedback from users will lead to an updated capability in mid-1979 and a general IPAD release in the Fall of 1980. This project is proceeding with strong support and interaction with the potential users in the aerospace industry.

In the Materials and Structures area, the use of composites is projected in just about every advanced vehicle system concept. As a complement to the primary structures activity in the ACEE program, NASA has begun a technology effort focused on composites durability. The objective is to provide the statistically valid quantitative information necessary for a high degree of confidence in prediction of durability and integrity of composite structures. The effort in FY 1978 extends the R&T Base work on laboratory specimens to subcomponent tests under combined loading. Techniques of damage detection and quality control will also be investigated, leading to extensive statistical data on life prediction and environmental effects, and to continued extension of service life.

The Digital Fly-By-Wire program involves flight research and technology demonstration on a triplex digital fly-by-wire flight control system. In FY 1978 we will be conducting an average of two flights per month to complete the evaluation of advanced transport control laws in a representative environment, leading to a design base in FY 1979.

The Stratospheric Cruise Emissions Reduction Program (SCERP) was begun in FY 1977 (Figure 18). The objective of the SCERP program is to demonstrate advanced combustor technology which could enable significant reductions in nitrous-oxides (NO_x) emissions of future subsonic aircraft during high altitude cruise operations. The SCERP emissions index target is set at or below the recommendation of the Climatic Impact Assessment Program (CIAP). Contracts have been let for the initial part of the program, in which advanced combustor and fuel preparation concepts will enter hardware phases during FY 1978.

The foregoing discussion of technology programs and highlight areas illustrates how concepts and technology applications are carried forward toward eventual readiness for operational use. Before reaching Experimental Program or Systems Technology status, they all had their beginnings in the R&T Base Program. Accounting for nearly one-half of the OAST program budget and engaging the majority of aeronautics Research Center personnel, the R&T Base continues to be an active source of new technology in each of the aeronautical disciplines. The program contains far too many items to permit even an attempt at full coverage. I will, however, cite some examples which illustrate representative segments of our FY 1978 R&T Base activity.

Two examples in the high-temperature materials area are: (1) a process for applying thermal barrier coatings to metallic turbine blades and (2) recent progress in the design of ceramic turbine blades. The Lewis Research Center has developed the coating process (Figure 19), in which two layers are applied -- an inner, metallic layer for compatibility with the substrate, and an outer layer of insulating oxide. This coating reduces the temperature of the metal turbine blade 200°F below the outer surface temperature. Operation at the allowable higher inlet temperature would substantially increase jet engine efficiency and reduce operating cost accordingly. Oxidation and erosion would also be reduced. In FY 1978, turbine wheels with coated blades (the light-colored blades in the photo) will be tested

in full-scale engines, and the method of application will be automated.

The second materials example is ceramic turbine blades. Ceramics have long been of interest as high temperature materials for gas turbine applications. Compared to state-of-the-art superalloys, ceramics have the potential of operating at higher temperatures with superior corrosion resistance. They may also be much less costly and use non-strategic materials. The major problem with ceramics, however, is their brittleness. This shortcoming may often times be avoided through careful design. The Lewis Research Center recently made significant progress in this area by successfully testing a new ceramic turbine blade and root design for use in a metal disc (Figure 20). This design was successfully tested at 2200°F for 100 thirty-minute cycles (50 hours). In FY 1978 additional testing will be conducted and necessary design changes will be incorporated to approach more nearly the high-temperature potential of ceramics. Incidentally, this technology is currently being applied to the design of a Navy marine turbine and an ERDA automotive turbine.

Another application for ceramics in gas turbines has to do with minimizing the loss of gas turbine efficiency by improved seals (Figure 21). The gap between the shroud or seal that encases the turbine wheel normally increases with operating time due to the oxidation of the shroud and the occasional rubbing of the blades against the shroud. An increase of 0.010-inch in clearance results in about one percent loss of turbine efficiency. The Lewis Research Center has sponsored the development of ceramic abradable seals that are much more resistant to oxidation and erosion than metallic seals. Recent results show that abradable ceramic seals offer the potential of uncooled operation at turbine temperatures at which metallic seals suffer significant inefficiencies due to cooling air flow requirements. For example, the two percent improvement in fuel consumption (Figure 21) if applied to the 747 fleet, would save 15 million gallons of fuel per year. Research efforts in FY 1978 will be aimed at optimizing the abradable characteristics of ceramic seals and increasing their high temperature resistance to 2500°F.

Research is also being conducted to enhance the fire resistance of aircraft interiors. Whereas, in other R&T activities we seek ways of preventing fire, in this activity we are concerned with slowing the spread of fire across and through materials in the cabin and unattended areas such as cargo bays. The results

of the research will be materials with much improved overall fire resistance (Figure 22) in terms of ignition temperature, flame spread and toxicity. We are preparing to test nine different panels representing the best materials now commercially available and advanced materials which will become available in the near future. Tests have begun on one panel. Further testing in FY 1977 is expected to show that this panel is a 100 percent improvement over current materials. In FY 1978 we will complete the testing of all nine developmental panels. Our estimate of the improvement that can be expected for panel materials in terms of controlling ignition, flame spread and flash-over is a total fire resistance some 4 to 5 times that of currently used materials. These efforts, along with complementary research on fire characterization and related systems technology testing in the Fire Resistant Materials Engineering program, are expected to result in improved technological options for cabin design and fire control.

In the area of aircraft structures, our research on aeroelasticity is aimed at developing the capability to predict and avoid wing flutter. Flutter is due to interactions between unsteady aerodynamic loading and structural response. Success in this effort will pay off through increased maneuver performance, payload, range and energy efficiency. Prediction methods have developed into integrated programs which can be used to predict both flutter boundaries of aircraft and their response to external disturbances such as gusts and turbulence. Simultaneously, we have conceived and evaluated techniques for the avoidance of flutter and minimization of aircraft response -- especially active control technology and passive control via aeroelastic tailoring of control surfaces -- using correlations of analytical, wind-tunnel and flight-test data. As reported to the subcommittee last September, one such program (Figure 23) involves the use of the Navy FIREBEE II drone as a remotely piloted research vehicle (RPRV). The use of an RPRV permits investigation of flight regimes which could not be explored with manned vehicles. The vehicle has been modified to accept a variety of wing planforms, including research wings designed to flutter within the vehicle's flight envelope. The first flight tests of such a research wing will be conducted in FY 1978. During these tests the vehicle will be flown beyond the flutter boundary (in the cross-hatched region on the altitude-speed plot), both with and without active controls.

Several times in preceding discussions the use of advanced analytical tools has been mentioned. An example of our efforts to extend computational aerodynamics capabilities, as a low-cost adjunct of wind-tunnel and flight testing, is an attempt to exploit recent advances in the disciplines of computer science and fluid mechanics. We are in the process of defining a special facility -- an optimized fluid dynamics processor -- to provide numerical flow simulations at processing speeds some four orders of magnitude faster than now possible with the world's fastest multi-purpose computer, the ILLIAC IV. The definition and preliminary design of the processor will continue in FY 1978.

In the area of aircraft noise and exhaust emissions, our research programs will continue to expand our basic understanding of the phenomena associated with the generation, propagation, prediction and reduction of both noise and exhaust pollution emissions. As we noted in greater detail to this subcommittee in the September 1976 Pre-Authorization Hearings, we are exploring the feasibility and effectiveness of attractive concepts for noise and pollution reduction in realistic applications. The FY 1978 efforts will include wind-tunnel and flight tests to improve our capability to predict accurately flight noise from ground static measurements. We will also be examining techniques and concepts for reducing piston engine emissions for general aviation.

The research and technology efforts in propulsion components will continue to emphasize energy conservation. Fan and compressor research will explore the limits of pressure ratio obtainable from high performance compressor stages without sacrificing efficiency. The combustor and turbine R&T programs will be directed toward resolving the problems of operating at the high pressures and temperatures identified with energy efficient engines. In the engine drive system component research area, our efforts will be focused on improving high-speed, highly loaded gears, seals, shafts and bearings.

Another potentially fruitful area of propulsion research is concerned with the integration of engines and airframes (Figure 24). For example, current nozzle installations in high-performance aircraft often result in excessive boat tail drag. Non-axisymmetric nozzles, generally two-dimensional in configuration, offer significant drag reduction and other advantages such as the ability to vector thrust for maneuverability and safety and improvements in mechanical

reliability, cost and service life. The research effort involves detailed flow analyses, conceptual design studies and the development of methods for predicting overall installation effectiveness.

Another example of the diverse but essential nature of our R&T Base program is that of alternate fuels research. NASA activities with respect to alternate hydrocarbon fuels are conducted in close cooperation with corresponding DOD, ERDA and FAA investigations. The FY 1978 effort will continue the testing of broadened fuel specifications for fuel-use flexibility. Both petroleum-based fuels and those which in the future will be refined from shale or coal will be included. Engine compatibility with these fuels will be investigated through assessments of "hot section" durability, fuel-system materials behavior, and exhaust emissions, leading to design criteria for both existing and future energy efficient aircraft and engines.

The aim of our research in aircraft operating problem areas and aviation safety is to provide a technological basis for eliminating or avoiding serious hazards of the operational environment. In one such activity (Figure 25), and in cooperation with other agencies, we seek further understanding of atmospheric processes, including severe turbulence and wind shear. The FY 1978 effort will include development of measurement techniques and simulation capabilities, tools with which operational procedures for coping with these anomalies can be perfected. We also seek improved safety in the ground-run phase of takeoff and landing (Figure 26), chiefly through (1) the use of a moving-base simulator for investigating directional control problems on the runway, (2) experiments with crosswind landing gear and (3) improvements in aircraft tire tread materials. This research is carried out with unique facilities and equipment designed to extend the limits of testing and understanding beyond what is usually attainable with exploratory and developmental flight testing.

A last example of R&T Base activity (Figure 27) is in avionics, in which a recent review of future directions has led to redefinition of emphasis on three electronics technology drivers: digital operations, integrated control and cockpit avionics. The aim of digital operations technology (Figure 28) is low-cost aircraft navigation and digital communications to permit all-weather operations and minimal fuel consumption. This would be achieved through advanced onboard systems and data links that can be used with the DOD satellite

Global Positioning System (GPS) to provide air route traffic control, precision navigation, collision warning, and automated weather, route and status reporting. Potential benefits include both reduced costs of onboard systems and ground operations and greatly improved safety and efficiency of aircraft flight operations. For example, the cost of onboard equipment compatible with the GPS could be as low as \$50,000 for a transport and \$5,000 for a light aircraft. FY 1978 efforts will consist of preliminary design studies to define aircraft navigation equipment and coding requirements to interface with GPS and to explore the potential of the digital data link.

The second new direction in avionics R&T, integrated control (Figure 29), concentrates on the integration of airframe, propulsion and subsystem control to enhance the efficiency and economics of future aircraft. Functions which are independent on current aircraft (such as fuel management, airframe control, propulsion control and landing loads control) will be combined both operationally and through the use of multipurpose hardware. The results should be improved control, reduced aircraft weight and fuel consumption, fewer black boxes, and reduced maintenance -- all achieved with greater reliability. The potential reduction in black boxes is significant: from 64 to 20 in a B-737 class aircraft. The FY 1978 objective is to develop the conceptual specifications for such integrated control functions and systems.

Our work in cockpit avionics (Figure 30) focuses on the incorporation of advanced technology into the cockpit to optimize pilot workload and improve safety. More than 100 cockpit displays and controls are now required for operation of a typical transport. The development of advanced multipurpose displays and microprocessor-implemented mode controls for the various flight regimes could significantly simplify the pilot's tasks, as well as reduce avionics costs by better than 25 percent. Early elements of this program, to be initiated in FY 1978, will include the design and development of a multipurpose liquid-crystal-device display in a joint effort with the Air Force. Related efforts will address information input/output technology and design of alternate overall cockpit configurations. Later operational evaluations would be planned in the B-737 research cockpit.

The FY 1978 program we have presented is the result of considerable planning activity during which we examined

each of the program areas to define, initially without regard to cost, desirable research and technology activities. These potential activities were then reviewed, integrated, and scaled down to reflect realistic budget considerations.

In one significant action, we revised our approach to vertical-takeoff-and-landing flight research. We had been planning a joint Navy/NASA lift/cruise fan VTOL research aircraft project, coordinated with the Navy's development and testing of a multipurpose V/STOL prototype. As the Navy's prototype planning evolved, it became apparent that a single combined program would be a more efficient approach to satisfying both the flight research and the military prototype objectives. Under the new plan, NASA will provide research and technology support to the Navy, and the prototype design will be modified for increased versatility so that more complete technology data can be obtained in flight testing. Discussions are now in progress with the Navy to plan the details of NASA's participation and the reimbursement by the Navy for the NASA activity.

While energy efficiency for subsonic civil aviation is given our highest priority concentration this year, we are already involved in assessing our other programs, needs, and opportunities as we enter the planning cycle for FY 1979. Meanwhile, we are confident that our FY 1978 budget request provides for a balanced program which effectively addresses the technology problems of today and maintains a necessary core of research preparation for the future.

**OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY
AERONAUTICS FY 1978 BUDGET REQUEST**

FY 1977

\$190.1 M

FY 1978

\$231.0 M

22% INCREASE IN AERONAUTICS PROGRAM

FIGURE 1

NASA HQ 8077-1154 (1)
12-8078

20

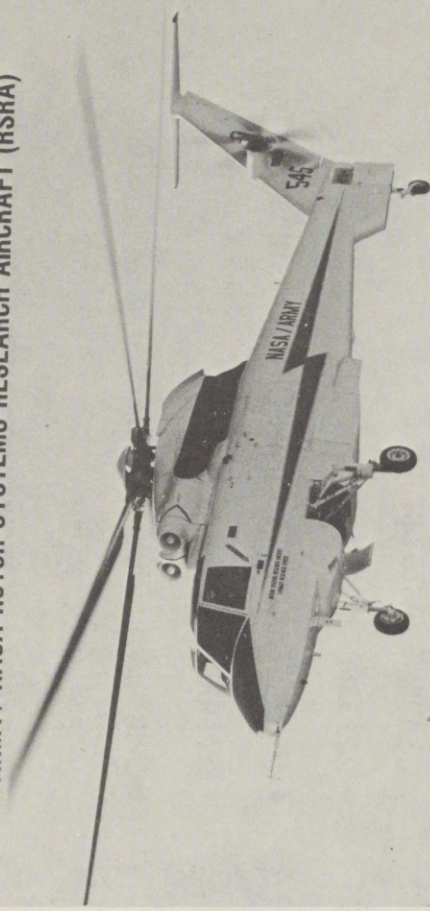
FY 1978 HIGHLIGHT AREAS

- AIRCRAFT ENERGY EFFICIENCY/CONVENTIONAL TAKEOFF & LANDING (ACEE / CTOL)
- SUPERSONIC CRUISE AIRCRAFT RESEARCH (SCAR)
- HELICOPTERS/VERTICAL TAKEOFF AND LANDING (VTOL)
- GENERAL AVIATION
- SHORT-HAUL/SHORT TAKEOFF AND LANDING (STOL)
- GENERIC TECHNOLOGY
- RESEARCH AND TECHNOLOGY (R&T) BASE

FIGURE 2

HELICOPTERS / VTOL

ARMY / NASA ROTOR SYSTEMS RESEARCH AIRCRAFT (RSRA)



22

FIGURE 3

HELICOPTERS / VTOL

ARMY / NASA TILT ROTOR RESEARCH AIRCRAFT (TRRA)

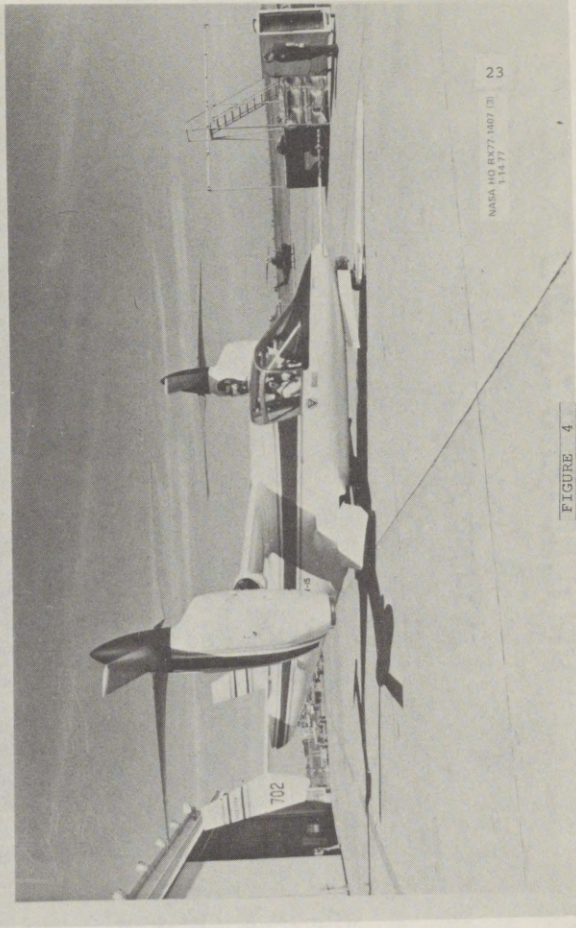


FIGURE 4

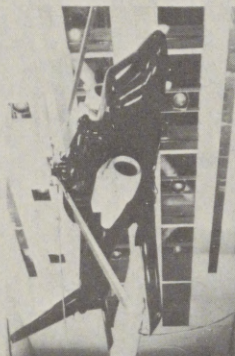
NASA HQ BX77-1407 (B)
114.77

23

HELICOPTERS / VTOL

ADVANCED ROTOR RESEARCH

WIND-TUNNEL



FLIGHT

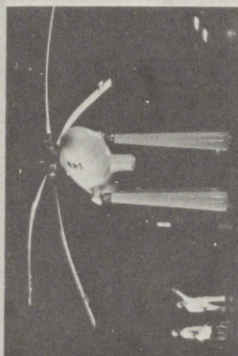
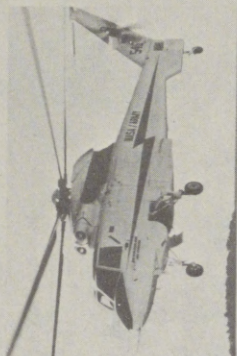


FIGURE 5

NASA HQ 6A7-1176 CR
12-87-26

HELICOPTERS/VTOL

ADVANCED HELICOPTER TRANSMISSION TECHNOLOGY

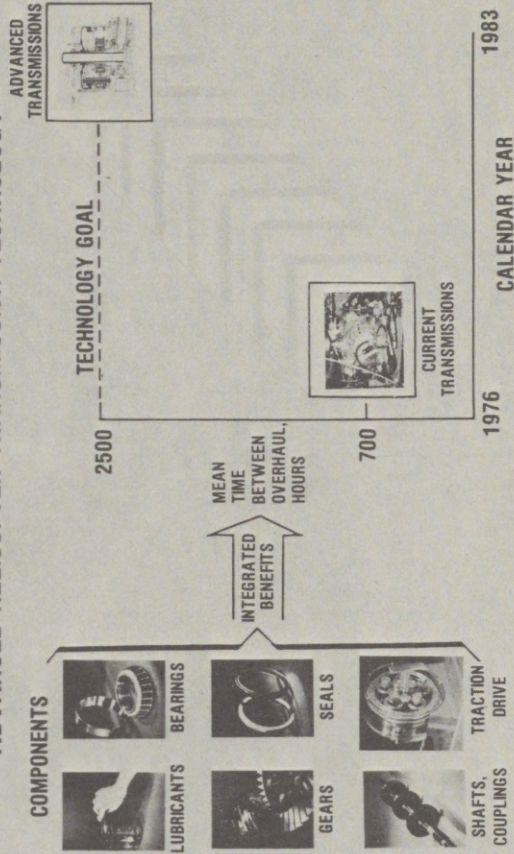


FIGURE 6

HELICOPTERS / VTOL



NASA
National Aeronautics and
Space Administration

Headquarters
Washington, D.C.

GENERAL AVIATION

GAW-1 WING ON BEECH 77 PROTOTYPE



FIGURE 8

NASA HQ 8A77-1674(3)
2-2-57

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GENERAL AVIATION

GENERAL AVIATION TECHNOLOGY

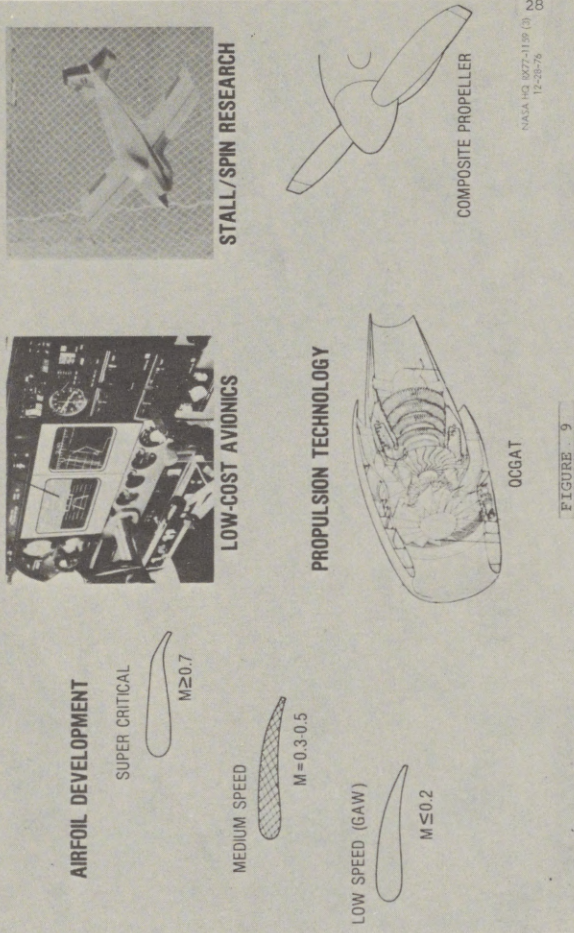


FIGURE 9

GENERAL AVIATION

AERIAL APPLICATIONS TECHNOLOGY

TECHNOLOGY OBJECTIVES

IMPROVED AIRCRAFT
CHARACTERISTICS

FLOW FIELD
MODIFICATION

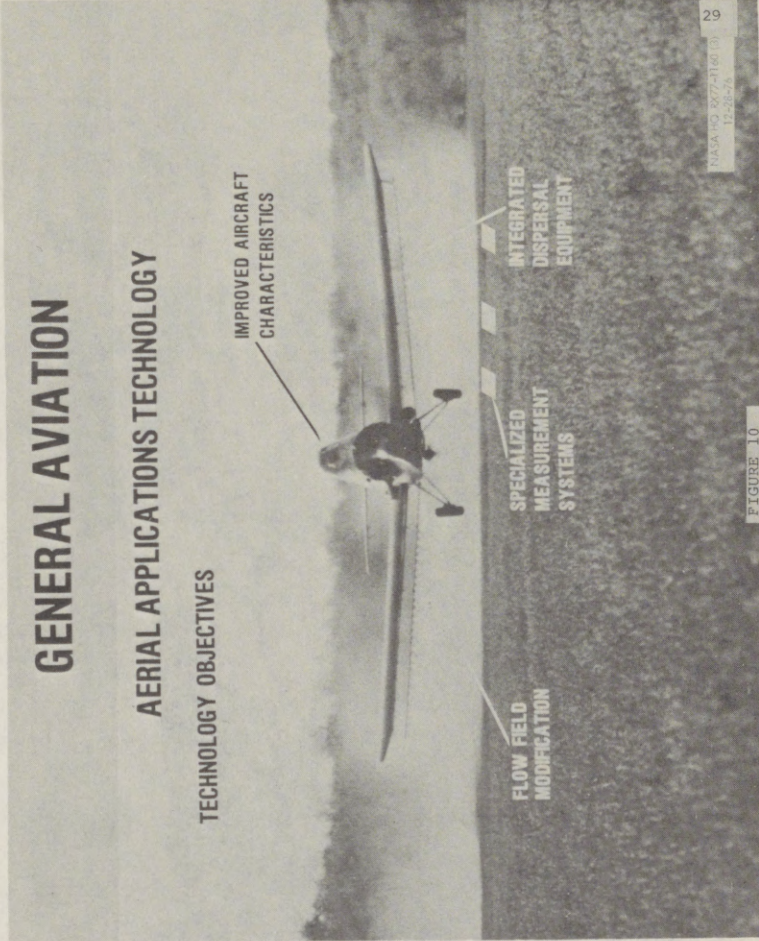
SPECIALIZED
MEASUREMENT
SYSTEMS

INTEGRATED
DISPERSAL
EQUIPMENT

29

NASA 40-507416C (3)
12-50-50

FIGURE 10



SHORT-HAUL / STOL

QUIET SHORT-HAUL RESEARCH AIRCRAFT (QSRA)

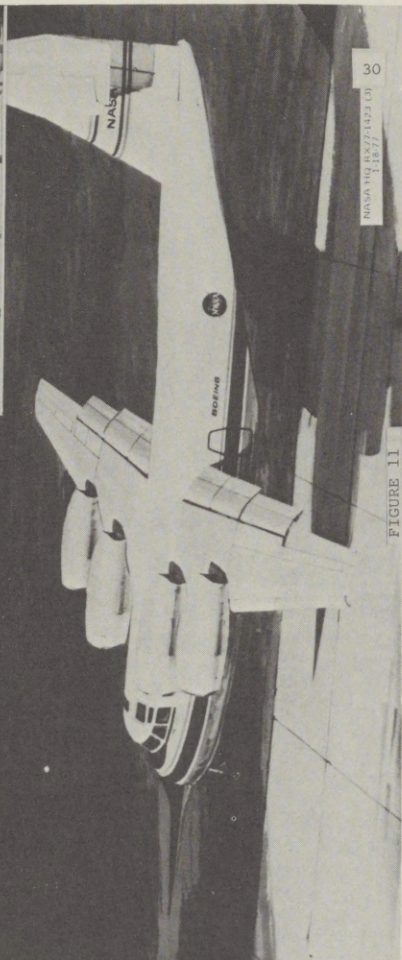
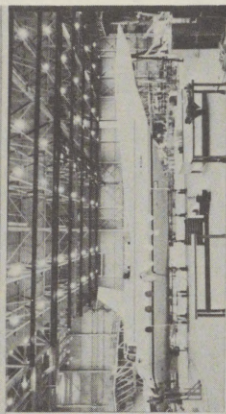


FIGURE 11

SHORT HAUL/STOL

NASA FLIGHT RESEARCH IN USAF AMST DEVELOPMENT PROGRAM



SHORT-HAUL / STOL

QUIET CLEAN SHORT-HAUL EXPERIMENTAL ENGINE - ON TEST AT GE

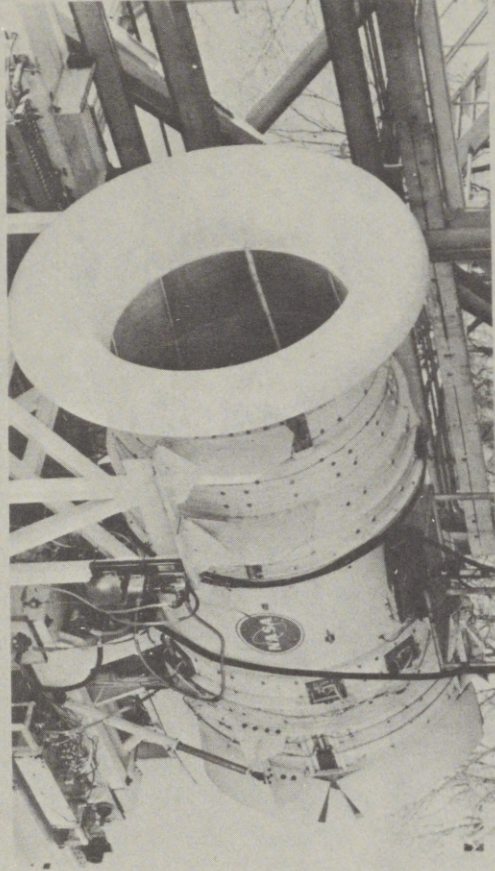


FIGURE 13

NASA FO 827-1315 (3)
1-2-77

32

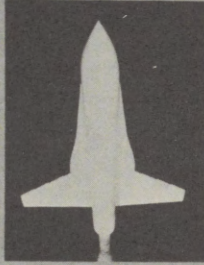
GENERIC TECHNOLOGY

CONFIGURATION RESEARCH LEADS TO COMBAT AIRCRAFT SUPERIORITY

EMERGING RESEARCH CONCEPTS



CANARDS



STRAKES



BLOWING AND VECTORIZING



F-15 WITH 2-D

FIGURE 14

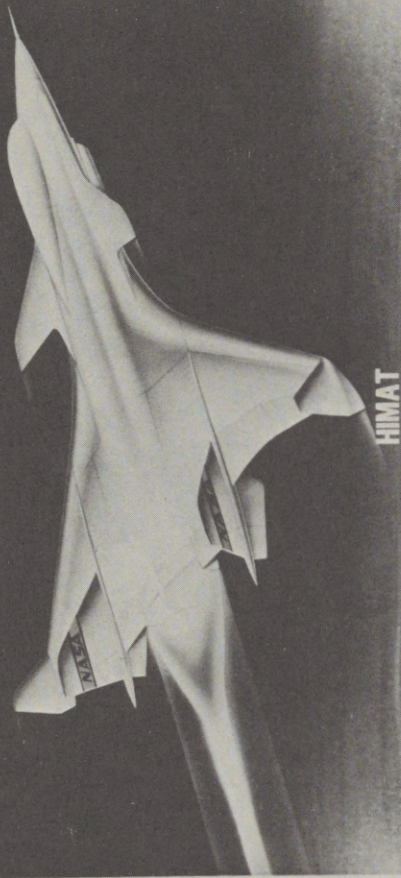
NASA HQ RD77-1138(2)
12-27-76

33

GENERIC TECHNOLOGY

CONFIGURATION RESEARCH LEADS
TO COMBAT AIRCRAFT SUPERIORITY

PROOF OF CONCEPT TESTING



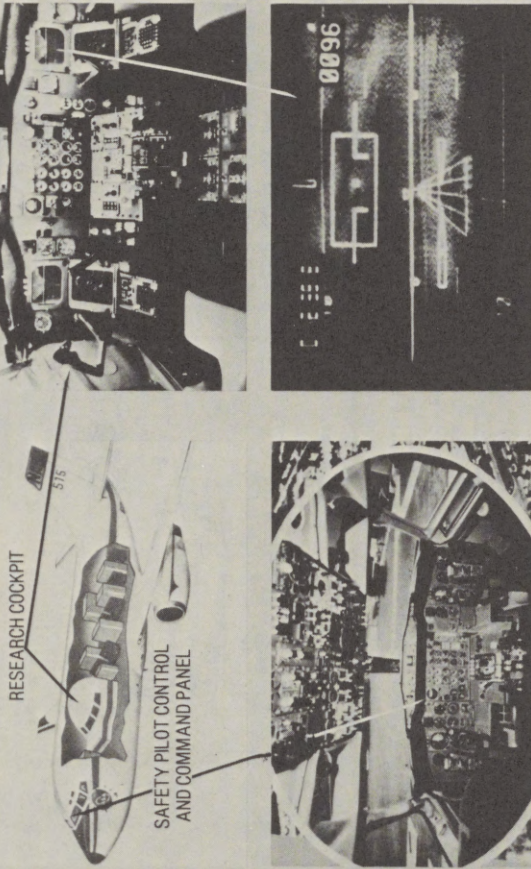
NASA HQ HQ77-1137(2)
12-27-76

34

FIGURE 15

GENERIC TECHNOLOGY

AERONAUTICAL OPERATING SYSTEMS TECHNOLOGY

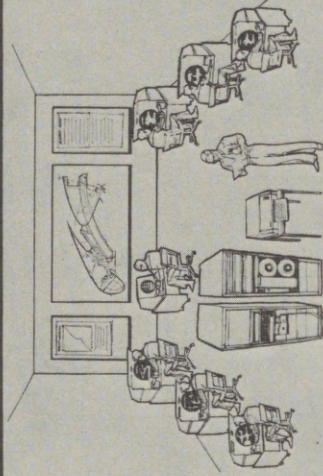


NASA HO BX77 (S89) (3)
1.2727

FIGURE 16

GENERIC TECHNOLOGY

IPAD INTEGRATED PROGRAMS FOR AEROSPACE VEHICLE DESIGN



IPAD YIELDS

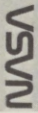
- 25% REDUCTION IN DESIGN COST
- 50% REDUCTION IN DESIGN TIME

FY 1978 HIGHLIGHT - FIRST RELEASE TO INDUSTRY

FIGURE 17

NASA HQ BW77-1214 (3)
1-5-77

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National Aeronautics and
Space Administration

Headquarters
Washington, D.C.

GENERIC TECHNOLOGY

TECHNOLOGY IMPACT ON AIRCRAFT POLLUTION LEVELS (NOX AT CRUISE CONDITIONS)

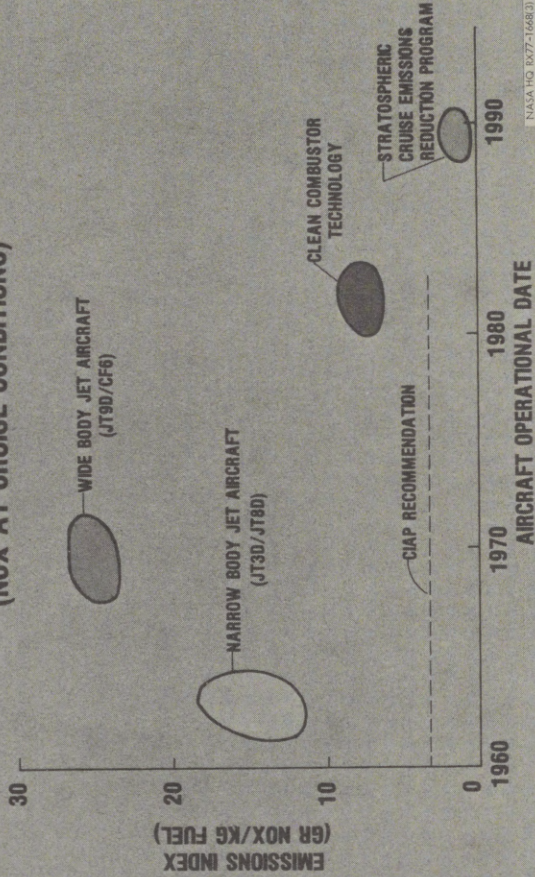


FIGURE 18

37
NASA HQ 8377-1 (68/3)
2-1-77

R&T BASE

THERMAL BARRIER COATING FOR TURBINE BLADES

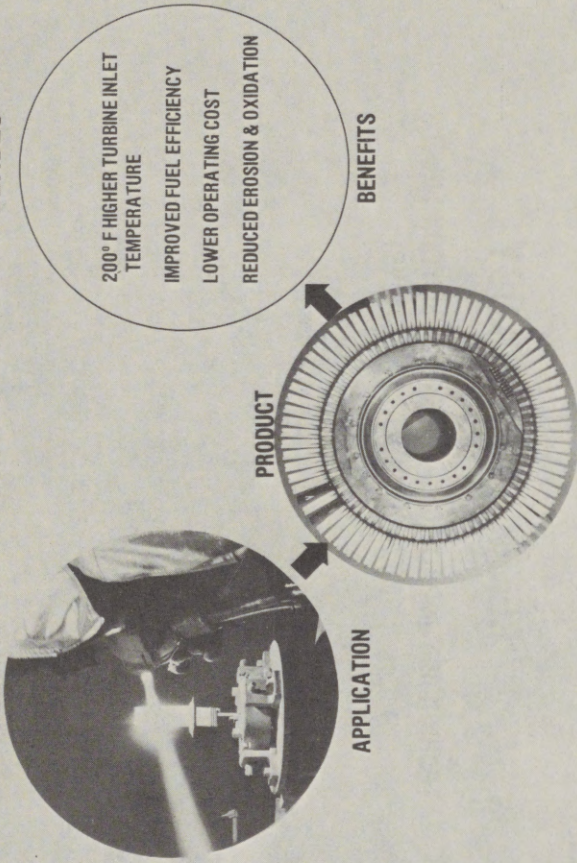
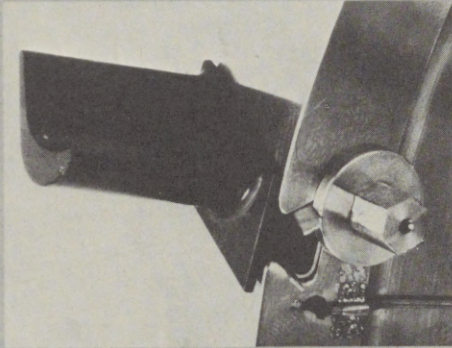


FIGURE 19

R&T BASE

CERAMIC TURBINE BLADES



OBJECTIVES

- CUT TOTAL BLADE COST BY 25%
- SUPERIOR CORROSION RESISTANCE
- USE OF NON-STRATEGIC MATERIALS

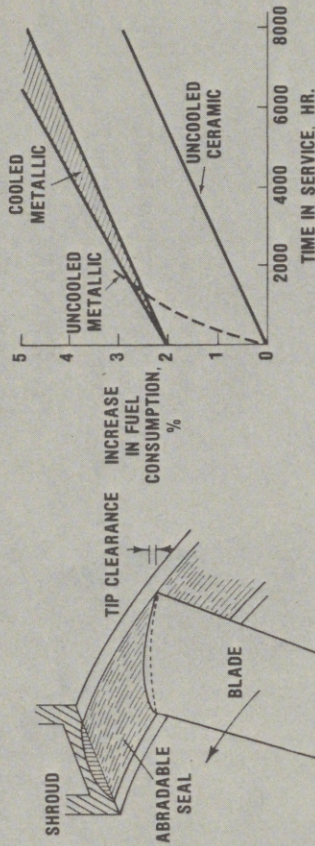
FY 1978 PLAN

- 500 HRS. TEST AT 2200° F

FIGURE 20

R&T BASE

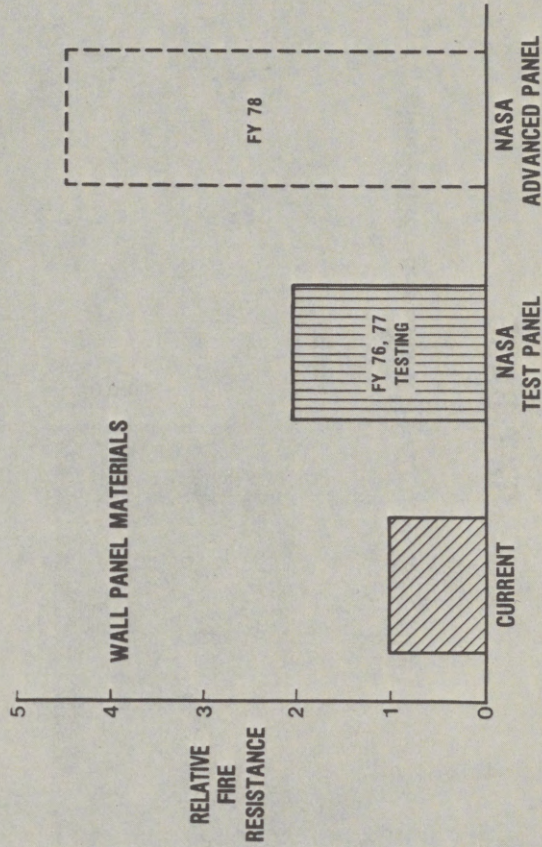
ABRADABLE CERAMIC SEALS



$\frac{1}{100}$ INCH INCREASE IN TIP
CLEARANCE MEANS 1% LOSS
IN TURBINE PERFORMANCE

FIGURE 21

R&T BASE FIRE RESISTANT AIRCRAFT INTERIORS



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NASA TM X-773-895-131
1-77

FIGURE 22

R&T BASE

FLIGHT TESTS TO CONFIRM FLUTTER PREDICTION

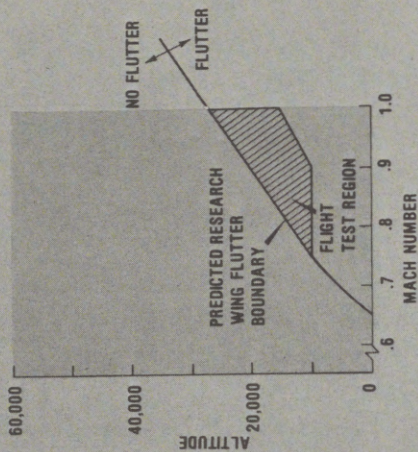
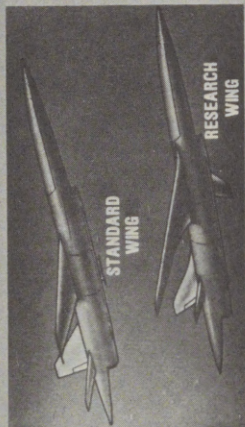


FIGURE 23

NASA HQ R&T-1211(3)
1-5-77

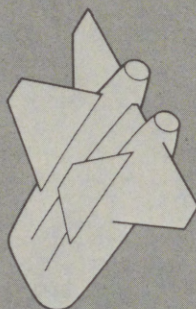
2

R&T BASE

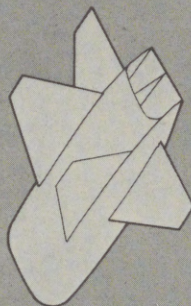
PROPULSION SYSTEM INSTALLATION RESEARCH

OBJECTIVES:

- REDUCED AIRCRAFT DRAG
- THRUST VECTORING FOR MANEUVERABILITY AND SAFETY
- SIMPLER MECHANISMS
- REDUCED WEIGHT
- LOWER COST
- LONGER NOZZLE LIFE

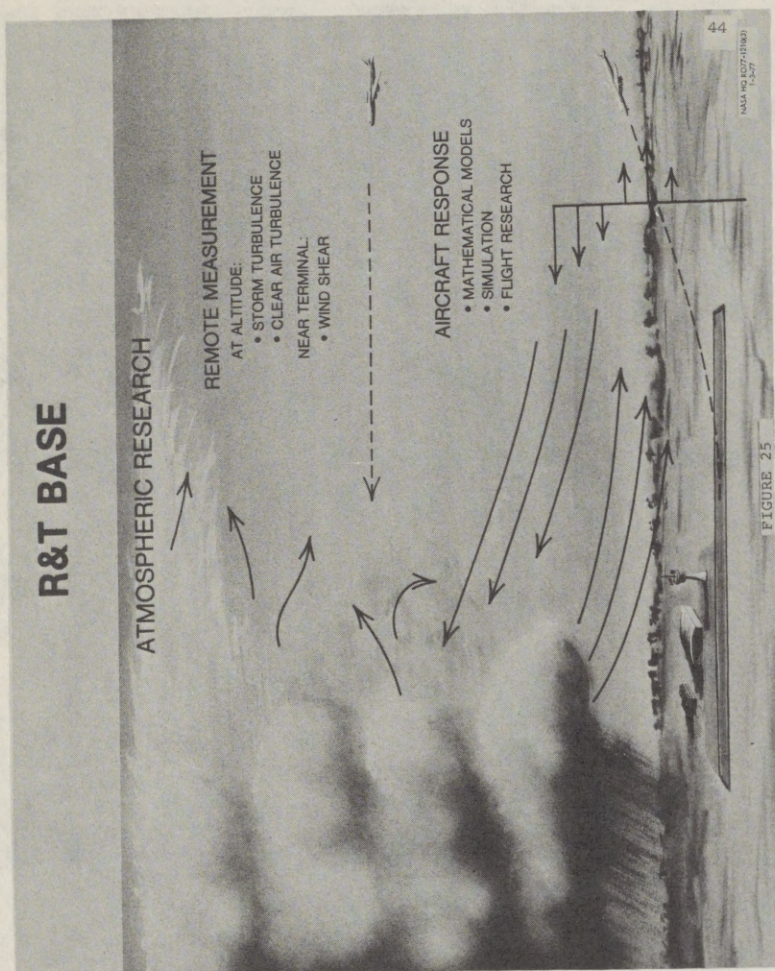


AXISYMMETRIC NOZZLE (CURRENT)



NON-AXISYMMETRIC NOZZLE (2-D)
(FUTURE)

FIGURE 24

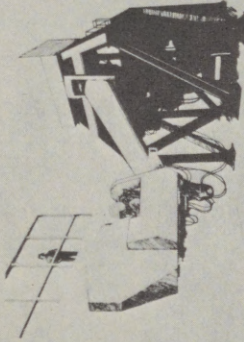


R & T BASE

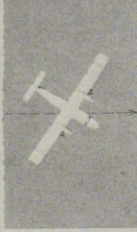
INCREASE LANDING SAFETY AND ECONOMY

MOVING-BASE SIMULATOR

CROSSWIND LANDING GEAR
FLIGHT TESTS



WIND

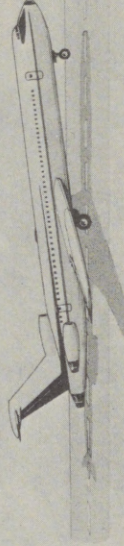


INVESTIGATE

- PILOTING TECHNIQUES
- MODES OF OPERATION
- OPERATIONAL LIMITS

EXPLORE DIRECTIONAL CONTROL
AND BRAKING PROBLEMS

AIR CARRIER EVALUATION



NEW TIRE MATERIALS FOR IMPROVED WEAR AND SAFETY

FIGURE 26

R & T BASE

NEW DIRECTIONS IN AVIONICS

DIGITAL OPERATIONS

- MINIMUM FUEL CONSUMPTION
- ALL WEATHER OPERATIONS

GLOBAL POSITIONING AND
DIGITAL COMMUNICATIONS

INTEGRATED CONTROL

- REDUCED COST
- REDUCED WEIGHT

ACTIVE AIRFRAME, PROPULSION,
AND SUBSYSTEMS CONTROL

COCKPIT AVIONICS

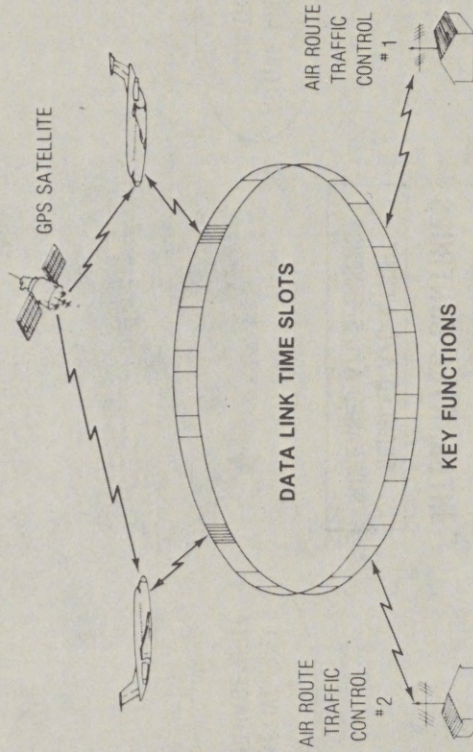
- OPTIMUM WORKLOAD
- INCREASED SAFETY

MODE DISPLAY, MICROPROCESSOR
OPERATION

FIGURE 27

R&T BASE

DIGITAL OPERATIONS



KEY FUNCTIONS

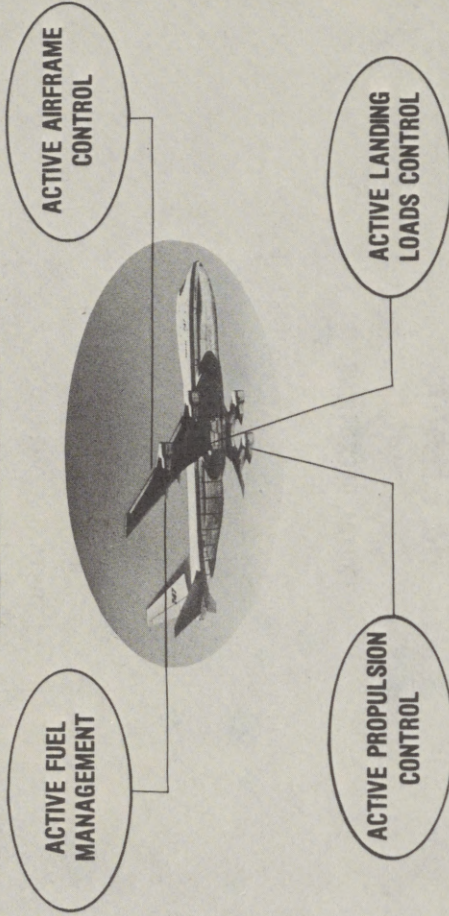
PRECISION NAVIGATION
COLLISION ASSESSMENT
AUTOMATED WEATHER & ROUTE DATA
AUTOMATED POSITION & VELOCITY DATA

FIGURE 28

R&T BASE

INTEGRATED CONTROLS

REDUCED A/C WEIGHT
INCREASED A/C EFFICIENCY



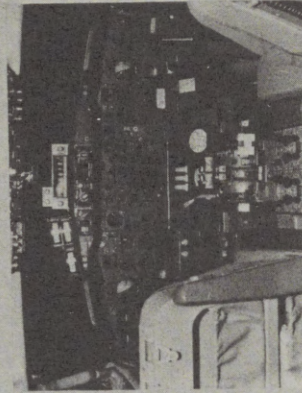
48

NASA HQ, RP-71-144 (3)
1/25/77

FIGURE 29

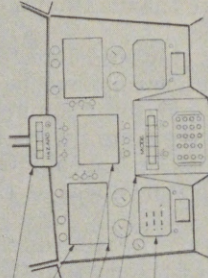
R&T BASE

COCKPIT AVIONICS



CURRENT TECHNOLOGY

- HAZARD WARNING/REC-
SYSTEM IMPLEMENTATION
- ADVANCED DISPLAY DEVICES
- REDUNDANT DISPLAY
MANAGEMENT
- AUTOMATED PROCEDURES
IMPLEMENTATION
- IMPROVED INFORMATION
DISPLAY TECHNIQUES



ADVANCED TECHNOLOGY INTEGRATED COCKPIT

NASA HC 8477-1162 (3)
12-86-26

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FIGURE 30

Dr. KRAMER. We would like to speak to the content of the program rather extemporaneously to permit an interchange with you and to make sure you have the maximum opportunity to get the information from us that you need.

One other point, I would like to express our appreciation for the time you spent in visiting our field centers. We feel that is a very important part of our total communication process with you, and I might add, also a very significant help to us in our management role of the centers. When such people as yourself express the level of interest and take the time spent at the centers, it is indeed an inspiration to our staff.

For the first part of my testimony I would like to read a somewhat condensed version of the written testimony that was presented for the record. It has to do with responses to your subcommittee's report on the future of aviation hearings. In our written statement, I have underlined recommendations from your report, and following that have a few remarks relative to the actions we are taking, and our reactions to the recommendations.

In preparing NASA's proposed fiscal year 1978 aeronautics program, we have had the benefit of the October 1976 report of this subcommittee on its review of the future of aviation. I think it is safe to predict that aviation will be materially improved by that report. In some instances, the recommendations in the report address issues much broader than the specific research and technology aspects which are NASA's primary concerns. A thorough response to the recommendations will require actions by NASA, other executive agencies, and Congress—and cannot be achieved in a short time. Nevertheless, your recommendations have influenced our fiscal year 1978 planning and I propose to introduce this discussion by expressing NASA's position on those recommendations which relate directly to our authorization request.

First, we agree completely that preeminence in aeronautics is absolutely vital to the national interest. We believe further that preeminence depends critically upon research and technology, and that Government aeronautical R. & T. must be constantly tuned to national needs. Creation of a national civil aviation R. & D. policy is certainly a worthy objective; so is the related recommendation concerning expansion of federally sponsored civil R. & D. efforts to compensate for reduced military fallout. NASA's experience in providing the technical foundations for both civil and military development has shown, however, that even when the developments diverge—the research and technology are usually commonly applicable. The civil/military commonality must also be given serious consideration in regard to the recommendation that coordination of all Government-sponsored aeronautical R. & D. be assigned to a centralized authority with jurisdiction over Federal agencies dealing with civil aviation. Under the present arrangement, our R. & T. programs fulfill both civil and military needs.

With regard to the recommended restructuring R, D, and D programs for better coordination with other modes of transportation, some comments appear in order. Far more than other established modes of transportation, aviation is highly dependent on advanced technology, cross-modal coordination of research and technology can

strengthen both the transportation system and the national posture—but it must not be permitted to retard progress in aeronautics or in any other mode by arbitrary pressures for equality among modes.

NASA also supports the view that Government activity should extend to the point where results can be readily applied by industry. For the past several years we have been increasing our efforts on technology demonstration to facilitate the application of research results by industry—as illustrated by the composite structure and active control flight demonstrations included in our aircraft energy efficiency program. We do not, however, view NASA's role as encompassing larger scale demonstrations such as prototypes or transportation system demonstrations.

One additional point should be made relative to the recommended restructuring and reorientation of R, D, and D programs. New generation air transport products require years of development and long-term financial commitments. The research and technology to make such development possible must be initiated long before general agreement can be reached as to which developments will be undertaken. Establishment of long-term stabilized goals, and identification of required Federal resources, must therefore, include substantial allowance for the conduct of R. & T. which provides options and not simply R. & T. which supports firmly committed programs.

NASA also endorses the recommendation that the Department of Transportation address the role of aviation within the national transportation system and the markets best served by air. We believe NASA can best contribute to this endeavor by continuing to identify desirable alternatives and opportunities for improved air transportation derived from technology advances. We will also continue to coordinate with the DOT our own transportation systems studies conducted to guide our early planning of long-leadtime research.

With respect to accelerating the technology availability date for supersonic transport aircraft, we are proposing this year to augment our supersonic cruise aircraft research (SCAR) program. Consistent with the recommendation for expansion of the aircraft energy efficiency (ACEE) program, the fiscal year 1978 request features a considerable expansion of the ACEE program, with emphasis on expediting practical application of results by industry. Finally, in regard to the recommendations concerning noise and emission suppression, NASA's R. & T. programs continue to emphasize these vital environmental concerns, providing results to the regulatory agencies as a basis for regulatory standards, and to the industry as a basis for design and production of equipment meeting the standards.

In summary, we have looked carefully at the subcommittee's report, and have taken actions responsive to those recommendations pertinent to NASA activity. A more thorough response will require additional action by other agencies and the Congress in which we are ready to participate.

I would like to turn now to a discussion of the more detailed technical highlights of our proposed fiscal year 1978 program.

Mr. MILFORD. Before you get there, a couple of comments.

On page two of your testimony, in the discussion of coordination of all Government-sponsored aeronautical R. & D., I think what we had in mind there was military and civil. Sometimes decisions have to be

made on trade-offs, whether the military might need something in preference to the civil, or vice versa in some instances. The subcommittee was addressing some central figure, whether it is a committee or a White House position, that could speak for aeronautics and speak with authority.

Dr. KRAMER. It is not just civil, not just military, but the total.

Mr. MILFORD. Of total aeronautics?

Dr. KRAMER. Yes.

Mr. MILFORD. This is what we were trying to get at in the report.

Dr. KRAMER. I understand that better now.

Mr. MILFORD. Also, on page 2, restructuring of research and development programs for better coordination with other modes, certainly there was no intent on the part of the committee to detract from efforts in any of the modes. Quite the contrary, we happen to feel, I think I can speak for the whole committee, that we need to look more toward research and development, and certainly there was no intent to try to even it across the board, to be sure that everybody gets the same in their research and development pots, because as you very aptly point out, some modes require more in the way of research and development. The intent of the committee report was to point out that some modes virtually have none, that what they call research and development is hardly more than an overhaul shop, reworking old modes and old systems, rather than looking for new technologies.

Dr. KRAMER. Very good.

Mr. MILFORD. So the record might be clear on that.

Dr. KRAMER. Very good.

Mr. MILFORD. Please proceed

Dr. KRAMER. We worried a little bit about that.

I appreciate that.

Thank you.

Mr. MILFORD. I wanted the record straight.

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY AERONAUTICS FY 1978 BUDGET REQUEST

FY 1977
\$190.1 M

FY 1978
\$231.0 M

22% INCREASE IN AERONAUTICS PROGRAM

**OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY
AERONAUTICS FY 1978 BUDGET REQUEST
(\$M)**

	1977	1978
AERONAUTICAL RESEARCH AND TECHNOLOGY	\$190.1	\$231.0
RESEARCH AND TECHNOLOGY BASE	89.1	97.6
SYSTEM STUDIES	2.9	3.0
SYSTEMS TECHNOLOGY PROGRAMS	57.2	72.2
EXPERIMENTAL PROGRAMS	40.9	58.2

Figure 2

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12-28-76

Dr. KRAMER. If I could have the first chart, figure 1. I would like to start by discussing our budget request for aeronautics in fiscal year 1978. As you can see on this chart, we are asking you to authorize an expenditure of \$231 million for the fiscal year 1978 aeronautical research and technology budget line item. The corresponding funding in fiscal year 1977 was \$190.1 million. Our fiscal year 1978 budget request represents a 22-percent increase in the aeronautics research and development program in NASA over that of fiscal year 1977. We are pleased to point out that this increase makes the aeronautics program the largest single percent increase element in the total NASA program.

Mr. MILFORD. I always get worried about using terms of percentage increase.

We had a budget last year, if you increased 1 dollar to 2 dollars, that means 100-percent increase, and that means you have added only a dollar.

Dr. KRAMER. We are working on this, Mr. Chairman.

The breakdown of those dollars is shown in more detail in figure 2. I would like to point out in particular the expansion of our research and technology base program, from \$89.1 million in fiscal year 1977 to \$97.6 million in fiscal year 1978.

I know you have been especially concerned about the health of our research and technology base program. I want to point out that there is approximately a 10-percent increase in the research and technology base dollars in the fiscal year 1978 budget request. We would be the first to agree with you that research and development dollars are not necessarily the pacing resource in our research and technology base program. Rather, I believe the more difficult issues concern the adequacy of the in-house scientific staff devoted to research and technology base activities.

Mr. MILFORD. What factor in this do you consider to be due to inflation?

Dr. KRAMER. We estimate that factor to be something like 6 or 7 percent.

Mr. MILFORD. So in effect, then you have raised it 3 percent?

Dr. KRAMER. Three percent, that is right. If you look at the aeronautics fiscal year 1978 budget as a whole, we would have to have about a \$12 million increase in order to break even; the fiscal year 1978 budget would have to be about \$202 million, so that real growth in the aeronautics budget is about \$29 million. Of course, the major growth in the program is in the systems technology programs and the experimental programs. These are particular areas which we can grow with the infusion of dollars more rapidly because efforts in these areas tend to be larger scale programs, which can be brought along by the infusion of more dollar resources. We will be talking about the systems technology and experimental programs later in more detail.

FY 1978 HIGHLIGHT AREAS

- **AIRCRAFT ENERGY EFFICIENCY/CONVENTIONAL TAKEOFF & LANDING (ACEE / CTOL)**
- **SUPERSONIC CRUISE AIRCRAFT RESEARCH (SCAR)**
- **HELICOPTERS/VERTICAL TAKEOFF AND LANDING (VTOL)**
- **GENERAL AVIATION**
- **SHORT-HAUL/SHORT TAKEOFF AND LANDING (STOL)**
- **GENERIC TECHNOLOGY**
- **RESEARCH AND TECHNOLOGY (R&T) BASE**

The topics we will be covering today are shown in figure 3. The largest single element in our fiscal year 1978 budget request is that associated with the aircraft energy efficiency technology program, which supports the conventional takeoff and landing-type vehicle technology. Dr. Raymond Colladay will give some specific testimony on that program to you later this morning.

The second important item is the supersonic cruise aircraft research program, the SCAR program. Mr. Aiken will be reporting on that.

I will discuss highlights from each of the other subject areas including helicopters, short-haul/short takeoff and landing, and general aviation technology. I will also discuss several topics which fall into a category of generic technology, and I will highlight a couple of items in our research and technology base, which is really a broadly based program.

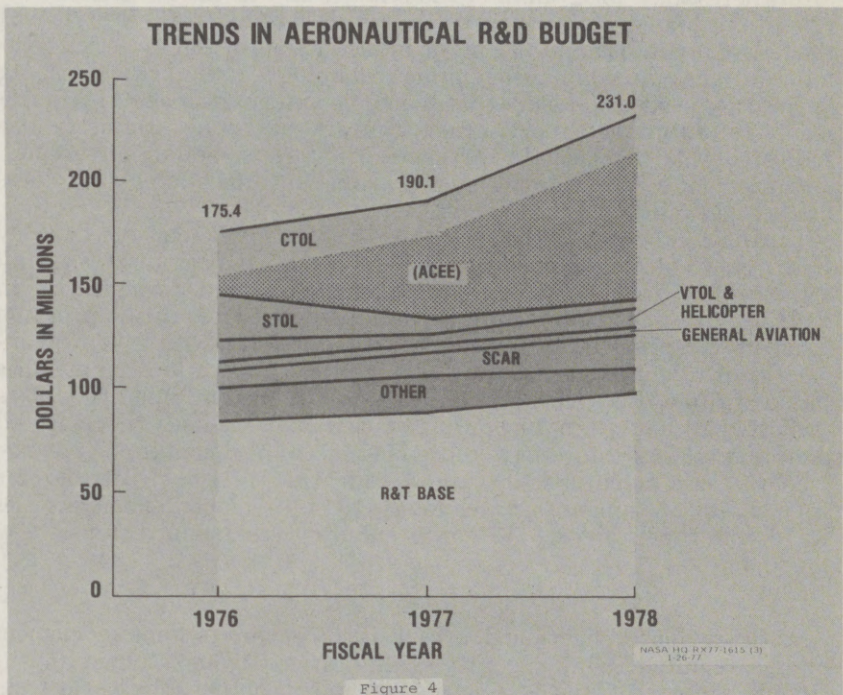


Figure 4 illustrates the distribution of research and technology dollars by kinds of activity (vehicle type). The research and technology base is approximated by the bottom section on the chart. It is indeed the basis of our program, and as you can see, it has modest growth in the period of fiscal year 1976 to fiscal year 1978.

Looking at the red band called supersonic cruise aircraft research (SCAR), you can see that we are attempting to augment the SCAR program, but it is still quite modest in size compared to our other activities.

Looking at the short takeoff and landing (STOL) efforts, you can see we are decreasing our investment in STOL, as we come off some of the peak funding years of the major projects. The large growth

in the NASA aeronautics budget in the last couple of years has been in the conventional takeoff and landing (CTOL) area, and in the aircraft energy efficiency (ACEE) program element, which you can see.

I would like to leave a couple of important points with you: We are trying to augment the dollars involved in the research and technology base; we are trying to build up our SCAR program, our STOL program is coming down in size, and the large growth in the past years has been in the ACEE/CTOL area.

I would like to ask Bill Aiken to talk about the SCAR program for a few moments.

Mr. AIKEN. Mr. Chairman, I thank you for this opportunity.

As a part of the NASA fiscal year 1978 hearings in September 1976, you invited industry to testify on the progress of the supersonic cruise aircraft research program and the relationship of the program to accelerate technology availability for this class of aircraft. A review of the testimony indicated that, in the industry's view, and in the subcommittee's view, variable cycle engine technology is the critical pacing technology needed to assure that economic and environmental requirements for future supersonic cruise aircraft can be met. Industry also indicated that research in structures, materials, aerodynamics and advanced control techniques must continue until technology readiness has been established.

During a 4-day conference on SCAR technology held at the Langley Research Center in November 1976, some 50 papers discussing all aspects of SCAR technology were presented to and discussed by an audience of almost 300 technical specialists. Progress in the program from its inception in 1972 was seen as impressive with potential increases in range from 3,300 to 4,500 nautical miles while achieving a payload three times that of Concorde, and with total operating costs projected to be within 10 percent of current wide-body aircraft; all of this while meeting noise and emission environmental constraints.

With these potentials for progress identified, there still remains a very significant amount of technology to be developed. The activities we plan in the fiscal year 1978 program are necessary next steps.

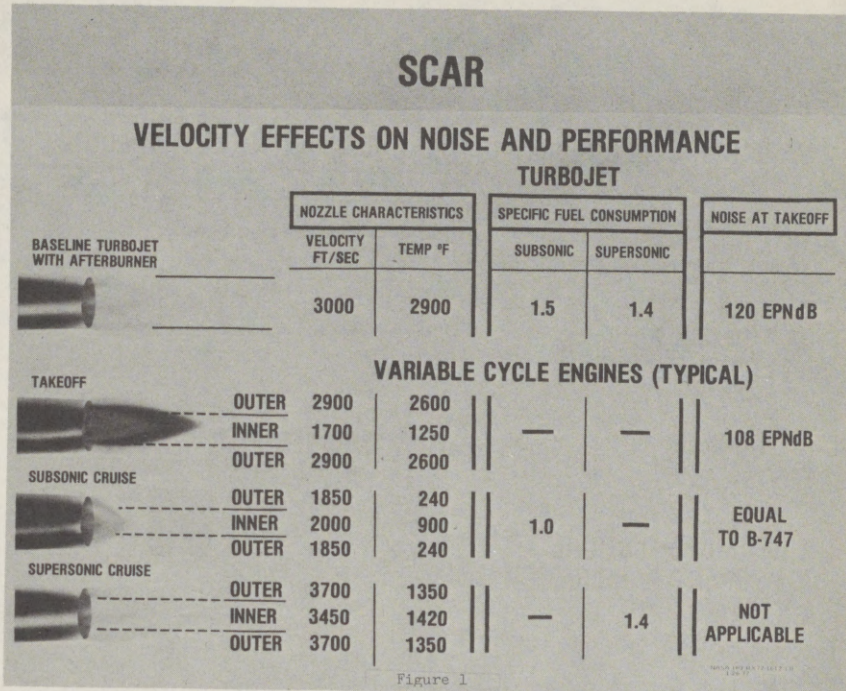
VARIABLE CYCLE ENGINE TECHNOLOGY

As I previously mentioned, a VCE is the pacing technology element and is required in all aircraft configurations being studied in the SCAR program. This is a new propulsion concept, the basic technology which, as far as we know, is being pursued only in the United States.

The major problem for the propulsion system on this type of aircraft is that it must functionally accommodate at least two distinct modes of operation: (1) a high airflow, low jet-velocity turbofan-like mode for low noise takeoff and efficient subsonic cruise; and (2) a turbojet-like, higher jet velocity, lower airflow mode for supersonic cruise.

It should also be noted that variable cycle engines also offer promise for military missions. However, the military missions cannot compromise performance to meet stringent noise and pollution reduction constraints which must characterize a civil version, and the component

technology which we are working on is necessarily different from that for military applications.

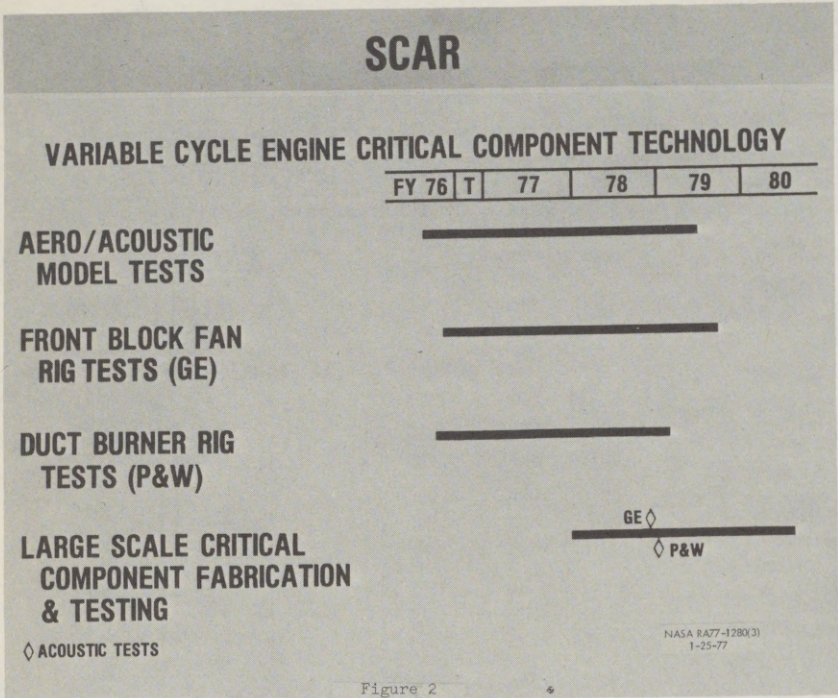


As shown at the top of the first chart (figure 1) the characteristics of a turbojet are given in terms of the nozzle flows and fuel consumption and estimated noise at takeoff. On the bottom for the variable cycle engines you can see the takeoff, the subsonic cruise and the supersonic cruise characteristics, and you will notice the difference in velocity at takeoff conditions, and also the difference in temperature. The net result of this is that there are potential large reductions in noise at takeoff from that which you would expect with a turbojet engine, the type that is used in Concorde, and was used in the U.S. SST, from 120 EPNdB to about 108 EPNdB. That 108 is about the level of noise for a 747, and it is equivalent to the present FAR-36 standards.

The big problem, as I mentioned, is trying to get some subsonic cruise performance out of this airplane, with its engines, which does not have a serious impact on the total mission, and here again, by adjusting the flow schedules of the inner and outer, you can get specific fuel consumption reduction for subsonic cruise. This permits range to inland airports as well.

In the subsonic cruise area, there is one item in this last column, of noise at takeoff, that should be noted, as being equal to a 747. Here we are talking about a subsonic cruise, where the airplane is out of the airport area and over the community, and in this case, it would be equivalent to a 747 without specifying the decibel level, so these are

some of the things we have been looking at, and the characteristics in general are for both the General Electric and Pratt & Whitney cycles.



An experimental VCE critical components program (figure 2) is underway to develop and evaluate the components which represent the major technological risks and uncertainties at this time. Aero/acoustic investigations will continue through fiscal year 1979 with coannular/annular inverted exhaust gas profile nozzle evaluations using small scale models. Primary emphasis will be placed on acoustic performance.

This is a rather abbreviated schedule of our activities for running variable-cycle-engine critical component tests and this program will be continuing until fiscal year 1979. The General Electric cycle requires some modification to the front fan for these engines, so we are looking at rig tests for those engine components. For the duct burner rig of Pratt & Whitney, we are conducting some performance tests on that part of the Pratt & Whitney cycle.

The output from all of these small-scale tests leads us to a large-scale critical component testing sequence in the late fiscal year 1978, early fiscal year 1979 timeframe for both the GE and Pratt & Whitney engine concepts. At this time we would be testing the components on existing engine cores, which would provide the acoustic data we need on a relatively large scale, not completely full scale, and it would hopefully—we are pretty optimistic about this—lead us to the information we need on the coannular noise reduction effects we are looking for.

SYSTEMS INTEGRATION STUDIES

While we propose to emphasize the variable cycle engine technology in fiscal year 1978, research is still necessary, and related disciplinary research programs are necessary.

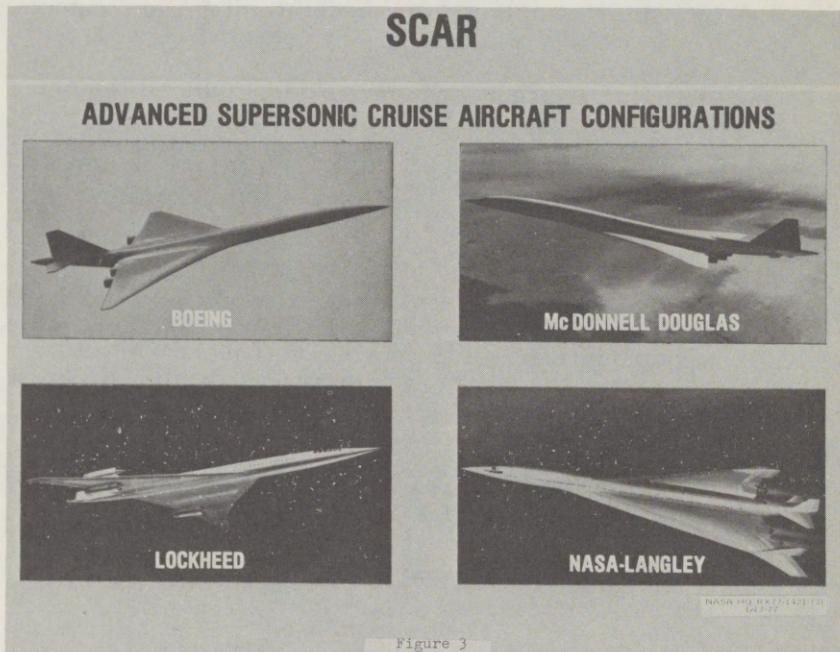


Figure 3

Three systems integration study contracts and in-house efforts are now underway, and will be completed in fiscal year 1978. These are key to the various concepts shown here (figure 3). The NASA-Langley concept is the baseline aerodynamic configuration which is used by the contractors to define their own approach to a possible transport aircraft. It is a Mach No. 2.7 design with an arrow wing. Douglas has come up with their own, as you heard last fall of a Mach No. 2.2, modified wing. This Boeing concept is a delta wing, but they also have an arrow wing in the works in their studies, and it is Mach No. 2.4.

The Lockheed arrow wing is the 2.55 version, it is somewhat different from the others. You will notice the over/under engine placement on the wing; there are additional noise benefits from shielding and induced airflow over the wing, which improves the landing characteristics.

These studies will provide NASA and industry detailed analysis and sensitivity assessments of the somewhat different technologies required for each configuration so that only the highest payoff ones are pursued within the limited scope of the program.

AERODYNAMICS

There are two specific disciplinary research activities planned for fiscal year 1978 that I would briefly like to discuss. The first is a pro-

posed expansion of the aerodynamics research activities. While we have made major progress in drag reduction such that the lift-to-drag ratio at supersonic speeds can be increased by as much as 30 percent, the systems integration studies have indicated that substantial additional improvements in aerodynamic performance are possible in several remaining areas. These areas include improved low speed operation by refinement of wing leading and trailing edge contours, and further reductions in transonic drag by improved engine nacelle/airframe integration.

These refinements and improvements would be pursued beginning in fiscal year 1978 through a series of wind tunnel model tests. Several new and somewhat larger wind tunnel models incorporating necessary refinements would be constructed and tested at critical low, transonic and supersonic speed conditions.

STRUCTURES

The second area is a proposed expansion of the structures and materials program in superplastic forming (SPF) and diffusion bonding (DB) of large titanium structural components. This very recent technology was developed by Rockwell International in the Air Force B-1 program.

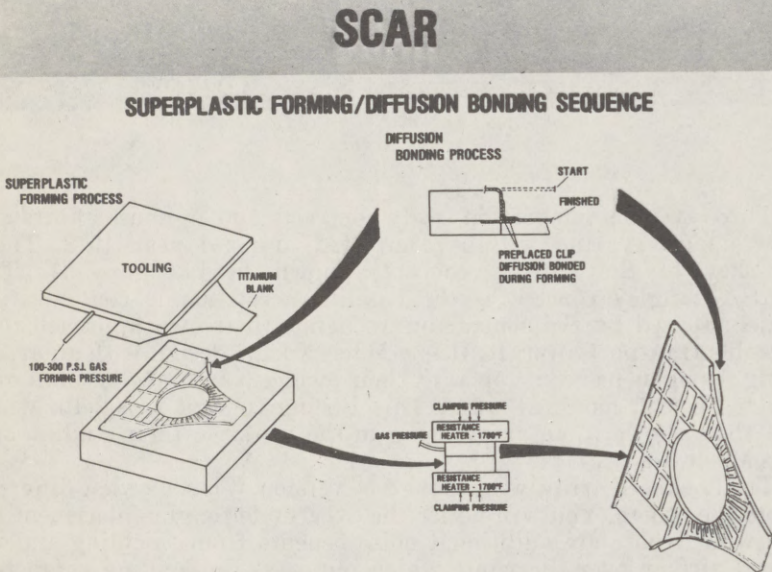


Figure 4

NASA HQ RA77-1630 (3)
1-28-77

The titanium superplastic forming and diffusion bonding process is illustrated schematically in the next chart (figure 4). Very complex structural elements may be produced when titanium is formed under conditions of pressure and temperature such that the material flows in a plastic fashion in the tooling molds. Diffusion bonding may be included in the process as illustrated when, for example, a preplaced attachment clip and the main piece being formed are both included in the tooling mold. The net result is a major savings in the amount of titanium used and a large reduction in the number of fasteners and secondary operations.

The tooling mold shown here would take a titanium blank, and under proper conditions of temperature and gas pressure, be forced to this shape, and be usable on aircraft structures. This process not only uses less material, but the number of fasteners needed when this had previously been made up of several parts would be drastically reduced. At the same time you are forming this part, small attachments, or even sections of skin may be included in the process so that when you are finished, you have it this way.

At the present time, there is not any particular limit, except in the size that one can make.

To establish the significance of superplastic forming and diffusion bonding technology for supersonic cruise aircraft, five separate structural areas—two on the fuselage and three on the wing—were selected for a study by Rockwell International. The arrow-wing Boeing SCAR designs for these areas were provided as the baseline reference. Each area was redesigned to identical load conditions using SPF/DB techniques. When the aircraft design is resized to reflect the component weight reductions of 25 percent in the airframe weight with concurrent fabrication and assembly cost reductions as high as 50 percent are anticipated. Rockwell International is now conducting a similar study under a Lockheed subcontract to evaluate the potential of this technology to components of their SCAR arrow-wing aircraft system.

The fiscal year 1978 activity in superplastic forming and diffusion bonding of titanium will be the initial effort in a continuing three-phase program to fully characterize and define this technology for application to long service life commercial aircraft structures and will complement a large effort by the Air Force to characterize this technology for military aircraft applications. The first phase is directed to verification of preliminary design methods for various structural components such as wing panels, fuselage sections and nacelle access panels. The second phase would be directed to determination of production design criteria, followed by the final phase devoted to validation of strength and life requirements in typical large structural components.

FISCAL RESOURCES

SCAR**SCAR/VARIABLE CYCLE ENGINE PROGRAMS**
(\$M)

	FY 1977	FY 1978
● SCAR DISCIPLINE RESEARCH	8.0	9.0
● VARIABLE CYCLE ENGINE COMPONENT TEST PROGRAM	<u>3.1</u>	<u>6.2</u>
TOTAL	11.1	15.2

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1-19-77

Figure 5

During fiscal year 1978, we propose to increase the funding levels for both SCAR discipline research and the variable cycle engine component test program as shown in the last chart (figure 4). The discipline research increase is provided in this level of effort program to permit the program expansions just described. The proposed variable cycle engine component test program increase of \$3.1 million is to provide the funding level necessary to conduct the critical component testing as expeditiously as possible for this pacing technology.

Last spring this subcommittee held a series of hearings on the "future of aviation." As a result of one of the subcommittee's findings (No. 12), it was recommended:

It is clearly in the national interest for the U.S. to build an environmentally acceptable, fuel efficient and economically viable supersonic air transport aircraft. Government action in the near term should be aimed at accelerating the technology availability date for such a project and at reducing barriers to development by the private sector.

In closing, I would suggest, as stated earlier by Dr. Kramer, that the SCAR program is providing technology advancements in consonance with the recommendations of the subcommittee. With continuing and sustained support, we are confident that this technology, when fully verified, can provide the basis for U.S. decisions on a commercially competitive, environmentally compatible, second generation supersonic cruise aircraft.

Thank you.

Mr. MILFORD. Mr. Aiken, your entire statement will be accepted for the record, with attachments, if you would prefer it that way.

Mr. AIKEN. Yes. Thank you.

[The prepared statement of Mr. Aiken follows:]

HOLD FOR RELEASE UNTIL
PRESENTED BY WITNESS
FEBRUARY 16, 1977

SUPERSONIC CRUISE AIRCRAFT RESEARCH (SCAR)

Statement of

William S. Aiken, Jr.

Director

Aerodynamics and Vehicle Systems Division

Office of Aeronautics and Space Technology
National Aeronautics and Space Administration

Before The

Subcommittee on Transportation, Aviation and Weather
Committee on Science and Technology
House of Representatives

Mr. Chairman and members of the Subcommittee:

As a part of the NASA FY 1978 hearings in September 1976, this Subcommittee invited industry to testify on the progress of the Supersonic Cruise Aircraft Research program and the relationship of the program to accelerating technology availability for this class of aircraft. A review of the testimony indicated that, in the industry's view, and in the Subcommittee's view, Variable Cycle Engine (VCE) technology is the critical pacing technology needed to assure that economic and environmental requirements for future supersonic cruise aircraft can be met. Industry also indicated that research in structures, materials, aerodynamics and advanced control techniques must continue until technology readiness has been established.

It is encouraging to those of us in NASA who are involved in the SCAR program to have the Subcommittee and the industry agree that our technology objectives and priorities are correctly oriented.

During a four-day conference on SCAR technology held at the Langley Research Center in November 1976, some fifty papers discussing all aspects of SCAR technology were presented to and discussed by an audience of almost 300 technical specialists. Progress in the program from its inception in 1972 was seen as impressive with increases in range from 3300 to 4500 nautical miles while achieving a payload three times that of Concorde, and with total operating costs projected to be within 10% of current wide-body aircraft, all of this while meeting environmental constraints.

With these potentials for progress identified, there still remains a very significant amount of technology to be developed. The activities we plan in the FY 1978 program are necessary next steps.

Variable Cycle Engine Technology

As previously mentioned, a VCE is the pacing technology element and is required in all aircraft configurations being studied in the SCAR program. This is a new propulsion concept, the basic technology for which is available only in the United States. It is complex and will be expensive to develop, but, in our view, it is absolutely necessary to assure efficient and economical operation of future aircraft of this class.

The significance of engine cycle flexibility to the concept of a truly efficient supersonic cruise aircraft cannot be overemphasized. The estimated improvement in specific fuel consumption of 20 to 30% during all subsonic flight conditions, which consume a large fraction of the total fuel burned on each flight, obviously strongly influences the economic performance. Variable cycle engines inherently provide significant noise reduction and we are confident that noise levels equivalent to B-747 (FAR-36) can be achieved.

Since supersonic cruise aircraft must simultaneously meet essentially contradictory performance and environmental requirements, our variable cycle engine critical component test program is directed to solutions which match these requirements. The major problem for the propulsion system on this type of aircraft is that it must functionally accommodate at least two distinct modes of operation:

- 1) a high airflow, low jet velocity turbofan-like mode for low noise takeoff and efficient subsonic cruise; and
- 2) a turbojet-like, higher jet velocity, lower airflow mode for supersonic cruise. The rationale for a Variable Cycle Engine (VCE) is its ability to provide a performance match at various operating conditions while also satisfying environmental constraints. It should be noted here that "variable cycle" engines also offer promise for military missions. However, the military missions cannot compromise performance to meet stringent noise and pollution reduction constraints which must characterize a civil version, and the component technology which we are working on is necessarily different from that for military applications.

The propulsion studies conducted by the Pratt & Whitney and General Electric companies to identify promising

Variable Cycle Engines have resulted in two quite different concepts: the Variable Stream Control Engine of Pratt & Whitney and the Double Bypass Engine of General Electric. The mechanization of these two concepts is quite different and both are very complex, but the principles on which they operate to reduce noise and improve fuel consumption are similar. These principles are illustrated in Figure 1. Shown here are two engine cycles, a standard turbojet and a typical variable cycle engine, the latter in its three different modes of operation: takeoff, subsonic cruise and supersonic cruise. The chart illustrates the effects of nozzle characteristics on specific fuel consumption and noise at takeoff. Nozzle characteristics are given in terms of stream velocity and stream temperature at the exit. The baseline turbojet cycle has a constant velocity and temperature profile across the nozzle exit. In a variable cycle engine the velocity of the stream varies across the nozzle. At takeoff such an engine cycle has a higher flow velocity and temperature in the outer annulus of the nozzle. It is this coannular effect which reduces noise at takeoff from 120 to 108 EPNdB. In the subsonic cruise mode the flow schedules between the inner core and outer annulus are inverted with higher temperatures in the inner nozzle section so that the engine performs as a turbofan with a major reduction in specific fuel consumption as compared to a straight turbojet.

In the supersonic cruise mode, the velocities and temperatures are essentially uniform and the cycle operates as a turbojet but without the very high temperatures required of an afterburning engine. In this flight regime there will be a small percentage savings in fuel consumption over that of a straight turbojet, but the amount will be determined by the specific engine design.

Such VCE concepts offer significant performance benefits combined with the potential of meeting future noise and pollution requirements. Achievement of these objectives is clearly dependent on the efficient functioning of the engine components unique to such cycles.

An experimental VCE critical components program (Figure 2) is under way to develop and evaluate the components which represent the major technological risks and uncertainties at this time. Aero/acoustic investigations will continue through FY 1979 with coannular/annular inverted exhaust gas profile nozzle evaluations using small scale models. Primary emphasis will be placed on acoustic performance.

A front block fan for the G. E. concept will be designed, fabricated and rig tested to demonstrate efficient operation over a wide range of flow conditions.

Duct burner design concepts are being screened and segments of promising designs will be fabricated and rig tested by P&W to establish performance and emission levels.

Finally, with the proposed increase in funding, larger scale tests of the critical components of the G. E. and P&W cycles would be conducted in FY 1978 to establish the almost full-scale acoustic characteristics of these engine cycles. The critical components, such as nozzles, duct burners, and front fan modifications, would be tested using existing high technology engine cores as the gas generators. Temperature, pressure and flow conditions which closely simulate those for a full-scale engine would provide the data required for a future decision to proceed with a variable cycle experimental engines program.

SCAR Systems and Disciplinary Research

While we propose to emphasize VCE technology in FY 1978, continued research is also still necessary and will be sustained in systems integration studies and the related disciplinary research programs.

Systems Integration Studies

Three systems integration study contracts and an in-house effort now under way will be completed during FY 1978. These studies will analyze major subsystem integration techniques and/or problems inherent in each of the candidate airframe configurations. The four configurations being studied by four different teams are illustrated in Figure 3. The Boeing Company blended delta-wing Mach 2.4 design is illustrated on the top left. The McDonnell Douglas Corporation Mach 2.2 design is shown on the top right. The Lockheed Aircraft Corporation engine over/under the wing Mach 2.55 design is illustrated at the lower left. The NASA Langley baseline Mach 2.7 arrow wing is shown at the lower right.

These studies will provide NASA and industry detailed analysis and sensitivity assessments of the somewhat different technologies required for each configuration. Because the performance of supersonic aircraft is so dependent upon the optimization of all subsystems and is so sensitive to the interaction and trade-offs of various technologies, the SCAR program has continuously emphasized the conduct of these studies, so that only the highest payoff technologies are pursued within the limited scope of the program. These studies are the basis for confidence in achieving the goals of the program.

Aerodynamics

There are two specific disciplinary research activities planned for FY 1978 that I would briefly like to discuss. The first is a proposed expansion of the aerodynamics research activities. While we have made major progress in drag reduction such that the lift-to-drag ratio at supersonic speeds can be increased by as much as 30%, the systems integration studies have indicated that substantial additional improvements in aerodynamic performance are possible in several remaining areas. These areas include improved low-speed operation by refinement of wing leading and trailing edge contours, further reductions in transonic drag by improved engine nacelle/airframe integration, and outboard wing camber and thickness changes to reduce structural weight penalties.

These refinements and improvements would be pursued beginning in FY 1978 through a series of wind tunnel model tests. Several new and somewhat larger wind tunnel models incorporating necessary refinements would be constructed and tested at critical low, transonic and supersonic speed conditions. Each configuration would be optimized to provide the best compromise over all flight speeds.

Structures

The second area is a proposed expansion of the structures and materials program in superplastic forming (SPF) and diffusion bonding (DB) of large titanium structural components. This very recent technology was developed by Rockwell International in the Air Force B-1 program.

The titanium superplastic forming and diffusion bonding process is illustrated schematically in the next chart (Figure 4). Very complex structural elements may be produced when titanium is formed under conditions of pressure and temperature such that the material flows in a plastic fashion in the tooling molds. Diffusion bonding may be included in the process as illustrated when, for example, a preplaced attachment clip and the main piece being formed are both included in the tooling mold. The net result is a major savings in the amount of titanium used and a large reduction in the number of fasteners and secondary operations. This technology, when applied to long life commercial aircraft applications, indicates a structural weight reduction of 14% over other forming and fabrication processes. However, the surprising result is the potential reduction of 30% in airframe cost. This cost reduction feature is particularly important to civil/commercial aircraft designs.

To further establish the significance of superplastic forming and diffusion bonding technology, five separate structural areas--two on the fuselage and three on the wing--were selected for a study by Rockwell International. The arrow-wing Boeing SCAR designs for these areas were provided as the baseline reference. Each area was re-designed to identical load conditions using SPF/DB techniques. Estimates of SPF/DB design indicate that up to 65% of fuselage and 61% of wing production costs may be saved. When the aircraft design is resized to reflect the component weight reduction in the full structure, reductions of 25% in the airframe weight with concurrent fabrication and assembly cost reductions as high as 50% are anticipated. Rockwell International is now conducting a similar study under a Lockheed subcontract to evaluate the potential of this technology to components of their SCAR arrow-wing aircraft system.

The FY 1978 activity in superplastic forming and diffusion bonding of titanium will be the initial effort in a continuing three-phase program to fully characterize and define this technology for application to long service-life commercial aircraft structures and will complement a large effort by the Air Force to characterize this technology for military aircraft applications. The first phase is directed to verification of preliminary design methods for various structural components such as wing panels, fuselage sections and nacelle access panels. The second phase would be directed to determination of production design criteria, followed by the final phase devoted to validation of strength and life requirements in typical large structural components.

Fiscal Resources

During FY 1978, we propose to increase the funding levels for both SCAR Discipline Research and the Variable Cycle Engine Component Test Program as shown in Figure 5. The Discipline Research increase is provided in this level of effort program to compensate for continuing inflationary effects and to permit the program expansions just described. The proposed Variable Cycle Engine Component Test Program increase of \$3.1M is to provide the funding level necessary to conduct the critical component testing as expeditiously as possible for this pacing technology.

Summary

Last spring this Subcommittee held a series of hearings on the "Future of Aviation." As a result of one of the Subcommittee's findings (No. 12), it was recommended:

"It is clearly in the national interest for the U. S. to build an environmentally acceptable, fuel efficient and economically viable supersonic air transport aircraft. Government action in the near term should be aimed at accelerating the technology availability date for such a project and at reducing barriers to development by the private sector."

In closing, I would suggest, as stated earlier by Dr. Kramer, that the SCAR program is providing technology advancements in consonance with the recommendations of the Subcommittee. With continuing and sustained support, we are confident that this technology, when fully verified, can provide the basis for U. S. decisions on a commercially competitive, environmentally compatible, second-generation supersonic cruise aircraft.

SCAR

VARIABLE CYCLE ENGINE CRITICAL COMPONENT TECHNOLOGY

FY	76	T	77	78	79	80

AERO/ACOUSTIC
MODEL TESTS

FRONT BLOCK FAN
RIG TESTS (GE)

DUCT BURNER RIG
TESTS (P&W)

LARGE SCALE CRITICAL
COMPONENT FABRICATION
& TESTING

◇ ACOUSTIC TESTS

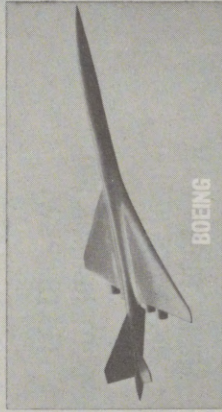
GE ◇ P&W

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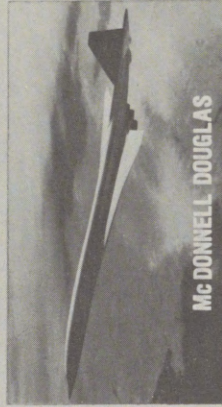
Figure 2

SCAR

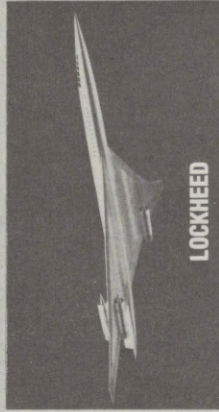
ADVANCED SUPERSONIC CRUISE AIRCRAFT CONFIGURATIONS



BOEING



Mc DONNELL DOUGLAS



LOCKHEED



NASA-LANGLEY

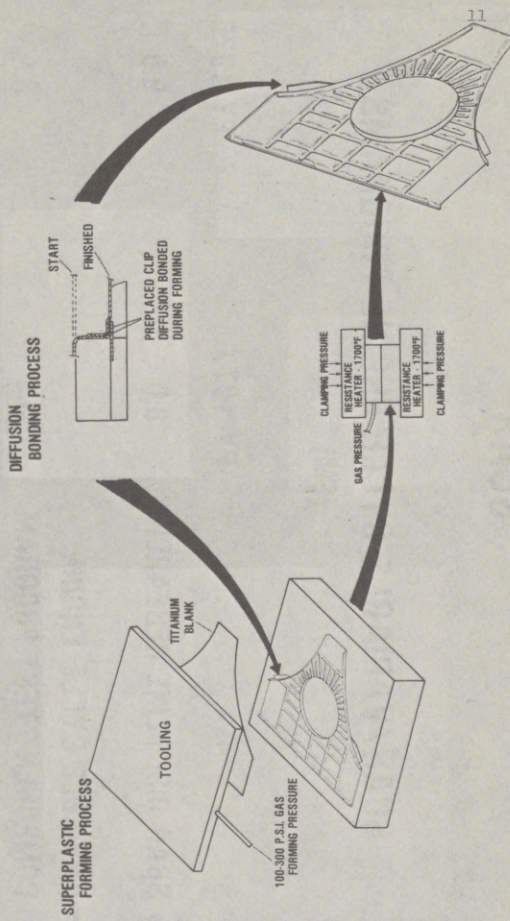
10

SCAR PROJECT OFFICE

Figure 3

SCAR

SUPERPLASTIC FORMING/DIFFUSION BONDING SEQUENCE



NASA MO 1477-1630 (3)
1-28-77

Figure 4

SCAR

SCAR/VARIABLE CYCLE ENGINE PROGRAMS

(\$M)

FY 1978

9.0

FY 1977

8.0

• SCAR DISCIPLINE RESEARCH

• VARIABLE CYCLE ENGINE

COMPONENT TEST PROGRAM

6.2

3.1

TOTAL 11.1

15.2

NASA HQ BX77 1466 (3)
1 1977

12

Figure 5

Dr. KRAMER. Mr. Chairman, shall we proceed with the other topics?

Mr. MILFORD. Yes; if you would like.

Go ahead.

Dr. KRAMER. The next topic I would like to discuss with you concerns our efforts on helicopters and vertical-takeoff-and-landing technology generally.



Figure 5 shows the rotor systems Research Aircraft, which is a joint program we are conducting with the Army. The rotor systems research aircraft flew for the first time in December 1976, and the second aircraft is now nearing completion. In the next few months, we will begin flight tests on the aircraft in the compound mode, that is, with the thrusting engines and wings in place. We look forward to this vehicle as being a significant expansion of our facility capability for rotor systems testing. This will enable us to do flight testing with good pilot safety and subject experimental rotors to a wide range of flight conditions which we are unable to duplicate in our wind tunnel facilities.

HELICOPTERS / VTOL

ARMY/NASA TILT ROTOR RESEARCH AIRCRAFT (TRRA)

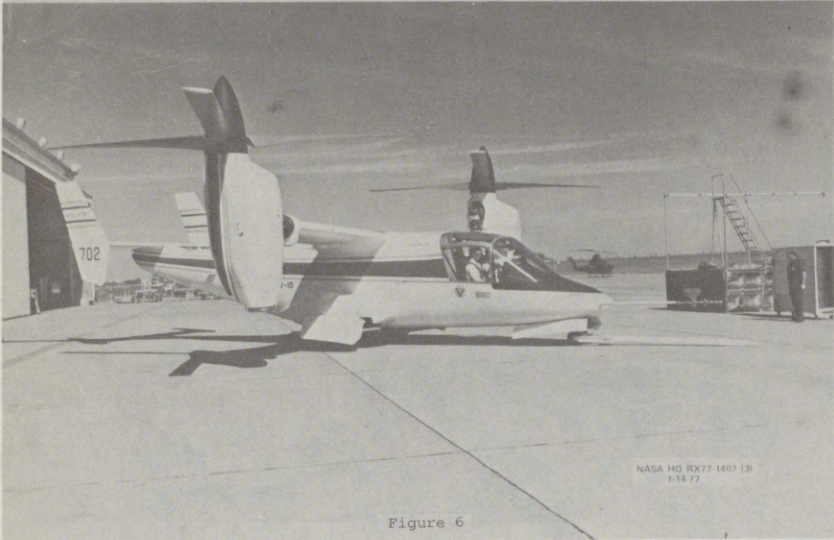


Figure 6

Figure 6 shows the tilt rotor research aircraft. Roll-out occurred last October. It is moving along, and we are looking forward to its first flight some time in the next few months. It is a very interesting concept, which will permit not only vertical-takeoff-and-landing operations, but also the achievement of forward flight speeds in the range of 300 knots with a significant payload. The first activity in the flight test program will be aimed at expansion of the operating mode, and in fiscal year 1978, the tilt rotor research aircraft will be delivered to us for flight tests at Ames where we will evaluate a number of performing parameters.

The next topic I would like to talk about is general aviation. We have quite a few interesting things going on in general aviation.

GENERAL AVIATION

GAW-1 WING ON BEECH 77 PROTOTYPE



Figure 7

NASA HQ 8A77-1678(3)
2-2-77

Figure 7 shows an application of supercritical technology, a GAW-1 wing on the Beech 77 prototype. Beech has announced its intention to put this aircraft into production in calendar year 1977. We are particularly pleased to see the NASA aerodynamic technology for general aviation as incorporated into a wing, beginning the transition into a production vehicle.

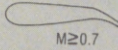
As you know, we have set up an institute at Ohio State for providing air foil design services to the general aviation community, that service is being conducted for us under contract by Ohio State, and has now been certified as fully operational to provide such design services to the general aviation community.

GENERAL AVIATION

GENERAL AVIATION TECHNOLOGY

AIRFOIL DEVELOPMENT

SUPER CRITICAL



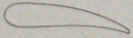
$M \geq 0.7$

MEDIUM SPEED

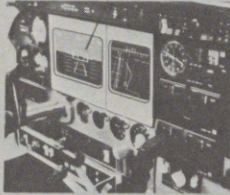


$M = 0.3-0.5$

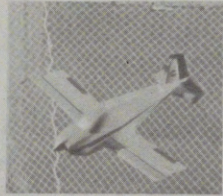
LOW SPEED (GAW)



$M \leq 0.2$

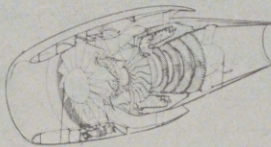


LOW-COST AVIONICS

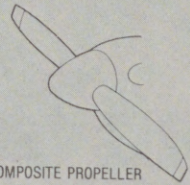


STALL/SPIN RESEARCH

PROPULSION TECHNOLOGY



QCGAT



COMPOSITE PROPELLER

NASA HQ 1077-1159 (3)
12-29-76

Figure 8

Figure 8 shows a variety of activities with which we are involved in our general aviation program. I spoke about the GAW-1 wing, and this is shown schematically on the lower left. We are working on a variety of applications. The high mark is the supercritical airfoil, but the same kind of computer design techniques are used throughout.

We are continuing our work in systems technology programs aimed at getting low-cost avionics equipment available to the general aviation community, with particular emphasis on navigation equipment and displays in late calendar year 1977. We signed contracts for work on the quiet, clean general aviation engine shown in the lower center. In the past year we have put a considerable amount of our efforts in stall-spin research which was identified by our general aviation research and technology advisory council panel as one of the most pressing research areas that needs NASA attention. We have increased not only the manpower, but also the R. & D. dollars available for work in this area. We are beginning to revive our work on propeller aerodynamics see the possibility of the use of composite materials in propellers to add flexibility in design and also cost savings in the future ultimately.

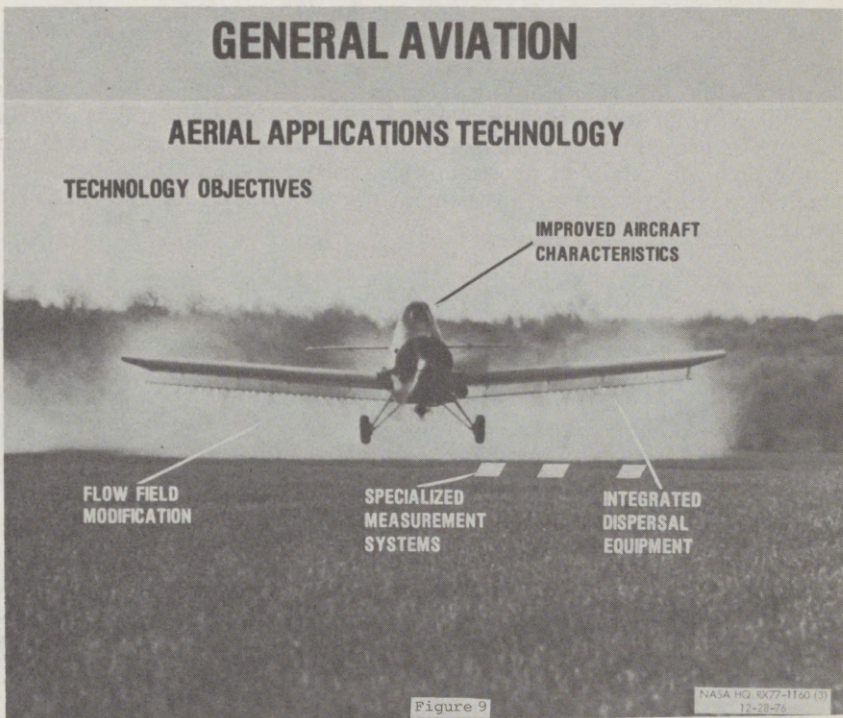


Figure 9

Another area we are working in and building up our efforts is that associated with aerial applications technology as shown in figure 9. We have been working with other government agencies, notably the Environmental Protection Agency, the Department of Agriculture, and the Federal Aviation Administration to define the needs and requirements for aircraft of this type. Our emphasis thus far has

been on defining the impact on the air-flow field by the presence of the aircraft and the dispersal equipment and how the flow field affects the dispersal of the applied materials. We are also looking at improved navigation techniques, and as you know, these aircraft are operating on a very tricky mission.

We are looking at ways of improving the dispersing equipment so they interact more favorably with the aerodynamic flow field of the vehicle, and we are also looking at measurement systems to update what are now rather crude systems for measuring the actual distribution of the fertilizer, seed and pesticides on fields. We expect that this area will grow; to exactly what size we do not know. We are not now working on any kind of total vehicle system, but merely sub-systems of the dispersal equipment.

I would like to move on to our work on short haul and STOL, and before talking about the specifics of that program, I would like to mention our response to the GAO recommendations on the total Federal STOL program. In response to that GAO report, we have examined our program regarding its content, the level of resources, and the pace at which we are bringing STOL technology along. We did this reassessment in conjunction with the other Government agencies involved, the DOT, the FAA, and the DOD.

It is very clear that we are in a difficult position of anticipating long-term technology needs, and that, to a person not intimately familiar with the pace of technology development, it could appear that we are out ahead of the pack. However, we feel the timing and the level of our investment in STOL is appropriate, and we are continuing on our previously planned program. That program plan, however, does include a reduction in our investment in STOL, as I mentioned earlier in the funding charts.

SHORT-HAUL / STOL

QUIET SHORT-HAUL RESEARCH AIRCRAFT (QSRA)

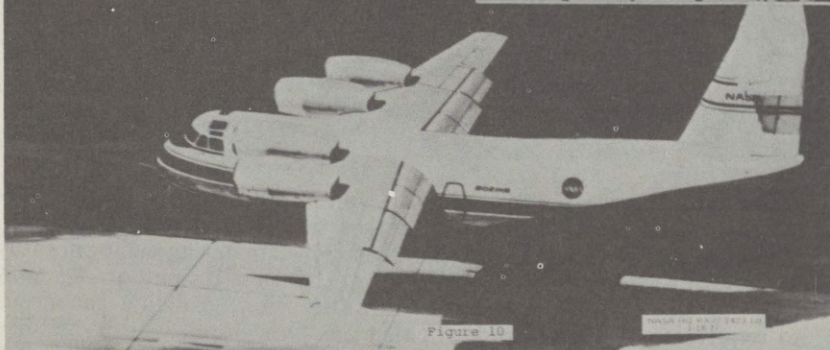


Figure 10

The quiet short-haul research aircraft (QSRA) is shown in the lower part of figure 10 as an artist's conception of what it will look like when it flies in fiscal year 1978. Today's reality is shown by the photograph in the upper right-hand corner, where the C8A-Buffalo airplane has been scrapped of its wing, and is in the shop at Boeing awaiting installation of new wings, new propulsion systems, and other major modifications. We expect fairly heavy activity on this program in the next year. The QSRA will be rolled out in about a year and be ready for flight test sometime in mid-1978. We have conducted wind tunnel tests on the aerodynamic configuration, and on the lift enhancement system. We feel quite confident that we are on the right track with this vehicle; as you well know, it is aimed at addressing peculiar technology requirements for civil STOL aircraft.



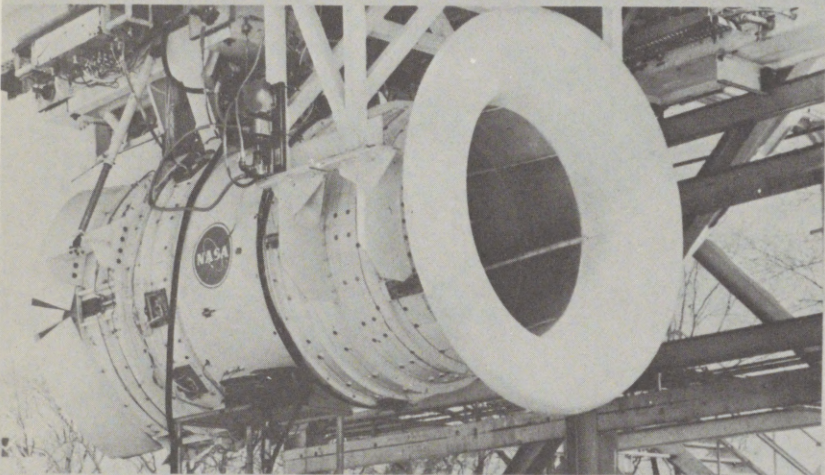
The military of course is involved in STOL activities. Figure 11 shows the Boeing entry into the AMST program, and we are working not only with Boeing on the YC-14 pictured here, but we have also worked on the YC-15. Most of our AMST activity is concerned with using those Air Force-sponsored vehicles as a convenient test bed for making measurements of parameters that we are interested in that are not of primary interest to the Air Force, and therefore are not included in their program. We do these tests, which are primarily concerned with noise characteristics, and we pay the Air Force for the costs associated with the tests.

We will have instrumentation on the YC-14 to get determinations of the internal noise generated by the engine. We are looking at the noise effects and temperature effects; and in general, mechanical and dynamic effects of the jet exhaust on the flap; at the acoustic loads, the loads associated with temperature and the static pressures. We are also looking at the potential impact of the exhaust on the fuselage.

We feel we are working effectively, but in a cost-efficient way, by using the AMST in this manner.

SHORT-HAUL / STOL

QUIET CLEAN SHORT-HAUL EXPERIMENTAL ENGINE - ON TEST AT GE

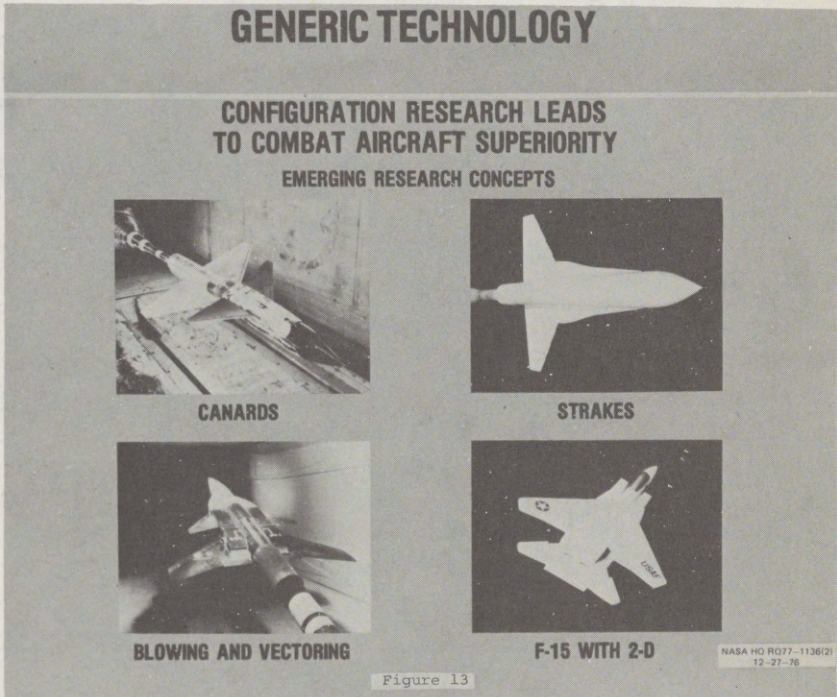


NASA HQ 8177-1215 (3)
1-3-77

Figure 12

Figure 12 shows our experimental engine, the quiet clean short-haul experimental engine (QCSEE), which is being executed for us by General Electric. The goal of the QCSEE engine, as used on a STOL airplane of reasonable size, is to have a 90 EPNdB footprint of less than 1 square mile. The QCSEE program will be completed in fiscal year 1978. It is shown here in the under-the-wing configuration, on test in an outdoor test facility at GE's test site in south-central Ohio which has been specifically designed to make accurate tests of noises in the system.

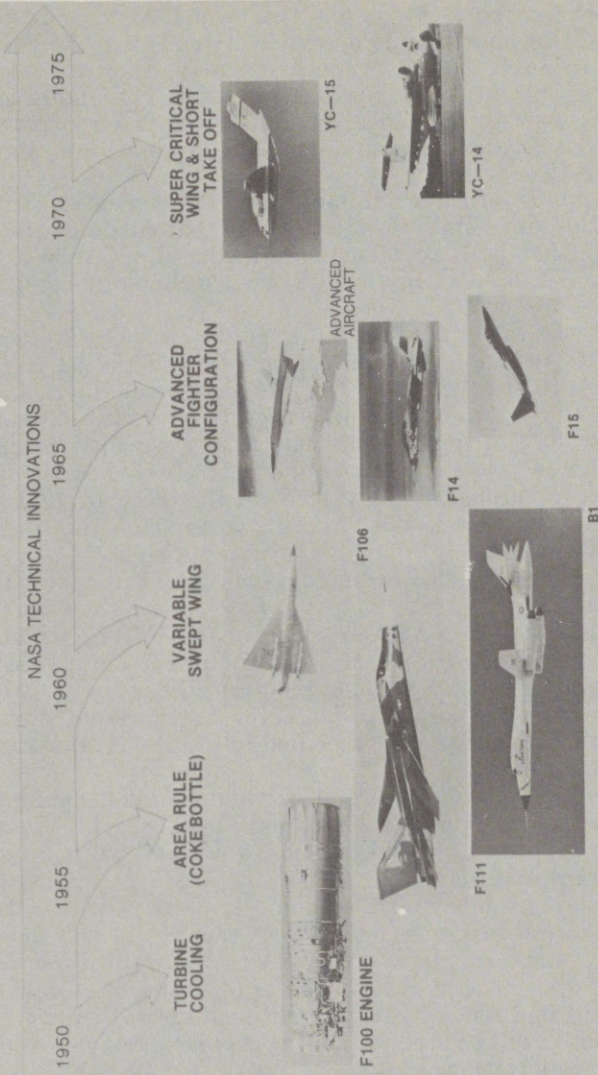
I would like to move on to generic technology. What we mean by generic technology is simply that the technology is such that it applies to a variety of aircraft types.



A good example of generic technology is shown in figure 13.

Shown are a number of photographs of models, either in the wind tunnel, or prior to being tested in the wind tunnel, where we examined various new concepts; canards; propulsion lift concepts, not for short takeoff and landing but for greater maneuverability of the vehicle; strakes for better control and maneuverability purposes; and in the lower right, a wind-tunnel model with a two-dimensional nozzle. Two-dimensional nozzles can reduce some of the drag problems that were encountered with the F-14 and F-15 airplane. They not only reduce the drag but they may be lighter weight structurally. There is a further military advantage that it may lead to some signature suppression such that it would be more difficult to detect the presence of these aircraft.

EXAMPLE OF NASA CONTRIBUTIONS TO MILITARY AIRCRAFT



NASA TECHNOLOGY IS USED ON EVERY U.S. MILITARY AIRCRAFT

Figure 14

The next chart, figure 14, is one that you have seen before. Dr. Fletcher used this chart in his overview statement to the committee. I would like to dwell on a few points, if I may. Shown is a time line at the top, starting with 1950 up to the present. This figure identifies some of the major technological spinoffs from NASA in the early days, from the NACA program, which had significant impact on military aircraft.

We could put together a similar figure for civil aircraft and we could make the same kind of statement as that made at the bottom of that chart; that is, NASA technology is used on every U.S. military aircraft. We could also point to NASA technology being used on every U.S. civil aircraft.

Starting in the early days of the jet engine, we clearly recognized that the key to reducing the fuel consumption of the jet engine and increasing its thrust-to-weight ratio was to increase the turbine inlet pressure and the maximum temperature of the cycle. The only way that could be done with the materials that were then available or available even now, was to find ways of effectively cooling the turbines.

A very heavy emphasis was placed on this area in 1951 when I started working at Lewis. We are still working on this technology because there is such a high payoff associated with it.

The advancements in this technology has found its way into all of the modern military engines.

In the middle 1950's, NACA worked on the F-106 airplane, and, indeed, made major contributions which helped make it possible for that airplane to achieve its mission requirements.

In the early 1960's, the technology for the variable sweep wing emerged, and it was, of course, embodied in the F-111. It is also being used on the B-1.

Our work in the middle 1960's on advanced fighter configurations contributed significantly to the F-16, and also the F-14. We are continuing to do that kind of configuration work, and work very closely with the military in this area.

Our work on propulsive-lift technology clearly demonstrates its applicability to military missions on both the YC-14 and the YC-15, and we expect that some day we will have some application in STOL aircraft. But even beyond STOL, the application of propulsive lift technology will find its way into conventional aircraft, and we see the possibility that it will be used to ease the problems related to advanced supersonic transportation.

Having highlighted our past accomplishments, I would like to turn now to what we will do in the future.

GENERIC TECHNOLOGY

CONFIGURATION RESEARCH LEADS TO COMBAT AIRCRAFT SUPERIORITY

PROOF-OF-CONCEPT TESTING

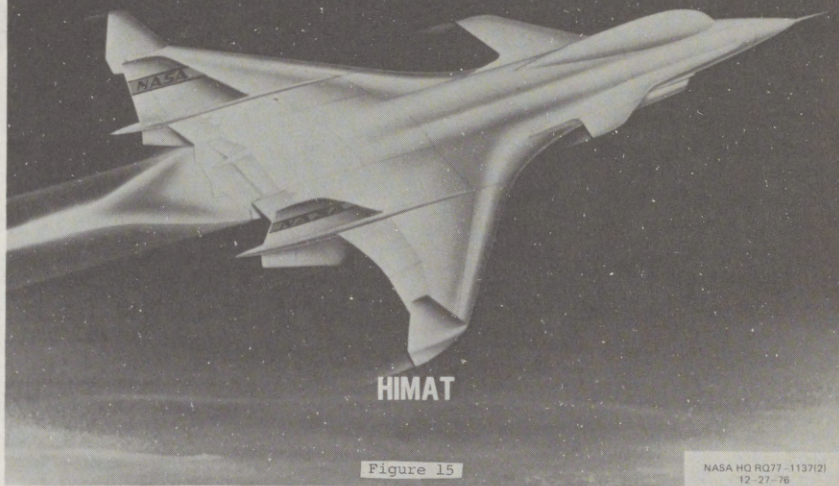


Figure 15

Some of the advanced concepts we are working on in the wind tunnel will be checked out in the HIMAT program, figure 15. As you know, HIMAT is a remotely piloted research vehicle which is a little less than half size. It has a 15-foot wing span and 23-foot length. It will enable us to investigate a wide variety of aerodynamic concepts, and it is made in such a way that it has a high degree of variability built into it. We expect that the HIMAT vehicle will be ready for flight test, of course, in the remote mode in the middle of fiscal year 1978.

Moving on to another area of generic technology, I will briefly describe our program where we are attempting to reduce the oxide emissions of aircraft.

GENERIC TECHNOLOGY

TECHNOLOGY IMPACT ON AIRCRAFT POLLUTION LEVELS (NO_x AT CRUISE CONDITIONS)

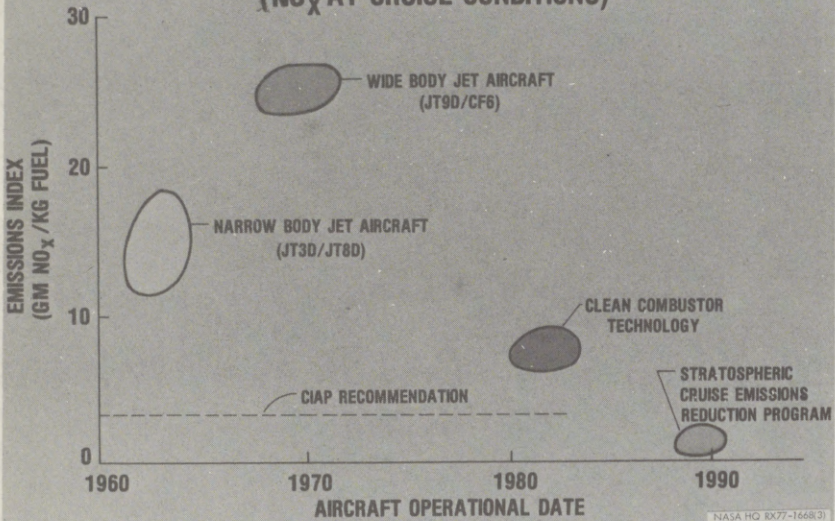


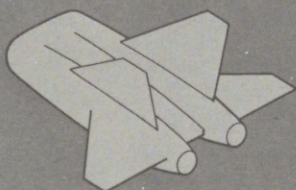
Figure 16

On this chart, figure 16, you can see that the narrow-bodied jet aircraft which came into widespread use in the early 1960's have an emission index in the range of 10 to 20, that is grams of oxide of nitrogen produced per 1,000 grams of fuel burned. As the engines went up in temperature and pressure, and as technology advanced, you can see that the JT9D and the CF6 engines, which are used on the wide-body jet aircraft, have emission indices in the range of 25.

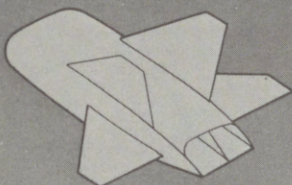
We have just about completed our clean combustor program with General Electric and Pratt & Whitney, and we see ways of getting down to emission indices in the range of 10 as shown by the dark green area. However, the climatic impact assessment program has indicated that it is very desirable to get down to emission indices less than 3. We are not there with our clean combustor technology. Therefore, we are actively engaged in this stratospheric cruise emissions reduction program. Both manufacturers—Pratt & Whitney and General Electric—are under contract but it will require very substantial technology advancement. We do not see how it would be possible to get that kind of technology into vehicles much before 1990.

R&T BASE

PROPULSION SYSTEM INSTALLATION RESEARCH



AXISYMMETRIC NOZZLE (CURRENT)



NON-AXISYMMETRIC NOZZLE (2-D)
(FUTURE)

OBJECTIVES:

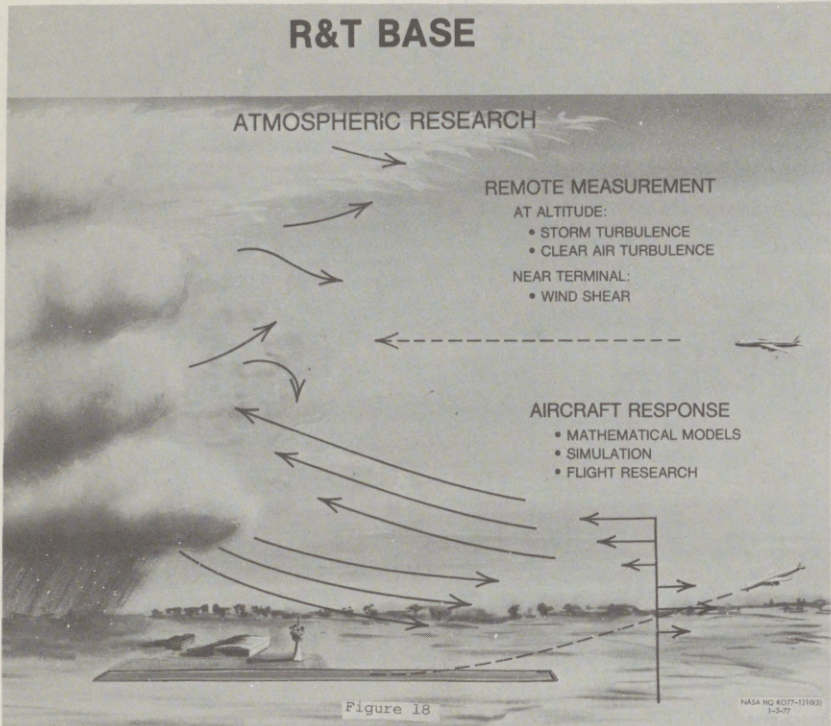
- REDUCED AIRCRAFT DRAG
- THRUST VECTORING FOR MANEUVERABILITY AND SAFETY
- SIMPLER MECHANISMS
- REDUCED WEIGHT
- LOWER COST
- LONGER NOZZLE LIFE

Figure 17

NASA HQ RA77-167(X3)
2-2-77

To go on now to our R. & T. base activity, figure 17, let me talk about a couple of selected items. We worked on propulsion system integration research. We are working with the DOD on the F-14 and F-15, and it is clear that there is a very complex problem associated with the installation of the propulsion system in such a way as not to get high base drag.

We see one way to reduce aircraft drag through the use of the 2-D nozzle. There are also other concepts to reduce aircraft drag, and as we pursue these concepts we always look for ways to get reduced costs and reduced weight and longer nozzle life.

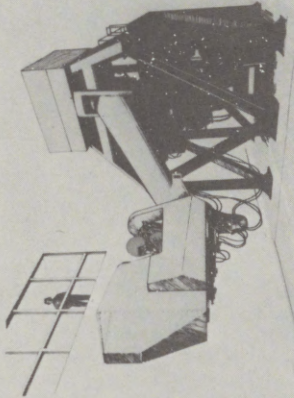


In figure 18 we schematically show a thunderstorm just to suggest to you that we are working on the definition of air turbulence at high altitudes and low altitudes. We are examining the effects of the atmospheric phenomena on the handling qualities and controllability of the aircraft and we are using the simulators that are in our research centers as a prime tool in that work. We have worked on the characteristics of the atmosphere, this work is being carried out at Langley and Marshall, and work is being done at Ames also, which is our primary center in simulation technology.

R & T BASE

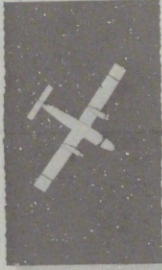
INCREASE LANDING SAFETY AND ECONOMY

MOVING-BASE SIMULATOR



EXPLORE DIRECTIONAL CONTROL
AND BRAKING PROBLEMS

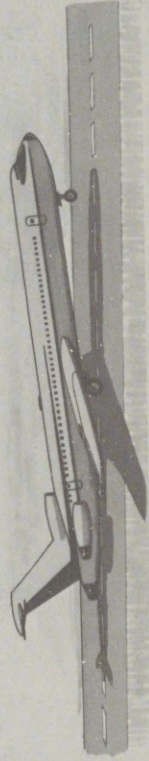
CROSSWIND LANDING GEAR FLIGHT TESTS



INVESTIGATE

- PILOTING TECHNIQUES
- MODES OF OPERATION
- OPERATIONAL LIMITS

AIR CARRIER EVALUATION



NEW TIRE MATERIALS FOR IMPROVED WEAR AND SAFETY

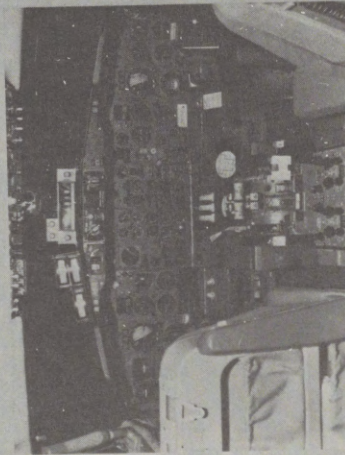
Figure 19

MASS INC. 60371601 01
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Figure 19 shows some of the things we are doing to increase the safety aspects of aircraft. We are using the simulators to simulate the performance of aircraft while they are on the ground; after touchdown; during landing; and are simulating various problems, such as braking and associated control problems using the moving-base simulator at Ames. We are also looking at using crosswind landing gear for increased freedom of pivot and we are looking at the support structure of the landing gear such that an aircraft could be landed with an increased sink rate. We have also developed some interesting new materials for tires, which can be viewed as either a safety benefit, because of the lower rate of heat buildup, or as an economic benefit, because the lower rate of heat buildup results in longer tire life. We are working with some of the air carriers to have some of these materials made up into recapped tires, and they are going to be tested, we feel, on some civil transport aircraft.

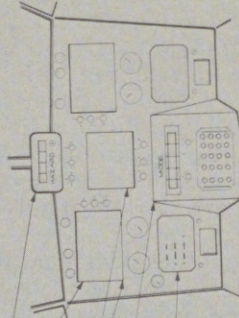
R&T BASE

COCKPIT AVIONICS



CURRENT TECHNOLOGY

- HAZARD WARNING/PRED. SYSTEM IMPLEMENTATION
- ADVANCED DISPLAY DEVICES
- REDUNDANT DISPLAY MANAGEMENT
- AUTOMATED PROCEDURES IMPLEMENTATION
- IMPROVED INFORMATION DISPLAY TECHNIQUES



ADVANCED TECHNOLOGY INTEGRATED COCKPIT

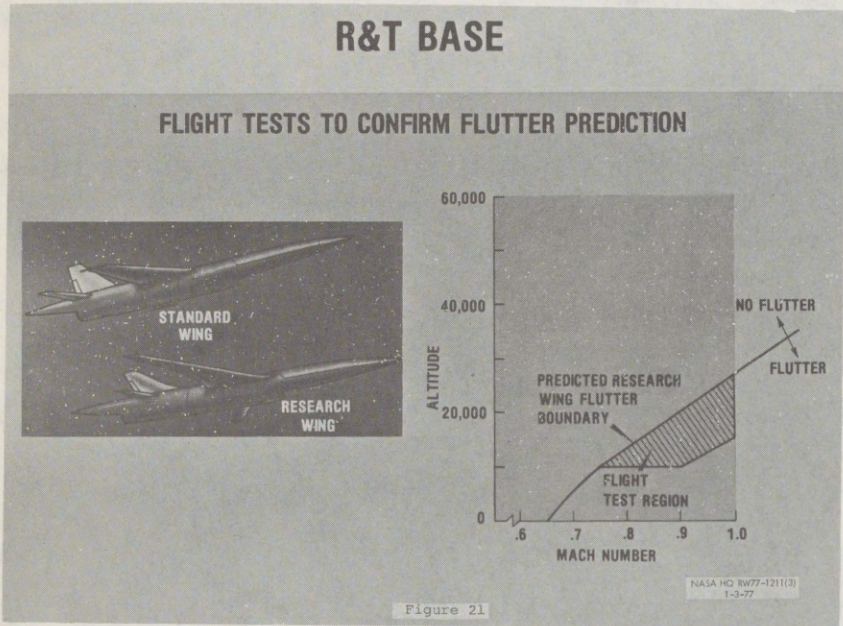
NASA HO 827-1162 (3)
12-88-76

Figure 20

In addition to these safety related programs, we have been working very closely with the FAA in the area of cockpit human factors. Figure 20. One program of particular importance is the collaborative program that we are developing with the FAA to investigate the role of displays to aid in the transition from instrument control to visual reference under all visibility conditions.

We are also working with the FAA in other areas of cockpit warning and alerting systems, and advance control and display concepts. We feel that we are working fairly well with the FAA in the human factors area.

Moving on to another item in our total R. & T. base program, you are no doubt familiar with the problem of where the airflow results in unstable structural response in the wings which can lead to catastrophic failure in very short time periods.



All airplanes have a flutter boundary, and in figure 21 a typical flutter boundary is presented which shows altitude versus mach number. In the cross-hatched area, it is predicted that the wing will flutter. The boundary lies in between the flutter and no-flutter regions.

As the wing aspect ratio of the airplane increase, you are eventually limited because of flutter considerations. Those limitations can be overcome somewhat by the use of stiffer materials, and they can also be overcome by the introduction of active control systems on the wing to sense when the wing will flutter and to move the control surfaces on the wing to get the airplane out of the flutter region. We will investigate this flutter region using a remotely piloted vehicle with research wings. The vehicle will have a standard wing and be flown into the

flutter region, and we will also be using a high-aspect research wing with active controls. We will explore not only the no-flutter region, but also the flutter regions, to see if we are successful in using active controls to obviate the flutter problems.

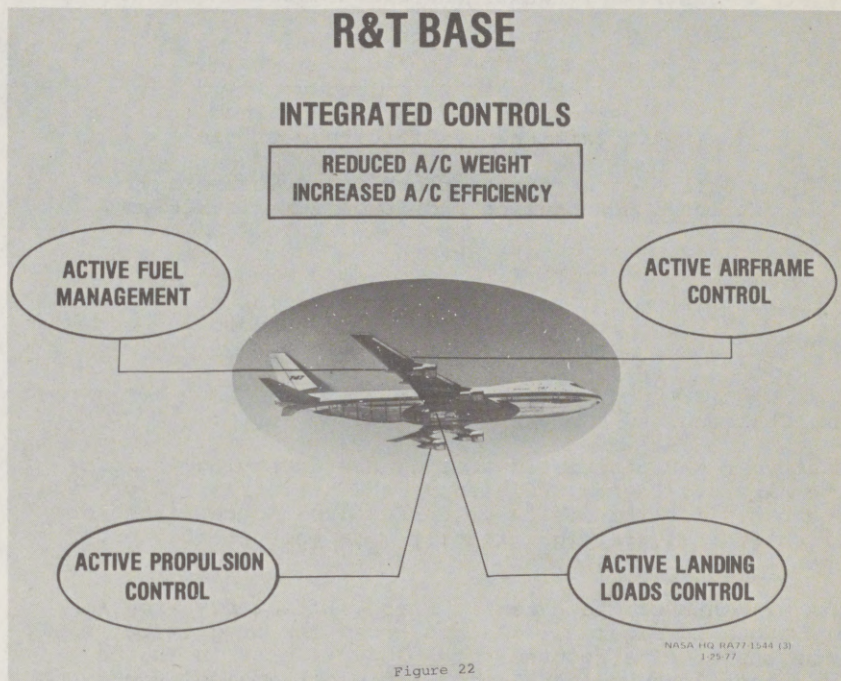


Figure 22

Relative to the active controls area, I would like to say a few words about the integrated controls as shown in figure 22. We believe that the computer will substantially impact the operation of aircraft in the future. We know that integrated controls can reduce the aircraft weight, and also increase the aircraft efficiency. Integrated controls can manage the fuel reserves more efficiently than the pilot instrumentation available now, and we have been working for some time on active propulsion controls and active aircraft controls. Eventually all of these control systems will be integrated together so we have one total system for the aircraft operation. That is a long-term objective for some of our research programs in the control area.

As I promised you earlier, we will have some testimony on the aircraft energy efficiency technology program. I would like at this point to introduce Dr. Raymond S. Colladay, who has spent a year on our staff. He is permanently assigned to our NASA Lewis Research Center, and he will tell you about our efforts in the aircraft energy efficiency technology program.

Mr. MILFORD. Dr. Colladay, we have your complete statement with attachments, which will be accepted for the record at this time.

[The prepared statement of Dr. Colladay follows:]

HOLD FOR RELEASE UNTIL
PRESENTED BY WITNESS
FEBRUARY 16, 1977

AIRCRAFT ENERGY EFFICIENCY TECHNOLOGY

Statement of

Raymond S. Colladay
Acting Chief, Propulsion Branch
Aircraft Energy Efficiency Office

Office of Aeronautics and Space Technology
National Aeronautics and Space Administration

Before the

Subcommittee on Transportation, Aviation and Weather
Committee on Science and Technology
House of Representatives

Mr. Chairman and members of the Subcommittee:

Last year NASA initiated a major new technology effort, the Aircraft Energy Efficiency (ACEE) Program, to provide the basis for the design of derivative and new transport aircraft that are significantly more energy efficient than today's transports.

The elements of the Aircraft Energy Efficiency Program are shown in Figure 1. As you know, the program currently consists of five focused technology efforts in Engine Component Improvement, Energy Efficient Engine, Energy Efficient Transport, Laminar Flow Control, and Composites. A major expansion of the ACEE Program is planned for FY 1978 with the addition of a new propulsion program in turboprops and the start of the second phases of the Energy Efficient Engine and Energy Efficient Transport.

The three ongoing programs which are proceeding as planned and for which no expansion is required in FY 1978 are the Engine Component Improvement, Laminar Flow Control, and Composite Programs. Briefly, in the Engine Component Improvement effort we are working with the engine manufacturers and the airlines to identify sources of in-service performance deterioration and to develop improved engine components which will reduce fuel consumption in current engines. The Laminar Flow Control Program is aimed at greatly reducing the drag of future aircraft by maintaining smooth, or laminar, flow over the surface. We are continuing work on systems definition and concept evaluation to assess alternative designs which are technically

feasible and economically attractive for a laminar flow aircraft of the 1990's. Through the Composite Primary Aircraft Structures program, we are attempting to accelerate the use of composite materials in commercial aircraft. Work is continuing on the design, development, certification, and flight service of a diverse mix of secondary structures and medium- and large-sized primary structures to give the industry experience and confidence in the use of composite materials to reduce the weight of new aircraft.

Turning now in more detail to the programs where new initiatives are planned for FY 1978, I will discuss each program in the order shown in Figure 2, starting with Advanced Turboprops.

Turboprops-Phase I: Modern high speed turboprops have the potential of saving significant amounts of fuel, on the order of 20 to 30 percent over modern high-bypass turbofan engines. The goal of this new propulsion program is to develop the technology to demonstrate that future airplanes powered by advanced turboprops will be comfortable, quiet, safe and economical to operate. Figure 3 shows what an advanced turboprop powered aircraft of the future might look like and lists the four phases of the Advanced Turboprop Program. Phase I calls for the extensive development of propeller aerodynamics and noise technology. Other phases shown in the figure, which are planned for FY 1980 and beyond, call for future decisions based on the success of the Phase I program.

Recent wind tunnel tests conducted in the R&T Base program and reported to the Subcommittee last fall have demonstrated that advanced multibladed propellers can achieve the same high efficiency levels as older propellers while operating at a much higher cruise speed and altitude. In FY 1978, wind tunnel tests to evaluate propeller aerodynamics will continue (Figure 4). In addition, propeller systems will be designed, fabricated, and tested to study the tradeoff between propeller efficiency, noise and structural limits.

A major technology area to be addressed in Phase I is propeller acoustics. Wind tunnel tests to measure and document the noise levels associated with modern high-tip-speed propellers will be conducted in FY 1978 and analytical models will be perfected to improve noise prediction and propeller design capabilities. Propeller source noise will be addressed through advanced design techniques, such as blade sweep, to reduce community noise. At a cruise Mach number of 0.8 and with the high

power loading required, the blade tips in the advanced design propeller rotate at supersonic speeds causing a potential noise problem. Blade sweep has been used in the model shown in the figure to weaken the shock wave at the tip, but noise is still likely to be a problem and other noise attenuation methods will be investigated, such as reducing the blade thickness, increasing the number of blades, or using dual counter-rotating propellers. Effective lightweight acoustic treatment of the cabin walls will also be investigated in order to preserve passenger comfort and avoid a severe installation weight penalty.

In addition to being a potentially efficient source of propulsion for commercial applications, advanced turboprops may have military applications as well. The Navy has expressed interest in the program in terms of its possible utility to a future long endurance land-based sea patrol aircraft.

Energy Efficient Engine-Phase II: The objective of the Energy Efficient Engine Program is to develop and demonstrate the technology base for achieving higher thermodynamic and propulsive efficiencies in future turbofan engines. The goal is to reduce specific fuel consumption by 10 to 15 percent over current high bypass ratio engines while simultaneously reducing direct operating costs, emissions, and noise levels. The program is divided into two phases as shown in Figure 5.

Phase I contracts have been awarded to the two manufacturers of large commercial engines, Pratt & Whitney Aircraft and General Electric, for the engine definition studies. In these studies, the contractors will select the optimum size, thrust, thermodynamic cycle, and basic configuration of a new experimental energy efficient engine. The engine designs that will emerge will reflect the thinking of the individual company with respect to the type and the levels of technology to explore. However, both manufacturers are predicting that the advanced engine will require higher cycle pressure ratios, higher turbine inlet temperatures and higher bypass ratios than current engines. In FY 1978, and as part of Phase II, fabrication will begin on the high-pressure compressor, combustor, and high-pressure turbine core components and on the fan and low-pressure turbine low spool components along with the mixer and nacelle. In Phase II, extensive development of these components is followed by refinement and further evaluation in high-pressure core and core/low spool engine system tests.

In response to industry recommendations to accelerate the program, Phase II has been structured to include the key elements necessary to demonstrate sufficient technology readiness by 1982 to give the engine companies confidence to commit to the development of a new engine which could be in service by the late 1980's.

The next 3 figures expand on each of the Phase II activities in more detail. First, to achieve the Energy Efficient Engine Program goals, major technology advances must be made in all the engine components shown schematically in Figure 6. The performance of the fan, compressor, combustor, and high- and low-pressure turbines will be evaluated experimentally in full-scale component tests to determine the performance characteristics in each of the areas listed on the bottom of the figure. The core components will then be assembled and tested as a core system for further refinement and modification (Figure 7). The core performance is critical in establishing a successful technology demonstration. It is in this rotating subsystem that the highest temperatures and pressures are encountered and where significant performance improvements can be made to reduce fuel consumption, using, for example, low aspect ratio blading in the compressor, active clearance control, ceramic coatings in the hot section, and advanced low emission combustors.

Similarly, Figure 8 illustrates some of the advanced concepts that will be investigated for the low spool system, such as the use of a geared fan with composite blades, a mixed flow exhaust, and a high work factor, low-pressure turbine. After separate full-scale component tests, the fan, low-pressure compressor, low-pressure turbine, and exhaust nozzle will be assembled and matched with the core to evaluate performance in the complete engine system.

It is not NASA's intention to carry this engine through to prototype, development, or production programs. The engine system will be experimental in nature but flight-type in principle. All items contributing to fuel consumption, acoustics, and propulsion characteristics will be of flight design and construction as required to demonstrate the program goals.

Energy Efficient Transport - Phase II: The objective of the Energy Efficient Transport Program is to develop and demonstrate advanced aerodynamics and active controls technologies for early application to derivative and new transport aircraft. The program is divided into two phases as shown in Figure 9.

Phase I includes specific technology developments in aerodynamics and active controls leading to the definition of an advanced, integrated configuration. Some of the work on supercritical wings, winglets and active controls was described to the Subcommittee last fall. An important additional activity in Phase I is called Selected Concepts Development and is a joint NASA/industry effort to investigate those concepts which are of primary interest to the manufacturers in relation to their planned derivative or new aircraft. That activity leads directly into the evaluation of the most promising concepts in FY 1978 in Phase II. The other major thrust of the Phase II program is the development of an advanced flight control system. These activities are discussed below.

The Selected Concepts Evaluation activity can be divided into two parts: developments which have application to derivative aircraft, and technology which will apply primarily to new aircraft designs. Shown in the figure (Figure 10) are the three current wide-body transports--the 747, DC-10 and L1011. Also listed are the technologies that are being investigated and the activities to be performed in Phase II.

Under Wing Geometry Modifications, NASA and industry are investigating the addition of either winglets or wing-tip extensions to current wide-body transports to improve fuel efficiency. Before commitment to these wing modifications can be made, extensive wind tunnel and flight tests are required to evaluate the aerodynamic and aeroelastic characteristics of the proposed configurations.

These wing geometry improvements will also mean higher aerodynamic loads which adversely affect structural design for strength, especially under maneuver load conditions. Active controls technology, particularly for gust alleviation, maneuver load control, and elastic mode suppression, will allow the incorporation of these wing modifications with the minimum corresponding structural changes. An important element of the Phase II activities is the design, construction and flight evaluation of a near-term active controls system for this purpose. The system will have nonflight-critical application, such that loss or disengagement of the system will not impact either the aircraft's mission or its safety.

Another opportunity for significant drag reduction is in improved propulsion system integration. Flow interactions among the large fan-jet nacelles, engine pylons and the wing lower surface can be improved through

careful selection of relative positions, angles and shapes. This activity will lead to work on a long-duct nacelle and mixer and will involve extensive wind tunnel tests, full-scale ground tests and flight experiments.

Figure 11 illustrates three possible new aircraft of the near future: the Douglas DCX-200, the Lockheed Reduced Energy RE1011, and the Boeing 7X7. The Selected Concepts Evaluation activity for these aircraft includes work on all-new wing designs with lower sweep and higher aspect ratio, using supercritical airfoil sections and compatible high-lift systems for takeoff and landing. The high-lift requirements for these new wing designs will be less demanding than for current transports, and there is promise that simpler, lower cost systems will be possible. This program will consist primarily of wind tunnel tests, with some detailed analysis of structural and aerodynamic trades.

In active controls, one of the more likely applications to the next-generation transports will be for augmented longitudinal stability. This will permit an aircraft design with a reduced-size horizontal tail, with corresponding lower weight and trim drag. Significant fuel savings are possible with reduced static margins, and early incorporation of active controls for this nonflight-critical application is expected. The Phase II program will include the demonstration of this technology through the flight test of a modified wide-body transport with a reduced-size horizontal tail and a stability augmentation system.

The last element under Selected Concepts Evaluation is the development of an advanced, flight-critical active controls system. Early work in this area, listed as Maximum Benefit Active Controls, is the preliminary configuration definition which will lead to a longer term effort on the full integration of advanced aerodynamics and active controls into the design of a new-generation, energy-efficient transport aircraft. The integration of technology developments in aerodynamics and active controls is indicated schematically in Figure 9, where the Phase I activities and the Selected Concepts Evaluation just described are combined with the design, hardware and software development, and demonstration of an advanced flight control system.

One of the most important requirements for the flight-critical application of active controls to commercial transports is the achievement of an extremely high level of reliability in all components of the system. The most

important element of the advanced flight control system is the central computer, which must be fault-tolerant, i.e., capable of failure detection, identification and recovery. One such advanced computer system is illustrated in Figure 12. The central computer consists of software and an assortment of memory and processing units. In its initial configuration, blocks of these microprocessing units are assigned to the various tasks to perform flight control, navigation, flight management, and display functions. The computer continuously monitors and evaluates these functions on-line during a flight. If a failure or anomaly is detected, the fault-tolerant computer has the capability of identifying the memory or processing unit that is in error and of correcting the fault. Considered in the example is the case where a simultaneous failure occurs in the processing unit performing the navigation function and in one of the memory units assigned to flight control. The software logic detects the failure, identifies the malfunctioning units and reconfigures the computer by reassigning the memory and processing units from the less critical display function so that the more important flight control and navigation functions continue undisturbed.

One of the major elements of the NASA program will be work on advanced computer systems such as the one just described. In FY 1978, laboratory breadboard hardware for the advanced computer system will be developed. This will lead to the evaluation of competitive approaches and the selection of the most promising computer system. Improved sensors and actuators will also be selected, leading to the preliminary design of an advanced flight control system. The system will be evaluated and optimized with the prime emphasis on system safety and cost effectiveness. These activities will then lead to a detailed flight control system design, hardware and software development, and demonstration to verify the control system performance and reliability.

The last figure (Figure 13) summarizes the Aircraft Energy Efficiency Program funding by element for FY 1978. As shown in the first column, the NASA budgeted amount for the ongoing programs totals \$53.8 million and the three new initiatives add an additional \$16.4 million. The total NASA funding for the ACEE program in FY 1978 is \$70.2 million given in the last column.

AIRCRAFT ENERGY EFFICIENCY PROGRAM

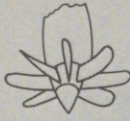
FISCAL YEAR												
FY	1976	T	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
ENGINE COMPONENT IMPROVEMENT	COMPONENT TECHNOLOGY • ENGINE TESTS • DIAGNOSTICS											
ENERGY EFFICIENT ENGINE	ENGINE DEF • COMPONENT DESIGN COMPONENT DEVELOPMENT • CORE / LOW SPOOL TEST PROPELLER TECHNOLOGY STRUCTURES • COMP • DESIGN • INTEGRATION EXPERIMENTAL ENGINE TESTS AIRPLANE FLIGHT DEMONSTRATION											
TURBOPROPS												
ENERGY EFFICIENT TRANSPORT	ADV AERO ACTIVE CONTROLS DEVELOPMENT CONCEPTS EVAL • ADV FLT CONTROL SYSTEM CONCEPT EVALUATIONS SYSTEM DESIGN • TEST VALIDATOR A/C MODIFICATION • FLIGHT TEST											
LAMINAR FLOW CONTROL	SECONDARY STRUCTURES (RUDDER, ELEVATOR, ALERONS) MEDIUM-SIZED PRIMARY STRUCTURES (FN - HORIZONTAL TAIL) LARGE PRIMARY STRUCTURE (WING) LARGE PRIMARY STRUCTURE (FUSELAGE)											
COMPOSITES												

Figure 1

 AIRCRAFT ENERGY EFFICIENCY PROGRAM
 1976-1986

AIRCRAFT ENERGY EFFICIENCY PROGRAM FY 1978 NEW EMPHASIS

ADVANCED TURBOPROP - PHASE I



ENERGY EFFICIENT ENGINE - PHASE II



ENERGY EFFICIENT TRANSPORT - PHASE II

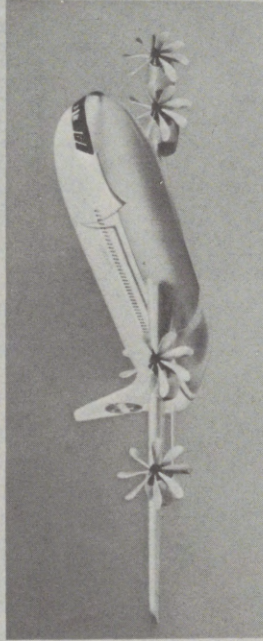


Figure 2

NASA HQ 8/J77-1178(3)
12-89-26



ADVANCED TURBOPROP PROGRAM

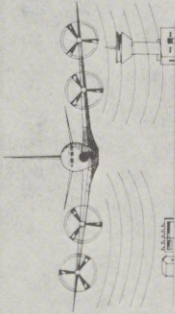
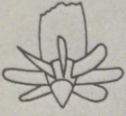


- I-PROPELLER AERODYNAMICS/NOISE TECHNOLOGY
- II-STRUCTURES/COMPONENT DESIGN/INTEGRATION
- III-EXPERIMENTAL ENGINE
- IV-TURBOPROP SYSTEM FLIGHT TEST

Figure 3

DAAG-112-004-2-400 (3)

ADVANCED TURBOPROP PROGRAM



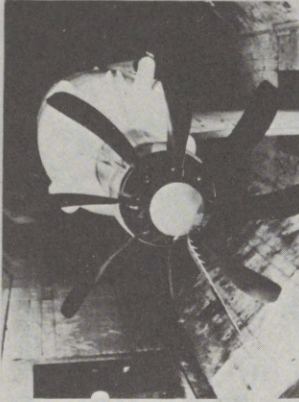
COMMUNITY NOISE REDUCTION

- PROPELLER DESIGN SUCH AS SWEPT TIP BLADES



CABIN NOISE ATTENUATION

- ADVANCED LIGHTWEIGHT MATERIALS FOR FUSELAGE TREATMENT

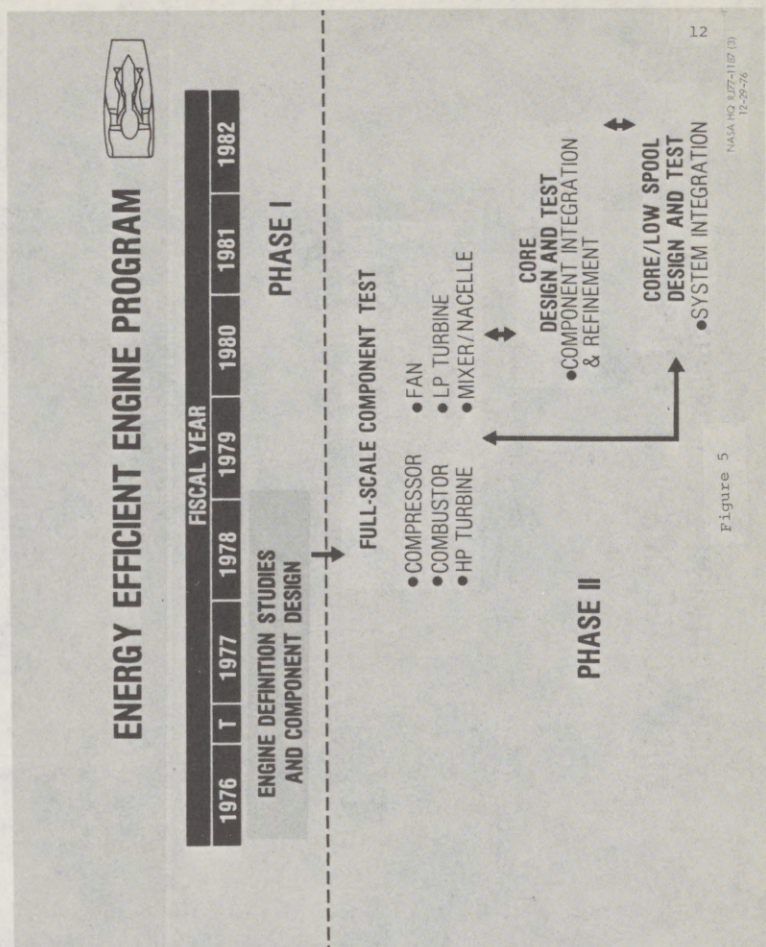


WIND TUNNEL TESTS

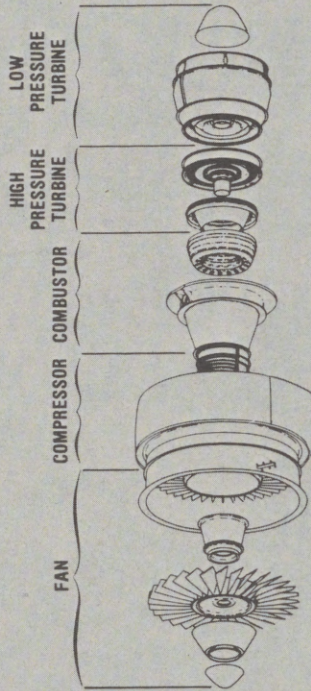
- DEFINE PROPELLER NOISE LEVELS
- DEVELOP ANALYTICAL MODELS FOR IMPROVED ACOUSTIC PREDICTION ANALYSIS
- AERODYNAMIC/ACOUSTIC/STRUCTURAL TRADES

AVIATION WEEK 1987

Figure 4



ENERGY EFFICIENT ENGINE PROGRAM FULL SCALE COMPONENT TEST



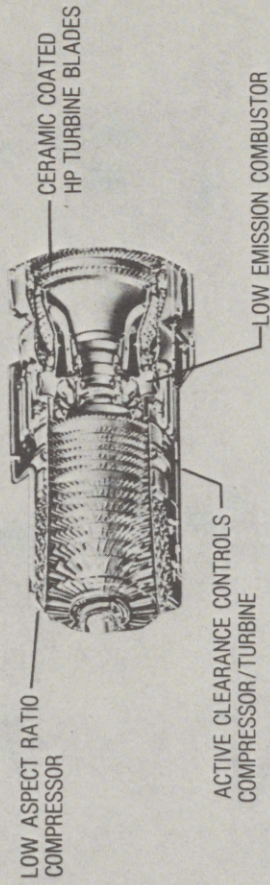
CORE AND LOW SPOOL COMPONENT PERFORMANCE EVALUATION

- AERODYNAMICS
- MECHANICAL INTEGRITY
- HEAT TRANSFER
- DURABILITY
- NOISE/EMISSIONS
- SEALS/CLEARANCE CONTROL

Figure 6

NASA/CRS 877-118 (3)
12-29-76

ENERGY EFFICIENT ENGINE PROGRAM CORE DESIGN AND TEST



EXPERIMENTAL CORE TESTS

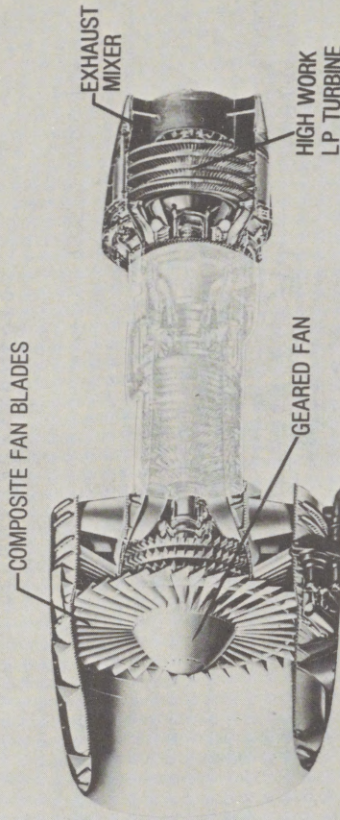
- VERIFY CORE PERFORMANCE
- OPTIMIZE COMPONENT DESIGN

Figure 7

NASA HQ EOT-1184 (3)
12-29-76



ENERGY EFFICIENT ENGINE PROGRAM CORE/LOW SPOOL DESIGN AND TEST



FULL SCALE SYSTEM INTEGRATION TESTS

- CORE AND LOW SPOOL COMPONENTS

Figure 8

NASA HQ DDT-118 (3)
12-29-76

ENERGY EFFICIENT TRANSPORT PROGRAM

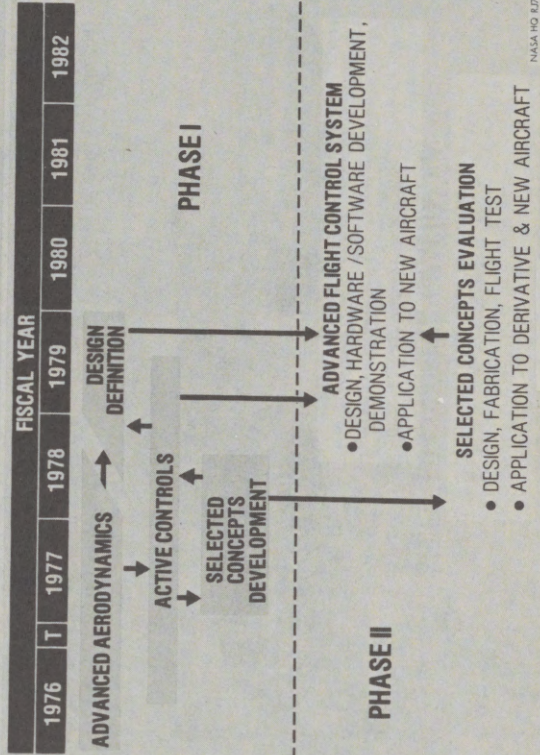
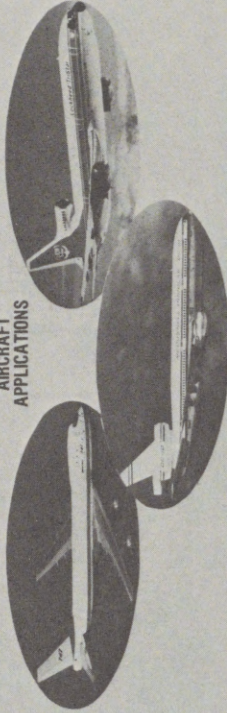


Figure 9

ENERGY EFFICIENT TRANSPORT PROGRAM SELECTED CONCEPTS EVALUATION



DERIVATIVE AIRCRAFT APPLICATIONS



WING GEOMETRY MODIFICATIONS

- WINGLETS/WING TIP EXTENSIONS

ACTIVE CONTROLS TECHNOLOGY

- GUST/MANEUVER LOAD/ELASTIC MODE CONTROL

PROPULSION SYSTEM INTEGRATION

- NACELLE/PYLON/WING INTERFERENCE

FLIGHT TEST OF MODIFIED TRANSPORT AIRCRAFT

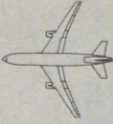
DESIGN, CONSTRUCTION, FLIGHT
EVALUATION OF CERTIFICATABLE
SYSTEM

LONG DUCT NACELLE FULL-SCALE
GROUND TESTS, FLIGHT EXPERIMENTS

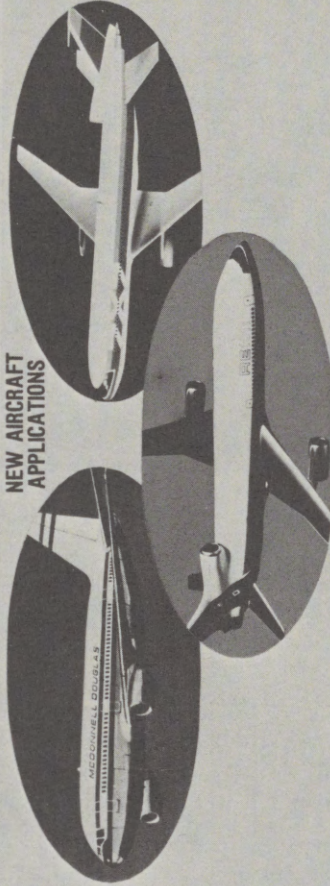
HAAS AND ZEFARIN (3)
1994

Figure 10

ENERGY EFFICIENT TRANSPORT PROGRAM SELECTED CONCEPTS EVALUATION



NEW AIRCRAFT APPLICATIONS



WING GEOMETRY IMPROVEMENTS

- SUPERCritical WING/HIGH LIFT DEVICES

ACTIVE CONTROLS TECHNOLOGY

- AUGMENTED LONGITUDINAL STABILITY

ADVANCED FLIGHT CONTROLS

- MAXIMUM BENEFIT ACTIVE CONTROLS

WIND TUNNEL VALIDATION, STRUCTURAL/

AERODYNAMIC TRADES

DESIGN AND FLIGHT TEST REDUCED SIZE

HORIZONTAL TAIL

ADVANCED CONTROL SYSTEM DESIGN,

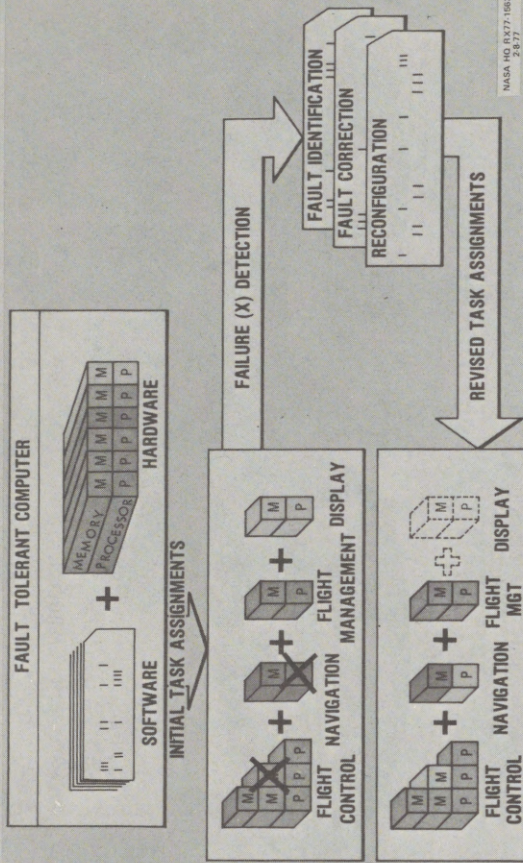
DEVELOPMENT, TEST

Figure 11

18

NASA HQ 877-181 (9)
12-87-76

ENERGY EFFICIENT TRANSPORT PROGRAM ADVANCED COMPUTER SYSTEM



AIRCRAFT ENERGY EFFICIENCY PROGRAM FY 1978 FUNDING (\$M)

	ONGOING PROGRAMS	NEW INITIATIVES	ACEE TOTAL
ENGINE COMPONENT IMPROVEMENT	10.0	—	10.0
ENERGY EFFICIENT ENGINE			18.5
PHASE I	8.5		
PHASE II	—	10.0	
TURBOPROPS - PHASE I	—	2.0	2.0
ENERGY EFFICIENT TRANSPORT			13.4
PHASE I	9.0	—	
PHASE II		4.4	
LAMINAR FLOW CONTROL	1.2	—	1.2
COMPOSITE PRIMARY STRUCTURES	25.1	—	25.1
TOTAL	53.8	16.4	70.2

Figure 13

NASA HQ BX77-1465 (3)
11977

Dr. COLLADAY. Thank you, Mr. Chairman.

I would like to review the aircraft energy efficiency technology program (ACEE) and plans for fiscal year 1978.

As you know, NASA initiated the ACEE technology program to provide the basis for the design of new and derivative aircraft, which are significantly more energy efficient than today's transports.

As you know, the program was started in fiscal year 1976 by restructuring ongoing efforts in the aeronautics R. & T. base program and then in fiscal year 1977, we received authorization to augment that baseline program with an expanded effort.

The first figure shows the elements of the ACEE technology program, which currently consist of five focused technology efforts, with the sixth focused program in advanced turboprops scheduled to begin in fiscal year 1978.

AIRCRAFT ENERGY EFFICIENCY PROGRAM

FISCAL YEAR												
FY	1976	T	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
ENGINE COMPONENT IMPROVEMENT	COMPONENT TECHNOLOGY • ENGINE TESTS • DIAGNOSTICS											
ENERGY EFFICIENT ENGINE	ENGINE DEF • COMPONENT DESIGN											
	COMPONENT DEVELOPMENT • CORE / LOW SPOOL TEST											
TURBOPROPS	PROPELLER TECHNOLOGY											
	STRUCTURES • COMP • DESIGN • INTEGRATION											
	EXPERIMENTAL ENGINE TESTS											
	AIRPLANE FLIGHT DEMONSTRATION											
ENERGY EFFICIENT TRANSPORT	ADV AERO ACTIVE CONTROLS DEVELOPMENT											
	CONCEPTS EVAL • ADV FLT CONTROL SYSTEM											
LAMINAR FLOW CONTROL	CONCEPT EVALUATIONS											
	SYSTEM DESIGN • TEST											
	VALIDATOR A/C MODIFICATION • FLIGHT TEST											
COMPOSITES	SECONDARY STRUCTURES (RUDDER, ELEVATOR, ALERONS)											
	MEDIUM-SIZED PRIMARY STRUCTURES (FN • HORIZONTAL TAIL)											
	LARGE PRIMARY STRUCTURE (WING)											
	LARGE PRIMARY STRUCTURE (FUSELAGE)											

Figure 1

 NASA 1984 REPORT 1244 1A
 1/26/77

In figure 1 and in those which follow, green will refer to the ongoing programs, and yellow will indicate the new start activities for fiscal year 1978.

As you can see, the major expansion in the program appears in the start of the second phases of the energy-efficient engine and energy-efficient transport, and in the first phase of the advanced turboprop program.

The three ongoing programs which are proceeding as planned, and for which no expansion is required in fiscal year 1978, are the engine component improvement, laminar flow control and composite primary aircraft structures programs.

Briefly, in the engine component improvement program, we are working with the engine manufacturers and the airlines to identify sources of inservice performance deterioration and to develop improved components to reduce fuel consumption in current engines.

In the laminar flow control program, the aim is to greatly reduce the drag of future aircraft by maintaining smooth or laminar flow over the surface. Work is continuing on the concepts evaluation and system definition to assess various alternative designs which are both technically feasible and economically attractive for a laminar flow aircraft of the 1990's.

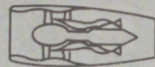
Through the composite primary aircraft structures program, we are attempting to accelerate the use of composite materials in commercial aircraft. Work is continuing on the design, fabrication, certification, and flight service of a diverse mix of secondary structures, and medium and large size primary structures, to reduce weight and thereby improve fuel efficiency of the new aircraft.

AIRCRAFT ENERGY EFFICIENCY PROGRAM FY 1978 NEW EMPHASIS

ADVANCED TURBOPROP - PHASE I



ENERGY EFFICIENT ENGINE - PHASE II

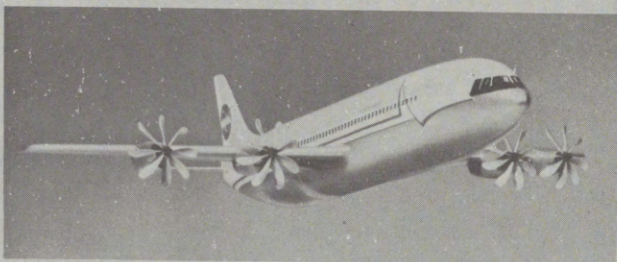
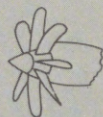


ENERGY EFFICIENT TRANSPORT - PHASE II



Figure 2

ADVANCED TURBOPROP PROGRAM



I-PROPELLER AERODYNAMICS/NOISE TECHNOLOGY

II-STRUCTURES/COMPONENT DESIGN/INTEGRATION

III-EXPERIMENTAL ENGINE

IV-TURBOPROP SYSTEM FLIGHT TEST

Figure 3

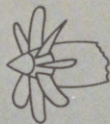
NASA HQ RD77-1428 (3)
1-18-77

Plans and recent accomplishments in each of the ongoing programs were discussed with the subcommittee last fall. At this point, I would like to proceed into a more detailed discussion of the new starts planned for fiscal year 1978, beginning with turboprops, figures 2 and 3.

Modern high-speed turboprops have the potential of saving significant amounts of fuel, on the order of 20 to 30 percent over current turbofan engines. The goal of this new propulsion program is to demonstrate that advanced turboprop-powered aircraft can be comfortable, quiet, safe, and very economical to operate.

I have here a model of an advanced turboprop, that I would like to pass up to you for your inspection, if you would like.

ADVANCED TURBOPROP PROGRAM



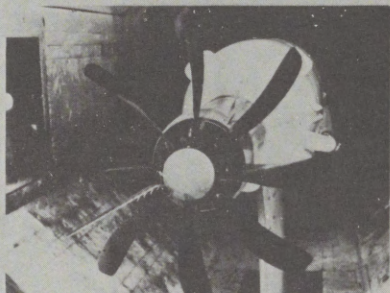
COMMUNITY NOISE REDUCTION

- PROPELLER DESIGN SUCH AS SWEEP TIP BLADES



CABIN NOISE ATTENUATION

- ADVANCED LIGHTWEIGHT MATERIALS FOR FUSELAGE TREATMENT



WIND TUNNEL TESTS

- DEFINE PROPELLER NOISE LEVELS
- DEVELOP ANALYTICAL MODELS FOR IMPROVED ACOUSTIC PREDICTION

ANALYSIS

- AERODYNAMIC/ACOUSTIC/STRUCTURAL TRADES

Figure 4

NASA DDC 81-117-1427-10
1-18-77

This particular model is often referred to as a propfan.

In figure 4, I have illustrated an advanced turboprop aircraft design, and list the four phases of the program.

Phase I calls for extensive development of propeller aerodynamics and noise technology. Other phases scheduled for fiscal 1980 and beyond require future decisions based on the success of the phase I effort.

Recent wind tunnel tests conducted in the R. & T. base program and discussed with the subcommittee last fall have demonstrated that advanced turboprops can achieve the same high efficiency levels as older propeller designs while operating at a much higher cruise speed and altitude, up to Mach 0.8 and 35,000 feet.

Wind tunnel tests to evaluate propeller aerodynamics will continue in phase I.

One of the major technology areas to be investigated in phase I will be propeller acoustics. Wind tunnel tests to measure and document the noise levels associated with these modern high tip-speed propellers will be conducted in fiscal year 1978, as well as developing and improving analytical models for improved acoustic prediction.

At a flight cruise Mach number of 0.8 and the high power loading required in these advanced propeller designs, the propeller tips rotate at supersonic speeds, causing a potential noise problem.

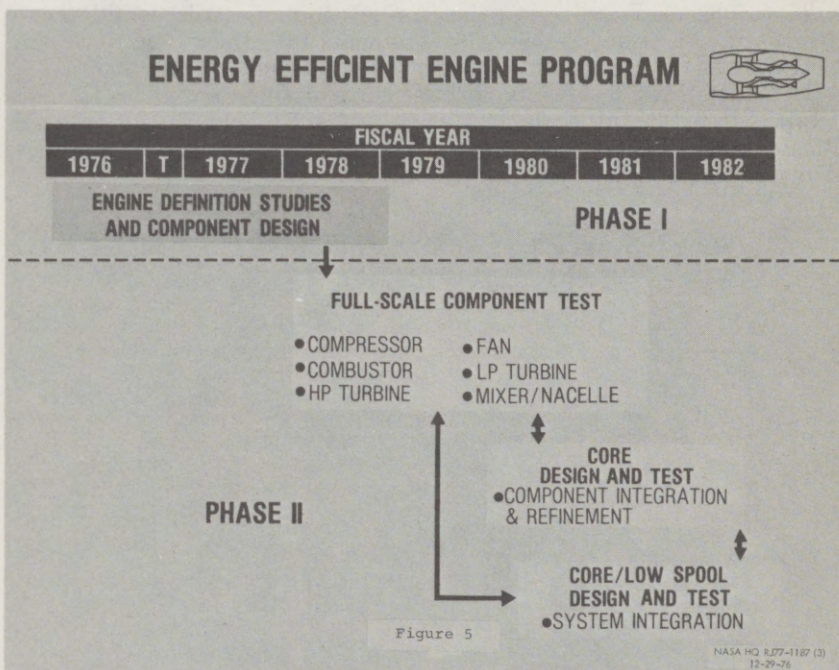
However, there are things that can be done in the way of advanced design techniques to reduce propeller source noise both in the far field as it affects the community, and its near field effect on the cabin environment.

The blade tips can be swept back as was done in this model, and that tends to weaken the shock wave at the tip, thereby reducing source noise and also reducing aerodynamic losses in the tip region.

Other advanced design techniques that will be investigated as part of phase I are the use of very thin blade sections, supercritical airfoil sections, increased number of blades, and dual counterrotating propellers.

Not only are turboprops a potentially efficient source of propulsion for commercial applications, they may have military applications as well. The Navy has expressed interest in the program in terms of its possible utility to future long-endurance land-based sea control aircraft.

I would like to turn now to the energy-efficient engine program. The objective of this program is to develop and demonstrate the technology base for achieving higher thermodynamic and propulsive efficiency in future turbofan engines. The goal is to reduce fuel consumption by 10 to 15 percent as compared to the current high-bypass engines, while at the same time reducing direct operating costs, emissions, and noise levels.



The program is broken into two phases as shown in figure 5. Phase I contracts have been awarded to the two manufacturers of large commercial engines, Pratt & Whitney and GE, for the engine definition studies.

In these studies, the contractors will select the optimum size, thrust, thermodynamic cycle, and basic configuration of a new experimental energy-efficient engine.

The results indicate that the advanced engine will require somewhat higher pressures and temperatures, and higher bypass ratios than current engines.

Following the detailed component design in phase I, phase II will begin in fiscal year 1978 with the full scale test of each of the components of the engine as listed here.

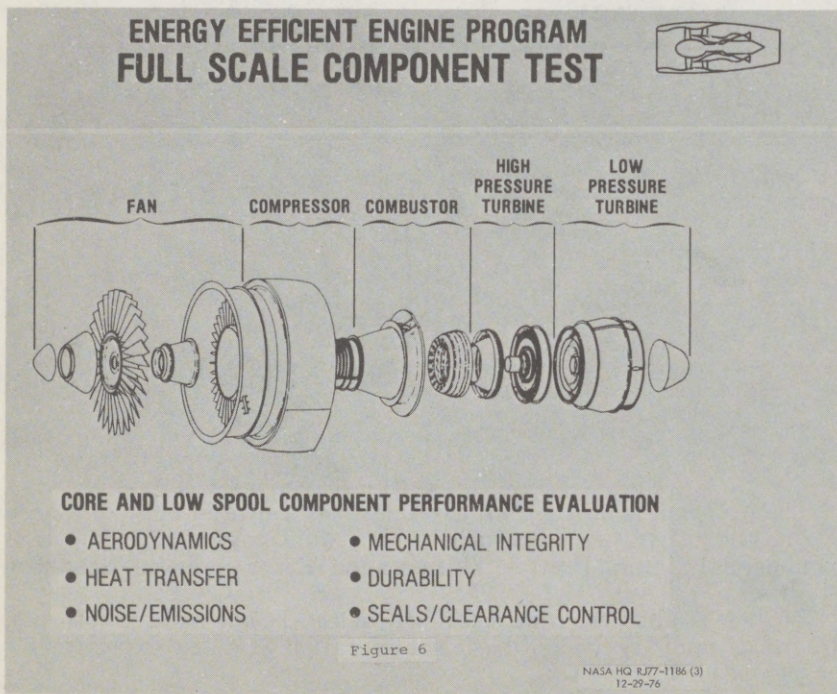
This activity will lead directly into the design and test for the core system and similarly into the low spool development for system integration.

Basically, the core combines the high pressure compressor, combustor, and high pressure turbine into an integrated assembly. The core is sometimes referred to as the high pressure spool or high spool of a two-spool engine.

Similarly, the low pressure spool is made up of the fan, the low pressure compressor and the low pressure turbine in an integrated unit, which, when matched with the core, essentially completes the engine system.

With these three activities involving the component development, integration, and refinement, phase II has been structured to include the key technology elements to demonstrate technology readiness by the end of 1982. This will give the engine companies the confidence to incorporate these technology developments into their derivative and new engines which could be in service by the mid-to-late 1980's.

The next three figures expand on each of these activities in more detail. First, the full-scale component tests. To achieve the programance characteristics in each of the areas listed here. Following these shown in figure 6.



The components will be tested in full-scale rigs to evaluate performance characteristics in each of the areas listed here. Following these tests, and based on the results, the components of the core, and low-spool system will be developed.

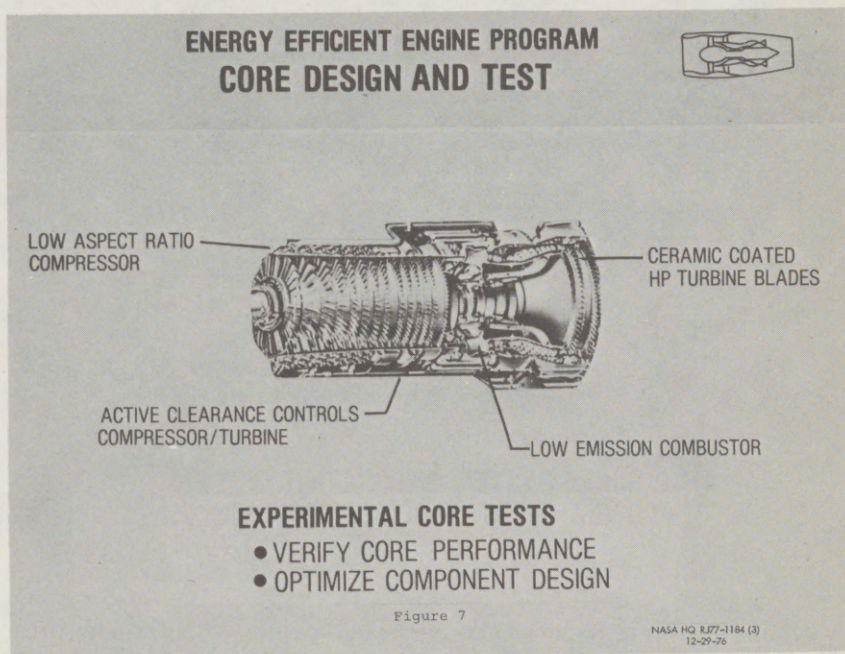
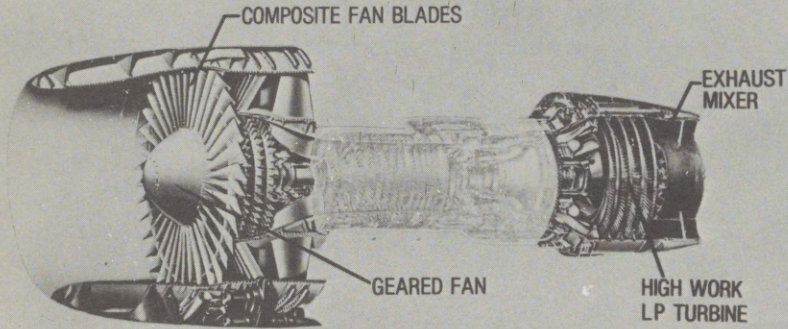


Figure 7 shows a core system in its integrated assembly. By proper conditioning of the inlet air, the core assembly can be run like an engine to verify performance and optimize component design. It is in this rotating subsystem that the highest temperatures and pressures are encountered and where significant advances can be made to reduce fuel consumption.

Some of the advanced concepts that will be investigated for the core are listed here. In addition, evolutionary technology advances are expected in such areas as improved aerodynamic designs, better seals, improved turbine cooling, better cooling air management, and higher temperature materials in the hot section.

ENERGY EFFICIENT ENGINE PROGRAM CORE/LOW SPOOL DESIGN AND TEST



FULL SCALE SYSTEM INTEGRATION TESTS • CORE AND LOW SPOOL COMPONENTS

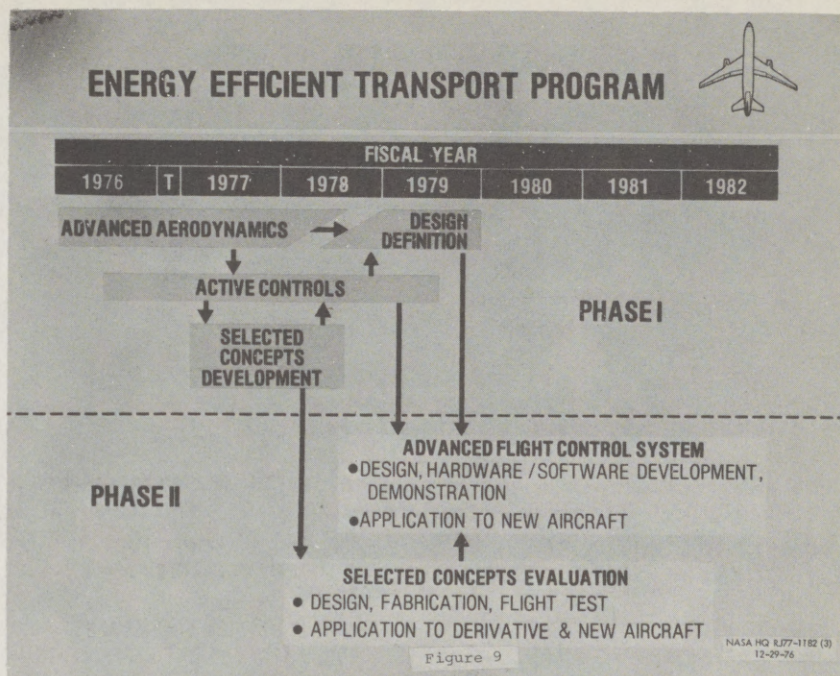
Figure 8

NASA HQ KJ77-1185 (3)
12-29-76

Similarly, figure 8 shows the low spool system with the low pressure turbine driving the fan. The low spool is shown in the darker area matched to the core in the lighter area.

Some of the advanced technology areas and concepts considered for the low spool are shown here. It is not NASA's intention to carry this engine system through to prototype, development, or production programs. The engine system will be experimental in nature, but all hardware contributing to fuel consumption, acoustics, and basic performance characteristics will be of flight design and construction as required to demonstrate program goals.

I would like now to turn finally to the energy efficient transport program. Its objective is to develop and demonstrate advanced aerodynamics and active controls technologies for early application to derivative and new transport aircraft.



This program is broken into two phases as shown on figure 9. In phase I, specific technology developments in advanced aerodynamics and active controls leads to the definition of an advanced integrated system.

I have here a model of such an integrated system that incorporates many of the concepts we will be considering in the energy efficient transport program that I would like to offer for your inspection.

Some of the work in supercritical wings, winglets and active controls was discussed with the subcommittee last fall. An important additional activity in phase I is called Selected Concepts Development. This is a joint NASA/industry effort to investigate concepts which the manufacturers, Boeing, Douglas and Lockheed are interested in, primarily in terms of their planned new and derivative aircraft. This activity will lead directly into the selection of the most promising concepts for further evaluation in phase II, beginning in fiscal year 1978.

Another additional activity in phase II is the development of advanced flight control system. Under Selected Concepts Evaluation, this activity can be broken into two parts, depending on whether the application is to derivative or new aircraft.

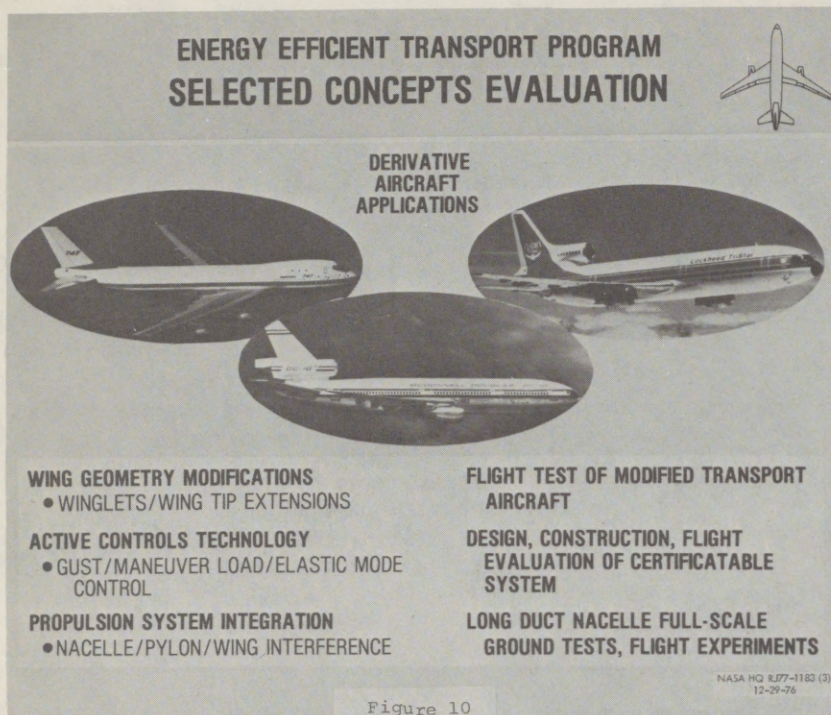


Figure 10 shows the three current wide-bodied transports and lists some of the technologies to be investigated and activities to be performed under phase II.

Under wing geometry modifications, NASA and industry are investigating the use of winglets and wingtip extensions to reduce fuel consumption in current wide-bodied transports.

The addition of these winglets or wingtip extensions will increase the aerodynamic load on the wings, which could adversely affect the structural design or strength, particularly under maneuver load conditions. However, when considered in conjunction with the near term application of active controls technology for gust alleviation, maneuver load control, and elastic mode suppression, these modifications can be made with a minimum of structural changes. A flight critical control system for this purpose will be evaluated in phase II.

Finally, under improved propulsion system integration, significant drag reduction can be achieved by optimizing flow interactions between the nacelle, the engine pylon, and the wing lower surface. This will lead to long duct nacelle full-scale ground tests and flight experiments.

ENERGY EFFICIENT TRANSPORT PROGRAM SELECTED CONCEPTS EVALUATION



NEW AIRCRAFT APPLICATIONS



WING GEOMETRY IMPROVEMENTS

- SUPERCRITICAL WING/HIGH LIFT DEVICES

ACTIVE CONTROLS TECHNOLOGY

- AUGMENTED LONGITUDINAL STABILITY

ADVANCED FLIGHT CONTROLS

- MAXIMUM BENEFIT ACTIVE CONTROLS

WIND TUNNEL VALIDATION, STRUCTURAL/ AERODYNAMIC TRADES

DESIGN AND FLIGHT TEST REDUCED SIZE HORIZONTAL TAIL

ADVANCED CONTROL SYSTEM DESIGN, DEVELOPMENT, TEST

Figure 11

NASA HQ R377-1181 (3)
12-29-76

Now turning to the technology which applies to new aircraft designs, figure 11 shows three possible aircraft of the near future.

The Selected Concepts Evaluation Activity for these new aircraft that you see here include all new wing designs with lower sweep, higher aspect ratio, and supercritical airfoil sections with compatible high lift devices for takeoff and landing.

Under active controls technology, one of the most promising applications to new aircraft is in augmented longitudinal stability. Reduced static margins will allow aircraft to be designed with smaller horizontal tails, and this will result in lower weight and trim drag. This technology will be demonstrated through the flight test of a modified wide-bodied transport with reduced size horizontal tail and augmented stability margins.

ENERGY EFFICIENT TRANSPORT PROGRAM ADVANCED COMPUTER SYSTEM

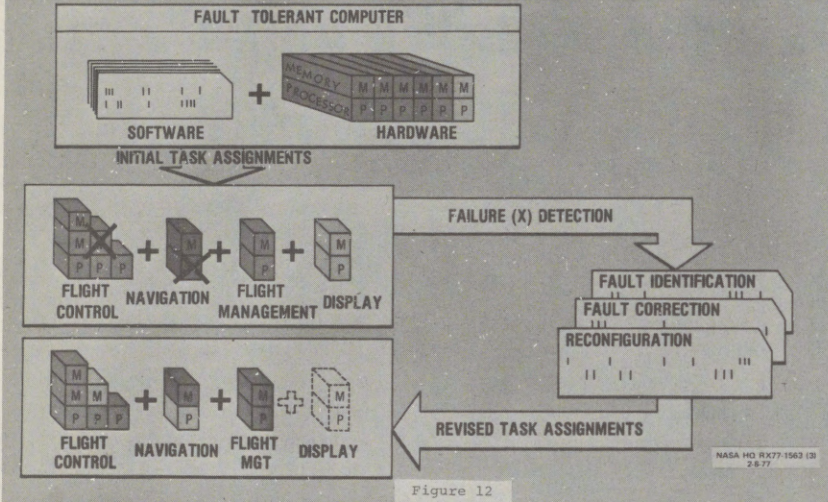


Figure 12

Finally, figure 12, under advanced flight controls, work in this area, listed as maximum benefit active controls, involves the preliminary definition of a flight critical control system which incorporates advances in aerodynamics and active controls into an integrated design.

This integration of technology developments in active controls, aerodynamics, and highly reliable fault-tolerant computer systems into aircraft design concepts, is a major activity in phase II. It involves the design, development, and flight evaluation of an advanced flight critical control system for a new generation energy efficient transport.

AIRCRAFT ENERGY EFFICIENCY PROGRAM FY 1978 FUNDING (\$M)

	ONGOING PROGRAMS	NEW INITIATIVES	ACEE TOTAL
ENGINE COMPONENT IMPROVEMENT	10.0	—	10.0
ENERGY EFFICIENT ENGINE			18.5
PHASE I	8.5		
PHASE II	—	10.0	
TURBOPROPS - PHASE I	—	2.0	2.0
ENERGY EFFICIENT TRANSPORT			13.4
PHASE I	9.0	—	
PHASE II		4.4	
LAMINAR FLOW CONTROL	1.2	—	1.2
COMPOSITE PRIMARY STRUCTURES	25.1	—	25.1
TOTAL	53.8	16.4	70.2

Figure 13

NASA HQ RX77-1465 (3)
1-18-77

I would like to conclude with figure 13 showing the funding for the Aircraft Energy Efficiency program for fiscal year 1978. Shown in the first column is the funding for the ongoing programs, totaling \$53.3 million for fiscal year 1978. The start of the second phases of the Energy Efficient Engine and Energy Efficient Transport programs, along with the first phase of Turboprops adds an additional \$16.4 million, bringing the ACEE total to \$70.2 million for fiscal year 1978.

Thank you.

Mr. MILFORD. Thank you, Dr. Colladay.

Have you been before this committee before?

Dr. COLLADAY. Last year I gave a brief testimony in ceramic coatings for turbine applications.

Dr. KRAMER. Mr. Chairman, Dr. Colladay was recognized as one of our outstanding researchers.

Last year we also recognized him as an outstanding young man, so we talked to him in coming to headquarters for a year.

Mr. MILFORD. Have you signed him up for a long-term basis?

Dr. KRAMER. To NASA, yes; for a long-term basis.

Mr. MILFORD. We appreciate very much your testimony.

Dr. KRAMER. I have a couple of concluding remarks to complete our testimony. Over the past year we have done a considerable amount of planning on the aeronautics program. We are trying to have a more systematic way of assessing the opportunities and determining what our response to the opportunities should be in the aeronautical area. We are continuing that, and indeed, we have already begun the cycle of planning for our fiscal year 1979 program. We have made some

changes in our program as a result of that planning. As we have gone along in the planning, some of the changes we have made; some of the changes were imposed upon us.

We had planned to request funds for a joint program with the Navy on a lift/cruise fan research aircraft. It was decided, however, that the program would be funded by the Navy, but I can assure you that we will be working very closely with the Navy to define a very active supporting role for NASA to be carried out primarily at the Ames Research Center. As we proceed with our planning cycle for fiscal year 1979, one of the significant areas we see before us is the question, which we know is of concern to you, of the health of our research and technology program. We have asked the Aeronautics and Space Engineering Board of the National Research Council to do a specific study of the health and quality of our aeronautics R. & T. base program. In addition, we are about to launch an in-house assessment of the balance and the adequacy of our R. & T. base program, both in terms of dollars and manpower. We will be reporting the results of these assessments to you and keeping in touch with you through your staff as these studies progress.

Thank you, sir.

Mr. MILFORD. Thank you very much, Dr. Kramer.

As a matter for the record, due to the technical nature of the testimony, the record will remain open, so any Member can submit any questions within 10 days to any of the witnesses, and the witnesses will have 10 days to respond to all questions, and the questions and answers will be made a part of this record.

I would like to know one thing.

What is the status of your plans for a joint program with the Air Force to build a hypersonic research aircraft.

You did not seem to touch on that.

Dr. KRAMER. I should have touched on this in my concluding remarks.

As a matter of fact, Mr. Chairman, we have been working with the Air Force on hypersonic research activity. Up until a couple of years ago, we referred to the vehicle part of that program as the X-24C. The intention was to use as much equipment as possible from the X-24B program to build an actively powered X-24C to explore the hypersonic speed range above mach 5.

We have extended a lot of effort over the last year in redefining the vehicle part of that program. We have departed substantially from the X-24C concept, to develop a vehicle concept which would have more experimental capability in it, specifically, which would be a more adaptable vehicle for doing the work that we see needs to be done on a hydrogen fuel supersonic combustion ramjet.

The current vehicle concept has come to be known as the National Hypersonic Flight Research Facility, which has the world's worst acronym of NHFRF, but in any event, the NHFRF vehicle is a good vehicle for both our experimental research purposes, and the Air Force's purposes.

We have been funding our hypersonics research at about \$6 million a year. We proposed that this funding be increased slightly to permit a more active program on the preliminary design definition of the NHFRF vehicle. That would be a very expensive program. If we add

up the cost of building the NHFRF, of building the experimental equipment to provide the NHFRF experiments, and supporting operations activities probably over a 10-year flight program, the total program on this hypersonic vehicle would come to about half a billion dollars. It has always been our plan, that this program should be done jointly with the Air Force, so that each of us would be putting up about a quarter of a billion dollars, \$250 million over the next 10 or 15 years.

We were not requesting approval to do that half-billion-dollar program. We were asking for a modest increase in the preliminary design activity, so that sometime around 1980, we could get serious about the total hypersonic vehicle program.

We were denied the modest increase in funds for the planning activity.

I think the general reaction of the people who reviewed our budget in-house, and at the OMB, was that this was such a major issue that they were very anxious to know more about the program content and the justification of the need for the program—which was of course driven primarily by Air Force needs—before they could permit us to scale up our efforts.

Mr. MILFORD. OK.

I would like to go back to the propeller research that you were talking about.

Dr. KRAMER. Yes, sir.

Mr. MILFORD. I was told by one researcher, not in NASA, that really we had not done much in the way of propeller research since the old NACA days.

Dr. KRAMER. That is absolutely true.

We only started up our propeller research activity from an aerodynamics standpoint in about the last 12 months, as I recall.

Mr. MILFORD. I wonder if we are putting enough emphasis on that. If we can reap energy savings, and we can reach the speed and altitudes, it would appear to me this would be a real area for NASA to get into with both feet.

Dr. KRAMER. Well, we feel like we are getting into it pretty well. We are building up an in-house test capability at Lewis in the 8-by-6-foot wind tunnel for testing rather large-scale propellers. Also the \$7 million activity part of the aircraft energy efficiency program for turboprops will fund quite a lot of experimental work in industry.

Mr. MILFORD. Are the programs that you have planned now really going to get into propeller research the way we should?

Dr. KRAMER. We think we are going to get there. I must admit that this year, we are not doing as much in turboprops as I wish we were. However, it is the nature of our research programs, because of the people and the facilities that are involved, that it takes time to build up a capability, I feel that we have a reasonable start.

Mr. MILFORD. You are giving me an in-house answer. Will we be working with other institutions outside of NASA on a contract basis?

Dr. KRAMER. We are working on a contract basis.

We funded propeller research in both fiscal year 1976 and fiscal year 1977, at a rate of about \$1 million. What we are doing now is increasing that funding level to \$2 million in fiscal year 1978 and \$3 million in fiscal year 1979, as was our plan.

Mr. MILFORD. Let me go into the area of STOL. We took a look at the military STOL, and we took a look at the modified Buffalo, which appeared to be two different programs, but aeronautically, what is the difference between STOL, the military version, and the modified Buffalo work you are doing?

Mr. KRAMER. I would say there are several differences. Aeronautically, I do not think the differences are primarily aerodynamics.

Their primary difference is in their environmental impact, that is, the reduced noise features which are built into QSRA, and which significantly compromise the vehicle in order to get the kind of noise footprint that we are looking for.

We also plan to use the QSRA for part of our control research in the terminal area to tie into our STOL program. It is that kind of environmental question which must be answered before STOL can routinely be used in the civil area, and, of course, it does represent an anomaly in the current operating systems. We have to accommodate it somehow or other.

Mr. MILFORD. Still another area. On one of your charts, you indicate atmospheric research work, and I immediately thought it looked like you are getting into the NOAA area, taking a look at thunderstorms.

Dr. KRAMER. Thunderstorms belong to NOAA, and airplanes belong to us. When the two meet, we have to get together.

Mr. MILFORD. You are looking at the airplane part of it?

Dr. KRAMER. Absolutely.

Mr. MILFORD. Mr. Wydler?

Mr. WYDLER. Dr. Kramer, I am delighted to be here to congratulate you on your new position.

I have just a few questions. The chairman is trying to hold down the time of the questions.

If you try to answer them as directly as you can, and if you cannot answer them, just say so.

We hear a lot of talk about upping the amount of money that goes into the aeronautics research and development budget. If we doubled the amount that you are receiving at the present time for next year's budget, what would you do with the money?

Dr. KRAMER. I think I would bankroll a considerable part of it. I think I would probably spend a major fraction of it rather ineffectively because we do not have the kind of program that can undergo that rapid an expansion. That is my honest answer.

Mr. WYDLER. It is a good answer.

If we were to increase it at all, what would be your idea of the sensible increase?

By that, I mean the amount you could use effectively to increase the speed of the programs in which you are operating, in a way that would be cost efficient.

Dr. KRAMER. Our fiscal year 1978 budget request to OMB for aeronautical research and technology was \$245.6 million, and our fiscal year 1978 budget request to the Congress is \$231 million. The \$231 million does not include the resources we expect from the Navy to reimburse us for the VTOL lift cruise fan research aircraft technology work that NASA would do for the Navy. This amount could be something like \$5 million to \$10 million in fiscal year 1978, so if we count

that, we could have a program on the order of \$240 million. Overall we are talking about a real budget increase in the order of 15 to 20 percent, and we have to take out the effects of inflation. That is a significant investment for aeronautical research and technology activity.

Mr. WYDLER. Just give me some idea of the manpower situation, as compared to last year's budget, as far as Government is concerned, and what it would be relative to contracts?

Dr. KRAMER. I know the in-house manpower breakdown better. We are holding steady on in-house manpower.

We have about 3,800 direct program people involved in the aeronautics program at our centers, and that is holding steady. As long as that is holding steady we would have a problem absorbing a very substantial increase in resources in the program.

One of the reasons we cannot use a lot more money effectively in our R. & T. base program is that one of the main items in the program is the manpower. This is not true in programs like aircraft energy efficiency. In the R. & T. base, a sudden infusion of a great deal of money does not help the situation appreciably.

Regarding contract manpower, I do not have a good estimate. Perhaps my resources man can help me.

Mr. PENARADA. We are going up about 15 percent in contract R. & D. dollars on the basis of real growth. That corresponds roughly to a 15-percent manpower increase.

Mr. WYDLER. I am a little bit interested in what if anything is going on of significance regarding advanced supersonic transport, something better than the one we have, which I consider a disaster, financially and otherwise.

What is the status of that program? Can you give me something where you make some kind of sense?

Can you give me something where you make some kind of sense?

Dr. KRAMER. I have a simple-minded view of the advanced supersonic transport. The key problem for advanced supersonic transports is that they must be economical, and a major factor in that regard is that it has to have an economical operation at subsonic flight speeds because it will not fly supersonic overland. It must be environmentally acceptable. That is to say, it has got to have the right emission characteristics, the right noise characteristics. Otherwise it will not get anywhere. It has got to have significant range and in a real market for an advanced SST, it is the trans-Pacific operation. That translates into roughly a 4,500 mile range. Now, in a way, range is very closely related to the engine. All of these factors drive back to the propulsion system. I honestly believe that the key element in an advanced supersonic transport is the propulsion system, and for that reason we are working very hard on components technology which will make it possible for us to move into a variable cycle engine program of some kind. The expansion that we are asking for in the fiscal year 1978 budget request, in the supersonic area, is for increased work in the variable cycle engine components technology area.

Mr. WYDLER. Do you think you are doing all you can do as a practical matter?

Dr. KRAMER. I think we have the right program in fiscal year 1978. We cannot, however, sustain the current level and really expect to get

to technology readiness for an advanced supersonic transport. Somewhere along the line we would have to get more serious about the technology program if there were to be a specific technology readiness date.

Mr. WYDLER. You mean a quantum jump?

Dr. KRAMER. Yes.

Mr. WYDLER. What kind of a jump, geometrically doubled?

Dr. KRAMER. More than a doubling.

We are running the component work on a variable cycle technology at about \$6 million. If we were to move up to an experimental engine program using the variable cycle engine concept, it will be a more complicated engine than an energy efficient engine. Speaking in rough order of magnitude, we would spend \$100 million with each of two contractors, \$100 million apiece on the energy efficient engine. The variable cycle experimental engine will be more complicated and more expensive. It would be about \$100 million plus per contractor. Plus what, I do not know precisely, but it will not be cheap.

Mr. WYDLER. I just want to say I want to encourage you in that program.

Now, can you tell us something regarding the FAA program?

Dr. KRAMER. We do have coordinated FAA programs but the real work is on an individual contact basis.

We have FAA representation on the planning of the program for the terminal configured vehicle.

This program uses a 737 aircraft with advanced electronic equipment, which is doing advanced operations research at Langley. We have very good dialogue with the FAA and are jointly planning activity in the human factors area. Across the board, I would say that we are pretty well glued together with FAA in our operations systems work. I am not aware of any big problems.

Mr. WYDLER. Are they giving you the type of information you want, or how does that really work?

The reason I ask is that I wonder what is going to happen to the research and development that you do.

In other words, whether it will ever be put into use.

Dr. KRAMER. Let us take an example—the Wake Vortex program. Obviously, if the FAA identified the problem, there was a problem associated with the Wake Vortex generated by some aircraft. The FAA identified the problem; they came to us; we identified the research program; we started the work at a small scale; we came to you and asked for resources which were supportive.

We conducted the flight tests and asked FAA to be involved. They were; they witnessed the flight tests and joined with us in interpretation of the data. We are now working with the FAA on what to do next in order to make it more clearly feasible for that wake technology to be incorporated into existing aircraft, or certainly into new aircraft. I think the process works very well.

The problem we consistently face is that operating problems are uncovered with the here and now system, the 2,300 airplanes in the commercial transport fleet and the crews that operate them. If we are going to change anything, we either have to change people, which is tough, or we have to change equipment, which is of course very expensive. Thus, the human and economical problems associated with

making major changes in the operations of the existing fleet are very difficult to achieve.

Mr. WYDLER. That we know.

Finally, can you tell me, I am a little bit concerned about the AEROSAT program.

I understand you have commitments to this program, but a lot of people question its real value.

I wonder, is there any duplication between that program and NAVSTAR at all?

Are these programs going to be duplicating efforts at all?

Dr. KRAMER. Mr. Wydler, I do not know.

I do not know about the AEROSAT program. I could ask the members of my staff to comment.

Dr. KURZHALS. I am Peter Kurzhals, director of the Electronics Division, Office of Aeronautics and Space Technology.

NAVSTAR is primarily oriented at global DOD navigation requirements, and thus covers a much larger scope than does AEROSAT which concentrates on North Atlantic communications.

The basic objectives of the programs are similar, in that they both could allow certain aircraft equipment economies.

The kind of costs that we are now projecting for related user navigation/communications equipment, which is the main interface that OAST has with such satellite systems, are on the order of \$50,000 for commercial aircraft systems, and less than \$5,000 for general aviation systems. It is our belief that either the NAVSTAR or the AEROSAT is compatible with the basic navigation functions that are required for the commercial fleet if addressed sufficiently far in advance.

Mr. WYDLER. I think I understood what you said.

It was that NAVSTAR could do the same job? Mr. Kurzhals. If the proper coding is programed into the NAVSTAR, it can handle the civil aircraft navigation requirements. However, NAVSTAR cannot provide the proposed aerosat communication services.

Mr. WYDLER. Thank you.

I will submit some additional questions for the record.

Mr. MILFORD. I think we have time for another round.

Let me get into facilities just a little bit.

What are the current total cost estimates for the 40-by-80-foot wind tunnel, and the National Transonic Facility?

Dr. KRAMER. The total cost for the 40-by-80-foot wind tunnel modifications at Ames, as I recall, is on the order of \$85 million.

Mr. MILFORD. Also in answer to that, would you give us your time reference for completion of these projects?

Dr. KRAMER. As you know, we initiated modifications to the 40-by-80-foot wind tunnel in fiscal year 1977 as a result of congressional action appropriating \$6 million for that purpose. The fiscal year 1978 budget request for the second increment of that activity is \$13.5 million.

As I recall, the 40-by-80-foot wind tunnel will come back into operational status, in its improved configuration sometime in mid-1981.

The National Transonic Facility is a slightly more complicated issue. We are already underway with one work package (demolition, piles and foundations).

As you know, the procurement for the National Transonic Facility was split into a number of work packages, some 15 or 20. The two major work packages were for the tunnel pressure shell, which is kind of tricky, and the other is the drive system, which includes the additional 60,000 horsepower motor that will go with the existing motors. This horsepower is the key to getting up to the right pressures to give us 120 million Reynolds number capability which the DOD clearly needs for its development and testing of new aircraft.

Well, those two bid packages went out for bid in the fall, and the bids came in around Christmas time. The responses were discouraging to us. They were substantially over what we had expected. I do not remember the numbers precisely, but the sum of the two exceeded our architect and engineers' cost estimates by over \$5 million.

It was our intention to build the NTF for \$65 million based on the cost estimates that we worked up, and that the architect and engineers worked up under contract for us. That meant that with this higher bid price the cost would have to grow to something in the order of \$70 million or more. I do not remember the numbers precisely, but we were within the \$70 to \$75 million cost range.

At the same time, we were concerned about some of the technical risk associated with the current design. We are at the moment reassessing our actions on the NTF. We have decided that on the shell there are some modifications to the design that can be made which we think can save us some money. Consequently, we have canceled the bid on the first design and we are reworking the design with the engineering contractor. In the case of the drive system, we are trying to assess whether there is a more economical way of achieving the 120 million Reynolds number capability through management of the installation and the drive system. We are reassessing that and we have asked the bidders to extend their bids for at least 30 days; both bidders have agreed to do that. During that 30 days, we are going to complete an intensive review of the cost estimates to try to get as good a fix as we can on the costs.

We are being assisted in that cost review by the consulting engineering firm, and we are also doing an intergovernment assessment of the technical risk associated with NTF.

All of this work will be completed in about the next month. We will be able to give you a much more intelligent answer to your question sometime toward the end of March.

Mr. MILFORD. I would appreciate it if you would, and I certainly appreciate NASA's efforts to save money.

Parenthetically, I would point out if we are fiddling around with losing several months to save \$2 million, that we have several billion dollars at stake in this Nation's national interest in maintaining pre-eminence in advanced technology aircraft.

That also must be weighed here. We must not get into a situation of delaying the construction of the facility, so that should be given equal importance along with the possibility of saving any money.

[The information requested above follows:]

NASA undertook in June 1975 the design, construction and operational start-up of the NTF for an estimated cost of approximately \$65 million. The target operational date, based on an FY 1977 construction start, was mid-1981. It was recognized at that time that only very preliminary engineering had been accomplished and that several risks were inherent in this project. However,

in view of the widely accepted importance and urgency of such a new major research and development "tool," it was determined that the best course of action would be to proceed. This determination took into account NASA's internal and independent architect-engineer cost reviews and validation efforts, as well as studies, testing and preliminary engineering then accomplished.

During 1976, confidence with respect to cost and schedule increased somewhat, in that all appraisals were in the \$65-70 million range, as indicated in NASA's fiscal year 1978 budget estimates documentation. However, during 1976, priority attention was given to the design of the tunnel pressure shell and the drive system, since these two major elements of the project were felt to be highly cost-sensitive, and both were long-lead items, impacting schedule. Together they represented about half the then-estimated project cost, and limited bidding competition was anticipated due to their highly specialized and complicated nature. Thus, NASA's decision was to test these two items of construction in the market place before committing to a significant expenditure of capital on the other aspects of the NTF construction. The priority accorded these two work packages resulted in limited design development on the remainder of the project. Major attention could not be redirected to design of the other work packages and to related materials testing until after the tunnel pressure shell and drive system were ready for contract procurement. This transition took place in the September-November 1976 time frame.

As previously mentioned, as of December 1976, NASA had confidence that, while cost estimates were obviously tight, this large, complex and unique tunnel could be built within the \$65-\$70 million range indicated. The bids for the drive system and the tunnel pressure shell were reviewed during the period of December 17-22, 1976. These bids exceeded NASA's estimates, as the Congress was informed at that time. Almost concurrently, newer and higher cost estimates, paralleling advancing design maturity on the other packages, began to emerge. By early January 1977, NASA faced a severe total project cost situation. In response to this situation, NASA undertook a series of actions, among which were:

- Bid price assessment of the tunnel pressure shell with resultant determination to reject the bids, to refine the design and to readvertize for 304 stainless steel only, as opposed to 9 percent nickel steel or stainless, as had previously been done;

- Bid price assessment of the drive system which, after prolonged review, indicated the interests of the government were best served by accepting the low bid; (this contract was awarded on March 16, 1977);

- Review and cost validation of all other work packages;

- Review of technical feasibility to determine if there were any unaddressed risks;

- Review of project management; and,

- Assessment of schedule impacts.

As a consequence of all that has been learned from these actions, it must unfortunately be concluded that a target cost of \$85 million is now more appropriate than the earlier stated \$65-70 million range. NASA considers this \$85 million to be a hard cost target. However, relative design immaturity of certain work packages, and a low potential for further unknowns must be recognized. It is therefore concluded that a range of \$85 million-\$90 million represents a realistic present cost appraisal of this construction project.

Recognizing that this increase in cost estimate includes additional design and construction effort, and taking into account the recent delays occasioned by detailed project reviews, rejection of the tunnel pressure shell bids, and delayed award of the drive system contract, it has also been determined that the project schedule must be slipped. It is now estimated that the NTF construction will be completed in late 1981, and that operational status will be achieved in early- to mid-1982.

The NTF, as has previously been reported, is a unique and very complex facility. It is conventional in the respect that it is a fan-driven wind tunnel and must be built to withstand attendant dynamic loads. But it also is a pressure vessel that must accommodate mechanical stresses caused by pressures up to 130 psi, and a cryogenic facility that must maintain its integrity under thermal stresses induced by temperatures that range from ambient down to -320° F. Coupled with the above complexities are the intricate process controls and instrumentation that are required for energy conservation and environmental compatibility. In combination, these conditions have caused unique design problems, and the

solutions to these problems have most often turned out to be more costly to construct than originally envisioned.

NASA's underestimation of the task of implementing this facility occurred even with the assistance of considerable expertise such as architect-engineer firms, consultants, and prospective fabricators during the planning stages. NASA's view of the market place had also indicated the probability of more competition for the drive system and tunnel pressure shell contracts than was experienced. A severe materials problem with the thermal insulation was also encountered, and NASA has elected to increase the model positioning capability to better satisfy Department of Defense (DOD) test requirements and reduce energy consumption during test operations. These and other problems and impediments taxed the entire project design and management structure. This situation is now being remedied by the assignment of additional architect-engineer and construction management support.

In reflection, this project could possibly have been deferred a year in budget presentation. By so doing, the design and related cost estimates and the test programs and special studies would have been further advanced. Even so, it is not at all certain that NASA would have projected an estimate of \$85 million under those conditions, especially lacking actual market place experience on the drive system and tunnel pressure shell.

NASA has high confidence in the revised cost and schedule for the NTF. This confidence is drawn from the very critical appraisals and assessments made during February and early March 1977. Management of the project has been strengthened and NASA will do the utmost to meet the new cost and schedule commitments indicated. Finally, it should be pointed out that the test capabilities of this unique facility have been in no way compromised through this review.

Dr. KRAMER. We understand your concern, and we share it.

Mr. WYDLER. Would the chairman yield?

You said it came in \$5 million over what you had hoped.

It was \$5 million over what you had budgeted for the item?

Dr. KRAMER. Yes.

Mr. MILFORD. In other words, we may get into a situation where we would ask you to come back to the committee, so we can take another look at it.

Dr. KRAMER. Let me say one further thing relative to the \$5 million. It was \$5 million relative to the total of \$65 million, but in the total for these two bid packages, it was about one-third of their value which is about 40 percent of the \$65 million or about \$25 million of the activity. Thus, we were over \$5 million out of \$25 million, not \$5 million out of \$65 million.

Mr. MILFORD. Looking down the road, and still on the facilities, and recognizing the fact that many of our facilities were constructed back in the old NACA days, what new aeronautical facilities do you see as being needed beyond those that we just talked about?

Dr. KRAMER. The only facility issue that we have on the horizon of that scale, of that level of cost which I will say is approaching \$100 million, is the question of what do we need to do about our propulsion system test capability at Lewis. As you know, propulsion system test facilities are extremely expensive.

As part of the national facilities plan, the Air Force is going ahead with building the facility at Tula, a very expensive facility, between \$400 million and \$500 million.

Now, there is obviously no point in NASA building a parallel facility at Lewis Research Center.

On the other hand, it is clear if we are going to have a propulsion research center, it will be deficient if it does not have a facility for some full-scale engine testing. The current facility at Lewis is getting old—it was being built as I recall in 1951 at Lewis—and engines have gotten a lot bigger and a lot more complex. We have to address the question

of what kind of facility needs do we have in the propulsion area, and that is an item on my agenda for the coming months.

On a smaller scale, a very interesting facility we have been talking about at the Langley Research Center is a quiet high-speed tunnel; quiet in the sense of having a very low turbulence tunnel for high speed work which would facilitate work on fundamentals of boundary layers. We will have boundary layers forever, and the key is getting low drag performance. We have some very able research activity in this area but it is inhibited by the capability of our tunnels to simulate boundary layers, because of the turbulence levels in the tunnel. We are thinking of considering coming forward with a proposal for the quiet tunnel.

Mr. MILFORD. Let me get into composites for a minute.

Just what success have you had in convincing air carriers to test fly composite primary structures?

Dr. KRAMER. None. Critical to safety flight, we have no such primary structures in service, nor do we have a commitment from any airline to test a primary structure in the sense of a primary structure such as a wing, which is obviously necessary for the safety of flight.

Mr. MILFORD. What part if any does air carrier concern for product liability have to do with whether or not they would be using composites?

Dr. KRAMER. I think it is a significant factor in their reaction. The airlines are quite rightfully concerned about the question of liability. They are even short of the question of liability. They are concerned about the confidence of the traveling public in their behavior, so that they are very loath to get into the situation where a small number of airlines are flying a small number of nontypical aircraft on a routine basis, that is to say, like one airplane with composite wings. They are concerned about being characterized as a risk taker, and the consequent effect on their business.

Mr. MILFORD. From your knowledge of the testing of these composite products, would I be correct in summarizing that the product would produce lower costs, greater strength, and would essentially produce a safer product than what we are now using. Is that a correct summary?

Dr. KRAMER. Without a doubt, the earlier products will be safer, because from pure engineering, we will not have failures. We do not want them so they will be conservative in their design. In that sense they will be safer. Over the long haul, as we get experience with composites and design more to the limits, from structural safety margins, they would be comparable to the construction of safety margins with homogeneous materials. Composites do offer some possibility of inherently being better from a fire resistant standpoint, and, therefore, there may be an inherent safety advantage to the use of composite structures.

Mr. MILFORD. It forces me to draw the conclusion that we have developed new technology that makes a better airplane and a safer airplane, and that technology is not being applied, simply because of the fear of air carriers facing liability lawsuit problems?

Dr. KRAMER. I think that is a little bit too strong a statement. Let me tell you how we are addressing the problem.

We are trying to get away from the concept of having a unique one or two of a kind of article in the public transportation system. What

we are doing in our composites program is first of all working on small-scale secondary composites, so we get engineering design experience, manufacturing knowhow, and to get some experience with these parts in the field. We are also scaling up and working on what we call medium-size primary structures. No, these are primary structures in the sense that they are important to the handling characteristics and safety characteristics of the vehicle, but they are not a full wing or semispan wing. The risk associated with the failure of such a part as that is significantly lower than the failure of a wing.

We have embarked on a program with three commercial air transport manufacturers, where we will do enough testing, and we will build enough parts on a pilot plan basis, such that when we get actual manufacturing costs, we will have valid manufacturing cost experience which will enable us to draw a learning curve and thereby get good manufacturing cost data. We will have an extensive ground test program so that we can answer all of the structural questions and service questions associated with the parts. At that point we hope the airlines will fully participate with us in the review of this data, and the definition of the test program.

What we are working toward then is putting these manufacturers in a position such that the economic and structural risk associated with not building just a few, but with a complete changeover in the production of the part from homogeneous aluminum to composite material will occur. Then from a certain point on in the production lifetime of an airplane, all those airplanes will have composite parts. Therefore, no airline will be in the unenviable position of having a unique airplane, which somebody might perceive as having a higher risk being associated with it.

Mr. MILFORD. Mr. Wydler?

Mr. WYDLER. Doctor, could you just tell me what the status of NASA's energy management reduced drag approach technique is?

Dr. KRAMER. Well, I am not very close to it, but we were running a flight test with the Convair 990. We did design some systems, some fairly simple navigation aids, which would enable a pilot to routinely fly such a trajectory. We have talked extensively to industry about it. We find there is considerable industry activity in this area, but at the moment we do not have an active flight test program.

Mr. WYDLER. So whatever you are going to do is finished?

Dr. KRAMER. It is on the back burner. As far as I know, things are going along pretty well. We are hopeful that this kind of hardware will be made available in the system.

Mr. WYDLER. Thank you, Mr. Chairman.

Mr. MILFORD. At this point in the record, I ask unanimous consent to revise and extend my remarks, and I will submit to you in writing, within the next 10 days, specifications, and I would like to ask that you initiate a study to determine various options that we might have in the development of technology in the advanced supersonic area, everything including the variable cycle engine, to other factors, and I will spell this out in writing to you, and include it in the record within the next 10 days.

Dr. KRAMER. Very good, sir.

Mr. MILFORD. Any other questions?

Dr. Kramer, we appreciate very much your appearing before the committee this morning.

Your testimony was very enlightening and that of your colleagues. The subcommittee will stand in recess until this afternoon at 1 p.m., to reconvene in room 2359.

[Whereupon, the subcommittee was recessed at 11:30 a.m.]

AFTERNOON SESSION

The subcommittee met, pursuant to notice, at 1 p.m. in room 2359, Rayburn House Office Building, the Honorable Dale Milford (chairman) presiding.

Mr. MILFORD. The subcommittee will come to order.

Each of our witnesses this afternoon has been asked to comment on one specific aspect of the NASA aeronautics program; namely, the health of the research and technology base. Putting that another way, this is the front-end "R" part of R. & D.

The subcommittee's interest in this subject is a longstanding one because of the downward trend in recent years and the implications of this trend for our continued national preeminence in aviation. Our concern was further highlighted recently during a trip to several major Government and industry aeronautical facilities. Nearly every knowledgeable person spoke of a serious deterioration of the climate for innovation in aeronautics. They pointed to the decline in the level of funding and manpower, the small number of young researchers coming into NASA, and the emphasis on near-term results.

Alarmed by these comments, the subcommittee decided to invite three highly respected experts to discuss the subject from a variety of perspectives.

Our first witness this afternoon is Mr. Robert Parker who is acting as the director of defense research and engineering.

Mr. Parker, we welcome you to the committee. We have your prepared statement which we will accept in full, with attachments, for the record and you may proceed as you would care to.

STATEMENT OF ROBERT PARKER, ACTING DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING, DEPARTMENT OF DEFENSE

Mr. PARKER. Thank you, Mr. Chairman and members. I would like to just talk informally on my observations and the Department's overall observations relative to this important question on the health of our aeronautics capability in this country and, in particular, will make some comments on the NASA activities as we see them, and also the Department of Defense activities and the industrial activities.

I am particularly pleased to be here because there is a very important relation that exists between ourselves and NASA because of our common concern for aeronautics based on many years of interaction between the agencies and the very close working relationship that we have been able to establish over the years and which continue today.

You are aware that we do have a quarterly meeting of the Aeronautics and Astronautics Coordinating Board which is actively attended and provides us the opportunity to make sure that our programs in the aeronautics area and the space area are very closely coupled. I think that if you look particularly at our activities last year in the area of the facilities for aeronautical research you will find that sort

of cooperative activity had, I believe, a major payoff. The NASA and the Department of Defense were able to look at the overall requirements of the facilities for aeronautical research in this country and agree between our organizations on what I consider to be a very economical, prudent management approach to the establishment of these facilities.

One of these activities was the aeropropulsion systems test facility, sometimes referred to by the acronym ASTF, which the Department of Defense took to its Military Construction Committee and was able, with NASA support, to get the support of Congress. Likewise in the area of the research facilities for Transonic and high Reynolds numbers activities, NASA and the Department of Defense were able to come together and, rather than indicating a need for two facilities, to integrate them into one. Again that was supported by the Congress, as the proper approach from the management of these two organizations toward getting these much needed facilities.

In addition, we have jointly agreed on the activities for 40 by 80 subsonic tunnel modification which will give us capabilities in the rotorcraft area and the powered lift programs which are an important part particularly of the Department of Defense activities.

As you know, we have a great dependence on our helicopters in our military, as well as a recent trend in the area of powered lift and other means of getting aircraft off the ground under short runway conditions. This is a NASA sponsored activity, but strongly supported by the Department of Defense.

The military construction request from the Department of Defense, as I think you know, last year for the ASTF facility was about \$437 million. This is one of the larger facility appropriations that have been made in an area like this, and we were very pleased that the Congress is willing to support this activity.

In the area of the NASA facilities, these have been incrementally funded and we would encourage the Congress to continue this funding because of the importance of these facilities to both the NASA and the Department of Defense and to the aeronautical industry in this country.

Turning for a moment to the NASA budget in aeronautics, we pointed out, this morning, that there is in the research and technology part of the NASA budget somewhere in the order of \$231 million which relates to this tech base for aeronautics. We could look at it in several different cuts. In terms of the cut which looks at it as building from technology on up to systems, about 42 percent or \$98 million of this activity is in what we would call tech base activity. The systems technology program is \$72 billion or 31 percent and the experimental programs, which we think are extremely important to bring all this technology together into something which is demonstrable and verifies these technology advances in its final form, is in the order of \$58 million or 25 percent.

I cannot overemphasize the importance of these kinds of activities, where we put things together in order to remove the major part of the risk that is involved in these programs. As you know from the past, the Department of Defense has been criticized and I think rightly so in many cases, for having moved out a little bit too fast with some areas of technology, not just in the aeronautics area but in some

of the other areas. As a result we have taken a much more conservative approach and the requirement now is that we have a much more definitive proof of concept of the approaches that we take in aircraft and avionics development or other parts of our overall DOD budget, so our interest in this is large.

You might recognize this by looking back at the last few years at our emphasis on the competitive prototyping programs. In the Department of Defense we have pushed on the advanced medium STOL transport, the F-16/F-17 activities, some of the helicopter activities where we have not necessarily had requirements but we have felt the need for putting all the technologies together to clearly demonstrate the performance of these systems before we decide to develop them for our inventory.

Another way to look at the NASA budget is in terms of their emphasis in the research and technology base part of their program. Basically I think that as a result of the advisory panel for aircraft energy efficiency programs, which met this last year, we find somewhat of a bias in the program structure relating to these activities. I do not think that this is an improper bias because of the importance of energy conservation, not only in aeronautics but elsewhere in our activities.

However, I would point out that when you look at the structure here, there is nonetheless a bias which takes away some of the areas of emphasis that we might like to have worked on from a DOD point of view. This is broken down in their budget into 30 percent—\$70 million—of their fiscal year 1978 budget for research and technology on aircraft energy efficiency, 14 percent on aircraft component improvement, 36 percent on composites primarily for transport aircraft, the prop fan activity for improved cruise efficiency, and then continuing activities on noise and emissions. All of these are very important topics. Most of them relate not only to the Department of Defense, but to the civil sector; however, as a result of the recommendations of that panel, it does I think, put a bias into the program.

In particular as we look at it, we might like to have additional support from NASA in the areas of research in the rotor technology or rotor wing technology activities, again because of the significance of these programs to our helicopter programs primarily for the Army and the Marines.

There are also some key areas of aerodynamics where we would like to see a bit more emphasis, such as in the area of buffet transonic flow, aeroelastic coupling which was formerly at Ames, the variable camber aerodynamics which was formerly at Langley. I would note also that the engine inlet work which was being done at Lewis has increased and for this we are appreciative of the support from NASA.

There are a number of benefits, of course, that come out of this activity for the Department of Defense. We have, over the last several years, been making some fairly major commitments to the modernization of our aircraft in defense. These are programs such as the B-1, the F-16, the F-18, and our helicopter programs. If you look, there is a grouping of programs which are going through their development stages fairly much together as opposed to stretched out.

The implication of this is to show the importance of the technology base that is available to us as a result of NASA's activities and our

own. We were fortunate, in terms of the NASA activity for the F-16 and F-18, to have the benefit of their vortex lift enhancement research. In the powered lift and air foils activity, NASA made a major contribution to the advanced medium STOL transport program where we are now flying two very successful aircraft; actually there are two versions but four aircraft. All four of those aircraft were very successful programs which had little in the way of technological hiccups or uncertainties, largely because of the activities that have gone on at NASA as well as in our own research establishment.

We have also for the B-1 been able to take advantage of the variable sweep wing which has been pioneered by the NASA folks and which also has been used in our F-111, and is currently in a large number of the Russian aircraft who have seen the merits of this kind of technology.

Last, the high angle of attack aerodynamics effects have allowed us to design the F-15 aircraft which is our first line fighter, with higher performance.

One other activity which has not been incorporated into our current program, but which we think may very well be important to some of our future activities, is in the prop fan area. As a matter of fact, if one looks at some of the activities going on in the efficiency area, you find that the Department of Defense has a keen interest because of some of the requirements for land-based aircraft for anti-submarine surveillance and other at-sea surveillance. In these cases we desire to have the possibilities of developing aircraft which could cruise for long periods of time and give needed surveillance continuity.

Turning next to the overall national aeronautics research and technology activity, there are really two primary parts. One is that we fund directly with the Department of Defense for our own programs and the other is the independent research and development going on in the industry which really has two aspects, one involves our compensation to industry as part of our cost of business (the research and development reimbursement in our contracts); and the second is the investment that the companies are making just as a commercial venture in new aircraft design, primarily for the civil sector.

If you look at the balance of these, clearly the Department of Defense activity is the largest of them. About 20 percent of our total R.D.T. & E. budget, which is this year close to \$11 billion, goes into aircraft and related equipment. Of this dollar sum, about 20 percent is spent on our aeronautical tech base, so you can see that that is a fairly vigorous activity on the part of the Department of Defense. Clearly, it is oriented toward our military applications. However, there is a fair percentage that has a direct fallout into the civil sector as it can be applied to civil aircraft developments.

The tech base in the Department of Defense is providing, I think, some very important contributions for our own aircraft, as well as the civil sector.

Advanced composites are one area that we have been placing a great deal of emphasis on, because of the additional strength we are able to get out of these composite structures and also the lightening, lessening of the weight, of aircraft as a result of this application. We feel that we can take a little bit more of a lead in some of these areas in getting them into aircraft and getting the hours and the experience and the

confidence in them as a result of our military needs; then this **can** directly apply into the civil sector as a result of demonstrated confidence in composites. Although clearly, as one moves the composites into primary structures on civil aircraft, there will be necessary certification process, but this will have a good base as a result of the Department of Defense programs.

These advanced composites are going, in increasing proportion, on the F-14, the F-15, the F-16, the F-18 and the B-1, because in each case it is important to provide strength while reducing weight.

Another area, which I think is kind of revolutionary in the way of aircraft design, involves flight control systems. We have in the F-16 an analog electric flight control system which provides not only reduced costs, but also improved performance in the overall flight characteristics of the aircraft.

In the F-18 we have a digital electronic flight control system backed up by a standard electrical mechanical system. These programs will provide a level of confidence in the design of this sort of flight control system which is applicable both to the civil and military sectors.

In the B-1, we have been using a similar application in the ride-control system. The B-1 flies at very high speeds at very low altitudes, and there is a requirement for a very precise control of the flight characteristics under those conditions.

In the helicopter area, there have been major advances in the elastomeric bearings and vibration control that have been incorporated into the UTTAS program and the AAH program. One of the amazing things for people who have not ridden in helicopters lately is to get abroad one of the newer helicopters and find the level of vibration so markedly reduced as a result of some of these technology developments.

The industrial related part of research and development, or independent research and development is in, I think, a fairly sad state. It has declined significantly since 1969. The other aspect which concerns me is that it is more and more oriented toward systems rather than the technology base. This tends to mortgage our future for the present. There are some good reasons for this. From the Department of Defense point of view, we now insist that programs have a higher level of confidence in the overall performance of what is proposed than we used to. As a result, companies go further in proving these technologies prior to proposing them to the Department or their being accepted by the Department. As a result of this rather conscious effort on our part, there has been a clear shift away from the technology areas that are important to the future, to the system technologies or system applications which are important to the present. I think that this is something that we have to recognize and compensate for; clearly this situation puts an increased premium on the efforts that are done at NASA and the Department of Defense in developing the technology base.

There are payoffs that come from these activities so far as the industry is concerned, particularly when they win a system contract as a result of having spent this money on an overall system. As an example of applying technology into the designs, we have on the AAH, what is called the Black Hole IR Suppressor, which is coupled into the engine to suppress the IR signature of the helicopter. This is of course a very important counter measure requirement for the Department of Defense and our helicopters, and this new technique can do it **with**

much less power drain than some of the more conventional approaches. I think that this was a significant factor in the winning of the competition by the particular company that had made this investment. So these kind of applications of technology are very important, but we see too few of them these days to be comfortable with it.

In conclusion, I would like to comment that I believe that the NASA and the overall National Aeronautics Research and Technology base is good, but declining in a way which makes me uncomfortable. I think there are areas for improvement, some of which I have cited and further are cited in the statement which has been entered into the record.

The funding of the NASA facilities to continue on what was initiated last year, is very important. One looks at the facilities that this country has. They do need an update and it has been recognized and should be continued. They are the basis for the kind of research that has to go on if we are going to have the technological advances that are important to the future.

The NASA activity is not only important to the Department of Defense, but I believe it is well coupled, well coordinated, with the Department and we would support it strongly.

In the area of the budget growth in aeronautics research that has been proposed for this year, going from \$190 million to \$231 million, I would strongly support it. It is a move in the right direction. The Department of Defense has been, as a policy matter, causing its research and technology base, the so-called 61 and 62 programs, in our budget to grow at a forced rate of 10 percent in the research area and 5 percent in the advanced development area. I think that is the kind of policy that should be followed for NASA to gain back some of the technological advantages that we have enjoyed in the past.

I would like to urge your support for that budget and your continued interest in the overall health of our aeronautics research and development. That, Mr. Chairman, is my statement, and I am available for questions.

Mr. MILFORD. Thank you, Mr. Parker.

You mentioned in your testimony that you take a conservative approach because of errors that have been made in the past both by DOD and NASA.

I wonder if maybe we have not reacted too much and have been too conservative in as much as there is a time factor involved here too, and because we are competing with others who might be willing to take a chance.

Mr. PARKER. Mr. Chairman, that is a very perceptive comment. As a matter of fact, one of the important subjects in my dialogue with our congressional committees this year is on that particular subject, and we have been discussing with our Defense Science Board the possibility of looking into this a little bit more in-depth for us.

We find that we are now taking on the order of 8 to 10 years to get something from the decision when we want to build it, even having a good tech base behind it, and getting it into the field, and this is too long. I would submit however, that this is going to take a lot of understanding on the part of the Congress, and it is going to take a lot of good management on the part of the Department of Defense and/or NASA. The reason I say this is because it has become vogue to question whether or not you have any concurrency in your program. In the event that there is concurrency in the program, it makes it a prime

candidate for removing the production money or slowing down the program in some form or another. Particularly when the objective is to whittle away a little bit at the budget, that is a very convenient way to say, it is not being managed properly.

We have taken the following kind of approach in relooking at this problem and rethinking it through and we are trying to establish what might be at risk in the investment in a particular program as a result of some concurrency or as a result of taking a little more risk in what it is that we are doing.

So I think that this is important. I think a corollary is the importance of the competitive prototyping activities, which can occur without a requirement existing. As you know, in the Department of Defense we find it fairly hard to spend a lot of money on something unless there is a specific requirement established by the military which said we want an aircraft or a system which will do the following kinds of things. Then the system cranks up and tries to turn out what is listed in the requirement. This is not the case on the F-16 or the F-17/F-18 program. This is not the case on the advanced medium STOL transport. These were clearly programs that had no requirement. There was a perceived need, however, for these and also a recognition of the fact that, if we were going to take this more conservative approach, we could not wait for the requirement to get established, but we would have to put a little risk capital out there in order to bring these programs into physical being so that they could be tested.

As you know, the F-16 has gone into engineering development and will go into production very shortly. The F-17, which became the F-18 did likewise. The voting is still out on the AMST or the advanced medium STOL transport. but there is a mechanism by which we can do that. So there are two parts to it. One is the support within the Department of Defense and the Congress for the prototyping activity, and also an understanding on the part of the Congress and in the management of the Department of Defense on the area of risk, because in your original point, it is taking us too long to get from where we are to where we want to be.

Mr. MILFORD. That is the purpose of my question—most members of this body are fairly reasonable. Most, also, have such a broad scope to consider that they cannot be knowledgeable in the details of every factor.

I was trying, for the record, to outline that it may sound very good to be conservative, to be sure, but on the other hand that you are going to be paying a price for that also.

As a case in point, I think you will probably be familiar with the XV-15, the NASA Army tilt rotor project.

Mr. PARKER. Yes, sir.

Mr. MILFORD. That airplane is sitting on the ramp right now. The engines run, the rotors turn, but it will never see a bit of air until sometime next year, as I understand. I can remember in the early days in the development of helicopters, we staked them down, and had that been an early model Bell for example, it would have been flying much sooner than that.

Mr. PARKER. You might have even had a commitment to put it into production.

Mr. MILFORD. That is right.

I am wondering if we should not in testimony before these committees point out what we are paying for this conservatism including the overhead costs of keeping the teams together until you finally get that airplane in the air.

Mr. PARKER. I think that that is a very powerful observation. I will give you another example where we have suffered in the same way, only more severely, and that is in the area of the thrust augmented wing program which we have been funding over the last few years. It is interesting to have a look; I think last week or the week before, "Aviation Week" summarized the program and showed the sort of funding perturbations that have gone into it and the problems that have resulted, not technical problems, but the problems of the full support of what is clearly a technology program.

Mr. MILFORD. Just for a case in point, let us take the XV-15 and when you get back to your shop, if you have the time, run that by with options as to how we could short circuit the time, so we could improve the concept of that experimental aircraft as opposed to the schedule we are actually following as to what it is costing us in time as opposed to how much money might speed the process up, so we could see proof of concept finished.

Mr. PARKER. Yes, sir, I will do that. In response to your request, I have reviewed the XV-15 tilt rotor research aircraft program for possible options which might accelerate the completion of the proof of concept flight tests. The demonstration of the concept viability actually starts with the first successful hover flight which, as you may recall, is expected within 1 month. I would like to point out, prior to discussing the options and their attendant cost and risks, some of the factors which make this joint Army/NASA technology demonstration program different from what might be considered a typical development program for a new type of helicopter.

First, the XV-15 is not a helicopter—it is far more than that. The complexities which arise from the requirements to transfer power through cross-shafting in the event of engine failure, to carefully phase control mechanisms with pylon angles, and the significant challenges to transmission technology and stability analyses which the concept presents all serve to justify a rather conservative approach in this development. You will recall that the first attempt to demonstrate tilt rotor technology was with the Bell XV-3 vehicle which experienced stability problems in flight, largely because analyses and tests which were conducted prior to flight were inadequate in both quantity and quality. Additionally, history shows that many vertical lift concepts were researched during the 1950's and 1960's. In most cases, inadequate homework was done prior to flight and catastrophic failures frequently resulted. When this occurred, any interest which had been generated in the concept was lost. I do not believe that we can afford to repeat that portion of history with the XV-15.

Second, the Army and NASA have undertaken the XV-15 program in order to advance the state of tilt rotor technology. There are no pressing military or civilian requirements for the vehicles at the present time. This situation allows the development to continue in a logical manner without the pressures inherent in a system development, and permits developmental problems to be attacked and resolved with minimum risk without excessive concerns over schedule delays and the re-

quirements for large sums of money. While we believe that a successful tilt rotor program without any highly visible technical shortcomings will generate user interest in the concept, it is important not to incur undue risk through program acceleration which might jeopardize the program success and thus destroy potential user confidence and interest.

With the above background, a number of options for the remaining portion of the XV-15 technology demonstration program have been reviewed. The currently funded program of \$40 million (\$20 million from each agency) was taken as a baseline.

The most recent estimates of the Bell Helicopter Textron contract cost growth make it apparent that the originally planned program cannot be accomplished within the \$40 million. If funds are constrained to this value, it appears that only one flyable aircraft would be available, the flight time would be reduced, and increased risk to successful program accomplishment would be incurred.

Additional funds on the order of \$7.8 million appear to be required to complete the entire planned program in the most expeditious manner with minimum risk. This option would require \$1.65 million additional in fiscal year 1977 which is extremely difficult to identify at this point in the budget year. The proof-of-concept flight tests would be completed in May 1979 under this plan. A variation of this option considered the possibility of deleting or deferring planned tests in order to further expedite proof-of-concept completion. At this point in the program the only major test which might even be considered for deferment or deletion is the wind tunnel test prior to flight. The significantly increased risk to successful program completion does not appear to be justified by the relatively short schedule compression of three months and an insignificant cost impact which would result.

A further option which requires approximately \$6 million of additional funds without the requirement for additional fiscal year 1977 funds would result in proof-of-concept test completion in September 1979 at a slightly increased risk above the higher cost option.

The Army and NASA headquarters have scheduled a review of the program in April 1977 at which time the program options will be examined in detail. Within the funding constraints imposed on each of the agencies, they are interested, as you are, in successfully completing the program in the most expeditious, prudent manner.

Mr. MILFORD. Let me go into another matter, and in this matter, if you were not advised to comment upon it, I will submit these questions in writing to be included in the record later, but I do want to get into it.

This committee is also very concerned, primarily through FAA, in the development of a microwave landing system. We are most interested in seeing that we come up with a system that would be common for military and civil use. I understand that the Army has a problem and that they are being forced to make a decision right now due to the UTTAS program. Is that correct, or again if you prefer to handle this at a later time and let me submit these questions to you in writing feel free to say so.

Mr. PARKER. No, I would be happy to discuss it, Mr. Chairman.

The microwave landing system program has been one fairly close to my heart having been involved in the Department of Transportation a

number of years ago when we embarked on the program, and now being on the receiving end of it in the Department of Defense. It has stretched out a bit in terms of its overall development time and, I think you and the committee know, there is some question as to whether we will get an agreement on an international basis.

Mr. MILFORD. Let me interrupt you at this point to say that this matter is before an international group and I do not in any way want to prejudice that decision. I am really trying to limit the discussion to the expression of any need that the Army might have at this particular point in time.

Mr. PARKER. Yes, we do have a need at this point in time. We have put off our development of landing systems. The Army had developed one called, I believe it was called TLS, Tactical Landing System. We built one or more models of it and tested it and then we have been in a holding pattern in waiting for the MLS decision, and the support of the MLS program for the development of the tactical version for the Army.

We do believe that we have to move out fairly soon and, while a few months one way or the other is not all that critical, we have now waited a fair amount of time and we believe that within the next year we are going to have to make a decision to move out with something, whether it is a TLS system which we developed by the Army, the MRAALS system which was developed for the Marines or hopefully a common military civil MLS program.

Mr. MILFORD. Would I be correct in assuming that all you are really waiting for is somebody to say what system?

Mr. PARKER. Yes, sir.

Mr. MILFORD. Let me go to one other area, and in this one I will submit the questions in writing to you to be answered at a later time.

This committee is primarily concerned with technology development, but at this time there is a tremendous amount of debate publicly about foreign military sales, and I will send you a series of questions designed to determine what effect, if any, foreign military sales might have on this Nation's ability to develop new technology. I will not do that in the record here now, but I would appreciate your response to those questions.

Mr. PARKER. I would be happy to do that.

Mr. MILFORD. By what date must the Army have a decision on MLS? Is this date critical, and if so, why?

Mr. PARKER. The Army must make a decision by this spring to meet new aircraft production schedules. The Army needs a tactical approach and landing system. This need has been established to be congruent with the acquisition of new aircraft. With the Department of Defense striving to obtain the advantages of civil-military interoperability, the Army is depending on the Federal Aviation Administration (FAA) to begin engineering development of a tactical configuration of MLS this spring. If FAA does not for any reason, the Army will have to consider alternatives.

Mr. MILFORD. If no international decisions were forthcoming by that date, would the Army be guided by the preference of the FAA? Why?

Mr. PARKER. The Department of Defense is sensitive to the preference of FAA irrespective of international decisions, but is not committed to follow the FAA lead under all circumstances. The Army has agreed to wait for the outcome of the All Weather Operations Panel (AWOP) expected by March 17, 1977. The Department of Defense would carefully consider any attempt by the FAA to standardize on a preferred system based in part on the likelihood that it would become the international system.

Mr. MILFORD. Let me go to one other question.

NASA has indicated that DOD requests for NASA help in solving aircraft development problems have impacted their in-house research and technology manpower. Do you see these requests which are entirely proper, I am not saying that the requests are improper, but do you see them continuing in the future?

Mr. PARKER. I see them continuing for the near future. Clearly we will always depend on NASA for this kind of support, but I would point out that we probably are requiring more of this support right now than would be the normal or the average levels because of the fact that we have a fairly large number of programs of overall modernization in being now.

We have the B-1. We have the F-16. We have the F-18. We have our UTTAS and AAH helicopter programs. We have the AMST programs. All of these are incorporating new technologies and they are in a critical phase of their development, so we are probably leaning on the support from NASA more than one would ordinarily anticipate just because of the heavy workload that we have in these programs.

Mr. MILFORD. You define near-time in some sort of a calendar term—this particular thing may be something the committee needs to look into insofar as additional assistance to NASA because we do not want our basic R. & T. manpower diverted away from their basic jobs.

Mr. PARKER. Yes, sir. I believe that is an appropriate thing to look at.

It would look to me like on the order of the next 2 years before we are really beginning to lighten that load because by then most of the aircraft that we have under development will be in flight and will be through most of the technical wickets that we put them through.

Mr. MILFORD. OK.

One final thing—due to the technical nature of testimony this committee receives, we would appreciate the opportunity for any member to submit to you additional questions within the next 10 days, and if we could have your response within 10 days following, we will have both the questions and the answers become a part of the written record.

Mr. PARKER. Mr. Chairman, I would be happy to do that.

Mr. MILFORD. We thank you very much for your very informative testimony, Mr. Parker, and we appreciate your coming before the committee.

Mr. PARKER. Thank you for the opportunity.

[The prepared statement and attachments of Mr. Parker follow:]

**HEALTH OF THE
AERONAUTICAL RESEARCH AND TECHNOLOGY BASE
AT THE
NATIONAL AERONAUTICS AND SPACE AGENCY
AND IN THE NATION**



STATEMENT

BY

THE ACTING DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND WEATHER

OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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THE DEPARTMENT OF DEFENSE

Statement

by

Mr. Robert N. Parker

Acting Director of Defense Research and Engineering

Before the

Subcommittee on Transportation, Aviation and Weather
of the

Committee on Science and Technology

House of Representatives

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I. INTRODUCTION

This statement presents the Department of Defense (DoD) evaluation of the health of the aeronautics research and technology base of the National Aeronautics and Space Agency (NASA) and the nation. The evaluation of NASA is contained in Section II and the national evaluation is contained in Section III. These evaluations are subdivided into the major constituent technologies, aeronautical vehicle, propulsion, structures and materials, avionics, and support systems.

My summary evaluation of the health of the aeronautics Research and Technology (R&T) base is that it is good but not excellent. I cannot agree with those who find the national R&T base effort to be poor or inadequate. The DoD is in the midst of a major reequipment cycle for fixed and rotary wing combat aircraft. All of these systems contain significant features that derive from recent innovations in the national aeronautics R&T base.

We have noted the downward trend in NASA R&T activity in recent years and the same situation has prevailed in the corresponding military and industrial effort. The downward trend in government sponsored R&T base appears to have been arrested in Fiscal Years 1976 and 1977 and the FY 1978 aeronautics R&T budget proposals of the respective agencies provide for the first

real growth in some time. In the case of the DoD, this increase reflects the conviction expressed by Dr. Currie in his final Defense RDT&E overview, that: "I believe that this nation must maintain a posture of unequivocal technological superiority."

For military aircraft, the DoD is laying the foundation for military unique aeronautics technology which will be needed for the next reequipment cycle which will probably begin a decade from now.

Value To DoD Missions

There is no question that we are in a military technological competition with the Soviet Union. Aeronautics technology is an important part of the competition--we, the DoD, annually allocate over 20 percent of our Research, Development, Test and Evaluation (RDT&E) budget to technology for aircraft and related equipment. Of that amount, over 20 percent is devoted to aeronautics technology base programs in vehicles, propulsion, materials, structures, and avionics. We depend on aircraft to gain superiority over enemy air in the battle area, to interdict the movements of enemy troop formations and materials, to augment and direct our ground and sea-based firepower, to provide critical forward area supply, to provide quick reaction long-range troop reinforcement and resupply, to maintain the freedom of our sea lanes and to provide a fundamental element of our strategic deterrent force. It is not possible nor is it effective for DoD to maintain a complete technology base activity for all these aspects of the application

of airpower to our mission. We rely strongly on the complimentary aeronautics technology base of the NASA, private industry through independent research and development, and our universities. In particular we are heavily dependent on NASA and private industry for technology for our strategic and tactical transport, long-range patrol aircraft, and rotary wing aircraft. We are moderately dependent on these sources for technology for tactical aircraft.

We are less dependent on NASA for missiles technology; however, NASA does provide a significant amount of support to the DoD in high-speed missile aerodynamic design and testing. In the area of aircraft propulsion, we expect significant benefits from the NASA Aircraft Energy Efficiency program and from other joint programs. From NASA-sponsored developments of variable cycle engines, we expect benefits for the next generation of air superiority fighters.

National Aeronautical Facilities Program

Since we are in the first session of a new Congress, I would like to recall the importance of the National Aeronautical Facilities Program, NAFP, to the overall long-range health of our nation's aeronautics technology. To review for a moment, the facilities contained in the final form of the NAFP are:

- Aeropropulsion Systems Test Facility (ASTF) - sponsored by the Air Force to support the economical development of advanced engines for fighter, large strategic transport, and

bomber aircraft.

- National Transonic Facility (NTF) - sponsored by NASA to permit research and development testing at high Reynolds number in the transonic Mach number range (combines the requirements of the earlier High Reynolds Number Tunnel, sponsored by USAF and Transonic Research Tunnel sponsored by NASA).
- 40 x 80 Foot Subsonic Tunnel Modification - sponsored by NASA to meet subsonic research needs for the study of rotor craft and large powered lift vehicles.

The DoD and NASA are convinced that these facilities are essential to continue the efficient development of aeronautical technology through the end of this century. The latter two NASA-sponsored facilities are especially important for aeronautics technology base activities. For FY 1977, the 94th Congress appropriated full funding for ASTF and incremental funding for the NASA-sponsored facilities; these facilities have moved from the definition phase into preliminary and detail design and construction. Continued incremental funding for the NASA facilities is included in the executive budget proposal for FY 1978.

II. EVALUATION OF NASA RESEARCH AND TECHNOLOGY BASE IN AERONAUTICS

This section discusses the aeronautics research and technology (R&T) base activities of NASA. In these discussions, we focus on the areas of expected contribution to future DoD needs in aeronautics. We also base our discussions of the NASA R&T base on a broader viewpoint than the standard NASA budget designation in that we include Systems Technology Programs and Experimental Programs as well as the nominal R&T Base. We take this broader view because, while NASA designates a portion of its program as Systems Technology, it is clearly not engaged in a program of engineering development of specific systems for procurement. We include the Experimental Programs in our discussions because of our belief that R&T without experimentation is nothing but a mirage which will disappear with the slightest passage of time or shift in point of reference.

A. Aeronautical Vehicle Technology. This area includes aerodynamics, flight control, dynamics, vehicle subsystems and ground support equipment.

NASA supports R&T needs in this area for tactical aircraft through portions of the low and high-speed vehicle aerodynamics and flight dynamics activities in the R&T base. In Systems Technology, the Military Aircraft Systems project and a portion of the

Aerodynamic Vehicle Systems project are related to military tactical interests.

The key experimental program which has tactical applicability is the Highly Maneuverable Aircraft Technology (HIMAT) program. This program exploits the unique Research Remotely Piloted Vehicle (RPRV) capability developed at the Dryden Flight Research Center (DFRC) to explore high risk innovative aerodynamic configuration features with an unmanned experimental aircraft. It compliments an Air Force sponsored program to demonstrate nearer term maneuver technology which is discussed in Section III of this statement. NASA is investigating the potential application of the HIMAT vehicle to demonstrate two-dimensional engine exhaust nozzles. We expect that this feature can enhance maneuver lift and improve survivability through reduced vehicle infrared and radar signatures.

NASA and the Air Force are jointly pursuing the development of supercritical wing technology for tactical applications in the Transonic Aircraft Technology (TACT) program. In this program, the Air Force supplied new wing outer panels for an F-111 and NASA is conducting the flight test at DFRC. The aircraft has demonstrated significant improvements in maneuver capability and reduction in buffet intensity as well as the first flight

of a supercritical wing at speeds greater than Mach 2. Both NASA and the Air Force are exploring extensions of supercritical airfoil geometry to variable camber concepts in the TACT II program.

NASA Systems Technology programs have contributed to the Navy program in V/STOL tactical aircraft particularly the lift cruise fan configuration. The NASA program was terminated at the end of the transition quarter and the Navy will carry on the prime responsibility.

The DoD is dependent on NASA for R&T base effort in support of transport, cargo and patrol aircraft needs. We welcome the revitalization of related effort through the Aircraft Energy Efficiency Program. We foresee strong military benefit from development of active controls and laminar flow control (LFC). In the latter technology, the NASA program is focused on the search for a workable maintainable mechanism to exploit the LFC performance payoff demonstrated by the Air Force several years ago with the X-21A aircraft. We are already studying application of these energy efficient concepts to our need for very long endurance aircraft for multipurpose naval missions.

NASA investigation of the oblique wing configuration could have eventual application to patrol aircraft where fast transit times and extended loiter on station are important.

In helicopter R&T base effort, it is difficult to evaluate the NASA program in isolation because of the highly integrated NASA and Army laboratory structure. We believe that this co-location arrangement has helped to energize the NASA program in helicopter aeronautics and that it has benefited both agencies. The recent successful first flight of the Rotor Systems Research Aircraft (RSRA) and the designation of the Ames Research Center as lead center for helicopter technology should further focus and accelerate NASA efforts in this important area.

We do believe that more NASA helicopter oriented R&T base effort would be useful in the areas of (1) compressibility and rotor blade tip Mach number effects on rotor performance, (2) rotor blade tip shape effects on performance and (3) auto-rotational characteristics as a function of rotor design. In all these areas we do not have adequate basic analytic tools or technology. The Army has been active in rotor blade tip shaping for noise reduction which is of strong interest to the DoD for its effect on the improved survivability of helicopters.

The joint Army and NASA program for the Tilt Rotor Rotor Research Aircraft is making progress toward first flight. We expect that this program will demonstrate an important option for helicopter-like takeoff and landing performance with higher and more efficient cruise speed.

NASA involvement in tactical missile R&D has been peripheral in the past. However in 1976 a meeting with the military services was conducted to determine if any gaps in tactical missile aerodynamic technology existed where NASA effort would be beneficial. As a result, NASA has begun the investigation of new aerodynamic shapes which provide body lift without the use of canard lifting surfaces.

NASA R&T programs in aeronautics technology are augmented through the loan of DoD aircraft and components to NASA at no charge and in pursuit of joint experimental programs on aircraft of interest. Outstanding recent loans include YF-12, F-15, and YF-17 fighter aircraft and numerous engines of which the latest is the F-100 engine. Both Advanced Medium STOL Transports (AMST) prototypes, the YC-14 and YC-15, include instrumentation to measure parameters of interest to NASA and we anticipate future loan of these aircraft following completion of our fly-off competition.

B. Propulsion Technology

Two NASA programs in the propulsion area are the Aircraft Energy Efficiency (ACEE) Program which is to provide data for the design of new transport aircraft that are more energy efficient than today's aircraft and the Supersonic Cruise Aircraft

Research (SCAR) Program in which propulsion technology for supersonic cruise aircraft is being developed.

The ACEE Program is initiating efforts in the advanced turboprop area and in the engine component improvement area to identify sources of performance deterioration as well as to provide better components to improve fuel utilization.

If successful, both of these programs have the potential of large fuel savings as well as providing improvements in the noise signature of advanced propulsion systems.

There has been little effort in the large turboprop technology program for several years and, as a result, it is not known whether advanced turboprops can provide efficient cost-effective propulsion systems as compared to our present-day large turbofans.

In the SCAR Program, the investigation of engine cycle flexibility in a variable cycle engine (VCE) is of great importance if a supersonic cruise aircraft is to be successful.

These programs should provide much needed technology for advanced propulsion systems for future transport-type aircraft.

The consolidation of NASA efforts in centers of excellence is also providing better control of basic technology efforts. The

shift of engine inlet work to the cognizance of the Lewis Research Center has resulted in better coordination and much more cost-effective work.

C. Structures and Materials Technology

The National Aeronautics and Space Administration has significant programs in the field of aircraft structures and materials which run the gamut from exploratory development through advanced development in their scope. These programs, while aimed specifically at civil aircraft, will generate technology which can have application in military systems and do not duplicate efforts currently under way in DoD.

The NASA Aircraft Energy Efficiency Program is aimed specifically at gaining flight experience on primary and secondary composite structures in order to establish confidence levels and the economic base for filamentary composite materials. This program will allow a production commitment by airframe manufacturers to incorporate these structures in future commercial aircraft. This flight experience program will seek to obtain three years of flight experience on a composite-reinforced C-130 center wing box, demonstrate a 25 percent weight savings on a vertical or horizontal tail on a commercial civil transport, and accumulate 20,000 flight hours by 1985, and also demonstrate a 30 percent weight savings on a commercial civil transport wing and accumulate 10,000 flight hours by 1985.

A program has been underway which seeks to reduce the vehicle design cycle time by 50 percent and design costs by 25 percent by 1980, through development of an automated design computer program. The Integrated Program for Aerospace Vehicle Design (IPAD) will provide the capability for more comprehensive systems analysis throughout the design and manufacturing process and make possible selection of optimum structural and other subsystems for maximizing vehicle performance and minimizing cost.

NASA is pursuing a program to apply fire-resistant materials to various parts of commercial aircraft. This program will provide the technology required to make future aircraft materials, structures, and subsystems as fire resistant as feasible and to reduce the toxicity of aircraft materials in a fire environment. In addition, the program will investigate means to inhibit the ignition of aircraft fuels in crash situations.

In a complementary program, NASA will synthesize new and improved polymers, composites, and lightweight metals for greater safety, longer lifetime, greater reliability, and improved structural efficiency for use in aircraft and to decrease flammability and fire-induced toxicity of aircraft materials.

The NASA program in the area of fatigue and fracture is aimed at understanding the behavior of both metal and composite materials in order to develop life-prediction procedures and

fracture-control technology for improved reliability and lower cost of aerospace vehicle structures and propulsion systems.

Work is also underway to extend the technology base in the field of structures by examining means of improving the safety, durability, and economy of commercial and general aviation aircraft by advancing the state-of-the-art in airframe structures through progress in the development of advanced structural concepts, analysis method for loads, aeroelasticity and structural dynamics, prediction and assessment of structural integrity, and composite structure.

Advancements in reliability and performance of US civil aircraft continue to depend on NASA-evolved structural concepts and analysis methods. The significant cost and performance benefits of composites will help to maintain the favorable balance of trade of the US commercial aircraft industry. Increased accuracy of static and dynamic response analysis through NASA-developed programs such as NASTRAN and Flexstab provide maximum safety of operation at minimum weight. Improved fatigue and fracture-prediction techniques will contribute to increased structural integrity and consequently reduce repair and maintenance costs.

NASA has three programs which are aimed at engine technology but have payoff to the airframe and structures community. One of

these programs deals with the use of new materials and includes demonstration of the feasibility of advanced composite fan blades, powder metallurgy turbine disks, and oxide-dispersion-strengthened alloy turbine vanes. The disks are to be capable of operation at increased temperatures (1400 F, 760 C) or of providing a 40 percent decrease in manufacturing cost, the vanes are expected to operate at 2000 F (1090 C) for 3,000 hours. The second program examines the aeroelasticity of turbine engines. The third program will examine other high-temperature materials which can be used in vane structures. These are worthy of appreciably increased funding because of the high payoff to both DoD and civilian industry.

The NASA helicopter structures R&D program is closely coordinated with Army by virtue of the joint co-funded programs between the AMRDL and NASA research centers. Approximately 70 percent of the Army program in fundamental research is co-funded with NASA and approximately 20 percent of exploratory development programs are co-funded.

Although the Army/NASA cooperative effort has been outstanding in this area there is a need to expand this cooperation to include development of advanced structural concepts equally applicable to military and civil helicopters. Advanced composite components for these aircraft can offer highly effective, low-cost

structures for the mutual benefit of the military and civil sectors. Cooperative advanced development programs are being planned at the present time for implementation in the FY 1979 time frame which need proper DoD-NASA joint funding in order to be accomplished.

D. Avionics and Flight Support Systems

The NASA program for avionics and flight support systems technology is primarily focused at demonstrating the practicability of new technical concepts and components developed in earlier NASA R&T base programs, and civil application related technology products of DoD and industrial independent research and development (IR&D) programs. In these demonstrations, the utility of new avionics components and concepts are evaluated in a systems, or operational, context. Examples are the energy efficient aircraft, VTOL all-weather terminal area, and digital electronic flight control demonstration programs. Through these demonstrations of technical feasibility, complemented by economic benefit analyses, NASA hopes to provide lower cost and higher performance options which will influence the future development directions of the commercial, and general aviation industries.

In addition to the systems demonstrators, the NASA R&T program in avionics includes investigations of new and promising innovative technologies, such as fault tolerant computer design concepts, microstrip (flush mounted) antennas, and map displays for cockpit navigation. These investigations constitute about 15 percent of the avionics R&T effort. An equally important aspect of the NASA investment strategy which must continue to be

emphasized is to build an understanding of the impact of the new technology on flight safety, system certifiability and energy efficient operations.

In our judgment, the NASA program in avionics and flight support systems is well formulated and directed toward the important areas requiring government investment. The current NASA funding (approximately \$24M in FY 1977) is marginally adequate to achieve the established objectives which are ambitious but necessary to ensure continued U. S. technological leadership in civil aviation avionics. The exploration of new technology has been relegated to a second priority relative to the near term objective of demonstrating the value of currently available technology.

Given the programmed NASA funding, we believe this management direction is justified, although we are concerned that the impact of deferring some new starts on innovative higher risk advancements may lead to some technology weakness in the longer range. However, these concerns emphasize the need for continuing the current trend of Defense and industrial research in avionics technology.

Areas we feel need continued support in the NASA program are active flight controls for energy efficient aircraft operations and ride control, cockpit displays technology for human factors issues impacting pilot approach, aircraft systems management, and "sphere of

influence" alerting (such as collision avoidance). Because of the overriding importance of flight safety, issues of redundancy and reliability are critical factors in the NASA demonstrations, and should provide an important data base for future Civil Aeronautics Board and industrial development decisions.

III. EVALUATION OF NATIONAL RESEARCH AND TECHNOLOGY BASE IN AERONAUTICS

As noted by Dr. Currie when he appeared before this Committee during the hearings on "The Future of Aviation," the DoD R&D effort in aeronautics is the largest single concentration in the United States so any evaluation of the national effort must start here.

In terms of constant dollars, the DoD Aeronautics R&T base funding has been in decline from FY 1970 through FY 1975. In FY 1976 it held steady, in FY 1977 we expect some small real growth, and in FY 1978 we project significant real growth in our budget request to the Congress. This turnaround is in accord with the policy laid down by Dr. Currie which stressed strengthening the technology base in all areas of importance for military application.

Beyond the funding for the technology base, we must judge its health on the quality of its output in support of our needs. By this measure I have to summarize the aeronautics technology base as healthy. We are in the midst of a major reequipment program which is producing new fighter, attack, bomber, and tactical transport fixed wing aircraft, new attack and utility rotary wing aircraft, and improved Vertical Takeoff and Landing aircraft. These designs incorporate major innovations that are products of our national technology base effort.

To cite a few examples of innovation resulting from DoD technology efforts:

- The new generation of fighters F-14, F-15, F-16, F-18, and our new strategic bomber B-1, all include components fabricated from advanced composite materials. These components were always lighter weight and they are becoming less costly as we master new manufacturing techniques.
- The Air Force Air Combat Fighter, F-16, is controlled by an analog electrical flight control system which offers improved survivability and control flexibility.
- The low-altitude penetration capability of the B-1 is made possible by a ride-control system demonstrated earlier on a B-52 test bed.
- Our new generation of rotary wing aircraft benefit from advances in elastomeric bearings and vibration reduction systems which reduce maintenance requirements.
- The AH-1 helicopter will be fitted with a composite materials rotor blade which will greatly increase blade life as well as improve survivability through reduced Radar Cross Section characteristics.

- The new T700 engine for use in the Utility Tactical Transport Aircraft System (UTTAS) and the Advanced Attack Helicopter (AAH) will permit better fuel utilization in the part power regime where a helicopter spends most of its time as well as greater reliability and maintainability of the system.

Aside from the DoD and NASA, industrially sponsored technology base activity is the third major portion of the national effort in aeronautics. By either measure of constant or actual dollars, this part of our national R&T base has been in a period of steady decline since 1969. This is undoubtedly traceable to the equally steady decline in aerospace sales and profits and employment of engineers and scientists which has occurred since the recent peak year of 1968. All these factors have impacted the resources available for industry to support independent research and development (IR&D).

Although the industry IR&D program appears to be quite large, the major portion of the effort is actually devoted to development programs and not technology efforts.

In terms of specific technical contributions, the industrial effort has been less pronounced in its impact on our military aeronautics. However, there are some key examples of note:

- The production Advanced Attack Helicopter will employ an infra-red signature suppression device resulting from company-sponsored programs.
- The B-1 and F-16 aircraft are blended wing-body designs that are largely the result of internal company-sponsored development of aeronautics technology.
- The prototype YC-14 contains a digital electrical flight control system developed by Boeing and its subcontractors although its lineage may be traced to some government-sponsored efforts on the US supersonic transport.
- Future tactical fighters may draw heavily on industrially sponsored efforts now in progress.

The industrial R&T base effort is a strong function of the level of business and profits. Both of these have trended downward since 1968 for the aerospace industry. We hope and intend that renewed emphasis on contracted R&T on the part of the DoD will have a positive influence on the magnitude of industrial funding.

A. Aeronautical Vehicle Technology.

This area includes aerodynamics, flight control, dynamics, subsystems, and ground support equipment that is directly associated with the air vehicle.

For future needs in tactical aircraft, the DoD is pursuing a major technology base activity in the Advanced Fighter Technology Integration (AFTI) program managed by the Air Force with selective joint participation by the Navy. This program encompasses technology development and demonstration for digital electronic flight control, active flutter suppression, engine nozzle and airframe integration, automatic airfoil shape control and integrated fire control. The Navy is supporting the AFTI digital electronic flight control project in order to maximize technology transfer for future Vertical and Short Takeoff and Landing (V/STOL) needs. The AFTI program is complemented by the NASA sponsored HIMAT program discussed earlier in Section II.

With the increased efficiency of precision guided munitions, we no longer need to carry so many weapons on each mission. We are able to seriously consider weapons which will be more carefully integrated with the aerodynamic configuration of our tactical aircraft. Such weapon shaping is in the early stage of shape and performance development.

V/STOL tactical and special purpose aircraft are of increasing interest to the Navy and Marines. For several years we have employed the X-22 Ducted Fan Demonstrator to explore V/STOL control criteria and procedures and we expect this aircraft to continue to support V/STOL R&T for several years. Most

recently it was used to simulate the flight characteristics expected of the XFV-12A Thrust Augmented Wing (TAW) technology demonstrator which is nearing its first flight. We are exploring other options for V/STOL capability such as the X-wing program which is sponsored jointly by the Navy and Defense Advanced Research Projects Agency (DARPA). This stopped-rotor vehicle will have helicopter-like Vertical Takeoff and Landing (VTOL) capability with high subsonic fixed wing performance. Navy technology for a lift-cruise fan VSTOL aircraft was developed in a joint configuration and experimentation program with NASA.

We rely heavily on NASA for R&T in support of our future transport, cargo, and patrol aircraft. However we are pursuing selected technologies such as ground effects phenomena mentioned in our statement to this subcommittee's hearings on "The Future of Aviation." We are continuing our theoretical and experimental investigations and we are planning for a future subscale demonstration vehicle.

A DoD unique requirement exists for over-the-shore supply in support of amphibious operations. We are developing technology for a hybrid vehicle combining bouyant lift with rotary wing lift for very low speed heavy lift capability.

DoD development of helicopter technology continues on a

broad front. Army experiments conducted in the NASA Ames water tunnel and 7 x 10 foot wind tunnel have demonstrated the true role of boundary layer flow separation in causing dynamic stall of rotary wings. These results have aided progress toward development of analytical methods for improving helicopter airfoil section characteristics. In the first operational use of the universal helicopter Rotor-Test Apparatus (RTA) developed jointly by Army and NASA, we completed initial full-scale wind tunnel tests of a Controllable Twist Rotor (CTR). The CTR has demonstrated improved stall boundary with rapid increase in power. The Navy has developed a hub pylon fairing design which demonstrated a 25 percent reduction in drag in wind tunnel tests. Navy development of the Circulation Control Rotor (CCR) technology demonstration aircraft passed a significant milestone with successful completion of the final design review; detail design and fabrication are proceeding. The Army is nearing successful completion of conventional rotor borne flight test of the Advancing Blade Concept (ABC) helicopter. Detailed program planning is underway for continuation of ABC testing in the compound flight mode with support of the Navy, Air Force and NASA. The ABC demonstrator has exhibited notable improvements in rotor efficiency and control.

DoD technology efforts directed toward high performance fixed wing and rotary wing aircraft have caused considerable

in impact on the need for additional effort in missile aerodynamics to solve new problems brought on by aircraft advancements. Additional DoD effort is being applied to missile aerodynamics in severe launch environments caused by rotary wing downwash and in maneuver requirement for air defense missiles designed to defeat high performance fixed wing aircraft. The three technology areas receiving renewed emphasis are flow field computational methods for missile launch and transonic flight, rocket plume interaction effects and configurations for maneuvering missiles. As a result of this emphasis, analytical flow field production techniques and jet plume effects on missile aerodynamics can now be modelled. The efforts have also identified model deficiencies for missile bodies at high angles of attack. Prediction models are now being updated so that new aerodynamic designs can meet a high performance air threat and better improve our overall military posture.

Industry Independent Research and Development (IR&D) programs related to government contracts and reviewed by government experts for relevance to government objectives prior to initiation reflect the overall aeronautics R&T distributions of industry. Out of a total of 50 contractors having IR&D programs in the aeronautical vehicle area, the top 10 perform over 75 percent of the work. Those contractors whose work is predominately aerospace have efforts in all technical domains and generally

follow the DoD emphasis. Non-aerospace contractors, on the other hand, tend to concentrate their efforts in a particular domain.

Most of the industry effort is directed toward new technological advances oriented toward product lines or toward engineering and manufacturing developments that will provide an improved cost position. Since these aerospace products (aircraft) are generally consistent with DoD needs, they directly strengthen and reinforce the DoD programs. On the other hand, a substantial portion of the contractors' IR&D effort is devoted to entering a new field or becoming more competitive with already established leaders so that limited new technology results. Table 1 presents the most recent available summary of IR&D levels of effort for areas of interest in aeronautical vehicle technology.

B. Propulsion Technology

The health of the national effort in propulsion technology can be classified as good in that the three major efforts, DoD, NASA and industry-sponsored, are well coordinated and complement each other. The NASA program is covering the advanced long-range subsonic transport propulsion system technology as well as the supersonic cruise type propulsion systems.

DoD efforts are continuing to improve the R&T base in aircraft turbine propulsion systems for high performance combat

TABLE 1
INDUSTRIAL IR&D IN AERONAUTICAL VEHICLE TECHNOLOGY
(CY 1975 - ACTUAL) (\$ IN MILLIONS TO NEAREST 0.1M)

	Flight Controls	Vehicle Dynamics	Vehicle Subsystems	Flight Mechanics	Vehicle Support	Total	Percent
1. Boeing						26.7	
2. McDonnell-Douglas						14.3	
3. United Technologies						10.7	
4. Lockheed						8.9	
5. Rockwell						8.3	
6. Textron						6.7	
7. Vought		*				6.4	
8. Grumman						4.4	
9. Northrop						3.6	
10. General Electric						3.4	
11. Bendix						2.8	
12. Sperry Rand		*	*			2.6	
13. General Dynamics						2.5	
14. Honeywell		*		*		2.4	
15. Hughes Aircraft		*		*		2.0	
16. Singer		*	*	*		2.0	
17. Garrett						1.9	
18. General Motors		*		*		1.4	
19. Litton		*		*		1.2	
20. Lear Siegler		*		*		1.2	
Sub-Total	41.1	12.5	11.7	48.1	Small	113.5	93
Remaining Firms (30)	5.5	0.4	1.3	1.6		8.8	7
Total	46.6	12.9	13.0	49.7		122.3	
Percent	38	10	11	41			100

*No activity in these areas

type aircraft, V/STOL aircraft and helicopters. The three basic programs which form the heart of the large turbine engine technology program are: (1) the Advanced Turbine Engine Gas Generator (ATEGG) program which evaluates advanced turbine engine technologies by testing turbine engine gas generators fabricated from advanced components where feasibility has been demonstrated in exploratory development; (2) the Advanced Propulsion Subsystem Integration (APSI) program which includes the development of advanced components such as inlets, fans, power turbines, augmentors, controls and exhaust nozzles and integrates them with the ATEGG program and (3) Joint Technology Demonstrator Engine (JTDE) program in which advanced components developed in Navy programs are integrated with ATEGG hardware for a joint Air Force/Navy demonstrator. As the Navy is emphasizing V/STOL operation from smaller ships, the Navy program is oriented toward providing advanced components for possible V/STOL propulsion systems.

A major concern to the DoD is the rising costs of propulsion systems. Emphasis is being placed on lower production costs as well as reduced life-cycle costs through increased engine durability and improved maintainability. Advanced components are being designed and fabricated to demonstrate technologies which will reduce the acquisition costs of future turbine engines.

With the increased requirements for small gas turbines for use in small remotely piloted vehicles, helicopters, targets and cruise missiles, additional emphasis is being placed on small engine technology programs. The Army is presently initiating a competitive demonstrator engine program in the 800 shaft horsepower class to demonstrate the latest small engine component technology in a complete engine. The Navy and the Air Force will continue to supplement the small engine technology program of the Army in areas where they have unique requirements.

Fuel Availability

The alternate fuels program is part of a long term coordinated effort with the Military Services, NASA, and ERDA to assure that acceptable aviation jet fuel will be obtainable at minimum cost from domestic sources such as oil shale, tar sands and coal. The next phase of the program will be to refine in a commercial refinery, 100,000 barrels of shale crude into military specification fuels. Problems of production and refining will be analyzed. Joint agency testing will investigate medical, chemical and material interactions, storage and handling questions, etc. The overall program will be managed by the Navy with the support of the Army and Air Force.

The total national research and development program for aircraft propulsion in FY 1976 was approximately \$500M. The IR&D portion totalled 43 percent of this and was split about 15 percent from DoD and 28 percent from commercial customers.

The Independent Research and Development (IR&D) programs of the major aircraft propulsion system manufacturers collectively represent more than 40 percent of the total national effort in aircraft propulsion research and development. The program is manufacturer performed, product oriented research and development encompassing basic and applied research, concept formulation and feasibility studies, and product development and improvement. These programs can either be associated with potential military applications or can be directed towards needs of commercial customers. The major dollar value of this program is usually directed towards the short-term development of new or improved commercial products rather than towards the long-term efforts to improve the basic state-of-the-art in propulsion systems.

1976 expenditures on industrial IR&D in direct support of ramjet propulsion for missiles totaled \$825K. The industrial program in this field for 1977 is expected to grow to approximately \$1.0M. The work in progress is focused upon component development--especially air inlet, combustor, and combustion chamber

insulation designs and materials--and upon possible improvements in the stability and efficiency of combustion in solid fueled ramjets. Important progress has also been made in defining and demonstrating air inlet designs and fabrication methods that are inherently much less expensive than those conventionally used.

In the past we have had a healthy R&T base effort that was well supported and permitted the development of advanced aircraft. We must continue to support this R&T base work in order to have efficient advanced propulsion systems for future aircraft.

In the DoD we have made a policy decision to increase the outside contract R&T base efforts as compared to in-house laboratory efforts. It is hoped that this will assist us in increasing our broad base technology efforts.

C. Structures and Materials Technology

This area includes both structural and non-structural materials development and a broad range of structures technology areas such as loads and environments, analyses and design, materials application, fabrication technology, test and evaluation, and cost-trade analyses. The structures and materials are limiting technologies in many DoD mission areas especially aircraft and missiles. Fortunately, they both have civilian sector parallels which permit the DoD to share financial support with other agencies such as NASA. In this way, the DoD can concentrate

its main efforts in areas specific to military needs while contributing to overall national R&T base.

The general requirements for structural materials include increased usable efficiency (primarily specific strength and moduli and higher fatigue strength), improved structural integrity, minimum vulnerability to battle damage from conventional and nuclear weapons, and maximum crash survivability. The structural materials being investigated include aluminum, steel, titanium, and organic-matrix and metal-matrix composites, and the needs encompass improved processing techniques to increase product quality and reduce cost.

The most promising concepts for achieving significant weight and size reductions in aircraft structures are those involving the application of high-performance organic and metal matrix composite materials. Used effectively, composites can result in structural weight savings as high as 50 percent which, in turn, can be used to increase payload or performance.

The extensive exploratory and advanced development efforts on advanced composite materials technology conducted over the past decade or more have had significant payoff in several major systems development and production programs. Boron/epoxy composites are incorporated into the structures of production

aircraft, resulting in significant cost and weight savings [20 percent cost, 20 percent weight savings in the F-14 horizontal stabilizer, four percent (\$4K) cost and 20 percent (366 lb) weight savings in the F-15 vertical and horizontal stabilizers]. Graphite/epoxy structures have been included in the YF-16 and YF-17 Air Combat Fighter prototypes (eight and ten percent weight savings, respectively, in the YF-16 horizontal and vertical stabilizers, and ten percent weight savings in the YF-17 secondary structure). The DoD presently has well over 1,000 components in service and the projections are for thousands more to be installed on military aircraft over the next few years. A very recent decision was made to utilize advanced composite materials in the horizontal stabilizers of the B-1 aircraft. This is a major milestone in that these are the largest load carrying components accepted for use in a major aircraft system. The Navy is also moving boldly ahead with the extensive use of composite materials in the Harrier AV-8B and F-18 aircraft.

The Army is projecting that significant advantages can be realized by fitting the helicopter fleet with composite rotor blades. Composite rotor blades for the AH-1 helicopter which show an approximate seven percent increase in performance and improvements in RCS reduction and survivability are planned for production early this year. The Army's UTTAS helicopter has an all-

composite main rotor blade with a titanium spar as well as a flex beam composite tail rotor. The CH-47 fan tandem helicopter modification program includes component blades that have significantly increased performance and survivability.

Over the past 10 to 15 years, the DoD has spent well over \$300M for the development of advanced composite materials for aircraft and missile applications. When this is added to the NASA investment in this area and that of private industry through IR&D and internal funds, a national investment of somewhere between one-half and one billion dollars has been made.

The IR&D programs of the major aeronautical contractors constitute a significant addition to the regularly funded Service and NASA programs in structures and materials. Work in excess of \$40M annually is being done on airframe and gas turbine materials and processes for their manufacture and inspection.

The funds being expended by the aerospace industry for IR&D cut across the entire spectrum of aircraft structures and structural development.

The largest number of IR&D efforts are aimed at developing computer programs and subroutines capable of doing design and analysis of aircraft structures.

These programs provide the computational tools to reduce the manpower and computational time requirements and they run the gamut of application from preliminary to detail design. In general, these computer programs are aimed specifically at the contractor's own internal programs, although there is some attempt to modify existing Air Force and NASA programs for internal use. These programs do have broad applicability to areas other than aircraft structures. They can be used in the design of all types of structures, both civilian and military.

The second area of IR&D work is in the field of fracture mechanics and fatigue analysis.

The programs are typified by efforts to solve material, tooling, and processing problems associated with fabricating complex, minimum gage, dimensionally stable parts from graphite/epoxy. In addition, these programs seek to determine the physical and mechanical properties of graphite/epoxy systems, high-temperature graphite thermoplastic systems, and high-temperature graphite/polyimide systems. Finally, these programs seek to reduce the costs of manufacturing graphite composite components in order to realize a wider usage in the fabrication of aerospace hardware.

The last of the major areas being pursued under IR&D is that of loads determination. These efforts are characterized by

programs in which aircraft loads and gust velocities are measured simultaneously during flight through turbulence.

D. Avionics and Flight Support Systems

The explosion in electronics continues to have major impacts in the field of avionics and flight support systems. The DoD R&T base program is stressing the evaluation of new electronic "building blocks" in conventional as well as new avionics roles. Navigation, flight control systems and flight computer development activities such as ring laser gyro and fiber optics are stressing low cost and improved reliability. In many cases, increases in performance are additionally possible, such as with airborne communications systems and electronic active flight controls (fly-by-wire control). New avionics roles include adaptive engine control, continuous equipment monitoring and test, and fault tolerant capabilities.

The nature of avionics systems in defense applications is also changing in revolutionary ways, providing system integration, flexibility, and automated flight systems management.

We are now at a major turning point in avionics architectures. The most recent aircraft avionics systems have stressed integration of functions in central computers. The emergence of microprocessors, computers on a "chip," are providing the motivation for distributed information processing using data buses to interconnect

distributed avionics, flight control, and weapons control components. More sophisticated network management concepts are required for control of these new distributed system architectures, but the major advances in multiplexing, fiber optics, and microprocessors are promising significant gains in flexibility, performance, interoperability, and system reliability as well as cost reduction in spite of the increases in sophistication.

A second associated revolutionary change is dawning in the avionics area involving cockpit display and aircraft systems management. Using the new avionics computers much of the mundane monitoring of aircraft gauges and instruments has been automated, with alerts in the form of computer printed messages presented to pilots on new displays. In addition to these new flight system monitoring innovations, new computer driven display technology such as "heads up" displays, horizontal (map) situation displays and vertical (landing or attack profiles) situation displays are entering our new fighter and attack aircraft. All these innovations offer the promise of revolutionary changes to the commercial and general aviation of the future. Cost is the most significant current commercial barrier, but the avionics capability of commercial aviation aircraft continues to increase as new opportunities are proven and new regulations dictate.

The avionics industry is highly competitive, not only within the U.S., but the entire industrialized world. The major customer continues to be the combined defense ministries, but commercial applications are growing rapidly. American advanced technological know-how is highly valued by our non-domestic competitors, and licensing agreements are widely cultivated. Foreign governments continue to invest heavily in this area in efforts, frequently successful, to capture for their industries, specific parts of the avionics market place.

The domestic avionics industry also invests heavily in R&D, with the major thrust directed at product improvements and new product ventures, such as strap down inertial, Omega or very low frequency navigators, and collision avoidance equipment. Corporate R&D investment is limited in innovative, high-risk technology and in systems development, such as advanced microwave landing systems, probably because of uncertainty about acceptability and certifiability. These two areas required continued government funding.

In perspective, the health of the U.S. avionics technology base and industry is good. Applications are maturing and corporate product advancements emphasize cost reduction, increased reliability, slightly improved performance, and increased flexibility

with functional integration. The defense market is the largest with commercial and general aviation markets continuing to attract a larger share.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. National Aeronautical Facilities Program. The Congress has taken a major step toward assuring that the future aeronautical needs of the nation will be met by providing full funding for the Air Force Aeropropulsion Systems Test Facility and initial incremental funding for the NASA National Transonic Facility and the 40 x 80 foot Subsonic Tunnel Modification. However, further appropriations will be needed this year for the NASA facilities in order to fully implement the National Aeronautical Facilities Program. I strongly urge you to approve the NASA FY 1978 funding request for these two facilities.

B. Impact of DoD Reequipment Program. It is important to note that several military aircraft are still in engineering development. During this crucial period, we frequently call on NASA for analysis and sometimes test support to resolve aeronautics problems as they occur. This assistance, which is within the proper charter of NASA, nevertheless reduces NASA resources available for normal R&T base activity. We expect this major reequipment phase to continue for some years.

C. Impact of NASA Shifts in Emphasis. Some internal shifts in R&T base responsibilities among the NASA centers have resulted in deemphasis of some key aerodynamic areas of importance to the DoD.

This has been the case for NASA work in buffet, transonic flow separation, and aeroelastic coupling which was formerly the responsibility of the Ames Research Center. Variable camber aerodynamics research has also suffered since a shift in responsibility from the Langley Research Center. I should note here that a shift in assignment of engine inlet work to the Lewis Research Center has resulted in an increase in this effort which is important for DoD needs.

D. Need for Rotary Wing Structures R&T Base. We are concerned that institution of the Energy Efficiency Program has heavily influenced NASA's composite structures program toward transport aircraft applications. We should not lose sight of the importance of rotary wing aircraft and the strong leverage of composites for weight savings and cost reduction here. We think that the NASA composite structures program should include greater consideration of rotary wing applications.

E. Need for Rotary Wing Aerodynamics R&T Base. We believe that NASA should strengthen its R and T base effort in rotary wing aeronautics technology generally. We hope that successful flight test of the Rotor Systems Research Aircraft and designation of the Ames Research Center as lead for helicopter technology will have this effect in the long term. This program should be augmented by establishment of a separate Research and Technology Council (RTAC) exclusively

devoted to rotary wing.

F. Importance of Aircraft Energy Efficiency Program. A significant amount of the increase requested for NASA aeronautics R&T base is attributable to the acceleration of the Aircraft Energy Efficiency program. We continue our coordinated effort with NASA in support of this program. All our future fixed wing military aircraft will benefit from the Engine Component Improvement and Composite Primary Structures elements of this program. Our future transport, cargo, and patrol aircraft can benefit from other elements of the program that emphasize improved cruise efficiency. NASA's new FY 1978 initiative in advanced prop-fan propulsion is especially important to us and it could be accelerated. Greater emphasis on metal-matrix composites for this application is warranted. The prop-fan development gives us an important option in the propulsion systems for long-range patrol and transport aircraft.

G. Importance of Reduced Engine Noise and Emissions. Although the principle benefit from reduction of aircraft engine noise and emissions lies in the civil sector, the Military Services desire to be good neighbors and stand to benefit from the NASA efforts in this area. We endorse the continued emphasis in NASA's program in this area.

H. Need for Young Talent. We agree with those who have expressed concern about the increasing average age of the NASA research staff. We believe that NASA needs to implement a stronger program to attract

new graduates to obtain a better balance in its staff for the long-range health of the technology. Our analysis of engineering enrollments indicates that sufficient talent is available for our national aeronautics needs, hence an imposed manpower ceiling, and not the availability of young talent, is causing staff average-age levels to increase.

I. Importance of NASA Innovation. The entire NASA aeronautics program in propulsion, aerodynamics, materials, computational aerodynamics, etc., which are too numerous to list, is really the seed bed for our nation's aeronautical R&T base effort. It is from this large pool of R&T base efforts that future applications will come.

We detect an increasing tendency for NASA to depend heavily on programmatic justification for efforts in the R&T base. The DoD and industry are strongly influenced by program relevance considerations leaving only NASA and the universities as agents of innovative research and experimentation. Therefore, we believe that it is especially important for NASA to be permitted a greater degree of freedom in the aeronautics technology base.

J. Health of NASA Aeronautics R&T Base. Overall, we believe that the health of the NASA aeronautics R&T base is good and we are pleased to see increased FY 1978 funding proposed to help maintain this base. NASA technology has made significant contributions to our new generation of aircraft. To note a few:

- Both Air Force and Navy Air Combat Fighters gain improved maneuver performance from vortex lift enhancement derived from NASA efforts.
- Both prototype Advanced Medium STOL Transport (AMST) configurations are based on powered lift and advanced airfoil technology developed by NASA.
- The B-1 is our most recent application of the variable sweep wing which resulted from NASA efforts.
- The F-15 configuration benefited strongly from NASA configuration development in engine and airframe integration and high angle of attack aerodynamics.

The NASA FY 1977 appropriation for aeronautics R&T base was the first for some time which could be considered to keep even with inflation. We appreciate that reversal of a downward trend. The NASA FY 1978 proposed budget will represent the first real growth in aeronautics for NASA in many years. I urge you to approve this NASA budget request.

Mr. MILFORD. Our next witness is Dr. Arthur Bryson, Department of Aeronautics and Astronautics of the Stanford University.

Dr. Bryson, welcome to the committee.

We have your formal statement which we accept for the record at this time and you may either read it or proceed informally whichever you like.

STATEMENT OF DR. ARTHUR BRYSON, DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS, STANFORD UNIVERSITY

Dr. BRYSON. If I may, sir, I would like to paraphrase it as I go along.

First I would like to state that the reason I was invited to testify is because of my chairmanship of the Aeronautics and Space Engineering Board in the National Research Council, but I do not represent them today. The statement I am making is my own. I have had the benefit of some criticism from the board members, but not by any means all of them.

I thought of several things that I could say and I thought that one thing you may not have heard as much as you perhaps should is the concern that the university community has concerning the R. & T. base in NASA. My message here is primarily concerned with the people, the research people at NASA as I see them from my viewpoint which is necessarily limited.

I believe there are some serious problems developing here. I do not think they are serious yet, but I think that they could become serious if we do not do something about it.

I think you will all recall that the NACA, the predecessor of NASA, was without a doubt regarded as the most eminent aeronautical research establishment in the world. When we transformed it into NASA in 1958-59, it was divided into three offices—the Office of Manned Space Flight, the Office of Space Sciences and Applications, and the Office of Advanced Research and Technology.

The Office of Manned Space Flight and the Office of Space Science and Applications took some of NACA's best people as a nucleus and began what I considered to be very successful large contract managing organizations. All of us know that their performance was outstanding and culminated in the manned landings on the moon in 1969 and just recently the unmanned Mars landings in 1976.

The remaining NACA people went into OART, whose name was changed a few years ago to OAST, and about 60 percent of these people were redirected into space research and technology development while the other 40 percent continued on aeronautical research and technology development.

OART hired additional personnel for their space research and technology development, which roughly doubled the number of people in that category, but very few new people were hired to work in aeronautical research and technology.

As one example, the NASA Lewis Research Center completely dropped aeronautical propulsion research and technology development from 1959 to 1966. Putting together figures that I got from talking to people at NASA and reading Aviation Week, which of course is the source of most information, I estimate that the number of NASA

engineers and scientists who are working on aeronautical research and technology development dropped from a level of about 5,000 people in the 1945 to 1955 period, to about 1,500 in 1960. In the middle 1960's, the research and technology development for the Apollo program began to taper off as it began to go into hardware and operations, and some of these people were redirected back into aeronautical work while many others were laid off.

Putting all these things together, I estimate that the number of people in OAST who are working on aeronautical research and technology development is about 20 percent less now than it was in 1955. Furthermore a significant fraction of these people—NASA estimates between 5 and 10 percent—are primarily engaged in monitoring contracts to the aerospace industry. In addition, there is pressure within NASA to direct your research and technology development to support these contracts.

NACA's research had a great deal to do with the preeminence of U.S. aviation. The jet bombers and the commercial jet transports of the late 1950's came as a result of the research and technology development during the war and in the decade just after the war before NASA was formed.

There is a lot of disagreement on my next statement, but I think that our failure to develop a viable V/STOL aircraft until just recently—and I am not sure that they are even viable yet—and an economically successful supersonic transport is closely related to the fact that NASA decreased its aeronautical R. & T. D. in this period.

We have been living off the aeronautical research and technology development done in the 1950's and the R. & T. base now is severely eroded. NASA and industry in my opinion need to invest in new facilities and particularly in new young engineers and scientists to build up the technological base in aeronautics in this country.

What is more difficult is this needs to be done with little promise of early results as it takes a long time to reinvigorate an important technical area like this.

I do not mean to indicate that the research and technology development going on in NASA has gone to zero or that our technology base has gone to zero. I am just saying that it is declining and I am worried, and I think that all of us should be worried and should do something about it. I am not sure that I know what to do, but I have tried to indicate a couple of ideas, and that is all they are. I think it is very important that NASA's manpower limitations be somehow bent or changed and I do not know whether this comes from the Congress or the executive branch. If it comes from the executive branch, perhaps the Congress can lean on the executive branch, but the manpower limitation has been a very serious factor in this development in my opinion. Being at Stanford, we are close to the NASA Ames Research Center, so I get some very first hand indications of what is going on in that respect.

My feeling is that NASA really should have 100 new young people every year. These should be the top young people coming out of the universities in the Ph. D. and masters programs in aeronautics and the related areas. They have been hiring a few. They can as people retire, but this is at least in my observation, nowhere near enough, and I think the longer it is delayed the more serious it would be.

When I was just beginning my aeronautical career, I seriously considered going to NACA and almost did, although I did not at that time. At that time there was a very exciting atmosphere in NACA of talented people working together on interesting research problems. There is still some of that in NASA, but I think there is a morale problem, at least I detect one in talking with people in the laboratories. They see the system changing to one in which you get greater rewards for going into contract and program management. Whether it is real or not, it is perceived that way in certain areas of NASA.

Another reason for not waiting too long is that some of NASA's top aeronautical people are going to be retiring in the 1980's and it would certainly be advantageous to have them be the core of this reinvigorated atmosphere and have them pass on their know-how to the new younger personnel.

Of course, what I am talking about here is the R. & T. base. I am not talking about the systems studies, the system technology programs or the experimental programs. I am not denigrating those at all. I think they are important and worthwhile. I think the vastness of this enterprise is such that the Government has to be an important part of helping industry develop this new technology, but the new ideas, the innovations, the things that are going to be important 15, 20 years from now, come from having some very bright and excited young people working with some of the masters in the research areas in which they are allowed to come up and try some things that are higher risk, have a longer term pay-off, where they are free to fail a few times, but hopefully come up with some successes. The difference here is in time scale and in the predictability of results. For almost 10 or 20 years now, NASA has been pursuing what I perceive as short range development goals in aeronautics whose outcomes were fairly predictable and acceptable to the Office of Management and Budget and to the Congress. I think they have been using up this stored investment and at least in the centers there is a perception that what is going on, that the environment in OAST is being replaced by a contract monitoring environment with narrowly defined short-term goals and strong hardware associations. The internal research programs fall under a subordinate or supporting role to these external contracts.

As I said before the reward system is such the talent migrates to the program management and contract monitoring.

Now it happens, as Jim Kramer mentioned this morning in his testimony, that NASA has asked our board, the Aeronautics and Space Engineering Board of the National Research Council to form a subcommittee to assess precisely this question of the aeronautics research and technology program within NASA. In fact the first meeting of this subcommittee will be on Friday of this week. I will have a more informed opinion of course when this study is completed. But since I was asked to give an opinion now I give it to you as it appears to me now, but it may have some factual errors in it. It is my perception.

My current opinion is that the top researchers in NASA and in the universities should be allowed to generate more of their own kinds of projects, long-term, high-risk projects. When I say top researchers, I mean the men who have already proven that they have been able to generate some good ideas. It is hard to pick them until they do this. It is very difficult, but when you do find some young people in NASA and the universities who have shown a capability to do this, I think

we ought to be able to give them a little bit more of a *carte blanche* to work on the problems that they think will be important in the future.

As examples in the past, I am sure you have heard these many times, Dick Whitcomb's area rule for the "Coke-bottle" fuselage. This is not something that someone up in headquarters directed him to develop. This is an idea that came into his head as he was thinking about the problems of minimizing the drag of supersonic airplanes. The same thing with his other two great discoveries—the super critical wing and, just recently, his winglets for cutting down the drag due to lift.

I think of R. T. Jones out at the NASA Ames Research Center who dreamt up the swept-back wing in 1943 during World War II, and who recently has been talking about an oblique wing. You take the wing and put it on a pivot and move it sideways. NASA is following this up, rather slowly, I think, but they are following it up.

I think also of John Evvard at the NASA Lewis Laboratory, now retired, who developed a theory for supersonic flow past subsonic edges on wings. This was a very important step in our understanding of supersonic flow. I think of Harvey Allen's brilliant discovery of the fact that entry bodies should not have needle sharp noses; instead they should have blunt noses, so that they dissipate more energy in the strong bow shock wave.

These are the kinds of things you cannot direct from above. These come from brilliant ideas of researchers who are working hard on the problems. They have to be made aware of what people perceive as the problems ahead so that they can work in a general area, but they have to be left some latitude to work on what may seem like funny ideas. Some may turn out to be funny, but others will turn out to be brilliant.

I do not know how you do this. I have a couple of ideas, and one of them is kind of a NASA Fellows program. You may have heard of the IBM Fellows program. A young man in IBM who has made several contributions in the way of research, is given a higher salary and the title of Fellow. He is allowed to be somewhat of a roving researcher to work on things that interest him and that he sees as important to the company.

I would put Whitcomb and Jones in that category. They practically have that status now in NASA and I would like to see some young people coming along who might develop into the Whitcombs or the R. T. Joneses of the future.

Another approach to this would be what I call the Bell Laboratories approach, and I am not sure that this can be done anywhere else but Bell Labs. They bring in young people every year, and they pick the top young people in the country. They bring them in and they work there on exciting research projects with top people in Bell Labs. After 10 or 15 years there is a migration out into Western Electric and into other branches of A.T. & T. It is true that research is somewhat of a young man's game although less so, I think, in engineering than perhaps in science, and there should be a mechanism by which we can move people through in this way. Maybe even find a way to move people to other agencies of the Government where their talents can be used. That is a delicate kind of a thing to do, but the lifeblood of a research organization is to have an influx of young blood coming through and moving on. Perhaps this is why the university environment is fairly successful in that regard. We have the graduate stu-

dents come in and 4 or 5 years later they leave us and go into industry. We keep this young blood streaming through and presumably there are a few of us teaching who can inspire them to work on interesting problems, but they come up with the ideas many times themselves.

Another approach would be to set up what I would call technological focal points or centers of excellence at the OAST centers, Langley Lewis, Ames, and JPL, which would bring together some of these proven top researchers in various disciplines as distinct from programs, and talented young people to work with them on a basis somewhat similar to the professor-graduate student situation although these would be postgraduate fellows.

In summary I commend your attention to the fact that the NASA staff is getting older every year, and too few topnotch young people are being hired.

Second, that we need to renew the exciting climate that we had in NACA and in NASA in the space work. We need to get this into aeronautics work—an atmosphere of exciting research, high quality research, and technology development where you can take longer range looks and higher risk types of projects and programs.

Thank you.

Mr. MILFORD. Thank you, Dr. Bryson. Your testimony was very enlightening, in fact some parts of it might be stolen from some of my speeches. I find your suggestion of 100 new scientists per year to be really intriguing and something that we should find an answer to. I completely agree with you. We have got some mighty fine folks in NASA, but they are getting along in age and they themselves recognize the need for new blood on a continuing basis.

We are frustrated in trying to find an answer for it, since we must also live with civil service regulations, I wonder if some system could be worked out where the type of young scientists that you are talking about could be funded through university systems as opposed to having them become Government employees, as they would have to be if they were going into NASA.

Dr. BRYSON. That is an interesting thought, Mr. Chairman, I think one that could possibly be worked out.

There is a system now, as you know, of postdoctoral fellowships set up through the National Research Council which is not too attractive to American citizens because the salaries are not comparable to those in industry, but it is quite attractive to foreigners because the State Department has made it quite difficult in recent years for them to find jobs in the United States. This is one of the few outlets they have, but a postdoctoral program in which the salaries are a little higher and the promise of working with or at least in the vicinity of some of these top people in NASA I think might be a very interesting thing to pursue.

Mr. MILFORD. I think your observations about the outstanding employees of NASA such as Dick Whitecomb and Bob Jones really has merit. You are absolutely right, you cannot say, "Come up with an antigravity machine and do it within the next fiscal year." It is impossible to do that because in many instances we do not know where

we are going or what we should come up with, yet those avenues have to be pursued.

This is very much in conflict with a Congress which has to go back to the public and say, "We are spending so many millions of your dollars and here is what we are spending it for." Invariably you wind up in one of these sensational columns that speaks of research on the frisbee or some other asinine project. It is an internal conflict, but I feel that your suggestion in trying to continually attract new scientists is very important.

I would appreciate it if you will share your report with us, and I would like to leave a slot open in the record to have that included.

Dr. BRYSON. Being a volunteer board and meeting occasionally, it may take several months before that study is completed.

Mr. MILFORD. Well, if this record cannot hold it, we would still like to have it and would be very pleased to include individual views from any of the members from that subcommittee.

Dr. BRYSON. I will do that, sir.

Mr. MILFORD. How about in the university community itself, are we seeing enough aeronautical researchers coming out now?

Dr. BRYSON. Well, we went through a rather bad time in this last 6 years. As you know the aerospace industry was laying off a lot of people and the perception of students was that that is not a place to go, so that our enrollment and I think the enrollment at the other schools of aeronautics went down considerably. It is coming back. I think our low was 1973-74. Not only in the numbers, but the quality is coming back, and there seems to be no lack of opportunities, but I say most of these are in industry at the present time. The teaching areas are pretty much full now; because of the birth rate some years ago, the number of students is declining and the universities are not expanding, so that most of these young people are going to industry, and not always to the aerospace industry either. The training they have in high technology is of interest to many industries besides the aerospace industry. So we are getting people again who are very interested and very good. At one point, we dropped to an enrollment of about 30 percent of 1968-69; I think that was in 1973-74. I am speaking of the whole aeronautical student body in the United States, both undergraduates and graduates. It went down to 30 percent in 1973 of what it was in 1969 if my memory is correct. It is back now to about 60 percent of what it was in 1968 and 1969.

Mr. MILFORD. Dr. Bryson, some of our members could not be here today and others due to the technical nature of your testimony might have additional questions. We would appreciate it if these members could submit questions to you within the next 10 days and that you could respond in the following 10 days so that we could include both the questions and the answers in the record. Would you be able to accommodate us on that?

Dr. BRYSON. I would certainly be happy to try, sir.

Mr. MILFORD. Thank you very much for your very enlightening testimony.

[The prepared statement of Dr. Bryson follows:]

February 16, 1977

Proposed Statement to Committee on Science and Technology

(Subcommittee on Transportation, Aviation and Weather)

by

Arthur E. Bryson, Jr.

Stanford University

The U.S. has been and still is the world leader in aircraft design and production. Air travel has effectively replaced rail and ship travel in the last 25 years. The volume of world air travel is expected to increase by a factor of two or three by the year 2000 and the U.S. would like to supply a large fraction of the aircraft fleet that will be needed. It seems likely that the requirement for military aircraft and missile development will continue for some time. Thus the need for a high quality aeronautical research and technology base in the U.S. is readily apparent.

I assume the subcommittee has already heard extensive testimony on NASA's past, present and proposed aeronautics programs. The "NASA Outlook for Aeronautics, 1980-2000", dated March 1976, is an excellent study of possible futures which incorporates the thoughts of leaders in aeronautics from industry, government, and universities.

I should like to concentrate my remarks on NASA's most valuable asset, namely their professional staff. I believe there are some serious problems developing here which warrant the attention of the Congress. NACA (1920-1958) was, without a doubt, the world's most eminent aeronautical research establishment. When NACA was transformed into NASA, it was divided into three "offices" -- the Office of Manned Space Flight (OMSF), the Office of Space Sciences and Applications (OSSA), and the Office of Advanced Research and Technology (OART).

OMSF and OSSA took some of NACA's best people as a nucleus and became large contract-managing organizations, whose performance was outstanding, culminating in the manned landings on the moon in 1969 and the unmanned Mars landings in 1976.

The remaining NACA personnel went into OART, whose name was changed in 1973 to the Office of Aeronautics and Space Technology (OAST). About 60% of those people were re-directed into space research and technology development (R&TD), while the other 40% continued on aeronautical R&TD. OART hired new personnel for space R&TD, roughly doubling the number of people working in this area. Very few, if any, new people were hired to work in aeronautical R&TD. The NASA Lewis Research Center completely dropped aeronautical propulsion R&TD from about 1959 until 1966.

Thus I estimate that the number of NASA engineers and scientists working on aeronautical R&TD dropped from about 5000 in 1955 to about 1500 in 1960. The R&TD for the Apollo program began to taper off in the middle 60's and some of the space technical people in OART were directed back into aeronautical work while many others were laid off. I estimate that the number of people in OAST working on aeronautics R&TD is about 20% less now than in 1955. Furthermore a significant fraction of these personnel are primarily engaged in monitoring contracts to the aerospace industry.

NACA's research had a great deal to do with the pre-eminence of U.S. aviation. The jet bombers and commercial jet transports of the late 1950's came as a result of R&TD during the war and in the decade just after the war, before NASA was formed. I believe our failure to develop viable V/STOL aircraft and an economically successful supersonic transport in the 1960's is closely related to the fact that NASA was pre-occupied with space research and development during that period. We have been living off the aeronautical R&TD done in the 1950's and the R&T base is now severely depleted. NACA and industry need to invest in new facilities and in new young engineers and scientists to build up the U.S. technological base in aeronautics. Furthermore, this

must be done with little promise of early results, since it may take five to ten years to re-invigorate this important technical area.

The investment required is not large (a few hundred new people) compared to the total NASA budget, but it should be made now. The longer it is delayed, the more difficult it will be to re-capture the exciting atmosphere of talented people working together that existed in NACA in 1955. Also, many of NACA's top aeronautical people will be retiring during the 1980's and it would be advantageous to have them pass on their know-how to the new younger personnel.

I am talking here about personnel to work on the research and technology base and not on systems studies, systems technology programs or experimental programs. The differences lie in the time span when results are expected and in the ability to predict the likely results. For almost two decades NASA has pursued primarily short-range, development goals in aeronautics, whose outcomes were comfortably predictable and readily acceptable to OMB and the Congress. They have been using up the stored investment in R&T base. The R&T environment in OAST is rapidly being replaced by a contract-monitoring environment with narrowly-defined, short-term goals and strong hardware associations. Internal research programs fall into a subordinate or supporting role to these external contracts. The

reward system is such that talent migrated to program management or contract-monitoring. NASA has asked the Aeronautics and Space Engineering Board (ASEB) of the National Research Council to assess their aeronautics R&T program and a subcommittee of the board will meet for the first time on February 18 to begin this study.

Obviously we will have a more informed opinion when this study is completed. However, my current opinion is that NASA should set some longer-term, higher-risk goals whose outcomes are not so predictable, as NACA did in the 1940's and 1950's. They should be encouraged to hire about a hundred top-notch young engineers and scientists every year and to set up a reward system that keeps the best of these young people in R&TD; a "NASA Fellow" program that recognizes outstanding researchers by giving them a higher salary and more research autonomy would be one approach. Along with this a mechanism should be found to make it easier for middle-aged NASA personnel to move to responsible positions in other government agencies. I have in mind here the policy of Bell Laboratories (one of the most successful research laboratories in industry), where many young research people are brought in each year, but only a few stay there for more than ten or fifteen years. The vast majority move on to positions of responsibility in other parts of AT&T.

Another approach would be to set up "technological focal points" (or "centers of excellence") at the OAST centers which would bring together the top researchers in various disciplines and attract talented young people to work with them.

In summary, I commend to your attention the problems of (a) aging NASA staff in aeronautics with too few top-notch young people being hired, (b) re-newing a climate within NASA for high-quality research and technology development in aeronautics where longer-range, higher-risk goals are set.

AEB/cb

BIOGRAPHY

Arthur E. Bryson, Jr.

Pigott Professor of Engineering and Chairman, Dept. of
Aeronautics and Astronautics,
Stanford University

Attended Haverford College and Iowa State University (B.S. in Aeronautical Engineering, 1946) and served as an aircraft maintenance officer in the U.S. Navy in World War II. After the war, worked as a paper mill engineer with the Container Corporation of America and then as a wind tunnel engineer in the Research Department of the United Aircraft Corporation, before graduate study. Received Ph.D. in Aeronautics at the California Institute of Technology in 1951 and then worked as an aeronautical engineer at the Hughes Aircraft Company. In 1953 went to Harvard University as Assistant Professor of Mechanical Engineering, was appointed Associate Professor in 1956 and Professor in 1961. In 1968 went to Stanford University as Professor of Applied Mechanics, Aeronautics, and Astronautics; Chairman of Department of Applied Mechanics, 1969-1971; Chairman of Department of Aeronautics and Astronautics, September 1971-___. Paul Pigott Professor of Engineering, 1972-.

Has done consulting work for several aerospace companies. Author of 85 technical papers on fluid mechanics, flight mechanics, and automatic control. Co-author with Y. C. Ho of "Applied Optimal Control"; Blaisdell Publishing Company, Waltham, Massachusetts, 1969.

A Technical Director of AIAA (American Institute of Aeronautics and Astronautics), 1965-68 and Associate Editor, AIAA Journal, 1963-66. Jerome Hunsaker Professor of Aeronautics and Astronautics at MIT, 1965-66. Chairman of the National Committee for Fluid Mechanics Films, 1964-68. Engineering Concepts Curriculum Project, summers 1965 and 1966. Fellow of AIAA and of American Academy of Arts and Sciences, member ASEE (American Society of Engineering Education), Sigma Xi, and Tau Beta Pi. Pendray Award of AIAA, 1968. Westinghouse Award of ASEE, 1969. Member, National Academy of Engineering (NAE), 1970-___. Member Aeronautics and Space Engineering Board of NRC, 1970-___; (Chairman 1976-78) Member, National Academy of Sciences, 1973-___.

10/18/76

Mr. MILFORD. Our next witness is Dr. Russell Drew, Acting Director of the Office of Science and Technology Policy, Executive Office of the President, the White House.

Mr. Drew, welcome to the committee.

We have I believe your formal statement. It will be accepted in the record in full at this point and you may proceed formally or informally whichever is your pleasure.

STATEMENT OF DR. RUSSELL DREW, ACTING DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT, THE WHITE HOUSE

Dr. DREW. Mr. Chairman, I would like to use the statement to guide my testimony with you this afternoon, and paraphrase.

First of all, Mr. Chairman, I should point out the absence of a Director for our office, and we expect to have that situation corrected in the very near future. This fact should be reflected in the interpretation of my remarks today. I will present the views of our office as best I can express them for you and I am certain that when we have a Director, he would be pleased to comment in addition.

It is a particular pleasure for me to be here today to testify on the NASA fiscal year 1978 Aeronautical R. & D. Budget and related matters on behalf of this office.

This is the first time that a representative of the new Office of Science and Technology Policy has had an opportunity to appear before your subcommittee, and I thought I might review a few of the milestones that have affected the Office during its formative period because these I think will provide some background for the testimony.

The OTSP was established by Public Law 94-282 of May 11, 1976, but did not formally come into existence until the first Director was sworn in on August 12. The legislation provides a very comprehensive and basic framework for the operation of the Office in the Executive Office of the President and assigns a number of specific responsibilities and tasks. The legislation establishing the OSTP owes a great deal to the work of the committee of which this subcommittee is a part, and I do not plan to review the provisions in detail. Generally, it is clear from the statement of National Science and Technology Policy in title I and the overall thrust of the legislation that it is intended that we take a rather broad view of national issues that involve science and technology or to which science and technology can make a significant contribution. This broad view should be consistent with and supportive of the views of the President and his administration, and the relationship to the President is of course key to our office and its operation.

We also have the responsibility of being an objective source of advice on questions that involve one or more Federal agencies where our position in the Executive Office and the fact that we have no operational interests allows the OSTP to pay a constructive role in coordinating the various programs and viewpoints.

Mr. WYDLER. Doctor, could I interrupt you just a minute?

Dr. DREW. Yes, sir.

Mr. WYDLER. I am confused. In your statement you are listed as Assistant Director and on the list of witnesses, you are listed as Acting

Director, are they both correct, or is one more correct than the other, or what?

Dr. DREW. I am an Assistant Director in the Office, in the absence of the Director I am acting for the Director, so that is—they are both correct in part.

I am acting for the Director in of course a temporary status.

Mr. WYDLER. Thank you.

Dr. DREW. Our mandate covers national security as well as economic and foreign relations concerns and we have a number of mechanisms available to us in order to carry out our assigned role. Included in these mechanisms is an advisory function in connection with agency R. & D. budgets and participation by the Director in the White House staff process.

I should add that the past budget season and the early operation of the office have been very rewarding in that regard. We have been brought into budget discussions fully and we have also, in the person of the previous Director, been involved with the senior White House staff processes.

In addition, a formal means of coordination among Federal agencies is specified in title IV of the Act which calls for establishment of the Federal Coordinating Council for Science, Engineering and Technology. We call it FCCSET. The Director of the OSTP acts as Chairman of that group.

The group involves policy level representatives of major R. & D. performing agencies, thus we hope assuring agency responsiveness to Council actions.

One of the early tasks for our office has been the organization of the Council and the establishment of suitable agenda for its many committees. Of special interest to this subcommittee is a newly established committee of the council dealing with transportation and communications issues. The current Chairman is the Deputy Administrator of NASA, Dr. Alan Lovelace, and there is participation from Transportation, Defense, Commerce, State and other agencies.

While it is still too early in the lifetime of the Council to identify specific products from the committee, it does provide a forum in which many of the questions identified by your subcommittee particularly in the report on the future of aviation can be addressed. In addition, of course there are direct NASA to DOD and DOT agency coordination mechanisms.

In discussing the NASA aeronautical R. & D. budget request, Mr. Chairman, I will be taking a rather broad point of view, therefore consistent with the charter of our office, and I hope you also recognize that our recent creation will limit the indepth involvement that we have been able to take in looking at the NASA program, an indepth involvement we hope will be characteristic of a more mature office.

I will be covering aeronautical R. & D. policy questions, the strength of the R. & T. base and selected technology applications.

First, I would like to recognize the particularly valuable work of this subcommittee in focusing attention on aviation R. & D. and highlighting the issues, particularly as they affect civil aviation. Your report on the future of aviation is particularly noteworthy and the findings and recommendations are quite pointed and require very thoughtful consideration as we proceed to develop and further refine our aeronautical

R. & D. policy. The report is also particularly timely in that the new administration and our office will have it available to us as we carry out a general view of policies characteristic of this particular period.

I would like to discuss a few of these recommendations in the light of OSTP interests, national aeronautical R. & D. policy and the NASA aeronautical R. & D. budget submission.

It is clear that Government R. & D. whether for military purposes or as a product of the NACA/NASA aeronautical R. & D. program has made an important and continues to make an important contribution to the leadership position that the United States enjoys in civil aviation and to the competitive posture of U.S. military aircraft.

To the extent that these R. & D. investments were supported in response to a coherent set of objectives confirmed in such legislation as the National Aeronautics and Space Act of 1958 we have had statements of R. & D. policy to guide our programs. What is particularly of concern today is the adequacy of our current policies in enabling this Nation to meet its responsibilities and to continue its preeminence in civil aviation under changing international circumstances. Up to the present, it is my view that our view that our previous policies have served us well. Exports of aircraft and aircraft parts continue to grow despite worldwide economic conditions that have limited passenger growth generally. But there are clear danger signals on the horizon and the subcommittee has done an excellent job in identifying many of them. In seeking policy responses or program initiatives that respond to these changing external conditions, we must be particularly careful about actions that may appear to be effective in the short term but have rather opposite effects in the long term.

For example, let me address the question of information flow. There is quite often a concern raised about the flow of technology from the United States to both friendly and not so friendly competitors. There have been numerous studies which have attempted to characterize this flow and there are controlling mechanisms that operate to restrict the flow of certain types of information.

In particular I should call your attention to a bill introduced early in this session of Congress, S. 69, on the Export Administration Act. There are provisions in that bill which raise some very serious questions about interference with and potential regulation of free scientific inquiry and information flows and those provisions I think raise some very serious questions in our mind about the appropriateness of such actions, and indeed perhaps their constitutionality. These represent a clear attitude that I think we have to look at very carefully because of the nature of the information flow and its potential use by competitors of both sorts.

In the short term, it may appear to our advantage to restrict research results even more tightly than at present. In many areas of aeronautics, however, one finds that new ideas quite often come from overseas sources or people who have emigrated to the United States from overseas and the unique U.S. contribution has been the adoption of this information and technology into a product that outperforms our competitors at favorable price and with marketing, maintenance and refurbishment services not readily available from other sources.

Mr. WYDLER. If I might, give me an illustration of that, will you?

Dr. DREW. Well, think of the jet engine for example, brought in

from the United Kingdom. We have had the development of basic helicopter technology carried out external to the United States and refined by essentially immigrants, people who have come to the United States.

We have actually learned some very interesting things about helicopter systems from Soviet aircraft that have been available to us, particularly long lifetime seals and attention to maintainability under adverse conditions which are characteristic of the Soviet approach. I think in general there has been a significant communication across national borders that has quite often been to our significant advantage as contrasted to the potential loss of new ideas that comes by our communication to competitors. In general, our attitude has been to approach this question with a great deal of care because we profit from information flow as much as potentially we may lose from it.

Our competitive environment has fostered a system which is sensitive to such marketplace factors, the ones I have mentioned about marketing, maintenance, and refurbishment, and we can capitalize on desirable research results quickly and effectively. The situation therefore is not as simple as it may appear and restrictions on information flow, particularly if applied too broadly, can have a much more significant impact on an entrepreneurial industry such as ours, than a more controlled industry such as those of Western Europe and the Eastern bloc.

I should just reaffirm that I believe U.S. industry is capable of responding vigorously to external competitive threats if not artificially constrained by preferential purchase agreements or government/industry consortia that block entry of U.S. products.

Now, I would like to move on to the question of the health of the R. & D. base. This issue, that is, the adequacy of the research and technology base underlying aeronautical innovations is a particularly difficult one to address. To see this in perspective, it is appropriate to look at the overall Federal investment in basic research, particularly as you look at the more basic aspects of this R. & T. base. The investment in basic research sponsored by the Federal Government decreased in real dollar terms in the fiscal years 1968-75. Recognizing that this change in support was risking a future drop in fundamental new discoveries necessary for our continued technological strength there have been increases in support for basic research in the previous three fiscal years that reflects a desire to provide real growth in this area.

I should also add, Mr. Chairman, that certainly I would be very sympathetic with Dr. Bryson's comment about how important the young, innovative new ideas and people are in this field. It is, I think, a general concern throughout the various fields of activity that we provide suitable opportunities for the brightest and best young minds to enter into the fields of science. This matter has been discussed in the Special Advisory Committees on Science and Technology, and we would be very receptive to suggestions such as the ones that Dr. Bryson mentioned about means of providing incentives for such people to continue their activities and to contribute to the advancement of science and technology generally.

The general knowledge base on which our next generation technology depends, however, is not solely within the NASA aeronautical R. & D. budget, but is also reflected in other federally supported research in allied fields as well as industry supported research in technology development.

Materials research carried out by DOD, fluid mechanics supported by the National Science Foundation, alternate fuels production funded by ERDA and even problems in human physiology and psychology all contribute to the R. & T. base supporting aeronautical developments. This support for basic research generally has a bearing on the adequacy of support for the aeronautical R. & T. base. I am pleased to call your attention to the general increase of approximately 9 percent in basic research support across the Federal Government agencies that is proposed for fiscal year 1978. In this context growth in basic research in aeronautics for NASA this year will be from \$19 million to \$24 million. Of this amount approximately \$3 million was added as a direct result of the actions of the Science Adviser in reviewing basic research needs and specific fields where additional emphasis appeared appropriate. In this respect the increase of over 30 percent in the NASA program is a substantial step forward in strengthening the direct aeronautical R. & T. base represents a very positive response to the concerns identified by your subcommittee.

I should point out that the \$3 million that was added was part of a larger number of additional funds put into several Federal agencies to strengthen basic research programs.

Mr. MILFORD. Dr. Drew, so that the record is straight at this point you have actually added a little less than \$11½ million additional because 7 percent of that has been due to inflation. So the actual increase is more on the order of about \$11½ million.

Dr. DREW. Mr. Chairman, the basis for the additional funds that were added was a real growth rate of 3 percent above inflation. The estimated inflation rate for fiscal year 1978 which of course is somewhat speculative was approximately 5 percent, and it was on this basis that we came up with the dollar add-on. What the actual inflation rate will really be, we are not certain.

Mr. MILFORD. I understand that.

Dr. DREW. But the policy was 3 percent real growth above the best estimate we have for inflation.

We keep talking about increasing these millions and when we start looking at how much of it really is an inflationary factor, the actual increase does not sound quite as large.

Dr. DREW. That is quite true, Mr. Chairman, and recognizing this, of course, we have recently made a practice of attempting to look at both real growth as opposed to just increases which may in fact turn out to be no growth at all.

Mr. MILFORD. Proceed with your statement. I did not mean to interrupt you.

Dr. DREW. Now let me move on to a few specific program elements.

One of the more significant new thrusts of the NASA program has been the emphasis upon aircraft and engine efficiency. While improved efficiency has always been an objective of the aeronautical R. & D. effort, there are obvious forces at work that make elevation of this activity to such a high priority particularly appropriate.

There are incentives in the industry to move in this direction, but like many longer term energy activities, current conditions do not make economically attractive the adoption of changes requiring near

term capital outlays with the objective of longer term benefits spread out over a number of years, thus the conditions appropriate to Federal involvement are present.

Our program should respect the cautions that were raised by the former science adviser, Dr. Stever, in his response to your subcommittee last summer, in which a number of these criteria for Federal involvement were discussed and a number of questions raised. In particular he pointed out that:

In the commercial aviation market, the demand of the commercial airlines for new flight equipment must be carefully integrated into aeronautical R. & D. planning. The benefits of new technological developments may be long delayed if the airlines are either unwilling or unable to buy new flight equipment.

To insure close contact with industry, we have emphasized cost sharing in many of these elements of the program with the view that such contributions by the manufacturers will force a more rigorous examination of the type of technologies that are being tested, particularly whether the technology is adaptable to civil needs, consistent with cost and performance requirements and demonstrably safe in commercial use. These factors all require extensive exploratory and demonstration activities and a degree of risk which is consistent with governmental involvement. Translation of these technologies to specific aircraft modifications or production engines is, however, not appropriate for Federal involvement.

Another area of technology application that illustrates an appropriate role for Federal intervention is the NASA exploration of the prospects for development of new technologies for application of chemicals in the agricultural field. This is part of what we would hope NASA would view as their role, that is, being alert to new opportunities. In this case, the field in which they are proposing to operate has traditionally involved many small entrepreneurs using aircraft that are largely derivatives of previous aircraft, and systems which have not been subjected to the more detailed R. & D. analysis for application of materials that are required.

The ability of these small operators to conduct an appropriate R. & D. program to improve the systems they use and the distribution and application of agriculture chemicals is highly limited, and yet the benefits from such improved systems is potentially of great national importance. The fallout in terms of improved efficiency of application and possibly reduced collateral environmental hazard make it worthwhile to investigate the opportunities in this area.

I should point out however that there is no decision on a specific program that might follow from this investigation. That would await further decisions in future years.

In the area of V/STOL technology NASA is continuing programs which are intended to investigate various configurations and operations regimes in order to build a suitable technology base for the transportation oriented decisions that must be made by industry and the DOT if we are to move more aggressively into such V/STOL operations. NASA has some of the broadest capabilities and expertise available in the Nation in this area and we fully expect that the Agency will continue to make a substantial contribution in support of DOD programs, including the new Navy V/STOL prototype program. Our office believes it is particularly important to the success of DOD pro-

grams in this area for NASA to be integrally involved in such programs. This is particularly true when the flight regimes and the technologies both for propulsion systems and propulsion-airframe integration as well as avionics probe new areas where experience and technical background are very limited.

Finally, Mr. Chairman, I would like to comment very briefly on a technology support activity that is related to supersonic transport aircraft development. The Science Adviser's office in its previous form, the Office of Science and Technology, followed the U.S. SST program very closely and was instrumental in focusing early attention on the problems of sonic boom and aircraft noise. These environmental effects have continued to plague supersonic aircraft development. Although there have been significant improvements in our understanding of these phenomena and of the human responses to them, we still do not have the solutions in hand that would permit an environmentally attractive SST development. NASA programs are continuing with the objective of providing technology readiness for future development. I think it is entirely appropriate that they should do so.

There are very important financial barriers however which raise serious questions about the ability to translate technology readiness into an operational aircraft. The costs of the Concorde development should be very instructive in this regard and should certainly be a sobering prospect for development of a second generation aircraft. Acceleration of the NASA technology programs beyond the current levels would seem inappropriate until some of these barriers to utilization of this technology have been identified and an approach to meet the concerns is developed.

In summary, Mr. Chairman, the Office of Science and Technology Policy believes the proposed aeronautical R. & D. program for NASA for fiscal year 1978 is appropriately structured to support the Federal role in this area, to continue to provide the new results from the technology base that will feed our civil and military aircraft developments of the future, and is generally responsive to its role in support of other agencies' interests. The program has been expanded considerably over fiscal year 1977 representing a continuing recognition of the importance of this part of NASA's overall program. We appreciate the need to continually reexamine our policies and practices to insure our position of leadership in the field and to make sure that it is supported and extended by the R. & D. activities that are being proposed. I believe the NASA program is consistent with these objectives.

This ends my prepared testimony, Mr. Chairman. I would be happy to answer any questions.

Mr. MILFORD. Thank you very much Dr. Drew for your very informative testimony.

Mr. Wydler?

Mr. WYDLER. Dr. Drew, what if any changes have been made in the programs that you testified about here today since the new administration assumed office?

Dr. DREW. Mr. Wydler, I am not aware that there have been significant changes in the programs that we have testified to this morning. The President's revisions to the 1978 budget are not yet public.

Mr. WYDLER. Do you know if there are going to be any in this area?

Dr. DREW. We do not expect any significant change in this area, but I cannot comment beyond that at this time. This is still embargoed.

I would certainly expect that our office will participate in a number of reviews of policies involving major R. & D. program activities and that this area would be one of those areas covered. Until we get a Director however we cannot commit firmly——

Mr. WYDLER. What is going on in regard to that?

Dr. DREW. A new Director?

Mr. WYDLER. Yes.

Dr. DREW. We expect that we should see an announcement perhaps in 1 week or 10 days.

Mr. WYDLER. Do you know who it is going to be?

Dr. DREW. I cannot comment on that.

Mr. WYDLER. Can't you comment on whether you know? [Laughter.]

You can say you know without telling me who it is. That is a fair question.

Do you know whether the person has been selected, let me put it to you that way.

Dr. DREW. The selection process is very close to being complete, but to the best of my knowledge, it is not, it has not been finalized.

Mr. WYDLER. That is all I have, Mr. Chairman.

Mr. MILFORD. Dr. Drew, thank you very much for your testimony. We appreciate your appearing before the committee.

[The prepared statement of Dr. Drew follows:]

STATEMENT OF DR. RUSSELL C. DREW, ASSISTANT DIRECTOR
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
ON THE NASA FISCAL '78 AERONAUTICAL R&D BUDGET

BEFORE THE SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND WEATHER
COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES
FEBRUARY 16, 1977

Mr. Chairman and Members of the Subcommittee:

It is a pleasure to be able to respond to your invitation to testify on the NASA Fiscal '78 Aeronautical R&D Budget and related matters on behalf of the Office of Science and Technology Policy. Since this is the first appearance of a representative of the OSTP before this Subcommittee I would like to review very briefly some of the important activities that have marked our early formative period, particularly since this will provide some background for the testimony.

The Office of Science and Technology Policy was established by P.L. 94-282 of May 11, 1976 and formally came into existence when its first Director, Dr. H. Guyford Stever, was sworn in on August 12, 1976. The legislation establishing the office provides a basic framework for its operation in the Executive Office of the President and assigns a number of specific responsibilities and tasks. The legislation owes a great deal to the work of the committee of which this subcommittee is a part. and therefore, I will not review the provisions in detail. It is clear however that the office must take a very broad view of national issues that involve science and technology or to which science and technology can make a significant contribution. This broad view should be consistent

with and supportive of the views of the President and his Administration. We also have the responsibility of being an objective source of advice on questions that involve one or more Federal agencies where our position in the Executive Office and the fact that we have no operational interests allows the OSTP to play a constructive role in coordinating various programs and viewpoints. Our mandate covers national security as well as economic and foreign relations concerns and we have a number of mechanisms available to us in order to carry out our assigned role. Included in these mechanisms is an advisory function in connection with agency R&D budgets and participation by the Director in the White House staff process. In addition a formal means for coordination among Federal agencies is specified in Title IV of P.L. 94-282, which calls for establishment of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), with the Director of OSTP as Chairman. Policy level representatives of major R&D performing agencies are represented on the Council, thus ensuring agency responsiveness to Council actions. One of the early tasks for our office has been the organization of the Council and the establishment of suitable agenda for its committees. Of special interest to this subcommittee is a newly established committee of the council dealing with transportation and communications issues. The current Chairman is Dr. Alan M. Lovelace, Deputy Administrator of NASA with substantive participation that includes the DOT, DOD, Commerce, State and others.

While it is too early in the lifetime of the council to identify specific products from this committee, it does provide a forum in which many of the questions identified by your subcommittee may be addressed. You are, of course aware that direct NASA-DOD and NASA-DOT agency-to-agency coordination is a regular and on-going process.

In discussing the NASA aeronautical R&D budget request, Mr. Chairman, I will be taking a rather broad point of view and will not attempt to cover all of its many elements, in keeping with the general perspective of the office and recognizing that our relatively recent creation has not allowed the in-depth involvement that would be expected of a more mature office. I plan to cover aeronautical R&D policy, the strength of the R&T base, selected technology applications and advanced aircraft development.

First, I would like to recognize the particularly valuable work of this subcommittee in focusing attention on aviation R&D and highlighting the issues, particularly as they affect civil aviation. The report of the subcommittee on the Future of Aviation is particularly noteworthy and the findings and recommendations are pointed and require very thoughtful consideration as we proceed to develop and further refine our aeronautical R&D policy. The report is also particularly timely in that the new Administration and our office will have it available as the general status of policies are reviewed in a number of areas. Let me discuss a few of these recommendations in the light of the OSTP interests, national aeronautical R&D policy, and the NASA Aeronautical R&D Budget submission.

It is certainly clear that government R&D whether for military purposes or as a product of the NACA/NASA Aeronautical R&D Program has made an important contribution to the leadership position that the US enjoys in civil aviation and to the competitive posture of US military aircraft. To the extent that these R&D investments were supported in response to a coherent set of objectives confirmed in such legislation as the National Aeronautics and Space Act of 1958 we have had statements of R&D policy to guide our programs. What is particularly of concern today is the adequacy of our current policies in enabling this nation to meet its responsibilities and to continue its preminence in civil aviation under changing international circumstances. Up to the present our previous policies have served us well. Exports of aircraft and aircraft parts continue to grow despite worldwide economic conditions that have limited passenger growth generally. But there are clear danger signals on the horizon and the subcommittee has done an excellent job in identifying many of them. In seeking policy responses or program initiatives that respond to these changing external conditions, we must be particularly careful about actions that may appear to be effective in the short term but have rather opposite effects in the long term. For example, let me address the question of information flow. There is quite often a concern raised about the flow of technology from the US to both friendly and not so friendly competitors. There have been numerous studies which have attempted to characterize this flow and there are controlling mechanisms that operate to restrict the flow of certain types of information. In the short term, it may appear to our advantage to restrict research results even more tightly. In many areas

in aeronautics, however, one finds that new ideas have quite often come from overseas sources and the unique US contribution has been the adoption of this information or technology into a product that out performs our competitors at a favorable price and with marketing, maintenance and refurbishment services not readily available from other sources. Our competitive environment has fostered a system which is sensitive to such marketplace factors and can capitalize on desirable research results quickly and effectively. It is clear however that we have not relied exclusively on the marketplace and that significant military-to-civilian fall out and direct civil R&D support have also contributed to our current leadership position. The situation is therefore not as simple as it may appear and restrictions in information flow, particularly if applied too broadly, can have a much more significant impact on an entrepreneurial industry such as ours, than a more controlled industry such as those of Western Europe and the Eastern bloc.

I believe that U.S. industry is capable of responding vigorously to external competitive threats, if not artificially constrained by preferential purchase agreements or government-industry consortia that block entry of U.S. products. Financial considerations figure prominently in any look to the future for civil aviation manufacturers, and many of the most vital aspects go well beyond the purview of our office. I should emphasize that our concern is that the programs of NASA are consistent with its mandate, which, among other things calls for "...preservation of the U.S. role as a leader in aeronautical and space technology ..." Applying this general guidance, combined with policies

that affect financing and export sales of U.S. products, together with stable and enlightened environmental regulations should contribute substantially to the maintenance of the U.S. position as an aircraft manufacturer and supplier. It is my view that the proposed FY'78 NASA aeronautics budget, which is proposed to increase by \$41 million over FY'77 is consistent with these objectives.

Now, let me move on to the question of health of the R&T base. This issue, that is, the adequacy of the research and technology base underlying aeronautical innovations is a particularly difficult one to address. To see this in perspective, it is appropriate to look at the overall Federal investment in basic research. The investment in basic research sponsored by the Federal government decreased in real dollar terms in the fiscal years 1968-75. Recognizing that this change in support was risking a future drop in fundamental new discoveries necessary for our continued technological strength there have been increases in support for basic research in the previous three fiscal years that reflects a desire to provide real growth in this area. The general knowledge base on which our next generation technology depends is not solely within the NASA aeronautical R&D budget, but is also reflected in other Federally supported research in allied fields. Materials research carried out by DOD, fluid mechanics supported by the National Science Foundation, alternate fuels production funded by ERDA and even problems in human physiology and psychology all contribute to the R&T base supporting aeronautical developments. Thus, support for basic research generally has a bearing on the adequacy of support for the aeronautical R&T base. I am pleased to note a general increase of approximately 9% in basic research

support across the Federal government agencies proposed for FY'78. In this context growth in basic research in aeronautics for NASA this year will be from \$19 million in FY'77 to \$24 million requested for FY'78. Of this amount approximately \$3 million was added as a direct result of the actions of the Science Adviser in reviewing basic research needs and specific fields where additional emphasis appeared appropriate. In this respect the increase of over 30% in the NASA program is a substantial step forward in strengthening the direct aeronautical R&T base and represents a very positive response to the concerns identified by your subcommittee.

Now, let me move on to specific program elements. One of the more significant new thrusts of the NASA program has been the emphasis upon aircraft and engine efficiency. While such an objective has always been part of the aeronautical R&D effort, there are obvious forces at work that make elevation of this activity to such a high priority particularly appropriate. There are incentives in the industry to move in this direction, but like many longer-term energy activities, current conditions do not make economically attractive adoption of changes requiring near term capital outlays with the objective of longer-term benefits spread out over a number of years. Thus, the conditions appropriate to Federal involvement are present. Our program should respect the cautions that were raised by the former Science Adviser, Dr. Stever, in his response to your subcommittee:

"In the commercial aviation market, the demand of the commercial airlines for new flight equipment must be carefully integrated into aeronautical R&D planning. The benefits of new technological developments may be long delayed if the airlines are either unwilling or unable to buy new flight equipment."

To ensure close contact with industry, we have emphasized cost sharing in many of these elements of this program with the view that such contributions by the manufacturers will force a more rigorous examination of the type of technologies that are being tested, particularly whether the technology is adaptable to civil needs, consistent with cost and performance requirements and demonstrably safe in commercial use. These factors all require extensive exploratory and demonstration activities and a degree of risk which is consistent with governmental involvement. Translation of these technologies to specific aircraft modifications or production engines is, however, not appropriate for Federal involvement.

In another area of technology application the NASA program will be exploring the prospects for development of new technology for application in the agricultural distribution of pesticides. This is part of being alert to new opportunity in a field that has traditionally been the province of the small entrepreneur utilizing aircraft with specialized flight characteristics. The ability of the small operators to conduct appropriate R&D to improve distribution and application of agricultural chemicals is limited and yet the benefits from improved systems for this work is potentially of national importance. The fallout in terms of improved efficiencies of application and possible reduced collateral environmental hazard make it worthwhile to investigate important opportunities in this area.

In the area of V/STOL technology NASA is continuing programs which are intended to investigate various configurations and operating regimes in order to build a suitable technology base for the transportation oriented decisions that must be made by industry and the DOT if we are to move more aggressively into such V/STOL services. NASA has some of the broadest capabilities and expertise in this area and it is expected that the agency will continue to make a substantial contribution in support of DOD programs, including the new Navy V/STOL prototype program. Our office believes it is important to the success of DOD programs in this area for NASA to be integrally involved in such DOD programs. This is particularly true when the flight regimes and the technologies both for propulsion systems and propulsion-air frame integration probe new areas where our experience and technical background are very limited.

Finally, Mr. Chairman, I would like to comment very briefly on the technology support activity that is related to supersonic transport aircraft development. The Science Adviser's office in its previous form, the Office of Science & Technology, followed the U.S. SST program very closely and was instrumental in focusing early attention on the problems of sonic boom and aircraft noise. These environmental effects have continued to plague supersonic aircraft development and although there have been significant improvements in our understanding of these phenomena and of the human responses to them, we still do not have the solutions in hand that would permit an environmentally attractive SST development. NASA programs are continuing in these areas with

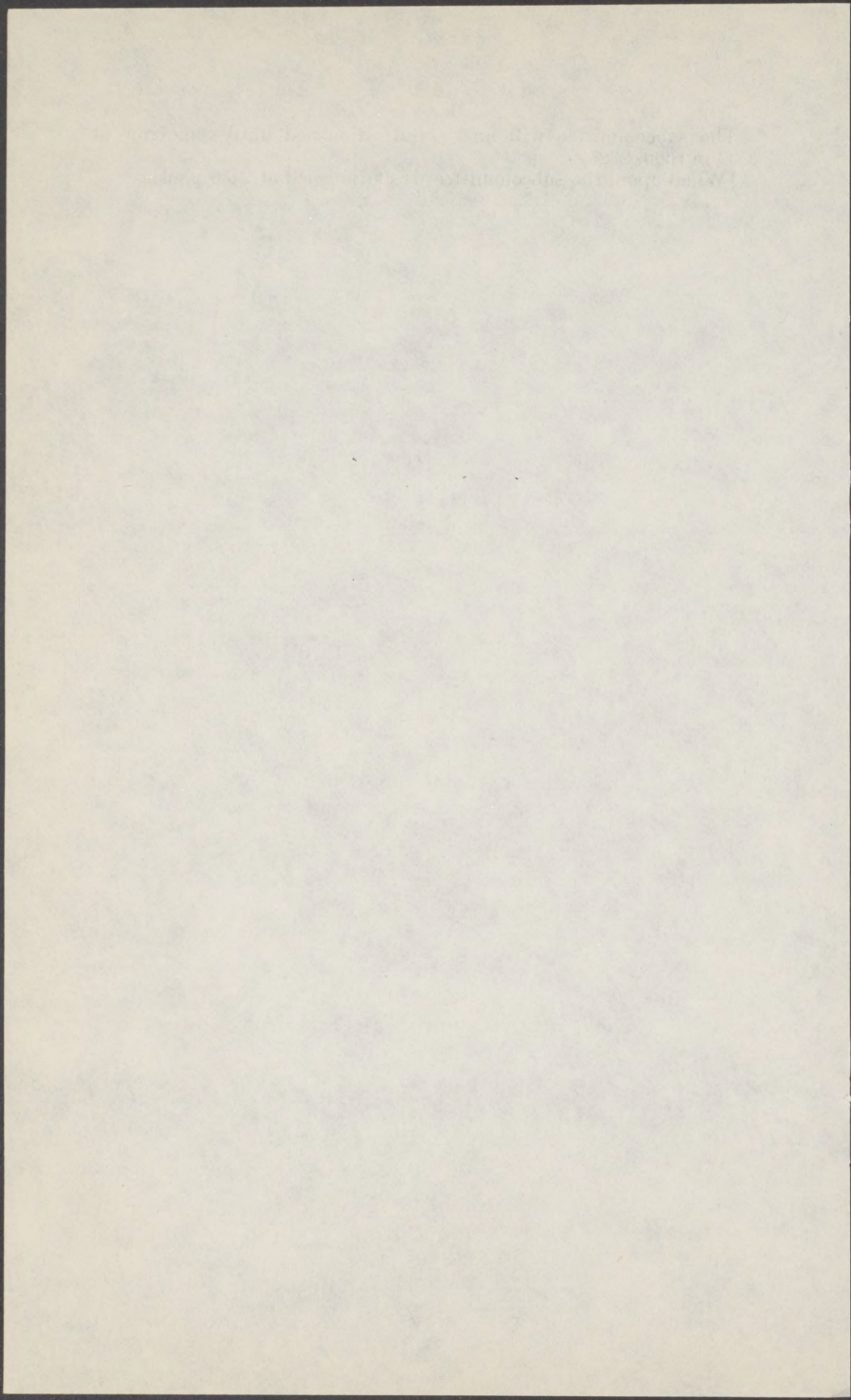
the objective of providing a technology readiness for future development. It seems reasonably clear that passenger acceptability of rapid, safe aeronautical transportation, including supersonic flight, is very high particularly if means of reducing the environmental effects can be developed. There are very important financial barriers, however, which raise serious questions about the ability to translate technology readiness into an operational aircraft. The costs of the Concorde development should be very instructive in this regard and should certainly be a sobering prospect for development of a second generation aircraft. Acceleration of the NASA technology programs beyond the current levels would seem inappropriate until some of these barriers to utilization of this technology have been identified and an approach to meet the concerns is developed.

In summary, Mr. Chairman, the Office of Science and Technology Policy believes the proposed aeronautical R&D program for NASA for FY'78 is appropriately structured to support the Federal role in this area, to continue to provide the new results from the technology base that will feed our civil and military aircraft developments of the future, and is generally responsive to its role in support of other agencies' interests. The program has been expanded considerably over FY'77 representing a continuing recognition of the importance of this part of NASA's overall efforts. We appreciate the need to continually reexamine our policies and practices to ensure our position of leadership in the field is being supported and extended by the R&D activities that are proposed. I believe this program is consistent with these objectives.

This ends my prepared testimony, Mr. Chairman. I will be pleased to answer any questions that you may have.

The subcommittee will now stand adjourned until tomorrow at 9:30 in room 2325.

[Whereupon, the subcommittee was adjourned at 2:50 p.m.]



1978 NASA AUTHORIZATION

THURSDAY, FEBRUARY 17, 1977

U.S. HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON TRANSPORTATION, AVIATION
AND WEATHER OF THE COMMITTEE ON
SCIENCE AND TECHNOLOGY,
Washington, D.C.

The subcommittee met, pursuant to recess, at 1 p.m., in room 2325, Rayburn House Office Building, Hon. Dale Milford (chairman) presiding.

Present: Representatives Milford, Goldwater, and Glickman.

Mr. MILFORD. The subcommittee will please come to order.

Today the Subcommittee on Transportation, Aviation and Weather will continue its review of NASA's aeronautics budget request for fiscal year 1978.

We have invited three witnesses to discuss the outlook for a short takeoff and landing transport system in this country.

NASA's budget in this area is not large, but questions have been raised by the GAO and others about the pace of that program.

Accordingly, we want to explore all the facts before reaching any decisions about this part of the NASA program.

Our first witness is Mr. Richard Gutmann, director of the Procurement and Systems Acquisition Division of the Government Accounting Office.

Mr. Gutmann, welcome to the subcommittee. We have your formal statement which will be accepted in full for the record, and you may proceed in whatever manner you care.

STATEMENT OF RICHARD W. GUTMANN, DIRECTOR OF PROCUREMENT AND SYSTEMS ACQUISITION DIVISION, GENERAL ACCOUNTING OFFICE

Mr. GUTMANN. Thank you, Mr. Chairman. It is a pleasure to be with you this afternoon. I would like to introduce my colleagues, if you do not mind.

To my right is Jerome H. Stolarow, who is the principal deputy director of my division, and to my left is Mr. Charles Finney, who is a supervisory auditor of the Division.

We plan, as you know, to summarize our report entitled, "Federal Short Takeoff and Landing Transport Programs—Status and Needs," which was issued on October 4, 1976.

What I would like to do is give you a very brief overview of the substance of the report, and then follow that with some of the details.

The major thrust of our report was to recommend that the Congress

and the several executive agencies involved, primarily Department of Transportation, Department of Defense, and the National Aeronautics and Space Administration, reassess the needs and priorities for short haul transportation systems. In essence, we noted that the Department of Transportation sees improved rail systems and better use of existing air transportation facilities as the preferred solutions to congestion problems in high density corridors. NASA, however, is proceeding with research on short takeoff and landing—so-called STOL—transports to solve airport congestion in the same markets. This, despite the fact that little or nothing is being done to resolve the significant questions concerning either the need and timing for a new short-haul system or the ground and air facilities that would permit efficient utilization of large STOL transports. It is also interesting to note that the Air Force contractors involved in the development of STOL cargo aircraft for military applications see no commercial passenger or cargo market for this type of aircraft and do not now intend to invest corporate funds in a commercial program.

Now, with respect to some of the details you will find in the report, several years ago a Government study recognized the need for the various agencies to work together to resolve the complex problems of initiating a STOL system.

That study group was composed of the Department of Transportation, NASA representatives, as well as Air Force, Army, Navy people, and some contractors' representation.

In 1974 a divergence of opinion surfaced concerning solutions to these problems and the cooperative approach was discontinued. As a result, each of several agencies appears to be pursuing its own solutions based on its specific areas of responsibility and interests. The current problem, therefore, is whether these solutions are all worth investing public and private funds in and whether they are paced or even compatible with each other and with long-term transportation needs.

I would like to briefly discuss some of the background to this problem and the significant points covered in our report.

IDENTIFICATION OF NEED

A short takeoff and landing—STOL—air transportation system has long been discussed as a possible solution to existing and forecasted constraints on the growth of air transportation in the United States.

A 1971 joint Department of Transportation and National Aeronautics and Space Administration policy study concluded that solutions to the air and ground congestion problems at major hub airports should have the highest priority, second only to seeking solutions to the aircraft noise problem.

The study also concluded that solutions to the complex problem of airport congestion requires an organized effort directed at the combination of air traffic control, runway capacity, ground control of aircraft, terminal processing, access and egress, parking, airport location, acquisition, and development.

The two agencies stated that STOL aircraft was the leading contender for a new short-haul system and that there was a need for a coordinated effort to assure that all system elements were integrated and proceeding at a consistent pace.

The study suggested that a special office be established in the Department of Transportation to manage a coordinated program to alleviate terminal congestion, and that joint enterprises between Government and industry be considered for major experimental hardware and demonstration programs.

COORDINATED FEDERAL RESPONSE—A SYSTEM APPROACH

As a result, a special office was established in the Federal Aviation Administration and a working group composed of representatives from FAA, NASA, Civil Aeronautics Board, Department of Defense, and the Office of the Secretary of Transportation was formed to coordinate Government actions.

Other significant events were that:

In 1971, NASA initiated a program to develop the technology for quiet short-haul takeoff and landing jet transports to serve high density markets.

In November 1972, the Air Force awarded contracts to two companies to develop, and flight test experimental transport prototypes employing two different lift concepts for achieving short takeoffs and landings.

In 1973, both the FAA special office and the working group drafted plans proposing actions to improve short haul air transportation. Like the 1971 policy study, the plans consider a new STOL system to be the leading contender for alleviating terminal congestion. A steering committee composed of prominent people in the aviation community was also organized to provide industry advice.

DISCONTINUANCE OF MULTIAGENCY SYSTEM APPROACH

However, no plan for coordinated action was ever adopted. A divergence of opinion had surfaced concerning solutions to short-haul transportation problems. Department of Transportation officials saw improvement of rail transportation in high density corridors and better use of existing air transportation facilities as preferred solutions to short-haul transportation problems.

Also, FAA no longer considered downtown STOL ports, as envisioned in the 1971 policy study, feasible because of environmental and safety considerations. In addition, the problems of terminal congestion appeared much less urgent because of (1) the utilization of wide-body jets, (2) the economic downturn, and (3) the 1973-74 fuel crises, all of which contributed to a reduced number of aircraft operations, and later to a smaller rate of growth.

In 1974, FAA's special office, was abolished. Although certain cooperative research and development efforts between the Air Force and NASA and between FAA and NASA continued, the multiagency approach to explore means for improving an air transportation system was discontinued.

In reporting these changing circumstances, we also noted that NASA research and development expenditures through 1979 are estimated to total approximately \$203 million, with follow-on efforts through 1984 still under study. The Air Force is spending \$229 million through 1978 to build and test its four full-sized prototypes. If ap-

proved, the Air Force will spend another \$250 to \$500 million in full-scale development of its prototypes.

Before the technology being developed by NASA and the Air Force could be used in the civil transportation field, substantial additional Federal resources will be required to develop the STOL system. In addition to aircraft technology, air traffic control system, and airport development, the Federal Government may be required to participate in the development of production aircraft, market demonstrations, and ground feeder systems. As I mentioned earlier, we think it is extremely significant that the two major commercial aircraft producers in this country see no market for a commercial passenger STOL aircraft. We were told, emphatically, that development and production of such an aircraft would have to be funded by the Government.

Because of the sizeable investments required and their long-run budget implications, at both Federal and local levels, we sought to determine whether the anticipated long-term needs, constraints and investments provided a rational basis for continuing STOL R. & D. We found that:

1. There is no real agreement on the specific requirements for a commercially viable STOL system. It appears that what is needed, as a minimum is (a) an aircraft that could operate at a seat-mile cost competitive with other short-haul systems, (b) ground facilities convenient to major downtown areas, and (c) an air traffic control system for relatively slow aircraft operating differently than current airliners.

2. Long-term actions are being taken to improve existing air traffic capacity and to develop competing rail passenger service. If successfully completed they will tend to alleviate the need for a STOL short-haul passenger system. These actions include: Upgraded air traffic control systems, reduced separation standards, jet wake detection, closely spaced parallel runways, capital improvements at primary airports, plans for additional general aviation airports, and plans for capital improvements and construction to upgrade intercity rail passenger service.

The Department of Transportation recently reported that if current trends continue, additional public investments in airports and airways from 1975 through 1990 will total about \$39 billion—\$17 billion to replace worn out or obsolete equipment and structures, and \$22 billion for expansion. None of these expenditures are directed toward the unique problems of a short-haul STOL system—but rather toward the improvement of the current air transportation system.

By the year 1980, grants and loan guarantees to sustain intercity rail passenger service are expected to be about \$700 million per year. Beyond this annual operating subsidy, the Federal Government is expected to provide \$1.2 billion for capital improvements and \$1.7 billion for construction of the Northeast corridor.

3. Because of the progress being made by NASA and the Air Force, development of jet STOL transport technology appears to be ahead of other system components—airports, terminal facilities, routes, air traffic control, and connecting transportation. Development of these other components are tied to complex governmental decisions at the Federal, State, and local levels, that have not been made.

I should mention that neither the Department of Transportation nor NASA agrees with our assessment that the STOL technology is ahead

of other system components. DOT states that the current national aviation system can accommodate STOL technology today. The 1971 policy study and subsequent feasibility studies, however, show that although STOL transports could be used in the existing system they would not realize the full benefits of their unique capabilities and would interfere with current airline operations.

We proposed that the Department of Transportation clarify its position on long-term transportation needs, constraints, and investments. We also suggested that NASA reassess the scale and pace of its research directly supporting the development of a STOL system with the purpose of bringing it more in line with the emerging Department position, and that the Office of Management and Budget reassess the Federal research and development activities.

AGENCIES RESPONSES AND OUR RECOMMENDATIONS

The Department of Transportation, NASA, and Office of Management and Budget agreed with the basic proposal that Federal programs should be reassessed, but the Department of Transportation and Office of Management and Budget stated that this is being done. The agencies generally concurred with the scale and pace of the NASA STOL technology program. The Department of Transportation stated while there is no agreement on when or if the STOL transport technology will be applied, there is general agreement that the technology is needed to provide future policy choices. If the STOL vehicle technology program is going to provide future policy choices, we believe it should be guided by, and responsive to, the requirements of the transportation system within which it will operate and by assessments of the market which it seeks to influence.

In summary, our report primarily questions the relevance and effectiveness of NASA's STOL research and development program because it is not part of a coordinated effort to solve the congestion problem and it is not user or market oriented.

We believe the Congress should take the lead in establishing a national transportation policy and in directing those research and development programs that would be consistent with that policy.

The amounts that are involved in developing either a workable STOL system—or in upgrading other forms of transportation—make it imperative that the costs and benefits of all competing and complementary systems be examined carefully.

Since the issuance of our report, the Secretary of Transportation has issued the "National Transportation Trends and Choices (to the year 2000)," dated January 12, 1977. It restates many of the observations and policy issues made in previous Department of Transportation documents cited in our report. In regard to airport congestion, it stated:

1. Rate of growth in air travel is expected to decline substantially in the next 15 years.

2. Current research, engineering and development programs will substantial improvements in the existing airway system including substantial gains in airport capacity.

3. Public investments in airport and airways will total about \$39 billion over the next 15 years if current trends in new airport investment continue.

4. Increased attention is being given to noncapital or relatively low-capital means of increasing airport capacity. For example, implementation of operational policies that shift general aviation concentrations in peak-periods to periods of excess capacity or to other airports could reduce overall capacity requirements for large hub airports by as much as 30 percent.

5. For most major airports, severe congestion problems during peak periods occur on the internal circulation system within the airport boundaries.

That sounds like a description of National Airport. I think all of us have experienced that.

Mr. GOLDWATER. It sounds like every airport.

Mr. GUTMANN. Yes; quite true, not just National. Improvements in this area offer the greatest potential for congestion reduction and improved airport access.

For intercity rail passenger service the report noted:

1. Financial viability studies of rail-passenger markets have shown the New York to Washington, D.C., corridor to be the most promising. "The United States Railroad Association's Preliminary System Plan" identifies 16 short-to-medium-distance corridors—300 miles or less—in densely populated areas—end points of 1 million persons or more—outside the Northeast corridor in which upgrading of rail passenger service might return substantial public benefits.

2. Increasing commitments to Amtrak and to improving the Northeast corridor have been made without any serious analysis of the public benefits and cost involved, or any evaluation of alternative uses.

3. It is essential that the Amtrak experiment be restudied to ascertain the best use of the resources available and to permit an evaluation and policy decision on the future of rail passenger service. This decision point should be reached by 1985 at the latest.

4. Any review must pay close attention to the effect of liquid fuel shortages on traffic congestion on the highway system now projected for 1990.

Mr. Chairman, this concludes my prepared statement. I shall be happy to answer any questions at this time.

Mr. MILFORD. Thank you very much, Mr. Gutmann.

You seem to be saying that one very good alternative to the proposed STOL plans would be going rail. Did I get that out of the gist of your paper?

Mr. GUTMANN. Well, we are not intending to take a position on that issue one way or the other.

What we are really saying is that the entire transportation system should be examined and decisions made with respect to which way to go so that there can be a cohesive Government position, and if it is to upgrade rail, if it is to provide for STOL transportation, or whatever, they should be part of a plan, and there should be a maximum degree of agreement among the agencies that are involved, as to their part in that plan.

Mr. MILFORD. I cannot disagree with that.

I have been one screaming for years to get a national transportation policy, which in effect is what you are saying?

Mr. GUTMANN. Yes.

Mr. MILFORD. You also seem to consider a STOL port as something removed from existing airports.

Was that part of your thinking?

Mr. GUTMANN. Well, there are some situations where a STOL transport system could be close to an existing airport, I should think.

There are a variety of ideas as to where a STOL port might be.

Mr. MILFORD. In making your report, had you considered STOL as being a separate facility from existing airports, or part of existing airports, or both?

Mr. GUTMANN. Not necessarily, no.

I think it could be either one, and there are plans to go either way, depending upon the situation at a particularly highly congested airport.

For example, it would be possible, it appears, not so much to us but to the people who have studied the problem from a technical standpoint, that where an airport is adjacent to a sizable river, or where there is a river close to a major transportation hub, that a STOL port could be constructed along the edge of the river, such as the Hudson River to service New York. Perhaps even the Potomac River, but there are also plans to utilize the existing real estate that might be available adjacent to the conventional takeoff aircraft.

Mr. MILFORD. Are you aware that there are many airports operating STOL aircraft right on the airport itself, and are using taxiways of existing airports, and doing so quite successfully?

Mr. GUTMANN. No; I am not aware of that.

I assume my colleagues have run into it in the course of their study, and the only qualifier is that, taking into consideration the conventional aircraft, and general purpose aviation, the volume of traffic has to be controllable by the infrastructure, and it has to be an infrastructure in terms of ground control of approaches, as well as ground transportation facilities serving that particular airport.

Mr. MILFORD. You mention on page 6, in relation to your conversation with commercial aircraft producers, that you were told emphatically that development and production of such an aircraft, a STOL, would have to be funded by the Government.

Did they also tell you they cannot produce any new generation aircraft without help from the Government?

Mr. GUTMANN. No; they did not mention that.

Mr. MILFORD. Did they tell you that the cost of tooling up and producing any new generation aircraft is around \$1 billion, which is beyond the capability of any one company?

Mr. GUTMANN. No; to my knowledge they did not mention that.

Mr. Stolarow perhaps can talk directly to some of that, for he talked directly to some of the contractors, and he could respond.

Mr. STOLAROW. The companies we were talking to already have a big leg up on the development of these aircraft, having been funded by the Air Force. But even with that experience, they said they would not invest any corporate funds in going the next step from a military cargo aircraft and attempting to convert it to passenger use.

The point they were making is that they saw no market at all for a large STOL transport aircraft, and unless the government completely funded further development, even over and above what the Air Force is doing now, they were not going to take any action along those lines.

Mr. MILFORD. Mr. Goldwater?

Mr. GOLDWATER. Mr. Gutmann, how was this study conducted by GAO?

Mr. GUTMANN. In what particular way, in terms of where we did it, and what records we looked at, and this kind of thing?

Mr. GOLDWATER. How many people were involved with it?

Mr. STOLAROW. Basically, it was done by examining records at the Department of Transportation, at NASA, and literature research, and going back into the studies that had been made by the various Government agencies, and attempting to compare the problems that were raised in previous studies, with what is happening today.

None of the agencies involved have really disagreed with the facts.

They disagree with our conclusion, or our preliminary evaluation, but we had about three people that did this study, and worked about 6 months on it.

Mr. GOLDWATER. Did these people that did the study have any background in aviation?

Mr. STOLAROW. Most of the people that worked on it had background in military systems, including aviation.

Mr. GOLDWATER. But no real familiarity with a national transportation program?

Mr. STOLAROW. That is correct, not until the point of getting involved in this study.

Mr. GOLDWATER. The study seems to downplay the importance of STOL development as a viable alternative in the scheme of transportation systems, is that an accurate conclusion?

Mr. GUTMANN. Well, I think it is close.

It might be a little more accurate to say that at the present time, we do not see a coordinated cohesive plan in which the STOL aircraft would fit.

Now, as far as the research and development aspect of it is concerned, we did not intend to downplay the value of that.

On the other hand, a great deal of STOL technology is already available through the efforts of the Air Force and others, so we are asking in essence whether or not there should not be a good determination of a need for the aircraft before the program advances from the developmental stage into advanced engineering.

Mr. GOLDWATER. In other words, you think we are putting the cart before the horse?

Mr. GUTMANN. Yes. That is a good way of putting it.

Mr. GOLDWATER. And your recommendation is that the Congress establish this overall national transportation plan?

Mr. GUTMANN. Yes, indeed.

Now, of course, what I mean is that the Congress through the executive branch, and working with the Department of Transportation and the FAA.

Mr. GOLDWATER. But you did not say that.

Mr. GUTMANN. All of the steps involved.

Mr. GOLDWATER. You did not say that in your recommendations.

Mr. GUTMANN. The intent was to take a lead in its development, the exact words that we used, I think it is on page 3, the Congress should take a lead directing those programs that would be consistent with the policy.

Mr. GOLDWATER. The thing that disturbs me is that Congress has already mandated that this be done, and it is significant by the absence in your report that you are taking to task those agencies we would naturally look at to develop that plan.

Why was that neglected?

Mr. GUTMANN. If I understand your question, you are asking why the departments did not undertake that?

Mr. GOLDWATER. Why did GAO not take to task the requirements set forth by the Congress as far back as 1971, that a national transportation system be developed?

Mr. GUTMANN. Well, we have in essence, I believe.

Mr. GOLDWATER. Show me where in your statement.

Mr. GUTMANN. We cite the 1971 study, and the fact that since then there have been a lot of changes made, there has been a divergence of opinion, among and between the agencies that are involved, and this to us indicates that the Congress has to take a stronger hand to bring together these diverse opinions and resolve them, and move ahead on something that everyone can agree upon.

Mr. GOLDWATER. Well, I think it has been made clear by this committee over the past several years that a system be developed, in order to properly fit STOL into, but it appears to me that you downplay STOL technology. In essence NASA is moving too fast because we do not have a system to place this in. It appears to me the problem is not so much with the technology, but with the failure of DOT specifically to establish a plan. Therefore, you support putting more money into rail systems, and into existing systems, upgrading capacities of our airport system. It just appears to me that this is a little bit short-sighted.

If your people had an opportunity to go out to some of these airports, one of the things you would recognize is that we are reaching our capacity regardless of what we do.

We can talk about air traffic control systems, saying we can do more of this, we can do more with the facilities at the airports, but what about the problems, the social and economic environmental problems that are created by further concentration of traffic and congestion in and around an airport. I would submit that no amount of money is going to alleviate those problems which are going to increase, as you bring more and more people into a central area.

You do not seem to recognize the need for support for some type of dispersion of traffic.

What we ought to be trying to do is making transportation more convenient for people, instead of building up the central hubs, to decentralize and to get traffic away from the central areas. One of the vehicles would be V/STOL type equipment. The thing that disturbs me about this is that you criticize our R. & D. efforts, but you do not really criticize the failure of DOT to establish a system in which this technology can be put into.

Mr. GUTMANN. Well, that last point is exactly the one we are trying to make, that the STOL program should be assessed in the light of the total transportation system in the area in which it is to serve, as well as in the light of the needed improvements or upgrading, or whatever it might be with respect to area traffic controls, et cetera.

The STOL aircraft, as you know, they are going to have to be controlled every bit as much as the conventional aircraft.

Now, I spoke of the possibility of having STOL ports adjacent to existing aircraft, or having them along a riverbank adjacent to a major metropolitan hub, the possibility of constructing them over

highways, as a matter of fact, where STOL aircraft could land, and have ready access to ground transportation, so we are not taking a position for or against STOL.

We are saying that the technology seems to be in hand, but before moving forward with it, it does indeed look as though it would be useful to consider STOL in its entirety in the system of traffic control, and in the infrastructure in general, and have it play a part in a master transportation plan.

Now, I think we are coming very close to saying the same thing.

Mr. STOLAROW. May I add something, Mr. Goldwater.

We are not supporting rail transportation or increased capabilities of the current terminals as substitutes.

What we are saying is that there is apparently an inconsistency between the various agencies.

It is the Department of Transportation that appears to be pushing or supporting the improvement in the current airways system, and the improvement of rail transportation.

What our report attempts to do is point out the Department of Transportation seems to be stressing one kind of preferred solution, while at the same time, NASA is proceeding with research on another form, and what we are saying, let us decide what has to be done, and get a consistent policy.

Those of us that work on the report tried very carefully not to say that there is a preferred solution.

We do not know what the solution is. All we are trying to do is point out that various Government agencies are each going in their own direction.

Mr. GOLDWATER. Mr. Chairman, in conclusion, the thing that disturbs me about this report is that short of DOT positive action, in establishing a national policy, they criticize STOL technology, as a viable transportation option, instead their thrust and their conclusion is that the Federal program should be reassessed.

Mr. STOLAROW. The whole transportation program should be looked at.

Mr. GOLDWATER. Why criticize STOL technology in a vacuum?

Mr. STOLAROW. I have to disagree with you, sir.

We are not criticizing STOL technology. We are criticizing the fact that there are various agencies spending money, at apparently cross-purposes.

We have no criticism of STOL technology.

If it is decided that it has a place in a national transportation system and should be advanced, then we would certainly support the national policy.

It is not our purview to make policy, or to recommend that type of policy, but to point out to the Congress that there are inconsistencies in what is being done today.

Mr. GOLDWATER. I would only say that the flavor of your report is very detrimental to a national effort to refine this technology regardless of whether we have a policy or not.

I think that the major criticism should be that we do not have a national policy, that we are putting money into a rail system, and we do not know whether there is a market for it. We are putting money into central hubs to increase their capacity. We do not know really

what the total picture is, and that is where the major criticism should lie.

Mr. MILFORD. Let me put a couple of loose ends together here.

In reference to your statement that the Department of Transportation seems to be pushing rails as an answer here, that does not seem to jive with Secretary Coleman's testimony, where he stated we are absolutely wasting our money to subsidize rail traffic.

Mr. FINNEY. To our knowledge, the Transportation Department is still supporting Amtrak as an experiment, Mr. Chairman.

Mr. MILFORD. You are saying that Secretary Coleman is not in keeping with the policy of the Department of Transportation?

Mr. FINNEY. As we understand the Department of Transportation's position after looking at documents and discussions with officials, we believe our statement accurately reports the Department's position.

Mr. MILFORD. But back to your contention. You say we were pushing the development of STOL without having solved or having plans to solve problems of air traffic control, and there are other allegations you have enumerated there. In making that conclusion, did you take into consideration our present development in such things as area navigation, developmental plans for automated air traffic control. Were all of those things taken into consideration when you drew that conclusion?

Mr. GUTMANN. It is my understanding they were.

Mr. FINNEY. Our report notes that the technology is being developed, to be ready by the early to mid-1980's, and the question is, is there a need at that time for this technology.

It is not a question of whether the technology is good or bad, but is it responding to a need as identified by those other agencies that must develop a system in which it can be used.

Mr. MILFORD. That is not the point I am questioning.

The point of my question is your conclusion that if we would develop a STOL aircraft, we could not use them after they were developed, because of lack of navigation facilities.

I am asking you in drawing that conclusion, did you take into consideration plans for development of area navigation systems, which provide almost unlimited routes, and for microwave landing systems, where we could have three or four landing systems operating in the same fields?

Mr. FINNEY. Yes, sir.

Mr. MILFORD. Category 3 landing facilities, and automated air traffic control?

Mr. FINNEY. Yes.

Mr. MILFORD. All would be in effect when these airplanes would be used?

Mr. FINNEY. Yes; we did take that into consideration.

Mr. MILFORD. And you still say there are not enough facilities to utilize STOL?

Mr. FINNEY. Yes; the airport facilities to handle these aircraft, to process the additional passengers, there is more to the development of a viable STOL system than the ATC.

Mr. MILFORD. Thank you very much for your testimony.

We appreciate your taking the time to come before the committee.

Mr. GUTMANN. Thank you.

Mr. GOLDWATER. Could we submit some additional questions?

Mr. MILFORD. Yes. Since the matters dealt with by this subcommittee are technical in nature, and since some of the members could not be here, we would ask that any member be able to submit questions within 10 days, and that you respond to those questions within 10 days, and the questions and your responses will be included in the record.

Mr. GUTMANN. Thank you.

Mr. MILFORD. Our next witness is Mr. Karl G. Harr, Jr., president, Aerospace Industries Association of America.

Mr. Harr, welcome to the subcommittee. We have your prepared testimony, which will be accepted in full for the record, and you may proceed in any manner you care to.

STATEMENT OF KARL G. HARR, JR., PRESIDENT, AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

Mr. HARR. Thank you, Mr. Chairman.

My prepared testimony is not very long, Mr. Chairman. It may get us off to a running start.

Mr. MILFORD. Would you care to introduce your associate?

Mr. HARR. This is Mr. Joseph C. Snodgrass, who is a member of the AIA staff, and he works on aviation matters within the AIA.

Mr. MILFORD. Thank you very much.

Mr. HARR. I will read my statement, Mr. Chairman.

I am Karl G. Harr, Jr., president of the Aerospace Industries Association of America, Inc., representing the Nation's major manufacturers of aircraft, spacecraft, missiles, and their components. We welcome this opportunity to comment on the two areas noted in your invitation, Mr. Chairman, specifically the general health of aeronautical research and technology at NASA and in the Nation and, in particular, the prospects for development of short takeoff and landing transport aircraft in the United States.

Turning first to the research and technology base, as you know from my previous appearances before your subcommittee, this is an issue of extreme concern to everyone involved in high technology industry and policy. It should be obvious to everyone at this time, in the midseventies, that research and development funding in the United States, in real dollars, is declining and has been doing so since 1968. We have been commenting on this year after year with negligible results. Perhaps part of the solution would be to concentrate on upgrading relatively small, manageable areas of research and technology. A case in point would be the aeronautical research and technology base at the National Aeronautics and Space Administration.

Although the total NASA research and technology budget has increased steadily since fiscal year 1975, the aeronautical R. & T. budget has lagged consistently until this year when the requirements of a significant new program are being partially, though in our view inadequately, recognized. I refer to the aircraft energy efficiency program, about which I will comment later. In total, however, the NASA aeronautical R. & T. budget has lingered between 6.3 and 7.7 percent of the total NASA R. & T. budget. Nowhere is this relative lack of emphasis and support more graphically demonstrated than by the mere five-line mention of the aeronautical portions of NASA's budget at the end of Dr. James Fletcher's statement on the fiscal year 1978 request.

There are important reasons why these percentages should be increased rather than maintained. First, as we have discussed in the past, military programs have traditionally provided a significant percentage of the Government's support of aeronautical technology and, in turn, the aviation industry. A large part of this military effort was directly applicable to subsonic commercial aircraft and engines. In recent years, however, military programs, particularly those transferable to civil programs, have been sharply reduced in number. In our view, this should be recognized by the Government and the resulting slowdown in technological feedback compensated for in the funding of NASA aeronautical programs.

Second, the regulatory agencies, such as the FAA and the EPA, provide limited technology funding to assist industry in the basic research needed to modify their products to meet newly promulgated rules and regulations. Therefore, we believe that here, too, NASA should increase its support of basic emissions and acoustics research.

Third, the pending shortage of petroleum-based hydrocarbon fuels may result in a requirement for synthetic or alternate fuels having a wider range of characteristics than fuels meeting current specifications. It is our belief that NASA has a real contribution to make in this area, including funding of studies to evaluate the impact of wider range fuels on aircraft and engine development and operating costs.

Helicopter development is another whole area of endeavor which might properly be addressed by NASA and funded accordingly. Rotor noise reduction, power transmission noise reduction, increased fuel efficiency and the continued development of viable helicopter navigation and air traffic control systems are all worthwhile areas of investigation.

Another key area which needs expanded effort is the aerodynamics of high aspect ratio—longer and narrower—wings which can lead to more efficient transport aircraft. New materials being developed by industry, for example, could be accelerated into further testing to provide data that the airframe industry could use to advantage in early production application. This in turn would lead to weight reduction and fuel conservation.

Fuel conservation, of course, represents the most significant aeronautical program undertaken by NASA in some time, although we might quarrel with their estimate that fuel consumption could be cut in half using foreseeable technology as being overly optimistic. The proposed budget for the aircraft energy efficiency program, however, is in our view insufficient to continue the progress toward an early application of this technology to the new generation of transport aircraft. The most notable deficiency is in the area of advanced structural composite materials where a 40-percent reduction from the original plan is being considered. This specific concept has the most promising potential for early application, inasmuch as such components could be substituted directly into current production aircraft to make them more fuel efficient. We would recommend, therefore, that the fiscal year 1978 budget be increased on the order of 25 percent in this area, while at the same time we would observe that the proposed emphasis on an energy-efficient transport and engine seems adequate for the planned year's work, as do the levels proposed for turboprop and laminar flow control funding.

Another fundamental contribution which can best be provided by NASA lies in the area of basic research. A healthy national aircraft and airline industry demands a continuing level of high quality research far in advance of practical application. The areas of supersonic and hypersonic flight would be prime examples. Additional technological contributions could come from parametric wind tunnel test data aimed at more efficient airfoils, digital electronics, and engine component design data for reduced noise, emissions, and fuel consumption.

Perhaps there remains a question in the minds of some as to why the U.S. Government, under NASA or any other agency, should increase its support of these functions or even perform them in the first place. Certainly it is no secret to this subcommittee after its long and dedicated work in these areas that the aircraft and airline industries are a vital segment of the U.S. transportation system as well as the economic base. As noted in the subcommittee's comprehensive report on "The Future of Aviation," over 1 million direct jobs result from aviation manufacturing, airline operations, and groundbased aeronautical activities. Furthermore, over 80 percent of the free world's aircraft are American made. To quote your report, Mr. Chairman:

Today's investments in R. & D. are the single most important determinant of the Nation's future air transportation options . . . (and) extensive R. & D. is a prerequisite to the delivery of the new aviation products that are needed to retain our worldwide commercial leadership.

For all of these reasons, we in the aircraft manufacturing industry are extremely concerned about NASA's apparent desire to keep its budget profile low by all but relinquishing its charter in important areas of aeronautical research. For the last several years, it would seem that the aeronautical R. & T. budget has been based on the philosophy of holding an approximate ratio with the space program rather than evaluating aeronautical needs on their own merits and in terms of their contributions to the well-being of the United States. In our view, gentlemen, this relative emphasis must be reevaluated and the aeronautical portions of this budget increased.

Within that general context, then, I turn to a specific area of research and technology: Short takeoff and landing aircraft. At present in the United States STOL technology is being developed through the QSRA, YC-14, YC-15, and Buffalo augmentor wing programs.

In the early 1970's, however, anticipated demand for full-scale commercial STOL systems had to be modified in light of the economic downturn and escalation of environmental and social objections to city-center to city-center aviation transport systems. At the same time, the increasing use of wide body aircraft began to relieve both congestion and noise and the economic state of the airlines strongly dictated against introduction of new lines of aircraft. As a consequence of all these factors, the Quiet Short Haul Air Transportation Office in the FAA was disbanded and the central focal point for Government-wide STOL development disappeared.

At the moment it is difficult to identify a significant market for such aircraft. In its report to Congress of October 4, 1976, entitled "Federal Short Takeoff and Landing Transport Systems—Status and Needs," the General Accounting Office cited both the lack of intergovernmental coordination of STOL programs and the apparent

absence of a ready market for such products as justification for a massive reassessment of the social, economic, and jurisdictional factors governing STOL system development and the establishment of priorities for funding of such systems. The implication was that such R. & T. should be virtually eliminated.

While we in industry would not dispute the scarcity of the present demand for STOL equipment, we feel there are good and sufficient reasons why powered lift and high lift technology should continue to be pursued aggressively, particularly the QSRA and the planned tests of the YC military aircraft. Our reasons are two: The expected continuing growth of air traffic and the evident limits to major new air carrier airports. These aircraft represent a viable technological response to the capacity and environmental consequences of air traffic growth—not only in the United States but overseas, as well, which will contribute to our favorable balance of payments. In fact, it is by offering this sort of adaptive potential that technology makes its greatest contribution to transportation and other areas of national life.

NASA was created to preserve and further such capabilities and, at least in the aeronautical areas, it should do so with greater—not decreasing—vigor.

Thank you, Mr. Chairman.

We would be happy to answer any questions.

Mr. MILFORD. Thank you, Mr. Harr.

I think I could respond to your testimony with one word, simply "amen."

You state on page 4 in your critique of NASA's budget that the proposed emphasis on energy efficient transport and engines seems adequate for the planned year's work, et cetera.

I am wondering, if due to the potential energy savings, we could make with advanced turboprops, that would not be kind of a potent area to get into?

Mr. HARR. We would not quarrel with efforts to increase those, Mr. Chairman.

We were trying to make as balanced a judgment as we could under all circumstances as to where emphasis should be applied.

We think the overall R. & T. budget is too small.

Mr. MILFORD. I could not agree with you more.

Mr. HARR. We think that we can argue that pretty forcefully, and in some detail.

We think the composite materials area offers an immediate payoff in terms of the potentiality for early introduction into aircraft now being produced.

We certainly feel that fuel conservation is one of the most important undertakings that NASA has engaged in.

If you ask me how big an increase we would realistically like to see, in the current R. & D. budget for NASA, recognizing capabilities for absorption, and time, et cetera, probably somewhere between where it is now and twice as much.

Mr. MILFORD. Let me throw another problem back in your lap.

Last year when we were working on the future of aviation report, we were very frustrated, because we could not actually find out how many Americans earned their daily bread in aeronautics.

We were frustrated in that we could go to Boeing. They could tell us exactly how many people they had working, but for all those at Boeing, there are at least twice that number working in little shops, making a piece here, a part there, or a service, or something else.

We cannot get the number of these people. The number of over a million, which is a very gross figure, we think is vast understatement of the actual number of Americans that are involved in aeronautics, and this is important, because one of the problems that we are having, whether it is in this research budget or other areas, is that Americans do not really realize the benefits, the national benefits that are coming from aeronautics.

I wonder if there is some way you can go back to your organization and see if we can come up with an accurate number of how many American jobs are involved. I think it would make a difference in people's toleration of noise at airports, if they realized the real benefits they are directly receiving from aeronautics. Even the number of jobs in their own community would be involved.

It seems we cannot get a number on it.

Mr. HARR. Well, I am very sensitive to the thrust of your remarks, Mr. Chairman, and it is obviously part of our job description to come up with such figures, and we have.

We break them down in a lot of different ways.

When you talk about aerospace in general, as distinguished from the commercial and private side of it, you are including military, and a lot of companies are involved in both activities, a lot of suppliers to airplanes are making components, or selling materials to producers of commercial aircraft, or military aircraft, or missiles.

There is also the factor of the large substructure of vendors or component manufacturers which you discussed, and you also get into the indirect impact. If a restaurant exists because it is at an airport, or exists because a certain number of people of the community are engaged in a given occupation, that is a recognized economic indirect factor.

Mr. MILFORD. At this stage we would settle for a direct.

Mr. HARR. We can give you the direct, broken down in a hundred different ways, but people like to use figures to prove whatever their hypothesis is, and there are those who will contest figures at all levels on that basis. If you take the Bureau of Census reports breakdown on categories of industrial activity, if you take direct company inputs, plus vendors, I could give you right now a couple of ballpark figures on the things you are talking about. Directly, I would say this is correct without going into the material vendors, 300,000 for the airlines and 400,000 for the industry, so you have 700,000 before you even start looking for direct vendors.

But we will certainly respond to your request, Mr. Chairman.

[The material referred to is as follows:]

Aircraft manufacturing and airline employment data¹ as of November 1976²

Direct airline employment (SIC 451.2)-----	336, 700
Direct manufacturing employment (SIC 372)-----	483, 600
Indirect/supporting jobs-----	574, 200
Total -----	1, 394, 500

¹ Includes manufacturing employment for both military and civil aircraft and parts.

² Based on Bureau of Labor Statistics Industrial Analysis, Bulletin 1672.

Mr. MILFORD. Mr. Goldwater.

Mr. GOLDWATER. Mr. Harr, would you agree that STOL-powered lift technology efforts by Government should be decreased until we have established some national transportation plan?

Mr. HARR. I certainly would not. Without backing away from the very strongly held conviction that a national transportation plan is the single most important missing ingredient in the picture now, I do not think that has any probative effect with respect to the other conclusions.

We are all trying to get at the truth here in these hearings, but we are dealing in an area where the truth is a matter of some speculation, and in trying to get at the truth, we freely admit that right now there is no established market for a given type of STOL vehicle.

That has long been the bug-a-boo, the history is pretty fascinating from a sociological/political point of view, I suppose. It is a chicken and egg proposition. I do not suppose I have to labor very hard to convince any of you gentlemen, or anybody in America, that there is a very easily whetted appetite nerve on the part of manufacturers to come up with a product when they see a market for it.

Our industry, for one, is criticized for coming up with too many products to try to sell in one area, such as the military.

The lacking ingredient in bringing STOL, or some variation of STOL, R/TOL, into its full social potential has been that the rabbit has never been put into the hat.

I can remember when Bozo McGee was FAA administrator, we argued about it. He said, "You give us the right vehicle, and we will find a system for it."

I said, "Bozo, that is not the way to do it, that is not the way it will work."

There is no right vehicle until there are at least some broad outlines of what the performance requirements are; however, very clearly there are some identifiable areas of need for technological advance in the STOL field that will greatly improve the creation of a market, and the planes suitability to a market, as that market is focused in on by some sort of national transportation plan.

Environmental factors, noise factors, reliability factors, performance factors, emission factors, are all proper subjects for NASA research and development.

If you take NASA, and I know I am taking a long time to answer the question, if you take NASA from its NACA days, and its mission, then, and transpose that into 1977, given the changes in technology and how its mission should be applied now, I should think STOL would be one of the most ideally suited areas for NASA to undertake research and technological development.

Mr. GOLDWATER. Do you feel that we have advanced technologically to the point where we can envision what a system would be like utilizing STOL technology?

Mr. HARR. I think we have some of the parameters of the need, Congressman Goldwater.

I think in a way it is what you were talking about with prior witnesses. There are crying needs to fill the gap in our transportation

system now, without excessively destroying our city centers, or the quality of life around the cities.

You just cannot put too many more bridges over the Potomac. You just cannot put too many more trains in certain areas effectively and efficiently. There is a very restrictive payoff on increasing investment in that kind of activity.

There is, I think, a clear need now for some way to get in and out of a city center, or approximate to a city base, on short stage lengths.

Our transportation system is jammed in many areas.

Mr. GOLDWATER. It disturbs me when DOT argues we should not emphasize STOL technology, because there is not a market.

I think it is very plain there is a market for transportation.

There are many ways of fulfilling that market, and DOT is pumping a tremendous amount of money into rail, which I would not criticize, as one mode to meet that market, but even that is limited.

In my limited experience and knowledge, I see a great demand for the short haul type vehicle, up to 500 miles, that a train is not going to fill.

You have the businessman, he needs to get up to San Francisco from Los Angeles, and back in the same day.

It takes a whole day to get to San Francisco by rail.

Recognizing the limited capacity of our hubs, it just stands to reason from a commonsense standpoint that utilizing STOL, not only to meet the short haul need, but also to answer the environmental questions of noise and pollution, that would be brought about by the new technology, that there is a viable base or place for this kind of vehicle.

I think you could argue that there is no market for a rail system, and yet we are pumping billions of dollars into it, and after billions of dollars, the system still does not support itself, or even come close to it.

If we can rationalize that, I certainly think we can rationalize a market for a short haul STOL aircraft, that is going to unload the central hubs, and provide a vehicle for the market that does exist. We are starting to see it out in my area. We are seeing airlines serving outlying areas, Orange County, Ontario, Burbank, we have seen these airports that are very close to Los Angeles International, spring up with traffic that is unloading the central hub.

Now, the problem with today's current airplanes, flying into those small communities, is the environmental problem, that the advanced technology would alleviate.

Shorter approaches and shorter takeoffs is what you have with the new technology.

Well, I do not want to continue on that vein, but I would like to ask you, is what are our foreign competitors doing in this area?

Mr. HARR. Well, speaking, let us say, of Western Europe, the differing circumstances there that are applicable to answering that question include I think, a much more highly developed and efficient and effective ground transportation system, particularly rail.

The lengths between cities, in a simplified statement, are shorter than ours, and the tendency now is to go the helicopter route for city center to city center transportation.

I am not aware—any more than I am in this country—of any major STOL development programs, and I do not think the Europeans are

committed to it yet. I think that market is available to us, if we can get it going.

Mr. GOLDWATER. In the GAO report, they state that the manufacturers, I believe McDonnell Douglas and Boeing, are not looking at commercial derivatives of the YC-14 and 15, is that a fact?

Mr. HARR. I believe it is true, yes, and I believe it to be true substantially for the reasons that they have said, that they do not yet see a direct and specific market to justify putting down that kind of investment money for commercial derivatives.

You can bet your bottom dollar they have boys in the backroom in both places studying the problem right now to see if they could do that.

Mr. GOLDWATER. One last question, Mr. Chairman.

In the area of technology research and development by the Federal Government, is there a cooperative effort by the Government with industry to put the dollars where they are most needed?

Mr. HARR. I think there is a very good one on the whole. I am talking of aeronautical. I would say the history of relations between NASA and American industry to do just that have been pretty remarkable, given the fact that they are operating from two different perspectives.

Mr. GOLDWATER. They are working in areas that are being practically usable to the industry?

Mr. HARR. Yes; I think they are stopping work when they should stop work, and moving on it when they should.

I think it has evolved into a very healthy and efficient interplay between industry and Government. In the Langley operation, say, or whatever else in NASA, to have the Government aware of what would seem from industry's point of view to be the biggest needs, and to have industry aware of what the Government is doing that might have some commercial application is very important.

We would have to say we are very pleased with that.

Mr. GOLDWATER. Just one last question, Mr. Chairman.

The Federal Government is putting a lot of money into the Northeast rail corridor. It is kind of a demonstration, in fact it is an operable system.

Could you recommend we do the same thing for V/STOL or STOL, to demonstrate a program between the Government and the manufacturers?

Mr. HARR. I would if the first dollar were spent on drawing up the system.

I would agree if the first dollar were spent on drawing up the system, because I think cooperation, effective cooperation, begins from the point where both sides know what they are talking about.

Mr. GOLDWATER. In other words, establish some kind of program or plan, and then proceed with the demonstration, much like the Northeast corridor?

Mr. HARR. I would think that would be the only way to do it.

Mr. GOLDWATER. Do you think that would help identify the markets, and in essence, the question of the chicken and the egg?

Mr. HARR. That is right, exactly what I think is necessary.

Mr. GOLDWATER. Thank you, Mr. Chairman.

Mr. MILFORD. Mr. Glickman?

Mr. GLICKMAN. No questions, Mr. Chairman.

Mr. MILFORD. Mr. Harr, we appreciate very much your taking the time to appear before the subcommittee.

Mr. HARR. It has been a pleasure and an honor, sir. Thank you very much.

Mr. MILFORD. Our next and final witness of the day is Mr. Robert Paullin, Chief of R. & D. Resources Management Division, Office of R. & D. Plans and Resources, Department of Transportation.

Mr. Paullin, welcome to the subcommittee. We have your formal statement which will be made a part of the record. You may proceed in any manner that you wish.

STATEMENT OF ROBERT L. PAULLIN, OFFICE OF R. & D. PLANS AND RESOURCES, DEPARTMENT OF TRANSPORTATION

Mr. PAULLIN. Thank you, Mr. Chairman. I would like to read my statement for you, and then respond to any questions that you may have.

[The prepared statement follows:]

STATEMENT OF ROBERT L. PAULLIN, OFFICE OF R. & D. PLANS AND RESOURCES, DEPARTMENT OF TRANSPORTATION

Mr. Chairman and members of the subcommittee, I am pleased to appear before you today to discuss the outlook for a short takeoff and landing transport system ("STOL"). The Department of Transportation, including the Federal Aviation Administration, has been concerned with planning and research and development efforts on STOL for many years. The subject has received considerable attention in the past ten years in particular.

As with any type of transportation system, STOL must demonstrate market demand, system technology and economic feasibility before financiers, manufacturers, operators, and regulatory agencies will become actively interested in developing and implementing a STOL system. From DOT's viewpoint, these factors are not now demonstrable.

At this time, development of a STOL system involves many technological, economic, and environmental risks and uncertainties. A STOL aircraft may be more costly and less fuel efficient than a conventional aircraft. These are serious considerations at a time when we are all aware of the great necessity to conserve fuel and other scarce resources. Improved rail passenger service, increased usage of satellite airports, and more efficient usage of conventional aircraft and ground facilities appear likely, at this time, to be more desirable solutions to the problems of short-haul transportation needs. These are some of the problems and considerations involved in the development of a STOL system, but on the other hand, it is possible that technology and other conditions may change to improve the viability and demand for a STOL system. In light of this uncertainty, we believe that we should not foreclose the option that is being kept open by the NASA research effort. The Department has worked closely in the past with NASA and the Department of Defense, and we shall continue our effort.

I would now like to answer the questions asked by the Committee.

Question 1. What do air traffic growth forecasts reveal about the need for greater capacity in various segments of the air transportation system, especially STOL?

Answer. The FAA aviation activity forecasts covering the next 12 years show continued growth in all segments of air transportation, including short-haul. Additional capacity requirements will be concentrated in the large-terminal areas. Short-haul STOL is only one possible contribution to a solution to this capacity problem. However, neither STOL technology nor economics are at a point where it can be considered a viable solution. Until that point is reached, meaningful STOL operations forecasts cannot be made.

Question 2. Is the present network of downtown STOL ports adequate to support a viable STOL system or will new or additional STOL ports be needed?

Answer. There are presently no downtown STOL ports in the sense of airports specifically designed and dedicated to handling STOL planes in the National

Aviation System nor are any contemplated in the near future. There are, of course, a few airports in the downtown areas of our cities which are used now by operators of conventional takeoff and landing aircraft and in a few cases by operators of vertical takeoff and landing aircraft. Characteristics of these two categories of aircraft are known and the downtown airports are designed to be compatible with them.

During the early 1970's, the FAA Quiet Short-Haul Air Transportation System (QSATS) Office investigated the feasibility of the concept of downtown STOL ports. Technology did not exist at that time for such a system to be either economically or environmentally viable. It is possible with the advent of future aircraft developments, that some time in the later 1980's there may be a need shown for downtown air passenger transportation in our major metropolitan areas.

If the demand exists for airports in such areas, we feel assured that airports will be provided for the STOL aircraft. We feel that such airports will come into being at the instigation of appropriate airport authorities of local communities. It is our policy that initiation of airport element projects should be the responsibility of local communities. Our job is to afford maximum flexibility to state and local jurisdictions to determine airport needs, and to make financial investments consistent with local needs and the development of the national airport system.

Question 3. What does the National Transportation Policy say about the relative merits of a STOL system versus other solutions to the short-haul transportation problem?

Answer. The National Transportation Policy issued in September 1975 made no specific reference to STOL operations. The statement does address the question in a more conceptual way. Throughout the statement, emphasis is placed on the need to promote the most cost and energy efficient and environmentally acceptable forms of transportation. For example, the Department believes that a diversion of short trips from aviation to other modes, particularly in the Northeast Corridor where improved rail passenger service will be available, might be the preferred means of accommodating increased demand for short-haul transportation. We also have a very efficient interstate bus system that could be expanded.

Question 4. Is the planned ATC system adequate to handle a STOL system?

Answer. With evolving improvements to today's air traffic control system, we anticipate that the system will have the capability to handle STOL system requirements for the 1980 time period, if those requirements occur. The Microwave Landing System with its inherent flexibility, area navigation system improvements, better surveillance capabilities through the Discrete Address Beacon System, and regulations supported by the results of our research development, and airport development, and aircraft certification programs are all providing an adequate base for a STOL system to proceed if the aircraft technology and the airline economic situation warrants introduction of the STOL alternative.

Question 5. Why was the QSATS office closed?

Answer. FAA's Quiet Short Haul Air Transportation Systems Office (QSATS) was abolished as a result of a reassessment of the state of technology in the short-haul aviation program. The office was established in 1971 at a point when there was a great deal of optimism regarding traffic growth and subsequent aircraft development. STOL system implementation was forecast to occur in the 1970's. The QSATS office thoroughly investigated many aspects of both STOL systems and the more general subject of short-haul aviation. The FAA then determined that sufficient work had been done for a response to statutory obligations if and when the technology for a STOL aircraft was available. The programs within the QSATS office were then distributed within two other offices—the planning and policy function was assigned to the Office of Aviation Policy and the research and technical function was given to the Systems Research and Development Service.

Question 6. Considering all the elements required, when might a STOL system be viable?

Answer. We do not anticipate the introduction of STOL aircraft into the transportation system before 1985-90 and see no immediate need for detail planning for implementation of a STOL system. It takes about seven to ten years, from the time a given technology is available, to achieve the operational introduction of its application. The scheduled readiness of NASA's STOL vehicle technology by the early 1980's, is consistent with our position.

Mr. Chairman, this concludes my prepared remarks. I hope that I have given you the Department's outlook for a short takeoff and landing system. I welcome any questions you may have.

Mr. MILFORD. Thank you, Mr. Paullin.

I have only one comment. It bothers me when too often we compare STOL technology, or the use of STOL aircraft with the Northeast corridor.

I really do not think this is an appropriate comparison at all, because the Northeast corridor is very much like Europe, where they have well-developed ground transportation systems.

I believe that STOL would be more appropriate in parts of the Nation where the rail system would not be operable, as in Texas, or in California, where you have relatively large city hubs 200 to 500 miles apart, yet there would be no way in the world we could ever develop a rail system in these parts of the country that would pay for itself.

I wonder if this is not the more appropriate role for STOL aircraft.

Mr. PAULLIN. You might be quite right, Mr. Chairman.

Of course, the Department is interested in providing mobility for all people.

Mr. MILFORD. I understand that.

Mr. PAULLIN. Our mention of the Northeast corridor was done in terms of the potential demand, in terms of the demand for trips from origin to destination, but of course the same thing would be true in any locality where there was a demand for trips.

Mr. MILFORD. With the congestion that you have in the Northeast corridor, I seriously doubt that STOL would be a good vehicle, but if you leave that area and go to any other place in the country, where you cannot put in fast passenger rail service, then you have real problems, and I get disturbed when people make reference to the Northeast corridor with reference to STOL aircraft.

I do not think the Northeast corridor will ever become a candidate for STOL.

Mr. PAULLIN. Yes, sir.

Mr. MILFORD. Mr. Goldwater?

Mr. GOLDWATER. Mr. Paullin, where is this whole STOL program right now within DOT?

Mr. PAULLIN. The subject of STOL is being considered along with all other forms of transportation. In our policy offices and in our R. & D. offices we are following quite closely the NASA vehicle technology program.

Also, we are following the development of technology, as it relates to a policy for transportation. The concern and interest in STOL, as with other forms of transportation, is throughout the Department and not located in any one particular area.

Mr. GOLDWATER. In answer to question No. 4, you say that today's air traffic control system with the evolving improvements in the air traffic control system, will have the capability of handling STOL system requirements in the 1980 time period.

The thing that has confounded a lot of people interested in STOL, is that they are not really sure where the whole concept fits in with other modes of transportation, and yet you conclude that the system

would fit, and it can be handled from the standpoint of air traffic control.

Why have you not defined a total transportation system that answers the questions raised by the presence and the potential of STOL?

Mr. PAULLIN. The answer has many parts.

Let me approach it first from what we have done historically on the question of STOL.

As I have indicated, we had a program in the late 1960's, and early 1970's, which addressed the question of STOL. At that time, we conducted demonstrations in several cities, using smaller aircraft. We, NASA, and the industry envisioned continued growth. The need for STOL aircraft as we have explained, has vanished for the reasons listed by me as well as others. With the disappearance of the urgent demand, we elected to focus upon STOL in relation to all other forms of transportation, and see, no immediate need to develop a detailed plan of implementation.

From an overall viewpoint, and coming back to the question of vehicle technology, in many respects the aircraft itself, its handling capabilities, its short-field length capabilities, its maneuverability, et cetera, are the forcing functions. The interdependence of the vehicle in the air traffic control system and in the airport system cannot be determined, if you will, until you have established a vehicle design and the characteristics of the vehicle.

Mr. GOLDWATER. But DOT was asked to coordinate this STOL effort, and too in essence come up with some kind of system that would utilize the STOL technology. They really have not adequately responded to that, would you not agree?

Do we have a master plan up here where we can look at it, and say here is where STOL would possibly interface?

Mr. PAULLIN. Well, we feel, Mr. Goldwater, knowing what we do now about the evolving vehicle technology, that the air traffic control system—with the improvements that we see, and as the chairman has mentioned, the microwave landing system capability which opens up a whole new potential in terms of landings and takeoffs in the terminal area—is capable and will be capable of handling STOL requirements, when and if they come about in the future.

Mr. GOLDWATER. Have you analyzed the social and the economic implications, as to just how this thing is going to fit in with rail, and freeways, and buses, and long haul?

Mr. PAULLIN. Yes. We are constantly doing that kind of review, to see what the policies should be, on a broad scale, for all means of transportation.

Mr. GOLDWATER. It seems to me you are putting the cart before the horse, if you are waiting for the technology to evolve.

I think we have testimony that indicates the technology is evolving quite rapidly, and in fact, there are some STOL aircraft being used today in commuter markets.

How much longer do you have to wait before you begin to take a leadership role, in perhaps driving this technology in the right direction?

Mr. PAULLIN. We feel that two of the most important requirements today, in terms of any mode of transportation, are fuel conservation and environmental acceptability of the mode of transportation. In

that sense, we are in total agreement with NASA's efforts to develop fuel efficient aircraft, including fuel efficient STOL technology, and reduce noise around airports. We are focusing on those two as being the social requirements. As I tried to indicate earlier, we feel that with the evolution of STOL technology, that the existing and planned air traffic control system, and the airport system which is already in existence, will be capable of handling adequately and safely the STOL requirements that emerge.

Mr. GOLDWATER. That is commendable, but you are really only addressing yourself to component parts or functions.

When do we begin seeing DOT move into a position of leadership of defining the parameters around meeting the market?

Mr. PAULLIN. As I said earlier, sir, we have that question under review. As results from our deliberations emerge, they will be integrated into the program of the Department. I cannot give you a specific date at this time.

Mr. MILFORD. The gentleman's time has expired.

Mr. Glickman?

Mr. GLICKMAN. I have one question. I am fairly new to this whole ball game.

I am a little bit new on the definition of STOL. I assume it has to do with runway length, and takeoff and landing, that is what its acronym seems to say, and also the number of passengers.

Congressman Goldwater alluded to the commuter. I wonder if you would tell me what the definition of the STOL aircraft is, and in terms of research and development, how does this apply to general aviation, where you have some aircraft that can take off and land at 2,000 feet, or 2,500 feet, or also carry 15, 20, 25 passengers.

Maybe we are boxed in on a STOL aircraft that is a 150-passenger jet, that can take off in 1,500 feet.

What about the aircraft we presently have, are we doing anything to improve those?

Mr. PAULLIN. Let me respond to your question of the definition of STOL. To my knowledge that is one of the questions still open for debate. There is no set definition of STOL. Most often STOL is referred to in terms of landing distance, and the numbers used are 2,000, 3,000, 4,000, and 5,000 feet. In general, the air carrier aircraft, the DC-9's, 727's, et cetera, need greater than 5,000 feet. Those that take less than 2,000 feet are truly STOL, in the sense that they are a different category of aircraft. In between is a category called reduced take-off and landing.

Mr. GLICKMAN. I am still a little bit confused, as to where would this technology take us.

I suppose it depends on what the users want, what sort of a market it is, but I see that we may be able to develop some sort of short takeoff and landing market, through the technology already in general aviation, by carrying, let us say 30 or less passengers.

Is this part of the DOD's framework in looking at the future of STOL?

Mr. PAULLIN. Well, certainly it is included in the framework. In the perspective we are talking about, all forms of transportation are included. Smaller aircraft and larger aircraft, are included.

The technology which NASA has underway now is oriented toward those aircraft which carry more passengers. It is in that area where we

do not have the technology in hand, so we can define the aircraft which I explained would then help determine the characteristics of the airports, and the air traffic control system.

Mr. GLICKMAN. Thank you.

Mr. MILFORD. If it would help you any, I have had it explained to me. There are four TOLS, the V/TOL, the STOL, the R/TOL and the C/TOL. In runway lengths, the vertical landing is zero, and that for the short takeoff and landing, or STOL is zero to 2,000 feet, and the reduced takeoff and landing, 2,000 to 5,000, and conventional takeoff, above 5,000.

Mr. GLICKMAN. There are general aviation aircraft, twin-engine aircraft that can take off at less than 2,000 feet.

Mr. MILFORD. Yes; they fall within that category, but I believe the NASA category is aimed at certain lift technologies.

Mr. Goldwater, do you have any further questions?

Mr. GOLDWATER. Mr. Paullin, in your statement on the first page, you state as in any type of transportation system, STOL must demonstrate market demand, system technology, and economic feasibility.

You are pumping billions of dollars in the Northeast corridor, and into other rail systems.

Would you say the rail systems meet those criteria?

Mr. PAULLIN. Mr. Goldwater, I would rather not speak at this time to the question of the rail system. I feel more prepared to talk about STOL aircraft.

Mr. GOLDWATER. You mentioned it in your statement.

You are implying that if you are showing leadership in the area of rail transportation, they must therefore meet those three criteria.

Mr. PAULLIN. That is the rail technology, sir?

Mr. GOLDWATER. Yes.

In other words, as with any type of transportation system, I would assume, you are saying that STOL does not meet those criteria, I would assume then therefore that the rail system does.

Would that be a logical conclusion of the attitude by DOT?

Mr. PAULLIN. It is fair to say that there is a substantial rail infrastructure in being at this time.

Mr. GOLDWATER. You mean there are rail lines running across the country?

Mr. PAULLIN. Yes.

Mr. GOLDWATER. There is quite an infrastructure of air traffic control across the country too, which would be the same thing.

We have railroads and rail lines in the sky, with a lot more flexibility.

Mr. PAULLIN. I am smiling, because when you said rail lines in the sky, I'm reminded of my early days as an Air Force pilot, when I was told never to fly down a railroad track, because I might meet a Navy pilot coming in the other direction.

Mr. MILFORD. Use the rivers.

Mr. PAULLIN. Use the rivers, yes.

Mr. GOLDWATER. I cannot understand why the Department of Transportation is putting so much emphasis on rails and other modes of transportation, but they completely ignore the potential for STOL, or vertical takeoff, or what have you.

They are critical of it, they deemphasize it, they do away with the offices, they show no leadership in ironing out these many barriers in the way of STOL application.

Mr. PAULLIN. The Department stands ready at any point in time to remove institutional barriers for any mode of transportation.

Mr. GOLDWATER. Let me ask you a question in that regard.

What are you doing to eliminate institutional barriers that are affecting the future growth of air commuters, and I will give you an example.

The conflict between CAB and the FAA on weight and passengers, what are you doing to eliminate those barriers that are prohibiting manufacturers from building aircraft that the commuter needs?

Mr. PAULLIN. I am not intimately familiar with that sir. I am only on the edges of those conversations. I could only give my personal opinion.

Mr. GOLDWATER. Well, the CAB and the FAA have two different weight and passenger requirements.

The commuter in certain markets finds himself with growing demand, but because of these regulations, he cannot buy aircraft that will have the higher capacity, both passengerwise and weightwise to meet that market.

Now, DOT was originally created to provide leadership and direction to iron out some of these difficulties, so we do have a smooth-flowing transportation system.

Now, we have a growing market in the commuter area, and in fact STOL would be a potential customer for that.

The commuters are growing by leaps and bounds. There is a definite market for that, and yet the commuter operator finds himself with institutional barriers in front of him. One of them is the conflict between FAA and CAB on weight and passengers.

There are other problems. Because they are unregulated from the CAB standpoint, they have difficulty in obtaining financing for new aircraft, and as a result, they often tend to operate on a marginal side of safety, using older aircraft, or aircraft that are perhaps not the best type of equipment for that market.

It seems to me the FAA should step into this void, and iron out these problems. Airline companies want to grow to meet this demand. The DOT should be providing the leadership. If you open up that market, I would contend that manufacturers would begin to respond by coming up with new configurations and new types of aircraft, maybe with an STOL type of capability, but because of the institutional barriers, the manufacturers are reluctant to respond. So what are you doing about this?

Mr. PAULLIN. We are not sitting back and taking a hands-off approach.

The thing we are doing is looking at STOL in the context of viability for all transportation systems. Insofar as the institutional differences between the FAA regulations and CAB regulations, I know that problem is being reviewed within the Department. I cannot report to you today what the status is, or when we might have something forthcoming. Insofar as STOL is concerned, within the context that we have been discussing it, the review by GAO and the NASA program, that we are up to speed with the NASA activities, and are in-

cluding it, the potential results of their technology in our determinations.

Mr. GOLDWATER. Well, I would contend that you are not up to speed.

GAO was critical of DOT from the standpoint of not having a national transportation system plan. It does not make sense to continue with STOL technology, and that we ought to assess that technology.

What we see all the time is a tremendous emphasis upon rail, with little consideration for future needs in the area of aviation. In fact, in your statement, you say that there is no market demand, that system technology is not here, that economic feasibility is not here.

Well, the question I ask is, What are you doing to overcome those things, what kind of leadership are you providing?

In the CARD studies, it said that a program should be established to determine accurately the market sensitivities to changes in services. You created this office, you took a short look at it, and then you abolished the office, and you are not doing anything about it right now.

NASA and the Department of Defense seem to be going along in the technology development, which is good, and you seem to support them, but they are floundering in looking for a place to set this technology down. Industry is floundering, not knowing really what kind of market they should be looking at, or what kind of aircraft will be required because there has been no definition of it, and on top of that, the Department of Transportation has refused to tear down the barriers that are in the way of developing this market. I did mention the commuter airlines, they desperately need to increase their capability to meet the market.

Now, we have a situation with Air New England, where they went from FAR 135 status up to a full certified airline, and they almost went bankrupt because it was too big of a jump, and they had not reached the financial stage where they were able to take on this additional burden. So I do not see any kind of leadership.

I would admit that it may be way off before we start applying this, but I think we have got our heads in the sand, if we close the door on the potential of STOL in meeting the demand for transportation, and I would just like to see you do a little bit more in this area.

Mr. PAULLIN. Although I am not intimately familiar with the proposals, last year we did have a regulatory reform proposal to increase the weight and passenger limits.

Mr. GOLDWATER. I recognize that you and the CAB are finally starting to get together, but only after the urging of this committee and the other committee, on Interstate and Foreign Commerce. It is sad that you had to wait until a committee in the Congress urged you to do so, but it is encouraging that you are beginning to, and I would like to see you continue on in that vein, and look at other barriers that are standing in the way of progress.

The certificated carriers' business is primarily long haul, using bigger equipment and higher capacity, where, as the commuter is struggling to meet a growing market, and yet, because of Government regulations, there are barriers in front of him, and DOT if it is going to serve its proper function, it seems to me ought to be stepping into that void, analyzing those barriers, and seeing what could be done to eliminate them, and at the same time, providing some guidance to industry

and to NASA and DOD, as to where this technology could conceivably fit.

I do not argue with you that rails also have some potential, but I would not say that the rail system meets those three tests of market demand, system technology, and economic feasibility.

Economic feasibility, I do not know how many billions of dollars we are pumping into the rail system, and it does not even begin to buy a front tire, and yet you seem so confident that the rail is going to meet all our transportation needs. You are placing 90 percent of your emphasis there, and yet here is a potential of applying aerodynamics, the state of the art of which is here, but needs refinement, needs direction, needs a place to come down in, and there is no leadership, and I think that is the kind of thing we are critical about.

Thank you, Mr. Chairman.

Mr. MILFORD. Just so our record would not mislead someone, the gentleman from California had made a statement, perhaps it was inadvertent, about our air carriers operating on a margin of safety. You would not infer that it would be unsafe to ride in them?

Mr. GOLDWATER. Absolutely not, because there is not the profit margin there, because of economics, they are not in a position I feel to adequately address themselves to some of the things they need, as far as equipment, new aircraft, upgrading of equipment, and what have you.

Mr. MILFORD. I totally agree with the gentleman.

Mr. GOLDWATER. I think our commuter system does a pretty good job and is operating in a very hazardous climate.

We need to do more to make commuter service safer. I am not inferring that they are not operating in an unsafe manner.

I am saying there is a lot we can do to make aviation safer, especially in this area of commuters. You have in Los Angeles, very dense areas of population, and there are a lot of things we can do to make it safer to fly in the Los Angeles Basin.

Mr. MILFORD. I would agree with the gentleman that there is a need for much more economically viable types of aircraft, larger capacity aircraft, and the point made concerning the weight limitation placed on them is absolutely correct.

I thought perhaps inadvertently you let that in, and I wanted to be sure you got the record straight, because the safety of air commuters is outstanding, and I would not want anybody to think it would be unsafe to travel on the air commuters.

We thank you very much for your testimony, Mr. Paullin.

We appreciate your taking the time.

Due to the fact that the type of testimony presented to this committee is technical in nature, and the fact that some of our members could not be here, we ask that any member of the subcommittee have the right to submit additional questions to you within the next 10 days, and you would respond to those questions within the following 10 days, and that both the questions and answers become a part of the record.

Mr. PAULLIN. Yes, sir, we would be happy to do that.

Mr. MILFORD. Thank you very much.

The subcommittee will stand adjourned until next Tuesday at 1:30 in room 2318.

[Whereupon, the subcommittee was recessed at 3 p.m.]

APPENDIX

STATEMENT OF CLIFTON F. VON KANN, SENIOR VICE PRESIDENT, OPERATIONS AND AIRPORTS, TRANSPORT ASSOCIATION OF AMERICA

VIEWS OF THE SCHEDULED AIRLINES ON THE NASA FISCAL YEAR 1978 AERONAUTICAL RESEARCH AND TECHNOLOGY PROGRAM AND BUDGET

We have noted that the NASA budget plan, released coincidentally with the President's budget message, proposes a substantial increase in fiscal year 1978 R. & D. expenditures in the field of aeronautics. We believe that this is a healthy sign, and that NASA is moving back to its traditional role as the world leader in aeronautical research and development.

It is hardly necessary to stress the importance for the United States to maintain world leadership in aeronautics both civil and military. The United States aircraft are preeminent throughout the world, and the airlines of the world operate over 90 percent using United States designed and U.S.-built aircraft. The impact on our balance of payments and peripheral benefits to our industry and foreign relations are well recognized. To maintain this position requires a strong continuing effort—an effort in which NASA must provide the cutting edge.

NASA has demonstrated time after time its ability to solve complex problems and to provide breakthrough developments even in a mature technology as represented by aeronautics. This is a vital input to the aviation industry, because there is probably no other field of endeavor where the payback for effective research and development is as great as in our industry. During the past fifty years, the airline industry has developed into an integral and necessary part of our economy; and, because of unanticipated problems, it has recently been forced to take unusual measures for its very survival.

As a result, the need for solution to pressing problems is greater today than ever before. Because of these immediate problems, there is difficulty in choosing between programs that will provide some immediate relief and those having long-term significance. Nevertheless, a balance must be struck between the immediate and long-term needs of the industry—to neglect the long-term programs is to simply push our problems off into the future.

In our 1977 testimony, we gave a list of programs based on the priority of airline problems. There has been no drastic change in the order of content of this list. Our testimony today will review these programs in light of airline developments and program progress during the past year as related to 1977 problems as we see them. Although not on the list of priority items, safety is a most important part of every program. The airline safety record, which is a source of great pride to the industry, must be the subject of constant vigilance.

We would like now to discuss those programs which the airlines feel deserve the greatest attention and resources in the NASA program.

The airlines solidly reaffirm their interest in the Fuel Conservative Aircraft and its importance to the long-term future of the industry. The bitter lessons learned as a result of the oil embargo have caused this program to be placed high on the priority list. The recent fuel shortage due to the long period of cold weather emphasizes again the critical importance of this program.

A truly important reduction in fuel consumption is a key to the ability to finance the modernization of the airline fleet, and to achieve this will challenge almost every discipline concerned with airline aircraft design and production. It includes:

Full exploitation of new aerodynamic developments such as the supercritical wing and winglets.

Work in propulsion technology.

Development of the variable cycle engine.

Investigation of compressor blade seals.

Use of higher turbine inlet temperatures and similar improvements.

These and many other programs designed to increase efficiency and fuel conservation of jet engines are keyed to the Fuel Conservative Aircraft.

The second item of major interest to the airlines is noise analysis and abatement. The problem of noise and its restrictive influence on airline operations is well known and need not be elaborated upon. We note that NASA seems to be concentrating on noise reduction in peripheral areas such as the Quiet, Clean Shorthand Experiment rather than on programs leading to noise reduction that will help the mainstream of aviation. Perhaps more effort needs to be expended in this area. The present method of rating aircraft noise leaves much to be desired, and the lack of correlation between decibel levels and annoyance to the persons affected is a strong indication that we are operating in an area that is not well understood. We must find out exactly what produces the annoyance; this is a subject for psychoacoustic research.

The variable cycle engine (VCE) shows promise of true reductions in noise level and improved efficiency for future engines; we think that the concept should be given a good chance to prove itself.

There appears to be a lack of predictability of noise in the design of new engines indicating that the noise sources need further analysis and understanding. More study of the fundamentals of noise propagation within jet engines should provide the understanding necessary to design quiet engines on a more confident basis.

Third in our list of priority items is aircraft operational efficiency, productivity, and reliability improvements. Many of the improvements sought by the airlines to increase efficiency, productivity, and reliability will be a natural fallout of a well-executed, Fuel Conservative Transport Program; and the two subjects cannot be completely separated. Special attention needs to be paid to the way airline aircraft are operated and research directed in recognition of these factors. Climb and descent characteristics dictated by the Air Traffic Control System, braking effectiveness, and tire wear are typical of factors influencing the suitability of an aircraft for airline type operations. Airlines are always seeking ways to reduce maintenance delays. With hundreds of passengers aboard and multi-million dollar aircraft involved, reliability takes on greatly increased importance; and NASA has a legitimate role in the development of technology which will lead to long-term improvement in reliability of operation.

NASA's weight reduction programs are typical of the research that will contribute to the operational desirability of airline aircraft, and we support the continuation of such programs.

We are monitoring a number of specific NASA programs which we feel should contribute to the betterment of airline aircraft in these areas I have just discussed. These include:

- The efficient engine program.

- Variable cycle engine (VCE).

- Integrated programs for aerospace vehicle design (IPAD).

- Thermal barrier coatings for turbine blades.

- Ceramic turbine blades.

- Abradable ceramic seals.

We also believe that there should be continued effort in:

- Active control technology.

- Stability augmentation systems.

- Improved runaway surface traction.

- More dependable and safer evacuation and escape systems.

- Lightning protection research.

- Improved deicing methods both integral and ground support.

- Cabin interior research in the areas of insect control, odor elimination, and contaminant removal.

- Fire prevention and control research.

Our fourth priority item involves propulsion systems and alternate energy (fuel) sources.

The airlines continue to be interested in a research program having as its objective propulsion systems.

Transition to fuels other than those currently in use by any industry would entail many problems but would be particularly difficult for the aviation industry. For this reason and since the airlines use less than 4 percent of the petroleum consumed in the United States and have an excellent record of fuel conservation (see attachment), NASA research on alternate fuels for aviation should be considered for long term—not short term—potential application.

Number five on our priority list is human factors research. We have given strong support to the NASA human factors program in the past and will continue to endorse those programs which can make positive contributions in areas such as approach and landing and in air traffic control. Included in this category are such programs as cockpit warning systems. Today's airplane pilot is faced with an assortment of horns, buzzers, lights, urgent voices, bells, or shaking controls to warn him of malfunction or a trend toward a dangerous situation. A systems approach is needed to organize the cockpit warning systems in a manner which will indicate the level of urgency and whether the need is for immediate or delayed response. Too many accidents have happened in the past merely because of either false or misleading warnings. We know FAA is doing work in this area and NASA's work should compliment these efforts.

Cockpit instrumentation continues to be an important subject for human factors research, and we know there is much room for improvement in this area.

We certainly do not include in our endorsement programs such as the NASA-sponsored study of "Passenger Satisfaction." This program was described at the Technical and Operational Symposium held at Langley in October. We feel strongly that this subject is the province of the marketplace, and that the term "human factors" used in this context is a misinterpretation of NASA's proper research direction.

Our sixth priority item is a program of research in airframe/aeronautical design structures and materials. The output of this program can play an important part in the high priority Fuel Conservative Transport program because of the efficiencies which can develop from successful research. The subject runs the gamut of technologies. It is from this source that we expect to get some relief from the escalating costs of materials and structures. We have been briefed on some NASA programs which promise important reductions in material and construction costs.

Among the programs which we see as having potential for airline applications are:

Integrated programs for aerospace vehicle design (mentioned earlier in this testimony).

Super plastic forming diffusing bonding of titanium structures. If this program meets the expectations of NASA, it can have a significant effect on the reduction of cost and improvement in the efficiency and maintainability of aircraft.

Composite primary structures offers weight-saving and simplification desirable for airline aircraft.

The airlines do not agree with large expenditures in several areas being pursued by NASA. Examples include:

Expensive and complicated fuel inerting systems.

Exotic approaches to reducing noise.

However, there are some other areas in which the airlines believe NASA could make a valuable impact. For example:

Wake turbulence prevention at the source

The elimination of the effects of wake turbulence carries the highest airline priority in the list of FAA programs. However, the elimination of wake turbulence at the source is a long-term program and therefore receives a lesser priority; but one that is nevertheless an extremely important program which could have long-term significance in overcoming this difficult problem. The major emphasis at the present time is detection and alerting of wake vortices; and we hope that the development of satisfactory systems of this type by the FAA will provide relief until the basic problem is solved by NASA.

Flight control avionics

We urge NASA to continue the program of active controls research because of the potential benefits possible through the elimination of structural weight now necessary to accommodate gust and turbulence forces.

The Terminal Configured Vehicle Program offers opportunities for validating instrumentation and flight control concepts not available by other means, and should be pursued actively. We feel that last year's program with the TCV was to some extent dominated by microwave landing system research; and while we recognize the need for solving problems in this area, we are concerned that this was done to the detriment of other programs. The work being done on the

Airborne Traffic Situation Display (ATSD) will be of interest to us; however, it does not require large expenditures.

Lightning

We have been advised that lightning research is being moved from Lewis to Langley. Although lightning has been more of an annoyance and an expense than a danger to airline operations, we feel that a continuing effort in this area is important. There are many things we do not know about the effects of lightning strikes on the new composite structures and on some of the new solid state electronic systems. There is also concern about the effect of lightning on fly-by-wire and control augmentation systems.

Atmospheric research

Of great importance is a better understanding of the conditions producing hazardous wind shears. Such research may lead to better methods of detection and to a more accurate determination of flight performance, control and structural requirements for aircraft.

The program of atmospheric research has important implications to airline operations particularly as air transport aircraft approach higher and higher altitudes and into areas of higher ozone concentration.

SUMMARY

It is evident from the preceding remarks that the airlines are counting heavily on NASA Research and Development for relief from many of the problems confronting the industry. It will be a true test of NASA's ingenuity and skill to increase efficiency of aircraft operations at a pace that will offset the mounting fuel costs and/or shortages.

It is for this reason that we support the increase in NASA aeronautical R. & D. and encourage those programs which will contribute to safety, reliability, efficiency, and noise reduction.

We have called attention to several items in which the airlines have little interest and believe to be outside of the basic objective of NASA programs. These, however, are minor and we strongly support the general thrust of the NASA effort.

We believe a great many of the R. & D. efforts included in the program come together in the Fuel Conservative Transport and that this represents the final product of a number of individual programs. The airlines will monitor this program with great interest and anticipation. Its successful conclusion could be the key to a sound future for the airline industry.

STATEMENT OF HON. PAUL S. TRIBLE, JR.

Mr. Chairman, the National Aeronautics and Space Administration is seeking approval of its budget request for more than \$4 billion. About \$160 million of which is earmarked for construction of facilities.

Of the funds for the construction of facilities, approximately \$13.5 million is designated for a project to upgrade a 40- by 80-foot wind tunnel at the Ames Research Center in California. It is the first installment in a project estimated to cost up to \$90 million. Another three-quarters of a million dollars is to be used for construction of a helicopter hangar at Moffett Field, California.

On top of these expenditures, an additional \$5 million will be applied toward the acquisition of a Cyber 175 computer to augment current flight simulation efforts.

All of these expenses, Mr. Chairman, will be borne by the taxpayers because of a decision made last summer to relocate NASA's helicopter research and development facilities from the Langley Research Center, where most of these facilities already exist, to the Ames Research Center, where these facilities would have to be built.

I am in complete sympathy with the desire of the NASA Administrator to consolidate facilities for reasons of mission suitability. This is the prudent course of action under normal circumstances.

However, Mr. Chairman, it is my firm belief that insufficient consideration was given by NASA Headquarters to the fiscal impact of the proposed relocation, and that NASA's current budget request—specifically the items I previously mentioned—cannot be justified.

According to the Comptroller General of the United States, in a letter of November 30, 1976, a cost study of the proposed relocation "was not of sufficient depth and scope to determine the total costs which may result from the decision."

To me, Mr. Chairman, this means that the Comptroller General was unable to evaluate the cost-effectiveness of the proposed relocation because NASA had not properly studied all the fiscal ramifications of the proposal before making it.

The NASA Administrator is on record as saying that costs were not a major factor in the decision to relocate the facilities from Langley to Ames. He was concerned only with mission suitability.

I submit, Mr. Chairman, that the Administrator's attitude displays a woeful lack of appreciation for the taxpayers' dollars, and indicates the need for a quick course in financial management and responsibility for the Agency's top Administrators.

Mr. Chairman, I would respectfully suggest that before this committee approves the current budget proposal as submitted by the Agency, NASA officials be required to explain and justify any expenditures related to the proposed relocation. Moreover, NASA should be required to prepare a thorough and complete cost-effectiveness study of the proposal before the current budget request is acted upon.

Thank you for your courtesy, Mr. Chairman.

RESPONSES TO QUESTIONS SUBMITTED BY THE SUBCOMMITTEE

Question 1. Please furnish a tabulation, by major program, for the fiscal year 1978 budget of the:

- (a) Original recommended budget to OMB;
- (b) Adjustments made;
- (c) Submission to Congress;
- (d) Brief comment on the adjustments made if any; and
- (e) Comparative fiscal year 1977 final operating plan figure.

Answer. See attached table.

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY FISCAL YEAR 1978 BUDGET PROCESS

[In thousands of dollars]

	Fiscal year 1977 operating plan	Fiscal year 1978 budget to OMB	Changes	Fiscal year 1978 budget to Congress	Comments
Aeronautics.....	190,100	245,600	-14,600	231,000	
R. & T. base.....	89,140	95,960	+1,590	97,550	\$1,400,000 reduction offset by \$3,000,000 increase specified for basic research.
Systems studies.....	2,935	3,000	-----	3,000	Management and funding responsibilities for technology associated with lift cruise fan research aircraft assigned to Navy; deletion of hypersonic research vehicle proposal; and minor reductions in various technology activities.
Systems technology programs..	57,145	79,190	-6,990	72,200	
Experimental programs.....	40,880	67,450	-9,200	58,250	
Lift/cruise fan research aircraft.....		4,200	-4,200	-----	Management and funding responsibilities for lift cruise fan research aircraft assigned to Navy.
Energy efficient engine.....	6,440	18,500	-----	18,500	ACEE program element.
Composite primary aircraft structures (CPAS).....	14,890	30,150	-5,000	25,150	Undistributed ACEE cut taken in CPAS.
Other.....	19,550	14,600	-----	14,600	

Question 2. Please furnish a tabulation, by NASA center and by major program, for fiscal year 1978 budget, of the:

- (a) Original center request to NASA Headquarters;
- (b) Adjustments made;
- (c) Brief comments on adjustments made;
- (d) Submission to Congress as allocated by center; and
- (e) Comparative fiscal year 1977 final operating plan figure, by centers.

Answer. See attached table.

ANALYSIS OF CHANGES FROM CENTER SUBMISSIONS TO FISCAL YEAR 1978 CONGRESSIONAL BUDGET SUBMISSIONS

[In thousands of dollars]

	Fiscal year 1977 operating plan	Fiscal year 1978 center request ¹	Fiscal year 1978 budget	Difference	Explanation
Aeronautics.....	190,100	279,532	213,000	-48,532	
JSC.....	810	1,840	810	-1,030	Reduction in proposed buildup of R. & T. base activities.
MSFC.....	750	1,149	950	-199	
GSFC.....	100				
JPL.....	915	1,070	1,000	-70	
WFC.....	490	500	500		
ARC.....	34,026	43,361	37,700	-5,661	Management and funding responsibilities for lift cruise fan research aircraft assigned to Navy.
DFRC.....	17,863	16,894	14,250	-2,644	Reduction of proposed increases to ongoing system technology program.
LRC.....	80,355	130,516	99,950	-30,566	Rescoping of composite primary structure technology demonstration and reduction in proposed new starts.
LeRC.....	52,764	80,702	72,350	-8,352	Reduction in proposed buildup of R. & T. base activities.
HQ.....	2,027	3,500	3,490	-10	

¹ Reflects POP 76-2 submission (space BLI adjusted to include low cost payload technology) and proposed initiatives iterated with Center Directors and submitted to the Administrator Aug. 13, 1976.

Question 3. Please furnish by major line item, the NASA operating plan for fiscal year 1976 and fiscal year 1977, with comments on adjustments, if any.

Answer. There has been no change to the aeronautics operating plan of \$175.4 million for fiscal year 1976. The fiscal year 1977 operating plan of \$190.1 million reflects an increase of \$1 million to augment the variable cycle engine components systems technology efforts, based on the recommendations of the Authorization Committee of Conference Report, 1977, to the extent feasible within congressional appropriations action.

Question 4. Please provide a tabulation for experimental programs, the projected total costs including:

- (a) Original estimate date and amount;
- (b) Current estimate; and

(c) NASA's estimate of what portion of any increased cost may be due to inflation and NASA's basis for the inflation calculation.

Answer. See attached table.

AERONAUTICS MAJOR PROJECT TOTAL COST HISTORY

[In millions of dollars]

Original estimate			Current estimate	Comments
Date		Estimate		
Experimental programs:				
Composite primary A/C structures (CPAS).....	September 1975..	147.5	148.8	Reflects restructuring of program.
Energy efficient engine (E).....	do.....	178.9	173.5	Do.
OPLT.....	February 1974..	35.2	35.2	
OCSEE.....	June 1973.....	33.8	33.9	
TRRA.....	February 1972..	21.6	21.7	
RSRA.....	do.....	17.6	19.0	Reflects redesigning costs and unanticipated man-hours required for fabrication and flight testing portions of program.
HIMAT.....	February 1974..	15.1	18.1	Reflects contractor proposals leading to baseline estimate of \$18,100,000.

Note: None of the above changes is due to inflation.

Question 5. Please furnish, by major program, the unobligated balance of funds for fiscal year 1976, transition, and fiscal year 1977 and the actual or estimated carryover.

Answer. The attached table provides the status of obligations as of December 31, 1976.

All of the funds are planned for obligation by the end of fiscal year 1977. Historically, however, there remains a relatively small amount of R. & D. funds in the procurement pipeline which is technically unobligated at the end of the fiscal year. This amount, statistically equivalent to a few weeks of procurement activity, is normally legally obligated in the next fiscal year. The level of unobligated balances in both the fiscal year 1976 and Transition Quarter are reflective primarily of the impact of the revised program implementation plan for Quiet Propulsive Lift Technology Program (QPLT), and the redirection of several ongoing programs in support of the new Aircraft Energy Efficiency (ACEE) activity. These efforts are progressing on schedule and current balances will cover contract requirements during the current year.

AERONAUTICS RESEARCH AND TECHNOLOGY STATUS OF OBLIGATIONS AS OF DEC. 31, 1976

[In millions of dollars]

	Fiscal year 1976			Transition quarter			Fiscal year 1977		
	Pro-gram	Obligated	Unobligated	Pro-gram	Obligated	Unobligated	Pro-gram	Obligated	Unobligated
Aeronautics.....	175.4	153.0	22.4	43.8	33.0	10.8	190.1	37.6	152.5
R. & T. base.....	84.7	82.1	2.6	21.0	18.0	3.0	89.1	23.6	65.5
System studies.....	2.7	2.7	-----	.6	.1	.5	2.9	.1	2.3
Systems technology programs.....	42.2	36.7	5.5	13.1	8.9	4.2	57.2	7.7	49.5
Experimental programs.....	45.8	31.5	14.3	9.1	6.0	3.1	40.9	6.2	34.7
Energy efficient engine.....	2.1	.9	1.2	.7	-----	.7	6.4	-----	6.4
HiMAT.....	4.9	4.9	-----	1.8	1.7	.1	5.5	2.5	3.0
Comp. primary A/C struct. (CPAS).....	4.0	3.9	.1	1.7	.1	1.6	14.9	-----	14.9
QCSEE.....	10.0	10.0	-----	2.0	2.0	-----	3.3	-----	3.3
SCAR.....	8.8	8.7	.1	2.1	1.8	.3	8.0	3.3	4.7
TRRA.....	2.0	.5	1.5	.3	.1	.2	.8	-----	.8
RSRA.....	3.1	1.9	1.2	.1	.1	-----	.3	-----	.3
QPLT.....	10.9	.7	10.2	.4	.2	.2	1.7	.4	1.3

Question 6. Please provide an itemized (by budget line item) accounting of the funds planned for fiscal year 1977 and requested for fiscal year 1978 in each of the following applications and functional categories:

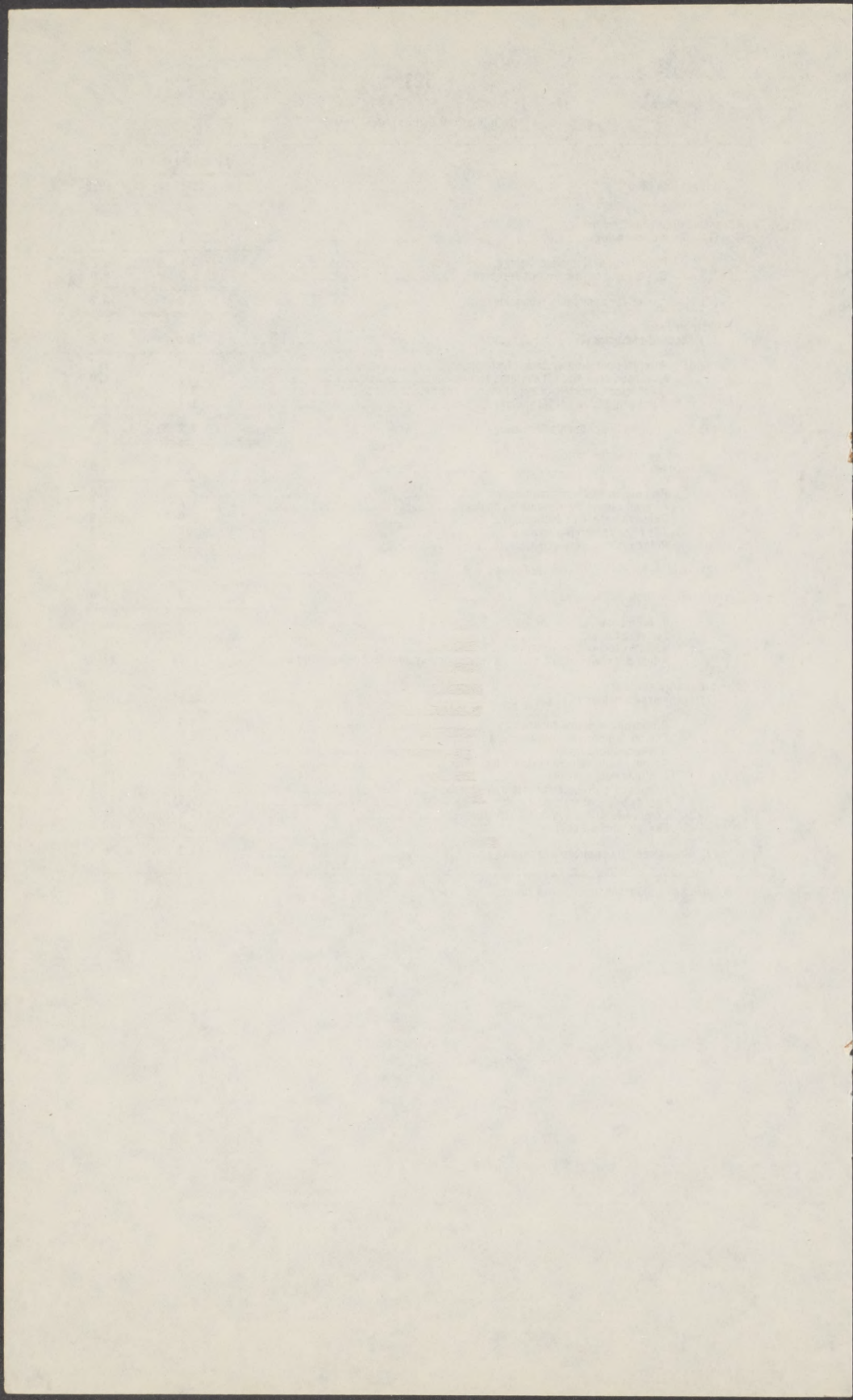
- Advanced supersonic technology;
- STOL technology;
- VTOL technology;
- Agricultural aviation technology; and
- Aircraft energy efficiency.

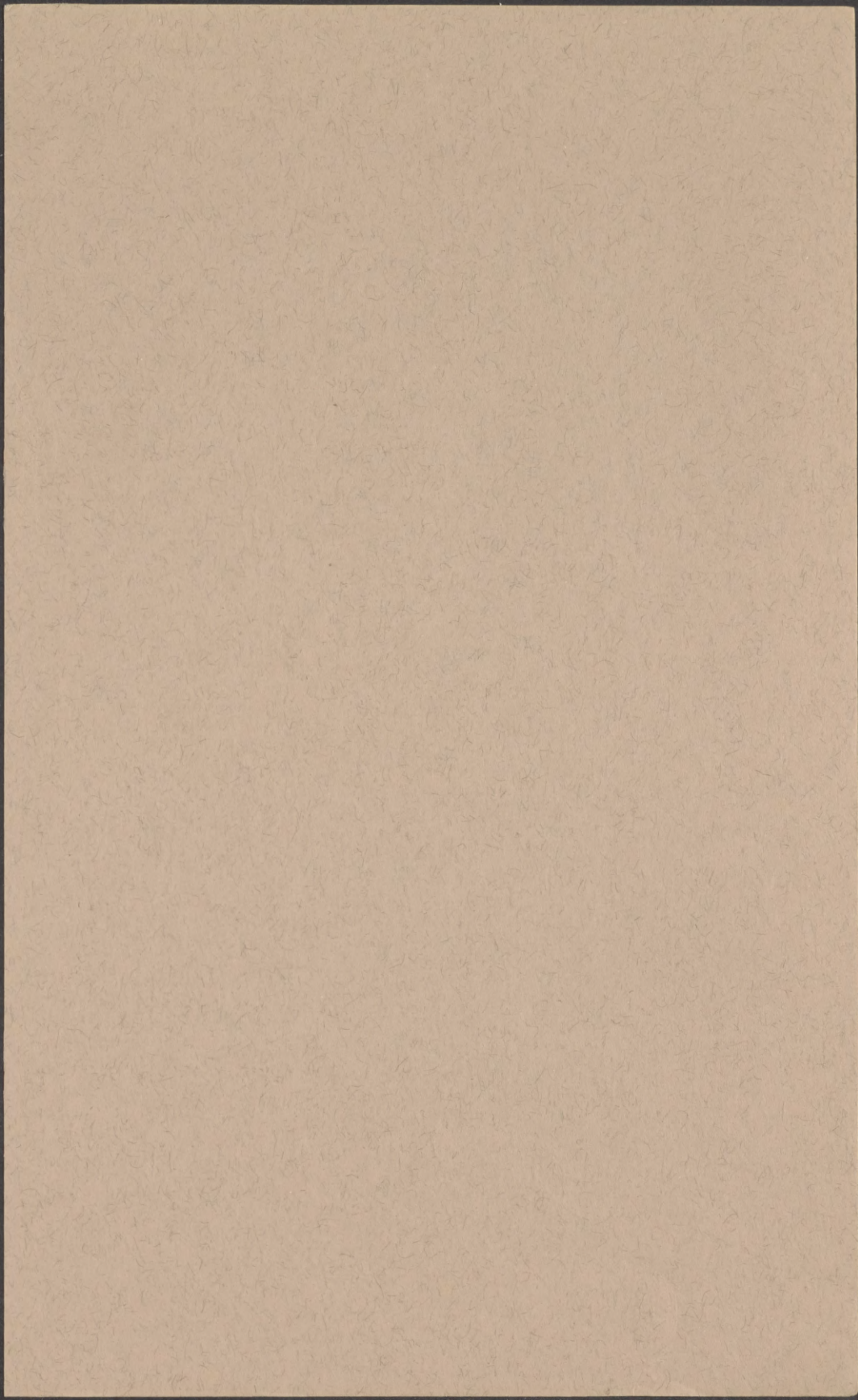
Answer. An estimate of the funds supporting the specified applications and functional categories is given below. In evaluating these estimates, it should be realized that a given piece of R. & T. effort, particularly R. & T. Base effort, can simultaneously support several applications and functional categories.

[In millions of dollars; fiscal years]

Budget line item	Estimated R. & D.	
	1977	1978
a. Advanced supersonic technology:		
(1) Focused technology.....	11.1	15.2
Propulsion systems technology.....	3.1	6.2
Supersonic cruise aircraft research.....	8.0	9.0
(2) More generally applicable technology.....	17.8	18.2
b. STOL technology:		
(1) Focused technology.....	7.1	5.2
Aircraft operating systems technology.....	1.8	1.7
Advanced civil aircraft systems technology.....	.3	1.0
Quiet, clean short-haul experimental engine.....	3.3	.6
Quiet propulsive lift technology.....	1.7	1.9
(2) More generally applicable technology.....	7.2	7.9
c. VTOL technology (includes helicopters):		
(1) Focused technology.....	4.6	5.9
Propulsion systems technology.....		1.0
Aircraft operating systems technology.....	1.6	1.7
Rotorcraft systems technology.....	1.9	2.9
Tilt rotor research aircraft.....	.8	.3
Rotor systems research aircraft.....	.3	
(2) More generally applicable technology.....	14.1	16.1
d. Agricultural aviation technology.....	1.7	1.0
R. & T. base.....	1.3	
System studies.....	.2	
Systems technology programs.....	.2	1.0
Advanced civil aircraft systems technology-system technology studies.....	(.2)	(1.0)
e. Aircraft energy efficiency:		
(1) Focused technology (CTOL).....	39.6	70.2
Propulsion systems technology.....	8.5	12.0
Engine component improvement.....	(8.5)	(10.0)
Advanced turboprops.....		(2.0)
Aerodynamic vehicle systems technology.....	4.0	1.1
Laminar flow control.....	(4.0)	(1.1)
Advanced civil aircraft systems technology.....	5.8	13.4
Energy efficient transport.....	(5.8)	(13.4)
Composite primary aircraft structure.....	14.9	25.2
Energy efficient engine.....	6.4	18.5
(2) More generally applicable technology.....	40.3	46.7

¹ Includes \$200,000 transition quarter funds.







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