INDEX

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TITLE

STUDY AND RESEARCH PROGRAM OF CRITICAL TECHNICAL AREAS TO SUPPORT THE DEVELOPMENT OF A COMMERCIAL SUPERSONIC TRANSPORT

FISCAL YEAR 1962

A Report by the Joint FAA-NASA-DOD Working Group

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This report is not for publication as it constitutes advanced procurement data.

FOREWORD

The "Commercial Supersonic Transport Aircraft Report," June 1961, outlined, in general terms, the critical technical areas in which research is required during the initial phase of the program.

The Working Group reviewed these general areas and reduced them to a series of project areas and prepared work statement synopses. The purpose of these synopses is to establish a more definitive work requirement which can be reviewed by higher authority. This also serves as a guide for the procuring agency in the writing and negotiation of definitized contracts.

Congress has appropriated $11 million in fiscal year 1962 to support direct contracts with organizations outside the government. An exhibit has been made which shows the possible funding of the work statement synopses. These amounts are to serve as a guide for contract negotiations and indicate the approximate limits of financial negotiation.

It is desired to retain as much flexibility as possible in the use of this report until the submission of contractor proposals or the execution of purchase requests. A final review of the definitized program should be made prior to the commitment of the government to contracts.

INTRODUCTION

The Federal Aviation Agency, in conjunction with the Department of Defense and the National Aeronautics and Space Administration, is undertaking a research and study program to assist the aviation industry in the development of an economically competitive commercial supersonic transport aircraft.

As a result of a joint analysis of industry and government views, a report entitled "Commercial Supersonic Transport Aircraft Report" was published in June 1961. The initial program requirements are contained therein and form the foundation of this FY 1962 research and study program. This program defines the direct contract support to industry required to complement the already existing knowledge and research prior to the design and fabrication of a specific aircraft.

The FY 1962 and FY 1963 budgets are considered to be a phased two-year research program which will provide industry with information for the design of a specific competitive aircraft. It will also provide government with a sufficient basis for review and consideration of the necessity and desirability of assisting industry in a development program. The fiscal year 1962 funds will provide for the initial investigation and study confined primarily to exploration and concept which is considered necessary before embarking upon the next phase of applied research.

Some research areas will require effort beyond one year; however, FY 1962 provides funds to initiate the research effort. The research areas recommended represent a minimum requirement and the relative effort may be adjusted within the limits of funds available.

STATEMENT OF MISSION

In order to compete in the world market in the 1970 period, a commercial supersonic transport having the following general characteristics and capabilities is indicated:

1. Cruise speed - Mach 3.0 regime.

2. Gross weight - 400,000 pounds maximum. The runways of present international airports are strong enough to permit the consistent operation of aircraft in the 400,000 pound class.

3. Runway length - 10,500 feet maximum (sea level). Shorter runway lengths are desirable.

4. Direct operating costs should be competitive with commercial subsonic jet aircraft.

5. Range - Approximately 3500 N.M.

6. Payload - 100-150 passengers (32,000 pounds approx.).

7. Safety and comfort should be comparable to commercial subsonic jets.

8. Utilization life - minimum of 30,000 hours (40,000 hours desirable).

9. Takeoff, landing, holding, and traffic pattern speeds must be comparable to commercial subsonic jets.

10. All weather capability.

11. Aircraft should operate without flight schedule limitations due to sonic boom or airfield noise.

12. The airplane must be eligible for type certification under Civil Air Regulations and be capable of operation under pertinent FAA operating rules.

13. Maintenance and reliability - the design of this aircraft should incorporate features of maintenance and reliability consistent with airline requirements.

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WORK STATEMENT SYNOPSES

Item No.

1 OFF-DESIGN PERFORMANCE
2 SKIN FRICTION
3 CRUISE LIFT-DRAG RATIO
4 STABILITY AND CONTROL
5 CONTROL SURFACES, SPEED BRAKES AND GLIDE CONTROL DEVICES
6 HIGH-LIFT DEVICES
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31 DUCT HEATER AUGMENTATION
32 AUXILIARY POWER EXTRACTIONS
33 ENGINE SEALS AND BEARINGS
34 ENGINE NOISE CRITERIA
35 ENGINE RELIABILITY AND LONG LIFE
36 FUELS AND OIL TESTS
37 ENGINE CONTROLS

SST Work Synopses Categories for FY 62 Research and Study Effort

Each work synopsis item has been placed in one of the following categories:

Category 1. In-house work in progress - industry capability required to supplement government program.

Category 2. In-house work inadequate, either no activity or extremely limited - industry capability required as main effort.

The purpose of placing the work synopses in different categories is to recognize in-house efforts to prevent duplication and to reflect the relative strength of government programs. It will serve as a guide to FAA, NASA and the USAF in preparing contractor guidance data on related programs. These data will be supplemental to the formal Work Statements.

ITEM 1: OFF-DESIGN PERFORMANCE

In addition to a high-performance level for the cruise condition, the mission profile of the supersonic transport calls for relatively high lift-drag ratios during other flight regimes. The critical off-design conditions requiring immediate research and development attention include take-off and subsonic climb, transonic climb, transonic acceleration, letdown, terminal hold, and emergency low-altitude subsonic cruise. In addition to the latter, it is highly desirable that the subsonic cruise performance be adequate for alternate scheduling to increase aircraft utilization as is done for the present intercontinental jet transports.

Most conceptual arrangements for the supersonic transports thus far proposed appear to have serious deficiencies with regard to off-design performance and the operating flexibility vital to commercial airline operation. The use of extensive wing-variable geometry in some form appears almost necessary to overcome these deficiencies. The research proposed in the area outlined should therefore include, but is not necessarily restricted to the variable geometry approach.

CATEGORY #1

ITEM 2: SKIN FRICTION

As skin friction is expected to contribute a major portion (approximately 40 percent) of the cruise drag of the supersonic transport, its prediction must be based upon accurate experimental data at conditions near those of full-scale flight, rather than from unsubstantiated extrapolation of low Reynolds number, zero heat transfer data. Flight and wind-tunnel studies at conditions of Reynolds number and temperature associated with supersonic cruise are therefore needed. ($RN_{max} = 300 \times 10^6$, $M = 3$)

Investigations can be focused mainly on the fully turbulent boundary-layer case, as the prospect for any substantial runs of laminar boundary layer is small. The subject investigations should include study of both the skin friction of smooth surfaces, and the drag (both shear and pressure) of rough surfaces that are typical of what may be expected to occur on the transport as a result of construction imperfections. Heat transfer effects on skin friction at high Reynolds numbers also should be considered.

The results obtained should be of a sufficiently fundamental nature as to have application over the range of configurations from which the transport may evolve.

CATEGORY #1

ITEM 3: CRUISE LIFT-DRAG RATIO

One of the more important factors controlling the economic feasibility of the supersonic transports will be the lift-drag ratio obtainable for the cruise condition. A major effort should be expended to obtain the highest possible supersonic lift-drag ratio compatible with satisfactory volume, structural, and off-design requirements. The variables to be considered are the zero-lift drag, drag-due-to-lift, and the turbulent skin friction drag.

Previous research on wings with the leading edge behind the Mach angle, conducted by the Ames and Langley Research Centers of NASA and several manufacturers, has indicated that a substantial program must be continued to determine the proper shape of the section of the wing (twist and camber) to realize the gains indicated as possible by linear theory. This work should be directed toward wing planforms, including variable-geometry arrangements, that would be applicable to the supersonic transport configurations being considered.

Preliminary theoretical and experimental work has indicated that the turbulent skin friction drag can be reduced by the injection of air into the boundary layer. At the present time, the magnitude of the possible gains that can actually be obtained through such an approach is in doubt since the penalty associated with such injection has not been thoroughly assessed. Studies to evaluate these penalties must be made.

CATEGORY #1

ITEM 4: STABILITY AND CONTROL

The supersonic transport, in accelerating from subsonic to supersonic speeds, may encounter performance and control problems as a result of changes in static stability characteristics. These changes, which are usually evidenced as increased longitudinal stability and reduced directional stability, are a result of various changes in the aerodynamic characteristics of the lifting surfaces and of changes in the interference effects between various components of the aircraft that occur with increasing Mach number.

Research effort should be directed toward:

1. Development of self-trimming supersonic cruise configurations.
2. Reduction of aerodynamic center shift with Mach number and with variations in geometry.
3. Developing means of achieving longitudinal and directional stability with a minimum of stabilizing surface area.
4. Development of lateral control devices for highly swept and variable-geometry wings.
5. Development of analytical techniques to treat effects of aeroelasticity and thermal elasticity and on stability and control characteristics.

CATEGORY #1

ITEM 5: CONTROL SURFACES, SPEED BRAKES AND GLIDE CONTROL DEVICES

The supersonic transport, because of its wide range of flight environments will require highly reliable and versatile control systems. Since these configurations will be unique in that very thin fixed or variable-geometry wings will be used, studies are needed to properly adapt control surfaces, speed brakes and glide control devices to such configurations. The over-all criteria must be that supersonic performance should not adversely affect the handling qualities of the airplane in any other speed regime, nor should the conditions of supersonic speed be allowed to add unduly to the complexity of the control systems.

The realization of these goals will require an extemsive study to ascertain the control requirements and to determine the control configuration necessary to meet these requirements and still be compatible with the over-all airplane design. The aim of these studies should be accomplished through extensive use of present methods of attaining control and adaptation of these methods to new and different airplane configurations. However, it is anticipated that new and unique devices should be investigated which will improve the effectiveness and adaptability of the controls for use in emergency and off-design operations as well as normal operating conditions. Canard and wing control devices should be investigated to determine their adaptability, effectiveness and in addition their effect on the aeroelasticity of the complete airplane. The study should be general enough to allow for the application of the resulting information to the various supersonic transport configurations under consideration.

CATEGORY #1

ITEM 6: HIGH-LIFT DEVICES

Since the civil air carriers, based on their experience with the current jet transports, feel that the current take-off and landing speeds are about as high as can be handled in commercial operations out of the Free World's airports, an intensive study of high-lift devices is needed.

This work should be directed toward improving the lifting capabilities of both fixed-wing and variable-geometry configurations. Studies are also needed relative to emergency landings in the supersonic cruise configuration as a consequence of the failure of variable-geometry or flaps.

It would be anticipated that this wind-tunnel and/or flight study would come up with original contributions in the field of new or unique combinations of leading- and trailing-edge devices that will improve the lifting capabilities and take-off performance of the thin wings anticipated for the supersonic transport. Boundary layer control should be considered in forms that will be suitable for commercial operations. The study should be general enough to allow application of the devices to other planforms using existing methods of estimation.

CATEGORY #1

ITEM 7: STABILITY AUGMENTATION

The supersonic transport airplane, because of its high operating altitude, speed and weight, is expected to exhibit very low inherent damping of oscillations about all three axes and will therefore require some artificial augmentation of its natural dynamic stability. Studies are needed to define the requirements of the stability augmentation system in all phases of the flight profile.

These studies should provide information in the following areas:

1. Definition of the relationships between period, damping, and mode shape of the various aircraft motions which must be satisfied to provide adequate handling qualities and passenger comfort in normal airline use.

2. Determination of the types and amounts of stability augmentation required to satisfy the above relations.

3. Determination of the effectiveness of aerodynamic control surfaces required to implement the above stability augmentation system.

4. Determination of effects of aerodynamic control cross-coupling on stability augmentation requirements.

5. Study of effects of structural elasticity on performance of the stability augmentation system.

6. Determination of the period, damping and mode-shape relationships which must be satisfied for safe operation by airline pilots following sudden, partial or complete failure of the stability augmentation system.

7. Determination of pilot capabilities for detecting stability augmentation failure and taking appropriate action.

8. Determination of control data sensing techniques

It is anticipated that this work will require flight simulation studies as well as analysis and literature surveys.

CATEGORY #1

ITEM 8: CONFIGURATIONS

The supersonic commercial transport must be able to operate efficiently over the Mach number range and must possesss low-speed characteristics at least equivalent to the improved present-day commercial jet transports. Aerodynamic studies are required for complete configurations which incorporate new research results. These configurations must be capable of performing the entire supersonic transport mission which is defined in the Statement of Mission. It is desired that complete configurations be wind-tunnel tested to demonstrate aerodynamic coefficients used in all phases of flight. The wind-tunnel results should be extrapolated to full-scale results using the T' method considering the effects of heat transfer with a 10-percent increase in turbulent C_f due to unknown roughnesses, gaps, etc. It is believed that research configurations suitable for the mission should have subsonic cruise lift-drag ratios of not less than 15, supersonic L/D of at least 7.5, and a take-off speed at maximum weight of not more than 150 knots, and a touch-down speed at 60 percent of maximum weight of not more than 110 knots.

CATEGORY #1

ITEM 9: HANDLING QUALITIES

Since a commercial supersonic transport must be operated over diversified route structures and into many different airports, the airplane handling qualities are of paramount significance in attaining the high level of safety and economy required of public air carriers. This study will consist of ground based simulator investigations, and/or variable-stability flight investigations to assure satisfactory handling qualities over the entire flight profile and includes the following items:

1. Static and Dynamic Stability.

2. Stall Characteristics. Definition of stall speed for configurations that do not exhibit conventional stall behavior. Development of control techniques for minimizing uncontrolled motions and recovery from stalls.

3. Trim Changes. Determination of special conditions of supersonic transport operation that introduce critical trim changes.

4. Control Effectiveness. Definition of critical control effectiveness situations considering the entire mission, including emergencies, and levels of effectiveness required.

5. Maneuver Capabilities. Investigation of unusual situations in mission profile that involve maneuvers. Determinations of stability and control levels required for restraining airplane motions within design limits during unusual situations.

6. Buffet Characteristics. Including the determination of effects of mild buffet in masking onset of an emergency condition.

7. Gust Response. Definition of handling qualities required for passenger comfort and for minimizing structural loads and piloting problems in gusty conditions. Development of optimum piloting techniques to be used after encountering areas of heavy turbulence.

8. Display Techniques. Determination of the most satisfactory display techniques to inform the pilot of the airplane motion to assure a minimum pilot workload during emergency conditions as well as during normal flight.

9. Aeroelastic Effects. Methods are required for predicting structural response in relation to piloting problems, passenger comfort and autopilot sensor locations. Definitions of maneuverability limitations due to dynamic overshoots.

ITEM 10: STRUCTURAL DESIGN CONCEPTS

This program will provide design parameters, fabrication techniques, detailed testing, structural analysis, and evaluation of various wing and fuselage structural components representative of typical construction required for supersonic applications for speeds up to Mach 3 or greater, altitudes up to 80,000 feet, and a minimum service life of 30,000 hours (40,000 hours desirable). The structural concepts shall be investigated for a temperature range of -65° F. to 650° F. under a combination of loads utilizing selected materials of stainless steel and titanium alloys.

The program will develop methods and procedures for predicting optimum structural utilization of the various selected concepts by considering the physical and mechanical properties, and producibility characteristics of the materials selected as well as the desired mission requirements. In addition, it would be anticipated that the proposed study should provide a basis for evaluating various design and fabricating methods and materials for (a) weight and cost per unit area, and (b) obtainable aerodynamic surface smoothness.

CATEGORY #2

ITEM 11: THERMAL STRESSES

The following problem areas shall be investigated:

Rectangular Plate Analysis

An experimental and theoretical analysis development program shall be developed to determine stresses and deformations in panels (including transparent assemblies) subjected to three dimensional temperature gradients. This program shall consider various degrees of edge support so that the analysis is applicable to any structure that can be resolved into flat plate elements.

Internal Heat Transfer

Techniques shall be evolved to improve existing heat transfer analyses to account for the new environment encountered in the supersonic transport regime. Consideration shall be given to such items as variable joint conductivity, variable thermophysical properties of the internal structure, and computer techniques to handle complex structures. In order to have reliable thermal stress information, the transient temperature distribution must be known in each primary load-bearing-element of the structure.

General Thermal Stress Problems

Analyses shall be developed to examine simple structural elements subjected to asymmetric thermal loads such as beam-columns, circular bulkheads, semimonocoque shells, etc. In addition to thermal stresses per se, the effect of changes in geometry caused by various thermal inputs upon the stability of compression elements shall be evaluated. This program shall also consist of the verification of some existing analytical techniques and the presentation of all data in a form which can be directly applied by the designer.

CATEGORY #1

ITEM 12: NOISE PREDICTION TECHNIQUES

Extend present methods for predicting noise. Probable engine arrangements shall be included (i.e., clustered, side by side, individual pods, etc.). This method shall apply specifically to the engine types considered for the SST. Methods shall also be developed to more accurately predict noise generated by flow phenomena such as boundary layer pressure fluctuations, wakes around discontinuities (i.e., cavities, canard surface-fuselage intersections, etc.). The above improvements in noise predicting techniques shall be capable of predicting the noise (levels, spectrum, distribution, etc.) at specific locations both interior and exterior on the aircraft at any time in the mission profile from engine start to engine shutdown at conclusion of the mission. Model testing techniques will be considered for the above.

Statistically define the noise loading encountered throughout the life of the aircraft. That is, define the time spent at high thrust during ground maintenance, take-off, thrust reversal, high speed flight, etc. The information derived shall be utilized in preparing a test program suitable for evaluation of the SST structure susceptible to sonic fatigue.

Investigate more efficient methods of controlling interior noise such as integrating soundproofing with the load carrying structure and making the soundproofing material structural rather than a special provision which decreases the useful load.

CATEGORY #1

ITEM 13: CRACK PROPAGATION

The need for fail-safe designs of pressure cabins for high-altitude flight is well recognized. However, principles of such fail-safe design are very poorly understood, and there is considerable doubt whether the methods used previously for aluminum-alloy designs are adequate for steel and titanium.

A literature search of recent applied and basic research programs will be accomplished and all pertinent data will be incorporated into the program. This is expected to yield useful data on crack propagation and residual strength of several of the alloys considered for the supersonic transport. A study of all of the recently generated formulations for crack propagation and fatigue life prediction must be studied and will be used or modified as required.

Pressure-cycling tests should be undertaken on stiffened cylinders made of titanium alloys and steels to establish whether these materisl behave in a similar manner as the aluminum alloys previously used as structural materials. The behavior during cycling and at failure must be studied over the range service temperatures anticipated. The crack-stopping abilities of rings, stringers, straps, and possibly other devices should be studied.

Structural configurations will be studied with special emphasis on crack-stopper methods and radius to thickness ratios. This information will be incorporated into typical panels which will subsequently be tested.

When the preliminary work has been accomplished, a limited number of stiffened cylinders will be tested. These cylinders will have design parameters based on the supersonic transport. They will be tested with loads derived from the mission of the supersonic transport (internal pressure, external load and temperature) and special emphasis will be placed on crack stopper effectiveness.

An attempt will be made to formulate an analysis which accounts for the complex stress field in a practical structure, the temperature, and the random load input. This analysis is expected to be semiempirical and may contribute to a parametric presentation of design data.

This effort will include development of improved inspection methods and techniques.

CATEGORY #2

ITEM 14: CREEP TESTS OF TITANIUM ALLOYS

The airplane structure should not deform or elongate when subjected to long periods of operation under the 600 to 700 F. temperatures associated with Mach 3 flight as a result of creep. There is a definite lack of creep data in this temperature range; consequently, creep test of the more promising alloys are indicated. Some of these alloys are: (8Al - 1 Mo - 1V), (6Al - 4V), and (4Al - 3 Mo - 1V). Tests will be made with special emphasis on equipment that can measure very low secondary creep rates. Some studies of the effect of temperature and stress variations representative of supersonic transport operating conditions on creep will also be made.

CATEGORY #1

ITEM 15: LARGE SCALE TEAR TESTS

The airframe companies have been engaged during the past decade in the development of tests designed to evaluate the tendency of various materials to catastrophic failure. Extensive work has been done to correlate such test results with the actual tests of pressured fuselages. This work was chiefly conducted with aluminum alloys at atmospheric temperatures for application to the current generation of subsonic transports. The same type of testing is now required for the supersonic transport utilizing the new materials at their operating temperatures. Large tear tests at high temperatures (600°F) to low temperatures (-60°F) will be started in FY 1962. The more promising alloys of each class such as: (15-7Mo), (AM350), (8Al - 1Mo - 1V), (6Al - 4V) can be utilized provided the materials and test methods are carefully selected for this preliminary phase.

CATEGORY #2

ITEM 16: FATIGUE

The supersonic transport will encounter fatigue inducing conditions throughout its entire flight envelope. Higher magnitude cyclic loading can be expected during take-off, climb out and flight at subsonic and transonic speeds at the lower altitudes. This will occur at the surfaces of panels and supporting structures which will be subject to sonic fatigue. In supersonic flight relatively low frequency flexure will occur as a result of local air flow disturbances. The intensity of sonic fatigue and air flow flexure will vary over the vehicle.

Very little is known of the fatigue properties of the various alloys under consideration for use in the supersonic transport. Consequently, fatigue tests will be undertaken as soon as possible utilizing some of the more promising alloys such as: (15-7Mo), (AM350), (8Al - 1Mo - 1V), (6Al - 4V).

CATEGORY #2

ITEM 17: NONMETALLIC MATERIALS

Research in this area will consist of the following:

Glass

Development of design criteria and the generation of design data for various glass compositions up to temperatures of 650° F. This will cover such important materials parameters as finishing techniques, specific coatings for de-icing and defogging, transparent interlayer materials for bird resistance, heat transfer for extended flight profiles, etc.

Hydraulic Fluids

Derive a hydraulic fluid having improved thermal stability, liquid range and fire resistance. The problem of cost and supply along with compatibility of this new fluid with standard hydraulic systems will be considered.

Solid Film Lubricants

Develop solid films capable of operating at supersonic transport skin temperatures for use on control surface actuators. These materials will operate under high loads and slow speed but at temperatures in the range of 650° F.

Aircraft Tires

Tires on current aircraft are failing because of heat (greater than 300° F.) being generated from various sources including excessive loads, high brake heat, high deflection, etc. The SST will not only be exposed to these sources of heat but also aerodynamic heating.

The natural rubber compounds and nylon reinforcing fiber which are presently used in all aircraft tires seriously degrade at temperatures in excess of 300° F. These materials are inherently unstable above this temperature and no amount of design modification or compound innovation has been found to overcome this basic deficiency.

Research is required to develop high temperature resistant elastomer compounds, reinforcing fibers and adhesives suitable for fabrication of aircraft tires which will operate on SST aircraft at temperatures up to 450° F. Elastomers to be studied will include butyl and those based on copolymers of ethylene-propylene. Both of these materials have exhibited in laboratory evaluations outstanding retention of physical and mechanical properties after exposure to temperatures up to 500° F. High temperature resistant fibers to be considered should include the experimental HT-1 and wire. Adhesives which maintain high strength at elevated temperatures as well as compatibility with the elastomer and reinforcing fiber will also be investigated.

Sealing Materials

Currently available organic elastomers which are used for fabrication of seals, sealants, gaskets, flexible connectors, etc., will not meet SST requirements.

Research is required to derive elastomeric and compliant materials which will be resistant for extended periods of time to the temperatures and fluids to be encountered in the SST. New inorganic elastomeric polymers and resilient composite systems of materials will be investigated to determine applicability to critical sealing problems.

The most promising elastomeric materials will be fabricated into shapes for use as seals, gaskets, flexible connectors, etc., for use in components and equipment simulating actual SST aircraft systems.

CATEGORY #1

ITEM 18: FLUTTER PREDICTION TECHNIQUES

The structural design of the supersonic transport may in many cases be influenced more by stiffness requirements to avoid aeroelastic instabilities than by strength requirements. Because of the wide range of operating conditions for the airplane and because of the wide range of configurations proposed, an extensive flutter program will be required.

The work should include tests of component designs under consideration and would include canard surfaces at the front of long, flexible fuselages, variable-sweep wings with various joint arrangements, fixed wings, and empennages. Large-scale models should be used in the component tests so that structural details and such devices as flutter dampers can be adequately simulated. Models of complete airplanes,which would include both fixed-wing and a variable-sweep wing design,also should be investigated. Tests of components and complete models should be made throughout the Mach number-altitude regime. Flutter analyses should be made in conjunction with all the tests.

The flutter study will provide information on which to base the structural designs, will help in determining the best component designs and over-all airplane designs on a weight basis, and will establish criteria for which weight and flight plan trade-offs may be made.

CATEGORY #1

ITEM 19: PANEL FLUTTER

The skin material for the supersonic transport is likely to have higher strength and, therefore, will be somewhat thinner than the skin on subsonic airplanes. Experience with current airplanes has indicated that the use of thin skins can lead to severe panel flutter problems. The use of currugated stiffened and honeycomb sandwich skin will not prohibit flutter unless the skin supports and restraints are carefully designed.

Panel flutter tests should be conducted at Mach numbers from transonic to supersonic speeds and should cover appropriate ranges of dynamic pressure, panel thickness ratio, panel aspect ratio, surface curvature, pressure differential, edge restraints, stress fields, aerodynamic heating, and size of acousting cavity behind the panel. Because of uncertainties in applying small-scale model test results to full-size designs, the tests should be made with large-size specimens.

The results of the panel flutter studies will help insure that the final design will not require extensive panel modifications.

CATEGORY #1

ITEM 20: BUFFETING LOADS

In flight through transonic speeds it may be necessary to permit limited buffeting during normal operation. It will be necessary to insure that the buffeting does not result in excessive loading on any part of the structure and is acceptable from a fatigue standpoint.

Buffeting investigations should be conducted in conjunction with flutter model investigations and, where possible, in conjunction with "force test model" investigations. The important structural frequencies should be simulated in the model to obtain the structural loadings for cases where buffet and structural frequencies coincide. The investigations should be made at subsonic to transonic speeds to determine buffeting characteristics and to develop techniques for predicting and analyzing buffeting on a typical supersonic transport.

The results of the buffeting studies may influence the aerodynamic and structural design and the aircraft operating requirements at transonic speeds.

CATEGORY #1

ITEM 21: GROUND LOADS

Current subsonic jet transports are experiencing significantly higher vertical velocities at touchdown than did previous piston airplanes. Although considerable effort has been expended to determine the cause of these increased velocities, the reasons are as yet unknown. In view of this situation, there is considerable question as to what vertical velocities may be experienced by the supersonic transport embodying new configurations. The vertical velocities will have an important bearing on the strength required in the landing gears, fuselage and wing structures.

In order to define the supersonic transport vertical velocities, analytical and simulator work must be carried out to determine the important parameters affecting the touchdown conditions. This work will make use of measurements on current transports for correlation of piloting techniques with sinking speeds. Simulator studies are required to validate this technique as a means of studying the effect of various parameters on the vertical velocities. If these simulator studies prove valid, then the flight characteristics of supersonic transports can be simulated as a means of studying the vertical velocities for the new transport.

CATEGORY #1

ITEM 22: MANEUVER LOADS

As with present subsonic jets, maneuver loads experienced by the supersonic transport will constitute a major source of loads in regard to both fatigue and limit design considerations. The maneuver loads will depend to a large extent on the manner in which the supersonic transport is integrated into the existing air traffic system and on the procedures required for test and pilot check flights.

Analytical and simulator studies of the maneuvers required for collision and weather avoidance and for emergency maneuvering (rapid descents, engine-out, etc.) are needed.

CATEGORY #1

ITEM 23: ELECTRICAL LIFE

Investigate extended life electrical power systems and equipment suitable for commercial SST airline operation at 600° ambient temperature conditions and altitudes to 80,000 feet. Investigations shall include systems under development as well as other approaches.

CATEGORY #2

ITEM 24: ENVIRONMENTAL CONTROL

To obtain techniques for pressurization, humidity and temperature control of cabin and equipment compartments under SST temperature conditions, including preliminary analysis of the following:

1. Catastrophic pressure loss criteria and emergency pressurization methods.

2. Analytical techniques for making heat transfer and control trade-off studies and determining cabin and equipment heat loads will be developed. Optimization of environmental control systems from the bases of parametric studies (size, weight, etc.), air cycle versus vapor cycle system, redundancy versus reliability, and integration with other vehicle subsystems.

3. Use of cryogenic fluids, liquid oxygen, and other nonconventional refrigerants for equipment and personnel cooling, including heat sink control techniques.

4. Non-conventional air conditioning cycles with maximum utilization of high temperature heat sinks.

5. Investigation of contaminant removal systems.

CATEGORY #2

ITEM 25: HAZARD PROTECTION

Preliminary studies to cover the following items:

1. Establish design criteria (equipment and vehicle) for minimizing the fire and explosion hazards associated with fuel and other combustibles utilized, induced and operational environment and the design configuration of the vehicle.

2. Provide rapid and reliable means of fire detection suitable for use up to 1300°F ambient temperatures, and capable of positive identification of fire in engine compartments and other fire zones located within the vehicle.

3. Provide a fire extinguishing agent effective for application on supersonic transport fuels and other combustibles and suitable for storage in 500°F ambient temperature areas of the vehicle. Present agents are unsatisfactory for storage in ambients in excess of 350°without provision for insulation or cooling means. This would require either heavier equipment for protection against excessive heat or a limitation placed upon location of agent containers. Such a limitation could result in a considerable weight increase and penalize system performance insofar as such factors as discharge time, etc. are concerned.

4. Establish design parameters and requirements for a crash fire prevention system for supersonic transport. Limited research and tests have thus far shown feasibility of such a system for subsonic aircraft only.

5. Establish significant data on fire and explosion characteristics of various combustibles utilized in the supersonic transport so that dangers can be recognized and appropriate fire and explosion preventative measures taken in storage, handling and utilization of these combustibles on the vehicle.

CATEGORY #2

ITEM 26: MAINTENANCE ANALYSIS

An analytical framework will be developed for use in the formulation of a maintenance plan for the SST. This analytical framework is a simulation of the entire maintenance system including all maintenance locations (in-flight will be considered), all equipment levels, and all maintenance procedures. This will be programmed on a computer.

CATEGORY #2

ITEM 27: INTEGRATED FLIGHT CONTROL DATA

The precise measurement and total integration of the data defining the dynamic and stored energy of the SST is necessary to achieve vehicle control, energy management, and mission accomplishment. Adequate measurement techniques must be provided, the interrelationships of these techniques and the required control data must be defined, and methods of integration must be established.

The effort will define through study and certain laboratory tests the requirements for the SST flight control data sensing system.

CATEGORY #1

ITEM 28: ENGINE CYCLE STUDIES

Studies which are currently under way will be expanded in scope and accelerated. These studies have already indicated in a general sense what type of engines are of interest for different cruise Mach number regimes. Further study of several types of engine cycles will be required in order to establish what engine design characteristics appear to provide the best compromise among the various factors affecting the performance and economics of a supersonic commercial transport aircraft. These factors include acceleration characteristics of the aircraft, sonic boom, cruise altitude, required aircraft range, mission profile, engine and fuel cost, maintenance cost, engine weight, and engine noise levels. After an extensive study of the interaction of all these factors by both aircraft and engine manufacturers, it will be possible to narrow the choice of engines considerably, perhaps to two or three attractive configurations. These configurations will be deserving of a very detailed study (including thorough design study) at least through the layout stage and complete performance estimation so that bona fide airplane design work can be carried to an advanced stage.

CATEGORY #2

ITEM 29: ENGINE COMPONENT TEST PROGRAM

Compressor Testing

The supersonic transport must combine extremely broad operating ranges with good performance capabilities. It is necessary to do rig testing on advanced aerodynamic compressors which may be utilized in new and/or novel engine designs and cycles. The purpose of this rig testing will be to improve the surge margin throughout the engine operating range; to increase the pressure rise per stage; permit variation in airflow to match inlet requirements; and conduct structural testing on different rotor concepts. Specific requirements for mean time to failure of at least 4,000 hours will be established as a design criteria for the compressor rotor parts.

Combustor Testing

Burner investigation is required to determine conditions and output while under supersonic flight. These tests should include conventional fuels and modifications of conventional fuels. Testing of the modified fuels will be limited to those which have been proven by laboratory tests to be suitable for the commercial supersonic transport environment, and are also economically competitive. Tests will also be run on conventional fuels to determine whether they are suitable and to determine what compromises are required if these fuels are used. It is necessary to determine from this program the proper design criteria for high intensity burner systems which are required for this application. A minimum life of 2,000 hours without repair will be established as design goal for the combustor.

Turbine Investigation

Investigate the potentials of variable turbine configurations to obtain a broader operational range than is now possible. It is anticipated that a reduction of 20-30 percent in SFC can be obtained at loiter conditions if a suitable solution can be found.

Very little is known of the effects of high turbine inlet temperatures on engine life resulting from sustained supersonic cruise operation. It is proposed that rig testing of a turbine be conducted simulating the supersonic transport operation. It is expected that this type of a test will provide design data based on qualitative values of disc and blade creep, high temperature oxidation and erosion and other factors due to sustained high turbine inlet temperatures. These test results will establish a feasible level of turbine inlet temperature for economical operation.

CATEGORY #2

ITEM 30: INLET-EXHAUST-THRUST REVERSER SYSTEM

The inlet ducts and exhaust nozzles are considered sensitive and important components affecting the performance of the supersonic transport and matching their performance will be a difficult task. Since these components affect each other's performance, it is necessary to explore their operation with regard to such variables as area variation, flow distortion, pressure recovery, flow coefficient control parameters, and mechanical design. These problems are, in addition, complicated by the use of thrust reversers, and both mechanical and aerodynamic ingenuity will be required to provide design compromises in a selected propulsion system.

Analytical and experimental research is needed for proper component matching.

CATEGORY #1

ITEM 31: DUCT HEATER AUGMENTATION

Studies to date indicate that an attractive engine configuration which gives good fuel consumption for both subsonic and supersonic operation consists of a turbofan engine with some fuel burned in the fan discharge air during transonic and supersonic cruise operation. Some recent research work has indicated that the problem of supporting combustion in the relatively cool fan discharge air may be overcome by the use of unconventional flameholders. Additional investigations are required for commercial application in order to achieve the highest possible combustion efficiency and to investigate problems associated with long-time operation.

CATEGORY #2

ITEM 32: AUXILIARY POWER EXTRACTIONS

It is recognized that large auxiliary or accessory power requirements for the SST will exist. An efficient means of obtaining this power is not known at this time. Therefore, it will be necessary that various means of power extraction be analyzed. Design and development will progress into rig testing which will simulate extremes of load conditions, high temperature, altitude and other environmental conditions introduced by supersonic flight.

CATEGORY #1

ITEM 33: ENGINE SEALS AND BEARINGS

In order to achieve the long life and reliability that will be required for economical commercial operation of a high Mach number power plant, additional development of bearings and seals is required beyond what has been accomplished to date. Most of the design knowledge required is already in hand and suitable materials are available, but an intensive rig testing program is required to provide assurance that the expected durability can be achieved in practice. Since the lubricants currently proposed for use in military Mach 3 engines are expected to cost in the order of $50 per gallon, it is essential to accomplish development running of bearings and seals using less expensive oils in order to establish limiting temperatures that are consistent with an acceptable oil cost.

CATEGORY #2

ITEM 34: ENGINE NOISE CRITERIA

It is essential for newly designed engines to produce the greater power required without an accompanying rise in noise level; preferably a reduction in noise level is to be sought. Due to lack of standards and criteria in this area, it is of great importance that an extended acoustical analysis relating to general engine noise from compressors, burners, engine inlets and exhaust ducts, etc. be made, and from this to establish general engineering methods for predicting, analyzing and correcting generated and radiated sounds. This will involve systematic exploration of engine components under varying flow conditions and configurations and arriving at a correlation between design parameters and noise characteristics. The data received from these tests will be compiled and referenced in the form of applicable design guides.

CATEGORY #2

ITEM 35: ENGINE RELIABILITY AND LONG LIFE

In the course of the proposed engineering study of propulsion systems for supersonic transport aircraft, particular attention must be given to the reliability of the various engine configurations considered to be of interest because of their performance potential. All the propulsion systems given active consideration will be investigated in detail as to their complexity, structural and functional integrity, ability to endure the physical and operational environments defined by mission requirements and specified flight envelopes. Estimates will be made of the inherent reliability of all the systems studied. The permissible tradeoff in maintenance expenditure and fuel cost to determine minimum DOC shall be identified. The selection of maintenance effectiveness shall not prejudice the mean time to failure of the components, nor degrade the reliability of the total engine. These estimates, together with performance considerations, will be used to evaluate the relative over-all merits of the different engine cycles and configurations.

CATEGORY #2

ITEM 36: FUELS AND OIL TESTS

Differences in aircraft speed and in treatment of the aerodynamic heating problem cause extreme changes in the conditions of the fuel and oil that are delivered to the engine. Fuel and oil system simulation tests must be made which will reproduce the extreme environmental variations including temperature and soak time. In addition to establishing parameters of airplane system variations, these tests also will serve as a method of determining the most desirable fuel and oil. The cost of fuel is one of the most acute problems in airline operations and will be even more pronounced for the supersonic transport.

CATEGORY #2

ITEM 37: ENGINE CONTROLS

Controlling the engine of a supersonic transport will dictate systems more complex and sophisticated than currently used in commercial service. Some use will be made of analytical programs on current engines in the design of the controls for the SST engine. With this as a background, further research will then be needed prior to the development of a new integrated control system. The range of all control parameters increases; therefore, a more accurate control of engine speed, exhaust nozzle area, and compressor and inlet geometry must be obtained for all cycles, be they single or dual cycle engines. A thorough analysis of engine stability and control problems in system design is required. Simplicity and reliability must be emphasized in design.

CATEGORY #2