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NASA OUTLOOK FOR AERONAUTICS

APPENDIX B

MARCH 1976

THE OUTLOOK FOR AERONAUTICS 1980-2000

APPENDIX B

STUDY GROUP REPORT ON AN INDUSTRY-UNIVERSITY-GOVERNMENT SURVEY

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INTRODUCTION

In light of NASA's close involvement with the U.S. aviation industry, with other government agencies (e.g., Department of Defense (DOD), Department of Transportation (DOT)), and with the universities, it was extremely important for the Study Group to obtain their views on the outlook for aeronautics, 1980-2000. Therefore, a comprhensive Survey of a large number of key representatives of the aeronautical community was conducted during the period of August, 1974 to September, 1975 at the request of the Nasa Administrator. Personal visits by the NASA Study Group team were made to 38 companies and industry representatives (e.g., Air Transport Association of America (ATA), Aerospace Industries Association of America, Inc. (AIA) and 21 local and federal government offices. In many cases, the Study Group was given specially prepared technical presentations which served to further stimulate discussion. In addition to the personal visits, 14 survey letter responses were obtained from engineering departments of leading universities with strong interests in aeronautics. While a complete coverage of all of the organizations involved in aviation was not possible, a sufficient number was included to provide a broad representation from each segment.

The Survey covered a wide range of topics relating to aviation but was focused on the three primary subjects of interest to the Study, namely:

- The *Future Directions* of aeronautical development for the remainder of the 20th century
- The *Role of NASA* and its relationship to industry and other government agencies
- The potential *Technical Programs* that may be required in aeronautics.

Prior to each visit, a list of questions regarding the above subjects was submitted to each organization. These questions were not intended to bound the discussion but, rather, to stimulate thinking about the future. A typical list of questions that was sent to the airframe manufacturers follows.

LIST OF QUESTIONS

Future Directions

- Could you briefly describe the process by which you arrive at long range plans within the company?
- Which factors do you foresee as being of prime importance in permitting the company to undertake new product developments? Technical factors? Financial factors? Market factors? How do you envision the relative importance of these factors changing in time during the next 25 years?
- Do you foresee any trends that will strongly impact the nature of future world markets for aircraft, such as depletion of resources, demographic changes, communications versus travel, changes in life style, international agreements, U.S. Government policy changes, the changing nature of military requirements, foreign competition, cooperative agreements with foreign countries?
- What are your views of the likelihood of introduction, and the possible timing, of major new aircraft developments for either civil or military purposes? For example:
  - New subsonic transport
  - Supersonic aircraft (including SST)
  - V/STOL aircraft
  - Large cargo aircraft
  - Alternate fuels (including hydrogen, synthetic JP, methane)
  - Hypersonic aircraft

- Nuclear-powered aircraft
- Other (e.g., remotely piloted vehicles, vehicles for laser warfare, etc.)

The Role of NASA

- What is your view of the role that NASA has traditionally played in aeronautical R&D? Do you foresee a modified role (either reduced or increased in scope or otherwise changed in character) that would be advantageous to the U.S. industry? Should NASA involve itself in the development of civil air transportation policy or confine itself primarily to research and technology development?
- In the event that the development of a new civil aircraft required government financial support, should NASA be the prime government agency in such an arrangement?
- What are your views of the type of activities NASA should be engaged in with respect to its role in aeronautics?
  - R&T Base (in-house only? Contracted?)
  - Technology demonstration to establish user confidence
  - The development of research aircraft to explore new flight regimes.
- What are your views in regard to the operation of NASA aeronautics facilities? Do you feel that there is a proper balance in the use of NASA facilities in response to research needs and developmental test needs in the industry? Should this balance change in the future? To what extent should industry be required to support NASA facilities' operations through industrial funding?
- How do you view NASA's role vis-a-vis the role of other agencies, (i.e., DOD, DOT, FAA, others), in the development of various aeronautical technologies?
- In light of the foregoing questions and your view of NASA's future role, is it feasible for NASA to fulfill such a role at its current level of resources (manpower, funding, facilities) or would additional resources be necessary?

Technical Programs

- What critical technology advances are required to permit the timely development of new aircraft (i.e., technology advances in aerodynamics, structures, propulsion, avionics)? Would these technology advances require substantial R&D investments by the industry or by the government? To what extent does your IR&D Program address these technology advances?
- What do you feel requires the greatest emphasis in the next decades: improvement in efficiency for the air vehicle, improvement in productivity, improvement in safety and environmental impact, improvement in the airways and airports systems? Do these require substantial R&D investments by the industry or by the government?
- Considering the diversity of possible aircraft developments that may be undertaken for either civil or military purposes, can you identify specific technology developments that may have multiple application and may therefore deserve priority in NASA's program?
- Civil aviation has seen substantial benefits from past military developments. Do you expect this trend to continue for the next several decades, or are the future needs of civil aviation sufficiently different that they will require independent technology programs?

The results of this Survey are documented and abstracted by the Outlook for Aeronautics Study Group in this Survey report, including a composite view of each of the segments (industry, universities, government agencies).

The industry, university and government groups were asked to summarize their thoughts on the three primary subjects of the Survey and include these in a company/organization letter, signed by high level management. The majority of the groups contacted were able to respond to this request.

LIST OF ACRONYMS

AAH	Advanced Attack Helicopter
ACF	Advanced Combat Fighter
AEC	Atomic Energy Commission
AEDC	Arnold Engineering Development Center
AFTI	Advanced Fighter Technology Integration
AIA	Aerospace Industries Association
AMST	Advanced Medium STOL Transport
AST/SCAR	Advanced Supersonic Transport/Supersonic Cruise Aircraft Research
ASW	Anti-Submarine Warfare
ATA	Air Transport Association of America
ATC	Air Traffic Control
ATT	Advanced Technology Transport
B.A.R.T.	Bay Area Rapid Transit
C.E.	Civil Engineer
CIAP	Climatic Impact Assessment Program
CTOL	Conventional Takeoff & Landing
DOD	Department of Defense
DOT	Department of Transportation
E.E.	Electrical Engineer
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FEA	Federal Energy Administration
"G"	Gravitational Acceleration
GNP	Gross National Product
HiMAT	Highly Maneuverable Aircraft Technology
HLH	Heavy-Lift Helicopter
HSGS	High-Speed Ground System
HUD	Department of Housing & Urban Development -
ICBM	Inter Continental Ballistic Missile
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IPAD	Integrated Program for Aerospace Design
IR&D	Industry Research & Development
JP	Jet Propulsion Fuel
JSC	L.B. Johnson Space Center
LAX	Los Angeles International Airport
L/D	Lift to Drag Ratio
M.E.	Mechanical Engineer
MLS	Microwave Landing System
MX	Missile, Experimental
NACA	National Advisory Committee for Aeronautics
NAS	National Airspace System
NASA	National Aeronautics & Space Administration
NO_2	Nitrogen Dioxide
NOX	Nitric Oxide plus NO_2
OAST	Office of Aeronautics & Space Technology
OMB	Office of Management & Budget
OMSF	Office of Manned Space Flight
PSA	Pacific Southwest Airlines
QCSEE	Quiet, Clean, Short-Haul Experimental Engine
QSRA	Quiet Short-Haul Research Aircraft
QUESTOL	Quiet Short Takeoff & Landing
R&D	Research & Development
R&T	Research & Technology
RPRV	Remotely Piloted Research Vehicle
RPV	Remotely Piloted Vehicle
RTAC	Research & Technology Advisory Council
RTM	Revenue Ton Miles
RTOL	Reduced Takeoff & Landing
SALT	Strategic Arms Limitations Talks
SST	Supersonic Transport
TACT	Transonic Aircraft Technology
U.S.	United States of America
USAF	United States Air Force
USSR	Union of Soviet Socialist Republics
UTTAS	Utility Tactical Transport Aircraft System
V/STOL	Vertical or Short Takeoff & Landing
VTOL	Vertical Takeoff & Landing
WW II	World War II

SURVEY REPORT
INDUSTRY VIEWS

This segment covers the information gathered from the visits made to aerospace industries and to commercial airlines. Since these companies are directly involved with aeronautics, either in the manufacture of aircraft or their commercial operation, there was a wealth of information collected that relates directly to the three main topics – *Future Directions, Role of NASA, and Technical Programs,* and a summary of this information follows. The companies that participated in the Survey and the principal contact at each company are tabulated below:

1. Aerospace Industries Association of America, Inc.
   1725 DeSales Street, N. W.
   Washington, DC 20036
   Karl G. Harr, Jr., President

2. Air Transport Association of America
   1709 New York Avenue, N.W.
   Washington, DC 20006
   Paul R. Ignatius, President

3. American Airlines, Inc.
   633 Third Avenue
   New York, NY 10017
   F. W. Kolk, Vice President, Systems Planning

4. American Institute for Aeronautics and Astronautics, Inc.
   1290 Sixth Ave.
   New York, N.Y. 10019
   Daniel J. Fink, President

5. Beech Aircraft Corporation
   Wichita, KS 67201
   James Lew, Vice-President, Engineering

6. Bell Helicopter Co.
   P. O. Box 482
   Fort Worth, TX 76101
   B. Kelley, Executive Vice President

7. Boeing Commercial Airplane Company
   P. O. Box 3707
   Seattle, WA 98124
   R. W. Taylor, Vice President & General Manager, Military Systems Group (BAC)

8. Boeing Vertol Company
   P. O. Box 16858
   Philadelphia, PA 19142
   L. L. Douglas, Assistant to the President

9. Cessna Aircraft Company
   Wichita, KS 67201
   Dwayne L. Wallace, Chairman & Chief Executive Officer

10. Delta Airlines, Inc.
    Hartsfield-Atlanta Int'l Airport
    Atlanta, GA 30320
    A. C. Ford, Assistant Vice President, Long Range Planning

11. Douglas Aircraft Company
    3855 Lakewood Blvd.
    Long Beach, CA 90846
    Charles M. Forsyth, Executive Vice President

12. Fairchild Industries, Inc.
    Sherman Fairchild Technology Center
    Fairchild Drive
    Germantown, MD 20767
    Dr. W. Von Braun, Vice President, Engineering and Development

13. Flying Tiger Line, Inc.
    International Airport
    Los Angeles, CA 90009
    J. E. Colburn, Vice President, Operations

14. Frontier Airlines, Inc.
    8250 Smith Road
    Denver, CO 80207
    A. Feldman, President & Chief Executive

15. General Aviation Manufacturers Association
    1025 Connecticut Avenue, N. W. – Suite 1215
    Washington, DC 20036
        Edward W. Stimpson, President

16. Grumman Aerospace Corporation
    Bethpage, NY 11714
        I. G. Hedrick, Senior Vice President

17. Garrett Corporation, The
    P. O. Box 92248
    9581 Sepulveda Blvd.
    Los Angeles, CA 90009
        Ivan E. Speer, General Vice President

18. General Dynamics (Forth Worth Division)
    P. O. Box 748
    Forth Worth, TX 76101
        Ted S. Webb, Vice President, Research & Engineering

19. General Electric Company
    1000 Western Avenue
    West Lynn, MA 01905
        Fred O. MacFee, Jr., Vice President, Planning

20. Institute for Defense Analysis
    400 Army-Navy Dr.
    Arlington, VA 22202
        Alexander H. Flax, President

21. Lockheed-California Company
    Burbank, CA 91503
        Dr. R. Smelt, Vice President & Chief Scientist

22. Lockheed-Georgia Company
    Marietta, GA 30603
        W. P. Freech, Vice President, Engineering & Operations

23. Metro Airlines, Inc.
    Box 58608
    Houston, TX 77058
        M. E. Weaster, General Manager

24. McDonnell Aircraft Company
    St. Louis, MO 63166
        G. W. Graff, President

25. National Air Transportation Association, Inc.
    1156 Fifteenth Street, N. W.
    Washington, DC 20005
        A. Martin Macy, Vice President, Operations

26. North Central Airlines, Inc.
    7500 Northliner Drive
    Minneapolis, MN 55450
        Daniel F. May, Vice President, Finance

27. Northwest Airlines, Inc.
    Minneapolis-St. Paul Int'l Airport
    St. Paul, MN 55111
        Donald W. Nyrop, President

28. Northrop Corp.
    1800 Century Park East
    Century City
    Los Angeles, CA 90067
        Don Warner, Vice President, Technology

29. Pan American World Airways, Inc.
    JFK Int'l Airport
    Jamaica, NY 11430
        J. Borger, Vice President & Chief Engineer

30. Piedmont Aviation, Inc. – Piedmont Airlines Division
    Smith Reynolds Airport
    Winston-Salem, NC 27102
        W. Magruder, Executive Vice President

31. Rockwell International Corp.
    1700 East Imperial Highway
    El Segundo, CA 90245
        D. D. Myers, President

32. Rocky Mountain Airways, Inc.
    Stapleton Int'l Airport
    Denver, CO 80207
        G. F. Autry, President

33. Shell Oil Company
    Two Shell Plaza
    Box 2105
    Houston, TX 77001
        Harold Bridges, President, Chief Executive Officer

34. Society of Automotive Engineers, Inc.
    2 Pennsylvania Plaza
    New York, NY 10001
        W. A. Gebhardt, President

35. Trans World Airlines, Inc.
    605 Third Avenue
    New York, NY 10016
        R. W. Rummel, Vice President, Technical Development

36. United Air Lines, Inc.
    P. O. Box 66100
    Chicago, IL 60666
        A. M. deVoursney, Sr., Vice President, Corporate Planning

37. United Aircraft Corp. – Pratt & Whitney Aircraft Division
    East Hartford, CT 06108
        Richard J. Coar, Vice President, Engineering

38. United Aircraft Corp. – Sikorsky Aircraft Division
    Stratford, CT 06602
        Jack McKenna, Executive Vice President

39. Vought Corporation – Systems Division
    Dallas, TX
        George Upton, Vice President, Engineering

40. World Airways, Inc.
    Oakland Int'l Airport
    Oakland, CA 94814
        D. M. Mendelsohn, Vice President and Deputy to Chairman of the Board and Chief Executive Officer

A summary of the information obtained from this Survey of the pertinent subject matter – *Future Directions, Role of NASA, and Technical Programs* – is presented in the following sections.

FUTURE DIRECTIONS

General

The industry organizations contacted in the Survey expressed a consistent view that fairly significant changes in the direction of aeronautical progress undoubtedly will take place. These changes will occur as a result of the rising importance of factors such as: costs of all types, fuel use, and concern for the environment. As a consequence, they expect that new concepts will be much more critically evaluated than in the past, and that relatively few will pass into the development stage. Such conditions may provide incentive for more intensive planning than has been undertaken in the past, which normally has involved a time span of only 5-10 years. The industry recognizes that there are many opportunities for new aeronautical applications in both civil and military sectors and these are expected to provide a base for continued vitality and profit for an indefinite time.

Civil Aircraft

National and International Factors – Due to the highly technical nature of the products developed and produced by the aerospace industry and the service provided by the airlines, these companies are keenly aware of the many factors, both on a national and international basis, that can affect future business prospects. Many of these factors which directly affect civil aviation were brought out during the course of this Study and they are summarized as follows:

- A change in life styles is underway with less emphasis on status, achievement, tradition, conformity, respect for institutions, regard of hard work as a virtue. More emphasis is being placed on quality of environment, variant life styles, and political activism.

- Factors which are changing are: the breakdown of the two-power structure, decline of use of force as national policy and rise of the use of economic pressure, and shortages of critical resources.

- World population and world per capita income is still increasing. In addition, world discretionary income is increasing along with increased leisure time, advancing education levels, and favorable travel patterns of the young.

- In developed countries, the population is expected to become more mobile; however, the resulting increase in transportation demand will be largely offset by a reduction in population growth. The shift in population since World War II has been a great stimulus for air travel. This trend will continue in the future, but at a decreasing rate.

- General readjustment of world wealth is expected. The dramatic shifts in world centers of purchasing power, currently to the oil-exporting nations, has permitted these nations to literally create markets for aircraft that otherwise would not exist. Less rapid growth of U.S. standard of living will mean less rapid growth of demand for goods.

- Capital risk is the most important factor impacting new product development. New ventures will be fewer in number and larger in size because increased financial and technological risks threaten the existence of manufacturers. Development costs for high technology aircraft are currently prohibitive.

- The lack of a rapidly growing market will make airlines cautious in purchasing new aircraft. The next near-term airplanes will be derivative versions of present aircraft, as the cost of all new aircraft for both manufacturer and the airlines will be substantial. Serious questions arise as to whether a single commercial airframe manufacturer is financially able to undertake alone the development of the next new (non–derivative) commercial aircraft. Therefore, such a program probably will be conducted by a consortium; perhaps an international consortium. These new commercial aircraft ventures will probably also require substantial government funding support to offset the risks involved unless a clear market is evident to justify the risks.

- Commercial aircraft technology evolves in an evolutionary rather than in a revolutionary manner. Therefore, several evolutionary gains are needed before a reduction of operating costs is achieved that makes the purchase of a new type of commercial airplane attractive to the airlines.

- There is more than an adequate supply of natural jet propulsion fuel to meet aircraft needs well into the 21st century. No alternative fuels are expected to be in general use for aircraft during the remainder of the 20th century because of the following considerations:

  - *Synthetic JP:* Produces high level of aromatics unless expensive refining techniques are used

  - *Hydrogen:* Little economic advantage because of high cost and logistics. Could become attractive if other applications became widespread

  - *Methane:* No significant advantages

  - *Nuclear:* Inherent high weight makes it economically unattractive; also, major safety problem

- Although petroleum fuel will be available, it will be expensive. Higher fuel costs will increase emphasis on reducing specific fuel consumption. High fuel prices will exert a great influence on the choice of new aircraft.

- Next "crisis" could be a shortage of critical raw materials. Possible scarcity of certain critical materials (titanium, nickel, cobalt, chromium) could impact future production of aircraft engines. Inter-dependence of nations for resources will limit national growth and thus, the growth of matured aircraft industry.

- Advanced communications systems which include videophones, large screen conference room arrangements, and hard copy real time transmission will be implemented in the mid-1980's. Their effects on air transportation is debatable. One manufacturer believes competition from communications will have a minor impact. It will reduce business travel but increase tourist travel.

- Foreign competition is not a very important factor in commercial aviation at the present time. New major foreign competitors are unlikely. However, foreign competition is being spurred by direct government subsidies for the development of new commercial airplane programs which are justified on the basis of national goals (e.g., A-300 and Concorde). As a result, foreign aircraft manufacturers will offer significant competition in new aircraft in the future. They are technically competitive and the government support provides the necessary economic stability.

- As part of the growing internationalism in business, the overseas market will become increasingly important. Competing for this increasing foreign market requires positive recognition of the overseas competitors. In fact, enforced partnerships with foreign national aircraft industries is likely as a condition for foreign sales. Such international collaboration could lessen the funding requirements for new aircraft start up costs.

Commercial Air Carrier Growth Factors — The projected growth of the domestic trunk airlines has been scaled down somewhat from projections of a few years ago. This leads to the view expressed by many of the contacts that this business is approaching maturity, and therefore, the rate of growth is nearly the same as that of the gross national product. This view appears to be justified only in a limited sense. The regional operations feel their business still is quite far from maturity, while the commuter, cargo, and charter carriers feel they are in an early stage of development with high probability for expansion. In addition to the concern for cost, fuel, and environment, the airlines are worried about increased government regulations as traffic increases. Many suggest an urgent need to review policy or regulation with the objective of permitting a more timely adjustment to the needs of expanding populations.

Some specific comments pertinent to growth of the U.S. commercial airlines are as follows:

- Free world passenger-mile markets are projected to increase by a factor of 1.9 to 2.2 by 1985 from 1974 levels. Following that, the influence of underdeveloped and emerging nations could expand the projection greatly during the 1985-2000 time period.

- Energy considerations, mode competition, life style changes imply an annual growth of about 7% in revenue passenger miles for the next ten years for domestic civil aviation.

- In particular, the trunk airline market has matured to the point where the growth rate is predicted to be comparable to the GNP. Even so, the market is large and the absolute increase is significant.

- Market growth depends on the general economic climate and on fares. Better understanding of fare elasticity is needed.

- Commercial airlines' safety records show a 6:1 advantage compared to automobiles in terms of fatalities per passenger-mile. This is an area of continuing effort.

- Low cost charter airlines (supplemental) are a significant competition for the trunk airlines. Current growth of supplemental airlines is excellent (about twice that of trunk airlines), but the future is unpredictable due to regulations.

- The supplemental airlines feel they are currently at a disadvantage with the regulatory structure they have to work with. In particular, they would like a liberalized regulation to allow one-stop inclusive tour service (currently three stops are required). In addition, they would like common ownership of surface mode, as well as, air mode transportation (*now* illegal in the U.S. but not in foreign countries).

- Bi-lateral agreements are needed with foreign countries. Currently there are none for the supplemental airlines, only for the scheduled international carriers. As a result, each foreign flight must be individually cleared.

- For cargo service, each *supplemental* airline is restricted to one shipper and one destination.

- International charter markets are very unstable but potentially lucrative because of long-range routes and high demand.

- Flag carriers need better U.S. Government support in foreign market agreements. Foreign flag carriers have an advantage outside the U.S. Increased legislative action is needed to support U. S. flag carriers abroad.

- The next 25 years will see a greatly expanding air cargo market which will have a significant effect on new airplane designs.

- Current estimates for the fraction of air cargo operations relative to total cargo transport range from 0.1% to 0.2% in terms of revenue ton miles (RTM). Considerable growth is projected due to both an increase in the fraction of the total cargo transported by air and the overall growth in total cargo transport. A five-fold increase is estimated for air cargo RTM by 1990 and an order of magnitude increase by the end of the century, based on 1974 levels given above.

- The growth in the air cargo market is keyed to fast and reliable service. Rate reduction would not be the dominant factor in increasing the system's capacity. There is a need to diversify the type of product being carried to provide economic stability of cargo operations. A major factor for the cargo business is generating revenue on each leg of the trip (backhaul problems).

- The congestion at airports is a limiting factor in air transportation growth – congestion on land and airside; but landside is currently more serious and will continue to be so. Landside congestion is more a social and political problem, than a technical one.

Industry Growth Factors – Results of the Survey indicated several factors which could directly affect the future of the U.S. aerospace industry. Included among those expressed were the rising costs of manufacturing in this country and the developing competition of foreign manufacturers.

The points made by industry are as follows:

- The aircraft manufacturers view the next 10-15 years as the age of the derivative aircraft.

- The technological development, to yield a sufficient jump in productivity and to justify a new aircraft, is undefined. Near term aircraft must have improved operational efficiency, a reduced fuel consumption, reduced noise levels, and reduced pollution.

- The aircraft industry is maturing and will reach maturity about 1990-2000. The trend for aircraft sales as a percentage of GNP is downward. Commercial, as opposed to military, aircraft will be the most rapidly growing sector of the aerospace market.

- The total fleet of commercial transports will be one to one, and one-half times the current levels by 1985. One effect of the fuel crisis has been to encourage the earlier-than-planned retirement of less-fuel-efficient aircraft.

- Aerospace employment at all levels will remain about constant over the next ten years.

- By 1984, the North American region (predominantly U.S.) air carriers will have 49% of the total world capacity in terms of available seats. This will be lower than the current capacity figure of 55%. Little change is seen in stage lengths.

- There will be a continuous need for conventional takeoff and landing (CTOL) medium- and long-range passenger aircraft cruising in the high subsonic speed range. CTOL medium- and long-range aircraft will be the bulk of the airlines operating fleet to the end of the 20th century.

- Short haul systems must be approached from an urban development standpoint to gain public acceptance.

- Key in short-haul system development is the integration of all air modes, (e.g., the concept of an intermodal terminal.) Potential relief of airport congestion is seen through the use of VTOL aircraft and rotorcraft.

- There will be competition between different configuration concepts in short-haul market (e.g., VTOL versus STOL). In addition, the interurban high speed and ground systems (HSGS) will represent real competition for V/STOL airplane systems in the mid-1980's.

New Aircraft Developments – Based on the general view of future civil aviation and on projected growth, requirements, and constraints, probable developments in air transportation that will occur within the next 25 years are as follows.

The industry forecasts a continuing need for the expansion of available seat miles. For the near future, this is expected to be satisifed by the current subsonic wide-body aircraft and their derivatives. New requirements exist in the short-haul market, where the development of advanced technology helicopters and highly efficient V/STOL aircraft could be beneficial, and in the intercontinental market, where a viable SST could be used, particularly in the Pacific Basin. Specific projections of aircraft types and dates of introduction, based on the concensus of the Survey are tabulated on next page.

Short-Range Subsonic

- Derivative Transport Aircraft (1980)
- Efficient Short-Haul Transport (1985)
- Utility/Business Rotorcraft (1990)
- Downtown V/STOL, Rotorcraft (1995)

Long-Range Subsonic

- Derivative Transport Aircraft (1985)
- Efficient Long-Haul Transport (1985)
- Large Cargo Transport (1995)

Long-Range Supersonic

- Advanced SST (1995)

Additional Far-Term Vehicles

- Hydrogen-Fueled Transport (2000+)
- Nuclear-Powered Transport (2000+)
- Hypersonic Transport (2000+)

Specific opinions expressed by industry officials on the subject of new aircraft developments are as follows:

- The aircraft manufacturers view the next 10-15 years as the age of the derivative aircraft. Commercial needs will be satisfied by stretched or derivative versions of existing subsonic transports.

- New advanced technology medium/long range subsonic transports to replace DC-8/B707 for low density routes may be the next airplanes to be introduced in the late 70's or early 80's. The majority of present-day and near-term commercial aircraft are in this category. These transports will be the major consumers of fuel used in aviation for the period 1980-2000.

- A B747 replacement could come a decade later, a new B727 replacement might come in the early- to mid-1980's and a new DC-9/B737 replacement could come in the early 1980's.

- Large freighters and supersonic transports may emerge in 1980's or 1990's depending on technology advances and funding availability. Long-range commercial supersonic air transports will bring about the next quantum increase in long-range commercial air transport productivity.

- Second generation commercial supersonic transport aircraft will emerge between 1990-2000 in limited quantity.

- Very large long-range cargo aircraft have both important commercial and military applications. Derivatives of existing passenger designed aircraft, specifically oriented to airfreight requirements will appear in the 1980's.

- STOL aircraft may be required as an essential part of a future, viable, total transportation system. STOL (more probably RTOL) may emerge in late 1980's or 1990's.

- Hypersonic and nuclear-powered aircraft are not foreseen in this century.

- Associated engine developments will be:

  - Advanced CTOL subsonic engine. Quiet, energy conserving, composite, long-duct nacelle for wide-body jets

  - Advanced commercial supersonic variable-cycle engine

  - CTOL – small, subsonic high-bypass, variable-pitch fan engine

  - VTOL – subsonic lift/cruise fan engine

  - VTOL – advanced helicopter turboshaft engine

Military Aircraft

A clear trend toward fewer military aircraft development programs was expressed by all manufacturers. Rising costs are viewed as the primary constraint to new aircraft development, although increasing concern for fuel and environmental factors are becoming more in evidence. The trend toward fewer development programs is accompanied by reduced funding for research and technology activities. This has brought on many observations that the expected level of support for R&T may not provide the base needed for probable future developments. There are many technical possibilities for achieving new capabilities that should be very useful under future conditions. These include improved range and maneuverability, more efficient air-lift, and application of laser weapons and highly-maneuverable missiles. Progress, of course, depends on the existence of an active technology program.

Some specific comments on the needs for future military aviation and on the constraints faced by the DOD are as follows:

- A declining percentage of GNP is expected to be spent on defense.
- The outlook is for fewer new programs in the future, longer time between programs, and sophistication in conflict with costs. Dependence on long-term planning is much more important than it has been in the past.
- The cost and availability of manpower limits the size of general purpose forces. Spiraling payroll costs, continuing budget deficits, and lack of a clear mission will result in a continued decline of general purpose forces.
- In terms of strategic forces, the present attitude of detente is aimed at preserving the strategic balance between the U.S. and U.S.S.R. There are developments which could alter the scope of our deterrent force levels and assigned missions: (1) emergence of a third major nuclear power; (2) further proliferation in the development or use of nuclear weapons somewhere in the third world; (3) political events leading to a breakdown of SALT; (4) technological breakthrough that undermines the credibility or effectiveness of strategic offensive missiles.

It is expected that a continuing upgrading of aircraft, now in the inventory, will take place over the next 25 years. The consensus forecast for the introduction of new aircraft is:

Short-Range Subsonic
- Reconnaissance RPV's (1980)
- Tactical STOL Transport (1985)
- Extended-range Rotorcraft (1985)
- V/STOL Carrier Transport (1990)

Long-Range Subsonic
- Derivative Transport/Tanker (1985)
- ASW & Reconnaissance Aircraft (1990)
- Large Logistic Transport (1995)

Short-Range Supersonic
- Maneuvering, Attack RPV's and Cruise Missiles (1985)
- V/STOL Fighter (1985)
- Advanced Tactical Fighter (1990)

Long-Range Supersonic
- Derivative Strategic Aircraft (1985)

Additional Far-Term Vehicles
- Nuclear-Powered Aircraft (2000+)
- Hypersonic Aircraft (2000+)

Comments on specific aircraft included:

- *Supersonic aircraft* – Between 1980-2000 time period, we see several military fighter aircraft in the Mach 2+ category
- *STOL aircraft* – STOL aircraft have important military applications; commercial applications will follow later.
- *VTOL aircraft* – The U.S. must increase ocean cargo tonnage and must maintain a strong Navy to ensure free passage. In order to accomplish this, the military requires smaller, faster aircraft carriers, and VTOL aircraft to support them. Those include: STOL supersonic attack aircraft, V/STOL fighter/attack aircraft, and advanced ASW aircraft.
- *Helicopters* – The military services require more efficient helicopters for better air mobility, "nap-of-the-earth" flight, logistics support, search and rescue, assault and attack missions, reconnaissance, anti-submarine and anti-ship-missile defense. These missions require unprepared land base operations and support and operations from ship bases at sea.
- Military operational usage of hypersonic cruise vehicles is a long way off – post-1990, probably post-2000.
- *Missiles* – The continued priority of strategic forces results in a long-term missile market slightly greater than the 1974-75 market. This market will, in addition, be supported by the continued tactical missile programs. As was

demonstrated in the Yom Kippur War, of 1973, sophisticated missiles have become an important part of land warfare. Thus, the U.S. will probably develop and produce advanced air- and surface-launched tactical missiles.

- Military programs foreseen include remotely piloted vehicles for surveillance and attack.

Civilian/Military Commonality

Military programs have contributed significantly over the last 25 years to the technological base from which civil aircraft designs have gained a great deal of benefit. There is general agreement that increasing divergence is underway between civil and military aircraft in the sense that environmental requirements for noise and emissions are more stringent for civil aircraft. It is expected, therefore, that future civil aircraft will derive fewer benefits from military aircraft designs. Advances in the technical disciplines, however, continues to be applicable to both classes of aircraft, to a relatively large degree. Because of this, a reverse flow of benefits is possible with future military aircraft designs benefiting from commercial aircraft designs. Some pertinent comments from the industry survey are:

- We have enjoyed a technological advantage in the past 25 years due to our past military aircraft development.

- Substantially fewer "spinoffs" will be possible between military and commercial aircraft programs due to far fewer military starts and diverging technical emphasis.

- New propulsion systems for civil and military aircraft will continue to be derived from the same R&D base.

- Beyond R&D base, expect diminishing benefits to civil aviation from military developments.

- For supersonic aircraft, the high degree of specialization required to meet divergent requirements for civil and military aircraft will result in largely independent system development efforts, particularly for propulsion systems.

ROLE OF NASA

The Role of NASA now and for the future as seen by the industry, is summarized in the following. In general, consensus or majority views are reported. In cases where important minority views are included, these are so identified.

Current View of NASA in Aeronautics

It was the unanimous view of industry that NASA's role of supplying basic aeronautical R&T was the backbone of the aerospace industry in this country. Traditionally, NACA/NASA through experimental and analytical research, provided the aviation industry with a data base of design information. The role of advancing the state-of-the-art of aeronautics technology should be continued and expanded, using a balance of "in-house" programs and contracted programs with industry. The NACA conducted parametric wind tunnel tests and analyses which provided an excellent technology base, however, experience in some segments of the industry with recent advanced design programs has identified considerable gaps in the data base. It is believed that the data base has not been systematically maintained, and this is attributed to a significant period of minimal funding for aeronautical research. It is believed that the impact of the space program has changed NASA from its traditional role of R&T "supplier" to "customer", with aeronautical R&T suffering as a result. It is also felt that while technology demonstrator (hardware) programs were valuable, that basic R&T has suffered as a result and that a re-emphasis on systematic parametric data acquisition and analytical technique verification is required.

Some very specific views were as follows:

- NASA's present mix of in-house and contract work is about right.

- NASA/Army joint activity is very good and should be continued.

- *The ATT and AST/SCAR* studies were valuable and appropriate for NASA.

- The Quiet Engine Program and the QCSEE Program are valuable and appropriate for NASA.

- The Experimental Clean Combustor Program is an excellent example of an appropriate contracted effort.

- NASA should not oversell technology.

- Some of the industry questioned the present RTAC organization's value as a medium for technological input and exchange.

One industrial organization expressed some rather positive views not necessarily in concert with the general views, as:

- Trends toward large-scale projects by NASA in the past has not been beneficial.

- The current trend for NASA and NASA/Army is to do most research in-house with a reduction in detailed study and research in close cooperation with industry.

- Industry must play its traditional role in research, analysis, design, manufacturing, and flight testing. If economic feasibility is established, then industry can proceed with production on its own capital investments. The aerospace industry should also do applied research under contract to various government agencies. The industry R&D program must be continued, and more important, in no way should industry be excluded or eliminated in undertaking any aeronautical program or project on its own initiative or on its own funds. One of the major engine manufacturers believes that the most effective application of government resources in the cause of aircraft propulsion is in full engine vehicles, developing and demonstrating major technological innovations and evolutions.

Role of Government in Aviation

Specific inputs relative to the government's role in aeronautical R&D were somewhat minimal; perhaps because the industry assumes that the support providied by the military and NACA/NASA over the past 60 years will always continue. There was no disagreement at all that government should continue its role in aeronautical R&D.

There was consideration of the government's possible future role in the development of possible civil aircraft. It was felt that government support should be provided for civil aircraft *only if* the aircraft is required for national prestige or national interest and is not sufficiently attractive economically to stimulate industry investment.

The following activities were considered to be fundamental to the success of future major developments in aeronautics:

- Conduct of basic R&T by NASA in-house.

- Continued ground-based research (wind tunnels, simulators, etc.) complemented by flight test vehicles, flying test beds, subscale RPV's, and subscale manned research/technology demonstrators.

NASA/Military/FAA Interfaces

There was a consensus that NASA has a major and vital role in the developing of the advanced aeronautical technology required by the military. One major manufacturer of military aircraft stated that, in addition, there should be close cooperation between NASA and DOD in the identification of technological requirements for military aircraft and that NASA should direct a considerable portion of their basic research to these military technology activities.

NASA was seen to be the primary force in the development of technology for other government agencies involved in aeronautics (DOT/FAA, EPA, FEA). Several organizations indicated that they believe NASA could address the technology problems of transportation from city-center to city-center, including the higher speed ground transportation from the city to the airport and air traffic control around airports, as well as, aircraft themselves. It was suggested by some that NASA should work with other government agencies on technology demonstrations, including ATC.

Interfaces with other government agencies in aeronautics invariably begin to touch on policy matters. In this regard, the general feeling was that NASA should not become involved in civil air transportation policy making. Specific comments from several organizations which reflect the full flavor of their views on this aspect were:

- Within the civil air transportation system, NASA's role is technical advice and counsel to a legislative and regulatory agency only. NASA should concentrate on research and development.

- NASA should not be involved in civil air transportation policy making.

- Policy matters are already complex; it is difficult to see the justification for NASA in this area.

- NASA's role in policy should be in supplying essential technical background data so that rational, achievable regulations can be invoked.

- NASA should not be drawn into policy decisions based upon technical demonstrations. NASA should be decoupled from the OMB-EPA/FAA-industry circle on policy.

Some additional specific inputs which help to indicate industry's views with regard to NASA-industry interfaces follow:

- NASA should demonstrate special technology applications via sponsored research aircraft development and flight test programs.

- Airlines should work closely with NASA in guiding research.

- R&T should be both in-house and contracted, and a balance should be maintained among in-house and industry and university contracts.

- NASA should develop new "tools" for industry such as IPAD, which require a strong technical non-partisan leadership.

- There is a need for closer cooperation between NASA and the VTOL industry.

NASA/Industry in Development

The overall role of NASA is to apply its efforts with a proper balance of aerospace industry contracted support toward the development of needed technology and should maintain, operate, and acquire, where necessary, the unique facilities required for this type of technological development. NASA is needed in developing high technology items, technology demonstrators, and in addressing problems that are beyond the capability of any one industry. The view that NASA should concentrate on is technology development and leave program aspects to other government organizations, and the integration of technology into systems to industry was expressed by one major airframe company.

On the other hand, another major supplier of military aircraft felt that NASA should plan, contract for, and supervise development of commercial prototype and major and higher risk programs in aeronautics but that in doing this, NASA should follow the example of DOD prototype development of YF-16 and YF-17, with minimal design participation and minimal documentation requirements.

Desired Emphasis Within NASA

The consensus of the industry was that NASA should conduct fundamental R&D in the key disciplines of aerodynamics, structures and materials, propulsion, flight control/flight management, acoustics, and computer aided design, with an emphasis on building a technology base. Occasionally, there was reference to the possibility of expanding NASA's activities into the manufacturing techniques area, but this was not a unanimous opinion. The airlines recognized the need to work on advanced concepts but felt that improving existing aircraft designs at the subsystem level should be equally emphasized.

It was seen to be necessary for NASA to develop and retain technical expertise, a la NACA, to provide a broad range of technical and consultative assistance to the industry. With regard to the need to assure dissemination of the results of research and development, NASA was seen to be the logical agency and should emphasize this aspect.

Developing, maintaining, and operating wind tunnels and other specialized facilities should be emphasized. Some specific inputs relative to facilities follow:

- Wind tunnel capability should be improved to incorporate expanded flight envelopes and the facilities should be made increasingly available to contractors.

- NASA should consider making wind tunnel time available on a rental basis and in a timely enough fashion so that it would be useful to industry proposal support.

- NASA should expand its role with emphasis on improved wind tunnel capabilities to cope with expanded operational flight regimes and the use of existing aircraft for systematic experimental data acquisition and verification of analytical prediction techniques.

The question of NASA's role in the demonstration of technological feasibility drew many varied responses with the majority in favor of this as a necessary role. The *full-range of responses* can be seen in the following individual company comments:

- NASA should demonstrate technology feasibility.

- NASA should concentrate on R&T base and *not* be involved in systems development.

- Technology demonstration to establish user confidence *is* appropriate for NASA.

- Programs such as refan and the short-haul airplane should be *avoided.*

- Technology demonstration can be done with existing flight systems or research aircraft. The motive shall be to derive technical answers, not to inspire user confidence.

- Technology demonstration and research aircraft should be joint NASA/Air Force/industry ventures.

- Great care should be exerted in instituting technology demonstration and research aircraft programs because of the budgetary impact on what is regarded as NASA's first priority, that is, research and technology.

- NASA should continue its active support of, and participation in, research/technology demonstration aircraft programs as a jointly defined effort with DOD.

- Technology demonstration is appropriate for NASA only when required to verify elements of the R&T base and to lower the risk of incorporating new technology to the point where it is acceptable to industry.

Although there was general agreement that NASA should engage in, and manage, research aircraft programs and not prototype aircraft programs, there were some opinions that, perhaps, if civil prototype aircraft programs would require government support, NASA would be the logical agency to run them. In a similar vein, there were inputs which indicated that NASA should devote a limited effort to such systems work as: QUESTOL, QCSEE, and Refan.

The general aviation industry, as a group, had these overall comments:

- The value of strictly research aircraft (general aviation) is questionable.

- NASA should stay out of hardware and stick to the development of technology.

- NASA should use the general aviation RTAC panel to develop and guide NASA research.

Some inputs relative to specific program elements follow:

- NASA should develop an adequate wind tunnel facility to evaluate the source and nature of aerodynamic noise.

- NASA should conduct basic research necessary for the design and manufacture of efficient liquid hydrogen-fueled aircraft after the year 2000.

- NASA should form a weight technology organization, develop weight evaluation capability, and sponsor weight research on advanced concepts.

- NASA should play a major role in the development of rotary wing technology.

- NASA should demonstrate technology feasibility.

- NASA should engage in systems studies to provide a rational guide for future research.

- NASA should accent the longer range research programs because industry tends toward doing the short range programs.

- Recent aircraft designs demonstrated the improved aerodynamic performance of canard/wing and strake/wing combinations. These individual design efforts have not, however, produced criteria for selecting canard or strake surfaces, nor for determining their planform size or location. Development of such criteria requires a large wind tunnel data base for parametric variations in canard and strake geometry and location.

- Since conventional technology appears to offer only modest evolutionary advances, an active research effort must be maintained in those areas where significant improvements are potentially possible.

- Continued assistance from NASA in basic technologies and new vehicle concepts is desired.

- We believe that the development of future digital fly-by-wire control systems will require an extensive use of expensive, sophisticated simulation facilities. We recommend that NASA obtain additional simulation facilities for flight control systems research and to provide these facilities to industry for aircraft systems development. This should be done much in the same manner as has been done with high-speed wind tunnels.

TECHNICAL PROGRAMS

The industry made recommendations of technical programs which they felt were required to fulfill their forecast of the future in aeronautics. However, these recommendations were inhibited by constraint considerations which suggested the following general areas of investigation.

- *Energy* – Long term studies of fuel alternatives are in order, (i.e., synthetic hydrocarbons, hydrogen, and nuclear propulsion.)

- *Cost* – Technology improvements must be sought without excessive penalties in cost and complexity.

- *Safety* – Research is needed to improve reliability and safety in the areas of propulsion, structures, flight controls, crew factors, and crashworthiness (fire resistant materials, improved structural integrity).

- *Environment* – A solid technical data base is needed to provide the knowledge regarding environmental questions on noise and pollution.

Basic and Applied Research

Industry was unanimous in its recommendations for a strong basic and applied research program within NASA. Most of these recommendations were for disciplinary oriented activities.

- *Aerodynamics* –

  - Boundary layer control
  - Aeroelasticity, including unsteady aerodynamics
  - Supercritical airfoil
  - Thick airfoil
  - Low supersonic, non-slender analysis methods
  - Wake vortex alleviation and control
  - Transonic buffet

- *Materials and Structures* –

  - Materials properties: advanced metallic structures; composite components; and hybrid
  - New alloy development
  - Adhesive bonding
  - Producibility techniques
  - Multi-disciplines structural analysis system: improved technology models; computerized design synthesis procedures; and integration of design analysis computer programs

- Testing of environmental response characteristics and non-destructive testing techniques development
- Compliant skins
- Materials combustion characteristics

- *Propulsion –*

  - Basic data: variable engine cycle development and demonstration; advanced engine cycle development; inlet design; engine component development
  - Analysis of alternate fuels and engine optimization
  - Testing of automated engine control system
  - Development of variable geometry engines, (i.e., with variable components (e.g., compressor blade pitch changes, valving to change bypass ratio.))

- *Avionics –*

  - Investigate application of digital systems to commercial aircraft
  - Develop low cost avionics components
  - Develop methods of redundancy management for new avionics systems
  - Develop criteria applicable to the use of active control concepts
  - Conduct system analysis of an integrated navigation, guidance, and control system
  - Conduct investigations leading to development of advanced cockpit displays.

In addition, industry strongly recommended that NASA's applied research programs include research aircraft and modified first line aircraft for research purposes.

Technology Needed for Future Aircraft and Operations

Industry indicated that there were critical needs that had to be satisfied prior to the development of new aircraft, both near and far term. They also indicated specific areas of technology improvement to enhance aircraft operations. Their summarized recommendations are as follows:

- The design of large (2 million lbs.) cargo aircraft will require a data bank on thick airfoils (>20%) and structural design data on distributed loads.

- The energy shortage will require a breakthrough in specific fuel consumption in engines for all future aircraft.

- Near term aircraft must employ improved operational efficiency, reduced fuel consumption, reduced noise levels, and reduced pollution.

- Major emphasis is required in advanced engine research, engine/airframe integration, supersonic cruise vehicles, and aerodynamic noise for the development of new transport aircraft.

- Large spanloader cargo aircraft designs will require data on thick supercritical airfoils, augmented high-life systems on thick airfoil sections, stability and control of flying wing designs, handling qualities of flying wings, and structural dynamics.

- The design of hydrogen-fueled transports will require technology emphasis on tank/airframe integration, tank/insulation cycling, and will also require a transport demonstrator.

- Nuclear aircraft designs will require technology advances in longer lifetime nuclear fuels, improved heat transfer systems, and more compact, lighter shielding for crash safety.

- Development of V/STOL multi-mission aircraft will require advances in thrust augmentation, variable geometry engines, advanced wing design, lightweight structures (composites), and fly-by-wire flight control systems.

- Critical areas for an advanced tactical fighter include low drag for supersonic dash/cruise, advance turbofan engines, compatible concepts for aero and composite structure, low drag but flexible weapon carriage, and supersonic ride qualities through control augmentation.

- A technology data bank on high angle of attack control, configuration synthesis, power plant integration, buffet/separation prediction, and transonic airfoils is needed for designing advanced fighters.

- High speed helicopter designs will require technology advances in rotor blade-tip shape, dynamic stall, multi-mode engines, all-weather navigation, wake theory, load prediction, and noise relief.

- To ensure an expanding helicopter market, cost and safety will have to be improved by an order of magnitude.

- Research is needed on both airborne and ground systems to improve airport terminal area operations technology.

- Short haul air transport systems will require economically efficient and highly reliable aircraft. These airplanes will require improved IFR capability including automatic landing ability and possibly fly-by-wire. Expansion of the ATC system will also be needed.

- Reduced separation distances will be needed to increase air space capacity and airport acceptance rates.

- The structure of the current system is a big factor in current congestion and costs problems, (i.e., there are better ways to do the job technically), and major changes are required.

Joint Industry/Government Developments

Joint aircraft development programs were recommended by a majority of industry in cases where the economical and/or technical risks were deemed too great for industry to accept. A summary of these recommendations is listed below:

- SST aircraft will be needed, and they will be much larger than the Concorde. This aircraft development will need government involvement. New SST aircraft should be efficient for ranges of 3500-4000 miles.

- Help is required from NASA in developing high technology items, technology demonstrators, and addressing problems that are beyond the capability of any one industry by reason of technology and financial requirements.

- Concerning technology demonstration and research aircraft, we feel such efforts should be joint NASA/Air Force/industry ventures with our current TACT program as an example.

- The three large airframe manufacturers (Boeing, Lockheed, and McDonnell-Douglas) would like more governmental support for technology development as applied to the next generation commercial aircraft.

- There is a need for "proof-of-concept" demonstrators to establish user confidence, show feasibility and economic competitiveness, and to show advances afforded by new technology.

SURVEY REPORT
UNIVERSITY VIEWS

The universities for many decades have stimulated advances in aeronautical engineering through their programs in basic and applied research. The large body of information on aerodynamic theory, guidance and control theory, structural analyses, and combustion that exists today is a result, in part, of university work. The existence of well-equipped university laboratories attests to their involvement in the experimental aspects of aeronautical engineering.

It should also be recognized that the U.S. aviation industry has been well-served with highly qualified graduates of the university schools of science and engineering throughout its growth period. The future of aviation in the U.S. will depend, to a large degree, on the quality of students who can be attracted to university engineering departments and on the caliber of university teaching.

For these reasons the views of the university community were sought by the Study Group. The individuals who contributed to the Survey are listed below:

California Institute of Technology
Professor H. W. Liepmann

Iowa State University
Professor R. F. Brodsky

University of Kansas, The
Professor J. Roskam

Massachusetts Institute of Technology
Professor E. E. Covert

University of Missouri – Rolla
Professor R. L. Bisplinghoff

New York University
Professor A. Ferri

Northwestern University
Professor M. W. Fine

Princeton University
Professor C. D. Perkins

Stanford University
Professor H. Ashley

Washington University
Professor K. Hohenemser

FUTURE DIRECTIONS

It was generally felt that the demand for air travel will increase and will stimulate the development of new aircraft of advanced design, although the introduction of visual-voice communication may in some cases become a substitute for business travel.

Some of the detailed comments made the following points:

- Currently no new subsonic or transonic transport aircraft are being introduced because they are not sufficiently improved over existing aircraft.
- The introduction of supersonic transport aircraft will produce a new surge in long range transportation and growth in air transportation can be expected particularly outside the U.S. and Europe.
- *A global growth of air freight can be* expected.

The importance of developing improvements in the air transportation system was stressed, including its interfaces with other modes, giving proper attention to fuel efficiency, land use, and the desires of the traveling public for reduction in travel time.

- There is a need to make transportation systems work rather than introduce new technology which is not energy/cost effective,

(i.e., improve current operations in regard to schedules, occupancy, land factor, and ground interfaces.)

- All transportation modes need to be improved with regard to their efficient use of fuel and in their interaction with each other.

- People object to having land converted to highways, and a demand for tilt rotor or quiet vertical takeoff and landing (VTOL) aircraft is anticipated. Helicopters are not efficient enough to be viable.

- There should be parallel development of short-haul aircraft and high-speed surface transportation.

- Continuously world-circling aircraft supported by STOL service aircraft for enplanement and deplanement of passengers are a possibility.

The problems that must be overcome by U.S. aviation were recognized, including the divergence of civil and military requirements, the large financial commitments required, and the impact of fuel shortages. However, there was no agreement on which of the problems were of the greatest concern.

- The U.S. leading position in world aircraft market is in jeopardy because of divergent military and civil requirements. The decline in the number of new military aircraft types puts the entire financial burden onto civil aircraft. The world transport market is being impacted by consortia providing competitive aircraft to U.S.

- The U.S. Government might be a partial financial contributor to future aircraft types, or a U.S. aircraft manufacturer could pool his capital with foreign partners to gain foreign government monetary support.

- Fuel shortages emphasize the need to make air transportation more fuel-efficient, influence design technology of future aircraft, lead to less growth rate for air transportation, and emphasize the need to develop alternate fuels.

- The current ATC system is a severe obstruction to air transportation growth. ATC should be automated and improved to permit all-weather landing capability. Ground systems for navigation in crowded local airport areas and "blind" traffic control are needed.

- Development of controlled fusion for production of hydrogen would spur new air transport development.

A number of specific suggestions regarding the types of civil aircraft needed for the future were made, including general aviation aircraft, V/STOL aircraft, large cargo aircraft, supersonic transports and hypersonic transports.

- Quiet and fuel conservative general aviation aircraft should be developed. A large, worldwide demand is seen for small business and commuter type aircraft.

- In the consensus view, there is a need to develop economic, efficient, and quiet V/STOL aircraft for short-haul.

- The use of helicopters as substitute for train/truck combinations in short-haul operations should be carefully studied.

- Large cargo aircraft operating at higher payload and gross weight ratios will reduce warehousing and inventory costs for major businesses.

- There is an interest in supersonic transports with 6,000-mile range capability to support interaction of U.S. with U.S.S.R., China, Japan, and South America.

- NASA should aid in the development of very inexpensive vehicles capable of saturating an opponent's defense as a substitute for current very sophisticated vehicles capable of avoiding destruction or detection. NASA should aid military in developing logistic vehicles to move large numbers of personnel and supplies at very high speed for 3000-4000 miles without refueling.

Engineering Education

Concern for the future of aeronautical engineering education in the U.S. was felt by many, particularly with regard to the ability of the aeronautics departments to attract the best students.

- There is a need to develop a national policy which will attract the best and broadest trained people to enter aeronautics. Presently, there is too little motivation to enter aeronautics; the best students are not being attracted; engineering enrollment is dropping and competition for graduates will be intense in the next few years. The U.S. future in aerospace is highly dependent on the quality of graduates.

- Aeronautical engineering graduates should be judged on quality, not quantity. The law of supply and demand works well in field of engineering manpower; and aerospace will borrow from C.E.'s, M.E.'s, and E.E.'s.

- A new generation of engineers is expected to find ways to roll back high cost by applications of new materials, new design concepts, and modular throw-away systems – "new industrial revolution."

The interaction between NASA and the universities was also discussed, including the need for university support through staff exchange arrangements with NASA, summer employment, etc., in addition to access to NASA facilities, and grants to universities for long range projects.

- Universities need long range projects, and current NASA short-sighted programs squeeze out university participation. One source suggested that NASA should consider spending of half of universities' dollars in four or five schools on four or five year projects with balance of dollars going to short term projects in the other schools.

- More direct university support by exchange of professors and students should be provided, along with consultation on curriculum, summer employment, and the donation of surplus or new facilities. NASA Headquarters should administer all university programs.

- Easy access to NASA facilities by university groups should be provided for thesis work. Under-utilized research facilities should be opened to universities for both research and teaching.

- University professors and graduate students should be used to prepare position papers, with pay.

- NASA should be a training ground for future engineers as well as for post-graduate work by exchange arrangements. NASA needs to keep influx of new blood to keep their in-house effort strong, such as a university-trainee program. NASA should promote a traineeship program; it is inexpensive for what it accomplishes.

- Current NASA/university roles should continue with university being the source to introduce people to NASA research. NASA should work more closely with students to motivate them into aeronautical field.

ROLE OF NASA

The current potential future roles of NASA were subjects of interest and evoked much candid response, particularly with regard to the function NASA should perform, and the possible scope of its program in research, technology, and development. The *full range of comments* are illustrated by the following:

- NASA has lived up to its charter. NASA is responsive to Congress, but it has difficulty in developing long-range research programs because they might be currently unfashionable or non-relevant. NASA operates its facilities better than most government agencies.

- There is a need to return to the NACA philosophy of basic research in all areas with continued applied research programs but at a lesser level. NASA should do research only through "proof of concept", and only rarely through development.

- Research should involve the use of unique NASA facilities and the combination of excellence in in-house research with support of testing from industry and university. NASA should overlap its R&D somewhat with DOD.

- NASA needs to continuously pursue development and improvement of research facilities. This should be a coordinated effort with DOD.

- NASA should do in-house and contracted research and technology at about a 50-50 ratio. Strictly in-house research tends toward inbreeding and stagnation, while the opening up of research to industry and university introduces fresh ideas.

- NASA should do less industry contracting of research and then only when it may be identified with a given objective.

- NASA should improve its capabilities and facilities to do structural fatigue and ground vibration tests and operate these facilities in a manner analogous to the wind tunnels wherein the manufacturers could obtain use in a scheduled manner. These tests are presently being performed by each manufacturer with varying levels of sophistication. This would be more cost effective as well as provide a direction for NASA's structural and material research in order to bring it up to a par with aerodynamics and fluid mechanics research.

- NASA should avoid a competitor stance and instead demonstrate its competence so as to be in demand. Public relations need to be improved so as to sell the public benefits from NASA. The understanding of NASA and its objectives must be fostered.

- A long range plan should be formulated that includes demonstrator vehicles from inception to operational status so as to get hard data. NASA should cooperate with DOD on military demonstrator aircraft where there is prospect of success.

- NASA needs to participate in aircraft demonstration and research aircraft with great care. Demonstrator aircraft often do not serve the research purpose. Demonstration projects should be done in conjunction with another agency. Trade-off studies should be done first. Only small-scale technology demonstrations should be done in-house. Full-size demonstrator programs should be done by contract to industry.

- The past performance by NASA in demonstrator projects has been poor (negative foreseeable results). Equivalent results could be obtained from trained analytical manpower at equivalent expenditure.

- NASA should push DOD into prototyping of new aircraft (VTOL and RPV).

The relationship between NASA and other government agencies also received attention, particularly its involvement with the DOD and DOT/FAA.

- NASA, in some government agencies' eyes, is a competitor rather than a support agency. NASA, DOT and FAA are working at cross or overlapped purposes. NASA supplies R&D services and DOT, FAA, and DOD are customers. We need a national aero research council to parcel out research between DOD, DOT, FAA and NASA.

- NASA needs to foster cooperative agency efforts in order to secure the R&D dollar. "Civil Air Transportation Policy" should be understood, as these policies can effect airplane designs.

- NASA should be willing to act as "subcontractor" to other agencies like DOD, DOT, AEC, etc.

- NASA should keep DOT and FAA out of areas of technology development. FAA and DOT should be regulatory and legal.

- NASA needs to be impartial as to where the best results may be found or obtained. NASA in-house talent is not always the most capable.

TECHNICAL PROGRAMS

In comparison with the views of industry and government in their segments of the Survey, the universities appeared to be somewhat more visionary with respect to the far term; however, there was not much inclination to relate expected developments to a particular time period. Concern was expressed over the trend toward reduced military R&D and the resulting question of the adequacy of total national R&D funds. A consensus indicated that NASA has a strong responsibility to carry out effective coordination of national aeronautics R&D to be sure that both civil and military needs are recognized and addressed.

Since the responses from the universities were characterized by considerable independence, it does not seem appropriate to consider only "consensus type" results. Hence, "singular comments" will also be included.

Technology Constraints

- There was almost complete agreement that energy efficiency is viewed as the most important consideration for airplane design. Two singular dissenting comments, however, stated that no significant impact of the petroleum crisis is expected in the 1980-2000 time period.

- It was noted that the development of controlled fusion for the production of hydrogen should spur air transport development to a "hydrogen economy." The importance of alternate fuel research was stressed. Several respondents were in agreement that the fuel outlook will delay the development of supersonic and hypersonic transports, but there was no disagreement that eventually such aircraft will emerge as viable long haul transportation.

- New developments for both civil and military uses are seriously constrained by rising costs. One response stated that the single most important future task is devising methods to roll back the cost of aerospace systems. For the military, the choice may be between a few complex aircraft or a larger number of low-cost aircraft.

- Consideration of environmental factors is accepted as a continuing problem for an indefinite period. However, the urgency may be lower than that of energy and costs as suggested by the singular comments: (1) much can be accomplished without undesirable side effects; and (2) it is important that NASA works on safety and environmental impact, but with a lesser priority. An example of item (1) is the impressive aircraft noise reductions attained through technology advances in the design of the B747, DC-10 and L-1011 transports.

Technology Needs

- A strong research effort is needed in improving aerodynamic efficiency. Efforts in drag reduction should include boundary layer control. Studies should be made of supersonic configurations having high L/D and low sonic boom (below 0.8 lbs/sq. ft.) to permit supersonic overland flights of the order of 5000-7000 miles.

- NASA should continue to develop better concepts for transonic and hypersonic vehicles with greater range and payload fraction. Improvements in computational aerodynamics should aid in these advancements. Better high-lift systems are needed as well as improved ride and handling qualities.

- A singular comment was that substantial improvements can be achieved for rotary wings, including new concepts for large cargo helicopters.

- There is a strong support for research in increased structural efficiency, particularly in lightweight, low-cost composite materials and structural design and analysis. Compared to other disciplines, structures and materials technology is underemphasized. More effort is needed, particularly in the area of *static* structures and materials. The suggestion was also made of a "unitary-plan" approach to structural facilities.

- There is need for increased effort on engine refinements to improve fuel efficiency and on the evaluation of alternate fuel candidates, with many expressions of interest in liquid hydrogen. There is also a need for more research on engine structural integrity, expecially for military vehicles.

- A continuing effort is required on reducing noise and emissions. New cycles are needed for high speed, reduced emissions, and improved efficiency.

- Another singular comment expressed the need for continuing the development of high-speed air-breathing engines with prototyping of engines and demonstration aircraft.

- Specific support was given the variable-cycle fan engine and the scramjet engine.

- New propulsion systems are needed having high-thrust at low altitudes, and high velocities, low thrust, and low drag for cruise.

- It is generally felt that the present aeronautical use of electronics and control technology is not providing the full benefits that are possible. Through automatic control there are significant potential benefits to safety, work load, ride qualities, and operating efficiency. Increased automation can reduce weather and traffic delays and save fuel.

- A singular suggestion proposes the goal of total automatic control of both small and large airplanes. A supporting effort to the FAA is needed on sensor development, displays, and other airborne systems. Significant advances are also needed in fault detection and analysis to define safe operating practices.

- New approaches are required to the problem of electrical power distribution and avionics for multi-use such as stability augmentation, flutter prevention, and engine performance control.

- A capability in "operations analysis" is needed to analyze complete systems to determine benefits and research voids. There is a need to make systems work rather than introduce new technology which is not energy cost-effective.

- It is agreed that basic research in the disciplines will generally benefit both military and civil aeronautical developments. Technology related to V/STOL and hypersonic aircraft also is expected to be useful in both areas, even though there may be little transfer value between specific designs for military and civil applications.

- Demonstrator aircraft constitute an effective means for reducing the risk of advanced technologies and may therefore permit applications to occur at an early date. It is especially important that such programs be organized and managed so as to provide maximum benefit to military and commercial users.

SURVEY REPORT
GOVERNMENT VIEWS

This segment covers the information gathered on a variety of visits made to governmental organizations. These visits covered a wide spectrum of agencies, from those directly concerned with aeronautics to those involved only in broad policy positions. The following organizations were visited:

- Airport Authorities
- Department of Commerce
- Department of Defense (DOD)
- Department of Transportation (DOT)
  - Federal Aviation Administration (FAA)
- Department of State
- Environmental Protection Agency (EPA)
- Federal Energy Administration (FEA)
- National Aeronautics and Space Administration (NASA)
- Staff of Senate Committee on Aeronautics and Space Sciences
- Staff of House Committee on Science and Technology
- Staff of Subcommittee (HUD-Space-Science-Veterans, etc.) to House Committee on Appropriations

This segment summarizes the information gathered from these organizations into three categories: *Future Directions, Role of NASA, and Technical Programs.*

DEPARTMENT OF DEFENSE

The following visits were made within the DOD:

Air Force

(1) Major General Kenneth R. Chapman
Assistant Deputy Chief of Staff/Research & Development
Headquarters, U.S. Air Force

(2) Brigadier General William W. Dunn
Deputy Chief of Staff/Development Plans
Air Force Systems Command

(3) Honorable Walter B. LaBerge
Assistant Secretary of the Air Force
Research & Development

(4) General Samuel C. Phillips
U.S. Air Force
Commander, Air Force Systems Command

(5) Major General Alton D. Slay
Assistant Chief of Staff/Research & Development
Headquarters, U.S. Air Force

(6) Dr. Michael I. Yarymovych
Chief Scientist of the Air Force

Army

(7) Mr. Charles L. Poor
Deputy Assistant Secretary of the Army (R&D)
Department of the Army

(8) Dr. Irving C. Statler
Director, Army Air Mobility Research and Development Lab (Ames Research Center)
Department of the Army

Navy

(9) Mr. William Koven
Director, Advanced Aircraft Development – Systems Objective Office
Naval Air Systems Command

(10) Vice Admiral Kent L. Lee
Commander, Naval Air Systems Command

(11) Vice Admiral William J. Moran
Director, Research, Development, Test & Evaluation
Office of the Chief of Naval Operations
Department of the Navy

A repeat visit was made to Dr. Yarymovych, Chief Scientist of the Air Force, to obtain inputs from the Air Froce "New Horizons" planning study. An additional visit was also made to Mr. William Koven, Naval Air Systems Command, to obtain additional data and study Navy planning documents. Much of the detailed information gathered is classified. Broad trends can be discerned, however, that are unclassified and are presented below.

FUTURE DIRECTIONS

The following areas reflect our current environment and constraints. Lacking truly major changes in economic and political environments, they will be with us for some time. Overall budget limitations dictate energetic efforts in a number of areas. The effect on new aircraft starts is significant, forcing consideration of derivative aircraft to meet needs, as with the civilian market. There is interest in consideration of multiple use aircraft, especially in the Navy. Designers of future aircraft must explore commonality with the civilian fleet. Particular general problems can be noted.

Fuel Conservation

- The energy crisis we know to be more than a temporary problem. The aeronautics industry needs strong guidance toward design and operational methods which will result in overall fuel conservation.

- One thing that needs to be done is to rank and set priorities on those things which drive the use of fuel and determine those things which the aircraft industry (builders and users) can do. The consideration of alternative fuels is appropriate.

Cost

- Cost, including the acquisition costs of each part of the aircraft and system, and the life cycle costs, are clearly of growing importance. Although traditionally the DOD has had less concern for these problems than commercial carriers, in today's economic environments DOD is in the same box.

- Not only must these tradeoffs be done better, but those areas of technology which can be expected to make the greatest contribution to cost as well as fuel saving must be identified and pursued vigorously.

- There is a need for the same kind of reliability and maintainability effort on aeronautical systems as was done on space systems.

Aircraft Manufacturing Technology

- In a time in which costs are rising and demand for aircraft appears to be decreasing, there is a danger that the U.S. will lose the industrial leadership which has been maintained for many years.

- There are several possible scenarios. One is the dropping out of participants in the aircraft industry until the U.S. might be left with a wholly uncompetitive industry, subject to all of the ills of government regulations and internal bureaucracies or even socialization. The alternative is an industry which remains viable by use of the most advanced manufacturing methods well tailored to realistic peacetime procurement quantities and with quick-reaction capability needed in case of major conflict.

- Such capabilities will require, among other things, the use of increasingly interchangeable computer aided design and manufacturing technology. No single firm can be expected to pay the bill for this. Accordingly, not only a spirit of cooperation in this area but a point of leadership is required.

- Having "common language" for design automation would also help greatly in permitting major aircraft procurements to be subcontracted to a number of firms, with better assurance that all parts would fit.

Variable-mode Operation

- The variable-sweep wing and the VTOL aircraft are but two examples of aircraft technology in which the aerodynamic configuration of aircraft is variable, permitting operation in different flight regimes. The aircraft using these technologies have been more expensive and performed less well in a given mode than aircraft optimized for one mode.

- It is to be hoped that this will not always be the case; in some other technologies, innovations have resulted in both functionally broadening and reducing the cost of products. Such innovations could be used in military aircraft. So long as there is a considerable uncertainty in the locale and conditions under which future conflicts might occur, aircraft will be needed which can adapt to the operating environment.

- Though maneuverability today relates principally to vertical climb ability, high G turns, and high burst speeds, there are probably other maneuvering motions even perhaps involving a rapid air speed deceleration, which would be advantageous.

Endurance

- Today, global military preparedness requires global basing of aircraft or the use of aircraft carrier bases. Not only logistics, but also our relations with other nations are keys to strategic, as well as, tactical Air Force operations.

- Better answers to the problems of quick reaction in a tactical sense are needed. The aircraft itself is a key element, either through its inherent range or its ability to operate with very limited logistical support.

Missiles

- The final responsibility for weapon firepower delivery falls upon a missile which may be carried part of the way toward its target by a manned aircraft.

- As anti-aircraft weapon threat increases, manned aircraft take on less of the delivery requirements and the missiles must do more of the job. Missiles have the potential for flight regimes unacceptable to human pilots.

- In missile airframe technology, the surface has been hardly scratched. Improved flight control in a missile may mean better survivability against surface-to-air missiles, or it may conceivably permit a lower-cost guidance system.

Testing Facility

- Costs are rising precipitously. Some facilities must be unique national resources and coordination of the management and utilization of such facilities is essential. Consideration of ways to eliminate duplication, provide efficient response operation, and cut costs must be found.

Jet Engines

- Superior engines have played a large role in U.S. commercial aircraft superiority. The Air Force's and Navy's engine requirements have provided a basis for the development of profitable commercial engines. DOD sees no new jet engine developments in the next 5-10 years and thus may have to abdicate its traditional role.

- Basically, resources are lacking to stimulate engine development. No company has all the resources required to develop new engines in the absence of specific aircraft requirements. Whether such considerations as the continuing energy crisis can provide motivation is presently moot.

Structural Fatigue

- These problems have always been with us in the high-stress environments in which USAF aircraft must be operated. Although perhaps the problems are less severe in commercial aircraft, life cycle costs in any application are dependent on careful attention to safety without over-design.

Environmental Considerations

- The military are not exempt from noise and other environmental regulations. Efforts at compliance must be made.

Demonstration Aircraft

- There was a general consensus of the need for demonstration aircraft in selected cases. Joint efforts of DOD and NASA were suggested as most appropriate.

Vehicle Requirements

- Current aircraft and aircraft needed in the future by DOD must be capable of meeting all threats in order to help assure U.S. military supremacy. Therefore, they require continual supply of the most advanced technology that the nation can produce.

- The various types of aircraft needed cover the full range of performance in the aeronautical flight envelope. There is a scheduled replacement of each type of aircraft as they age and unscheduled replacement to meet new threats or to fill new roles. Listed below are general vehicles felt to be needed as replacement of aging aircraft, response to a new threat, or to take advantage of new technology to provide new or more cost effective performance.

  - *RPV's* – Multi-purpose families are needed. Requirements will include high altitude, low to medium altitude, and long endurance. Key technologies are control and data links, launch and recovery systems, and low-cost subsystems.

  - *Strategic Airlift* – Need cargo convertible or all new cargo vehicle. Air Force/civil commonality is important.

  - *Laser Equipped Aircraft* – Potential seen for laser systems in the future.

  - *Tanker* – Need new air tanker in 1980's.

  - *Missiles* – Interest in high-performance missiles.

  - *Advanced Concepts* – Although definitive needs for development efforts on such concepts as surface vehicles, nuclear powered aircraft, air-to-air and air-to-ground missiles, lighter-than-air, etc., are not present, NASA was encouraged to perform far term research on such concepts. The need for hypersonic vehicles is not clear, however, technology efforts are encouraged including possible demonstration vehicles.

  - *Rotary Wing* – Helicopters have been the most important new factor in Army combat techniques since WW II. Army aeronautical activities will continue to stress low-speed vertical risers; there is no intention to infringe on other aircraft types in the province of the Navy or Air Force. They are planning a complete replacement of their current aircraft by 1985. These will be:

    - *UTTAS* replacing the UH-1. The UTTAS is expected to have a 200% improvement in reliability over the UH=1. It has an advanced engine (T-700, GE).

    - *AAH* replacing the Cobra. The design emphasis on the AAH is on payload, all-weather operations, and not performance.

    - *HLH* to replace the CH-47 and CH-54. The HLH is currently a technology demonstrator only, using a hybrid fly-by-wire system to provide precise controllability at reduced pilot workloads.

    With their commitment to these aircraft, the Army feels that unless there are large performance/payload gains (15-20%) to be realized, procurements through 1990 will be derivatives of these.

    All of these vehicles are comparatively low speed and short range. Agility is believed to be more important than speed. Long, self-ferry range might prove useful in some situations. But the major typical need is for low-level, nap-of-the-earth operation in both day and night, under adverse weather conditions at affordable cost in weight and dollars.

  - *VTOL* – VTOL has considerable interest to the Navy for use in conjunction with sea control ships and with the Marines. The Air

Force is only interested in tracking efforts of other agencies at this time.

- *STOL* – Modest interest exists in the Air Force based on the AMST. Some interest in the Army exists on smaller aircraft of the STOL category.

ROLE OF NASA

The role of NASA in production of basic aeronautical technology was universally and strongly endorsed. The budget crunch was also noted and the point made that cooperative programs between NASA and DOD were not only desirable but essential. Interdependency, (i.e., establishment of programs where the DOD and NASA would divide up the efforts on a worthy project), was praised and suggested for expansion. The future of aeronautics depends on NASA assuming a strong leadership role.

General problem areas such as fuel conservation, weapon integration, need for off-shore test range capability, reliability, maintainability, life cycle cost reduction, production technology, environmental (noise and emissions), etc., were brought up many times. The role that NASA might play on such problem areas was not explicitly defined. Questioning on the area of reliability/maintainability/life cycle costs produced no clear indication of suggested activity by NASA. Specific responses are summarized as follows:

- Continued support and interaction with DOD in environmental factors (noise and emissions) was strongly endorsed.

- Fuel conservation is a source of concern and NASA activity in this regard would be helpful even to making suggestions on appropriate legislation. Study of various alternative fuels was encouraged and even a study of Air Force operations with regard to conservation would be helpful.

- The area of manufacturing technology and computer aided manufacturing was mentioned with a suggestion that NASA assume a role in developing low cost fabrication technology. No definitive recommendation was made on computer aided manufacturing.

- It was suggested that NASA take the lead in developing computer aided design techniques including establishment of a library. It was stated as being grossly inefficient for a number of companies to do the same thing.

- In the engine development area, it was mentioned that the DOD will find it difficult to carry on new engine development. There is a need to rethink how to stimulate engine development and joint efforts of NASA and DOD are appropriate.

- Cost of ownership is extremely high for current aircraft. There is a need for the same kind of effort on reliability and maintainability of aeronautical systems as on space systems. NASA could assume an important role in this area.

Specific comments of significance to the role of NASA were made by a number of senior DOD persons. These are given below.

- In response to questioning regarding the role of NASA on research vehicles, "proof of concept" demonstrators, and prototypes, activity by NASA was strongly endorsed. Such efforts should be joint efforts between NASA and the Air Force. The independent evaluation of military vehicles, especially prototypes by NASA flight tests, was supported as an appropriate role for NASA.

- The Army-NASA association was definitely of high value to the Army and praise for NASA's support of Army aeronautical R&D was expressed. The Army's long term strategy is to identify and work on a few systems which are clearly important to the Army. Collaboration with NASA should be continued, with the anticipation that the close NASA-Army association will not be disturbed in the ensuing years. We need to understand systems, therefore flight demonstration is important. Joint NASA/Army programs were encouraged and near term cooperation on HLH technology demonstrator was suggested. A continuation of NASA/Army working agreements at NASA centers is seen. Helicopter technology deficiencies of major interest to the Army were pointed out. NASA support in the areas of controllability, detectability of noise, and community annoyance was sought.

- In a discussion of tactical requirements, man-machine interface problems were emphasized. No good programs exist in government or industry. NASA should get involved. Great effort is needed to make the relationship comfortable between man and the machine. The kinds of technology that industry could afford to do were discussed, (i.e., those with a near term and identifiable payoff), and those which NASA is best suited for, (i.e., the higher risk, far term R&T.) NASA should work on a range of technologies, and NASA was the only agency which could really afford to work seriously on projects with low probabilities of payoff. NASA should develop cells of expertise.

- It was not certain that government sponsorship for new aircraft developments (e.g., the SST) was a good thing. There is concern about the difficulty in achieving the historical close coupling between customer and airline interests, in a development program which the government was sponsoring. NASA's involvement as program manager, for instance, would put it in a new and difficult role of trying to accommodate the customer and airline interests.

- It was suggested that NASA work on things like the aerodynamic design of trucks and automobiles. NASA has the right kind of people and equipment. A large energy payoff could be achieved by significantly reduced drag associated with surface transportation of all types.

- Regarding the building of experimental aircraft, concern was expressed that NASA would be tempted to build aircraft that could be converted to commercial, or military, use. NASA must stay away from anything that appeared to be a solution or an approach to one, which could be viewed as a prototype.

- A continuation of efforts to integrate the aircraft into the traffic control situation was suggested.

- NASA has provided the aeronautical technology base for many years. The U.S. is preeminent in aviation because of NASA's work. The Navy is no longer able to do sufficient applied research and must depend on NASA. NASA's freedom to do basic innovative work must be preserved.

- The long and productive team work between NASA and the Navy was cited and the continuation of this association was encouraged.

- A stronger role for NASA in simulation development was suggested with a goal of a 50% cut in training costs.

- Work on hydrofoil and surface effect ship/aircraft is needed and there is a potential role for NASA in this work.

- Hope was expressed that NASA would identify things that NASA can do and others cannot do, or cannot do as well, and pursue them.

- The question of facilities needed for the next generation of vehicles was raised. Joint planning and interaction between the Air Force and NASA was encouraged with consolidation of facilities were appropriate. The question of operation of AEDC under NASA direction is a possibility for consideration.

- A strong conviction was expressed that NASA should head back toward the NACA mode.

- In view of the money crunch on the industry, NASA can play an important role in protecting critical elements of the industry from disappearing. Manufacturing technologies and processes may be an important role for NASA to address.

- No obvious need for hypersonic vehicles was seen, however, appropriate technology development should be continued. Strong support of joint efforts between NASA and the Air Force on such programs as AFTI/HiMAT was expressed. Although the Air Force has low interest in VTOL at present, it is an appropriate role for NASA to continue development of such technology.

- Important roles for NASA include: (a) coordination of technologies, (b) provision and sharing of facilities, and (c) promotion of basic research. Joint programs between NASA and the Air Force stand a much better chance in Congress than independently proposed programs. There is a need to study how to keep the industry going, in particular the industry's design capability. Support by NASA and the Air Force in this regard is important.

TECHNICAL PROGRAMS

The DOD sector was universal in supporting a strong technology base effort by NASA in the mode of the old NACA. Strong support was indicated for generalized aerodynamic efforts, development of production methods and criteria. Support for "far out" research was generally noted. Support for demonstrator vehicles was general with the suggestion that these normally be in concert with the services. A number of the general problems mentioned as worthy of being included in the NASA technical program are listed below:

- Costs – acquisition costs and life cycle costs, methods of prediction and tradeoff analysis.
- Manufacturing technology
- Simulation – potential of simulation for reducing training costs
- Penetration of enemy defenses
- Fuel and energy conservation
- All-weather operation
- Night tactical operation
- Environmental considerations
- Engine development
- Computer aided design methods
- Synthesis techniques to integrate technologies into a coherent design

The DOD segment indicated that many disciplines needed advancing, both to solve deficiencies that now exist and to provide a data base on which to judge future options. Specific areas that were pointed out by various individuals include:

Aerodynamics

- Airfoils – parametric studies of airfoils for both fixed and rotor winged aircraft.
- Effects of stores – store separation
- Innovative aerodynamics allowing aircraft to do unusual things
- High-lift devices
- Computational methods

Structures and Structural Dynamics

- Design criteria
- Weight prediction techniques
- Materials and structural concepts (composites and advanced metallic)
- Fatigue and fracture mechanics prediction techniques
- Loads prediction methods for aerodynamic and heat loads and for stores

Propulsion

- Integrated propulsion systems
- Development of a variable cycle engine
- Secondary power generation
- Reliability and maintainability through research on seals, bearings, combustors, turbines, and compressors
- Scramjet research and development
- Alternate fuels

Flight Control and Avionics

- Tradeoff studies for control configured vehicles/active control technology and design techniques for these aircraft
- Command and control system
- Air traffic control system
- Positioning and navigation systems
- Landing aids and systems
- Sensors for better target acquisition and identification, and for obstacle avoidance such as overhead wires, etc.
- Man-machine interface to define pilot needs
- Fly-by-wire digital flight control
- Missile flight dynamics
- Control systems for drones and RPV's

Flight Demonstration Vehicles

- Research vehicles for hypersonic research and ramjet development
- Technology demonstrators for advanced technological innovations

The Air Force indicated that technology efforts by NASA that would be of value to the B-1, F-15, and the ACF or their derivatives would be of great significance to the Air Force and such focused technology would be appreciated. Other specific efforts brought up by the Air Force included the following:

- Prediction of fatigue damage of structural life
- Tradeoff methodology for design, considering the system problem and all elements
- Improved reliability and maintainability
- Survivability
- Lower life cycle costs
- Improved manufacturing technology
- Environmental considerations including stratospheric emission control – standards – need low NO_2 combustor
- Fuel conservation
- Modular avionics
- Crash fire reduction
- Wet runway technology

Vehicle concepts of interest to the Air Force included:

- Advanced fighters
- Large logistics, long endurance aircraft
- Surface effect vehicles
- Air cushion vehicles
- RPV's – various sizes and missions
- Single stage to orbit vehicles
- Hypersonic aircraft
- STOL
- Stand-off weapons
- Tactical missiles
- Laser equipped aircraft

The Navy is clearly interested in VTOL capability. There is a need for "lifting" engine development. NASA should consider such development. The Navy is currently unable to do so. Joint efforts should be pursued. Other specific technology needs identified include:

- Airbreathing propulsion – ramjets – missiles
- High-lift systems – for 45 knots approach speeds
- Alternate fuels

- High-speed surface ship technology
- Laser weapons and its effect on aircraft
- "Surface effects" aircraft

Specific recommendations for rotorcraft programs were made by the Army as follows:

- The aerodynamic deficiencies were defined as high dynamic loads, inadequate controllability, and high noise levels.
- Reduce vibration levels
- Define blade dynamic stall
- New airfoils for blades
- Drag prediction techniques
- Develop hingeless rotors
- Minimize transition effects
- Prediction of dynamic stability
- Develop handling qualities goals and criteria
- Reduce impulsive noise
- Trade of noise/service/performance

DOT/FAA AND AIRPORT AUTHORITIES

The U.S. civil aviation sector is regulated, for the primary purpose of safety, by the Federal Aviation Administration (FAA) under the Department of Transportation (DOT). The civil aviation sector is also subject to rulings of local airport authorities whose main concern, again, is safety, along with efficient operations. At the same time the airport authorities must minimize the airport's present and future impact on the local community. The following federal and local airport authorities were visited:

Deleware Valley Regional Planning Commission
Dr. Richard Hubbell

Los Angeles Department of Airports
Mr. Clifton A. Moore
General Manager

Department of Transportation

Honorable Benjamin O. Davis, Jr.
Assistant Secretary for Environment, Safety and Consumer Affairs

Honorable Robert H. Binder
Assistant Secretary for Policy, Plans and International Affairs

Honorable W.E. Stoney
Assistant Secretary for Systems and Technology (Acting)

- Climatic Impact Assessment Program Office (CIAP)
- Federal Aviation Administration

Mr. William M. Flener
Associate Administrator for Air Traffic and Airway Facilities

Department of Commerce
City of Philadelphia
Mr. Austin Brough
Assistant Director of Aviation

Port Authority of New York and New Jersey
Mr. Ceasar B. Pattarini
Director, Aviation Department

FUTURE DIRECTIONS

DOT/FAA

- With respect to long range projections for U.S. transportation, the DOT says that such projections cannot be made definitely. Continued growth is expected at a rate lower than the last decade. Evolutionary improvements in air transportation is anticipated, but major new aircraft developments in the next few years are unlikely. Improvement in the compatibility of air operations in the terminal area requires technological innovation which can enhance the basic systems.

- DOT believes that the development of a supersonic transport must await substantial improvements in fuel conservation and the minimization of the NOX and sulphur derivative emissions (i.e., engine/fuel technology advances).

- In the case of short-haul, the assets and advantages of air transportation in terms of flexibility of destination, delivery time, unit productivity, etc., are substantially impacted by congestion and inefficiencies in the terminal area. It is felt there is a significant portion of the spectrum of short haul services which air transport can serve best, some portion where highway vehicles would provide the most desirable service, and a small portion where high speed guideway (rail, etc.) may be the most effective.

- The ability to integrate the services provided by the various modes into a cohesive pattern of service is a subject that attracts great interest in new approaches. The Department has encouraged the development of multimodal terminals and the cooperative operation of them by the various carriers. In areas where the need for commodity and passenger flow is very high, such as the Northeast Corridor spine, it appears more productive to enhance the use of current investments, both rail and air, and to improve the feeder, regional, or collection and distribution (pick up and delivery) aspects of the air service. In the long term, DOT thinks that quiet, energy-effective VTOL systems may provide important services in areas surrounding major metropolitan centers, working cooperatively with surface capabilities. Perhaps the ultimate in dual-mode operations is an air/surface connection.

- In regard to both the airport terminal area and enroute air traffic control, FAA efforts are currently directed to the development phase of upgrading the so-called third generation control system. This system is expected to meet the operational needs of the National Airspace System (NAS) through the 1980's. Accommodating the increased traffic demands, both in level and diversity of operations projected for the 1990's and beyond, however, will probably impose substantial R&T requirements for the development of avionics, communications, navigation and other electronically based systems. A prerequisite for planning R&T programs in this area is resolution of such fundamental concepts as positive control versus man-as-manager and decisions between contending approaches such as satellite versus ground based surveillance and control systems and NAS through ground versus air-to-air control. One possible combination of such decisions would lead to the requirement for automated flight regimes by the year 2000 in order to meet safety and system cost objectives while accommodating demand within acceptable service levels. At the least, improved traffic flow control and landing system requirements would generate R&T requirements directly within or impacting on NASA programs. For similar objectives, improvements in navigational and flight service systems and in lower density or non-air-carrier terminal control systems could generate R&T requirements in areas of NASA programs.

- In regard to capacity and service levels of the airports element of the NAS, the FAA believes that the combination of increasing operations demand and foreseeable constraints on new airport siting (responsive primarily to environmental concerns) impose immediate and substantial R&T requirements. Not only must the efficiency of airside systems be greatly improved starting in the mid-1980's, but landside and intermodal interfaces must be improved thereafter if these areas are not to become the constraining portal of the total NAS system.

AIRPORT AUTHORITIES

The airport operators are concerned about developments to at least 25 years in the future because of the long time to bring a new airport into being. With perhaps a few exceptions, it is likely that there will be no new major airports built in the U.S. before the end of the 20th century. Instead, existing airports will be improved and expanded as requirements dictate. Specific comments are summarized as follows:

Noise

- There will be a continuing effort to reduce noise for many years and therefore they strongly support efforts to advance the science of acoustics and to identify design approaches to reduce aircraft noise. Community resistance is so high that airports could be forced to close down, have their operations curtailed, or have a curfew imposed.

Air System

- The concept of treating the aircraft as an element of a complex system made up of many air and ground components is essential. To achieve greater efficiency, it is as important to improve non-aircraft elements such as the ATC and ground equipment, as it is to improve the aircraft. The operators of airports feel that large gains are to be realized by looking critically at the interacting elements of the total operating systems

- All are worried about ground-site transportation that serves the airport, since this is close to being a limiting factor for the air traffic that can be handled. They also point out that projections of traffic demand, and the balance of capacity versus frequency, are critically important, and that such information being supplied by the airlines is not always relaible.

- Improvements in the ATC are long overdue in that procedures that must be imposed with the present equipment frequently result in waste of time and fuel. There also are opportunities for expediting air cargo growth by providing better facilities and equipment.

Short-Haul Aircraft

- The growing problem of congestion on the ground and in the air suggests a serious effort to improve the short-haul air transportation system. It is important to view the airplane as a part of an inter-modal system in which air or ground modes are proportioned from efficiency and practical considerations. The success of short-haul is related to possibilities for separation from other traffic in the air and on the ground and the availability of local service airports.

- The New York Port Authority has followed the progress of STOL aircraft technology for many years and has supported studies of potential STOL-ports and evaluations of operations in the New York area. They feel that STOL aircraft with a capacity of 80 to 100 passengers could significantly alleviate congestion in their geographical area.

- It was observed by spokesman for the Los Angeles Department of Airports that small commuter-type STOL aircraft are an unsatisfactory solution to the congestion problem, since the number of passengers is too small compared to the required number of aircraft operations. In the mid-1960 boom of commuter airline operators, commuter aircraft constituted 30% of the LAX operations while only moving 3% of the passengers and generating only 1% of the revenue. Many of these companies have since gone out of business and those remaining, such as Golden West, are carrying good load factors. Also, the successful commuters have a tendency to grow into large airlines, (e.g., PSA), creating more traffic flow.

- The possibilities for STOL, when properly applied, are of interest to each of the organizations visited. Efficient traffic handling was described as being of critical importance to short-haul operations. Unfortunately, recent overloading of the ATC system frequently has resulted in increased trip time even when new aircraft having substantially improved cruise speed are introduced.

- The possibilities for viable application of civil VTOL aircraft also seemed to be generally accepted; however, VTOL was not expected to make a very significant impact on mass transportation for quite a few years. There does not appear to be a strong preference for a particular type of VTOL aircraft. Advanced rotary-wing may do the job at least until a good fixed-wing VTOL comes along.

Long-Haul Aircraft

- Although there was little discussion specifically on subsonic long-haul, it seemed to be generally accepted that this class of aircraft would continue to capture most of the air passenger revenue. All-new subsonic transports are not expected in the foreseeable future.

- Spokesmen for each of the airport authority organizations expressed the belief that the supersonic transport has a place in the future transportation system, but that it probably would not have a very important role until late in this century. One spokesman expressed the view that the U.S. must have an SST to market, if it is to stay competitive in air transportation.

Performance improvement is not strongly on the minds of airport operators at this time, however, they anticipate renewed interest in speed and range improvements after concern for the more immediate problems is lessened and the current reduced passenger projections are improved.

The air cargo market is generally on the increase, with the trend toward dedicated all-cargo aircraft. A large advanced all-cargo airplane is a very probable future need.

Fuel

The projected fuel situation is viewed as a long-range problem requiring technical efforts to reduce fuel consumption and costs. It also is essential to look at alternate fuels and their effects on design and operations of airports. Nuclear-powered aircraft should receive attention in view of the uncertain future of aircraft fuel.

ROLE OF NASA

DOT policy regarding research and development in the transportation area is contained in Secretary Brinegar's recent policy statement:

> *"Federal research and development work on transportation should be directed to a limited number of programs with a high potential payoff to the nation as a whole and with little likelihood of being adequately handled without some federal support. Near-term programs that meet this criteria include: (a) improving the energy efficiency in all transportation systems, but especially automobiles; (b) improving motor vehicle, driver, and highway safety; (c) improving the air traffic control system to increase the capacity of the airways; (d) improving highway traffic control for automobiles and buses; and (e) increasing the operational efficiency of the nationwide rail freight system"*

- With regard to NASA's role, technological innovation which enhances the use of facilities currently dedicated to air service will be needed. DOT believes that NASA's role in pursuing that technology is not limited to aeronautical subjects alone but is also of importance in the support of technological developments in related appliations. It is felt that the vitality of NASA's contributions, throughout its history, has been stimulated by separation from institutional and programmatic constraints (e.g., transportation policy). It is advocated that NASA continue to focus its attention on the development of practical, useful technologies in pursuit of solutions to problems identified by DOT, FAA, DOD and other government organizations.

- It is felt that NASA should conduct flight programs involving research or experimental aircraft, when such activities will contribute to the development of new operational techniques and demonstrate the technological innovations included therein. Such programs, however, are significant in their dollar commitment; therefore, the DOT should be expected to support such programs by advocacy, as well as collaboration, and that they should be pursued only when the need for such demonstration is clearly supported.

- Since the need for the federal government to sponsor the development of a new civil aircraft is not foreseen, it is not appropriate to generalize NASA's role in a hypothetical civil air transportation development program.

- The FAA believes that requirements for the operation of the NAS developing over the 1980-2000 time period can have significant impacts on the NASA aeronautics program. Foremost, there is the need to assure that R&T development efforts in aircraft hardware and systems are compatible and supportive of development efforts in the NAS system, particularly as to air traffic control. Secondly, NASA resources may be called upon to assist directly in DOT R&T efforts even through developmental and operational responsibilities continue to reside in that department. Thirdly, indirect or secondary applications of NASA R&T efforts to support developments in the NAS is an important prospective benefit.

The need for a system approach in considering the transportation needs of an area was stressed by the airport authorities. No specific recommendations for such activity by NASA were made but much of the discussions dealt with airport access, freeways, commuter airlines, railway extensions, etc. Their comments on the role of NASA were as follows:

- NASA's background in fundamental research was recognized as the qualification needed to find solutions to the very difficult problems confronting the industry and the airport managers. It is important to continue the far term R&T base effort; however, the near term situation also needs attention.

- Many of the emerging problems are of massive proportions and are not likely to be disposed of by quick solutions. Noise, emissions, fuel use, congestion in the cities, and safety all become of greater concern as the demand for air transportation increases and as the population in communities surrounding the airports becomes greater.

- NASA should organize an effort to address such problems in a way to ensure that improvements will be forthcoming over a period extending several years in the future.

- NASA's efforts need to be coordinated closely with the FAA in order to be certain that the programs are not overlapping or in conflict. NASA also needs to be sensitive to the impact of its publicity releases on the activities of another agency..

- The approach NASA has taken in its STOL program, that is, evaluating airplane designs, operating characteristics,and criteria for certification, is supported as being a proper role for NASA. This view seems to imply that NASA should analytically evaluate advanced aircraft in terms of their mission and that the results should be made known to interested groups, such as airport planners and the users in industry.

- In order to appreciate the problems of bringing a new airport into existence and the problems of satisfying its users and its neighbors, it is good for NASA to establish communication with airport people as is being done in connection with "Outlook for Aeronautics." This should improve NASA's understanding of the airplane/airport/airway system so that a better focus on the main problems can be achieved.

TECHNICAL PROGRAMS

The technical problems and needs as seen primarily by the airport operators can be divided into three groups: generalized problems, aircraft needs, and specific technical needs. Specific technical programs can be inferred from each of the items.

Generalized Problems

- Regulations
  - Sound technical base for regulation
  - NASA/FAA coordination on implementation of regulations

- System Efficiency
  - Ground-side transportation has become severe constraint
  - Need guidance on question of airplane size versus frequency
  - Need improved ATC to reduce delays
  - Facilities and equipment for cargo

- Fuel Conservation
  - Aircraft design modifications and concepts
  - Detailed evaluation of alternate-fuel candidates

- Short Haul System
  - Aircraft as part of intermodal system
  - Separate runway and ATC handling from other traffic
  - Consider potential of local-service airports.

- Performance Improvement
  - Anticipate future interest in speed and range advances

Propulsion refinement was emphasized as a means for achieving a number of benefits that are high among current priorities. There also is a view that the fundamentals of noise, including subjective reaction, are not fully understood, so a greater effort on acoustics would be welcome. The fuels outlook is sufficiently uncertain to call for a detailed understanding to the implications of the various options in terms of fuel properties. It is recognized that the ATC system is a responsibility of the FAA; however, improvements will depend strongly on development of basic technologies which are in NASA's area of competence. The potential performance benefits that can result from developments of composite materials are well understood, however, the operators also are interested in a complete definition of material properties, so surprises will be avoided. To support their interest in STOL and VTOL for improved short-haul systems, encouragement is given to further refinements in the area of propulsive lift. A continuing effort on performance aerodynamics is required to prepare for advanced aircraft of the future. To comply with the expressed interest in the elements of complete operating systems and of providing information on far-term aircraft development, it appears that efforts in system design integration are desired.

Aircraft Needs

- Cargo
  - Trend toward large all-cargo aircraft
- Subsonic Transports
  - Apparent trend toward increased size
- Supersonic Transports
  - General agreement on their need in future transportation system
- STOL Aircraft
  - Can have strong impact on congestion in some areas (NY)
  - Available small STOL aircraft are limited help to large cities
- VTOL Aircraft
  - Potential valuable service to city centers could have significant impact farther in future than for STOL

Specific Technical Needs

The technical needs summarized below were given by the airport operators, however, they also are inferred by the items above on "generalized needs" and "aircraft needs." The first few items are believed to be in the order of relative emphasis as seen by the airport operators.

- Propulsion Refinement
  - Base for improved fuel use, noise, emissions service lift, etc.
- Acoustics
  - Base for design approaches to reduce propulsive and non-propulsive noise
  - Base for noise standards
- Alternate Fuels
  - Definition of critical fuel properties
- ATC Technologies
  - Base for improving ATC efficiency (electronics, displays, computers, automation, etc.)
- Materials
  - New lightweight materials and definition of properties
- Propulsive Lift
  - Base for further improvements of STOL, VTOL
- Performance Aero
  - Base for advances in speed, range, efficiency
- System Design Integration
  - Base for defining aircraft in optimized intermodal system

NASA

The Directors of the NASA aeronautical centers were visited. Their views are summarized in this section. An attempt was made to place those views which were repeated most often at the beginning; however, all views presented were held by one or more of the Directors. Discussions were held with:

Dr. Hans Mark, Director
Ames Research Center

Mr. Lee R. Scherer, Director
(Dryden) Flight Research Center

Dr. Edgar M. Cortright, Director
Langley Research Center

Mr. Bruce Lundin, Director
Lewis Research Center

Dr. Christopher Kraft, Director
Johnson Space Center

Additional information was obtained from staff members of NASA Headquarters who provided written views on the future of aeronautics in NASA. Discussions were also held with the Research and Technology Advisory Committee and the Aeronautics and Space Engineering Board. These statements and opinions are included in the information below.

FUTURE DIRECTIONS

General Views

Replies from NASA personnel generally showed a strong awareness of the significance of the national environment (social, political, economic, and military) in relation to the future of aeronautics. In some cases, the emerging problems, such as political changes, energy depletion, rising costs, and the environment seemed to dominate views on the proper emphasis of NASA's program. Other responses placed more weight on the anticipated needs and opportunities in the far term. There is general support for a strong program in the traditional disciplines of propulsion, structures, electronics and aerodynamics. To a larger extent than had been noted in other segments, potential benefits to aeronautics from advances in the electronics area were described. There is a feeling that more advantages should be taken of electronic advances related to the space program and that a strong effort should be undertaken to reduce costs to permit wider use. Evaluation of advanced engine cycles probably requires the development and test of experimental engines, perhaps at reduced scale and of simplified design.

In addition to the usual disciplines, interest was expressed in learning to cope with the problems of complex systems, which seem to call for increased activities in integrated design and operations analysis. Demonstrator programs, with full-scale hardware, may be a necessary activity in order to evaluate new systems that differ significantly from experience. Human factors may require more consideration in conjunction with pressures for more automation.

A relatively close relationship between military and civil technology is indicated by several responses. This includes the applicability of disciplines, and also aircraft needs, such as large subsonic and V/STOL aircraft.

NASA center Directors believe that the future of our country and our part in world activities will continue to grow at a moderate rate despite the current fuel shortage and the recession in the U.S. economy. They saw the near term need for steady improvements to the commercial aircraft fleet, e.g., quieter and more economical engines. They perceive the need for derivative aircraft rather than for new models in the near term to the 1985-90 period. They believe that commercial aviation will continue to grow but not at the accelerated rate of 15-20% as was seen during the past decade. They consider 5-10% growth rate more probable. They believe that a new, large-capacity, long-haul transport will be needed by both military and commercial users as soon as the technology permits its development. Similarly, a STOL/VTOL aircraft for use by the Navy on its projected sea control ships would also be useful to short-haul commercial aviation and its development has early priority.

Views on more specific subjects were as follows:

Civil Aviation

- NASA personnel viewed civil aviation problems as seen from the "airside," as contrasted with the "ground-side."

- Of major concern is the slowness with which electronic automation techniques are being applied to the air traffic control system and to the flight control systems of the aircraft which operate in the traffic system environment. These techniques have been in use in the space program for years and currently are being further refined for redundancy, safety, and repetitive operation in the shuttle program. Adaptation to commercial aviation and to the air traffic control system is considered a system engineering job that should be undertaken without further delay.

Military Aviation

While there is agreement or concensus with respect to defense needs, individuals within NASA perceive DOD's possible needs in military aviation as follows:

- An airmobile, air-launched ICBM system of the MX type may be developed. This would require new large subsonic aircraft, new solid-propellant missiles, and new guidance systems.

- Cheaper and less sophisticated bombers may be needed. They could be derivatives of commercial aircraft.

- Large aircraft carriers are too expensive and vulnerable, and therefore future fleets will use small ships which can launch and retrieve VTOL or STOL aircraft. Development of V/STOL aircraft for fighters, reconnaissance, and systems delivery will be required.

- More long-range transports will be needed to retain "remote presence" with limited remote bases. These will be added to our current fleet of C-5's and C-141's.

- New fighter aircraft will be required which will incorporate laser weaponry.

- The concept of RPRV and RPV is good but limited to cases where high thrust and maneuverability need to be introduced. RPV's may even have potential for air to air combat. A proliferation of RPV's for civil applications could occur.

Civil/Military Commonalities

The NASA responses seemed to express a higher degree of commonality between future civil and military needs than had been indicated by other segments. Certainly, in the basic disciplines, there is little question about the applicability of advances to both sectors. However, there also seems to be a feeling of much similarity in aircraft.

- Both military and civil sectors need large efficient subsonic aircraft for transporting personnel and cargo.

- An airborne platform for ICBM's also is likely to be a subsonic aircraft of the same general type as a large civil transport, or at least based on the same technologies.

- Both sectors have needs for STOL, VTOL, and advanced rotorcraft.

- Both share the same concern for fuel depletion, rising costs, and to some degree environmental effects. Obviously, however, there is no civil counterpart to the military needs for fighters and missiles.

ROLE OF NASA

Basic and Applied Research

- NASA's long range emphasis has been diminishing in aeronautics with the emphasis on relevance to more near-term problems but this trend needs to be reversed. It is as difficult to visualize the important breakthroughs of the next 25 years, as it was impossible in 1940 to foresee the key roles jet engines and transistors would play. Such future breakthroughs only come from continued broad-based long range research.

- NASA should continue its aeronautics role in the tradition of NACA without direct involvement in the development of civil air transportation policy.

- NASA was described as the U.S. organization with a "corporate memory" in all aspects of aeronautical technology. This concept of NASA as a major repository of technology is a large U.S. asset which NASA should recognize and preserve. NASA should consciously organize, correlate, store, print, and distribute this data.

- NASA must continue its R&T base type work with increasing emphasis on in-house output. Research aircraft to explore new flight regimes or to demonstrate technology are a necessary part of in-house activities.

- The view was expressed that NASA should always be willing to work on "long shot" technology, and that NASA is the only agency that really has the necessary freedom of action to do high risk work – from which major breakthroughs are derived.

Demonstration Projects

- NASA should engage in flight research, including the building and flying of experimental aircraft, either in concert with the military services or independently, as with QSRA. However, it should stop short of building prototypes.

- NASA may have to take on an expanded role in R&T, particularly in the propulsion area since USAF finds it difficult to fund the advancement of new engine concepts. If such programs are to be pursued another agency (most likely NASA) will have to participate. It was suggested that the NASA budget may have to include an item of 30- to 40-million dollars per year to bring along several experimental engines representing advanced concepts related to both civil and military needs. NASA's activity normally would extend through a preprototype phase, stopping short of prototype hardware. At appropriate times, the interested government agencies would decide what prototype programs to pursue. Policy needs to be established as to the management and funding in the prototype phase. The possibility of NASA taking on the management role for some engine developments is not ruled out. A procedure would have to be defined for a mechanism to make the R&T needs of the military known to NASA and for reaching agreement on specific tasks and schedules.

- NASA's present role in flight demonstration vehicles is appropriate and there is a continued need for proof-of-concept flight demonstrations and flight research for NASA to close the loop with the real world. There probably should be less emphasis on contracting out and more emphasis on in-house research.

Aviation Safety

- NASA needs to become more actively involved in aviation safety. Recent accidents were cited. All were preventable by automation in the aircraft and in the air traffic control system. All flight procedures should be programmed in the computer and analyzed, and NASA has a real role to play in getting automatic flight into commercial aviation. "Systems engineering" is not well understood by industry. JSC is pioneering in digital systems applications related to the shuttle program and there is no corollary aircraft industry work. OMSF may be better equipped to pursue this work in NASA than OAST.

Military Support

- Perhaps the strongest individual view expressed was that the central national objectives include the following:

  - Maintenance of a deterrent posture
  - Maintenance of open sea lanes
  - "Monroe Doctrine"
  - Less reliance on resources of others

  A main implication of this view is that NASA should assume a strong supportive role to the military services. NASA should "go to the hilt" in aiding the military in meeting these objectives. Civilian aeronautics will benefit in a "fallout" manner from this role.

- NASA has a function (role) to cooperate in the exploration of military possibilities well prior to the point in time where a military requirement is established. There are many areas in *military* aircraft NASA has never worked on and does not understand (maintenance, logistics, avionics, and such important details as radar cross sections) and therefore should avoid in order to concentrate on our own areas of expertise. It was suggested that a better definition of NASA role vis-a-vis the military could come through the assignment of *high* level officers at Headquarters and the Centers who would assist in managing NASA aeronautics. The country is not doing enough about U.S.S.R. threat aircraft and it is necessary to look beyond the Mig 23 to the next generation Soviet fighter and work now on its U.S. competitor, and there is a NASA role here.

Joint Agency Programs

- NASA should aid FAA in the area of flight safety and the development of the criteria and regulations needed in furthering this goal.

Aircraft Development

- In one response to a direct question with regard to a NASA role for a new government supported aircraft development, it was indicated that industry should be directly subsidized without NASA in a program management role.

- It was indicated that the foreign competition argument, cited by a number of companies as requiring government support of development projects, was questioned as a basis for NASA involvement in such ventures.

- In the event that a radically new civil aircraft program (such as SST) which requires government financial support is given a go-ahead, NASA could be the program manager for both technical and financial aspects. However, NASA should only have responsibility for a research prototype development with no NASA involvement beyond consultation and support to the industry after that stage.

TECHNICAL PROGRAMS

As expressed by NASA personnel, views of technology needs are discussed in the following paragraphs:

Pursuit of the propulsion area can provide many benefits pertinent to near-term objectives such as fuel conservation, cost reduction, and environmental improvement, as well as to provide a base for far-term needs such as hypersonic and alternate-fueled aircraft.

- A continuing effort to explore advanced-cycle engines is essential; in fact, it has been recommended that promising concepts should be carried through an experimental engine state (short of prototype development).

- Emphasis would be placed on those approaches that would tend to minimize cost, including exploration of low-cost test techniques and the use of subscale, simplified experimental engines for evaluating new concepts.

- Much more needs to be known about the physics of engine materials to better understand the process of failure so that design margins can be minimized.

- Some continuing effort is needed on nuclear propulsion, not only from the basis of providing an alternate to petroleum fuel, but also to allow for new opportunities involving very long duration and range.

Regarding aircraft materials and structures, many comments were received on the need to reduce weight, both by further development of composites and by improved structural efficiency. For example, distributed span loading plus the use of active controls to control the aeroelastic modes could reduce aircraft weight.

- It was pointed out that shortages of some materials could arise for various reasons, and therefore it may be in order to give more attention to non-critical alternates.

- One respondent noted that the use of cryogenic fuel to actively cool aircraft surfaces should be subjected to a hypersonic flight test.

- In view of the rising concern for costs, there could be a significant payoff from improved techniques for inspection and maintenance.

There is widespread feeling that the advances made in the electronics and control areas during the space program have not been utilized in aeronautics to the extent that should be possible. The hold-up is largely a matter of cost but also to some degree a resistance by pilots and operators toward reducing the human role.

- Certainly any achievable cost reductions for electronic equipment, along with proof of reliability, could lead to important benefits.

- Potential applications for advanced electronic systems should permit improvements in energy efficiency, operating reliability, evaluation of the condition of the aircraft, and other benefits (all of which should improve safety and allow better utilization of aircraft and ground facilities).

- Support for the advancement of laser technology has been primarily for use in communications and guidance systems. Other uses such as military weapons, data transmission, and possibly power transmission may be significant for the far term.

The traditional primary thrust of aerodynamics, that is, to increase performance and maneuverability, should have continuing support to assure superiority in the future environment.

- Interest in the possibilities for efficient transportation of cargo provides incentive to explore radically new aerodynamic designs and aircraft sizes considerably beyond previous experience.

- There is continued interest in replenishing and updating the supply of systematic aerodynamic data that has proven to be so useful to designers in the past.

- It is suggested that to provide for future needs, capabilities in theoretical aerodynamics should be used in conjunction with test data to provide a much broader base than could be possible with test data alone.

A miscellaneous category is given to include items that are outside the usual technical disciplines.

- Several responses suggested more activity in integrated design to achieve a better appreciation of all the interrelated elements of complex aircraft systems and of the efficient use of different types of data.

- Some suggestions also would require more emphasis on operations analysis for early evaluation of potential systems and for identification of problems.

- The human element requires more detailed evaluation in order to define the role of man in future systems

- Actual demonstration of full-scale operating systems continues to be attractive as a means for evaluating advanced systems and possibly achieving application much earlier than would be possible through normal developments.

- The matter of atmospheric contamination is viewed as a very real problem. It is suggested that aircraft designers might consider the possibility of emissions that might stabilize properties rather than just minimize effects known to be adverse.

COMMENTARY REGARDING OTHER GOVERNMENT ORGANIZATIONS VISITED

The following government agencies and organizations were visited to gain insight into trends and directions of national policy and viewpoints from agencies with a broad outlook. This diverse group included:

Department of Commerce
Mr. Lawrence A. Fox, Deputy Assistant Secretary for Domestic and International Business

Department of State
Mr. R. Waldman, Deputy Assistant Secretary, Bureau of Economic and Business Affairs

Environmental Protection Agency
Mr. Alvin F. Mayer, Jr.

Federal Energy Administration
Messrs. Earle, Eldridge, and Peters, Office of Policy Analysis, Mr. John G. Muller, Office of Conservation & Environment

Staff of House Committee on Science and Technology
Mr. William G. Wells, Jr., Technical Consultant

Staff of Senate Committee on Aeronautics and Space Sciences
Messrs. Wilson, Voorhees, Lombard, and Gehrig

Staff of Subcommittee, (HUD-Space-Science-Veterans, etc.) to House Committee on Appropriations
G. Homer Skarin, Staff Director
Richard N. Nalow, Staff Member

The comments and opinions gathered from the above government organizations are not included in this report; however, their views are reflected in the Survey Findings (Appendix A of the main report).