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Bibliography of Supersonic Cruise Aircraft Research (SCAR) Program From 1972 to Mid-1977

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PREFACE

This bibliography documents publications of the Supersonic Cruise Aircraft Research (SCAR) Program that were generated during the first 5 years of effort. The reports are arranged according to Systems Studies and five SCAR disciplines: Propulsion, Stratospheric Emissions Impact, Structures and Materials, Aerodynamic Performance, and Stability and Control. The specific objectives of each discipline are summarized. Annotation is included for all NASA inhouse and low-number contractor reports.

This report supersedes NASA TM X-73950.

CONTENTS

INTRODUCTION

In July 1972, approximately 1 year after the cancellation of the United States Supersonic Transport Program, the National Aeronautics and Space Administration initiated the Advanced Supersonic Technology (AST) Program. This name was later changed to Supersonic Cruise Aircraft Research (SCAR). The overall objectives of this program were as follows:

(1) To provide an expanded technology base for future civil and military supersonic aircraft

(2) To provide the data needed to assess environmental and economic impacts on the United States of present and, in particular, future foreign supersonic transport aircraft

(3) To provide a sound technical basis for any future consideration that may be given by the United States to the development of an environmentally acceptable and economically viable commercial supersonic transport (SST)

SCAR MANAGEMENT

The SCAR program was managed by the Office of Aeronautics and Space Technology (OAST) Advanced Supersonic Technology/Hypersonic Research Office (Code RT) with the Langley Research Center designated as the lead center. An Advanced Supersonic Technology Office (ASTO) was established at Langley for technical management and coordination of the program. In addition to the Langley Research Center, the Ames Research Center, the Lewis Research Center, the Dryden Flight Research Center, and the Jet Propulsion Laboratory implemented the program through contracts with the aircraft industry, research grants to universities, and inhouse experimental and analytical work.

PROGRAM STRUCTURE

A block diagram showing the initial structure of the program is given in figure 1. The scope of the SCAR program included system studies and the following disciplines:

Propulsion
Stratospheric Emissions Impact
Structures and Materials
Aerodynamic Performance
Stability and Control

The results of the SCAR study are accumulated in the development base for future use.

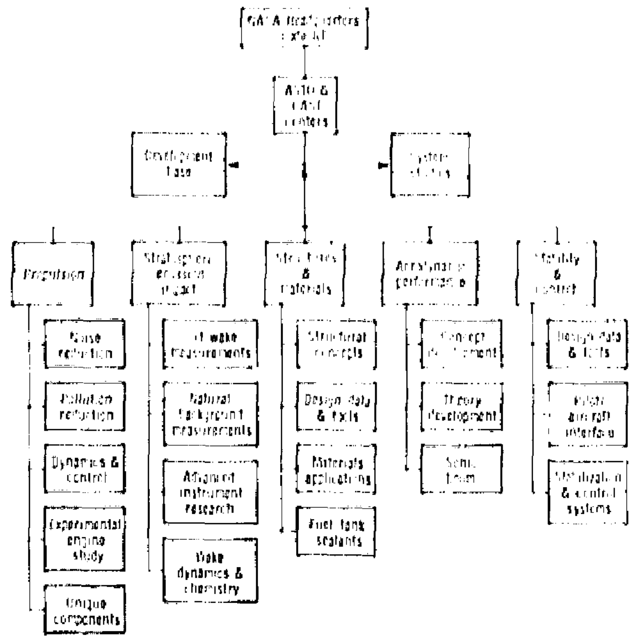


Figure 1.- SCAR project structure in 1972.

As progress was made during the first 5 years of work, the program structure gradually changed to that shown in figure 2. The relative level of effort expended for each discipline from fiscal year 1973 to fiscal year 1977 is presented in figure 3.

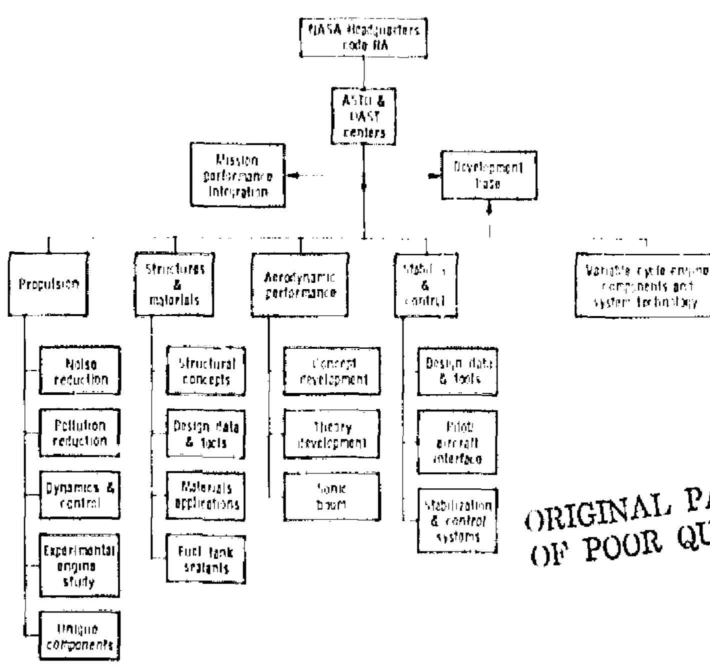


Figure 2.- SCAR project structure in 1977.

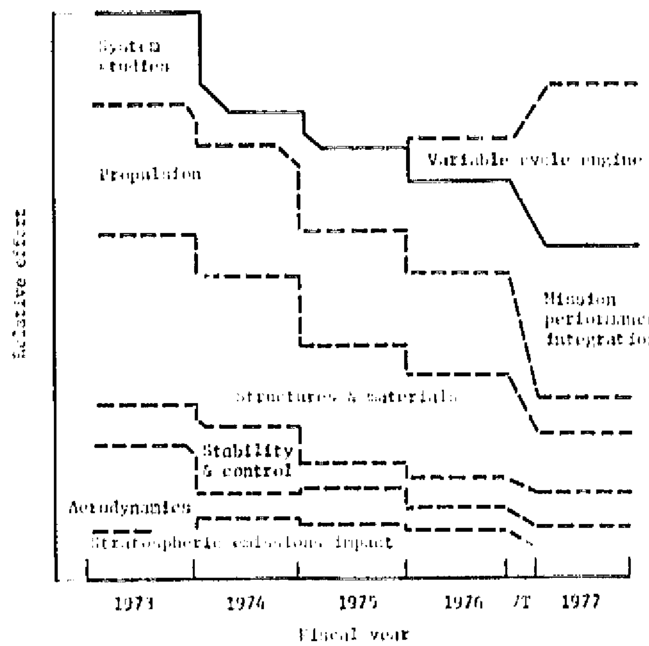


Figure 3.- Relative effort of SCAR disciplines.

OBJECTIVES FOR SYSTEM STUDIES AND SCAR DISCIPLINES

System Studies

The specific objectives for system studies are to identify and assess the impact of new technologies applicable to future supersonic commercial aircraft; to determine how these technologies can be successfully integrated into a design for a supersonic cruise aircraft (in particular, investigate such ar as as subsonic and supersonic performance, economics, safety, comfort, and those characteristics, noise, pollution, etc., which interact with the social community); and to perform Arrow Wing Feasibility Studies, from primary structural design to flexibility effects, in order to assist in defining aerodynamic configurations which will advance arrow wing structural designs.

Propulsion

The specific objectives for propulsion are to acquire performance data for engine cycles suitable for an advanced supersonic transport; to reduce engine noise; to provide technology for a turbine engine primary combustor which has minimum attainable nitric oxide emission at supersonic cruise conditions; to provide experimental verification of the facts of upper atmosphere pollution; to develop and test an integrated airframe/propulsion digital control system; to develop advanced materials for applicable engines; and to provide an advanced experimental engine so that a complete system is available for examining the interactions of components and for determining the overall performance and operating characteristics.

Stratospheric Emissions Impact

The specific objectives for stratospheric emissions impact are to determine the composition of the jet wake and perturbations (chemical and hydrodynamic) in the stratosphere that are caused by the passage of supersonic aircraft; to develop and apply advanced instrumentation to measure the trace constituents in the stratosphere; and to develop techniques to analyze and describe the possible detrimental effects on the natural stratosphere of aircraft exhaust systems from fleets of supersonic aircraft.

Structures and Materials

The specific objectives for structures and materials are to evaluate metallic materials, composites, and composite reinforced metals for potential use in an advanced supersonic transport; to design, fabricate, and test under appropriate loading and environmental conditions typical structural elements and components that were fabricated from advanced materials, with particular emphasis on fatigue and fracture tests; to assess the relative merits of advanced structural concepts and demonstrate the effectiveness of these concepts by construction and test of major assemblies; to develop the analytical techniques and design methods for advanced arrow wings; and to develop and evaluate analytical techniques for predicting flight effects, ground loads effects, and aeroelastic effects.

Aerodynamic Performance

The specific objectives for aerodynamic performance are to develop preliminary designs of promising supersonic configuration concepts based on the application of control configured vehicle (CCV) and low sonic boom technology; to optimize an arrow wing configuration which would have high aerodynamic efficiency in supersonic cruise and satisfactory low-speed characteristics; to develop rational stability and control power criteria to be applied to proposed configuration concepts; to develop and validate methods for use in predicting low-speed and high-speed aerodynamic characteristics for both design and off-design flight conditions; to incorporate the new methods into computerized design tools in order to provide the aircraft designer the means to accurately and rapidly accomplish the design trades necessary for an efficient transport; and to conduct sonic boom simulations to obtain subjective response data and thereby establish criteria for sonic boom exposure characteristics that are acceptable to the public.

Stability and Control

The specific objectives for stability and control are to develop an improved data base for the design of aerodynamic control surfaces; to conduct piloted simulation studies for the determination of handling qualities criteria for advanced CCV supersonic transports; to determine failure modes to alternative redundant control system mechanizations and the ability of the pilot to react to these failures; to predict the effect of aeroelasticity on the airplane's flight characteristics; to develop control laws applicable to active control concepts; to establish the feasibility of wind-tunnel simulation of active control concepts; and to develop improved control systems to cope with interactions between the airframe and propulsion systems.

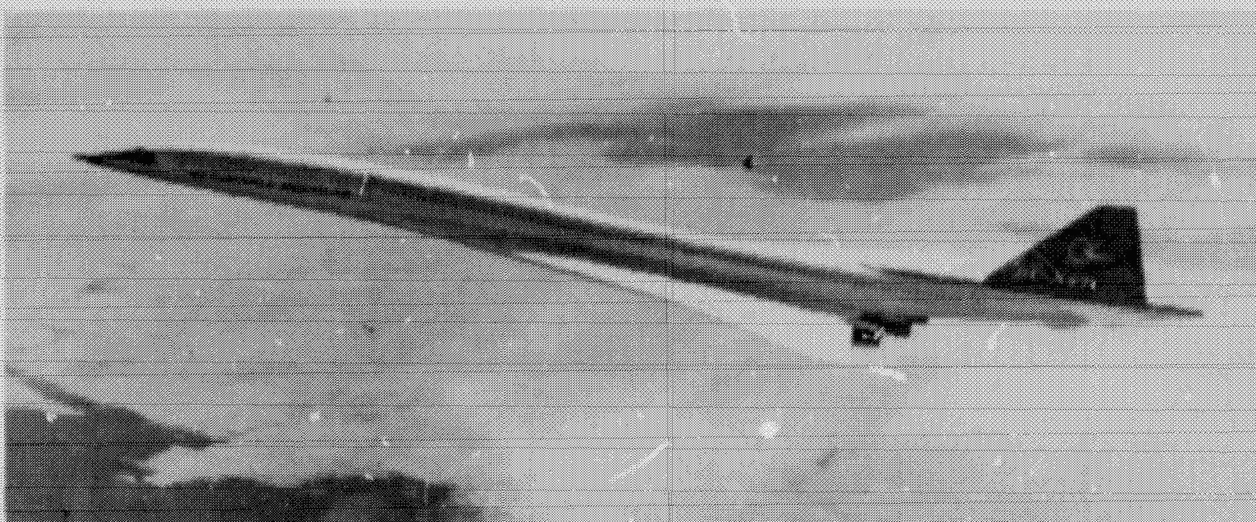
BIBLIOGRAPHIC ENTRIES

The present SCAR bibliography lists the publications that resulted from SCAR support from the inception of the program in 1972 to mid-1977. The bibliography is arranged according to system studies and the five SCAR disciplines. Each discipline is subdivided into three groups:

NASA Inhouse Reports
NASA Contractor Reports
Articles, Meetings, and Company Reports

In certain groups, the publications are further divided into such sections as material applications, noise, and inlet stability valve. There are 444 papers or articles included in this issue. When a paper appeared as more than one publication by the same organization (for example, an AIAA paper which was later published in the Journal of Aircraft), only the later publication is given. Annotation is included for all NASA inhouse and low-number contractor reports.

Figure 4 is presented to help the reader visualize the typical subject material of this bibliography. Figure 4(a) shows an artist's representation of a supersonic cruise commercial transport which was the basis for the technology integration studies of one of the system study contractors. Figure 4(b) shows a large scale arrow wing model placed in the Langley full-scale tunnel for low speed tests. Figure 4(c) is a sketch of a finite-element structure model of an arrow wing with 2000 nodes, 4200 elements, and 8500 degrees of freedom. Figure 4(d) presents a schematic of two typical advanced engine concepts studied by the engine study contractors.



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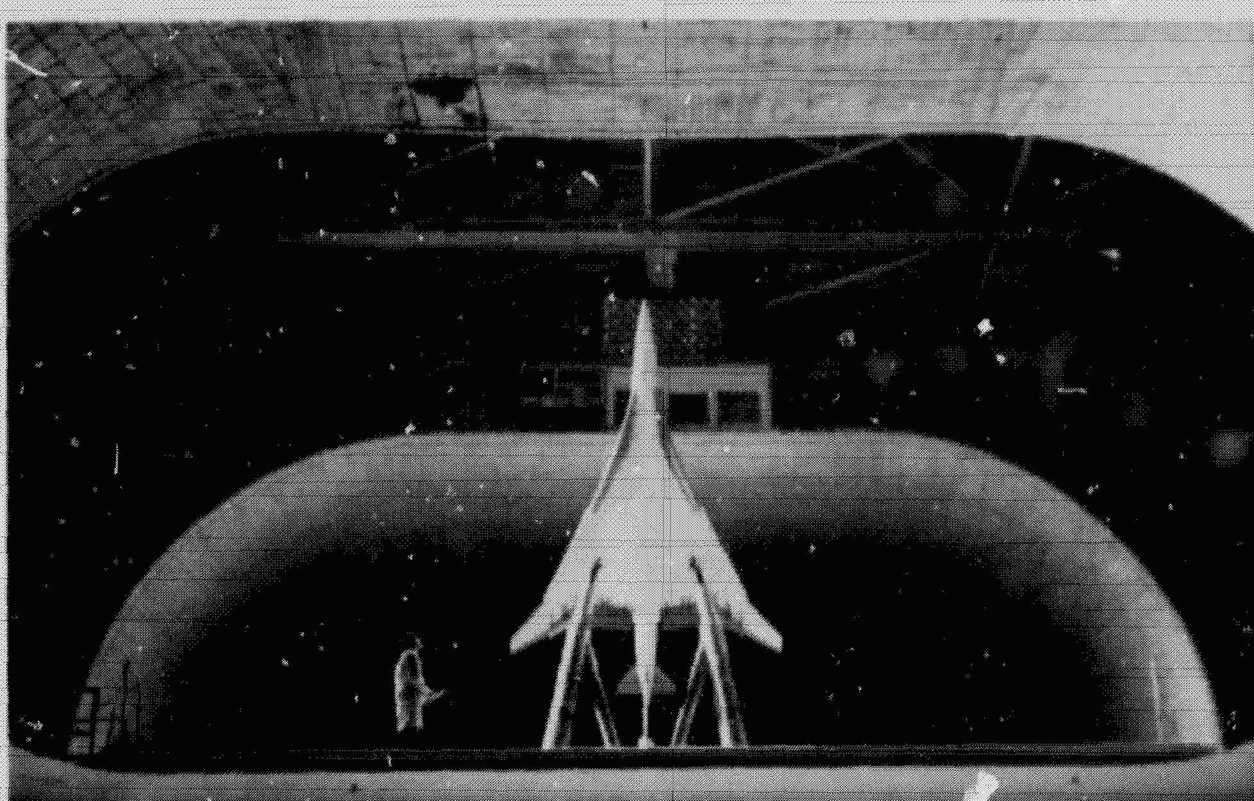
(a) A system-study cruise vehicle.



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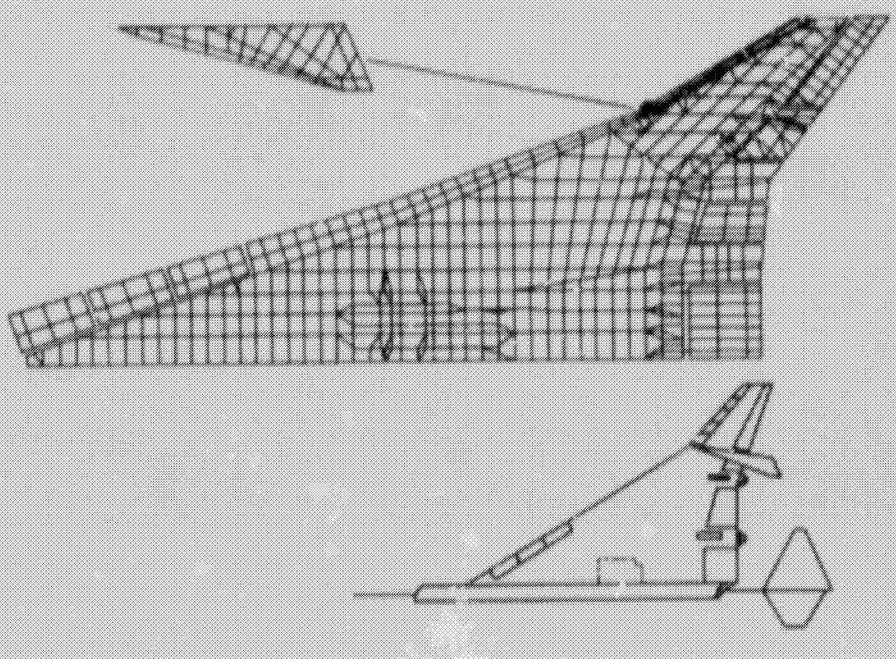
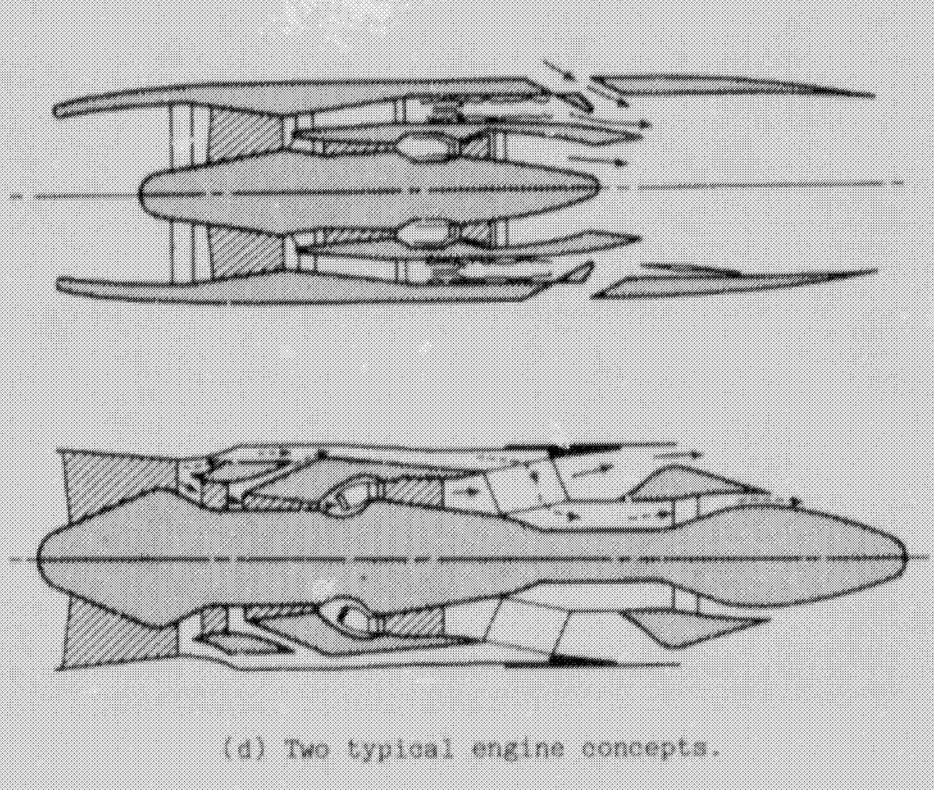
(b) Large wind-tunnel model.

Figure 4.- Examples of advanced supersonic technology studies.



(c) Finite-element model of wing.



(d) Two typical engine concepts.

Figure 4.- Concluded.

SYSTEM STUDIES

NASA Inhouse Reports

1. Mascitti, Vincent R.: Systems Integration Studies for Supersonic Cruise Aircraft. NASA TM X-72781, 1975.

Technical progress in each of the disciplinary research areas affecting the design of supersonic cruise aircraft is discussed. The NASA AST/SCAR Program supported the integration of these technical advances into supersonic cruise aircraft configuration concepts. Although the baseline concepts reflect differing design philosophy, all reflect a level of economic performance considerably above the current foreign aircraft as well as the former U.S. SST. Range-payload characteristics of the study configuration not only show significant improvement but also meet environmental goals such as take-off and landing noise and upper atmospheric pollution.

2. Baber, Hal T., Jr.; and Swanson, E. E.: Advanced Supersonic Technology Concept AST-100 Characteristics Developed in a Baseline-Update Study. NASA TM X-72815, 1976.

The Advanced Supersonic Technology Configuration, AST-100, is described. The combination of wing thickness reduction, nacelle recontouring for minimum drag at cruise, and the use of the horizontal tail to produce lift during climb and cruise resulted in an increase in maximum lift-to-drag ratio. Lighter engines and lower fuel weight result in a 6-percent reduction in take-off gross weight. The take-off maximum effective perceived noise was 114.4 dB.

3. Fetterman, D. E., Jr.: Preliminary Sizing and Performance Evaluation of Supersonic Cruise Aircraft. NASA TM X-73936, 1976.

The basic processes of a method that performs sizing operations on a baseline aircraft and determines their subsequent effects on aerodynamics, propulsion, weights, and mission performance are described. Results obtained by applying the method to an advanced supersonic technology concept are discussed. These results include the effects of wing loading, thrust-to-weight ratio, technology improvements on range performance, and possible gains in both range and payload capability that become available through growth versions of the baseline aircraft. The results from an in-depth contractual study are also included.

4. Morris, S. J.; Foss, W. E., Jr.; and Russell, J. W.: Assessment of Variable-Cycle Engines for Mach 2.7 Supersonic Transport: A Status Report. NASA TM X-73977, 1976.

This report evaluates each of three proposed SCAR propulsion systems in terms of aircraft range for a fixed payload and take-off gross weight with a design cruise Mach number of 2.7. The effects of various noise and operational restraints are determined and sensitivities to some of the more important performance variables are presented for the most probable design noise and operational restraint case. Critical areas requiring new or improved technology for each cycle are delineated. This report describes the status of the NASA SCAR Mach 2.7 design studies as of its publication.

5. Proceedings of the SCAR Conference - Parts 1 and 2. NASA CP-001, [1977].

Since 1972 the SCAR program has provided an accelerated and focused technology effort which has resulted in development of improved analytical techniques, design procedures, and an expanded experimental data base. Major advances have been achieved and were reported to the technical community at the SCAR Conference held at the Langley Research Center, November 9-12, 1976.

This document is a compilation of papers presented by 49 speakers representing airframe and engine manufacturers, the Federal Aviation Administration, and four NASA research centers.

The Conference was organized in six sessions as follows: Aerodynamics, Stability and Control, Propulsion, Environmental Factors, Airframe Structures and Materials, and Design Integration.

6. Fischler, J. E.: Structural Design of Supersonic Cruise Aircraft. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 911-925.

The McDonnell Douglas supersonic cruise aircraft structures effort is discussed and includes: (a) the analysis methods used to improve the structural model optimization and compare the structural concepts, (b) the analysis and description of the fail-safe, crack-growth, and residual-strength studies and tests, (c) baseline structural trade studies to determine optimum structural weights including effects of geometry changes, strength, fail-safety, aeroelastics, and flutter, (d) comparison of British, French, and U.S. aluminum alloys with 6Al-4V annealed titanium in structural efficiency after 70 000 hr at temperature, (e) the study of three structural models for aircraft at cruise speeds of $M = 2.0$, 2.2, and 2.4, (f) the study of many structural concepts to determine their weight efficiencies, and (g) the determination of the requirements for large-scale structural development testing.

7. FitzSimmons, Richard D.: Market Trends. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 985-1000.

The public, by its reception and patronage of the widening Concorde supersonic service, will dictate whether a need exists for a second-generation supersonic transport. A second-generation supersonic transport must meet society's needs and at the same time be profitable for the operators and manufacturers. A very large segment of the over water, long haul passenger market, 31 percent of the passengers who provide 42 percent of the passenger revenue, offers a significant market for an advanced supersonic transport. The civil aircraft market through the year 2000 could reach 250 to 300 supersonic aircraft, given the timely availability of the necessary resources to undertake such a venture. Every indication to date is that a multination, multigovernment program may offer the only way such a program will come to fruition.

8. FitzSimmons, Richard D.: Performance and Benefits of an Advanced Technology Supersonic Cruise Aircraft. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 927-938.

The results of 4 yr of research on technology by the McDonnell Douglas Corporation are synthesized in an advanced supersonic cruise aircraft design. Comparisons are presented with the former U.S. SST and the British-French Concorde, including aerodynamic efficiency, propulsion efficiency, weight efficiency, and community noise. Selected trade study results are presented on the subjects of design cruise Mach number, engine cycle selection, and noise suppression. The critical issue of program timing is addressed and some observations are made regarding the impact that timing has on engine selection and minimization of program risk.

9. Hoy, James M.: Toward a Second Generation Fuel Efficient Supersonic Cruise Aircraft - Structural Design for Efficiency. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 867-879.

The unique challenge of this Boeing concept to the structural designer is discussed. The potential of the application of advanced structural design concepts and new titanium fabrication processes is emphasized. The results of a detailed structural analysis, including weight and flutter, show successful use of the ATLAS structural design and analysis system. It is concluded that the blending of the structure may not have an adverse impact on structural efficiency, weight, and manufacturing complexity.

10. Neumann, Frank D.: Toward a Second Generation Fuel Efficient Supersonic Cruise Aircraft - Design Characteristics and Feasibility. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 849-866.

Studies at Boeing Commercial Airplane Company in recent years have focused on the definition, analysis, and evaluation of the blended wing-fuselage concept. This paper reviews the basis and objectives of design improvement studies. Design changes that lead to improved aerodynamic and structural efficiency are presented. Practical design constraints and approaches for a blended wing fuselage are discussed, as well as the integration of the configuration that leads to aerodynamic and structural efficiency. Highlighted are new approaches used to provide for structural efficiency, airline and passenger acceptance, passenger evacuation, and subsystem integration. Results of full-scale passenger cabin mock-up evaluations are presented showing the feasibility of the concept.

11. Rowe, William T.: Design Feasibility of an Advanced Technology Supersonic Cruise Aircraft. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 895-909.

Research and development programs by McDonnell Douglas Corporation and NASA provide confidence that technology is in hand to design an economically attractive, environmentally sound supersonic cruise aircraft for mid-1980 worldwide commercial operations. The principal results of studies and tests are described, including those which define the selection of significant design features. These typically include the results of (a) wind-tunnel tests, both subsonic and supersonic; (b) propulsion performance and acoustic tests on noise suppressors, including forward-flight effects; (c) studies of engine/airframe integration which lead to the selection of engine cycles and sizes to meet future market, economic, and social requirements; and (d) structural testing.

12. Vachal, John D.: Toward a Second Generation Fuel Efficient Supersonic Cruise Aircraft - Performance Characteristics and Benefits. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 881-894.

This Boeing paper briefly reviews the characteristics of the 1971 U.S. SST. The need for greatly improved fuel efficiency and off-design subsonic characteristics is discussed. Engine-airframe matching studies are presented which show the benefits of a configuration designed for much lower supersonic drag levels (blended wing fuselage) and show how well this airframe matches with the new advanced variable-cycle engines. The benefits of advanced take-off procedures and systems, together with the coannular noise effect in achieving low noise levels with a small cruise-size engine, are discussed. It is concluded that the SCAR technology advances, when carefully integrated through detailed engine-airframe matching studies on a validated baseline airplane, lead to a much improved supersonic cruise aircraft.

13. Wright, Bruce R.; Sedgwick, Thomas A.; and Urie, David M.: An Advanced Concept That Promises Ecological and Economic Viability. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 939-984.

Economic and ecologically acceptable supersonic travel throughout the world can be a reality in the 1990's. The actuality of supersonic commercial service being provided by the Concorde is demonstrating to the world the advantages offered by supersonic travel for both business and recreation. Public acceptance will gradually and persistently stimulate interest to proceed with a second-generation design that meets updated economic and ecological standards. This Lockheed paper identifies an advanced technology supersonic cruise vehicle developed under the NASA SCAR program that could be available for commercial service in the 1990's. It is estimated that this concept could operate profitably on worldwide routes with a revenue structure based upon economy fares. This airplane will meet all present-day ecological requirements regarding noise and emissions.

NASA Contractor Reports

14. Interim Summary Report. Volume I - Studies of the Impact of Advanced Technologies Applied to Supersonic Transport Aircraft. LR 25827-1 (Contract NAS 1-11940), Lockheed-California Co., Mar. 30, 1973. (Available as NASA CR-145051-1.)

15. Interim Summary Report. Volume II - Market Analysis. LR 25827-2 (Contract NAS1-11940), Lockheed-California Co., Mar. 30, 1973. (Available as NASA CR-145051-2.)

16. Studies of the Impact of Advanced Technologies Applied to Supersonic Transport Aircraft. Interim Summary Report. Volume 1 - Summary. D6-22529 (Contract NAS1-11938), Boeing Commercial Airplane Co., Apr. 1973. (Available as NASA CR-145052-1.)

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74. Sigalla, A.: Supersonic Cruise Aircraft Technology Demonstrator. Design Conference Proceedings - Technology for Supersonic Cruise Military Aircraft, Volume I, AFFDL-TR-77-85, Vol. I, U.S. Air Force, 1976.

75. Ulsamer, Edgar: The Technological Case for a Supersonic Cruise Aircraft. Air Force Mag., vol. 59, no. 6, June 1976, pp. 34-39.

76. Welge, H. R.; Radkey, R. L.; and Henne, P. A.: Nacelle Aerodynamic Design and Integration Study on a Mach 2.2 Supersonic Cruise Aircraft. AIAA Paper No. 76-757, July 1976.

77. Wolliver, B.: Power Plants for Supersonic Cruise Vehicles. Design Conference Proceedings - Technology for Supersonic Cruise Military Aircraft, Volume I, AFFDL-TR-77-85, Vol. I, U.S. Air Force, 1976.

78. Withington, H. W.: Statement on 1978 NASA Authorization. Hearings Before the Subcommittee on Aviation and Transportation R. & D. of the Committee on Science and Technology, U.S. House of Representatives, Ninety-fourth Congress, Second Session, No. 101, vol. II, pt. 1, Sept. 15, 1976, pp. 156-197.

79. Baber, Hal T., Jr.; and Driver, Cornelius: Advanced Supersonic Cruise Aircraft Technology. Acta Astronaut., vol. 4, no. 1/2, Jan./Feb. 1977, pp. 111-129.

80. Czysz, Paul: Supersonic Cruise New Capabilities and Inappropriate Requirements. McDonnell Douglas paper presented at Conference on the Operational Utility of Supersonic Cruise (Wright-Patterson Air Force Base), Apr. 1977.

81. FitzSimmons, Richard D.: The Advanced Supersonic Transport: What It Is and How It Compares. Acta Astronaut., vol. 4, no. 1/2, Jan./Feb. 1977, pp. 131-143.

82. FitzSimmons, Richard D.; and Newton, Floyd C.: Supersonic Cruise Aircraft - The Potential for Military Roles and Missions. McDonnell Douglas paper presented at Conference on the Operational Utility of Supersonic Cruise (Wright-Patterson Air Force Base), Apr. 1977.

83. Mijares, Robert D.; and Salvaggio, Joseph C.: Why Fly Supersonically? SAWE Paper No. 1154, May 1977.

84. Peace, M. A.; and Francis, J.: Some Operational Experience of Concorde Weight and Balance. SAWE Paper No. 1152, May 1977.

85. Wright, Bruce R.: Rationale for a Second-Generation Supersonic Transport. Acta Astronaut., vol. 4, no. 1/2, Jan./Feb. 1977, pp. 145-162.

PROPULSION

NASA Inhouse Reports

Engine Studies

86. Franciscus, Leo: Jet Noise of an Augmentor Wing-Advanced Supersonic Transport. NASA TM X-68177, 1972.

A preliminary mission study was made of the range and jet noise of an advanced supersonic transport employing an augmentor wing and four duct-burning turbofan engines. The airplane weight and aerodynamic characteristics of the Boeing 2707-300 airplane were used. The study showed that an augmentor wing can reduce the bypass jet noise sufficiently so that total noise levels below those recommended in FAR 36 can be attained without significant range penalties if the augmentor wing can be designed without severe weight and performance penalties.

87. Whitlow, John B., Jr.: Comparative Performance of Several SST Configurations Powered by Noise-Limited Turbojet Engines. NASA TM X-68178, 1972.

A simplified study was made in which the mission performances of three Mach 2.7 airplane configurations were compared. Both wing loading and the size of the unaugmented turbojet engines were varied at different levels of suppressor technology. The lowest gross weight and the best return on investment were obtained with an advanced arrow wing configuration. A modified delta configuration is a close competitor; a swing wing configuration was too structurally heavy.

88. Dugan, James F., Jr.: Preliminary Study of Supersonic-Transport Configurations With Low Values of Sonic Boom. NASA TM X-2746, 1973.

A parametric study of low boom, supersonic transport airplanes with conventional configurations was made to identify the features of specific configurations that promise relatively low sonic boom overpressures (less than 47.9 N/m^2). The ranges of values considered were gross weight from 28 300 to 170 000 kg; cruise Mach numbers of 2 to 3.2; and wing loadings of 1436, 2870, and 4309 N/m^2. Fuselage length was varied from 49.1 to 102.4 m and fuselage diameter from 2.75 to 3.98 m. A nominal Mach 2 configuration weighing 56 700 kg and having a wing loading of 2870 N/m^2 was selected; its gross geometric, aerodynamic, and structural features were estimated.

89. Dugan, James F.: Preliminary Study of Turbojets With Rotary Flow Inductors for a Low-Noise Supersonic Transport. NASA TM X-68233, 1973.

In a simplified airplane mission study for a Mach 2.61 supersonic transport, dry turbojets with and without real suppressors and dry turbojets with ideal rotary flow inductors were studied for sideline noise levels as low as those recommended in FAR 36-20. Compressor pressure ratio was varied from 5 to 30 and turbine temperature from 982° C to 1698° C. For no noise constraint and without a suppressor for the best dry turbojet, payload dropped rapidly for lower noise goals, becoming 6.3 percent of the gross weight required by FAR 36, for the ideal inductor was far superior to the real suppressor, giving payloads of 6.6 percent of that required by FAR 36-10 and 5.7 percent of that required by FAR 36-20.

90. Whitlow, John B., Jr.; Weber, Richard J.; and Civinskas, Kestutis C.: Preliminary Appraisal of Hydrogen and Methane Fuel in a Mach 2.7 Supersonic Transport. NASA TM X-68222, 1973.

The higher heating value of hydrogen relative to jet propulsion (JP) fuel is estimated to reduce fuel weight by threefold and gross weight by 40 percent for comparably designed airplanes of equal payload and range. At current fuel prices, the direct operating cost (DOC) of a hydrogen airplane would be much higher than that of a JP airplane. A methane airplane could offer an 8.5-percent lower DOC than JP. If in the future all three fuels are postulated to have equal costs per unit of energy, the DOC for hydrogen could be as much as 20 percent below that for JP on the reference mission of 4000 n.mi.

91. Weber, Richard J.: The NASA Research Program on Propulsion for Supersonic Cruise Aircraft. NASA TM X-71666, 1975.

The objectives and status of the propulsion portion of a program aimed at advancing the technology and establishing a data base appropriate for the possible future development of supersonic cruise aircraft are reviewed. Research related to exhaust nozzles, combustors, and inlets that is covered by the noise, pollution, and dynamics programs is described.

92. Whitlow, John B., Jr.: Comparison of Parametric Duct-Burning Turbofan and Nonafterburning Turbojet Engines in a Mach 2.7 Transport. NASA TM X-71679, 1975.

A parametric study was made of duct-burning turbofan and suppressed dry turbojet engines installed in a supersonic transport. A range of fan pressure ratios was considered for the separate flow fan engines. The turbofan engines were studied both with and without jet noise suppressors. Trades were made between thrust and wing area for a constant take-off field length. The turbofans produced lower airplane gross weights than the turbojets at and below the requirements of FAR 36.

93. Whitlow, John B., Jr.: Supersonic Propulsion. Aeronautical Propulsion, NASA SP-381, 1975, pp. 441-457.

The Supersonic Cruise Airplane Research technology program is reported. Mission requirements, cycle considerations, engine evaluation, and SCAR study results are discussed. It is concluded that improved aerodynamics and structures, greater use of composites, and more refined active controls are needed in the airframe area for designing an economically viable, environmentally acceptable, supersonic aircraft.

94. Whitlow, John B., Jr.: Effect of Airplane Characteristics and Takeoff Noise and Field Length Constraints on Engine Cycle Selection for a Mach 2.32 Cruise Application. NASA TM X-71865, 1976.

Sideline noise and take-off field length were varied for two types of Mach 2.32 cruise airplanes to determine their effect on engine cycle selection. One of these airplanes was the NASA Langley LTV arrow wing; the other was a Boeing modified delta plus tail derived from the earlier 2707-300 concept. Advanced variable-cycle engines (VCE) were considered. A more conventional advanced low-bypass turbofan engine was used as a baseline for comparison. Appropriate exhaust nozzle modifications were assumed to allow either inherent coannular or annular jet noise suppression benefit. All the VCE's outperformed the baseline engine by substantial margins in a design range comparison.

95. Willis, E. A.; and Welliver, A. D.: Supersonic Variable-Cycle Engines. NASA TM X-73524, 1976.

The evolution and current status of selected recent variable-cycle engine studies are reviewed and how the results were influenced by airplane requirements is described. Promising VCE concepts are described; their designs are simplified; and the potential benefits in terms of aircraft performance are identified. These include range, noise, emissions, and the time and effort it may require to insure technical readiness of sufficient depth to satisfy reasonable economic, performance, and environmental constraints. A brief overview of closely related, ongoing technology programs in acoustics and exhaust emissions is also presented. Selected VCE concepts can lead to significantly improved economic and environmental performance relative to first-generation SST predictions.

96. Willis, Edward: Variable-Cycle Engines for Supersonic Cruise Aircraft. NASA TM X-73463, 1976.

Progress and the current status of the variable-cycle engine study are reviewed, with emphasis placed on the impact of technology advancements and design specifications. A large variety of VCE concepts are also examined.

97. Albers, James A.; and Olinger, Frank V.: YF-12 Propulsion Research Program and Results. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 417-456.

This report discusses the objectives and status of the propulsion program, along with the results acquired in the various technology areas. The instrumentation requirements for and experience with flight testing the propulsion systems at high supersonic cruise are discussed. Propulsion system performance differences between wind tunnel and flight are given. The effects of high

frequency flow fluctuations (transients) on the stability of the propulsion system are described, and shock position control is evaluated. The report discusses present and future program plans and schedules.

98. Bowditch, David N.: Supersonic Cruise Inlets for Variable-Cycle Engines. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 387-397.

Variable-cycle engines have the potential to operate very efficiently over the wide speed range of a supersonic cruise aircraft. The performance of candidate supersonic cruise inlets is reviewed and the aerodynamic installation penalties for each type are defined. The main characteristics that affect the airflow schedules of variable-cycle engines are defined. These schedules are compared with the airflow schedules of the candidate inlets, and appropriate inlets are matched to the variable-cycle engine characteristics. Auxiliary inlets are also considered.

99. Hiller, Kirby W.; and Drain, Daniel I.: Control of Propulsion Systems for Supersonic Cruise Aircraft. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 399-415.

The unique propulsion control requirements of supersonic aircraft are presented. Integration of inlet, engine, and airframe controls is discussed. The application of recent control theory developments to propulsion control design is described. Control component designs for achieving reliable, responsive propulsion control are also discussed.

100. Howlett, Robert A.: Variable Stream Control Engine Concept for Advanced Supersonic Aircraft - Features and Benefits. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 341-352.

The variable stream control engine being studied at Pratt & Whitney Aircraft for advanced supersonic cruise aircraft shows potential for significant environmental and performance improvements relative to first-generation supersonic turbojet engines. This engine concept has two separate flow streams - each with independent burner and nozzle systems. By unique control of the exhaust temperatures and velocities in these two coannular streams, significant reduction in jet noise may be obtained. This engine has the potential for other major improvements. Technology programs are required to qualify and demonstrate these potential improvements.

101. Krebs, J. N.: Advanced Supersonic Technology Study - Engine Program Summary: Supersonic Propulsion - 1971 to 1976. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 353-370.

In 1972 NASA initiated study programs to identify the required propulsion system and airplane technology necessary for an environmentally acceptable supersonic cruise vehicle. The Advanced Supersonic Propulsion System Technology

Studies at General Electric Company screened conventional turbojets, mixed flow and duct-burning turbofans, and variable-cycle engines. This resulted in the selection of a variable-cycle engine concept that provides high airflow for low take-off noise levels, using a coannular acoustic exhaust nozzle, and a cruise airflow matched to the airplane inlet flow schedule. Technology predicted to be available for start of development in 1985 is incorporated in the engine. The propulsion system technology has improved to the point that definition of a second-generation supersonic cruise aircraft propulsion system that is much improved from the 1971 GE4 turbojet is now possible.

102. Powers, Albert G.; Whitlow, John B.; and Stitt, Leonard E.: Component Test Program for Variable-Cycle Engines. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 371-385.

The NASA Lewis Research Center SCAR program involves propulsion study contracts with the General Electric Company and Pratt & Whitney Aircraft. Through these contracts, promising variable-cycle engine concepts for a supersonic cruise aircraft have been identified. These VCE concepts incorporate unique critical components and flow-path arrangements that provide good performance at both supersonic and subsonic cruise and appear to be economically and environmentally viable.

Noise

103. Soderman, Paul T.; and Noble, Stephen C.: A Four-Element End-Fire Microphone Array for Acoustic Measurements in Wind Tunnels. NASA TM X-62,331, 1974.

A prototype four-element end-fire microphone array was designed and built for evaluation as a directional acoustic receiver for use in large wind tunnels. The microphone signals were digitized, time delayed, summed, and reconverted to analog form in such a way as to create a directional response with the main lobe along the array axis. The measured array directivity agrees with theoretical predictions confirming the circuit design of the electronic control module.

104. Stone, James R.: Interim Pediction Method for Jet Noise. NASA TM X-71618, 1974.

A method is provided for predicting jet noise for a wide range of nozzle geometries and operating conditions of interest for aircraft engines. Jet noise theory, data, and existing prediction methods were reviewed. This method predicts only the noise generated by the exhaust jets mixing with the surrounding air and does not include other noises emanating from the engine exhaust, such as combustion and machinery noise generated inside the engine (i.e., core noise). It does, however, include thrust reverser noise. Prediction relations are provided for conical nozzles, plug nozzles, coaxial nozzles, slot nozzles, and thrust reversers.

105. Abtye, Warren F.; and Karel, Steven: The Accuracy of Far-Field Noise Obtained by the Mathematical Extrapolation of Near-Field Noise Data. NASA TM X-62,434, 1975.

Results are described of an analytical study of the accuracy and limitations of a technique that permits the mathematical extrapolation of near-field noise data to far-field conditions. It is shown that the most important parameters describing predictive accuracy are the number of microphones, the ratio of source length to acoustic wavelength, and the error in location of near-field microphones.

106. Atencio, Adolph, Jr.: Wind Tunnel Measurements of Forward Speed Effects on Jet Noise From Suppressor Nozzles and Comparison With Flight Test Data. NASA TM X-62,449, 1975.

The results of a test program conducted in the NASA Ames 40- by 80-Foot Wind Tunnel to determine the effect of forward speed on the noise levels emanating from a conical ejector nozzle, a 32-spoke suppressor nozzle, and a 104-elliptical-tube suppressor nozzle are reported. It is shown that noise levels are reduced as forward speed is increased and that, for one suppressor configuration, forward speed enhances suppression. Comparisons of noise measurements made in the wind tunnel with those obtained in flight tests show good agreement.

107. Stone, James R.: On the Effects of Flight on Jet Engine Exhaust Noise. NASA TM X-71819, 1975.

Differences between flight data and predictions of jet engine exhaust noise were reconciled by considering the combined effects of jet mixing noise and internally generated engine exhaust noise. The source strength of the internally generated noise was assumed to be unaffected by flight. The directivity was assumed to be the same statically as that given in the NASA interim prediction method for core engine noise. However, it was assumed that, in flight, internally generated noise is subject to the convective amplification effect of a simple source. It was shown that, in many cases, much of the flyover noise signature is dominated by internally generated noise.

108. Gutierrez, Orlando A.; and Stone, James R.: Developments in Aircraft Jet Noise Technology. Aircraft Safety and Operating Problems, NASA SP-416, 1976, pp. 497-512.

This paper briefly describes significant developments in two areas of jet noise technology: the development of jet noise technology relative to coannular nozzles of all types, and a recent approach to the analysis of flight effects that appears to allow simulated flight effects results to be transformed to actual flight conditions with a high degree of confidence. The coannular nozzle section presents results applicable to high-bypass-ratio turbofan engines, as well as current work on inverted-profile coannular nozzles applicable to low-bypass-ratio turbofan engines suitable for use in future supersonic cruise aircraft.

109. Mixson, John S.; Mayes, William H.; and Willis, Conrad M.: Effects of Aircraft Noise on Flight and Ground Structures. Aircraft Safety and Operating Problems, NASA SP-416, 1976, pp. 513-525.

This paper discusses three examples involving structural response to aircraft noise. Acoustic loads measured on jet-powered STOL configurations are presented for externally blown and upper surface blown flap models ranging in size from a small laboratory model up to a full-scale aircraft model. Noise transmission characteristics of light aircraft structures are presented. Acceleration responses of a historic building and a residential home are presented for flyover noise from subsonic and supersonic aircraft. The results from these three examples show that aircraft noise can induce structural responses that are large enough to require consideration in the design or operation of the aircraft.

110. Stone, James R.: Flight Effects on Exhaust Noise for Turbojet and Turbofan Engines - Comparison of Experimental Data With Prediction. NASA TM X-73552, 1976.

Recent experiments on the effects of flight on jet engine exhaust noise have produced apparently conflicting results. Some of these results do not agree with classical jet noise theories nor with model jet simulated flight tests. In some of the cases reported, the proper corrections were not made to account for the distributed nature of the jet noise sources. The remaining discrepancies can be reconciled by considering the combined effects of jet mixing noise, internally generated engine exhaust noise, and shock noise. This paper demonstrates that static and in-flight jet engine exhaust noise can be predicted with reasonable accuracy when the multiple source nature of the problem is taken into account. Jet mixing noise is predicted from an improved version of the NASA interim prediction method.

111. Stone, James R.; Miles, Jeffrey H.; and Sargent, Noel B.: Effects of Forward Velocity on Noise for a J85 Turbojet Engine With Multitube Suppressor From Wind Tunnel and Flight Tests. NASA TM X-73542, 1976.

Flight and wind-tunnel noise tests were conducted to obtain an understanding of forward velocity effects on jet exhaust noise. Nozzle configurations of primary interest were a 104-tube suppressor with and without an acoustically treated shroud. The installed configuration of the engine was as similar as possible in the flight and wind-tunnel tests. The wind-tunnel maximum Mach number was approximately 0.27, and the flight Mach number was approximately 0.37. The nominal jet velocity range was 450 to 640 m/sec. In the present tests, the observed directivity and forward velocity effects for the suppressor are more similar to predicted trends for internally generated noise than for unsuppressed jet noise.

112. Atencio, Adolph, Jr.. The Effect of Forward Speed on J85 Engine Noise From Suppressor Nozzles as Measured in the NASA-Ames 40- by 80-Foot Wind Tunnel. NASA TN D-8426, 1977.

The nozzles were tested at three J85 engine power settings and at wind-tunnel forward speeds up to 91 m/sec. In addition, outdoor static tests were conducted at the Ames Outdoor Static Test Facility to determine (1) the differences between near-field and far-field measurements, (2) the effect of an airframe on the far-field directivity of each nozzle, and (3) the relative suppression of each nozzle with respect to the baseline conical ejector nozzle. It was found that corrections to near-field data are necessary to extrapolate to far-field data and that the presence of the airframe changed the far-field directivity as measured statically. The results show that the effect of forward speed was to reduce the noise from each nozzle more in the area of peak noise, but the change in forward quadrant noise was small or negligible.

113. Darden, Christine M.; and Mack, Robert J.: Current Research in Sonic-Boom Minimization. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 525-541.

A review is given of several questions as yet unanswered in the area of sonic boom research. Efforts, both at Langley Research Center and elsewhere, in the area of minimization, human response, design techniques, and in developing higher order propagation methods are discussed. In addition, a wind-tunnel test program being conducted to assess the validity of minimization methods based on a forward spike in the F-function is described.

114. Gutierrez, Orlando A.: Aeroacoustic Studies of Coannular Nozzles Suitable for Supersonic Cruise Aircraft Applications. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 471-490.

Research programs have been conducted to investigate experimentally the aeroacoustic characteristics of scale-model, inverted-velocity-profile coannular nozzles. These programs include studies of unsuppressed configurations with and without center plugs over a variety of radius ratios and area ratios. Also included in these studies have been suppressed configurations, the effect of ejectors, and some simulated flight effects. Unsuppressed inverted-velocity-profile coannular nozzles seem to allow jet mixing noise compliance with present FAR 36 regulations when applied to supersonic cruise aircraft engine cycles. Simulated flight tests suggest that the aeroacoustic benefits of the inverted-velocity-profile coannular nozzles would be maintained in flight.

115. Kozlowski, Hilary: Coannular Nozzle Noise Characteristics and Application to Advanced Supersonic Transport Engines. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 491-504.

Recent programs in the field of jet noise carried out by Pratt & Whitney Aircraft and sponsored by the NASA Lewis Research Center have indicated that the variable stream control engines which are being considered for advanced supersonic cruise aircraft have inherent jet noise advantages over earlier engines. This characteristic is associated with the exit velocity profile produced by such an engine. The high velocity fan stream on the outer perip' ‿ry is acoustically dominant while the primary stream is held to a low ve!ocit, .nd therefore contributes little to the overall noise.

116. Lee, Robert: Coannular Plug Nozzle Noise Reduction and Impact on Exhaust System Designs. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 505-524.

Two programs were carried out by the General Electric Company under the sponsorship of the NASA Lewis Research Center from 1973 to 1976. The f st program aimed mainly at the investigation of multielement suppressors added to the outer stream of the coannular plug nozzle for possible application to duct-burning turbofan cycle. The second program was confined to the unsuppressed coannular plug nozzle but with extended range of configurations and test parameters such that possible applications of the unsuppressed coannular nozzle concept to variable-cycle engine exhaust systems, with or without outer stream burning, can be fully evaluated.

Materials

117. Signorelli, Robert A.: Metal Matrix Composites for Aircraft Propulsion Systems. NASA TM X-71685, 1975.

Compressor fan blades and turbine blades have been identified as components with high payoff potential. This paper will present the current status of development of five candidate materials for such applications. Boron fiber/aluminum, boron fiber/titanium, and silicon carbide fiber/titanium composites are considered for lightweight compressor fan blades. Directionally solidified eutectic superalloy and tungsten wire/superalloy composites are considered for application to turbine blades for use at temperatures to 1100° C.

118. McDanels, David L.; and Signorelli, Robert A.: Effect of Angleplying and Matr_x Enhancement on Impact-Resistant Boron/Aluminum Composites. NASA TN D-8205, 1976.

Efforts to improve the impact resistance of B/Al are reviewed and analyzed. Tensile and dynamic modulus tests, thin-sheet Charpy and Izod impact tests, and standard full-size Charpy impact tests were conducted on 0.20-mm-diameter B/1100 Al matrix composites. Angleplies ranged from unidirectional to ±30°. The best compromise between reduced longitudinal properties and increased transverse properties was obtained with ±15° angleply. The pendulum impact strengths of improved B/Al were higher than that of notched titanium and appeared to be enough to warrant consideration of B/Al for application to fan blades in aircraft gas turbine engines.

119. McDanels, David L.; and Signorelli, Robert A.: Effect of Fiber Diameter and Matrix Alloys on Impact-Resistant Boron/Aluminum Composites. NASA TN D-8204, 1976.

Efforts to improve the impact resistance of B/Al are reviewed and analyzed. Nonstandard thin-sheet Charpy and Izod impact tests and standard full-size Charpy impact tests were conducted on composites containing unidirectional 0.10-, 0.14-, and 0.20-mm-diameter boron fibers in 1100, 2024, 5052, and 6061 Al matrices. Impact failure modes of B/Al are proposed. The impact strength of B/Al was significantly increased by proper selection of materials and processing. The use of a ductile matrix (1100 Al) and large-diameter (0.20-mm) boron fibers gave the highest impact strengths.

120. McDanels, David L.; and Signorelli, Robert A.: Improved Impact-Resistant Boron-Aluminum Composites for Use as Turbine Engine Fan Blades. NASA TM X-71875, 1976.

Efforts to improve the impact resistance of B/Al are reviewed and analyzed. Thin-sheet Charpy and Izod impact tests and standard full-size Charpy impact tests were conducted on unidirectional and angleply composites containing 0.10-, 0.14-, and 0.20-mm boron in 1100, 2024, 5052, and 6061 Al matrices. Impact failure modes of B/Al are proposed in an attempt to describe the mechanisms involved and to provide insight for maximizing impact resistance. The impact strength of B/Al was significantly increased by proper selection of materials and processing.

121. Signorelli, Robert A.: Composite Materials Research in Support of Supersonic Propulsion Systems. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 451-468.

Two engine components, fan blades and exhaust systems, have been selected for composite materials development efforts in support of the SCAR engine program. The materials selected were boron/aluminum for fan blades and silicon carbide/superalloy sheet for the exhaust system. The current status of the research in applying these two composite materials to SCAR engines is reviewed in this paper.

Inlet Stability Valve

122. Cole, Gary L.; Dustin, Miles O.; and Neiner, George H.: A Throat-Bypass Stability System for a YF-12 Aircraft Research Inlet Using Self-Acting Mechanical Valves. NASA TM X-71779, 1975.

Results of a wind-tunnel investigation are presented. The inlet was modified so that airflow can be removed through a porous cowl-bleed region in the vicinity of the throat. The bleed plenum exit flow area is controlled by relief-type mechanical valves. Unlike valves in previous systems, these are made for use in a high Mach flight environment and include refinements so that the system could be tested on an NASA YF-12 aircraft. The valves were designed to provide their own reference pressure. The results show that the system can absorb internal airflow transients that are too fast for a conventional bypass door control system. Increased tolerance to angle-of-attack and Mach number changes is indicated. The valves should provide sufficient time for the inlet control system to make geometry changes required to keep the inlet started.

123. Dustin, Miles O.; and Neiner, George H.: Evaluation by Step Response Tests of Prototype Relief Valves Designed for YF-12 Inlet Stability Bleed System. NASA TM X-3262, 1975.

Two stability bleed system relief valves were tested in a special dynamic test facility. These poppet valves are prototypes for a stability bleed system designed for use in a YF-12 flight inlet. One valve is unshielded, and the other has a special shield to eliminate the flow effect pressures on the piston. The tests determined the size of a damping orifice to be used during wind-tunnel tests of the bleed system and verified an analog simulation of the valves.

124. Webb, John A., Jr.; and Dustin, Miles O.: Analysis of a Stability Valve System for Extending the Dynamic Range of a Supersonic Inlet. NASA TM X-3219, 1975.

A stability valve system designed for a full-scale supersonic mixed-compression inlet was modeled dynamically by using analog computer techniques. The system uses poppet valves mounted in the inlet cowl to bypass airflow and augments the inlet shock position control system by preventing unstarts caused by high-frequency perturbations. The model was used as a design aid to investigate the effects of varying both the physical configurations of the valve and the flight and wind-tunnel conditions.

Pollution Reduction

125. Rudey, R. A.; and Reck, G. M.: Advanced Combustion Techniques for Controlling NO_x Emissions of High Altitude Cruise Aircraft. NASA TM X-73473, 1976.

An array of experiments designed to explore the potential of advanced combustion techniques for controlling the emissions of aircraft into the upper atmosphere was discussed. Of particular concern are the oxides of nitrogen (NO_x) emissions into the stratosphere. The experiments utilize a wide variety of approaches varying from advanced combustor concepts to fundamental flame tube experiments. Results indicate that substantial reductions in cruise NO_x emissions should be achievable in future aircraft engines. A major NASA program is described.

126. Rudey, Richard A.: The Impact of Emission Standards on the Design of Aircraft Gas Turbine Engine Combustors. NASA TM X-73490, 1976.

Effective emission control techniques have been identified and a wide spectrum of potential applications for those techniques to existing and advanced engines are being considered. Results from advanced combustor concept evaluations and from fundamental experiments are presented and discussed and comparisons are made with existing EPA emission standards and recommended levels for high altitude cruise. The impact that the advanced low emission concepts may impose on future aircraft engine combustor designs and related engine components is discussed.

127. Rudey, Richard A.: Status Review of NASA Programs for Reducing Aircraft Gas Turbine Engine Emissions. NASA TM X-71861, 1976.

Programs initiated by NASA to develop and demonstrate low emission advanced technology combustors for reducing aircraft gas turbine engine pollution are reviewed. Program goals are consistent with urban emission level requirements as specified by the U.S. Environmental Protection Agency and with upper atmosphere cruise emission levels as recommended by the U.S. Climatic Impact Assessment Program and National Research Council. Preliminary tests of advanced technology combustors indicate that significant reductions in all major pollutant emissions should be attainable in present-generation aircraft gas turbine engines without adverse effects on fuel consumption. Preliminary test results from fundamental studies indicate that extremely low emission combustion systems may be possible for future-generation jet aircraft.

128. Rudey, Richard A.; and Lezberg, Erwin A.: Status of NASA Aircraft Engine Emission Reduction and Upper Atmosphere Measurement Programs. Aircraft Safety and Operating Problems, NASA SP-416, 1976, pp. 319-336.

NASA is conducting programs to evaluate advanced emission reduction techniques for five existing aircraft gas turbine engines. Varying degrees of progress have been made toward meeting the 1979 EPA standards in rig tests of combustors for the five engines. Results of fundamental combustion studies suggest the possibility of a new generation of jet engine combustor technology that would reduce oxides-of-nitrogen (NO_x) emissions far below levels currently demonstrated in the engine-related programs. The Global Air Sampling Program (GASP) is now in full operation and is providing data on constituent measurements of ozone and other minor upper-atmosphere species related to aircraft emissions.

NASA Contractor Reports

Engine Studies

129. Sabatella, J. A., ed.: Advanced Supersonic Propulsion Study Final Report. NASA CR-134633, 1974.

130 Szeliga, R.; and Allan, R. D.: Advanced Supersonic Technology Propulsion System Study - Final Report. NASA CR-143634, 1974.

131. Allan, R.: Advanced Supersonic Technology Propulsion System Study - Phase II Final Report. NASA CR-134913, 1975.

132. Howlett, R. A.; Sabatella, J.; Johnson, J.; and Aronstamm, G.: Advanced Supersonic Propulsion Study - Phase II Final Report. NASA CR-134904, 1975.

133. Trucco, Horacio: Study of Variable Cycle Engines Equipped With Supersonic Fans. NASA CR-134777, 1975.

Noise

134. Beulke, M. R.; Clapper, W. S.; McCann, E. O.; and Morozumi, H. M.: A Forward Speed Effects Study on Jet Noise From Several Suppressor Nozzles in the NASA/Ames 40- by 80-Foot Wind Tunnel - Final Report. NASA CR-114741, 1974.

135. Chun, K. S.; Berman, C. H.; and Cowan, S. J.: Effects of Motion on Jet Exhaust Noise From Aircraft. NASA CR-2701, 1976.

The various problems involved in the evaluation of the jet noise field prevailing between an observer on the ground and an aircraft in flight in a typical take-off or landing approach pattern were studied by the Boeing Commercial Airplane Company. Areas examined include (1) literature survey and preliminary investigation, (2) propagation effects, (3) source alteration effects, and (4) investigation of verification techniques. Sixteen problem areas were identified and studied. The results and the proposed follow-on programs provide a practical general technique for predicting flyover jet noise for conventional jet nozzles.

136. Jaeck, Carl L.: Static and Wind Tunnel Near-Field/Far-Field Jet Noise Measurements From Model Scale Single-Flow Baseline and Suppressor Nozzles. Volume 1: Noise Source Locations and Extrapolation of Static Free-Field Jet Noise Data. NASA CR-137913, 1976.

137. Jaeck, Carl L.: Static and Wind Tunnel Near-Field/Far-Field Jet Noise Measurements From Model Scale Single-Flow Baseline and Suppressor Nozzles. Volume 2: Forward Speed Effects. NASA CR-137914, 1976.

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138. Kozlowski, Hilary; and Packman, Allan B.: Aerodynamic and Acoustic Tests of Duct-Burning Turbofan Exhaust Nozzles. NASA CR-2628, 1976.

This experimental program conducted by Pratt & Whitney Aircraft established the static aerodynamic and acoustic characteristics of duct-burning turbofan (DBTF) exhaust nozzles. Scale models simulating unsuppressed coannular nozzles and mechanically suppressed nozzles with and without ejectors (hardwall and acoustically treated) were tested in a quiescent environment. Far-field acoustic data, perceived noise levels, and thrust measurements were obtained for 417 test conditions. Jet noise reductions relative to synthesized prediction from 8 PNdB (with the unsuppressed coannular nozzle) to 15 PNdB (with a mechanically suppressed configuration) were observed at conditions typical of engines being considered under the Advanced Supersonic Technology Program. The inherent suppression characteristic of the unsuppressed coannular nozzle is related to the rapid mixing in the jet wake caused by the velocity profiles associated with the DBTF. Since this can be achieved without a mechanical suppressor, significant reductions in aircraft weight or noise footprint can be realized.

139. Lockheed-Georgia Co.: Effects of Forward Velocity on Turbulent Jet Mixing Noise. NASA CR-2702, 1976.

Flight simulation experiments were conducted by the Lockheed-Georgia Company in an anechoic free jet facility over a broad range of model and free jet velocities. The resulting scaling laws were in close agreement with scaling laws derived from theoretical and semiempirical considerations. Additionally, measurements of the flow structure of jets were made in a wind tunnel by using a laser velocimeter. These tests were conducted to describe the effects of velocity ratio and jet exit Mach number on the development of a jet in a coflowing stream.

140. Strout, Frank G.: Flight Effects on Noise Generated by the JT8D-17 Engine in a Quiet Nacelle and a Conventional Nacelle as Measured in the NASA-Ames 40- by 80-Foot Wind Tunnel. NASA CR-137797, 1976.

141. Strout, Frank G.: Flight Effects on Noise Generated by the JT8D-17 Engine in a Quiet Nacelle and a Conventional Nacelle as Measured in the NASA-Ames 40- by 80-Foot Wind Tunnel - Summary Report. NASA CR-2576, 1976.

A JT8D-17 turbofan engine was tested in the NASA Ames 40- by 80-Foot Wind Tunnel by the Boeing Commercial Airplane Company to determine flight effects on jet and fan noise. Baseline, quiet nacelle with 20-lobe ejector/suppressor, and internal mixer configurations were tested over a range of engine power settings and tunnel velocities. Flight effects derived from the 40- by 80-Foot Wind Tunnel test are compared with 727/JT8D flight-test data and with model data obtained in a smaller wind tunnel. Noise results compare favorably for both the baseline and quiet nacelle configurations.

142. Shields, F. Douglas; and Bass, H. E.: Atmospheric Absorption of High Frequency Noise and Application to Fractional-Octave Bands. NASA CR-2760, 1977.

Pure tone sound absorption coefficients have been measured at 1/12 octave intervals from 4 kHz to 100 kHz at 5.5° K temperature intervals between 225.4° K to 310.9° K and at 10 percent relative humidity increments between 0 percent to saturation. The measurements were made by Mississippi University in a large cylindrical tube (25.4 cm i.d. by 4.8 m long). The absorption was measured by varying the transmitter receiver separation from 1 m to 4 m and observing the decay of multiple reflections or changes in amplitude of the first received burst. The resulting absorption was compared with a proposed procedure for computing sound absorption in still air and the agreement was found to be quite good. A recommended prediction procedure is described for 1/3-octave-band absorption coefficients.

Inlet Stability Valve

143. Blausey, G. C.; Coleman, D. M.; and Harp, D. S.: Feasibility Study of Inlet Shock Stability System of YF-12. NASA CR-134594, 1972.

Pollution Reduction

144. Bahr, D. W.; and Gleason, C. C.: Experimental Clean Combustor Program - Phase I Final Report. NASA CR-134737, 1975.

145. Roberts, P. B.; White, D. J.; and Shekleton, J. R.: Advanced Low NO_x Combustors for High-Altitude Supersonic Aircraft Gas Turbines. NASA CR-134889, 1975.

146. Roberts, R.; Peduzzi, A.; and Vitti, G. E.: Experimental Clean Combustor Program, Phase I. NASA CR-134736, 1975.

147. Roffe, Gerald; and Ferri, Antonio: Prevaporization and Premixing To Obtain Low Oxides of Nitrogen in Gas Turbine Combustors. NASA CR-2495, 1975.

Tests were conducted by Advanced Technology Laboratories, Inc. to determine the effectiveness of prevaporization and premixing in reducing the formation of oxides of nitrogen in a gas turbine type combustor using liquid JP-5 fuel at the supersonic cruise condition. The combustor inlet temperature was 833 K at a pressure of 4 atm and a reference velocity of 46 m/sec. An order of magnitude reduction in nitric oxide emissions was achieved. Nitric oxide emission indices as low as 0.6 g NO_2/kg fuel were measured.

148. Roffe, Gerald; and Ferri, Antonio: Effect of Premixing Quality on Oxides of Nitrogen in Gas Turbine Combustors. NASA CR-2657, 1976.

Experiments were conducted by General Applied Science Laboratories, Inc. to determine the effectiveness of several premixing prevaporizing gas turbine combustor designs in reducing formation of oxides of nitrogen at the supersonic cruise condition. An atomized spray from a single injector mounted on the axis of the mixer tube produced a high initial concentration of fuel near the axis and only moderate premixed conditions entering the combustor. A fuel spray produced by 12 flush-mounted normal injection orifices in the mixer tube wall produced a good initial dispersion of fuel and resulted in nearly complete premixing.

Materials

149. Cornie, J. A.; Cook, C. S.; and Andersson, C. A.: Fabrication Process Development of SiC/Superalloy Composite Sheet for Exhaust System Components. NASA CR-134958, 1976.

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Engine Studies

150. Hines, Richard W.; and Sabatella, Joseph A.: Benefits of Advanced Propulsion Technology for the Advanced Supersonic Transport. [Preprint] 730896, Soc. Automot. Eng., Oct. 1973.

151. Hines, Richard W.; and Sabatella, Joseph A.: Influence of Noise Constraints on Supersonic Transport Engine Design. AIAA Paper No. 73-1295, Nov. 1973.

152. Szeliga, R.: Development of Parametricized Computations for AST Study Engines. [Preprint] 730895, Soc. Automot. Eng., Oct. 1973.

153. Howlett, Robert A.: Engine Design Considerations for 2nd Generation Supersonic Transports. [Preprint] 750628, Soc. Automot. Eng., May 1975.

154. Howlett, Robert A.; and Kozlowski, Hilary: Variable Cycle Engines for Advanced Supersonic Transports. [Preprint] 751086, Soc. Automot. Eng., Nov. 1975.

155. Klees, G. W.; and Welliver, A. D.: Variable-Cycle Engines for the Second Generation SST. [Preprint] 750630, Soc. Automot. Eng., May 1975.

156. Johnson, J. E.: Variable Cycle Engines - The Next Step In Propulsion Evolution? AIAA Paper No. 76-758, July 1976.

157. Weber, Richard J.: NASA Propulsion Research for Supersonic Cruise Aircraft. Astronaut. & Aeronaut., vol. 14, no. 5, May 1976, pp. 38-45.

158. Welliver, B.: Engine Airframe Optimization Has Yet To Be Done. Design Conference Proceedings - Technology for Supersonic Cruise Military Aircraft, Volume I, AFFDL-TR-77-85, Vol. I, U.S. Air Force, 1976.

159. Willis, E. A.; and Welliver, A. D.: Variable-Cycle Engines for Supersonic Cruising Aircraft. AIAA Paper No. 76-759, July 1976.

160. Payzer, Robert J.: Variable Cycle Engine Applications and Constraints. Variable Geometry and Multicycle Engines, AGARD-CP-205, Mar. 1977, pp. 13-1 - 13-13.

161. Willis, Edward: Variable-Cycle Engines for Supersonic Cruise Aircraft. Variable Geometry and Multicycle Engines, AGARD-CP-205, Mar. 1977, pp. 7-1 - 7-19.

Noise

162. Atencio, Adolph, Jr.; and Soderman, Paul T.: Comparison of Aircraft Noise Measured in Flight Test and in the NASA Ames 40- by 80-Foot Wind Tunnel. AIAA Paper No. 73-1047, Oct. 1973.

163. Soderman, Paul T.; and Noble, Stephen C.: Directional Microphone Array for Acoustic Studies of Wind Tunnel Models. J. Aircr., vol. 12, no. 3, Mar. 1975, pp. 168-173.

164. Soderman, Paul T.: Instrumentation and Techniques for Acoustic Research in Wind Tunnels. ICIASF '75 Record, IEEE Publ. 75 CHO 993-6 AES, pp. 270-276.

165. Bass, H. E.; Shields, F. D.; and Bolen, L. N.: Absorption of Sound in Moist Air. J. Acoust. Soc. America, vol. 59, suppl. no. 1, Spring 1976, pp. S92-S93.

166. Kozlowski, H.; Packman, A. B.; and Gutierrez, O.: Aeroacoustic Performance Characteristics of Duct Burning Turbofan Exhaust Nozzles. AIAA Paper No. 76-148, Jan. 1976.

167. Morfey, Christopher L.; and Tester, Brian J.: Noise Measurements in a Free-Jet, Flight Simulation Facility: Shear Layer Refraction and Facility-to-Flight Corrections. AIAA Paper No. 76-531, July 1976.

168. Morris, Philip J.: Turbulence Measurements in Subsonic and Supersonic Axisymmetric Jets in a Moving Stream. AIAA Paper No. 76-25, Jan. 1976.

169. Packman, A. B.; Kozlowski, H.; and Gutierrez O.: Jet Noise Characteristics of Unsuppressed Duct Burning Turbofan Exhaust System. AIAA Paper No. 76-149, Jan. 1976.

170. Shields, F. D.; Bolen, L. N.; and Bass, H. E.: Pulse Method for Measuring Sound Absorption in the Kilohertz Range. J. Acoust. Soc. America, vol. 59, suppl. no. 1, Spring 1976, p. S61.

171. Strout, Frank G.; and Atencio, Adolph, Jr.: Flight Effects on JT8D Engine Jet Noise as Measured in the NASA Ames 40- by 80-Foot Wind Tunnel. AIAA Paper No. 76-556, July 1976.

172. Tanna, H. K.; and Morris, P. J.: Inflight Simulation Experiments on Turbulent Jet Mixing Noise. AIAA Paper No. 76-554, July 1976.

Inlet Stability Valve

173. Cole, Gary L.; Dustin, Miles O.; and Neiner, George H.: A Throat-Bypass Stability System Tested in a YF-12 Inlet. J. Aircr., vol. 14, no. 1, Jan. 1977, pp. 15-22.

Pollution Reduction

174. Overcamp, T. J.; and Fay, J. A.: Dispersion of SST Trails in the Stratosphere. AIAA Paper No. 72-650, June 1972.

175. Appleton, John P.: Soot Oxidation Kinetics at Combustion Temperatures. Atmospheric Pollution by Aircraft Engines, AGARD-CP-125, Sept. 1973, pp. 20-1 - 20-11.

176. Flagan, Richard C.; and Appleton, John P.: A Stochastic Model of Turbulent Mixing With Chemical Reaction: Nitric Oxide Formation in a Plug-Flow Burner. Publ. No. 73-10, Fluid Mech. Lab., Massachusetts Inst. Technol., Dec. 1973.

177. Heywood, John B.; and Mikus, Thomas: Parameters Controlling Nitric Oxide Emissions From Gas Turbine Combustors. Atmospheric Pollution by Aircraft Engines, AGARD-CP-125, Sept. 1973, pp. 21-1 - 21-16.

178. Flagan, Richard C.; and Appleton, John P.: A Stochastic Model of Turbulent Mixing With Chemical Reaction: Nitric Oxide Formation in a Plug-Flow Burner. Combust. & Flame, vol. 23, no. 2, Oct. 1974, pp. 249-267.

179. Morr, A. R.; and Heywood, J. B.: Partial Equilibrium Model for Predicting Concentration of CO in Combustion. Acta Astronaut., vol. 1, no. 7/8, July/Aug. 1974, pp. 949-966.

180. Mikus, Thomas: Nitric Oxide Formation in Gas Turbine Engines: A Theoretical and Experimental Study. Ph. D. Thesis, Massachusetts Inst. Technol., 1975.

181. O'Leary, Joseph Anthony: A Model for Predicting Nitric Oxide and Carbon Monoxide Emissions From Gas Turbine Combustors. M.S. Thesis, Massachusetts Inst. Technol., 1975.

182. Roberts, P. B.; Shekleton, J. R.; White, D. J.; and Butze, H. F.: Advanced Low NO_x Combustors for Supersonic High-Altitude Aircraft Gas Turbines. Paper 76-GT-12, American Soc. Mech. Eng., Mar. 1976.

Materials

183. Klees, G. W.; and Swan, W. C.: Prospects for Variable-Cycle Engines. 1972 JANNAF Propulsion Meeting - Aircraft Propulsion Sessions. CPIA Publ. No. 232 (Contract N00017-72-C-4401), Appl. Phys. Lab., Johns Hopkins Univ., Dec. 1972, pp. 93-127.

184. Roberts, P. B.; White, D. J.; Shekleton, J. R.; and Butze, H. F.: Advanced Low NO_x Combustors for Aircraft Gas Turbines. AIAA Paper No. 76-764, July 1976.

STRATOSPHERIC EMISSIONS IMPACT

NASA Inhouse Reports

185. Holdeman, James D.: Dispersion of Turbojet Engine Exhaust in Flight. NASA TN D-7382, 1973.

The dispersion of the exhaust of turbojet engines into the atmosphere is estimated by using a model developed for the mixing of a round jet with a parallel flow. Calculations of the dispersion of the exhaust plumes of three aircraft turbojet engines with and without afterburning at typical flight conditions are presented. Calculated average concentrations for the exhaust plume from a single engine jet fighter are shown to be in good agreement with measurements made in the aircraft wake during flight.

186. Holdeman, James D.: Emission Calibration of a J-58 Afterburning Turbojet Engine at Simulated Supersonic, Stratospheric Flight Conditions. NASA TM X-71571, 1974.

Emissions of total oxides of nitrogen, unburned hydrocarbons, and carbon monoxide from a J-58 engine at simulated flight conditions of Mach 2.0, 2.4, and 2.8 at an altitude of 19.8 km are reported. For each flight condition, measurements were made for four engine power levels from maximum power without afterburning to maximum afterburning. These measurements were made 7 cm downstream of the engine primary nozzle using a single point traversing gas sample probe. Results show that emissions vary with flight speed, engine power level, and with radial position across the exhaust.

187. Holdeman, James D.: Gaseous Exhaust Emissions From a J-58 Engine at Simulated Supersonic Flight Conditions. NASA TM X-71532, 1974.

Emissions of total oxides of nitrogen, unburned hydrocarbons, carbon monoxide, and carbon dioxide from a J-58 engine at simulated flight conditions of Mach 2.0, 2.4. and 2.8 at an altitude of 19.8 km are reported. For each flight condition, measurements were made for four engine power levels from maximum power without afterburning to maximum afterburning.

188. Wong, E. L.; and Bittker, David A.: Effect of Pollutant Gases on Ozone Production by Simulated Solar Radiation. NASA TM X-71573, 1974.

Experiments using simulated solar radiation in a chamber with a controlled atmospheric pressure near 1 atm were conducted to evaluate O_3 production. The effects of CO and H_2O were analyzed to determine if the CO and H_2O addition could reduce NO destruction of O_3. The results show that NO is destroyed while destroying O_3.

189. Von Thüna, Peter C.: Tuneable Diode Laser Spectrometer With Integral Grating. NASA Tech Brief B75-10262, 1975.

A novel optical arrangement was developed during a design study for an airborne infrared spectrometer by using tuneable laser diodes. A grating is used in place of one of the required folding mirrors and is thus made an integral part of the optical system.

190. Holdeman, James D.: Exhaust Emission Calibration of Two J-58 Afterburning Turbojet Engines at Simulated High-Altitude, Supersonic Flight Conditions. NASA TN D-8173, 1976.

Emissions of total oxides of nitrogen, nitric oxide, unburned hydrocarbons, carbon monoxide, and carbon dioxide from two J-58 afterburning turbojet engines at simulated high-altitude flight conditions are reported. Test conditions included flight speeds from Mach 2 to 3 at altitudes from 16.0 to 23.5 km. Oxides of nitrogen emissions decreased with increasing altitude and increased with increasing flight speed. Oxides of nitrogen emission indices with afterburning were less than half the value without afterburning. Carbon monoxide and hydrocarbon emissions increased with increasing altitude and decreased with increasing flight speed. Emissions of these species were substantially higher with afterburning than without.

191. Holdeman, James D.: Measurement of Exhaust Emissions From Two J-58 Engines at Simulated Supersonic Cruise Flight Conditions. NASA TM X-71826, 1976.

Emissions of total oxides of nitrogen, unburned hydrocarbons, carbon monoxide, and carbon dioxide from two J-58 afterburning turbojet engines at simulated high-altitude flight conditions are reported. Test conditions included flight speeds from Mach 2 to 3 at altitudes from 16 to 23 km. The data show that exhaust emissions vary with flight speed, altitude, power level, and radial position across the exhaust. Oxides of nitrogen (NO_x) emissions decreased with increasing altitude and increased with increasing flight speed. Carbon monoxide and hydrocarbon emissions increased with increasing altitude and decreased with increasing flight speed. Emissions of these species were substantially higher with afterburning than without.

192. Broderick, Anthony J.; and Krull, Nicholas P.: Considerations of High Altitude Emissions. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 565-574.

This paper describes the status of the Federal Aviation Administration's High Altitude Pollution Program, which was instituted in 1976 to develop the detailed quantitative information needed to judge whether regulatory action to limit such emissions would be necessary. The complexities of this question and the nature and magnitude of uncertainties still present in our scientific understanding of the potential interactions between aircraft exhaust emissions and

stratospheric ozone and climate are reviewed. The direction and scope of future federal and international activities are described.

193. Reck, Gregory M.; and Rudey, Richard A.: Technology for Controlling Emissions of Oxides of Nitrogen From Supersonic Cruise Aircraft. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 543-564.

Various experiments have been and continue to be sponsored by and conducted by the NASA Lewis Research Center to explore the potential of advanced combustion techniques for controlling aircraft engine emissions into the upper atmosphere. Of particular concern are the oxides of nitrogen (NO_x) emissions into the stratosphere. The experiments utilize a wide variety of approaches varying from advanced combustor concepts to fundamental flame-tube experiments. Results are presented which indicate that substantial reductions in cruise NO_x emissions should be achievable in future aircraft engines.

NASA Contractor Reports

194. Von Thüna, Peter C.: Design Study for an Airborne Infrared Spectrometer Using Tuneable Laser Diodes. ADL C-76976 (Contract No. NAS1-13045), Arthur D. Little, Inc., Nov. 1974. (Available as NASA CR-145100.)

195. Von Thüna, Peter C.: Design of an Airborne Laser Spectrometer. NASA CR-145131, 1977.

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196. Allario, Frank; Seals, R. K., Jr.; Brockman, Philip; and Hess, R. V.: Tunable Semiconductor Lasers and Their Application to Environmental Sensing. Paper presented at 10th Anniversary Meeting of the Society of Engineering Science (Raleigh, N.C.), Nov. 5-7, 1973.

197. Anderson, J. G.; and Kaufman, F.: Kinetics of the Reaction $OH (v = 0) + O_3 \rightarrow HO_2 + O_2$. Chem. Phys. Lett., vol. 19, no. 4, Apr. 15, 1973, pp. 483-486.

198. Anderson, J. G.; Margitan, J. J.; and Kaufman, F.: Gas Phase Recombination of OH With NO and NO_2. J. Chem. Phys., vol. 60, no. 8, Apr. 15, 1974, pp. 3310-3317.

199. Brockman, Philip; and Seals, R. K., Jr.: Analysis of Laser Measurement of High-Altitude Aircraft Emissions. AIAA J., vol. 12, no. 5, May 1974, pp. 651-655.

200. Farlow, N. H.; Watson, V. R.; Loewenstein, M.; Chan, K. L.; Hoshizaki, H.; Conti, R. J.; and Meyer, J. W.: Measurements of Supersonic Jet Aircraft Wakes in the Stratosphere. Second International Conference on the Environmental Impact of Aerospace Operations in the High Atmosphere - Preprints, American Meteorolog. Soc., July 1974, pp. 53-58.

201. Farmer, C. B.: Infrared Measurements of Stratospheric Composition. Canadian J. Chem., vol. 52, no. 8 (pt. 2), Apr. 15, 1974, pp. 1544-1559.

202. Holdeman, James D.: Dispersion and Dilution of Jet Aircraft Exhaust at High-Altitude Flight Conditions. AIAA Paper No. 74-41, Jan.-Feb. 1974.

203. Margitan, J. J.; Kaufman, F.; and Anderson, J. G.: The Reaction of OH With CH_4. Geophys. Res. Lett., vol. 1, no. 2, June 1974, pp. 80-81.

204. Zahniser, M. S.; Kaufman, F.; and Anderson, J. G.: Kinetics of the Reaction of OH With HCl. Chem. Phys. Lett., vol. 27, no. 4, Aug. 15, 1974, pp. 507-510.

205. Kaufman, Frederick: Hydrogen Chemistry: Perspective on Experiment and Theory. Atmospheres of Earth and the Planets, B. M. McCormac, ed., D. Reidel Pub. Co., c.1975, pp. 219-232.

206. Margitan, J. J.; Kaufman, F.; and Anderson, J. G.: Kinetics of the Reaction OH + D $\rightarrow$ OD + H. Chem. Phys. Lett., vol. 34, no. 3, Aug. 1, 1975, pp. 485-489.

207. Margitan, J. J.; Kaufman, F.; and Anderson, J. G.: Kinetics of the Reaction OH + $HNO_3 \rightarrow H_2O + NO_3$. Chemical Kinetics Data for the Upper and Lower Atmosphere, Int. J. Chem. Kinet. Symp. No. 1, 1975, pp. 281-287.

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211. Davidson, J. A.; Sadowski, C. M.; Schiff, H. I.; Streit, G. E.; Howard, Carleton J.; Jennings, D. A.; and Schmeltekopf, A. L.: Absolute Rate Constant Determinations for the Deactivation of $O(^1D)$ by Time Resolved Decay of $O(^1D) \rightarrow O(^3P)$ Emission. J. Chem. Phys., vol. 64, no. 1, Jan. 1, 1976, pp. 57-62.

212. Davidson, J. A.; Schiff, H. I.; Streit, G. E.; Schmeltekopf, A. L.; and Howard, Carleton, J.: Temperature Dependence of $O(^1D)$ Reactions of Atmospheric Importance. The 12th Informal Conference on Photochemistry - Extended Abstracts, Natl. Bur. Stand., U.S. Dep. Commer., June-July 1976.

213. Farmer, C. B.; Raper, O. F.; and Norton, R. H.: Spectroscopic Detection and Vertical Distribution of HCl in the Troposphere and Stratosphere. Geophys. Res. Lett., vol. 3, no. 1, Jan. 1976, pp. 13-16.

214. Holdeman, J. D.: Measurement of Exhaust Emissions From Two J-58 Engines at Simulated Supersonic Cruise Flight Conditions. Paper 76-GT-8, American Soc. Mech. Eng., Mar. 1976.

215. Menzies, R. T.; Allario, F.; Duewer, D.; Gjessing, D. T.; Gürs, K.; Little, C. G.; Lund, T.; Nordø, J.; Ottar, B.; Peckham, G. E.; and Rothe, K. W.: Working Group Reports - Global and Regional Monitoring From Airborne and Satellite Platforms. Opt. & Quantum Electron., vol. 8, no. 2, Mar. 1976, pp. 185-187.

216. Streit, G. E.; Howard, Carleton J.; Schmeltekopf, A. L.; Davidson, J. A.; and Schiff, H. I.: Temperature Dependence of $O(^1D)$ Rate Constants for Reactions With O_2, N_2, CO_2, O_3, and H_2O. J. Chem. Phys., vol. 65, no. 11, Dec. 1, 1976, pp. 4761-4764.

217. Zahniser, M. S.; Kaufman, F.; and Anderson, J. G.: Kinetics of the Reaction $Cl + O_3 \rightarrow ClO + O_2$. Chem. Phys. Lett., vol. 37, no. 2, Jan. 15, 1976, pp. 226-231.

STRUCTURES AND MATERIALS

NASA Inhouse Reports

Structure Concepts Studies

218. Cooper, Paul A.; and Heldenfels, Richard R.: NASA Research on Structures and Materials for Supersonic Cruise Aircraft. NASA TM X-72790, 1976.

The technology and data base necessary for sound technical decisions regarding long-haul supersonic cruise aircraft transportation systems are considered. The objectives and status of the research elements in the structures and materials phase of the program are reviewed. Emphasis is placed on reductions in structural mass by research on advanced structural concepts, lightweight materials, improved loads, aeroelastic predictive techniques, and by development of efficient structural design procedures.

219. Sakata, I. F.; and Davis, G. W.: Advanced Structures Technology Applied to a Supersonic Cruise Arrow-Wing Configuration. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 603-636.

The application of advanced technology to a promising aerodynamic configuration was explored to investigate the improved payload-range characteristics over the configuration postulated during the National SST Program. Highlighted are the results of an analytical study performed by the Lockheed-California Company to determine the best structural approach fo design of a Mach number 2.7 arrow wing supersonic cruise aircraft. The data from this study, conducted under the auspices of NASA, established firm technical bases from which further trend studies were conducted to quantitatively assess the benefits and feasibility of using advanced structures technology to arrive at a viable advanced supersonic cruise aircraft.

220. Sobieszczanski, Jaroslaw; McCullers, L. Arnold; Ricketts, Rodney H.; Santoro, Nick J.; Beskenis, Sharon D.; and Kurtze, William L.: Structural Design Studies of a Supersonic Cruise Arrow Wing Configuration. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 659-683.

Structural member cross sections were sized with a system of integrated computer programs to satisfy strength and flutter design requirements for several variants of the arrow wing supersonic cruise vehicle. The resulting structural weights provide a measure of the structural efficiency of the planform geometry, structural layout, type of construction, and type of material, including composites.

A study was conducted at Langley Research Center to determine the material distribution for a baseline metallic structure. A study was performed on a reduced wing area configuration. The use of composite materials on the baseline configuration was explored.

221. Turner, M. J.; and Hoy, J. M.: Titanium and Advanced Composite Structures for a Supersonic Cruise Arrow Wing Configuration. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 579-602.

Two structural design studies were made by the Boeing Commerical Airplane Company based on current technology and on an estimate of technology to be available in the mid-1980's to assess the relative merits of structural concepts and materials for an advanced arrow-wing configuration cruising at Mach 2.7. Material and concept selection, detailed structural analysis, structural design, and airplane mass analysis were completed for the first study based on current technology. In the second study, based on estimated future technology, structural sizing for strength and a preliminary assessment of the flutter of a strength designed composite structure were completed. In both studies, an advanced computerized structural design system was used in conjunction with a relatively complex finite element model for detailed analysis and sizing of structural members.

Structure Technology

222. Haftka, Raphael T.; and Starnes, James H., Jr.: WIDOWAC (Wing Design Optimization With Aeroelastic Constraints): Program Manual. NASA TM X-3071, 1974.

User and programer documentation for the WIDOWAC programs is given. WIDOWAC may be used for the design of minimum mass wing structures subjected to flutter, strength, and minimum gage constraints. The wing structure is modeled by finite elements; flutter conditions may be both subsonic and supersonic; and mathematical programing methods are used for the optimization procedure. Program input and output are described, and example problems are presented. A discussion of computational algorithms and flow charts of the WIDOWAC programs and major subroutines is also given.

223. Adelman, Howard M.; Walsh, Joanne L.; and Narayanaswami, R.: An Improved Method for Optimum Design of Mechanically and Thermally Loaded Structures. NASA TN D-7965, 1975.

The problem of obtaining the minimum mass design of mechanically and thermally loaded structures is presented. The special nature of thermal stresses with regard to their response to resizing of structural members is discussed. An improved algorithm for resizing of structures subjected to thermal stresses is presented. The mechanical portions of the stresses were driven to their maximum allowable values. The new algorithm was exercised for a number of truss structures of varying complexity and compared with ordinary fully stressed design.

224. Adelman, Howard M.; and Narayanaswami, R.: Resizing Procedure for Optimum Design of Structures Under Combined Mechanical and Thermal Loading. NASA TM X-72816, 1976.

An algorithm is reported for resizing structures that are subjected to combined thermal and mechanical loading. The algorithm is applicable to uniaxial stress elements (rods) and membrane biaxial stress members. Thermal fully stressed design (TFSD) is based on the basic difference between mechanical and thermal stresses in their response to resizing. The TFSD technique is found to converge in fewer iterations and demonstrated its improvement with a study of a simplified wing structure, built-up rods and membranes, and subjected to a combination of mechanical loads and a three-dimensional temperature distribution.

225. Atta, E. H.; Kandil, O. A.; Mook, D. T.; and Nayfeh, A. H.: Unsteady Flow Past Wings Having Sharp-Edge Separation. Vortex-Lattice Utilization, NASA SP-405, 1976, pp. 407-418.

A vortex-lattice technique is developed to model unsteady, incompressible flow past thin wings. This technique predicts the shape of the wake as a function of time; thus, it is not restricted by planform, aspect ratio, or angle of attack as long as vortex bursting does not occur and the flow does not separate from the wing surface. Moreover, the technique can be applied to wings of arbitrary curvature undergoing general motion; thus, it can treat rigid-body motion, arbitrary wing deformation, gusts in the free stream, and periodic motions.

Numerical results are presented for low aspect rectangular wings undergoing a constant-rate, rigid-body rotation about the trailing edge. The results for the unsteady motion exhibit hysteretic behavior.

226. Kandil, Osama A.; Mook, Dean T.; and Nayfeh, Ali H.: New Convergence Criteria for the Vortex-Lattice Models of the Leading-Edge Separation. Vortex-Lattice Utilization, NASA SP-405, 1976, pp. 285-300.

Predicted pressure distributions have some irregularities which are the result of discrete vortex lines coming close to the lifting surface. Here it is shown that one can eliminate these irregularities and predict pressure distributions which agree fairly well with experimental data by replacing the system of discrete vortex lines with a single concentrated core. This approach has the additional desirable feature of requiring less computational time.

227. McGehee, John R.; and Carden, Huey D.: A Mathematical Model of an Active Control Landing Gear for Load Control During Impact and Roll-Out. NASA TN D-8080, 1976.

A mathematical model of an active control landing gear (ACOLAG) was developed and programed for operation on a digital computer. The mathematical model includes theoretical subsonic aerodynamics; first-mode wing bending and torsional characteristics; oleopneumatic shock strut with fit and binding friction; closed-loop, series-hydraulic control; empirical tire force-deflection characteristics; antiskid braking; and sinusoidal or random runway roughness. Computed results for the series-hydraulic active control in conjunction with the simply modified passive gear show that 20- to 30-percent reductions in wing force relative to those occurring with the modified passive gear can be obtained during the impact phase of the landing.

228. McWithey, Robert R.: Analytical Structural Efficiency Studies of Borsic/ Aluminum Compression Panels. NASA TN D-8333, 1976.

Analytically determined mass-strength curves, strain-strength curves, and dimensions are presented for structurally efficient hat-stiffened panels, corrugation-stiffened panels, hat-stiffened honeycomb-core sandwich panels, open-section corrugation panels, and honeycomb-core sandwich panels. The panels were assumed to be fabricated from either titanium, Borsic/aluminum, or a combination of these materials. Results indicate Borsic/aluminum panels and titanium panels reinforced with Borsic/aluminum are lighter and stiffer than comparably designed titanium panels. Furthermore, reinforced titanium panels have the same extensional stiffness as comparably designed Borsic/aluminum panels. For a given load, the structural efficiency of the hat-stiffened honeycomb-core sandwich panel is higher than the structural efficiency of the other stiffened panels.

229. Ruhlin, Charles L.; Doggett, Robert V., Jr.; and Gregory, Richard A.: Geared-Elevator Flutter Study. NASA TM X-73902, 1976.

A study was made of the transonic flutter characteristics of a supersonic transport tail assembly model having an all-movable horizontal tail with a geared elevator. Two model configurations, namely, one with a geared elevator (2.8 to 1.0 gear ratio) and one with locked elevator (1.0 to 1.0 gear ratio), were flutter tested in the Langley transonic dynamics tunnel with an empennage that was cantilever mounted on a sting. The geared-elevator configuration fluttered experimentally at dynamic pressures about 20 percent higher than the locked-elevator configuration. A comparison of the experimental and analytical results shows that the discrete-elevator method predicted best the experimental flutter dynamic pressure level. However, the single warped-surface method predicts more closely the experimental flutter frequencies and Mach number trends.

230. Giles, Gary L.: Computer-Aided Methods for Analysis and Synthesis of Supersonic Cruise Aircraft Structures. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 637-657.

The design and analysis of proposed supersonic cruise aircraft structures have requred extensive use and new development of computer-aided methods. This paper reviews computer-aided methods which have been and are being developed by Langley Research Center inhouse work and by related grants and contracts. Synthesis methods to size structural members to meet strength and stiffness (flutter) requirements have been emphasized in this work and are described. Because of the strong interaction among the aerodynamic loads, structural stiffness, and member sizes of supersonic cruise aircraft structures, these methods have been combined into systems of computer programs to perform design studies.

231. Goetz, Robert C.: Loads Technology for Supersonic Cruise Aircraft. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 685-706.

A SCAR Loads Technology Program was initiated in 1973 and includes research in aeroelastic loads, landing loads, acoustic loads, and the measurement of atmospheric turbulence. This paper presents the current status and some results obtained to date for the latter three research areas.

A flight program to measure atmospheric turbulence at high altitudes in a variety of meteorological conditions is described. Results are also presented from wind-tunnel test programs to measure fluctuating pressures associated with over-the-wing engine configurations. Two analyses, a flexible aircraft take-off and landing analysis and an active control landing-gear analysis, have been developed and their capabilities are described.

232. Haskins, J. F.; Kerr, J. R.; and Stein, B. A.: Time-Temperature-Stress Capabilities of Composites for Supersonic Cruise Aircraft Applications. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 799-828.

Advanced composite materials have the potential of reducing the weight of future supersonic cruise aircraft structures. However, information on the effects of long-time cyclic exposure to environments and loadings representative of long-time supersonic cruise aircraft service for the composite materials of interest is not available. A program to generate such information was initiated in 1973. A range of baseline properties was determined for representatives of five composite materials systems: B/Ep, Gr/Ep, B/PI, Gr/PI, and B/Al. This paper presents selected results from the environmental exposure studies with emphasis placed on the 10 000-hr thermal aging data. Results of residual strength determinations and changes in physical and chemical properties during high-temperature aging are discussed and illustrated using metallographic, fractographic, and thermomechanical analyses. Some initial results of the long-term flight simulation tests are also included.

233. Yates, E. Carson, Jr.; and Bland, Samuel R.: Developments in Steady and Unsteady Aerodynamics for Use in Aeroelastic Analysis and Design. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 707-737.

A review is given of seven research projects which are aimed at improving the generality, accuracy, and computational efficiency of steady and unsteady aerodynamic theory for use in aeroelastic analysis and design. These projects indicate three major thrusts of current research efforts: (1) more realistic representation of steady and unsteady, subsonic and supersonic, loads on aircraft configurations of general shape with emphasis on structural design applications, (2) unsteady aerodynamics for application in active controls analyses, and (3) unsteady aerodynamics for the frequently critical transonic speed range.

Materials Application

234. Bales, Thomas T.; Royster, Dick M.; and Arnold, Winfrey E., Jr.: Development of the Weld-Braze Joining Process. NASA TN D-7281, 1973.

A joining process, designated weld-brazing, was developed which combines resistance spotwelding and brazing. Resistance spotwelding is used to position and aline the parts, as well as to establish a suitable faying-surface gap for brazing. The process was used successfully to fabricate Ti-6Al-4V alloy joints. Tests results obtained on single-overlap and hat-stiffened panel specimens show that weld-brazed joints were superior in tensile shear, stress rupture, fatigue, and buckling compared with joints fabricated by conventional means.

235. Brooks, William A., Jr.; and Dow, Marvin B.: Service Evaluation of Aircraft Composite Structural Components. NASA TM X-71944, 1973.

The advantages of the use of composite materials in structural applications have been identified in numerous engineering studies. Technology development programs are underway to correct known deficiencies and to provide needed improvements. However, in the final analysis, flight service programs are necessary to develop broader acceptance of, and confidence in, any new class of materials such as composites. Such flight programs, initiated by NASA Langley Research Center, are reviewed.

236. Imig, L. A.; and Garrett, L. E.: Fatigue-Test Acceleration With Flight-by-Flight Loading and Heating To Simulate Supersonic-Transport Operation. NASA TN D-7380, 1973.

Possibilities for reducing fatigue-test time for supersonic-transport materials and structures were studied in tests with simulated flight-by-flight loading. The effects of design mean stress, the stress range for ground-air-ground cycles, simulated thermal stress, the number of stress cycles in each flight, and salt corrosion were studied. The flight-by-flight stress sequences were applied to notched sheet specimens of Ti-8Al-1Mo-1V and Ti-6Al-4V titanium alloys. Fatigue accelerated testing seems feasible.

237. Rosser, R. W.; and Parker, J. A.: Chemical Research Projects Office Fuel Tank Sealants Review. NASA TM X-62,401, 1974.

The status of high-temperature fuel tank sealants for military and potentially commercial supersonic aircraft is examined. The NASA's sealants program comprises synthesis and development of new fluoroether elastomers, sealant prediction studies, flight simulation, and actual flight testing of best state-of-the-art fluorosilicone sealants. The technical accomplishments of these projects are reviewed.

238. Serafini, Tito T.; Delvigs, Peter; and Vannucci, Raymond D.: In Situ Polymerization of Monomers for Polyphenylquinoxaline-Graphite Fiber Composites. NASA TN D-7793, 1974.

In situ polymerization of monomers was used to prepare graphite-fiber-reinforced polyphenylquinoxaline composites. Six different monomer combinations were investigated. Composite mechanical property retention characteristics were determined at 316° C over an extended time period.

239. Imig, L. A.: Crack-Growth in a Ti-8Al-1Mo-1V With Real-Time and Accelerated Flight-by-Flight Loading. NASA TM X-72754, 1975.

Crack growth in Ti-8Al-1Mo-1V was measured and calculated for real-time and accelerated simulations of supersonic airplane loading and heating. Calculated crack-growth rates were slower than the experimental rates for all tests with flight-by-flight loading. For room-temperature accelerated tests, the calculated rates agreed well with the experimental rates; but the calculations became progressively less accurate for progressively more complex test conditions (tests that included elevated temperature).

240. Royster, Dick M.; Wiant, H. Ross; and Bales, Thomas T.: Joining and Fabrication of Metal-Matrix Composite Materials. NASA TM X-3282, 1975.

Manufacturing technology associated with developing fabrication processes to incorporate metal-matrix composites into flight hardware is studied. The joining of composite to itself and to titanium by innovative brazing, diffusion bonding, and adhesive bonding is examined. The effects of the fabrication processes on the material properties and their influence on the design of YF-12 wing panels are discussed.

241. Serafini, Tito T.: Processable High Temperature Resistant Polymer Matrix Materials. NASA TM X-71682, 1975.

In 1968 investigators at the Systems Group of TRW, Inc., working under NASA sponsorship, developed an approach to prepare polyimides by means of an addition reaction. Low molecular weight amide-acid prepolymers end-capped with norbornane rings were cured without the evolution of volatile material. Subsequent studies at the NASA Lewis Research Center led to the development of an improved method for preparing addition-cured polyimides. In this approach in situ Polymerization of Monomer Reactants (PMR) occurs on the surface of the reinforcing fibers. The purpose of this report is to review the studies conducted with addition-type polyimides. Particular emphasis is given to the studies concerned with the development of the PMR approach.

242. Haskins, J.; and Kerr, J.: Time-Temperature-Stress Capabilities of Composite Materials for Advanced Supersonic Technology Applications. Third Conference on Fibrous Composites in Flight Vehicle Design - Part I, NASA TM X-3377, 1976, pp. 383-403.

Time-temperature-stress characteristics of four classes of high-temperature composite materials are established to assess their suitability for advanced supersonic technology considerations. The tests discussed include thermal aging, ambient aging, fatigue, tensile, shear, fracture, and flight simulation with some results being available for 10 000-hr exposure.

243. Ascani, Leonard A.; and Pulley, John K.: New Advancements in Titanium Technology and Their Cost and Weight Benefits. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 757-782.

A new technology is emerging that promises to revolutionize the field of metal fabrication and design, particularly that of titanium. A process that combines both the superplastic and diffusion bonding properties of metal into one concurrent operation is being developed at Rockwell International. Estimates using this technology have indicated that this combined process will result in cost savings up to 70 percent when compared with conventional construction methods, while also saving weight. Many structural forms are possible including sandwich structures made by expanding face sheets and core against die forms. The classic difficulties normally associated with fabricating sandwich structures, such as parts fit-up, close tolerances, and adhesive or braze alloy strength, do not exist with this technique. Rockwell's patented new processes are expected to significantly affect future airplane concepts and criteria.

244. Bales, Thomas T.; Hoffman, Edward L.; Payne, Lee; and Carter, Alan L.: Fabrication and Evaluation of Advanced Titanium and Composite Structural Panels. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 783-797.

Advanced manufacturing methods for titanium and composite material structures are being developed and evaluated by NASA in support of the Supersonic Cruise Aircraft Research Program. The program with the Lockheed-California Company involves design, fabrication, ground testing, and Mach 3 flight service of full-scale structural panels and laboratory testing of representative structural element specimens.

Results discussed include the manufacturing methods and test results for weld-brazed and RohrBond titanium panels fabricated by aerospace contractors and the development of fabrication methods for producing Borsic/aluminum and graphite/PMR-15 polyimide panels at the Langley Research Center. Test data presented on the titanium panels include results obtained from flight service on the YF-12 aircraft and from ground exposure to [illegible] K for 10 000 hr.

245. Bales, Thomas T.; Wiant, H. Ross; and Royster, Dick M.: Brazed Borsic/ Aluminum Structural Panels. NASA TM X-3432, 1977.

A fluxless brazing process has been developed at the Langley Research Center that minimizes degradation of the mechanical properties of Borsic/ aluminum composites. The process, which employs 718 aluminum alloy braze, is being used to fabricate full-scale Borsic/aluminum-titanium honeycomb-core panels for Mach 3 flight testing on the NASA YF-12 aircraft and ground testing in support of the SCAR Program. The manufacturing development and results of shear tests on full-scale panels are presented.

246. Imig, L. A.: Fatigue of Titanium Alloys in a Supersonic-Cruise Airplane Environment. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 739-756.

Many fatigue tests have been conducted to explore thermal effects on structural materials in the time since supersonic commercial flight first received serious consideration. Most of the testing has been conducted with coupons of structural materials because large numbers of realistic simulated structures are prohibitively expensive. The test programs conducted by several aerospace companies and NASA and summarized in this paper studied several titanium materials previously identified as having high potential for application to supersonic cruise airplane structures.

247. Rosser, Robert W.; and Parker, John A.: Advanced Supersonic Technology Fuel Tank Sealants. Proceedings of the SCAR Conference - Part 2, NASA CP-001, [1977], pp. 829-843.

The Advanced Supersonic Technology (AST) Fuel Tank Sealants Program is reviewed. Status of the fuel tank simulation and YF-12A flight tests utilizing a state-of-the-art fluorosilicone sealant is described. New elastomer sealant development at the Ames Research Center is detailed, and comparisons of high- and low-temperature characteristics are made to baseline fluorosilicone sealants.

Atmospheric Turbulence

248. Ehernberger, L. J.; and Love, Betty J.: High Altitude Gust Acceleration Environment as Experienced by a Supersonic Airplane. NASA TN D-7868, 1975.

High altitude turbulence experienced at supersonic speeds is de... terms of gust accelerations measured on the YF-12A airplane. The d... obtained during 90 flights at altitudes above 12.2 km. The air cre... given gust accelerations as being more intense during high altitude s... flight than during low altitude subsonic flight.

The median thickness of high altitude turbulence patches was less than 400 m; the median length was less than 16 km. The distribution of the patch dimensions tended to be log normal.

249. Larson, Terry J.; and Ehernberger, L. J.: Techniques Used for Determination of Static Source Position Error of a High Altitude Supersonic Airplane. NASA TM X-3152, 1975.

Variations of a radar tracking method for the precise determination of aircraft static source position error during accelerating or decelerating flight are described and evaluated. Data from supersonic flights of a YF-12 airplane are presented to illustrate the technique. A combination of level and ascending or descending flight runs proved to be an efficient way to obtain aircraft position error.

250. Sidwell, Kenneth: A Mathematical Examination of the Press Model for Atmospheric Turbulence. NASA TN D-8038, 1975.

The random process used to model atmospheric turbulence in aircraft response problems is examined. The Press model accounts for both the Gaussian and nonGaussian forms of measured turbulence data. The effects of the distribution of the intensity process upon calculated exceedances are examined. It is concluded that the Press model with a Gaussian intensity distribution gives a conservative prediction of limit load values.

251. Keisler, Samuel R.; and Rhyne, Richard H.: An Assessment of Prewhitening in Estimating Power Spectra of Atmospheric Turbulence at Long Wavelengths. NASA TN D-8288, 1976.

Synthetic time histories were generated and used to assess the effects of prewhitening on the long wavelength portion of power spectra of atmospheric turbulence. Prewhitening is not recommended when using the narrow "spectral windows" required for determining power spectral estimates below the "knee" frequency (that is, at very long wavelengths).

252. Meissner, Charles W., Jr.: A Flight Instrumentation System for Acquisition of Atmospheric Turbulence Data. NASA TN D-8314, 1976.

A flight instrumentation system for the acquisition of atmospheric turbulence data is described. Airflow direction transducers and an impact-pressure transducer are the primary instruments for measuring vertical and lateral gust velocity, and a sensitive incremental pressure transducer is used to measure longitudinal gust velocity. Salient engineering features of the instrumentation are discussed, and a complete description of the instrumentation is presented.

253. Rhyne, Richard H.: Flight Assessment of an Atmospheric Turbulence Measurement System With Emphasis on Long Wavelengths. NASA TN D-8315, 1976.

A flight assessment has bee made of a system that measures the three components of atmospheric turbulence in the frequency range associated with airplane motions (0 to approximately 0.5 Hz). Results of the assessment indicate acceptable accuracy of the resulting time histories and power spectra. Small residual errors at the airplane short period and Dutch roll frequencies would not be detectable on the power spectra. However, errors at approximately 0.25 Hz can be present in the time history of the lateral turbulence component. An assessment of the quantities comprising the vertical turbulence component leads to the conclusion that the vertical component is essentially accurate to zero frequency.

254. Rhyne, Richard H.; Murrow, Harold N.; and Sidwell, Kenneth: Atmospheric Turbulence Power Spectral Measurements to Long Wavelengths for Several Meteorological Conditions. Aircraft Safety and Operating Problems, NASA SP-416, 1976, pp. 271-286.

Use of power spectral design techniques for supersonic transports requires accurate definition of atmospheric turbulence in the long wavelength region below the "knee" of the power spectral density function curve. Examples are given of data obtained from a current turbulence flight sampling program. These samples are categorized as (1) convective, (2) wind shear, (3) rotor, and (4) mountain-wave turbulence. Time histories, altitudes, root-mean-square values, statistical degrees of freedom, power spectra, and integral scale values are shown and discussed.

255. Sidwell, Kenneth: A Method for the Analysis of Nonlinearities in Aircraft Dynamic Response to Atmospheric Turbulence. NASA TN D-8265, 1976.

An analytical method is developed which combines the equivalent linearization technique for the analysis of the response of nonlinear dynamic systems with the amplitude modulated random process (Press model) for atmospheric turbulence. The method is initially applied to a bilinear spring system. The analysis of the response shows good agreement with exact results obtained by the Fokker-Planck equation. The method is then applied to an example of control-surface-displacement limiting in an aircraft with a pitch-hold autopilot.

NASA Contractor Reports

Structural Concept Studies

256. LTV Hampton Technical Center: Computer Aided Structural Methods With Application to a Supersonic Arrow-Wing Configuration. NASA CR-132551, 1974.

257. Tinoco, E. N.; and Mercer, J. E.: FLEXSTAB - A Summary of the Functions and Capabilities of the NASA Flexible Airplane Analysis Computer System. NASA CR-2564, 1975.

A brief description is provided by the Boeing Commerical Airplane Company of NASA's aeroelastic stability and control computer program, FLEXSTAB. Information is provided to aid potential users in evaluating possible use of FLEXSTAB. A summary of the program's capabilities, the scope and limitations of its formulation, and a description of its documentation is provided. Computer program hardware and software requirements and recent user experience are also discussed.

258. Preliminary Design Dep., Boeing Commercial Airplane Co.: Study of Structural Design Concepts for an Arrow Wing Supersonic Transport Configuration - Volume 1. NASA CR-132576-1, 1976.

259. Preliminary Design Dep., Boeing Commercial Airplane Co.: Study of Structural Design Concepts for an Arrow Wing Supersonic Transport Configuration - Volume 2. NASA CR-132576-2, 1976.

260. Sakata, I. F.; and Davis, G. W.: Arrow-Wing Supersonic Cruise Aircraft Structural Design Concepts Evaluation. Volume 1. NASA CR-132575-1, [1976].

261. Sakata, I. F.; and Davis, G. W.: Arrow-Wing Supersonic Cruise Aircraft Structural Design Concepts Evaluation. Volume 2. NASA CR-132575-2, [1976].

262. Sakata, I. F.; and Davis, G. W.: Arrow-Wing Supersonic Cruise Aircraft Structural Design Concepts Evaluation. Volume 3. NASA CR-132575-3, [1976].

263. Sakata, I. F.; and Davis, G. W.: Arrow-Wing Supersonic Cruise Aircraft Structural Design Concepts Evaluation. Volume 4. NASA CR-132575-4, [1976].

264. Sakata, I. F.; and Davis, G. W.: Evaluation of Structural Design Concepts for an Arrow-Wing Supersonic Cruise Aircraft. NASA CR-2667, 1977.

An analytical study was performed by Lockheed-California Company to determine the best structural approach for design of primary wing and fuselage structure of a Mach 2.7 arrow wing supersonic cruise aircraft. Emphasis was placed on the complex interactions between thermal stress, static aeroelasticity, flutter, fatigue and fail-safe design, static and dynamic loads, and the effects of variations in structural arrangements. A hybrid wing structure incorporating

low-profile convex beaded and honeycomb sandwich surface panels of titanium alloy 6Al-4V were the most efficient. The fuselage shell consists of hat-stiffened skin and frame construction of titanium alloy 6Al-4V.

Structure Technology

265. Morino, Luigi: A General Theory of Unsteady Compressible Potential Aerodynamics. NASA CR-2464, 1974.

The general theory of potential aerodynamic flow around a lifting body having arbitrary shape and motion is presented by Boston University. By using the Green function method, an integral representation for the potential is obtained for both supersonic and subsonic flow. For the important practical case of small harmonic oscillation around a rest position, the equation reduces to a two-dimensional Fredholm integral equation of second type. It is shown that this equation reduces properly to the lifting surface theories as well as other classical mathematical formulae.

266. Ruo, S. Y.: Calculation of Unsteady Transonic Aerodynamics for Oscillating Wings With Thickness (Computer Program). NASA CR-132477, 1974.

267. Dick, J. W.; and Benda, B. J.: Addition of Flexible Body Option to the TOLA Computer Program. Part I - Final Report. NASA CR-132732-1, 1975.

268. Dick, J. W.; and Benda, B. J.: Addition of Flexible Body Option to the TOLA Computer Program. Part II - User and Programmer Documentation. NASA CR-132732-2, 1975.

269. Goree, James G.: Crack Growth in Bonded Elastic Half Planes - Final Report. NASA Grant NSG-1104, Dep. Mech. Eng., Clemson Univ., Dec. 31, 1975. (Available as NASA CR-145905.)

270. Kuo, Ching-Chiang; and Morino, Luigi: Steady Subsonic Flow Around Finite-Thickness Wings. NASA CR-2616, 1975.

The general method for analyzing steady subsonic potential aerodynamic flow around a lifting body having arbitrary shape is presented by Boston University. Comparison with existing results shows that the proposed method is at least as fast and accurate as the lifting surface theories.

271. O'Connell, R. F.; Hassig, H. J.; and Radovcich, N. A.: Study of Flutter Related Computational Procedures for Minimum Weight Structural Sizing of Advanced Aircraft - Supplemental Data. NASA CR-132722, 1975.

272. Ruo, S. Y.; and Theisen, J. G.: Calculation of Unsteady Transonic Aerodynamics for Oscillating Wings With Thickness. NASA CR-2259, 1975.

An analytical approach is presented by the Lockheed-Georgia Company to account for some of the nonlinear characteristics of the transonic flow equation for finite thickness wings undergoing harmonic oscillation at sonic flight speed in an inviscid, shock-free fluid. The thickness effect is accounted for in the analysis through use of the steady local Mach number distribution over the wing at its mean position by employing the local linearization concept and a coordinate transport. Computed results are compared with experiment.

273. Weatherill, Warren H.; Ehlers, F. Edward; and Sebastian, James D.: Computation of the Transonic Perturbation Flow Fields Around Two- and Three-Dimensional Oscillating Wings. NASA CR-2599, 1975.

Analytical and empirical studies of a finite difference method for the solution of the transonic flow about an harmonically oscillating wing are presented by the Boeing Commercial Airplane Company, along with a discussion of the development of a pilot program for three-dimensional flow. In addition, some two- and three-dimensional examples are presented.

274. Chu, C. S.; Anderson, J. M.; Batdorf, W. J.; and Aberson, J. A.: Finite Element Computer Program To Analyze Cracked Orthotropic Sheets. NASA CR-2698, 1976.

A two-dimensional orthotropic sheet with through-the-thickness cracks and temperature gradient was analyzed by the Lockheed-Georgia Company. The program includes special crack-tip elements that account for singular stress fields associated with crack opening and crack sliding displacements at the crack tip. The program also includes a linear spring element and a constant-strain, triangular element. A number of problems for which closed-form solutions exist were analyzed to demonstrate the capabilities of the program.

275. O'Connell, R. F.; Hassig, H. J.; and Radovcich, N. A.: Study of Flutter Related Computational Procedures for Minimum Weight Structural Sizing of Advanced Aircraft. NASA CR-2607, 1976.

Results of a study of the development of flutter modules applicable to automated structural design of advanced aircraft configurations such as a supersonic transport are presented by the Lockheed-California Company. Automated structural design is restricted to automated sizing of the elements of a given structural model. Methods of solving the flutter equation and computing the generalized aerodynamic force coefficients in the repetitive analysis environment of a flutter optimization procedure are studied. Results of numerical evaluations, applying the five methods of flutter optimization to the same design task, are presented.

Materials Application

276. Boeing Aerospace Co.: Cyclic-Stress Analysis of Notches for Supersonic Transport Conditions. NASA CR-132387, 1974.

277. Ochieano, Mario L.; and Kaneko, Russell S.: Survey of Titanium Structural Shape Fabrication Concepts - Final Report. NASA CR-132384, 1974.

278. Elliott, S. Y.: Boron-Aluminum Skins for the DC-10 Aft Pylon - Final Report. NASA CR-132645, 1975.

279. Webb, B. A.; and Dolowy, J. F., Jr.: Brazed Bonding of Borsic/Aluminum Composite Sheet to Titanium. NASA CR-133730, 1975.

280. Fahmy, Abdel A.; and Cunningham, Thomas G.: Investigation of Thermal Fatigue in Fiber Composite Materials. NASA CR-2641, 1976.

Graphite-epoxy laminates were thermally cycled by North Carolina State University to determine the effects of thermal cycles on tensile properties and thermal expansion coefficients of the laminates. Three 12-ply laminate configurations were subjected to up to 5000 thermal cycles. The materials' tensile strength, moduli, and thermal expansion coefficients were significantly lower than for the materials as fabricated. Most of the degradation of properties occurred after only a few cycles. The property degradation was attributed primarily to the progressive development of matrix cracks whose locations depended upon the layup orientation of the laminate.

281. Watanabe, R. T.: Acceleration of Fatigue Tests for Built-up Titanium Components. NASA CR-2658, 1976.

A study was made by the Boeing Commercial Airplane Company of the feasibility of a room-temperature scheme of accelerating fatigue tests for Mach 3 advanced supersonic transport aircraft. The test scheme used equivalent room-temperature cycles calculated for supersonic flight conditions. Verification tests were conducted by using specimens representing titanium wing lower surface structure. The fatigue behavior of the specimens generally correlated well with the proposed correction method.

282. Payne, L.: Fabrication and Evaluation of Advanced Titanium Structural Panels for Supersonic Cruise Aircraft. NASA CR-2744, 1977.

Flightworthy primary structural panels were designed, fabricated, and tested by the Lockheed-California Company to investigate two advanced fabrication methods for titanium alloys. Skin-stringer panels fabricated by using the weld-braze process, and honeycomb-core sandwich panels fabricated by using a Rohr Industries, Inc. diffusion bonding process, were designed to replace an existing integrally stiffened shear panel on the upper wing surface of the NASA YF-12 research aircraft. The investigation included ground testing and Mach 3 flight testing of full-scale panels and laboratory testing of representative structural element specimens.

283. Waterman, A. W.: Testing of Polyimide Second-Stage Rod Seals for Single-Stage Applications in Advanced Aircraft Hydraulic Systems. NASA CR-135191, 1977.

Atmospheric Turbulence

284. Scoggins, James R.; Clark, Terry L.; and Possiel, Norman C.: Relationships Between Stratospheric Clear Air Turbulence and Synoptic Meteorological Parameters Over the Western United States Between 12-20 km Altitude. NASA CR-143837, 1975.

285. Mark, William D.; and Fischer, Raymond W.: Investigation of the Effects of Nonhomogeneous (or Nonstationary) Behavior on the Spectra of Atmospheric Turbulence. NASA CR-2745, 1976.

A new series expansion of the instantaneous power spectrum is used by Bolt Beranek and Newman, Inc. that has for its first term the usual quasi-stationary spectrum approximation. The minimum duration of a burst of turbulence and the minimum rise time of an abrupt onset of turbulence that will not give rise to changes in the spectrum due to the nonstationary behavior are determined. A general criterion for envelope behavior that will not give rise to changes in the spectrum is also determined. Spectra computed from recorded turbulence time histories are shown to be consistent with the theoretical predictions.

Articles, Meetings, and Company Reports

Structure Concepts Studies

286. Robinson, James C.; Yates, E. Carson, Jr.; Turner, M. Jonathan; and Grande, Donald L.: Application of an Advanced Computerized Structural Design System to an Arrow-Wing Supersonic Cruise Aircraft. AIAA Paper No. 75-1038, Aug. 1975.

287. Sakata, I. F.; Davis, G. W.; Robinson, J. C.; and Yates, E. C., Jr.: Design Study of Structural Concepts for an Arrow-Wing Supersonic Cruise Aircraft. AIAA Paper No. 75-1037, Aug. 1975.

Structure Technology

288. Morino, Luigi: Unsteady Compressible Potential Flow Around Lifting Bodies: General Theory. AIAA Paper No. 73-196, Jan. 1973.

289. Morino, Luigi; and Kuo, Ching-Chiang: Unsteady Subsonic Compressible Flow Around Finite Thickness Wings. AIAA Paper No. 73-313, Mar. 1973.

290. Chen, Lee-Tzong; Suciu, Emil O.; and Morino, Luigi: A Finite Element Method for Potential Aerodynamics Around Complex Configurations. AIAA Paper No. 74-107, Jan.-Feb. 1974.

291. Haftka, Raphael T.; Starnes, James H., Jr.; and Barton, Furman W.: A Comparison of Two Types of Structural Optimization Procedures for Satisfying Flutter Requirements. AIAA Paper No. 74-405, Apr. 1974.

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AERODYNAMIC PERFORMANCE

NASA Inhouse Reports

Aerodynamics

338. Medan, Richard T.: Geometry Program for Aerodynamic Lifting Surface Theory. NASA TM X-62,309, 1973.

A computer program that provides the geometry and boundary conditions appropriate for an analysis of a lifting, thin wing with control surfaces in linearized, subsonic, steady flow is presented. The kernel function method lifting surface theory is applied. The data which are generated by the program are stored on disc files or tapes for later use by programs which calculate an influence matrix, plot the wing planform, and evaluate the loads on the wing.

339. Medan, Richard T.: Steady, Subsonic, Lifting Surface Theory for Wings With Swept, Partial Span, Trailing Edge Control Surfaces. NASA TN D-7251, 1973.

A method for computing the lifting pressure distribution on a wing with partial span, swept control surfaces is presented. This method is valid within the framework of linearized, steady, potential flow theory. This technique is valid for both the flap pressure mode and regular pressure modes and could be used to improve existing lifting surface methods. It is concluded that the method can lead to an efficient and accurate solution of the mathematical problem when a partial span, trailing-edge flap is involved.

340. Medan, Richard T.; and Ray, K. Susan: Boundary Condition Program for Aerodynamic Lifting Surface Theory. NASA TM X-62,323, 1973.

Users' manual is described for a USA FORTRAN IV computer program which determines boundary conditions for a thin wing lifting surface program. This program, the geometry program, and several other programs are used together in the analysis of lifting, thin wings in steady, subsonic flow according to a kernel function lifting surface theory. The program calculates specific types of boundary conditions automatically such as those necessary to determine pitch and roll damping derivatives. The program also accepts descriptions of the camber or downwash and twist in the form of tables and/or coefficients of equations.

341. Medan, Richard T.; and Ray, K. Susan: Influence Matrix Program for Aerodynamic Lifting Surface Theory. NASA TM X-62,324, 1973.

A description and users' manual are presented for a USA FORTRAN IV computer program which computes an aerodynamic influence matrix and is one of several computer programs used to analyze lifting, thin wings in steady, subsonic flow according to a kernel function method lifting surface theory. The most significant features of the program are that it can treat unsymmetrical wings, control points can be placed on the leading and/or trailing edges, and a stable, efficient algorithm is used to compute the influence matrix.

342. Medan, Richard T.; and Ray, K. Susan: Plotting Program for Aerodynamic Lifting Surface Theory. NASA TM X-62,321, 1973.

Description and a users' manual are presented for a USA FORTRAN IV computer program which plots the planform and control points of a wing. The program also plots some of the configuration data such as the aspect ratio. The planform data are stored on a disc file which is created by a geometry program. This program, the geometry program, and several other programs are used together in the analysis of lifting, thin wings in steady, subsonic flow according to a kernel function lifting surface theory

343. NASA YF-12 Flight Loads Program. NASA TM X-3061, 1974.

The YF-12 research program in aerodynamic loads concentrated on both the measurement of flight loads and the evaluation of state-of-the-art loads prediction techniques. Experimental data were acquired from flight tests, wind-tunnel model tests, and static thermal tests of the airplane, and aerodynamic and structural analyses were made for correlation with the experimental results. The experimental data also form a reference source for the verification of other methods of aeroelastic and structural analysis.

This volume includes papers that describe the tests performed and appendixes that contain measured deflection, temperature, strain, and airloads from laboratory and flight tests of the airplane. It also includes aerodynamic and structural descriptions of the airplane to permit the reader to make analyses using his own methods. A supplement on microfilm and microfiche contains wind-tunnel pressure survey data, results from NASTRAN and FLEXSTAB computer analyses, and the structural section properties necessary to set up a structural analysis model. Such extensive documentation is unusual, but it was felt that the unique and comprehensive nature of the project warranted the effort necessary to make the data available.

344. Medan, Richard T.: Improvements to the Kernel Function Method of Steady, Subsonic Lifting Surface Theory. NASA TM X-62,327, 1974.

The application of a kernel function lifting surface method to three-dimensional, thin wing theory is discussed. A technique for determining the influence functions is presented. The report introduces and employs an aspect of the kernel function method which apparently has never been used before and which significantly enhances the efficiency of the kernel function approach.

345. Medan, Richard T.; and Lemmer, Opal J.: Equation Solving Program for Aerodynamic Lifting Surface Theory. NASA TM X-62,325, 1974.

A description and users' manual are presented for one of a group of FORTRAN programs, which, together, can be used for the analysis and design of wings in steady, subsonic flow according to a kernel function method lifting surface theory. This program has the capability of striking out rows and columns of the aerodynamic influence matrix and rows of the associated boundary condition vectors (right-hand sides). This capability significantly enhances the effectiveness of the kernel function method of lifting surface theory because the number of control points can be done with the calculation of only a single influence matrix.

346. Medan, Richard T.; and Ray, K. Susan: Normal Loads Program for Aerodynamic Lifting Surface Theory. NASA TM X-62,326, 1974.

A description and users' manual are presented for a USA FORTRAN IV computer program which evaluates spanwise and chordwise loading distributions, lift coefficient, pitching-moment coefficient, and other stability derivatives for thin wings in linearized, steady, subsonic flow. The program is based on a kernel function method lifting surface theory and is applicable to a large class of planforms including asymmetrical ones and ones with mixed, straight, and curved edges.

347. Ehlers, F. Edward; Johnson, Forrester T.; and Rubbert, Paul E.: Advanced Panel-Type Influence Coefficient Methods Applied to Subsonic and Supersonic Flows. Aerodynamic Analyses Requiring Advanced Computers - Part II, NASA SP-347, 1975, pp. 939-984.

Advanced techniques are presented for solving the linear integral equations of subsonic and supersonic potential flow in three dimensions. Both analysis (Neumann) and design (Dirichlet) boundary conditions are treated. Influence coefficient methods are used that encompass both source and doublet panels as boundary surfaces. The methods employ curved panels possessing singularity strengths which vary as polynomials. These and other features were selected to produce a stable, reliable, accurate, and economical scheme that overcomes many problems experienced with earlier methods.

348. Manro, Marjorie E.; Tinoco, Edward N.; Bobbitt, Percy J.; and Rogers, John T.: Comparisons of Theoretical and Experimental Pressure Distributions on an Arrow-Wing Configuration at Transonic Speeds. Aerodynamic Analyses Requiring Advanced Computers - Part II, NASA SP-347, 1975, pp. 1141-1188.

A wind-tunnel test of an arrow-wing—body configuration employing both a twisted and a flat wing, as well as a variety of leading- and trailing-edge flap deflections, has been conducted to provide an experimental data base for comparison with theoretical methods. The purpose of these comparisons was to delineate conditions under which the theoretical predictions are valid for aeroelastic calculations and to explore the use of empirical methods to correct the theoretical methods where theory is deficient.

349. Miller, David S.; and Middleton, Wilbur D.: An Integrated System for the Aerodynamic Design and Analysis of Supersonic Aircraft. Aerodynamic Analyses Requiring Advanced Computers - Part II, NASA SP-347, 1975, pp. 1049-1055.

An integrated system of computer programs for the aerodynamic design and analysis of complete supersonic aircraft has been developed as a result of research efforts conducted over a period of years at Langley Research Center and a recent Langley contract with The Boeing Company. The goals of the system have been to develop an easily used supersonic design and analysis capability with recognition of the need for constraints on linear theory to provide physical realism and with inclusion of interactive graphics capability for increased control over the design and analysis iteration cycles.

350. Morino, Luigi; and Chen, Lee-Tzong: Indicial Compressible Potential Aerodynamics Around Complex Aircraft Configurations. Aerodynamic Analyses Requiring Advanced Computers - Part II, NASA SP-347, 1975, pp. 1067-1110.

A general theory for indicial potential compressible aerodynamics around complex configurations is presented. The motion is assumed to consist of constant subsonic or supersonic speed for time $t \leq 0$ (steady state) and of small perturbations around the steady state for time $t > 0$. The theory is embedded in a computer code, SUSSA ACTS, which is briefly described. Numerical results are presented for steady and unsteady, subsonic and supersonic, flows and indicate that the code is not only general, flexible, and simple to use, but also accurate and fast.

351. Weber, James A.; Brune, Guenter W.; Johnson, Forrester T.; Lu, Paul; and Rubbert, Paul E.: A Three-Dimensional Solution of Flows Over Wings With Leading Edge Vortex Separation. Aerodynamic Analyses Requiring Advanced Computers - Part II, NASA SP-347, 1975, pp. 1013-1032.

The application of a new, general, potential flow computational technique to the solution of the subsonic, three-dimensional flow over wings with leading-edge vortex separation is presented. The present method is capable of predicting forces, moments, and detailed surface pressures on thin, sharp-edged wings of rather arbitrary planform. The wing geometry is arbitrary in the sense that leading and trailing edges may be curved or kinked and may have arbitrary camber and twist distributions. The method is verified by numerous computed results.

352. Coe, Paul L., Jr.; and Fournier, Paul G.: Application of Powered-Lift Concepts for Improved Cruise Efficiency of Long-Range Aircraft. Powered-Lift Aerodynamics and Acoustics, NASA SP-406, 1976, pp. 89-101.

The present paper summarizes results of recent studies conducted at the NASA Langley Research Center to explore the use of powered-lift concepts for improved low-speed performance of long-range subsonic and supersonic cruise vehicles. The results indicate that powered lift can provide significant improvements in low-speed performance, as well as substantial increases in cruise efficiency and range for both subsonic and supersonic cruise configurations.

353. Coe, Paul L., Jr.; McLemore, H. Clyde, and Shivers, James P.: Effects of Upper-Surface Blowing and Thrust Vectoring on Low-Speed Aerodynamic Characteristics of a Large-Scale Supersonic Transport Model. NASA TN D-8296, 1976.

Tests were conducted in the Langley full-scale tunnel to determine the low-speed aerodynamic characteristics of a large-scale arrow wing supersonic transport configured with engines mounted above the wing for upper-surface blowing, and conventional lower-surface engines with provisions for thrust vectoring. A limited number of tests were conducted for the upper-surface engine configuration in the high-lift condition for a sideslip angle of 10° in order to evaluate lateral-directional characteristics, and with the right engine inoperative to evaluate the engine-out condition.

354. Davis, J. E.; Bonnett, W. S.; and Medan, R. T.: NASA Ames Three-Dimensional Potential Flow Analysis System (POTFAN) Equation Solver Code (SOLN) Version 1. NASA TM X-73,074, 1976.

A computer program known as SOLN was developed as an independent segment of the NASA Ames Three-Dimensional Potential Flow Analysis Systems of linear algebraic equations. Methods used include: LU decomposition, Householder's method, a partitioning scheme, and a block successive relaxation method. Due to the independent modular nature of the program, it may be used by itself and not necessarily in conjunction with other segments of the POTFAN system.

355. Mascitti, Vincent R.: Aerodynamic Performance Studies for Supersonic Cruise Aircraft. NASA TM X-73915, 1976.

Technical progress made in each of the disciplinary research areas affecting the design of supersonic cruise aircraft is discussed. The NASA SCAR program has supported an expanded research program in aerodynamics including an evergrowing experimental data base, methodology development across the Mach number range, and sonic boom. Progress in the aerodynamics area could facilitate the choice of the highly swept subsonic leading-edge arrow wing known for superior supersonic cruise efficiency.

356. Medan, R. T.; and Bullock, R. B.: NASA Ames Potential Flow Analysis (POTFAN) and Geometry Program (POTGEM) - Version 1. NASA TM X-73127, 1976.

A computer program known as POTGEM is reported which has been developed as an independent segment of a Three-Dimensional Linearized, Potential Flow Analysis System and which is used to generate a panel point description of arbitrary, three-dimensional bodies from convenient engineering descriptions consisting of equations and/or tables. Due to the independent, modular nature of the program, it may be used to generate corner points for other computer programs.

357. Parlett, Lysle P.; and Shivers, James P.: Low-Speed Wind-Tunnel Tests of a Large-Scale Blended-Arrow Advanced Supersonic Transport Model Having Variable-Cycle Engines and Vectoring Exhaust Nozzles. NASA TM X-72809, 1976.

Variables tested include (1) engine mode (cruise or low-speed), (2) engine exit nozzle deflection, (3) leading-edge flap geometry, and (4) trailing-edge flap deflection. Test variables included values of gross thrust coefficient from 0 to 0.38, values of angle of attack from -10° to 30°, values of angle of sideslip from -5° to 5°, and values of Reynolds number from 3.5×10^{6} to 6.8×10^{6}.

358. Shivers, James P.; McLemore, H. Clyde; and Coe, Paul L., Jr.: Low-Speed Wind-Tunnel Investigation of a Large-Scale Advanced Arrow-Wing Supersonic Transport Configuration With Engines Mounted Above Wing for Upper-Surface Blowing. NASA TN D-8350, 1976.

Tests were conducted in the Langley full-scale tunnel to determine the low-speed aerodynamic characteristics of a large-scale advanced arrow wing supersonic transport configuration with engines mounted above the wing for upper-surface blowing. Configuration variables included trailing-edge flap deflection, engine jet-nozzle angle, engine thrust coefficient, engine-out operation, and asymmetrical trailing-edge boundary-layer control for providing roll trim. Downwash measurements at the tail were obtained for different thrust coefficients, tail heights, and at two fuselage stations.

359. Bobbitt, Percy J.; and Manro, Marjorie E.: Theoretical and Experimental Pressure Distributions for a 71.2° Swept Arrow-Wing Configuration at Subsonic, Transonic, and Supersonic Speeds. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 85-122.

A wind-tunnel test of an arrow wing body configuration consisting of flat and twisted wings, as well as a variety of leading- and trailing-edge control-surface deflections, has been conducted at Mach numbers from 0.40 to 2.50 to provide an experimental data base for comparison with theoretical methods. Theory-to-experiment comparisons of detailed pressure distributions have been made by using current state-of-the-art and newly developed attached- and separated-flow methods. Current state-of-the-art linear and nonlinear attached-flow methods were adequate only at small angle-of-attack cruise conditions. Of the several "separated-vortex" methods evaluated, only the one utilizing a combination of linear source and quadratically varying doublet panels showed promise of yielding accurate load distributions at moderate to large angles of attack.

360. Coe, Paul L., Jr.; and Graham, A. B.: Results of Recent NASA Research on Low-Speed Aerodynamic Characteristics of Supersonic Cruise Aircraft. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 123-136.

The present paper summarizes the results of recent NASA research on the low-speed aerodynamic characteristics of supersonic cruise aircraft. Although acceptable low-speed performance is obtainable for the configurations currently under study, the low-speed deficiencies dictate a design compromise which prohibits such configurations from achieving maximum range potential. However, through the use of more efficient high-lift systems and the application of propulsive-lift concepts, it is possible to optimize the entire airframe design for maximum range potential and also to provide good low-speed performance. The results also indicate that nose strakes provide significant improvements in directional stability.

361. Erickson, Larry L.; Johnson, Forrester T.; and Ehlers, F. Edward: Advanced Surface Paneling Method for Subsonic and Supersonic Flow. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 25-54.

Numerical results illustrating the capabilities of an advanced aerodynamic surface paneling method are presented. The method is applicable to both subsonic and supersonic flow, as represented by linearized potential flow theory. The method is based on linearly varying sources and quadratically varying doublets which are distributed over flat or curved panels. These panels can be applied to the true surface geometry of arbitrarily shaped three-dimensional aerodynamic configurations. The method offers the user a variety of modeling options and is both stable and accurate, the numerical results displaying a marked insensitivity to panel arrangement.

362. Gloss, Blair B.; and Johnson, Forrester T.: Development of an Aerodynamic Theory Capable of Predicting Surface Loads on Slender Wings With Vortex Flow. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 55-67.

With the advent of supersonic cruise aircraft that utilize vortex lift at some point in their flight envelope, the need for an analytical method capable of accurately predicting loads on wings with leading-edge separation has become evident. The Boeing Commercial Airplane Company, under contract to NASA Langley Research Center, has developed an inviscid three-dimensional lifting surface method that shows promise in being able to accurately predict loads, subsonic and supersonic, on wings with leading-edge separation and reattachment.

363. Heyson, Harry H.; Riebe, Gregory D.; and Fulton, Cynthia L.: Theoretical Parametric Study of the Relative Advantages of Winglets and Wing-Tip Extensions. NASA TM X-74003, 1977.

This study provides confirmation, for a wide range of wings, of the recommendations of Whitcomb in NASA TN D-8260. For identical increases in bending moment, a winglet provides a greater gain in induced efficiency than tip extension. Winglet tow angle allows design trades between efficiency and root moment. Both induced efficiency and bending moment increase with winglet length and outward cant. Root bending moment is proportional to the minimum weight of bending material required in the wing; thus, it is a valid index of the impact of tip modifications on a new wing design.

364. Mercer, Charles E.; and Carson, George T., Jr.: Upper Surface Nacelle Influence on SCAR Aerodynamic Characteristics at Transonic Speeds. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 137-154.

An investigation has been conducted in the Langley 16-foot transonic tunnel to determine the influence of upper-surface nacelles on the aerodynamic characteristics of a SCAR configuration at Mach numbers from 0.6 to 1.2. Tests were made with various nacelle chordwise, spanwise, and vertical height locations over the Mach number, angle-of-attack, and jet total-pressure ratio ranges. The results show that deflecting the wing-tip leading-edge flap from 0° to -10° increased the maximum lift-drag ratio by 1.0 at subsonic speeds. Installation of upper-surface nacelles (no wing/nacelle pylons) increased the wing-body pitching moment at all Mach numbers and decreased the drag of the wing-body configuration at subsonic Mach numbers.

365. Miller, Davis S.; Carlson, Harry W.; and Middleton, Wilbur D.: A Linearized Theory Method of Constrained Optimization for Supersonic Cruise Wing Design. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 9-24.

A linearized theory wing design and optimization procedure which allows physical realism and practical considerations to be imposed as constraints on the optimum (least drag due to lift) solution is discussed and examples of application are presented. In addition to the usual constraints on lift and pitching moment, constraints can also be imposed on wing surface ordinates and wing upper surface pressure levels and gradients. The design procedure also provides the capability of including directly in the optimization process the effects of other aircraft components such as a fuselage, canards, and nacelles.

366. Roensch, Robert L.: Aerodynamic Validation of a SCAR Design. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 155-168.

The results of a wind-tunnel test of a model of the McDonnell Douglas supersonic cruise aircraft justify the design procedures used to develop the configuration. The data obtained with a baseline fuselage model and an improved performance wing support the analysis and design methods. The minimum drag is almost exactly as predicted. Despite small discrepancies in the predicted level of drag due to lift, the increments between configurations are as predicted and can be used to identify further improvements in performance. The results also verified the aerodynamic efficiency of the configuration with a demonstrated maximum lift-drag ratio of 9.1.

367. Townsend, James C.: The Role of Finite-Difference Methods in Design and Analysis for Supersonic Cruise. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 69-84.

Finite-difference methods for analysis of steady, inviscid supersonic flows are described, and their present state of development is assessed with particular attention to their applicability to vehicles designed for efficient cruise flight. As an illustration, calculations of the supersonic flows over delta wings are compared with experimental pressure distributions. The overall agreement with experiment is very good, even well beyond the angles of attack where linearized theory methods are applicable. Current work is described which will allow greater geometric latitude, impove treatment of embedded shock waves and relax the requirement that the axial velocity must be supersonic.

Noise

368. Carlson, Harry W.; Barger, Raymond L.; and Mack, Robert J.: Application of Sonic-Boom Minimization Concepts in Supersonic Transport Design. NASA TN D-7218, 1973.

The applicability of sonic boom minimization concepts in the design of large supersonic transport airplanes capable of a range of 2500 n.mi. at a cruise Mach number of 2.7 is considered. Aerodynamics, weight and balance, and mission performance, as well as sonic boom factors, have been taken into account. Further study of qualified airplane design teams is required to ascertain sonic boom shock-strength levels actually attainable for practical supersonic transports.

369. Lung, J. L.; Tiegerman, B.; Yu, N. J.; and Seebass, A. R.: Advances in Sonic Boom Theory. Aerodynamic Analyses Requiring Advanced Computers - Part II, NASA SP-347, 1975, pp. 1033-1047.

This paper discusses recent advances in three aspects of sonic boom theory and briefly addresses the role of numerical calculations in each. First, the maximum extent to which the sonic boom of supersonic aircraft can be reduced by careful aerodynamic design is discussed, and a computer program is described that determines the aircraft area development required to minimize various sonic boom signature parameters. Next, a result that predicts the minimum sonic boom of hypersonic vehicles is described. Finally, a report is given on numerical results that advance our understanding of the behavior of sonic boom signals in the vicinity of a caustic surface. The numerical procedures developed for the latter problem have proved effective in calculating transonic flows with embedded shock waves.

370. Davis, J. E.; and Medan, R. T.: NASA Ames Three-Dimensional Potential Flow Analysis System (POTFAN) Boundary Condition Code (BCDN) Version 1. NASA TM X-73,187, 1976.

This document describes a computer program known as BCDN which has been developed as an independent segment of the NASA Ames Three-Dimensional Potential Flow Analysis System (POTFAN). This segment of the POTFAN system is used to generate right-hand sides (boundary conditions) of the system of equations associated with the flow field under consideration. These specified flow boundary conditions are encountered in the oblique derivative boundary value problem (boundary value problem of the third kind) and contain Neumann boundary condition as a special case. Arbitrary angle-of-attack and/or sideslip and/or rotation rates may be specified, as well as arbitrary, nonuniform external flow field and the influence of prescribed singularity distributions.

NASA Contractor Reports

Aerodynamics

371. Rubbert, Paul E.: Sideslip of Wing-Body Combinations. NASA CR-114716, 1972.

372. Mercer, J. E.; Weber, J. A.; and Lesferd, E. P.: Aerodynamic Influence Coefficient Method Using Singularity Splines. NASA CR-2423, 1974.

A numerical lifting surface formulation, including computed results for planar wing cases is presented by The Boeing Company. This formulation, referred to as the "vortex spline" scheme, combines the adaptability to complex shapes offered by paneling loading function methods. The current formulation uses the elementary horseshoe vortex as the basic singularity and is therefore restricted to linearized potential flow. Also, a second-order sideslip analysis based on an asymptotic expansion was investigated by using the singularity spline formulation.

373. Radkey, R. L.: An Analysis of the Impact of Cabin Floor Angle Restrictions on L/D for a Typical Supersonic Transport. NASA CR-132508, 1974.

374. Brune, Guenter W.; Weber, James A.; Johnson, Forrester T.; Lu, Paul; and Rubbert, Paul E.: A Three-Dimensional Solution of Flows Over Wings With Leading-Edge Vortex Separation. Part I - Engineering Document. NASA CR-132709, 1975.

375. Fromme, J. A.; and Halstead, D. W.: Solutions to Küssner's Integral Equation in Unsteady Flow Using Local Basis Functions. NASA CR-137719, 1975.

376. Middleton, W. D.; and Lundry, J. L.: Aerodynamic Design and Analysis System for Supersonic Aircraft. Part 1 - General Description and Theoretical Development. NASA CR-2520, 1975.

An integrated system of computer programs has been developed by the Boeing Commercial Airplane Company for the design and analysis of supersonic configurations. The system uses linearized theory methods for the calculation of surface pressures and supersonic area-rule concepts in combination with linearized theory for calculation of aerodynamic force coefficients. Interactive graphics are optional at the user's request. This part presents a general description of the system and describes the theoretical methods used.

377. Manro, Marjorie E.; Manning, Kenneth J. R.; Hallstaff, Thomas H.; and Rogers, John T.: Transonic Pressure Measurements and Comparison of Theory to Experiment for an Arrow-Wing Configuration - Summary Report. NASA CR-2610, 1976.

Wind-tunnel tests of an arrow-wing—body configuration consisting of flat and twisted wings, as well as a variety of leading- and trailing-edge control-surface deflections, were conducted at Mach numbers from 0.4 to 1.1 by the Boeing Commercial Airplane Company to provide an experimental pressure data base for comparison with theoretical methods. Theory-to-experiment comparisons of detailed pressure distributions were made using current state-of-the-art attached- and separated-flow methods.

378. Middleton, W. D.; Lundry, J. L.; and Coleman, R. G.: A Computational System for Aerodynamic Design and Analysis of Supersonic Aircraft. Part 2 - User's Manual. NASA CR-2716, 1976.

An integrated system of computer programs was developed by the Boeing Commercial Airplane Company for the design and analysis of supersonic configurations. The system uses linearized theory methods for the calculation of surface pressures and supersonic area-rule concepts in combination with linearized theory for calculation of aerodynamic force coefficients. Interactive graphics are optional at the user's request. This users' manual contains a description of the system, an explanation of its usage, the input definition, and example output.

379. Radkey, R. L.; Welge, H. R.; and Felix, J. E.: Aerodynamic Characteristics of a Mach 2.2 Advanced Supersonic Cruise Aircraft Configuration at Mach Numbers From 0.5 to 2.4. NASA CR-145094, 1977.

Noise

380. Kane, Edward J.: A Study To Determine the Feasibility of a Low Sonic Boom Supersonic Transport. NASA CR-2332, 1973.

A study was made by the Boeing Commercial Airplane Company to determine the feasibility of supersonic transport configurations designed to produce a goal sonic boom signature with low overpressure. The results indicate that, in principle, such a concept represents a potentially realistic design approach assuming technology of the 1985 time period. Two sonic boom goals were selected which included: (1) a high-speed design that would produce shock waves no stronger than 48 N/m^2, and (2) an intermediate Mach number (mid-Mach) design that would produce shock waves no stronger than 24 N/m^2. The high-speed airplane design was a Mach 2.7 blended arrow wing configuration which was capable of carrying 183 passengers a distance of 7000 km while meeting the signature goal. The mid-Mach airplane design was a Mach 1.5 low arrow wing configuration with a horizontal tail which could carry 180 passengers a distance of 5960 km.

381. Guinn, Wiley A.; Balena, Frank J.; and Soovere, Jaak: Sonic Environment of Aircraft Structure Immersed in a Supersonic Jet Flow Stream. NASA CR-144996, 1976.

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Aerodynamics

382. Mercer, J. E.; Weber, J. A.; and Lesferd, E. P.: Aerodynamic Influence Coefficient Method Using Singularity Splines. AIAA Paper No. 73-123, Jan. 1973.

383. Callaghan, J. G.: Aerodynamic Prediction Methods for Aircraft at Low Speeds With Mechanical High Lift Devices. Prediction Methods for Aircraft Aerodynamic Characteristics, AGARD-LS-67, May 1974, pp. 2-1 - 2-52.

384. Fromme, J.; and Halstead, David: The Use of Local Basis Functions in Unsteady Aerodynamics. AIAA Paper 75-100, Jan. 1975.

385. Johnson, F. T.; and Rubbert, P. E.: Advanced Panel-Type Influence Coefficient Methods Applied to Subsonic Flows. AIAA Paper 75-50, Jan. 1975.

386. Campbell, J. F.; Gloss, B. B.; and Lamar, J. E.: Vortex Maneuver Lift for Super-Cruise Configurations. Design Conference Proceedings - Technology for Supersonic Cruise Military Aircraft, Volume I, AFFDL-TR-77-85, Vol. I, U.S. Air Force, 1976.

387. Coe, Paul L., Jr.: Propulsive-Lift Concepts for Improved Low-Speed Performance of Supersonic Cruise Arrow-Wing Configurations. Proceedings - AIAA 3rd Atmospheric Flight Mechanics Conference, June 1976, pp. 65-69.

388. Coe, Paul L., Jr.; and Gilbert, William P.: Application of Low-Speed Aerodynamic Characteristics of Highly Swept Arrow-Wing Configurations to Supersonic Cruise Tactical Fighter Designs. Design Conference Proceedings - Technology for Supersonic Cruise Military Aircraft, Volume I, AFFDL-TR-77-85, Vol. I, U.S. Air Force, 1976.

389. Dollyhigh, Samuel M.; Ayers, Theodore G.; Morris, Odell A.; and Miller, David M.: Designing for Supercruise and Maneuver. Design Conference Proceedings - Technology for Supersonic Cruise Military Aircraft, Volume I, AFFDL-TR-77-85, Vol. I, U.S. Air Force, 1976.

390. Ehlers, F. Edward; Johnson, Forrester T.; and Rubbert, Paul E.: A Higher Order Panel Method for Linearized Supersonic Flow. AIAA Paper No. 76-381, July 1976.

391. Rettie, Ian H.: Computer-Aided Aerodynamic Design for Supercruise. Design Conference Proceedings - Technology for Supersonic Cruise Military Aircraft, Volume I, AFFDL-TR-77-85, Vol. I, U.S. Air Force, 1976.

392. Shrout, Barrett L.; Morris, Odell A.; Robins, A. Warner; and Dollyhigh, Samuel M.: Review of NASA Supercruise Configuration Studies. Design Conference Proceedings - Technology for Supersonic Cruise Military Aircraft, Volume I, AFFDL-TR-77-85, Vol. I, U.S. Air Force, 1976.

393. Sorrells, Russell B.; and Foss, Willard E.: Trade Studies on a Long Range Mach 2.7 Supercruiser. Design Conference Proceedings - Technology for Supersonic Cruise Military Aircraft, Volume I, AFFDL-TR-77-85, Vol. I, U.S. Air Force, 1976.

394. Manro, Marjorie E.; Bobbitt, Percy J.; and Rogers, John T.: Comparisons of Theoretical and Experimental Pressure Distributions on an Arrow-Wing Configuration at Subsonic, Transonic, and Supersonic Speeds. Prediction of Aerodynamic Loading, AGARD-CP-204, Feb. 1977, pp. 11-1 - 11-14.

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395. Ferri, Antonio; Siclari, Michael; and Ting, Lu: Sonic Boom Analysis for High Altitude Flight at High Mach Number. AIAA Paper No. 73-1034, Oct. 1973.

STABILITY AND CONTROL

NASA Inhouse Reports

396. Abel, Irving; and Sandford, Maynard C.: Status of Two Studies on Active Control of Aeroelastic Response. NASA TM X-2909, 1973.

The application of active control technology to the suppression of flutter has been successfully demonstrated during two recent studies in the Langley transonic dynamics tunnel. The first study involved the implementation of an aerodynamic energy criterion using both leading- and trailing-edge controls to suppress flutter of a simplified delta-wing model. The second study was conducted to establish the effect of active flutter suppression on a model of the Boeing B-52 Control Configured Vehicle (CCV).

397. Brown, Stuart C.: Computer Simulation of Aircraft Motions and Propulsion System Dynamics for the YF-12 Aircraft at Supersonic Cruise Conditions. NASA TM X-62,245, 1973.

A computer simulation of the YF-12 aircraft motions and propulsion system dynamics is presented. The propulsion system was represented in sufficient detail so that interactions between aircraft motions and the propulsion system dynamics could be investigated. Effects of inlet moving geometry on aircraft forces and moments as well as effects of aircraft motions on the inlet behavior were simulated. The simulation was capable of operating in real time.

398. Gilyard, Glenn B.; Berry, Donald T.; and Belte, Daumants: Analysis of a Lateral-Directional Airframe/Propulsion System Interaction. NASA TM X-2829, 1973.

Lateral-directional flight data from a YF-12 airplane operating with the yaw damper off showed positive Dutch roll damping during inlets-fixed operation and a divergent response during automatic inlet operation. With inlet geometry variables considered as control inputs, the Newton-Raphson and time vector derivative extraction techniques were applied to data from a set of supersonic maneuvers displaying these dynamic characteristics to determine the cause of the instability. A root locus analysis with the resulting force and moment coefficients showed that a time lag of approximately 0.5 sec in the sideslip sensor used to control the inlet geometry caused the instability.

399. Gilyard, Glenn B.; and Belte, Daumants: Flight-Determined Lag of Angle-of-Attack and Angle-of-Sideslip Sensors in the YF-12A Airplane From Analysis of Dynamic Maneuvers. NASA TN D-7819, 1974.

Magnitudes of lags in the pneumatic angle-of-attack and angle-of-sideslip sensor systems of the YF-12A airplane were determined for a variety of flight conditions by analyzing stability and control data. The three analysis techniques used are described. Because Mach number was closely related to altitude for the available flight data, the individual effects of Mach number and altitude on the lag could not be separated clearly. However, the results indicated the influence of factors other than simple pneumatic lag.

400. Tinoco, Edward N.: An Aeroelastic Analysis of the YF-12A Airplane Using the FLEXSTAB System. NASA YF-12 Flight Loads Program, NASA TM X-3061, 1974, pp. 559-623.

An aeroelastic analysis of the Lockheed YF-12A airplane was made with the FLEXSTAB system of computer programs. A description of the FLEXSTAB system and its use in analyzing the airplane is presented. Aerodynamic modeling techniques used in representing the airplane are discussed.

Comparisons are made between computed results, wind-tunnel test data, and flight test data. These comparisons verify that the FLEXSTAB system of computer programs is capable of analyzing complex aircraft configurations like that of the YF-12A airplane. Theoretical results generally compare well with experiment except in the region of the forebody. In this region, there is significant discrepancy between the theoretical analysis, wind-tunnel data, and flight test data. The discrepancy may be attributed to vortex flow on the forebody chine, which the theory cannot simulate and which differs for wind-tunnel and flight conditions.

401. Sandford, Maynard C.; Abel, Irving; and Gray, David L.: Development and Demonstration of a Flutter-Suppression System Using Active Controls. NASA TR R-450, 1975.

The application of active control technology to suppress flutter was demonstrated successfully in the Langley transonic dynamics tunnel with a delta-wing model. The model was a simplified version of a proposed supersonic transport wing design. An active flutter-suppression method based on an aerodynamic energy criterion was verified by using three different control laws. Analytical methods were developed to predict both open-loop and closed-loop stability, and the results agreed reasonably well with the experimental results.

402. Albers, James A.: Status of the NASA YF-12 Propulsion Research Program. NASA TM X-56039, 1976.

The YF-12 research program was initiated to establish a technology base for the design of an efficient propulsion system for supersonic cruise aircraft. The major technology areas under investigation in this program are inlet design analysis, propulsion system steady-state performance, propulsion system dynamic performance, inlet and engine control systems, and airframe/propulsion system interactions. Discussed are the results obtained to date by the NASA Ames, Lewis, and Dryden Research Centers.

403. Berry, Donald T.; and Gilyard, Glenn B.: A Review of Supersonic Cruise Flight Path Control Experience With the YF-12 Aircraft. Aircraft Safety and Operating Problems, NASA SP-416, 1976, pp. 147-163.

Flight research with the YF-12 aircraft indicates that solutions to many handling qualities problems of supersonic cruise are at hand. Airframe/propulsion system interactions in the Dutch roll mode can be alleviated by the use of passive filters or additional feedback loops in the propulsion and flight control systems. Mach and altitude excursions due to atmospheric temperature fluctuations can be minimized by the use of a cruise autothrottle. Autopilot instabilities in the altitude hold mode have been traced to angle-of-attack sensitive static ports on the compensated nose boom. For the YF-12, the feedback of high-pass pitch rate to the autopilot resolves this problem. Manual flight-path control is significantly improved by the use of an inertial rate of climb display in the cockpit.

404. Berry, Donald T.; and Schweikhard, William G.: Potential Benefits of Propulsion and Flight Control Integration for Supersonic Cruise Vehicles. Advanced Control Technology and Its Potential for Future Transport Aircraft, NASA TM X-3409, 1976, pp. 433-452.

Typical airframe/propulsion interactions such as Mach/altitude excursions and inlet unstarts are reviewed. The improvements in airplane performance and flight control that can be achieved by improving the interfaces between propulsion and flight control are estimated. A research program to determine the feasibility of integrating propulsion and flight control is described. This program includes analytical studies and YF-12 flight tests.

405. Doggett, Robert V., Jr.; Abel, Irving; and Ruhlin, Charles L.: Some Experiences Using Wind-Tunnel Models in Active Control Studies. Advanced Control Technology and Its Potential for Future Transport Aircraft, NASA TM X-3409, 1976, pp. 831-892.

A status report and review of wind-tunnel model experimental techniques that have been developed to study and validate the use of active control technology for the minimization of aeroelastic response are presented. The studies include flutter mode suppression on a delta-wing model, flutter mode suppression and ride quality control on a 1/30-size model of the B-52 CCV airplane, and an active lift distribution control system on a 1/22-size C-5A model.

406. Nissim, E.; Caspi, A.; and Lottati, I.: Application of the Aerodynamic Energy Concept to Flutter Suppression and Gust Alleviation by Use of Active Controls. NASA TN D-8212, 1976.

The effects of active controls on flutter suppression and gust alleviation of the Arava twin turboprop STOL transport and the Westwind twinjet business transport are investigated. The control law is based on the concept of aerodynamic energy and utilizes previously optimized control law parameters based on two-dimensional aerodynamic theory. The best locations of the activated system along the span of the wing are determined for bending-moment alleviation, reduction in fuselage accelerations, and flutter suppression. The results indicate that flutter speed can be significantly increased (over 70 percent increase) and that the bending moment due to gust loading can be almost totally eliminated by a control system of about 10 to 20 percent span with reasonable control surface rotations.

407. Pratt, Kermit G.: A Survey of Active Controls Benefits to Supersonic Transports. Advanced Control Technology and Its Potential for Future Transport Aircraft, NASA TM X-3409, 1976, pp. 639-659.

Results are drawn from studies of the impact of advanced technologies on the design of an arrow wing configuration. Information presented includes estimated benefits, effects of combinations of active control concepts, and constraints. Emphasis is placed on characteristics that are uniquely related to a large airframe featuring a slender body with a fixed wing of low aspect ratio, high sweep, and small thickness ratio.

408. Berry, Donald T.; Mallick, Donald L.; and Gilyard, Glenn B.: Handling Qualities Aspects of NASA YF-12 Flight Experience. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 193-213.

This paper reviews the handling qualities of the YF-12 airplane as observed during NASA research flights over the past 5 years. Aircraft behavior during take-off, acceleration, climb, cruise, descent, and landing are discussed. Pilot comments on the various flight phases and tasks are presented. Handling qualities parameters are compared with existing and proposed handling qualities criteria. The influence of the propulsion systems, stability augmentation, autopilot systems, atmospheric gusts, and temperature changes are also discussed. The results indicate that YF-12 experience correlates well with flying qualities criteria.

409. Doggett, Robert V., Jr.; and Townsend, James L.: Flutter Suppression by Active Control and Its Benefits. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 303-333.

A general discussion of active flutter suppression systems is presented with focus on supersonic cruise aircraft configurations. Topics addressed include a brief historical review; benefits, risks, and concerns; methods of application; and applicable configurations. Results show that significant increases in flutter speed (or flutter dynamic pressure) can be accomplished by using active flutter suppression.

Results of a study are presented where the direct operating costs and performance benefits of an arrow wing supersonic cruise vehicle equipped with an active flutter suppression system are compared with corresponding costs and performance of the same baseline airplane where the flutter deficiency was corrected by passive methods (increases in structural stiffness). The design, synthesis, and conceptual mechanization of the active flutter suppression system are discussed. The results show that a substantial weight savings can be accomplished and direct operating costs reduced by using the active system.

410. Grantham, William D.; Nguyen, Luat T.; Neubauer, M. J., Jr.; and Smith, Paul M.: Simulator Study of the Low-Speed Handling Qualities of a Supersonic Cruise Arrow-Wing Transport Configuration During Approach and Landing. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 215-248.

A fixed-based simulator study was conducted to determine the low-speed flight characteristics of an advanced supersonic cruise transport having an arrow wing, a horizontal tail, and four dry turbojets with variable geometry turbines. The primary piloting task was the approach and landing.

The results of the study indicated that the statically unstable (longitudinally) subject configuration has unacceptable low-speed handling qualities with no augmentation. Therefore, a hardened stability augmentation system (HSAS) will be required to achieve "acceptable" handling qualities should the normal operational stability and control augmentation system (SCAS) fail. Although the SCAS developed in this study to achieve satisfactory handling qualities was complex, it is within current technology.

411. Perkin, Brian R.; and Erickson, Larry L.: FLEXSTAB - A Computer Program for the Prediction of Loads and Stability and Control of Flexible Aircraft. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 249-280.

This paper describes and illustrates capabilities of the FLEXSTAB Computer Program System. FLEXSTAB is a system of computer programs for performing aeroelastic analysis of a wide variety of current and future aircraft configurations. There are two versions of FLEXSTAB: an NASA controls-fixed version, identified as Level 1 FLEXSTAB; and an Air Force version, identified as Level 2 FLEXSTAB, which provides for active controls analysis at low frequencies. The aerodynamic theory used in FLEXSTAB is applicable to both steady and unsteady, subsonic and supersonic, flow for multiple wing-body-tail-nacelle configurations with a plane of symmetry. FLEXSTAB will trim the aircraft in steady reference flight and compute both static and dynamic stability and control derivatives and the stability behavior about the trim condition. The airplane lifting pressure distribution, aerodynamic and inertia loads, and deflected shape are also computed.

412. Reukauf, Paul J.; and Burcham, Frank W., Jr.: Propulsion System/Flight Control Integration. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 281-302.

The NASA Dryden Flight Research Center is engaged in the YF-12 cooperative control program. In this program, the existing analog air-data computer autothrottle, autopilot, and inlet control systems are to be converted to digital systems by using a general purpose airborne computer and interface unit. First, the existing control laws are to be programed and tested in flight. Then, integrated control laws, derived by using accurate mathematical models of the airplane and propulsion system in conjunction with modern control techniques, are to be tested in flight. Analysis indicates that an integrated autothrottle-autopilot gives good flight-path control and that observers can be used to replace failed sensors.

413. Sudderth, Robert W.; and McNeill, Walter E.: Development of Longitudinal Handling Qualities Criteria for Large Advanced Supersonic Aircraft. Proceedings of the SCAR Conference - Part 1, NASA CP-001, [1977], pp. 171-192.

A piloted simulation study was conducted with the aim of advancing the development of longitudinal handling qualities criteria for large supersonic cruise aircraft. The areas of study, using the NASA Ames Flight Simulator for Advanced Aircraft, included high-speed cruise maneuvering, stall-recovery control power, and landing approach for normal and minimum-safe operation. Only the first two areas are discussed in this paper. Comparisons were made with existing criteria and, for the cruise condition, a time response criterion was developed which correlated well with pilot ratings and comments. For low-speed stall recovery, a new criterion was developed in terms of nose-down angular acceleration capability.

NASA Contractor Reports

414. Sevart, F. D.; Patel, S. M.; and Wattman, W. J.: Analysis and Testing of Stability Augmentation Systems - Final Report. Doc. D3-8884, Boeing Co., June 1972. (Available as NASA CR-132349.)

415. Edinger, Lester D.; Schenk, Frederick L.; and Curtis, Alan R.: Study of Load Alleviation and Mode Suppression (LAMS) on the YF-12A Airplane. NASA CR-2158, 1973.

The potentials and capability for implementing a LAMS (load alleviation and mode suppression) system on the YF-12A for the purpose of flight research were evaluated by Lockheed Aircraft Corporation. The nature of the research is to minimize the design risk in application of LAMS to future aircraft. The results of the study show that the YF-12A would be a suitable test bed for continuing development of LAMS technology. This was demonstrated by defining five candidate LAMS systems and analytically evaluating them with regard to performance and mechanization.

416. Sevart, Francis D.; and Patel, Suresh M.: Analysis and Testing of Aeroelastic Model Stability Augmentation Systems - Final Report. NASA CR-132345, 1973.

417. Webb, W. L.; and Zewski, G. J.: J58 Cooperative Control System Study - Volume I. NASA CR-121195, 1973.

418. Webb, W. L.; and Zewski, G. J.: J58 Cooperative Control System Study - Volume II. NASA CR-121195, 1973.

419. Webb, W. L.; and Zewski, G. J.: J58 Cooperative Control System Study - Volume III. NASA CR-121195, 1973.

420. Boeing Commercial Airplane Co.: A Method for Predicting the Stability Characteristics of Control Configured Vehicles. Volume IV - FLEXSTAB 2.01.00 B-52E LAMS Demonstration Case and Results. AFFDL-TR-74-91, Vol. IV, U.S. Air Force, Nov. 1974. (Available from DDC as AD B005-730L.)

FLEXSTAB is a system of computer programs designed to predict the stability and control characteristics of an elastic airplane in the subsonic and supersonic flight regimes from geometry, mass distribution, and flexibility information. The numerical process is based on linear aerodynamic and structural influence coefficient theory. The resulting FLEXSTAB 2.01.00 system is capable of analyzing flexible airplane response to atmospheric turbulence or control system commands. The FLEXSTAB 2.01.00 B-52E LAMS Demonstration Case and Results is the fourth volume of a report prepared under AFFDL contract. The results from an analysis of one flight condition were compared with the results of a similar analysis conducted by The Boeing Company, Wichita Division, and Honeywell, Inc. Major capabilities of FLEXSTAB have been demonstrated and the results are shown in this volume.

421. Dornfeld, G. M.; Bhatia, K. G.; Maier, R. E.; Snow, R. N.; and Van Rossum, D. A.: A Method for Predicting the Stability Characteristics of an Elastic Airplane - Volume IV: FLEXSTAB 1.02.00 Demonstration Cases and Results. NASA CR-114715, 1974.

422. Dusto, A. R.; Brune, G. W.; Dornfeld, G. M.; Mercer, J. E.; Pilet, S. C.; Rubbert, P. E.; Schwanz, R. C.; Smutny, P.; Tinoco, E. N.; and Weber, J. A.: A Method for Predicting the Stability Characteristics of an Elastic Airplane. Volume I - FLEXSTAB Theoretical Description. NASA CR-114712, 1974.

423. Hink, G. R.; D'Auria, P. V.; Bailey, D. C.; Bills, G. R.; and Henderson, D. M.: A Method for Predicting the Stability Characteristics of an Elastic Airplane. Volume III - FLEXSTAB 1.02.00 Program Description. NASA CR-114714, 1974.

424. Hink, G. R.; Snow, R. N.; Bhatia, K. G.; Maier, R. E.; Bills, G. R.; Henderson, D. M.; Bailey, D. C.; Dornfeld, G. M.; and D'Auria, P. V.: A Method for Predicting the Stability Characteristics of an Elastic Airplane. Volume II - FLEXSTAB 1.02.00 User's Manual. NASA CR-114713, 1974.

425. Nissim, E.: Flutter Suppression and Gust Alleviation Using Active Controls. TAE Rep. No. 198, Technion - Israel Inst. Technol., 1974. (Available as NASA CR-138658.)

426. Chenoweth, C. C.; Fain, D. M.; and Svensson, C. I.: Redundant Actuator Development Program. NASA CR-137656, 1975.

427. Miller, Ronald D.; and Rogers, John T.: Requirements for Implementation of Küssner and Wagner Indicial Lift Growth Functions Into the FLEXSTAB Computer Program System for Use in Dynamic Loads Analyses. NASA CR-137718, 1975.

428. Redman, M. C.; and Rowe, W. S.: Prediction of Unsteady Aerodynamic Loadings Caused by Leading Edge and Trailing Edge Control Surface Motions in Subsonic Compressible Flow - Computer Program Description. NASA CR-132634, 1975.

429. Rowe, W. S.; Redman, M. C.; Ehlers, F. E.; and Sebastian, J. D.: Prediction of Unsteady Aerodynamic Loadings Caused by Leading Edge and Trailing Edge Control Surface Motions in Subsonic Compressible Flow - Analysis and Results. NASA CR-2543, 1975.

A theoretical analysis and computer program was developed by the Boeing Commercial Airplane Company for the prediction of unsteady lifting surface loadings caused by motions of leading-edge and trailing-edge control surfaces having sealed gaps. Comparisons of theoretical and experimental pressure data are made for several control surface configurations. The comparisons indicate that reasonably accurate theoretical pressure distributions and generalized forces may be obtained for a wide variety of control surface configurations. Spanwise symmetry or antisymmetry of motion and up to six control surfaces on each half span can be accommodated.

430. Sudderth, Robert W.; Bohn, Jeff G.; Caniff, Martin A.; and Bennett, Gregory R.: Development of Longitudinal Handling Qualities Criteria for Large Advanced Supersonic Aircraft. NASA CR-137635, 1975.

431. Kroll, Richard I.; and Miller, Ronald D.: Comparisons of Several Aerodynamic Methods for Application to Dynamic Loads Analyses. NASA CR-137720, 1976.

432. Pyle, R. S.; Sykora, R. G.; and Denman, S. C.: FLEXSTAB on the IBM 360. NASA CR-137900, 1976.

433. Gordon, C. K.; and Visor, O. E.: SCAR Arrow-Wing Active Flutter Suppression System. NASA CR-145147, 1977.

434. Roberts, Philip A.; Swaim, Robert L.; Schmidt, David K.; and Hinsdale, Andrew J.: Effects of Control Laws and Relaxed Static Stability on Vertical Ride Quality of Flexible Aircraft. NASA CR-143843, 1977.

Articles, Meetings, and Company Reports

435. Gilyard, Glenn B.; Berry, Donald T.; and Belte, Daumants: Analysis of a Lateral-Directional Airframe/Propulsion System Interaction of a Mach 3 Cruise Aircraft. AIAA Paper No. 72-961, Sept. 1972.

436. Rainey, A. Gerald; Ruhlin, Charles L.; and Sandford, Maynard C.: Active Control of Aeroelastic Response. Stability and Control, AGARD CP-119, 1972, pp. 16-1 - 16-5.

437. Berry, D. T.; and Gilyard, G. B.: Some Stability and Control Aspects of Airframe/Propulsion System Interactions on the YF-12 Airplane. Paper 73-WA/Aero-4, American Soc. Mech. Eng., Nov. 1973.

438. Berry, Donald T.; and Gilyard, Glenn B.: Airframe/Propulsion System Interactions - An Important Factor in Supersonic Aircraft Flight Control. AIAA Paper No. 73-831, Aug. 1973.

439. Abel, Irving; and Sandford, Maynard C.: Status of Two Studies on Active Control of Aeroelastic Response at NASA Langley Research Center. Active Control Systems for Load Alleviation, Flutter Suppression and Ride Control, AGARD-AG-175, Mar. 1974, pp. 23-47.

440. Gilyard, Glenn B.; Smith, John W.; and Falkner, Victor L.: Flight Evaluation of a Mach 3 Cruise Longitudinal Autopilot. AIAA Paper No. 74-910, Aug. 1974.

441. Schweikhard, William G.; and Berry, Donald T.: Cooperative Airframe/Propulsion Control for Supersonic Cruise Aircraft. [Preprint] 740478, Soc. Automot. Eng., Apr.-May 1974.

442. Reukauf, Paul J.; Burcham, Frank W., Jr.; and Holzman, Jon K.: Status of a Digital Integrated Propulsion/Flight Control System for the YF-12 Airplane. AIAA Paper No. 75-1180, Sept.-Oct. 1975.

443. Sandford, Maynard C.; Abel, Irving; and Gray, David L.: Transonic Study of Active Flutter Suppression Based on an Energy Concept. J. Aircraft, vol. 12, no. 2, Feb. 1975, pp. 72-77.

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16. Abstract

This bibliography documents publications of the Supersonic Cruise Aircraft Research (SCAR) Program that were generated during the first 5 years of effort. The reports are arranged according to Systems Studies and five SCAR disciplines: Propulsion, Stratospheric Emissions Impact, Structures and Materials, Aerodynamic Performance, and Stability and Control. The specific objectives of each discipline are summarized. Annotation is included for all NASA inhouse and low-number contractor reports. There are 444 papers and articles included.

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