NASA
Reference
Publication
1117

July 1984

NASA-RP-1117 19840019606

Bibliography of Supersonic Cruise Research (SCR) Program From 1980 to 1983

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NASA

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Reference
Publication
1117

1984

Bibliography of Supersonic Cruise Research (SCR) Program From 1980 to 1983

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and Space Administration

Scientific and Technical
Information Branch

CONTENTS

INTRODUCTION

The charter of the National Aeronautics and Space Administration (NASA) under the Space Act of 1958, included conducting advanced fundamental research applicable to aeronautical vehicles throughout the speed range available for atmospheric flight. Its predecessor in aeronautics, the National Advisory Committee for Aeronautics (NACA), had borne this responsibility for the United States since 1917. The X-1 aircraft, which flew supersonically first in 1947, was the product of supersonic research conducted by NACA in the late 1930's and early 1940's. NASA continued to provide the research for the technology base for both future civil and military aircraft.

The United States Supersonic Transport (SST) Program (Boeing supersonic transport) was canceled near the end of 1971. This program had its beginnings in research conducted in the laboratories of NACA/NASA. NASA configurations were part of the mix of options available to Boeing, and a NASA configuration (SCAT-15F) was the closest contender to the selected prototype design (Boeing 2707-300). However, technological problems existed which directly led to the termination of the SST program. Some of these factors were concern for engine noise levels; upper atmospheric pollution; flutter characteristics; requirement for stability augmentation systems not within the state of the art; sonic boom characteristics; and low range/payload characteristics caused by excessive structural weight fraction, high specific fuel consumption, a marginal configuration concept with insufficient lift-drag ratio, and economics.

The Supersonic Cruise Research (SCR) Program was initiated in fiscal year 1973 by the National Aeronautics and Space Administration at the direct request of the Executive Office of the President and Congress following termination of the U.S. SST program. Originally, the program was entitled Advanced Supersonic Technology (AST); this was later changed to Supersonic Cruise Aircraft Research (SCAR) and, finally, to SCR. Funding for the SCR Program was terminated in fiscal year 1981. The program was implemented through contracts and grants with industry and universities and by in-house investigations at the NASA/OAST Centers. The studies included system studies and five disciplines: propulsion, stratospheric emissions impact, materials and structures, aerodynamic performance, and stability and control. The NASA/Lewis Variable-Cycle Engine (VCE) Component Program was initiated in 1976 to augment the SCR program in the area of propulsion. After about two years, the title was changed to VCE Technology Program. The total number of contractors and grantees on record at the AST office in 1982 was 101 for SCR and 4 for VCE. A report summarizing the contracts, grants, and funding for these programs was published as NASA TM-85650 (ref. 1). The total program authority was about $86,982,000 for SCR and was about $31,730,000 for VCE.

In order to keep the technical community informed of progress, two conferences were held, and the proceedings were published as NASA CP-001 (ref. 2) and NASA CP-2108 (ref. 3). The conference presentations only highlighted the progress; therefore, more technical documents were published. All the NASA formal reports, articles, presentations, and contractor reports are listed in three bibliographies, NASA RP-1003 (ref. 4), NASA RP-1063 (ref. 5), and this report. Due to the overlapping time periods of the bibliographies, some duplicate entries were made for completeness. The total number of publications was about 1,030—approximately 690 formal reports and 340 articles and presentations.

DISCUSSION

The SCAR program was a focused Research and Technology (R&T) effort. The overall objectives 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 future supersonic transport aircraft
3. To define the potential benefits and trade-offs of advancements in aerodynamics, materials and structures, propulsion systems, and stability and control methods applied to promising advanced supersonic cruise aircraft concepts

This program included system studies and the following subprogram elements:

Propulsion
Stratospheric emission impact
Structures and materials
Aerodynamic performance
Stability and control

The specific objectives for the system studies and the subprogram elements (disciplines) are given in

detail in NASA RP-1063 (ref. 5). They are summarized herein as follows:

Systems Studies: To assess the impact of new technologies on future supersonic commercial aircraft and to investigate subsonic and supersonic performance, economics, safety, comfort, noise, and emissions, and community interactions with supersonic aircraft operations.

Propulsion: To acquire performance data for (uninstalled) new engine cycles, to provide technology for engine combustors with low nitric oxide emissions, to develop an integrated inlet/engine system, to develop advanced materials for engines, to reduce engine noise, to acquire data base for coannular jet noise suppression, and to conduct sensitivity trade-offs to optimize new engine cycles for performance, noise reduction, and economics.

Propulsion-System/Airframe Interaction: To generate a data base for engine/airframe installation, to use it to develop design procedures for optimized installation of multiengine systems, inlets, and nozzles for variable-cycle and suppressed jet engines, and to analyze their influence on operations, economics, and environmental compatibility.

Stratospheric Emission Impact: To determine the composition of jet engine exhausts in the stratosphere and to analyze possible detrimental effects on the stratosphere of exhausts from fleets of supersonic aircraft.

Structures and Materials: To assess the relative merits of advanced structural concepts and demonstrate their effectiveness by construction and tests of new metallic materials, composites, and composite-reinforced metals; to fully explore superplastic-forming/diffusions bonding (SPF/DB) of titanium; to evaluate composite materials for high-temperature applications; to develop and evaluate analytical techniques for predicting aeroelastic effects, flight effects, and ground load effects; and to develop active control techniques for optimizing supersonic transport aircraft.

Aerodynamic Performance: To develop highly advanced supersonic cruise configuration concepts based on optimized arrow wings, applications of control configured vehicle (CCV) concepts, aeroelasticity, aircraft shaping for low sonic boom, and wind tunnel tests; and to incorporate new methods into computerized design tools to accurately and rapidly accomplish trade-off studies (i.e., weight and performance).

Stability and Control: To develop criteria and an improved data base for the design of control surfaces; to develop control laws applicable to active control concepts, interactions between airframe and propulsion systems, and aeroelastic effects; to determine alternate redundant control system mechanizations; and to conduct simulation studies for determining handling quality criteria and noise abatement procedures for advanced supersonic transports.

The NASA/Lewis Variable-Cycle Engine (VCE) Component Program was initiated in fiscal year 1976 to augment the overall SCR technology effort in the area of propulsion. Phase I provided for the initial development and evaluation of certain critical component technologies unique to VCE concepts for a supersonic cruise aircraft. VCE Phase II Technology Program was intended to build upon the results of the VCE Component Test Program and allow the evaluation of component/system performance and environmental characteristics of the General Electric Double-Bypass Engine (DBE), the Pratt & Whitney Variable-Stream Control Engine (VSCE), and the Turbine Bypass Engine (TBE).

Two YF-12 aircraft were utilized in the SCAR program for demonstration of technological solutions to problems in high-temperature structures, control of engine performance (i.e., inlet and bypass air flow), control for cruise Mach number, and control for altitude.

A block diagram showing the initial organization of SCR in fiscal year 1973 is shown in figure 1(a). As progress was made during the first 7 years, the program structure gradually changed to that shown in figure 1(b). The major disciplines (namely, propulsion, materials and structures, aerodynamic performance, and stability and control) plus system studies remained essentially the same. Stratospheric emissions impact was absorbed into propulsion, and a new discipline which addressed propulsion-system/airframe interaction was initiated in fiscal year 1978. The Variable Cycle Engine Component Program and the flight research experiments shown in figure 1(b) are other OAST programs which provided technology data for the SCR development base. The relative level of effort expended for each discipline from fiscal year 1973 to fiscal year 1981 is presented in figure 2.

The SCR program was managed by the Aeronautical Systems Division, Office of Aeronautics and Space Technology (OAST), with the Langley Research Center designated as the lead Center. The Advanced Supersonic Technology (AST) Office was established at Langley for technical management and coordination of the program. Ames Research Center, Lewis Research Center, Dryden Flight Research Center, and the Jet Propulsion Laboratory, in addition to Langley Research Center, implemented the program through contracts with the aircraft industry, research grants to universities, and in-

house experimental and analytical work. The VCE program and the SCR YF-12 program were conducted by the Lewis Research Center and the Dryden Flight Research Center, respectively, under OAST management.

The SCR and VCE programs have made continuous and significant progress in all the disciplines since their beginning. The programs have provided an accelerated and focused technology effort for future commercial supersonic transports in three main areas: concept development, design data and tools, and applications. New problems were defined and work was initiated on them within the constraints of the program. Considerable progress was made over the last 10 years, and some of the more recent advances are included in the following summary.

The propulsion studies of the SCR Program and the VCE Component Program included large-scale experiments to investigate critical components of double bypass engines, variable stream control engines, fixed cycle turbofan engines, and other candidates. Significant portions of the engine effort were concentrated on understanding engine noise. Coannular streams, shielding, and suppressors were studied and combined to reduce takeoff and landing noise levels. Satisfying noise and emission constraints without unduly penalizing airplane performance and economics continued to be a major challenge. Studies of the influence of propulsion-system cycle selection and installation and power/flight-path optimization on environmental factors were made. The airplane, in fact, would be quieter than many of the subsonic aircraft in operation today. The key elements in achieving this noise reduction were the inverted velocity profile nozzle, light-weight efficient (low thrust loss) suppressors, acoustically treated ejectors, the thermal shield, and a low-emissions staged duct burner with excellent combustion and thrust efficiency. Another significant achievement was the forward Variable Area Bypass Injector (VABI) concept, which allowed two bypass streams to be combined. In conjunction with the rear VABI, this combined flow could then be combined with the turbine discharge flow into a single exhaust stream for efficient cruise performance.

In the area of structural analysis and design, computational procedures are available now to quickly design a vehicle structure that meets the requirements for strength, divergence, and flutter with active controls included. Methods are provided for sizing thermally stressed structures including those containing laminates. Increased emphasis has been given to titanium structure technology, particularly the SPF/DB process. Significant accomplishments have been reported in unsteady aerodynamics, measurement of atmospheric turbulence, aircraft landing loads, temperature capabilities of composites, graphite-polyimide composite applications, and fuel tank sealants. At present, a need exists for a high-temperature structures program for metal-matrix titanium structures similar to that which was started under the McDonnell Douglas contracts.

In aerodynamics, considerable effort has been expended on arrow-wing and multibody aircraft to improve methods for predicting cruise lift-drag ratios, improve wing-body blending, develop nacelle integration methods to reduce interference, and minimize the effects of leading-edge flow separation and vortices on performance, stability, and control. The improvement in lift-drag ratio has been less than desired since the late 1960's, and there is very little transonic data on supersonic transport configurations. The scope of SCR did not allow the coverage of all Mach numbers, and there is a need for laminar flow control research, low-speed lift research, and transonic wind-tunnel testing to improve the overall SST performance.

The effort under stability and control was to expand the relatively small data base on handling quality criteria to aid the certification process for advanced aeroelastic supersonic cruise aircraft. The relatively long distance between the cockpit and the airplane center of gravity was found to affect design criteria during maneuvers. Design concepts to improve the stability and control features of the configuration, the flight profiles for community noise abatement, the degree of stability augmentation required, and the need for pilot information displays were investigated with both in-flight simulations and piloted moving-base or fixed-base simulations.

The system studies provided an opportunity to integrate the newly identified technologies, in all disciplines, into advanced supersonic transport concepts. The trends indicate commercial transports capable of carrying about 330 passengers over the Atlantic Ocean or about 220 passengers over the Pacific Ocean at cruise Mach numbers between 2.0 and 2.7. In order to help the reader visualize such airplanes, illustrations are presented in figure 3. Figure 3(a) presents a collage of nine artist concepts of commercial supersonic airplanes which were conceived by the SCR contractors and a photograph of a Concorde in the landing configuration for comparison. Enlarged photographs of each concept are presented in the remaining parts of figure 3 to identify the aircraft and show the details more clearly. Figures 3(b) through 3(e) show the Boeing, Douglas, and Lockheed configurations with the arrow wing and one Boeing blended delta-wing concept. Figure 3(f) illustrates an SST with a double-decker

fuselage. Figures 3(h) and 3(i) show the USA/Boeing swing delta wing (B-2707) and the British/French Concorde, respectively. Finally, figures 3(j) and 3(k) present ideas of what a small SST may look like if designed for use as an executive jet airplane. These aircraft represent efficient commercial SST's. However, some major problems remain, such as the overland sonic boom and jet fuel consumption. It appears that future work should be done to optimize the current SST concepts and to study transport airplanes for cruising at high Mach numbers.

CONCLUDING REMARKS

This report is the third and final bibliography for the Supersonic Cruise Research (SCR) and Variable-Cycle Engine (VCE) Programs. Prior bibliographies (NASA RP-1003 and RP-1063) cover the reporting time period from 1972 to mid-1980. The reports and articles published in 1980 through 1983 are listed herein and include all the publications that were received by the end of 1983.

Funds expended by SCR between fiscal year 1973 and fiscal year 1981 on contracts and grants were $63,174,000 and $3,015,000, respectively. The SCR net R&D was $73,227,000 and total program authority (506 W) was $86,982,000. The corresponding level of effort for VCE was $27,103,000 for contracts and $750,000 for grants, out of a net R&D of $31,177,000 (506 W was $31,730,000).

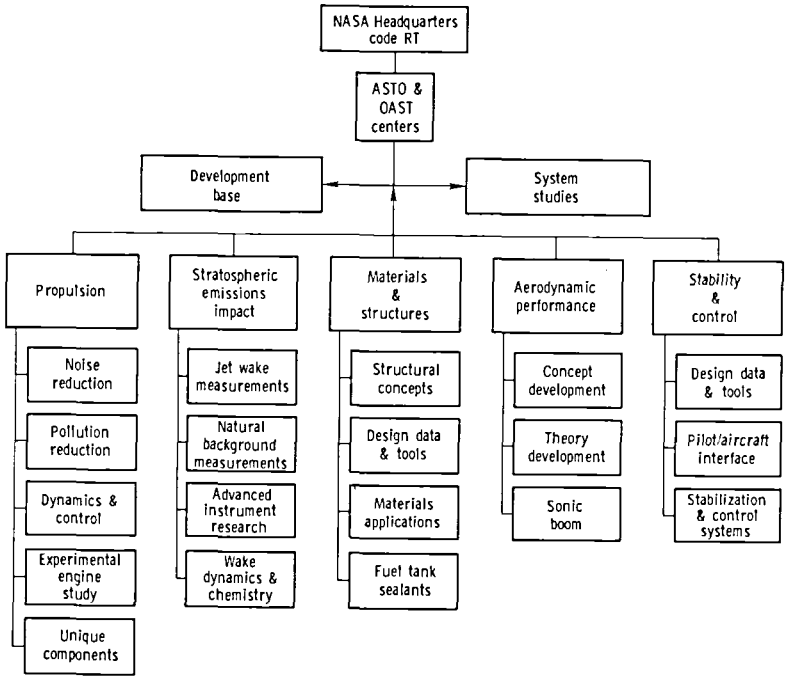
The total number of contractors and grantees on record at the close of the program was 105 for both SCR and VCE. The studies they performed plus those undertaken by the NASA Centers during the decade of work produced approximately 690 formal reports and about 340 articles. This final paper presents an annotated bibliography for the last 123 formal reports and a listing of titles for 44 articles and presentations.

The programs were very successful in conducting advanced technology studies for future supersonic commercial and military jet transports. The conclusions and recommendations may be summarized concisely by quoting from an article by Maglieri and Dollyhigh in the February 1982 issue of Astronautics and Aeronautics, as follows:

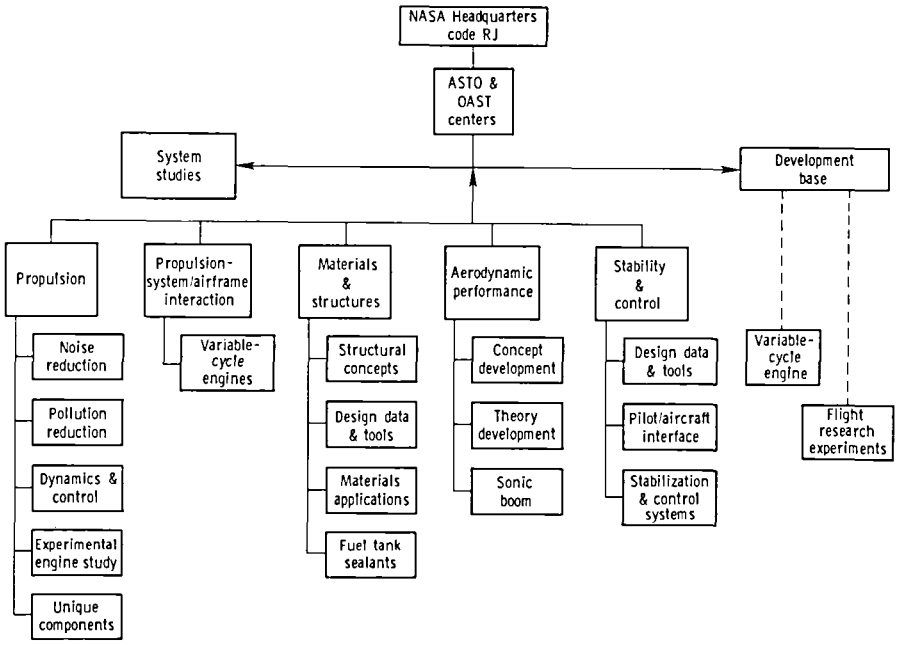
> "The SST, an exception, has the potential to provide a burst in expansion. Technology studies have shown that an advanced SST does not have to be less acceptable environmentally or less profitable than a comparably sized subsonic airplane. In fact, recent studies show that an advanced SST can achieve three times the productivity of a similar size subsonic aircraft at the same payload while burning slightly less than two times the fuel.
>
> The SST can be competitive with subsonic aircraft of comparable size even with the great increase in fuel price that has taken place since the introduction of supersonic transports. Continuing efforts on all the appropriate technologies can lead to a successful SST in the foreseeable future."

REFERENCES

1. Hoffman, Sherwood; and Varholic, Mary C.: Contracts, Grants, and Funding Summary of Supersonic Cruise Research and Variable-Cycle Engine Technology Programs—1972–1982. NASA TM-85650, 1983.
2. Proceedings of the SCAR Conference—Parts 1 and 2. NASA CP-001, [1977].
3. Supersonic Cruise Research '79. NASA CP-2108, 1980.
4. Hoffman, Sherwood: Bibliography of Supersonic Cruise Aircraft Research (SCAR) Program From 1972 to Mid-1977. NASA RP-1003, 1977.
5. Hoffman, Sherwood: Bibliography of Supersonic Cruise Research (SCR) Program From 1977 to Mid-1980. NASA RP-1063, 1980.



(a) Fiscal year 1973.



(b) Fiscal year 1979.

Figure 1. SCR Program structure.

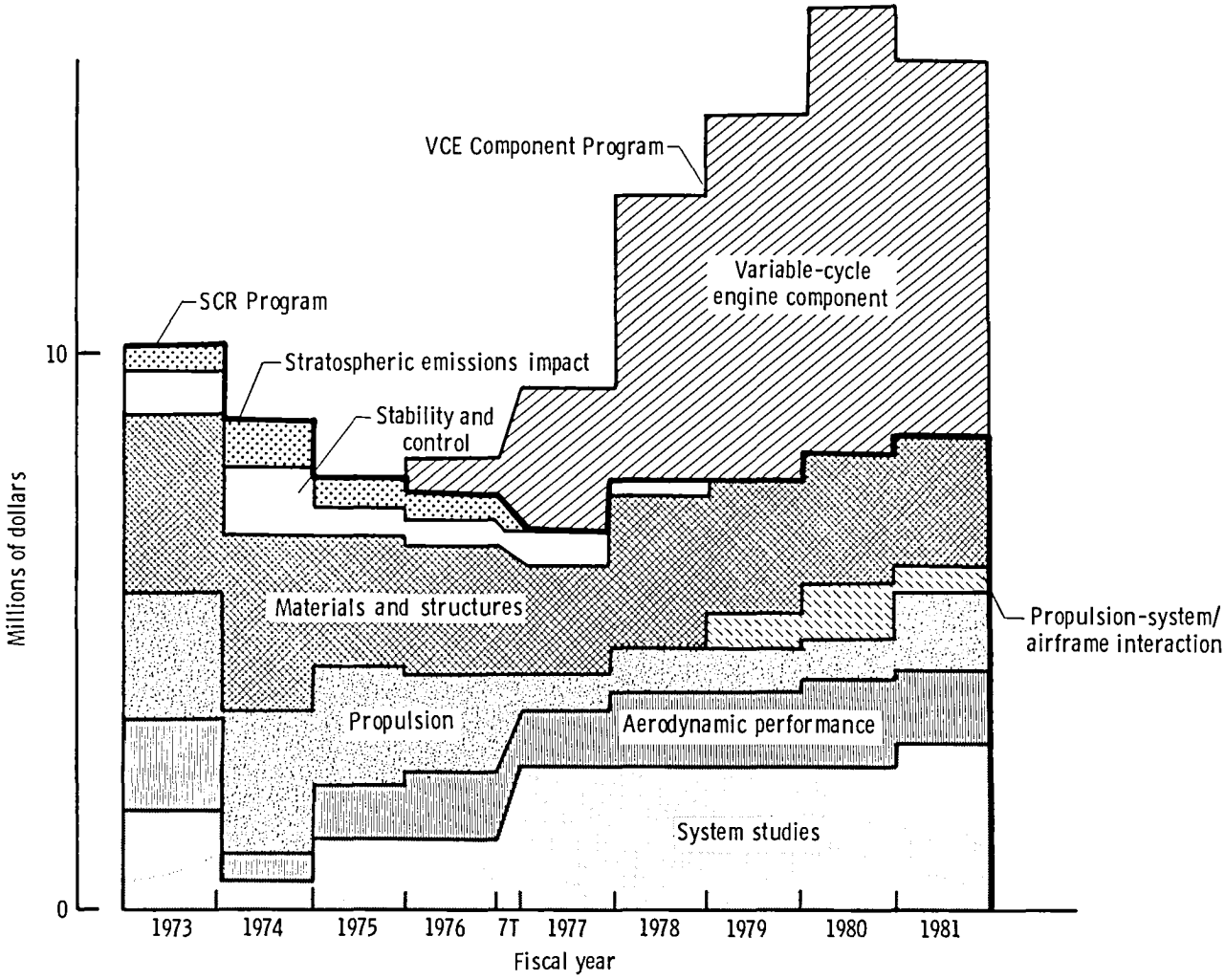
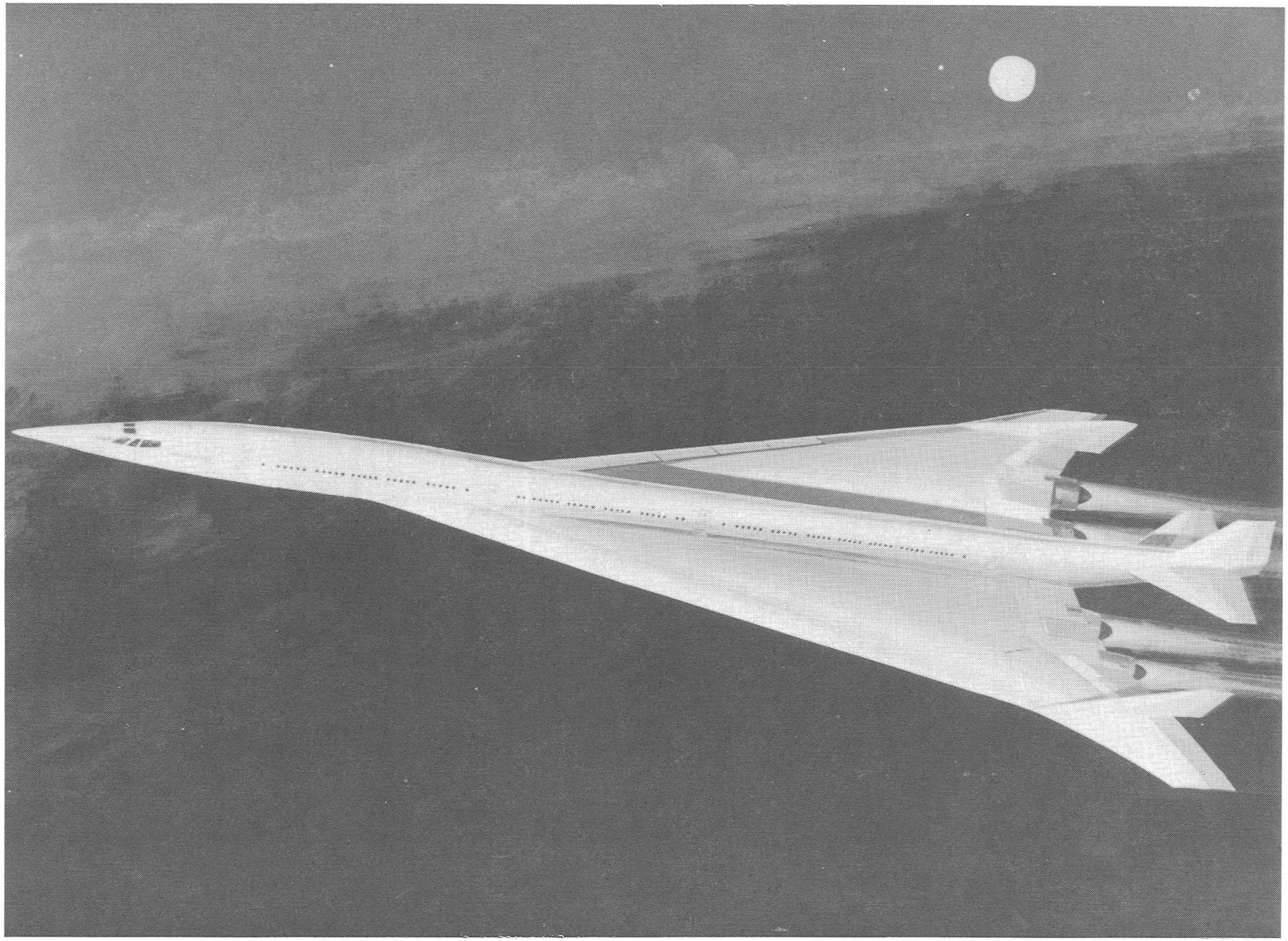


Figure 2. Net R&D history for SCR and VCE Programs.

L-83-4911

(a) Artist concepts and photograph of Concorde.

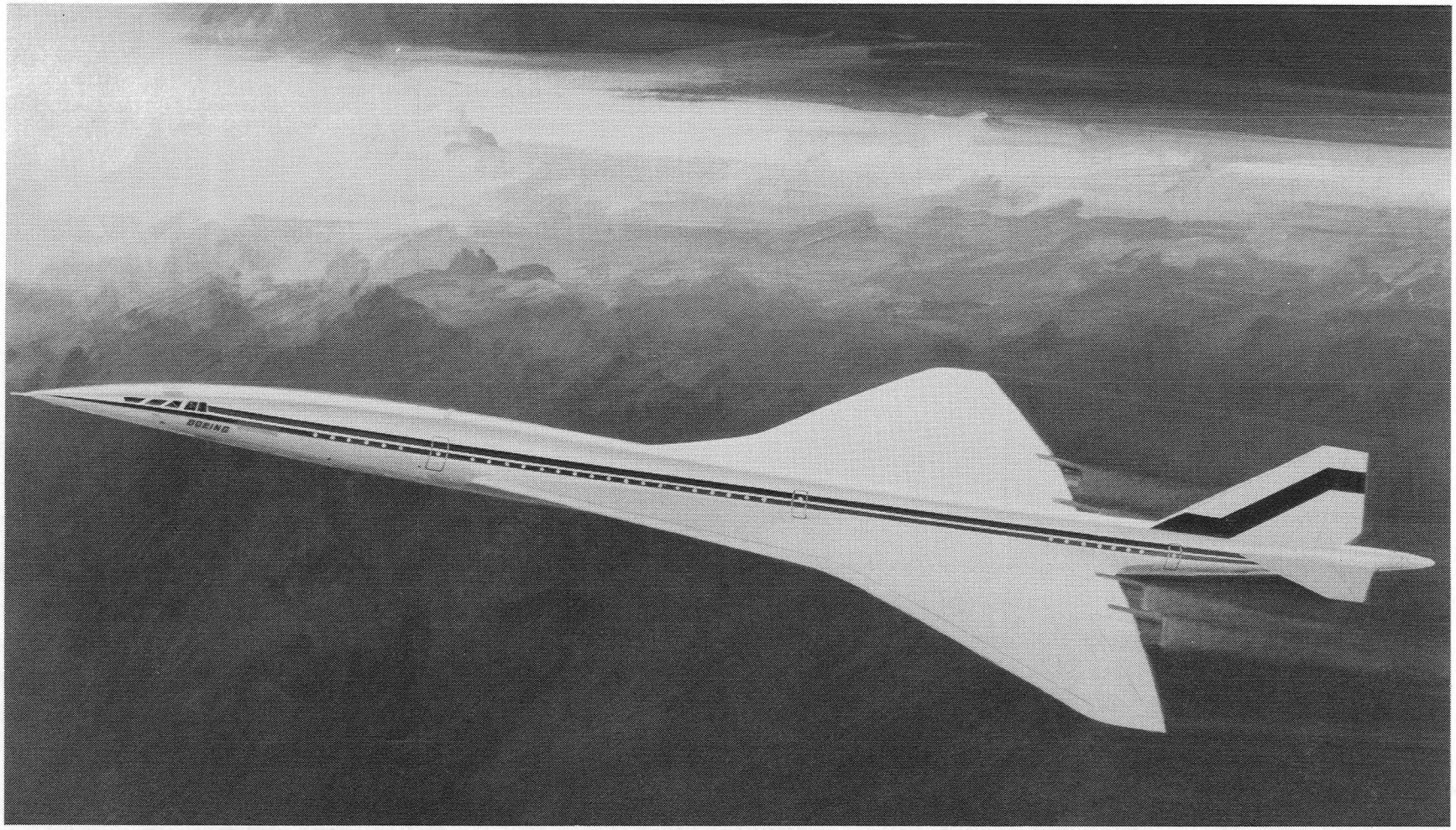
Figure 3. Supersonic transport aircraft concepts.



L-84-16

(b) Boeing arrow-wing concept.

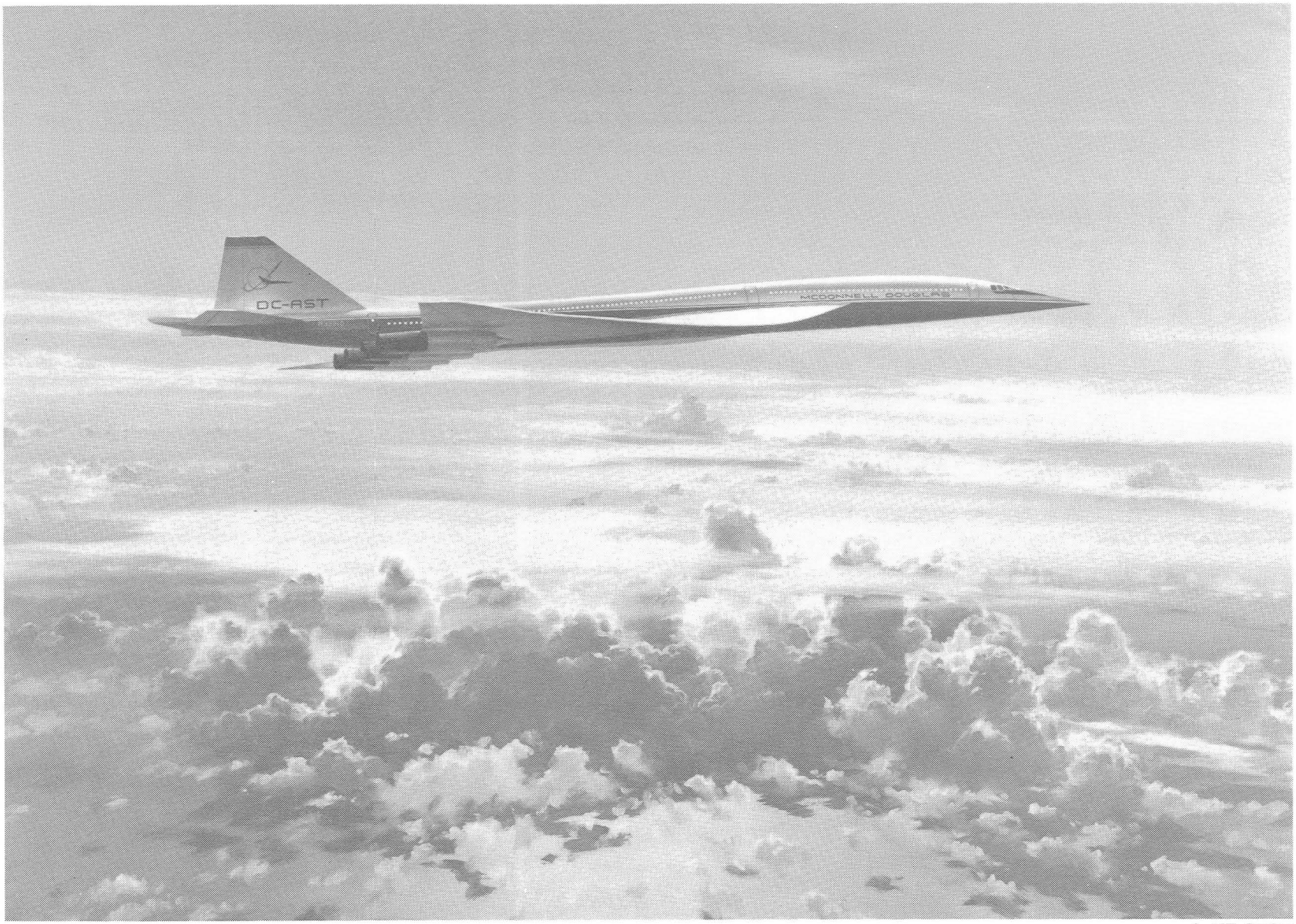
Figure 3. Continued.



L-84-17

(c) Boeing blended-wing concept.

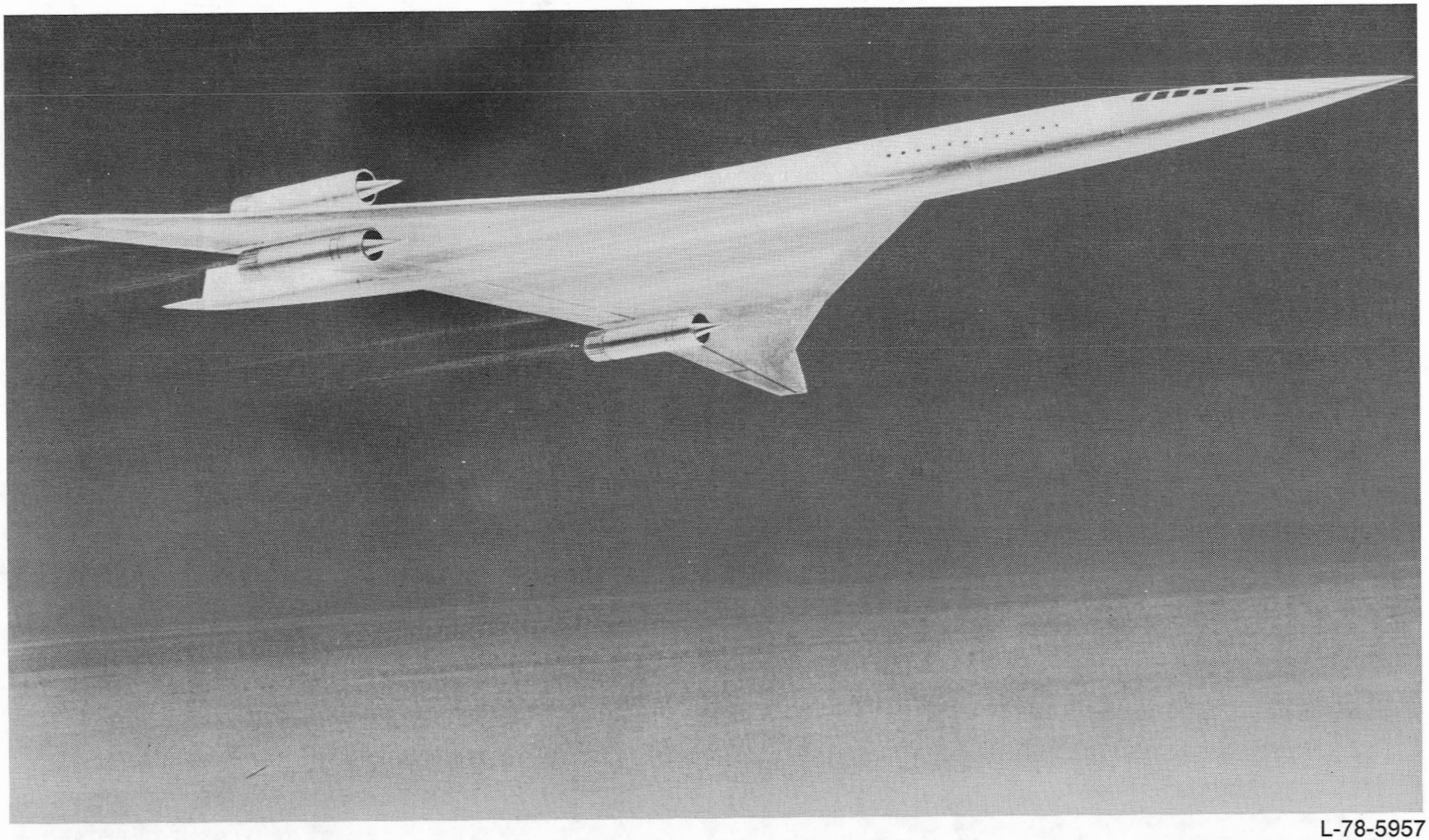
Figure 3. Continued.



L-77-2737

(d) Douglas arrow-wing concept.

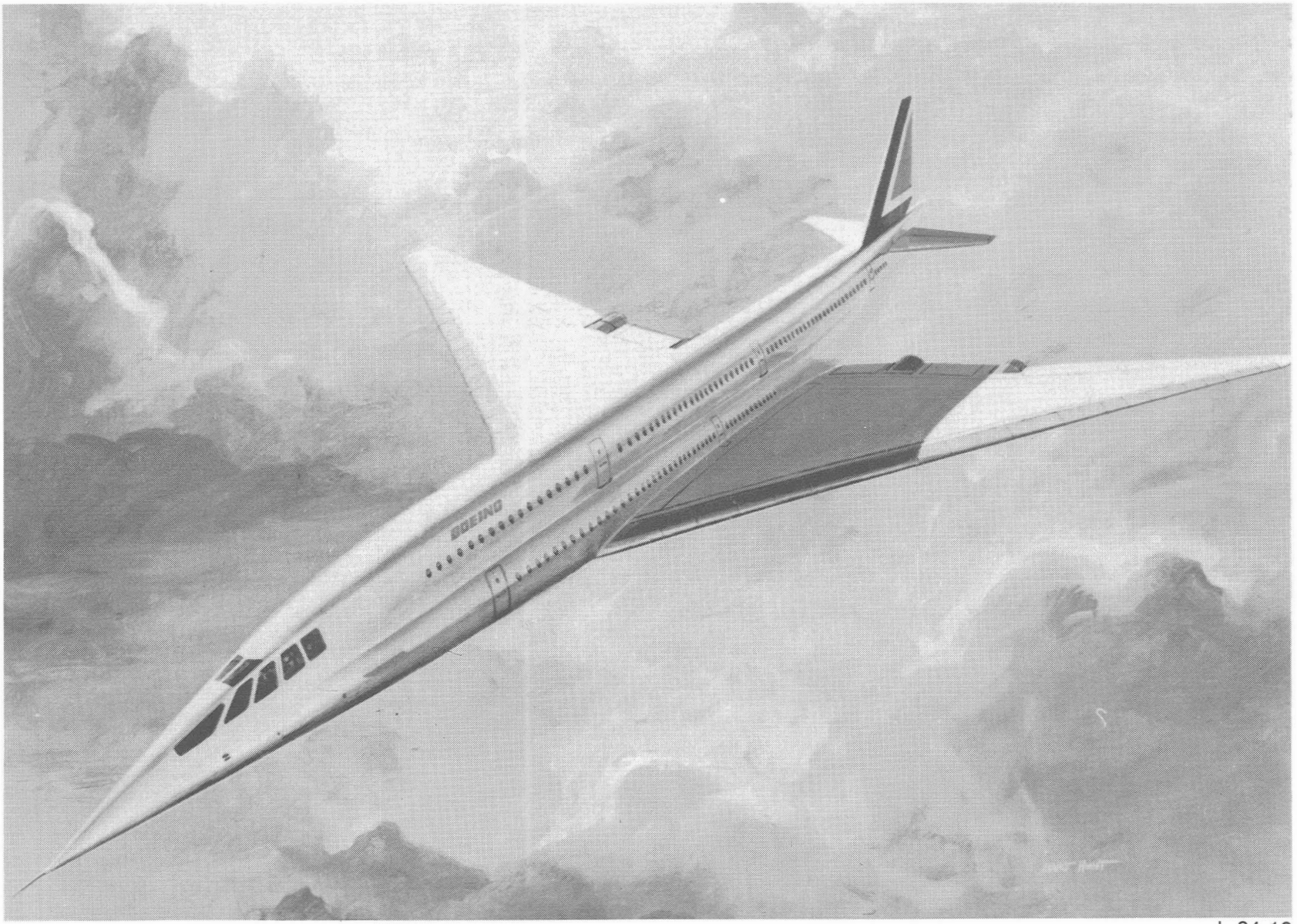
Figure 3. Continued.



L-78-5957

(e) Lockheed over/under, arrow-wing concept.

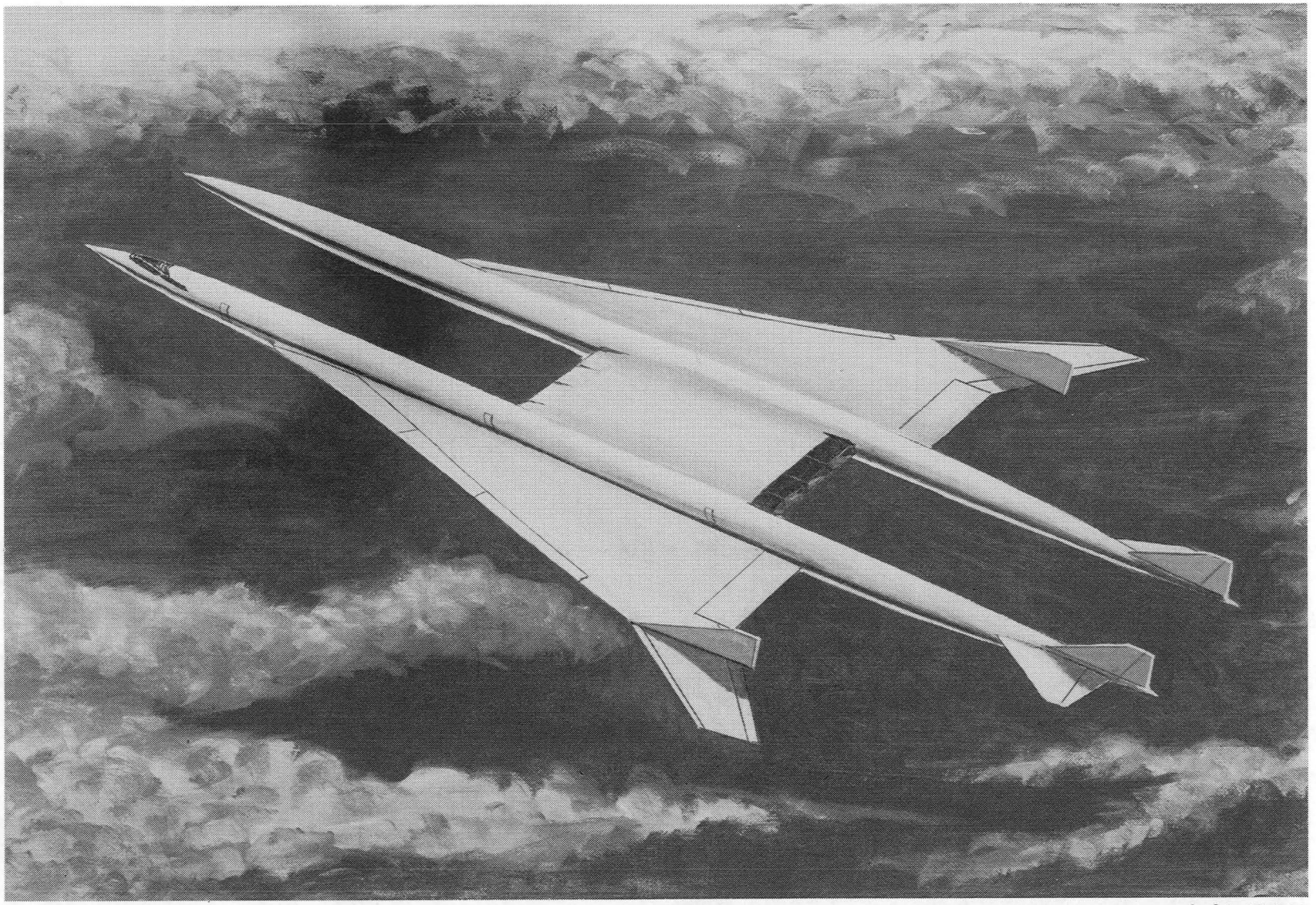
Figure 3. Continued.



L-84-18

(f) Boeing double-decker concept.

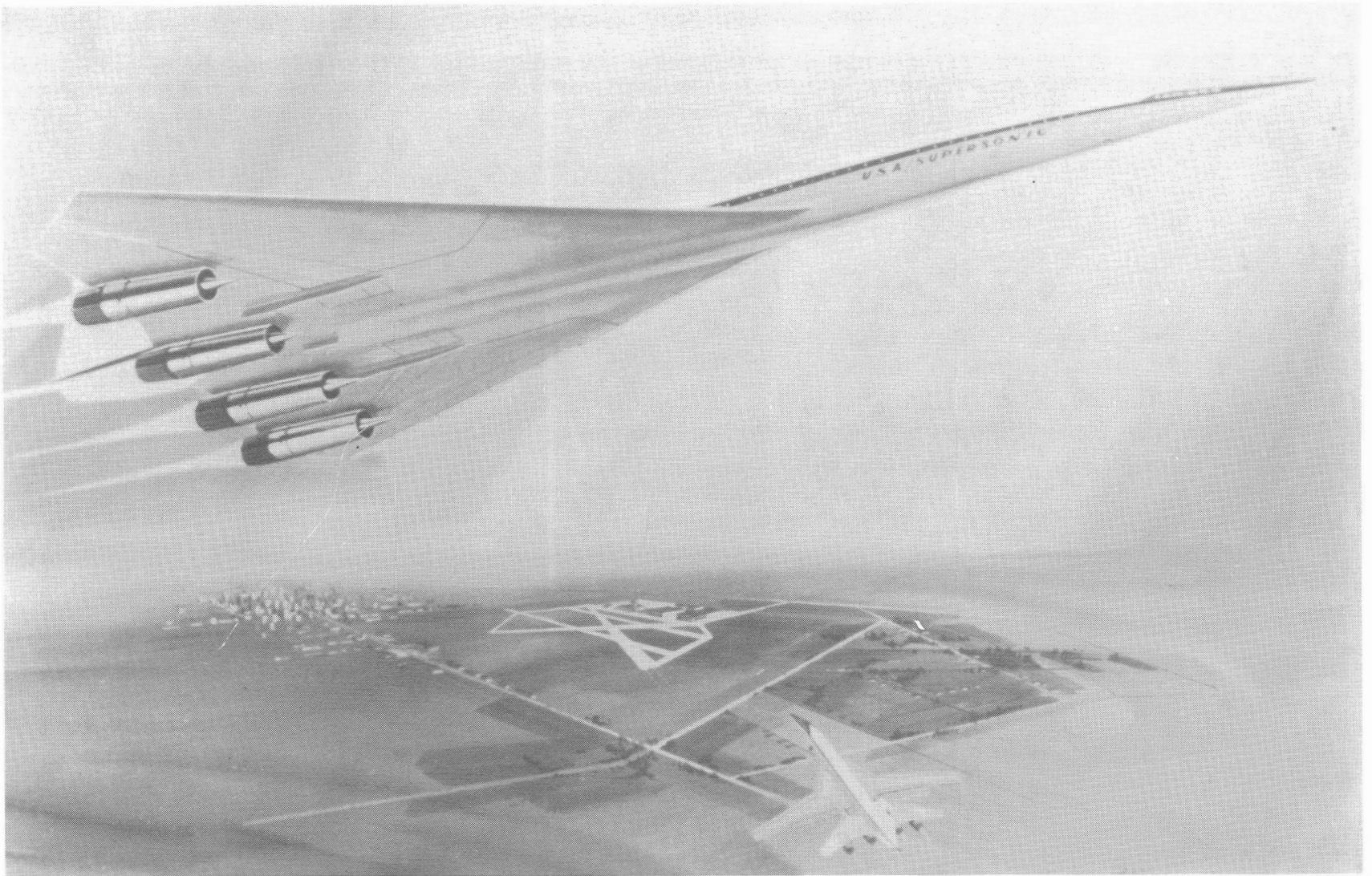
Figure 3. Continued.



L-81-12,023

(g) LRC/Kentron twin-fuselage concept.

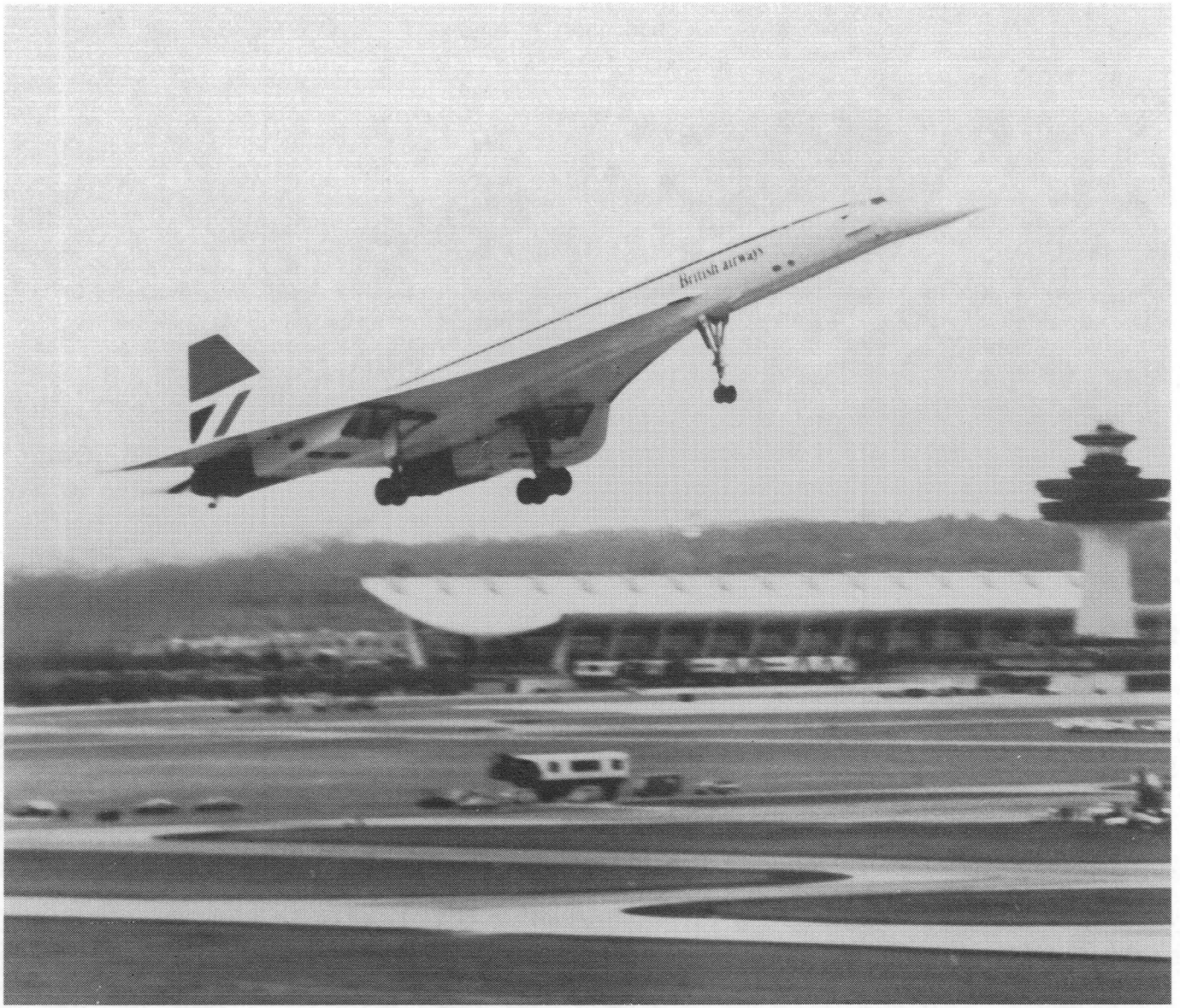
Figure 3. Continued.



L-79-6887

(h) USA/Boeing swing delta-wing concept (B-2707).

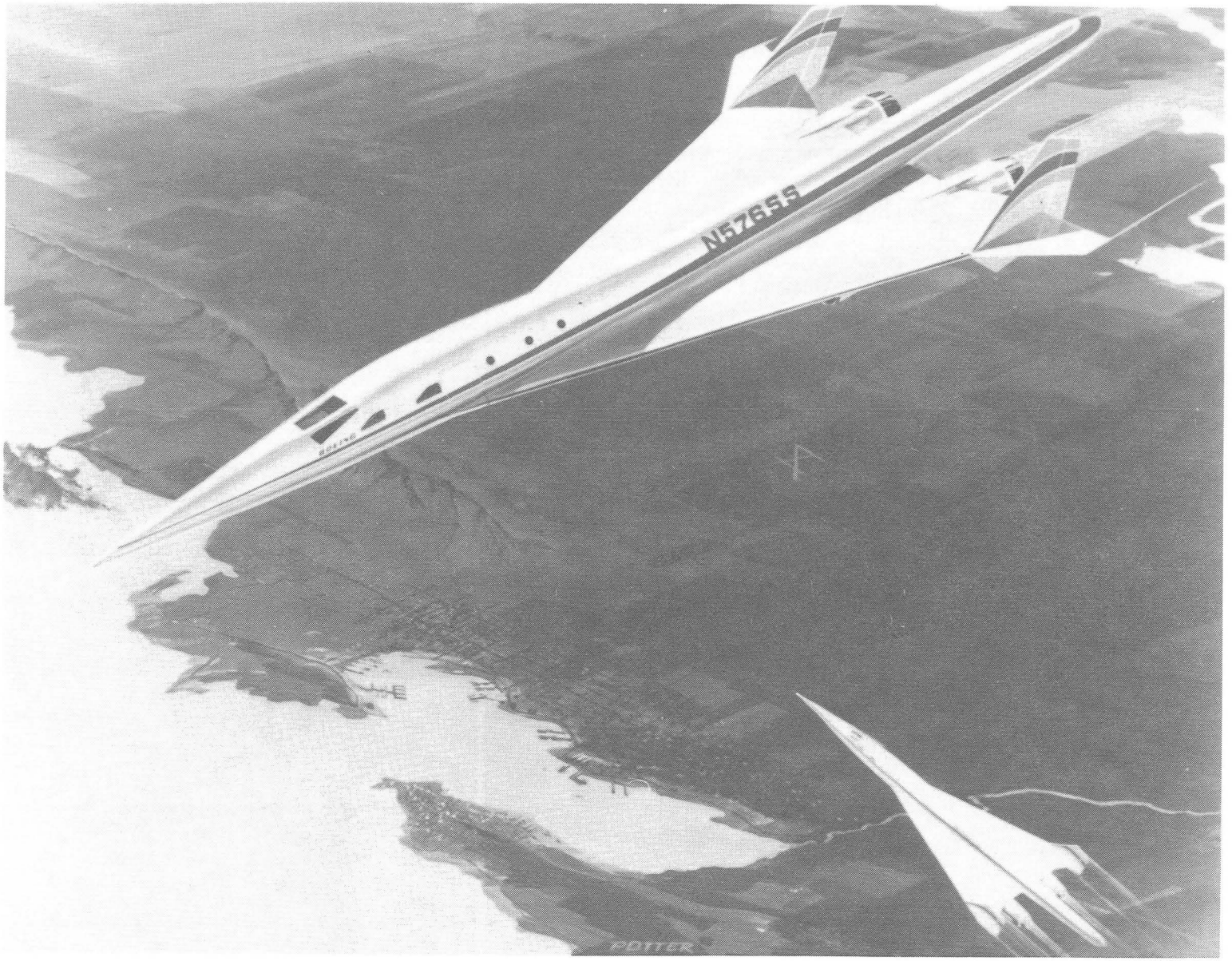
Figure 3. Continued.



L-82-1449

(i) British/French Concorde.

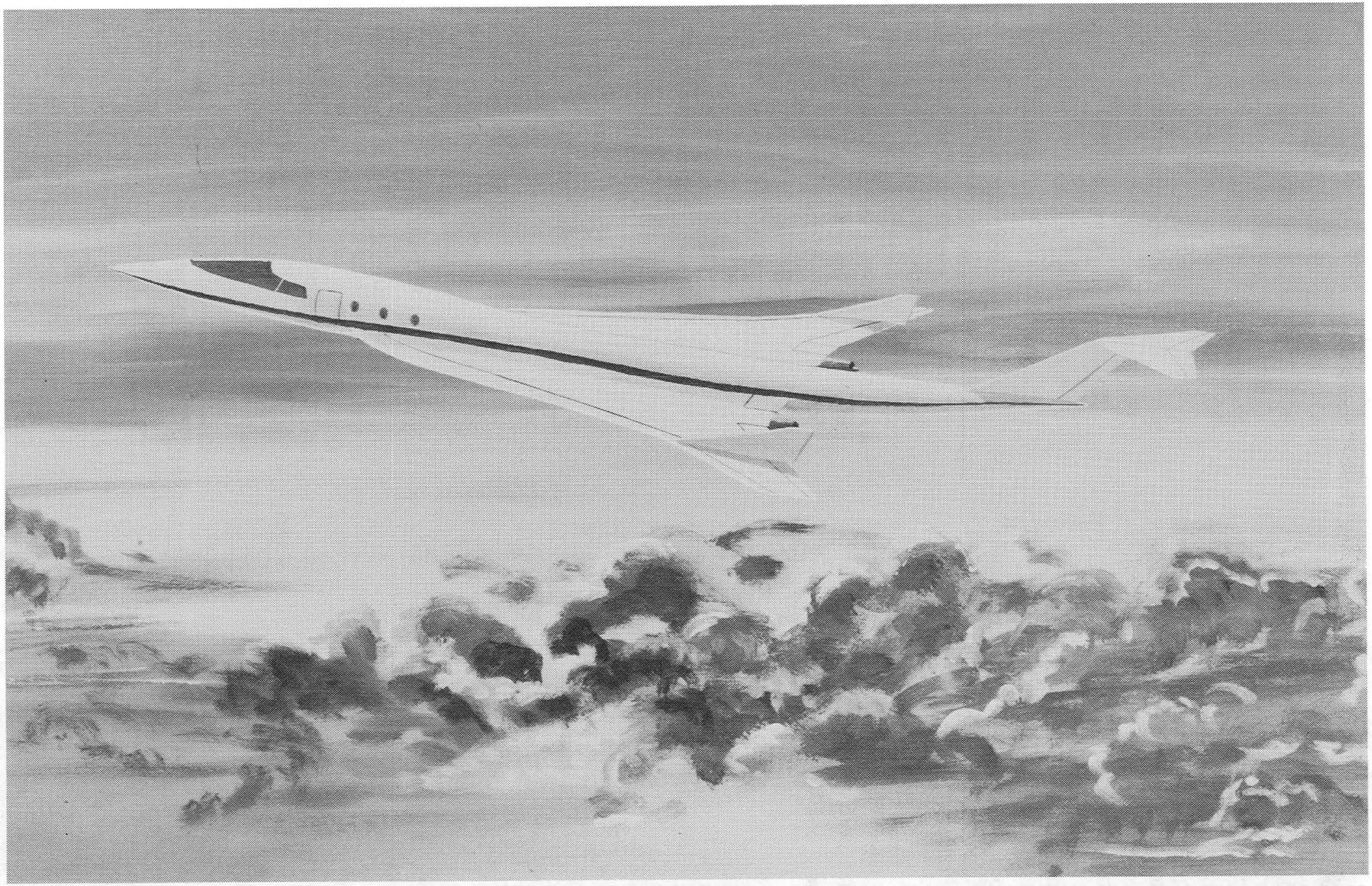
Figure 3. Continued.



L-80-9730

(j) Boeing executive-jet concept.

Figure 3. Continued.



L-80-7699

(k) LRC/Kentron executive-jet concept.

Figure 3. Concluded.

BIBLIOGRAPHIC ENTRIES

This bibliography covers the time period from 1980 to 1983. Two previous bibliographies, NASA RP-1003 and RP-1063, cover respectively the program years from 1972 to mid-1977 and from 1977 to mid-1980. For completeness, the present report also includes a few publications that were omitted earlier and some non- SCR papers which support the program. Unfortunately, some relevant classified papers and company reports are not generally available and therefore could not be included. When material was published in more than one form, the most recent and/or the most accessible document is cited.

The bibliography is alphabetically arranged by author according to system studies and the SCR/VCE disciplines[1] as follows:

Propulsion

Structures and materials

Aerodynamic performance

Stability and controls

The propulsion-system/airframe interaction discipline was initiated in fiscal year 1979 and is reported under propulsion. A multidisciplinary document is listed under the primary discipline addressed. For example, a document on unsteady aerodynamics is listed under structures and materials when it addresses structural criteria, loads, and design, and under aerodynamic performance when it addresses theoretical methodology and aerodynamics. The reports within each discipline are subdivided into three groups:

NASA Formal Reports

NASA Contractor Reports

Articles, Meeting Papers, and Company Reports

Abstracts are provided for all NASA formal reports and NASA contractor reports. License was taken to modify or shorten abstracts. Included with the citations are NASA accession numbers (when useful and available), contractors, and contract numbers. Indexes of authors and NASA report numbers are presented at the end of the bibliography. There are 123 NASA reports and 44 articles, meeting papers, and company reports cited in this document.

[1] There are no stratospheric emission impact (SEI) reports for this bibliography, and the SEI section is omitted.

SCR SYSTEM STUDIES

NASA Formal Reports

1. Supersonic Cruise Research '79. NASA CP-2108, 1980. (Part 1: X80-72343, Part 2: X80-72367)

Since 1972, the Supersonic Cruise Research (SCR) 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. Progress made in the first four years was highlighted in a conference at Langley Research Center in 1976. (See NASA CP-001, Parts 1 and 2.) Subsequent to the 1976 conference, NASA had conducted and monitored additional supersonic cruise vehicle studies and enhanced the advanced supersonic technology data base through further tests. Significant achievements in the interim since the previous conference were reported to the technical community at the SCR '79 Conference held at Langley Research Center, November 13–16, 1979. This document is a compilation of 43 papers, authored by representatives of airframe and engine manufacturers, the Federal Aviation Administration, three NASA research centers, and the Office of Technology Assessment (Congress of the United States), which were presented at the latter conference.

2. Astill, D. L.; and Jones, A. D.: **A Mathematical Model of a Supersonic Transport.** NASA TM-84242, 1983. (X83-10185)

The mathematical models and data used to simulate the flying qualities and characteristics of a supersonic transport, which was flown on the Flight Simulator for Advanced Aircraft (FSAA) at Ames Research Center, are described. The generalized equations, block diagrams, and data used by NASA, as well as the approximations and simplifications deemed necessary to produce a real-time aircraft simulation within the constraints of the available computing equipment, are included.

3. Baber, Hal T., Jr.: **Characteristics of an Advanced Supersonic Technology Transport (AST-106-1) Configured With Variable-Cycle Engines for Transpacific Range.** NASA TM-81879, 1982.

An advanced supersonic technology (AST) transport configuration (AST-106-1) has been defined by application of the following: an extensive aerodynamic data base; several computer programs such as aircraft sizing and performance, takeoff and approach performance, and noise prediction; and a new engine concept which has potential for noise reduction attributable to the coannular nozzle. This configuration has a transpacific range capability of 8438 km (4556 n.mi.) when cruising at a Mach number of 2.62 on a hot day (standard-day temperature + 8°C) with 273 passengers. Centerline and sideline traded noise are both in excess of the Federal Aviation Regulation limit. However, it appears that takeoff with accelerating climb followed by engine cutback can reduce the land area enclosed by the 108 EPNdB noise contour to about one-third that for the non-cutback condition. With a ticket price of approximately $220 (1976 dollars) for 100-percent load factor, the configuration could yield a rate of return of 15 percent.

4. Driver, Cornelius: **The Role of Technology as Air Transportation Faces the Fuel Situation.** NASA TM-81793, 1980. (N80-20260)

Perspectives on the air transportation fuel situation are discussed, including intercity air traffic, airline fuel consumption, fuel price effects on ticket price, and projected traffic and fuel usage between now and the year 2000. Actions taken by the airlines to reduce consumption are reviewed, as well as efforts currently under way to improve fuel consumption. Longer range technology payoffs resulting from NASA research programs are reviewed, and results from studies on the use of alternate fuels are discussed.

5. Fishbach, L. H.; Stitt, L. E.; Stone, J. R.; and Whitlow, J. B., Jr.: **NASA Research in Supersonic Propulsion—A Decade of Progress.** NASA TM-82862, 1982.

At the close of the United States' attempt in the commercial supersonic transport market in the early 1970's, both the government and the aircraft industry recognized that significant technical advancements would be required to make a second generation supersonic aircraft economically viable and environmentally acceptable. Consequently, in 1972, NASA initiated a limited effort to advance supersonic technology. The intent was to identify and investigate areas requiring new and/or improved technology that would lead to substantial improvements in performance. This paper describes the in-house and contracted efforts of NASA Lewis Research Center in the areas of engine selection, test-bed experiments, and noise reduction research over the decade from 1972 to the termination of the effort in 1981.

6. FitzSimmons, Richard D.: **Effects of an AST Program on U.S. Titanium Story.** Supersonic Cruise Research '79—Part 2, NASA CP-2108, 1980, pp. 713-736. (In X80-72367)

The singular importance of titanium as the primary structural material for an efficient advanced supersonic transport (AST) is outlined. The advantages of titanium over other metals are shown to apply to future subsonic aircraft as well as to supersonic designs. The cost problem of titanium is addressed and shown to be markedly reduced by the emerging technologies of superplastic forming/diffusion-bonding sandwich and hot isostatic pressing of titanium powders; also, isothermal forging (IF) demonstration programs should validate preliminary findings. The impact of an AST program on the United States titanium supply and demand picture is postulated.

7. Foss, Willard E., Jr.: **A Computer Technique for Detailed Analysis of Mission Radius and Maneuverability Characteristics of Fighter Aircraft.** NASA TP-1837, 1981.

A computer technique to determine the mission radius and maneuverability characteristics of combat aircraft was developed. The technique was used to determine critical operational requirements and the areas in which research programs would be expected to yield the most beneficial results. In turn, the results of research efforts were evaluated in terms of aircraft performance on selected mission segments and for complete mission profiles. Extensive use of the technique in evaluation studies indicates that the calculated performance is essentially the same as that obtained with the proprietary programs in use throughout the aircraft industry.

8. Grantham, William D.; Smith, Paul M.; and Deal, Perry L.: **A Simulator Study for the Development and Evaluation of Operating Procedures on a Supersonic Cruise Research Transport To Minimize Airport-Community Noise.** NASA TP-1742, 1980.

Piloted-simulator studies have been conducted to determine for a supersonic cruise research transport concept takeoff and landing operating procedures that result in predicted noise levels which meet current Federal Aviation Administration (FAA) certification standards. The results indicate that with the use of standard FAA noise-certification test procedures, the subject simulated aircraft did not meet the FAA traded-noise-level standards during takeoff and landing. However, with the use of advanced procedures, this aircraft meets the traded-noise-level standards for flight crews with average skills. The advanced takeoff procedures developed involved violating some of the current Federal Aviation Regulations (FAR), but it was not necessary to violate any FAR noise-test conditions during landing approach. Noise contours were also determined for some of the simulated takeoffs and landings in order to indicate the noise-reduction advantages of using operational procedures other than standard. The takeoff and landing approach procedures, developed and evaluated during this study, did not compromise flight safety.

9. Hoffman, Sherwood; and Varholic, Mary C.: **Contracts, Grants, and Funding Summary of Supersonic Cruise Research and Variable-Cycle Engine Technology Programs—1972-1982.** NASA TM-85650, 1983.

The NASA-SCAR (AST) program was initiated in 1972 at the direct request of the Executive Office of the White House and Congress following termination of the U.S. SST Program. The purpose of SCR was to conduct a focused research and technology program on those technology problems which contributed to the SST termination and, also, to provide an expanded data base for future civil and military supersonic transport aircraft. Funding for the Supersonic Cruise Research (SCR) Program was initiated in fiscal year 1973 and terminated in fiscal year 1981. The program was implemented through contracts and grants with industry, universities, and by in-house investigations at the NASA/OAST centers. The studies included system studies and five disciplines: propulsion, stratospheric emissions impact, materials and structures, aerodynamic performance, and stability and control. The NASA/Lewis Variable-Cycle Engine (VCE) Component Program was initiated in 1976 to augment the SCR program in the area of propulsion. After about two years, the title was changed to VCE Technology Program. The total number of contractors and grantees on record at the AST office in 1982 was 101 for SCR and 4 for VCE. The net research and development costs for both programs was about 104 million dollars.

10. Molloy, John K.; Grantham, William D.; and Neubauer, Milton J., Jr.: **Noise and Economic Characteristics of an Advanced Blended Supersonic Transport Concept.** NASA TP-2073, 1982.

Noise and economic characteristics were obtained for an advanced supersonic transport concept that utilized wing-body blending, a double-bypass variable-cycle engine, superplastically formed and diffusion-bonded titanium in both the primary and secondary structures, and an alternative interior arrangement that provides increased seating capacity. The configuration has a cruise Mach number of 2.62, provisions for 290 passengers, a mission range of 4423 n.mi., and an average operating cruise lift-drag ratio of 9.23. Advanced operating procedures, which have the potential to reduce airport-community noise, were explored by using a simulator. Traded jet noise levels of 105.7 and 103.4 EPNdB were obtained by using standard and advanced takeoff operational procedures, respectively. A new method for predicting lateral attenuation was utilized in obtaining these jet noise levels. Therefore, if jet noise is considered representative of total noise, it appears that a supersonic transport could achieve the noise levels required by Federal Aviation Regulations, part 36, stage 2. Direct and total operating costs were calculated. Total operating costs of approximately 5.5 cents/passenger-km (10 cents/passenger-n.mi.) and a fuel efficiency of 16.4 seat-km/L (33.6 seat-n.mi./gal) were predicted for the design range and load factor of 100 percent.

11. Morris, Shelby J., Jr.; Foss, Willard E., Jr.; and Neubauer, Milton J., Jr.: **Conceptual Study of an Advanced Supersonic Technology Transport (AST-107) for Transpacific Range Using Low-Bypass-Ratio Turbofan Engines.** NASA TM-81872, 1980. (N80-33342)

A new advanced supersonic technology configuration concept (AST-107) which uses a low bypass-ratio-turbofan engine is described and analyzed. The aircraft had provisions for 273 passengers arranged 5 abreast. The cruise Mach number was 2.62. The mission range for the AST-107 was 4576 n.mi., and an average lift-drag ratio of 9.15 during cruise was achieved. The available lateral control was not sufficient for the required 15.4 m/s (30 knots) crosswind landing condition, and a crosswind landing gear or a significant reduction in dihedral effect would be necessary to meet this requirement. The lowest computed noise levels, including a mechanical

suppressor noise reduction of 3 EPNdB at the flyover and sideline monitoring stations, were 110.3 EPNdB (sideline noise), 113.1 EPNdB (centerline noise), and 110.5 EPNdB (approach noise).

NASA Contractor Reports

12. *Ausrotas, Raymond A.: **Predicting the Impact of New Technology Aircraft on International Air Transportation Demand.** NASA CR-165654, 1981.

International air transportation to and from the United States is analyzed. Long-term and short-term effects and causes of travel are described. The applicability of econometric methods to forecast passenger travel is discussed. A nomograph is developed which shows the interaction of economic growth, airline yields, and quality of service in producing international traffic.

*Flight Transportation Laboratory, contract NAS1-15268.

13. *Beissner, F. L., Jr.; Lovell, W. A.; Robins, A. Warner; and Swanson, E. E.: **Effect of Advanced Technology and a Fuel-Efficient Engine on a Subsonic-Cruise Executive Jet With a Small Cabin.** NASA CR-172190, 1983.

An analytical study of a supersonic-cruise, executive, jet aircraft has indicated the effects of using advanced technology. The twin-engine, arrow-wing vehicle was configured with a cabin of minimum practical size to hold one pilot, eight passengers, and their baggage. The primary differences between this configuration and that of a previous report were the reduction in cabin size and the use of engines that are more fuel efficient. Both conceptual vehicles are capable of performing the same mission. The current vehicle has a range of 3350 n.mi. at Mach 2.3 cruise and 2700 n.mi. at Mach 0.9. The concept description includes configuration definition, aerodynamic and propulsion-system characteristics, and mass properties. Performance analyses are documented for intercontinental and transcontinental flight profiles. In the latter case, a reduction in sonic-boom overpressure from 1.3 to 1.0 lb/ft^2 was achieved by varying the flight profile slightly from that for optimum performance.

*Kentron International, Inc., contract NAS1-16000.

14. *Boeing Commercial Airplane Co.: **Advanced Concept Studies for Supersonic Vehicles.** NASA CR-159244, 1980.

In the past few years, technical studies have been performed to define the characteristics and research requirements for future supersonic cruise aircraft that would offer superior performance, reduced fuel consumption, and less noise and environmental impact, as well as economical acquisition and operating cost. As a result, many technical advances, important to the design of supersonic cruise aircraft, have emerged. At the same time, environmental and performance goals that such airplanes will have to meet have become more clearly defined and are more stringent. In response to these new goals, specific technological advances have been identified, developed, and verified to some extent. Some of these advances are reported in this document and it is shown that their judicious integration into practical airplane design concepts is feasible. Thus, the features, performance, and economic capabilities of possible future supersonic cruise aircraft are beginning to emerge. The studies were supported by General Electric and Pratt & Whitney Aircraft to provide data for respective variable-cycle engines, by The Pace Company of Houston to provide crude oil and refinery data projected for the late 1990's, and by Pratt & Whitney Aircraft to evaluate the impact of candidate fuels on engine design and operation. Areas of future required research are recommended to establish technology feasibility and to verify the potential of future efficient and economical supersonic cruise aircraft and variable-cycle engines.

*Boeing Commercial Airplane Co., contract NAS1-14623.

15. *Boeing Commercial Airplane Co.: **Advanced Concept Studies for Supersonic Vehicles.** NASA CR-165771, 1981. (X82-10002)

In the past few years, technical studies have been performed to define the characteristics and research requirements for future supersonic cruise aircraft that would offer superior performance, reduced fuel consumption, and less noise and environmental impact, as well as economical acquisition and operating cost. As a result, many technical advances important to the design of supersonic cruise aircraft have emerged. At the same time, environmental and performance goals that such airplanes will have to meet have become more clearly defined and are more stringent. In response to these new goals, specific technological advances have been identified, developed, and verified to some extent. Some of these advances are reported in this document, and it is shown that their judicious integration into practical airplane design concepts is feasible. Thus, the features, performance, and economic capabilities of possible future supersonic cruise aircraft are beginning to emerge. The studies were supported with data from General Electric and Pratt & Whitney Aircraft for respective variable-cycle engines, and by the Vought Corporation, which provided data on advanced control surface actuator concepts. Areas of future required research are recommended to establish technology feasibility and to verify the potential of future efficient, economical supersonic cruise aircraft and variable-cycle engines.

*Boeing Commercial Airplane Co., contracts NAS1-14623 and NAS1-16150.

16. *Bruckman, F. A.; Clauss, J. S., Jr.; Bangert, L. H.; Sakata, I. F.; Godby, L.; and Sarames, G. N.: **Integrated Technology Studies for Advanced Supersonic Cruise Vehicles.** NASA CR-165819, 1981.

A compilation of engineering analysis and testing of integrated technology studies for advanced supersonic cruise vehicles (SCV) is provided. A systems study involving selective in-depth design, analysis, and testing of significant aircraft components for possible future

commercial transports was made. The major technical areas studied were: propulsion/airframe integration, subsonic flight noise attenuation, advanced aluminum alloy powder metallurgy, and advanced hybrid structural concepts. Economic viability of the supersonic cruise vehicle potential markets for supersonic transports are identified, giving considerations to aircraft range, route restrictions, and subsonic traffic that is divertible to SCV aircraft.

*Lockheed-California Co., contract NAS1-16048.

17. *Carichner, G. E.: **Investigation of a Mach 2.55 Cruise Aircraft Design With an Over/Under Engine Arrangement at Mach Numbers = 0.6 to 2.7.** NASA CR-159314, 1980. (X80-10230)

The Lockheed-California Co. has designed and tested a high-speed wind tunnel model based on the Lockheed Supersonic Cruise Vehicle (SCV) configuration under NASA Contract NAS1-15314. This configuration is of interest because it places the engines in an over/under arrangement rather than the conventional four-engines-under-the-wing arrangement. Using a NASA/Boeing wing-design program, the wing was cambered for minimum induced drag at a cruise Mach number of 2.55. The selection of the NASA/Boeing design program was based on preliminary efforts which compared the prediction capability of three known aerodynamic analysis programs. Existing data bases for the McDonnell Douglas Corp. (MDC) AST and NASA SCAT-15F were used for comparison. An aerodynamic data base (force and pressure) has been generated for the Lockheed SCV configuration from tests conducted in the Lockheed 4 feet by 4 feet wind tunnel. The data were obtained to assess the aerodynamic prediction capability of known analysis methods. The test data indicate that the over/under engine arrangement poses no unusual drag problem as compared to the conventional four-under configuration. A widebody (8-abreast rather than 6-abreast seating) configuration was also tested, and the data indicate a 6 to 7 percent lower L/D. Aerodynamic data comparisons between theory and experiment show fair agreement for the wing-body near the 2.55 design Mach number. The agreement with predicted drag, however, is poor for off-design Mach numbers and/or when nacelles are added.

*Lockheed-California Co., contract NAS1-15314.

18. *Clauss, J. S., Jr.; Bruckman, F. A.; Bangert, L. H.; Carichner, G. E.; Guess, M. K., Jr.; Hays, A. P.; Jurey, L.; and Sakata, I. F.: **Supersonic Cruise Vehicle Technology Assessment Study of an Over/Under Engine Concept.** NASA CR-159247, 1980.

This report describes the work completed by Lockheed during the FY 1979 NASA LaRC Supersonic Cruise Vehicle Technology Assessment studies. Analytical planform studies are conducted to examine the variation of supersonic cruise lift-drag ratio, weight, and mission range due to arrow wing planform changes such as sweep, aspect ratio, and notch ratio. Airframe/propulsion integration studies include inlet technology and low speed aerodynamic/acoustic tasks for supersonic inlets. Preferred inlets are selected for Mach 2.0 and 2.3 cruise speeds and the performance compared with that for Mach 2.55 baseline vehicles. A preferred auxiliary inlet system is selected for the aero/acoustic task; preliminary model design and formulation of a test plan also are accomplished. Takeoff noise reduction studies address noise attenuation by optimizing flap and throttle schedules as well as flight path shape. Both heuristic and mathematical optimization approaches are included. The application of active controls technology to a supersonic cruise vehicle is assessed with respect to the integration of requirements for longitudinal handling qualities, flutter suppression, and dynamic load and ride quality characteristics associated with gust response. The development of a family of aluminum alloys, having specific properties comparable to titanium alloys, is initiated.

*Lockheed-California Co., contract NAS1-14625.

19. *DaCosta, R. A.; Espil, G. J.; Everest, D. L., Jr.; Lovell, W. A.; Martin, G. L.; Swanson, E. E.; and Walkley, K. B.: **Concept Development Studies for a Mach 2.7 Supersonic Cruise Business Jet.** NASA CR-165705, 1981.

The development of a revised and improved version of an advanced supersonic cruise business jet aircraft concept is discussed. The impact of applying advanced technologies on the performance and characteristics of this type vehicle was determined. The aircraft was configured for a maximum cruise Mach number of 2.7. Performance analysis was conducted at Mach 2.62 cruise on a standard plus 8°C day condition for a 5926 km (3200 n.mi.) range with a payload of 8 passengers plus baggage. Superplastic formed/diffusion bonded primary structure was assumed and resulted in a maximum gross weight of 284 686 N (64 000 lbf).

*Kentron International, Inc., contract NAS1-16000.

20. *Goebel, T. P.; and Bonner, K. E.: **Advanced Supersonic Cruise Aircraft Blended Wing/Body Study.** NASA CR-159289, 1980.

A study has been conducted to evaluate the potential improvement in AST performance due to wing-body blending. Wing leading-edge planform blending was relatively small due to the high sweepback angle (74°) of the baseline leading edge. Wing trailing-edge blending to provide good low-speed flap effectiveness results in a drag penalty at supersonic cruise. Optimization to achieve minimum volume wave drag or total wave drag transferred wing volume to the fuselage with minimal cross-section blending. Optimization to minimize drag due to lift had to be constrained to give a practical mounting of the wing onto the fuselage. Viscous optimization was implicitly pursued by minimizing wetted area consistent with volume requirements. A transport configuration was defined by allowing optimization programs to seek the best wing body shape with underslung axisymmetric nacelles. Due to reduced drag and structural weight, 6 to 14 percent

less fuel per passenger-kilometer was used than in three earlier unblended transport studies.

*Rockwell International Corp., contract NAS1-15720.

21. *Howison, W. W.; and Cronin, M. J.: **Electronic/Electric Technology Benefits Study.** NASA CR-165890, 1982.

In this study, the benefits and payoffs of advanced electronic/electric technologies were investigated for three types of aircraft. The technologies evaluated in each of the three airplanes included advanced flight controls, advanced secondary power, advanced avionic complements, new cockpit displays, and advanced air traffic control techniques. For the advanced flight controls, the "near term" considered relaxed static stability (RSS) with mechanical backup; the "far term" considered an advanced fly-by-wire system for a longitudinally unstable airplane. In the case of the secondary power systems, trades were made in two steps: in the near term, engine bleed was eliminated; then, in the far-term bleed air, air plus hydraulics were eliminated. Using three commercial aircraft in the 150-, 350-, and 700-passenger range, the study quantified by means of Lockheed's Advanced System Synthesis and Evaluation Techniques (ASSET) program the technology value and payoffs, with emphasis on the fiscal benefits. Weight reductions deriving from fuel saving and other system improvements were identified, and the weight savings were cycled for their impact on TOGW (takeoff gross weight) and upon the performance of the airframes/engines. Maintenance, reliability, and logistic support were the other study criteria. The conclusions of the study are that all three aircraft benefit by the advanced avionic/electric technologies to a varying degree. The air traffic control technology, the all electric airplane, and advanced all-electric flight controls offered the most attractive payoffs, with the other technologies offering lesser benefits. Typically, the study identified direct operating cost (DOC) reductions of 10 percent to 20 percent and weight reductions of 13 000 to 77 000 lb. Details of fleet size, service life, fuel costs, and other pertinent data are included in the report.

*Lockheed-California Co., contract NAS1-16199.

22. *Hunt, R. B.; et al.: **Noise and Economic Study for Supersonic Cruise Airplane Research.** NASA CR-165423, 1981.

Analytical comparisons of engine/airplane direct operating cost versus traded noise were generated for three study engines based on the National Aeronautics and Space Administration Advanced Supersonic Transport (AST)-105-1 airplane concept adjusted to a design range of 7408 km (4000 n.mi.). The three study engines evaluated were the Low Bypass Engine (LBE), Variable Stream Control Engine (VSCE), and Inverted Flow Engine (IFE). The economic comparisons were evaluated on a 5926-km (3200-n.mi.) mission with a 556-km (300-n.mi.) subsonic leg, which was chosen as being representative of North Atlantic service.

*Pratt & Whitney Aircraft Group, Commercial Products Div., contract NAS3-22111.

23. *Hunt, R. B.; et al.: **Noise and Economic Study for Supersonic Cruise Airplane Research—Phase II.** NASA CR-165613, 1982.

Analytical estimates of engine/airplane direct operating cost versus traded noise were generated for a single-spool turbine bypass concept (VCE-702) based on the NASA Advanced Supersonic Transport (AST-105-1) airplane concept adjusted to a design range of 7408 km (4000 n.mi.). Comparisons were made to the Low Bypass Engine, the Inverted Flow Engine, and the Variable Stream Control Engine on a 5926-km (3200-n.mi.) subsonic leg, which was chosen as being representative of North Atlantic Service. The turbine bypass concept appears to be a viable approach to improve the off-design performance characteristics of a turbojet without significant compromise in nonaugmented thrust capability for a supersonic cruise vehicle.

*Pratt & Whitney Aircraft Group, Commercial Products Div., contract NAS3-22111.

24. *Jacobson, Ira D.; and Kuhlthau, A. Robert: **Identification of Terms to Define Unconstrained Air Transportation Demands.** NASA CR-165961, 1982.

The factors involved in the evaluation of unconstrained air transportation systems have been carefully analyzed. By definition, an unconstrained system is taken to be one in which the design can employ innovative and advanced concepts no longer limited by present environmental, social, political, or regulatory settings. It is found that four principal evaluation criteria are involved: (1) service utilization, based on the operating performance characteristics as viewed by potential patrons; (2) community impacts, reflecting decisions based on the perceived impacts of the system; (3) technological feasibility, estimating what is required to reduce the system to practice; and (4) financial feasibility, predicting the ability of the concepts to attract financial support. For each of these criteria, a set of terms or descriptors has been identified, which should be used in the evaluation to render it complete. It is also demonstrated that these descriptors have the following properties: (a) their interpretation may be made by different groups of evaluators; (b) their interpretations and the way they are used may depend on the stage of development of the system in which they are used; and (c) in formulating the problem, all descriptors should be addressed independent of the evaluation technique selected. Although the work is not concerned with evaluation techniques, the results of using the descriptor for the evaluation of a specific problem are discussed.

*University of Virginia, contract NAS1-14908.

25. *Kelly, R.; Tyson, R. M.; Dunn, K. M.; Berry, J. V.; Sherrill, D. E.; Lancon, C. J.; Robinson, D. A.; and Cassidy, J. E.: **Study of a Small Supersonic Cruise Research Business Jet.** NASA CR-159226, 1980.

A study was conducted to define a small supersonic cruise vehicle which could validate the critical supersonic cruise technologies. The study involved a comparison of a 1984 state-of-the-art (SOA) multimode integrated propulsion system (MMIPS) and a 1984 SOA GE21 Variable Cycle Engine (VCE) propulsion system installed in a small supersonic cruise vehicle capable of carrying 8 to 10 passengers. The aircraft were designed for a transatlantic range of 5926 km (3200 n.mi.) with cruise at Mach 2.7. The aircraft were sized to the same range, constrained to a 2591-m (8500-ft) balanced field length, and then compared at the same sideline noise level. The MMIPS was found to be the heavier propulsion system, although it had superior performance except in the supersonic cruise leg. The single inlet requirement for MMIPS when installed in a small vehicle was a major penalty.

*Rockwell International Corp., contract NAS1-15720.

26. *Martin, Glenn L.; and Walkley, Kenneth B.: **Aerodynamic Design and Analysis of the AST-204, -205, and -206 Blended Wing-Fuselage Supersonic Transport Configuration Concepts.** NASA CR-159223, 1980. (N80-20232)

The aerodynamic design and analysis of three blended wing-fuselage supersonic cruise configurations providing four-, five-, and six-abreast seating has been conducted using a previously designed supersonic cruise configuration as the baseline. The five-abreast configuration was optimized for wave drag at a Mach number of 2.7. The four- and six-abreast configurations were also optimized at Mach 2.7, but with the added constraint that the majority of their structure be common with the five-abreast configuration. Analysis of the three configurations indicated an improvement of 6.0, 7.5, and 7.7 percent in cruise lift-drag ratio over the baseline configuration for the four-, five-, and six-abreast configurations, respectively. Validation of the design is planned through supersonic wind tunnel tests.

*Kentron International, Inc., contract NAS1-16000.

27. *Pratt & Whitney Aircraft Group: **Technology Application Study of an Advanced Supersonic Cruise Vehicle. Phase 7—Advanced Supersonic Propulsion Studies.** NASA CR-159323, 1980. (X80-10121)

This report summarizes a contracted study of supersonic propulsion systems conducted for the McDonnell Douglas Corp. by Pratt & Whitney Aircraft. This study, referred to as Phase 7, was conducted during the period from March 1979 to December 1979. Phase 7 was part of an overall Supersonic Cruise Research (SCR) study sponsored by NASA Langley Research Center under contract number NAS1-14624 and was a continuation of the integration studies performed by Pratt & Whitney Aircraft for McDonnell Douglas Corp. in Phase 6. The scope of work consisted of conducting propulsion refinement analyses for two Pratt & Whitney Aircraft engine concepts, a Variable Stream Control Engine (VSCE) and a Low Bypass Engine (LBE), establishment of a VSCE automated teleprocessing communications system, and a detailed performance assessment of the Pratt & Whitney Aircraft candidate nozzle exhaust systems for the LBE. The main conclusion derived from this work is that both engine concepts are fully compatible with the advanced supersonic cruise vehicle defined by McDonnell Douglas.

*Pratt & Whitney Aircraft Group, contract NAS1-14624.

28. *Preliminary Design Dep., Boeing Commercial Airplane Co.: **Large Payload Capacity SST Concept—Technical and Economic Feasibility.** NASA CR-165934, 1982.

A matrix of configuration possibilities was investigated for large payload capacity (500–700 passengers), supersonic transport configurations. The matrix of fuselages included circular, double-deck, side-by-side multilobe, and twin-body options. Integration with delta- and arrow-wing planforms was studied. Overall trends of supersonic aerodynamic efficiency versus number of passengers were defined and show a decrease that varies between 0.2 and 1.6 percent for each 100-passenger increase, depending upon configuration choice. Preliminary investigations of large payload concept structural characteristics showed all structural design requirements can be met at acceptable weight. Judicious application of graphite-composite material to primary structure showed an OEW-reduction potential of up to 10 percent. These large weight savings alone were estimated to improve fuel efficiency 30 percent on a long-range SST—an improvement twice as great as on subsonic long-range airplanes because of the peculiar sensitivity of SST's to changes in airplane empty weight. Studies of subsystems, that is, flight control actuation, environmental control, thermal management, and flight management systems and passenger accommodations, showed that previously defined and well-understood baseline subsystems could be scaled up to meet relevant design requirements of the large payload concepts and that specific advanced technology could be defined for further improvements. Fuel efficiency is almost doubled relative to the 1971 U.S. SST with a further 30 percent improvement projected for a year 2000 SST. An economic study showed that relative to projected, advanced subsonic airplanes, SST surcharges would be about 15 percent at 450 passengers, equal return on investment, North Atlantic range, and $1.10 fuel (1980 dollars). A scheduling study, using a large international airline route system, confirmed that airplane use can approach 12 hours daily. This study was supported by a network analysis.

*Boeing Commercial Airplane Co., contract NAS1-16150.

29. *Preliminary Design Dep., Boeing Commercial Airplane Co.: **Studies of Advanced Supersonic Technologies.** NASA CR-166076, 1983. (X83-10331)

Several propulsion and structural technology advancements that offered high potential for application to future supersonic transports were investigated:

Propulsion—

Inlet Flow Analysis: A 3-D boundary layer program and a 3-D shock/boundary layer interaction program were completed and combined with a method-of-characteristics program to yield a flow analysis procedure for a supersonic diffuser of an axisymmetric inlet at angle of attack. The analysis was applied to the P-inlet operating at angle of attack to illustrate the procedure.

Inlet Controls: Modern technology was applied to the controls of a mixed-compression inlet to develop an integrated airframe, inlet, engine simulation, and baseline inlet and engine controllers. The inlet control was implemented in a flight-type, fault-tolerant, triple-channel controller.

Nacelle Integration Analysis: Coupling of a nonlinearized potential flow solution embedded in a general solution of a larger domain using linearized potential flow was accomplished through a four-step process and was applied through a preliminary analysis of a nacelle-wing combination.

NACA Nozzle Test: Analysis, design, and laboratory testing was accomplished to verify predicted performance and secondary flow pumping capabilities of the Naturally Aspirated Coannular (NACA) nozzle concept.

Installed Nozzle Test Program: Test techniques and procedures for evaluating various nozzle concepts and installations were investigated as to their effect on airplane performance at transonic speeds and as a means of establishing configuration preliminary drag values.

Structures—

Titanium Panel Tests: Fifty-seven polyimide bonded titanium structural panels were subjected to tests (1 compression and 56 crack growth and residual strength) to evaluate design properties considered crucial to use of the material for supersonic transport structures.

Wing Structural Analysis: The structural analysis of the model 733-633 supersonic delta wing was revised to account for changes in aerodynamic lift lines and to reflect changes in structural criteria and internal arrangement. The model 733-636 arrow wing was subjected to structural analysis using essentially the same criteria as for the model 733-633.

In all cases recommendations were made regarding future needed research.

*Boeing Commercial Airplane Co., contract NAS1-16150.

30. *Rowe, W. T.; and Advanced Supersonic Transport Project Leaders: **Technology Study for Advanced Supersonic Cruise Vehicles.** NASA CR-165723, 1981.

This report summarizes work completed by McDonnell Douglas (MDC) under the NASA Langley Technology Study for Advanced Supersonic Cruise Vehicles contract. These efforts support NASA in evaluating the improved technologies and in defining research programs for development of a solid technology base from which an advanced supersonic cruise aircraft can be derived. Propulsion technology (use of a bicone inlet instead of a translating centerbody) and structural technology (use of composites instead of aluminum in nonprimary areas) studies result in a range improvement of 5 percent for the Mach 2.2 baseline aircraft. A low-speed inlet model is being fabricated to obtain acoustic and performance data. Configuration studies have been completed to increase the passenger capacity to 350 at maximum takeoff gross weight of 340 200 kg (750 000 lb). Initial tests of an improved supersonic cruise vehicle wing verify that current analytical performance estimating methods are accurate. These methods are based on data (both force and pressures) from previous testing of the high-speed model. A low-speed leading-edge-slat system design for the MDC baseline configuration has been completed for testing on the NASA low-speed generic model. Augmented control systems evaluations on a moving-base simulator have been completed to validate previous results obtained by both linear analysis and by fixed-base simulations. Structural analysis of applications of SPF/DB titanium sandwich in detail design shows substantial payoff in weight and cost of fabrication. An upper-surface wing panel with an access door has been fabricated. Propulsion integration studies update the technology for the variable cycle engines and suppression schemes to a September 1984 go-ahead date. The improved performance data are summarized for six different engines.

*Douglas Aircraft Co., contract NAS1-16147.

31. *Wald, G. G.: **Supersonic Cruise Vehicle Technology Assessment Study of an Over/Under Engine Concept—Advanced Aluminum Alloy Evaluation.** NASA CR-165676, 1981.

This report describes the work completed by Lockheed during the FY 1979 NASA Langley Research Center Supersonic Cruise Vehicle Technology Assessment studies in the area of advanced aluminum alloy evaluations for supersonic cruise applications. Alloys are being developed for cruise temperatures between 394 K (250°F) and 450 K (350°F) using powder metallurgy and mechanical alloying techniques. Development work was conducted by the Aluminum Co. of America (ALCOA) and the International Nickel Co. (INCO) under subcontract to the Lockheed-California Co.

*Lockheed-California Co., contract NAS1-14625.

32. *Walkley, K. B.; Espil, G. J.; Lovell, W. A.; Martin, G. L.; and Swanson, E. E.: **Concept Development of a Mach 2.7 Advanced Technology Transport Employing Wing-Fuselage Blending.** NASA CR-165739, 1981.

Recent wind tunnel tests of a blended wing-fuselage advanced supersonic technology concept demonstrated improved levels of supersonic cruise efficiency. These improved aerodynamics form the basis for the AST-205-1, a 290-passenger configuration designed for cruise at Mach 2.7 using four variable-cycle engines. Use of superplastic formed/diffusion bonded titanium results in a takeoff gross weight of 2846.9 kN (640 000 lbf) for the 8334 km

(4500 n.mi.) design range. Aerodynamic configurations, propulsion system design, high-speed aerodynamics, a mission analysis, and drag analysis results are presented. Computer programs used for sizing studies are discussed.

*Kentron International, Inc., contract NAS1-16000.

33. *Wright, B. R.; Clauss, J. S.; Averett, B. T.; Oatway, T. P.; Hays, A. P.; and Sakata, I. F.: **Supersonic Cruise Vehicle Technology Assessment Study of an Over/Under Engine Concept.** NASA CR-159003, 1978. (Volume I: X79-10014, Volume II: X79-10015)

Volume I.–The effects of arrow-wing planform geometry variations on airplane low-speed handling qualities are investigated using piloted flight simulation techniques. Baseline aircraft engine/airframe integration and installation studies increased aircraft range and defined more realistic engine/nacelle designs. Alternative engine candidates were investigated. Advantages of integrated digital control for engines are identified. A design performance and noise comparison study was conducted on axisymmetric mixed-compression inlets featuring translating and collapsing bicone centerbodies in conjunction with auxiliary inlets. A noise/cost sensitivity study was completed. Parametric aircraft weight estimating methods were further validated for application to arrow-wing designs. Advantages of Ti-15-3 beta alloy over Ti-6-4 alloy were experimentally verified.

Volume II.–This volume contains appendixes to Volume I and presents data and discussion on the following topics: (1) low-speed wind tunnel test L-423, (2) noise/cost sensitivity configuration data, (3) Pratt & Whitney aircraft engines, (4) General Electric Co. engines, and (5) jet noise shielding theory.

*Lockheed-California Co., contract NAS1-14625.

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35. Driver, Cornelius; and Maglieri, Domenic J.: **Some Unique Characteristics of Supersonic Cruise Vehicles and Their Effect on Airport Community Noise.** AIAA-80-0859, May 1980.

36. Hays, Anthony P.: **Optimization of Takeoff Flight Paths With Respect to FAR Part 36 Noise Using Dynamic Programming.** Proceedings—Noise Control for the 80's—Volume II, George C. Maling, Jr., ed., Noise Control Foundation, c.1980, pp. 851–854.

37. Impact of Advanced Air Transport Technology. Part 1— Advanced High-Speed Aircraft. Off. Technol. Assess., U.S. Congress, [1978]. (N80-28326)

38. Maglieri, Domenic J.; and Dollyhigh, Samuel M.: **We Have Just Begun to Create Efficient Transport Aircraft.** Astronaut. & Aeronaut., vol. 20, no. 1, Feb. 1982, pp. 26–38.

39. Maglieri, Domenic J.; Carlson, Harry W.; and Hubbard, Harvey H.: **Status of Knowledge of Sonic Booms.** Noise Contr. Eng., vol. 15, no. 2, Sept.-Oct. 1980, pp. 57–64.

40. Padula, S. L.: **Prediction of Noise Constrained Optimum Takeoff Procedures.** Presented at the AIAA 6th Aeroacoustics Conference, AIAA- 80-1055, June 1980.

41. Rich, Ben R.: **Sixteen Years of Mach 3 Flight.** Interavia, vol. XXXV, no. 7, July 1980, pp. 636–637.

42. Rowe, W. T.: **Technology Status for an Advanced Supersonic Transport.** SAE Paper 820955, Aug. 1982.

43. Rowe, William T.; Welge, H. Robert; Johnson, Earle S.; and Rochte, Lucian S.: **Advanced Supersonic Transport Propulsion and Configuration Technology Improvements.** AIAA-81-1595, July 1981.

44. Spearman, M. Leroy; and Driver, Cornelius: **Supersonic Flight—Past, Present, and Future.** AIAA Stud. J., vol. 18, no. 1, Spring 1980, pp. 10–19.

SCR PROPULSION

NASA Formal Reports

45. Fishbach, L. H.; Stitt, L. E.; Stone, J. R.; and Whitlow, J. B.: **NASA Research in Supersonic Propulsion—A Decade of Progress.** NASA TM-82862, 1982. (N82-26300) (Also available as AIAA-82-1048, June 1982.)

At the close of the U.S. attempt in the commercial supersonic transport market in the early 1970's, both the government and aircraft industry recognized that significant technical advancements would be required to make a second-generation supersonic aircraft economically viable and environmentally acceptable. Consequently, in 1972, NASA initiated a limited effort to advance supersonic technology. The intent was to identify and investigate areas requiring new and/or improved technology that would lead to substantial improvements in performance. This paper describes the in-house and contracted efforts of NASA Lewis Research Center in the areas of engine selection, testbed experiments, and noise reduction research over the decade from 1972 to the termination of the effort in 1981.

46. Goodykoontz, J.: **Effect of a Semi-Annular Thermal Acoustic Shield on Jet Exhaust Noise.** NASA TM-81615, 1980. (N81-11770)

Reductions in jet exhaust noise obtained by the use of an annular thermal acoustic shield consisting of a high-temperature, low-velocity gas stream surrounding a high-velocity central jet exhaust appear to be limited by multiple reflections. The effect of a semi-annular shield on jet exhaust noise was investigated with the rationale that such a configuration would eliminate or reduce the multiple reflection mechanism. Noise measurements for a 10-cm conical nozzle with a semi-annular acoustic shield are presented in terms of lossless free-field data at various angular locations with respect to the nozzle. Measurements were made on both the shielded and unshielded sides of the nozzle. The results are presented parametrically, showing the effects of various shield and central system velocities and temperatures. Selected results are scaled up to a typical full-scale engine size to determine the perceived noise level reductions.

47. Goodykoontz, J.; and Von Glahn, U.: **Noise Suppression Due to Annulus Shaping of an Inverted-Velocity-Profile Coaxial Nozzle.** NASA TM-81460, 1980. (N80-22046)

Previous studies have shown that an inverted-velocity-profile coaxial nozzle for use with supersonic cruise aircraft produces less jet noise than an equivalent conical nozzle. Furthermore, decreasing the annulus height (increasing radius ratio with constant flow) results in further noise reduction benefits. In the present model-scale study, the annulus shape, that is, height, was varied by an eccentric mounting of the annular nozzle with respect to a conical core nozzle. Acoustic measurements were made in the flyover plane below the narrowest portion of the annulus and at 90° and 180° from this point. The model-scale spectra are scaled up to engine size (1.07-m diameter) and the perceived noise levels for the eccentric and baseline concentric inverted-velocity-profile coaxial nozzles are compared over a range of operating conditions. The implications of the acoustic benefits derived with the eccentric nozzle to practical applications are discussed.

48. Stone, James R.; and Montegani, Frances J.: **An Improved Prediction Method for the Noise Generated in Flight by Circular Jets.** NASA TM-81470, 1980. (N80-22048)

A semiempirical model for predicting the noise generated by jets exhausting from circular nozzles is presented and compared with small-scale static and simulated-flight data. The present method is an updated version of that part of the original NASA Aircraft Noise Prediction Program (1974) relating to circular jet noise. The earlier method has been shown to agree reasonably well with experimental static and flight data for jet velocities up to approximately 520 m/sec. The poorer agreement at higher jet velocities appeared to be due primarily to the manner in which supersonic convection effects were formulated. The purely empirical supersonic convection formulation is replaced in the present method by one based on theoretical considerations. Other improvements of an empirical nature have been included based on model-jet/free-jet simulated-flight tests. The effects of nozzle size, jet velocity, jet temperature, and flight are included.

49. Toon, O. B.; Turco, R. P.; Pollack, J. B.; Whitten, R. C.; Poppoff, I. G.; and Hamill, P.: **Stratospheric Aerosol Modification by Supersonic Transport Operations With Climate Implications.** NASA RP-1058, 1980.

The potential effects on stratospheric aerosols of supersonic transport emissions of sulfur dioxide gas and submicron-size soot granules are estimated. Recently, exhaust particles from large aircraft have been characterized experimentally; these new data have been adopted where appropriate. An interactive particle-gas model of the stratospheric aerosol layer is used to calculate changes due to exhaust emissions, and an accurate radiation transport model is used to compute the effect of aerosol changes on the Earth's average surface temperature. It is concluded that the release of large numbers of small soot particles into the stratosphere should not lead to a correspondingly significant increase in the concentration of large, optically active aerosols. On the contrary, the increase in large particles is severely limited by the total mass of sulfate available to make large particles in situ and by the rapid loss of small seed particles via coagulation. It is shown that a fleet of several hundred supersonic aircraft, operating daily at 20 km, could produce about a 20 percent increase in the concentration of large particles in the stratosphere. Moreover, aerosol increases of this magnitude would reduce the global surface temperature by less than 0.01 K; the climatic implications of a temperature change of this magnitude are negligible.

NASA Contractor Reports

50. *Allan, R. D.: **Advanced Supersonic Propulsion Studies.** NASA CR-159338, 1980. (X80-10132)

Studies were conducted for Douglas Aircraft Co. to provide propulsion system support for their Supersonic Cruise Research Studies under contract from NASA Langley Research Center. Computer programs were provided which give engine performance for the GE21/J10 Study B7 and GE21/J11 Study B18 single- and double-bypass variable-cycle engines. An exhaust system design study was also performed for the GE21/J11 Study B18 VCE, which included a 20 shallow chute mechanical suppressor in the outer stream of the coannular exhaust nozzle.

*General Electric Co., contract NAS1-14624.

51. *Allan, R. D.; Johnson, J. E.; Joy, W.; Brown, R. H.; and Barrial, H. J.: **Engine Cycle Studies Program.** NASA CR-159500, 1980.

The Engine Cycle Studies Program examined the General Electric Co. double-bypass, variable-cycle engine (VCE) used as the propulsion system for a Mach 2.4 cruise

supersonic commercial transport. The areas examined in this study were: the acoustic and performance payoffs of the high-flow mode of the double-bypass VCE; possible cycle improvements for noise goals lower than FAR 36, 1969; manufacturing cost, reliability, and maintainability of the VCE compared to other engine concepts; and an assessment of the performance and economics payoffs of the features used in the double-bypass VCE. The high-flow capability of the double-bypass VCE did show acoustic and performance payoffs both with unsuppressed and with mechanically suppressed coannular exhaust systems. At lower noise goals, down to 104 EPNdB, changes to the baseline VCE cycle improved takeoff gross weight for a design version by up to 4 percent. The double-bypass feature of the VCE provided performance and acoustic flexibility that resulted in lower takeoff gross weight for all noise levels, utilizing an unsuppressed coannular nozzle, a suppressed coannular nozzle, and a single-stream fully suppressed nozzle. The manufacturing cost, reliability, and maintainability of the double-bypass VCE compares favorably with the simpler concepts studied (within 1 to 5.5).

*General Electric Co., contract NAS3-21388.

52. *Allan, R. D.; Hines, B. G.; and Wines, W. L.: **Effect of Design Temperature on Double Bypass Engine for SCR.** NASA CR-167854, 1982.

NASA is engaged in a study of the application of advanced technology to long range, supersonic, commercial transport aircraft under the Supersonic Cruise Research (SCR) Program. As part of this study, General Electric Co. has defined and refined variable cycle engine (VCE) concepts that meet the performance and environmental requirements for an advanced, supersonic cruise vehicle. Studies have shown that the double bypass VCE with an oversize front block fan and outer stream mechanical suppressors can meet low-noise goals. The technology utilized for most of these engines is considered advanced technology which will be available to start engine development programs in the late 1980's. Component efficiencies, materials, turbine temperatures, and cooling techniques are all affected by the selected technology levels. This current study effort (NASA Contract NAS3-22749) examines the effect of varying the turbine inlet temperature of the cycle from 1427°C to 1649°C (2600°F to 3000°F) and shows the effect of these temperature levels, as measured by airplane takeoff gross weight (TOGW) to fly a 7408 km (4000 n.mi.) mission, and by engine operating and acquisition cost. At each temperature level, a parametric cycle study was performed to select the best bypass ratio, fan pressure ratio, and overall pressure ratio. The analysis was conducted at two takeoff noise levels, FAR 36 (1969) and FAR 36 (1969) minus 4 EPNdB. All the results were determined at the actual engine size required to meet the two noise levels and three turbine inlet temperature levels. At a noise level of FAR 36 (1969), increased temperature from 1427°C to 1649°C (2600°F to 3000°F) reduced the aircraft TOGW by 2.1 percent (15 500 lb), and the relative engine operating cost (less fuel) was reduced by 5.5 percent. At FAR 36 (1969) minus 4 EPNdB, the TOGW was reduced by 2.7 percent (20 500 lb) and the engine operating cost by 10.9 percent. Direct operating cost was reduced by about the same percentage as the TOGW for each noise level. The parametric cycle study showed that the base cycle used in previous NASA-sponsored studies should change for low noise (FAR 36 (1969) minus 4 EPNdB) and high turbine inlet temperatures (3000°F). At the high temperature, the best bypass ratio for low noise increases from 0.35 to 0.64, while the fan pressure ratio and overall pressure remain the same.

*General Electric Co., Contract NAS3-22749.

53. *Allan, R. D.: **Engine Technology Study for SCR.** NASA CR-165183, 1980.

Previous NASA-sponsored studies have shown that the double bypass VCE with an oversize front block fan and outer stream mechanical suppressors, can meet low noise goals. The technology utilized for most of these engines is considered advanced technology, which will be available to start engine development programs in the late 1980's. Component efficiencies, materials, turbine temperatures, and cooling techniques are all affected by the selected technology levels. This current study effort examined the effect of selectively adding advanced technology items to a current (1980) technology baseline double bypass VCE and shows the payoff of the technology items, as measured by airplane takeoff gross weight (TOGW) to fly a 4000-n.mi. mission, engine reliability, operating cost, and acquisition cost. This study showed that the effect of technology level on a double bypass VCE is large. The decrease in TOGW for the 4000-n.mi. mission in changing from current (1980) to advanced (1987–89) technology at a traded noise level of FAR 36 (1969) minus 2 EPNdB is 145 000 pounds, or 16 percent. At the same time, the direct operating cost (DOC) dropped by almost 10 percent, and the engine removal rate dropped by 11 percent; the operating cost went down by 5 percent and the engine acquisition cost showed almost no change. The technology that showed the largest payoff was the increased turbine inlet temperature in combination with the advanced technology turbines. This addition reduced TOGW by 8.7 percent (78 000 lb), reduced DOC by 5.4 percent, and improved engine removal rate by 11 percent and operating cost by 5 percent.

*General Electric Co., contract NAS3-22000.

54. *Gaffin, W. O.: **Engine Component Improvement—Performance Improvement—JT9D-7 3.8 Aspect Ratio Fan.** NASA CR-159806, 1980. (N80-25332)

As part of the NASA-sponsored Engine Component Improvement Program, a redesigned, fuel efficient fan for the JT9D-7 engine was tested. Tests were conducted to determine the effect of the new 3.8 AR fan on performance, stability, operational characteristics, and noise of the JT9D-7 engine relative to the current 4.6 AR Bill-of-Material fan. The 3.8 AR fan provides increased fan efficiency due to a more advanced blade airfoil with

increased chord, eliminating one part span shroud and reducing the number of fan blades and fan exit guide vanes. Engine testing at simulated cruise conditions demonstrated the predicted 1.3 percent improvement in specific fuel consumption with the redesigned 3.8 AR fan. Flight testing and sea level stand engine testing demonstrated exhaust gas temperature margins, fan and low pressure compressor stability, operational suitability, and noise levels comparable to the Bill-of-Material fan.

*Pratt & Whitney Aircraft Group, Commercial Products Div., contract NAS3-20630.

55. *Hunt, R. B.; and Kardas, G. E.: **Supersonic Cruise Nozzle Exhaust Systems: An Aeromechanical Design Study and Improvements to Analytical Techniques.** NASA CR-165416, 1981. (X81-10346)

The aeromechanical design definition of supersonic cruise nozzle exhaust systems for the Variable Stream Control Engine and the evaluation, improvement, and application of analytical techniques for ejector nozzles are described. Two ejector nozzle systems were defined during the aeromechanical design study: an actuated inlet ejector nozzle and a long variable flap ejector nozzle. Both systems offer potentially significant improvement in subsonic nozzle performance and aircraft range capability relative to nozzle systems tested previously. Two advanced analytical procedures for predicting nozzle performance, the General Supersonic Flow Analysis code and the Supersonic Ejector Nozzle code, were evaluated. Analytical results generated with the Supersonic Ejector Nozzle code showed reasonable agreement with data obtained during previous wind tunnel tests. Based on the evaluation, the Supersonic Ejector Nozzle code was selected for modification and enhancement. The improved code was subsequently used to estimate the performance of the actuated inlet and long variable flap ejector nozzles.

*Pratt & Whitney Aircraft Group, contract NAS3-20061.

56. *Johnson, E. S.; and McKinnon, R. A.: **Cooperative Wind Tunnel Tests of Douglas Advanced Supersonic Technology Jet Noise Suppressor—Using RR Viper 601 Engine.** NASA CR-165672, 1981.

An experimental investigation of mechanical jet noise suppressors installed on an uprated Viper 601 turbojet engine with a simulated HS-125 fuselage has been conducted at the NASA Ames Research Center, Moffett Field, California. Static tests were performed at an outdoor test site, in addition to tests in the NASA Ames 40- x 80-foot wind tunnel with and without tunnel air flow. Seven nozzle configurations were tested, including sonic nozzles, a 12-lobe/24-tube suppressor mixer, and an acoustically treated ejector. Results of the NASA Ames outdoor static tests show that the noise levels recorded from moving microphones located in the near field at multiple sidelines when projected to the far field compare favorably with noise levels measured in the far field. Further, the noise levels measured by moving microphones at multiple near field sidelines in the wind tunnel (with tunnel velocity zero) when projected to the far field, agree well with both sets for outdoor data.

*Douglas Aircraft Co., contract NAS1-14601.

57. *Lohmann, R. P.; and Mador, R. J.: **Experimental Evaluation of a Low Emissions High Performance Duct Burner for Variable Cycle Engines (VCE).** NASA CR-159694, [1979]. (N80-17074)

An experimental evaluation was conducted with a three-stage Vorbix duct burner to determine the performance and emissions characteristics for this concept and to refine the configuration to provide acceptable durability and operational characteristics for its use in the VCE Testbed Program. The tests were conducted at representative takeoff, transonic climb, and supersonic cruise inlet conditions for the VSCE-502B study engine. The carbon monoxide and unburned hydrocarbon emissions were low at all three operating conditions with combustion efficiencies in excess of 99.7 percent as compared to the goal of 99.0 percent. NO_x emissions were moderate but in excess of the program goal of 1 g/kg at takeoff. The thrust efficiency exceeded the goal level of 94.5 percent, reaching a value of 97 percent at supersonic cruise. Soft ignition, the absence of combustion generated acoustic instabilities, and liner temperature levels acceptable for experimental hardware were also demonstrated. The total pressure loss across the duct burner exceeded the program goal, with the measured loss at supersonic cruise being 6.76 percent as opposed to a goal of 4.5 percent. However, the loss mechanisms have been identified, and in one configuration 40 percent of this excess loss was eliminated without compromising the emissions or thrust efficiency.

*Pratt & Whitney Aircraft Group, Commercial Products Div., contract NAS3-20602.

58. *Lohmann, R. P.; and Hershberger, R. J.: **Further Evaluation of a Low Emissions High Performance Duct Burner for Variable-Cycle Engines (VCE).** NASA CR-165199, 1980. (X81-10005)

A three-stage Vorbix duct burner was evaluated with the objective of introducing refinements to the high-power stage that would simplify the configuration and enhance the performance and emissions characteristics. Six additional configurations were evaluated at conditions representative of takeoff, transonic climb, and supersonic cruise operation of an advanced supersonic transport engine. Parametric variations of the density, axial location, type and flow size of the fuel injectors in the high-power stage, and alterations to the rotation sequence of the swirler tubes led to definition of configurations that employed, on a full annular basis, only half the number of high-power stage fuel injectors without compromising thrust efficiency and with only a small reduction in combustion efficiency. At the beginning of this phase, the total pressure loss was the only performance parameter that exceeded the program goals. The loss mechanism has been identified

and in one configuration tested, 40 percent of the excess pressure loss was eliminated without compromising the emissions or thrust efficiency.

*Pratt & Whitney Aircraft Group, contract NAS3-20602.

59. *Nelson, D. P.: **Model Aerodynamic Test Results for Two Variable-Cycle Engine Coannular Exhaust Systems at Simulated Takeoff and Cruise Conditions.** NASA CR-159818, [1980]. (N81-13057)

Wind tunnel tests were conducted to evaluate the aerodynamic performance of a coannular exhaust nozzle for a proposed variable-stream control supersonic propulsion system. Tests were conducted with two simulated configurations differing primarily in the fan duct flowpaths: (1) a short flap mechanism for fan stream control with an isentropic contoured flow splitter, and (2) an iris fan nozzle with a conical flow splitter. Both designs feature a translating primary plug and an auxiliary inlet ejector. Tests were conducted at takeoff and simulated cruise conditions. Data were acquired at Mach numbers of 0, 0.36, 0.9, and 2.0 for a wide range of nozzle operating conditions. At simulated supersonic cruise, both configurations demonstrated good performance, comparable to levels assumed in earlier advanced supersonic propulsion studies. However, at subsonic cruise, both configurations exhibited performance that was 6 to 7.5 percent less than the study assumptions. At takeoff conditions, the iris configuration performance approached the assumed levels, while the short-flap design was 4 to 6 percent less.

*Pratt & Whitney Aircraft Group, contract NAS3-20061.

60. *Nelson, D. P.; and Morris, P. M.: **Experimental Aerodynamic and Acoustic Model Testing of the VCE Coannular Exhaust Nozzle System.** NASA CR-159710, 1980.

Aerodynamic performance and jet noise characteristics of a one-sixth scale model of the Variable Cycle Engine (VCE) testbed exhaust system were obtained in a series of static tests over a range of simulated engine operating conditions. Model acoustic data were acquired that can be scaled directly to full-scale engine data at the same thermodynamic conditions. Data were also compared to predictions of coannular model nozzle performance. The model, tested with and without a hardwall ejector, had a total flow area equivalent to a 0.127-m (5-in.) diameter conical nozzle with a 0.65 fan-to-primary-nozzle-area ratio and a 0.82 fan-nozzle radius ratio. A total of 39 acoustic data points was acquired. Fan-stream temperatures and velocities were varied from 422 to 1089 K (760°R to 1960°R) and 434 to 755 m/sec (1423 to 2477 ft/sec). Primary stream properties were varied from 589 to 1089 K (1060°R to 1960°R) and 353 to 600 m/sec (1158 to 1968 ft/sec). Exhaust plume velocity surveys were conducted at one operating condition with and without the ejector installed. Thirty aerodynamic performance data points were obtained with an unheated air supply. Fan nozzle pressure ratio was varied from 1.8 to 3.2 at a constant primary pressure ratio of 0.6; primary pressure ratio was varied from 1.4 to 2.4 while holding fan pressure ratio constant at 2.4. Agreement between the acoustic test data and predictions without the ejector was generally within the accuracy of the prediction procedure. Acoustic data trends obtained by independently varying fan and primary stream properties were generally in agreement with the prediction procedure. Agreement between the measured performance and predicted thrust coefficients without the ejector was within one percent. Measured noise levels with the ejector were slightly higher than without the ejector. However, based on analysis of these and other ejector data, it is expected that a longer ejector would have lowered the noise level. Operation with the ejector increased nozzle thrust coefficient 0.2 to 0.4 percent.

*Pratt & Whitney Aircraft Group, contract NAS3-20061.

61. *Nelson, D. P.: **Model Aerodynamic Test Results for a Refined Actuated Inlet Ejector Nozzle at Simulated Takeoff and Cruise Conditions—Final Report.** NASA CR-168051, 1983. (N83-26816)

Wind tunnel model tests were conducted to demonstrate the aerodynamic performance improvements of a refined actuated inlet ejector nozzle. Models of approximately one-tenth scale were configured to simulate nozzle operation at takeoff, subsonic cruise, transonic cruise, and supersonic cruise. Variations of model components provided a performance evaluation of ejector inlet and exit area, forebody boattail angle, and ejector inlet operation in the open and closed mode. Approximately 700 data points were acquired at Mach numbers of 0, 0.36, 0.9, 1.2, and 2.0 for a wide range of nozzle flow conditions. Results show that relative to two ejector nozzles previously tested, performance was improved significantly at takeoff and subsonic cruise. Takeoff quiescent and fly-over performance was improved 0.3 and 1.6 percent, respectively. At subsonic cruise, a 4.2-percent improvement was demonstrated. Good supersonic cruise performance was attained equal to the high performance of the previous tests. The established advanced supersonic transport propulsion study performance goals were met or closely approached at takeoff and supersonic cruise. Subsonic cruise performance was within 2.3 percent of the target. Analysis of the data shows that further improvements are possible. Although a transonic cruise performance goal has not been established, results were less than desired. Analysis of the data shows that performance improvements are possible.

*Pratt & Whitney Aircraft Group, contract NAS3-22738.

62. *Packman, A. B.; Morris, P. M.; and Manzi, R. J.: **Acoustic Evaluation of the Variable Cycle Engine (VCE) Testbed.** NASA CR-165371, 1981.

The Pratt & Whitney Variable Cycle Engine Testbed Demonstrator was tested to determine the acoustic characteristics of a variable-stream control engine at takeoff conditions. The testbed, consisting of an F-100 engine modified to include a multistage annular duct burner, a coannular exhaust nozzle, and a treated ejector, was

tested over a range of duct burner fuel/air ratio settings ranging from duct burner off up to a fuel/air of 0.33. The fan-stream exhaust velocity and temperature reached maximum values of 792 m/sec (2600 ft/sec) and 1500 K (2700°R), respectively, at a constant core exhaust velocity of 457 m/sec (1500 ft/sec). Results of the testing indicated that the noise of the duct burner was up to 5 dB less than predicted and that the jet noise generated by the low-noise inverted-velocity-profile coannular jet (i.e., fan-to-core jet velocity ratio of 1) was in good agreement with data measured on a 1/6-scale model of the testbed nozzle. Supersonic cruise airplane takeoff noise levels predicted using the testbed data were up to 8 EPNdB less than the levels predicted for mixed-flow low-bypass-ratio turbofan engines at the same thrust and flow. The detailed performance and acoustic data obtained during the test are documented in the Comprehensive Data Report.

*Pratt & Whitney Aircraft Group, Commercial Products Div., contract NAS3-20048.

63. *Pratt & Whitney Aircraft Group: **Technology Application Study of an Advanced Supersonic Cruise Vehicle. Phase 7—Advanced Supersonic Propulsion Studies.** NASA CR-159323, 1980. (X80-10121)

This report summarizes a contracted study of supersonic propulsion systems conducted for the McDonnell Douglas Corp. by Pratt & Whitney Aircraft. This study, referred to as Phase 7, was conducted during the period from March 1979 to December 1979. Phase 7 was part of an overall Supersonic Cruise Research (SCR) study sponsored by NASA Langley Research Center under contract number NAS1-14624 and was a continuation of the integration studies performed by Pratt & Whitney Aircraft for McDonnell Douglas Corp. in Phase 6. The scope of work consisted of conducting propulsion refinement analyses for two Pratt & Whitney Aircraft engine concepts, a Variable Stream Control Engine (VSCE) and a Low Bypass Engine (LBE), establishment of a VSCE automated teleprocessing communications system, and a detailed performance assessment of the Pratt & Whitney Aircraft candidate nozzle exhaust systems for the LBE. The main conclusion derived from this work is that both engine concepts are fully compatible with the advanced supersonic cruise vehicle defined by Douglas Aircraft Co.

*Pratt & Whitney Aircraft Group, contract NAS1-14624.

64. *Preliminary Design Dep., Boeing Commercial Airplane Co.: **Low Speed Test of a Naturally Aspirated Co-Annular Nozzle—Volume I Final Report.** NASA CR-168043, 1983.

A wind tunnel test was conducted to determine the low-speed performance and ambient flow-pumping capability of a naturally aspirated coannular nozzle. The nozzle was designed for application to a supersonic cruise airplane, employing a turbojet engine cycle, with the objective of achieving jet-noise suppression through rapid mixing of the high-velocity primary (outer) stream with large quantities of aspirated ambient flow in the inner stream. Several variations in nozzle geometry were tested at static and Mach 0.28 conditions. A single-stream high-radius-ratio plug nozzle and a single-stream round-convergent nozzle were also tested for comparison. The results show the best configuration tested could pump ambient flows in excess of 37 percent of the primary flow (at primary nozzle pressure ratios greater than 3) with thrust-minus-drag performance exceeding that of the single-stream plug nozzle. At lower nozzle pressure ratios, the ambient-to-primary-flow ratio increased with a small reduction in relative thrust performance. Noise measurements were not made on the nozzle; however, it was estimated that the sideline jet-noise reduction (at takeoff thrust) would be on the order of 10 EPNdB relative to the round-convergent nozzle. This report is divided into two volumes. Volume I (CR-168043) contains a description of the test hardware and methods, summary data plots, and discussions of the results and noise reduction estimate. Volume II (CR-168044) contains the data sheets.

*Boeing Commercial Airplane Co., contract NAS1-16150.

65. *Preliminary Design Dep., Boeing Commercial Airplane Co.: **Low Speed Test of a Naturally Aspirated Coannular Nozzle—Volume II Comprehensive Data Report.** NASA CR-168044, 1983.

A wind tunnel test was conducted to determine the low-speed performance and ambient flow-pumping capability of a naturally aspirated coannular nozzle. The nozzle was designed for application to a supersonic cruise airplane, employing a turbojet engine cycle, with the objective of achieving jet-noise suppression through rapid mixing of the high-velocity primary (outer) stream with large quantities of aspirated ambient flow in the inner stream. Several variations in nozzle geometry were tested at static and Mach 0.28 conditions. A single-stream high-radius-ratio plug nozzle and a single-stream round-convergent nozzle were also tested for comparison. The results show the best configuration tested could pump ambient flows in excess of 37 percent of the primary flow (at primary nozzle pressure ratios greater than three) with thrust-minus-drag performance exceeding that of the single-stream plug nozzle. At lower nozzle pressure ratios, the ambient-to-primary-flow ratio increased with a small reduction in relative thrust performance. Noise measurements were not made on the nozzle, however, it was estimated that the sideline jet-noise reduction (at takeoff thrust) would be on the order of 10 EPNdB relative to the round-convergent nozzle. This report is divided into two volumes. Volume I (CR-168043) contains a description of the test hardware and methods, summary data plots, and discussions of the results and noise reduction estimate. Volume II (CR-168044) contains the data sheets.

*Boeing Commercial Airplane Co., contract NAS1-16150.

66. *Tanna, H. K.; Tam, C. K. W.; and Brown, W. H.: **Shock Associated Noise Reduction From Inverted-Velocity-Profile Coannular Jets.** NASA CR-3454, 1981.

Acoustic measurements show that the shock noise from the outer stream is virtually eliminated when the

inner stream is operated at a Mach number just above unity, regardless of all the other jet operating conditions. At this optimum condition, the coannular jet provides the maximum noise reduction relative to the equivalent single jet. The shock noise reduction can be achieved at inverted- as well as normal-velocity-profile conditions, provided the coannular jet is operated with the inner stream just slightly supersonic. Analytical models for the shock structure and shock noise are developed and indicate that a drastic change in the outer stream shock cell structure occurs when the inner stream increases its velocity from subsonic to supersonic. At this point, the almost periodic shock cell structure of the outer stream nearly completely disappears; the noise radiated is minimum. Theoretically derived formulas for the peak frequencies and intensity scaling of shock associated noise are compared with the measured results, and good agreement is found for both subsonic and supersonic inner jet flows.

*Lockheed-Georgia Co., contract NAS1-15971.

67. *Vdoviak, J. W.; Knott, P. R.; and Ebacker, J. J.: **Aerodynamic/Acoustic Performance of YJ101/Double Bypass VCE With Coannular Plug Nozzle.** NASA CR-168039, 1981. (X83-73251)

This report incorporates the results of a forward variable area bypass injector (VABI) test and a coannular nozzle test performed on a YJ101 Double Bypass Variable Cycle Engine. These components are intended for use on a variable cycle engine (VCE) being studied under the Supersonic Cruise Research Program. Both tests accomplished all objectives. The forward variable area bypass injector test demonstrated the mode shifting capability between single- and double-bypass operation with less than predicted aerodynamic losses in the bypass duct. The acoustic nozzle test demonstrated that coannular noise suppression was between 4 and 6 PNdB in the aft quadrant. The YJ101 VCE equipped with the forward VABI and the coannular exhaust nozzle performed as predicted, with exhaust system aerodynamic losses lower than predicted both in single- and double-bypass modes. Extensive acoustic data were collected including far-field, near-field, sound-separation/internal-probe measurements, and laser velocimeter traverses. This report supplements NASA CR-159869, Exhibit B, Final Report, by including more actual test data and the instructions for reading the various data sheets. It also contains a more thorough description of the test apparatus.

*General Electric Co., contract NAS3-20582. Exhibit B.

68. *Vdoviak, J.: **VCE Testbed Engine System Aero-Acoustic Test Exhibit C—Definition Study for Variable Cycle Testbed Engine and Associated Test Programs.** NASA CR-165542, 1982.

A YJ101 Variable-Cycle Engine (VCE) test was conducted as part of a multiphase, multiyear GE/NASA program to demonstrate key technology features desirable for an advanced supersonic transport application. This testbed engine was an extensively modified version of the Early Acoustic Test VCE and featured a close-coupled, rear-block, core-driven fan stage (CDFS). Over 100 hours of testing were conducted, and the CDFS concept was validated both from the aerodynamic and the aeromechanical aspects. Due to the complexity, scope, and uniqueness of the core-driven concept, the test phase was conducted in two sequential steps. An evaluation of the CDFS design integration with the core engine was successfully accomplished in 58 hours of testing in a ram test facility, during which the front-block fan conditions were simulated. This testing verified the matching characteristics of the CDFS with the core engine and also determined the variable-stator geometry for the ensuing full-engine test. The testbed VCE, including the double-bypass features, was built combining the core vehicle with the fan and low pressure turbine system and a slave variable exhaust system (prior to acoustic testing with the special coannular nozzle configuration). The engine mechanical and aerodynamic characteristics were successfully demonstrated in 43 hours of testing at the outdoor test site. Planned aero-acoustic tests on the VCE system (with combination of unsuppressed and suppressed coannular plug exhaust nozzles, ejector shroud, and accelerating inlet) were prematurely terminated as a result of a Stage 1 HP compressor blade failure. This failure was extensively investigated; it was concluded that the failure was not associated with the VCE configuration. A Comprehensive Data Report by General Electric for the NASA Lewis Research Center under contract NAS3-20582, Exhibit C, supports the findings and results of the program described in the Final Report (NASA CR-165542).

*General Electric Co., contract NAS3-20582. Exhibit C.

69. *Vdoviak, John W.; Knott, Paul R.; and Ebacker, Jon J.: **Aerodynamic/Acoustic Performance of YJ101/Double Bypass VCE With Coannular Plug Nozzle.** NASA CR-159869, 1981. (N80-26427)

Results of a forward variable area bypass injector test and a coannular nozzle test performed on a YJ101 Double Bypass Variable Cycle Engine are reported. These components are intended for use on a variable cycle engine. The forward variable area bypass injector test demonstrated the mode-shifting capability between single- and double-bypass operation with less than predicted aerodynamic losses in the bypass duct. The acoustic nozzle test demonstrated that coannular noise suppression was between 4 and 6 PNdB in the aft quadrant. The YJ101 VCE equipped with the forward VABI and the coannular exhaust nozzle performed as predicted with exhaust system aerodynamic losses lower than predicted both in single- and double-bypass modes. Extensive acoustic data were collected including far field, near field, and sound separation/internal probe measurements as laser velocimeter traverses.

*General Electric Co., contract NAS3-20582.

70. *Yetter, Jeffrey A.; and Evelyn, George B.: **Nozzle Installation Effects for Supersonic Cruise Configurations.** NASA CR-165835, 1982.

A wind tunnel test has been conducted to evaluate exhaust nozzle airframe interactions at transonic speeds for a representative supersonic cruise vehicle with an underwing nacelle installation. The purpose of the test was threefold: (1) to establish and validate a test approach from which the nozzle performance, nozzle drag, power sensitive boattail effects, and nozzle-airframe interactions could be evaluated; (2) determine the magnitude of the nozzle installation effects for use in related NASA-Supersonic Cruise Technology systems studies; and (3) provide a data base for validation of analytical codes. The test results indicated that the test approach does permit evaluation of nozzle-airframe interactions and the performance assessment of candidate nozzle concepts for development of low-drag supersonic exhaust system installations. Favorable installation effects were found to be significant at high subsonic cruise Mach numbers. A 3-D linearized potential flow analysis provided qualitative results that aided in interpretation of the test data.

*Boeing Military Airplane Co., contract NAS1-16150.

Articles, Meeting Papers, and Company Reports

71. Bangert, L. H.; Feltz, E. P.; Godby, L. A.; and Miller, L. D.: **Aerodynamic and Acoustic Behavior of a YF-12 Inlet at Static Conditions.** AIAA-81-1597, July 1981.

72. Bangert, L. H.; Burcham, F. W., Jr.; and Mackall, K. G.: **YF-12 Inlet Suppression of Compressor Noise: First Results.** AIAA-80-0099, Jan. 1980.

73. Bangert, L. H.; Santman, D. M.; Horie, G.; and Miller, L. D.: **Some Effects of Cruise Speed and Engine Matching on Supersonic Inlet Design.** AIAA-80-1807, Aug. 1980.

74. FitzSimmons, R. D.; McKinnon, R. A.; Johnson, E. S.; and Brooks, J. R.: **Flight and Wind Tunnel Results of a Mechanical Jet Noise Suppressor Nozzle.** AIAA-80-0165, Jan. 1980.

75. Franciscus, Leo C.: **Turbine Bypass Engine—A New Supersonic Cruise Propulsion Concept.** AIAA-81-1596, July 1981.

76. McKinnon, R. A.; Johnson, E. S.; and Atencio, A., Jr.: **Jet Noise Results From Static, Wind Tunnel, and Flight Tests of Conical and Mechanic Suppressor Nozzles.** AIAA-81-1995, Oct. 1981.

77. Shimabukuro, K. M.; Welge, H. R.; and Lee, A. C.: **Inlet Design Studies for a Mach 2.2 Advanced Supersonic Cruise Vehicle.** AIAA Paper 79-1814, Aug. 1979. (A79-51247)

78. Syberg, J.; Paynter, G. C.; and Carlin, C. M.: **Inlet Design Technology Development—Supersonic Cruise Research.** AIAA-81-1598, July 1981.

79. Turco, R. P.; Toon, O. B.; Pollack, J. B.; Whitten, R. C.; Poppoff, I. O.; and Hamill, P.: **Stratospheric Aerosol Modification by Supersonic Transport and Space Shuttle Operations—Climate Implications.** J. Appl. Meterol., vol. 19, no. 1, Jan. 1980, pp. 78–89.

80. Westmoreland, J. S.; and Packman, A. B.: **A Successful Step Toward an Advanced Supersonic Transport Engine—Acoustic and Emission Results From the Pratt & Whitney Aircraft Variable Cycle Engine Program.** AIAA-81-1593, July 1981.

SCR STRUCTURES AND MATERIALS

NASA Formal Reports

81. Bales, Thomas T., ed.: **SPF/DB Titanium Technology.** NASA CP-2160, 1980.

This document is a compilation of expanded abstracts and figures presented at the joint NASA/Air Force Symposium on the Superplastic Forming and Diffusion Bonding (SPF/DB) of Titanium held at the NASA Langley Research Center on October 27–28, 1980. Papers presented reviewed the technology developed on current research programs sponsored by NASA, the Air Force Materials Laboratory, or the Air Force Flight Dynamics Laboratory. Topics covered the establishment of superplasticity indices, metallurgical factors, process methods, process modeling, tooling materials and concepts, effects of processing on material properties, design and fabrication of complex components, structural performance of SPF/DB titanium components, potential cost and weight savings of the process, and the results of a limited survey of the state of the art.

82. Bales, Thomas T.; Hoffman, Edward L.; Payne, Lee; and Reardon, Lawrence F.: **Fabrication Development and Evaluation of Advanced Titanium and Composite Structural Panels.** NASA TP-1616, 1980.

Advanced manufacturing methods for titanium and composite material structures were developed and evaluated with the focus on the fabrication of full-scale structural panels designed to meet the requirements of a shear panel on the upper wing surface of the NASA YF-12 aircraft. Design, fabrication, laboratory testing, and Mach 3 flight service of full-scale structural panels and laboratory testing of representative structural element specimens were accomplished. Results discussed include the fabrication methods and test results for a superplastically formed, and diffusion bonded, titanium panel and four advanced composite panel concepts.

83. Bales, Thomas T.; Royster, Dick M.; and McWithey, Robert R.: **Fabrication Evaluation of Brazed Titanium-Clad Borsic®/Aluminum Skin-Stringer Panels.** NASA TP-1674, 1980.

A successful brazing process was developed and evaluated for fabricating full-scale titanium clad Borsic/aluminum skin-stringer panels. A unique panel design

was developed consisting of a hybrid composite skin reinforced with capped honeycomb core stringers. Six panels were fabricated for inclusion in the program which included laboratory testing of panels at ambient temperature and 533 K (500°F) and flight service evaluation on the NASA Mach 3 YF-12 airplane. All panels tested met, or exceeded, stringent design requirements and no deleterious effects on panel properties were detected following flight service evaluation on the YF-12 airplane.

84. Bigelow, C. A.: **An Assessment of Buffer Strips for Improving Damage Tolerance of Composite Laminates at Elevated Temperature.** NASA TM-83257, 1981.

Buffer strips greatly improve the damage tolerance of graphite/epoxy laminates loaded in tension. Graphite/polyimide buffer strip panels were made and tested to determine their residual strength at ambient and elevated (177°C) temperatures. Each panel was cut in the center to represent damage. Panels were radiographed and crack-opening displacements were recorded to indicate fracture, fracture arrest, and the extent of damage in the buffer strip after arrest. All panels had the same buffer strip spacing and width. The buffer strip material was 0° S-glass/PMR-15. The buffer strips were made by replacing narrow strips of the 0° graphite plies with strips of the 0° S-glass on either a one-for-one or a two-for-one glass basis. Half of the panels were heated to 177°C ± 3°C before and during the testing. Elevated temperature did not alter the fracture behavior of the buffer configuration.

85. Davis, John G., Jr., compiler: **Composites for Advanced Space Transportation Systems—(CASTS).** NASA TM-80038, 1979.

A summary is given of the in-house and contract work accomplished under the CASTS Project. In July 1975, the CASTS Project was initiated to develop graphite fiber/polyimide matrix (GR/PI) composite structures with 589 K (600°F) operational capability for application to aerospace vehicles. Major tasks include: (1) screening composites and adhesives, (2) developing fabrication procedures and specifications, (3) developing design allowable test methods and data, and (4) design and testing of structural elements and construction of an aft body flap for the Space Shuttle Orbiter Vehicle which will be ground tested. Portions of the information are from ongoing research and must be considered preliminary. The CASTS Project is scheduled to be completed in September 1983.

86. Doggett, Robert V., Jr.; and Ricketts, Rodney H.: **Effects of Angle of Attack and Vertical Fin on Transonic Flutter Characteristics of an Arrow-Wing Configuration.** NASA TM-81914, 1980.

Experimental transonic flutter results are presented for a simplified 1/50- size, 1.77-aspect-ratio wind-tunnel model of an arrow-wing design. Flutter results are presented for two configurations, namely, one with and one without a ventral fin mounted at the 0.694 semispan station. Results are presented for both configurations trimmed to zero lift and in a lifting condition at angles of attack up to 4°. The results show that the flutter characteristics of both configurations are similar to those usually observed. Increasing angle of attack reduces the flutter dynamic pressure by a small amount (about 13 percent maximum) for both configurations. The addition of the fin to the basic wing increases the flutter dynamic pressure. Calculated results for both configurations in the nonlifting condition obtained by using subsonic doublet-lattice unsteady aerodynamic theory correlate reasonably well with the experimental results. Calculated results for the basic wing obtained by using subsonic kernel-function unsteady aerodynamic theory did not agree as well with the experimental data.

87. Greene, W. H.; and Sobieszczanski-Sobieski, J.: **Minimum Mass Sizing of a Large Low-Aspect Ratio Airframe for Flutter-Free Performance.** NASA TM-81818, 1980. (N80-23683)

A procedure for sizing an airframe for flutter-free performance is demonstrated on a large, flexible supersonic transport aircraft. The procedure is based on using a two-level reduced basis or modal technique for reducing the computational cost of performing the repetitive flutter analyses. The supersonic transport aircraft exhibits complex dynamic behavior, has a well-known flutter problem, and requires a large finite element model to predict the vibratory and flutter response. Flutter-free designs were produced with small mass increases relative to the wing structural weight and aircraft payload.

88. McGehee, John R.; and Carden, Huey D.: **Analytical Investigation of the Landing Dynamics of a Large Airplane With a Load-Control System in the Main Landing Gear.** NASA TP-1555, 1979.

The results of an evaluation of an active load-control landing gear computer program (ACOLAG) for predicting the landing dynamics of airplanes with passive and active main gears are presented. ACOLAG was used in an analytical investigation of the landing dynamics of a large airplane with both passive and active main gears. It was concluded that the program is valid for predicting the landing dynamics of airplanes with both passive and active main gears. It was shown that the active gear reduces airframe-gear forces and airplane motions following initial impact and has the potential for significant reductions in structural fatigue damage relative to that which occurs with the passive gear.

89. McGehee, John R.; and Dreher, Robert C.: **Experimental Investigation of Active Loads Control for Aircraft Landing Gear.** NASA TP-2042, 1982.

Aircraft dynamic loads and vibrations resulting from landing impact and from runway and taxiway unevenness are recognized as significant in causing fatigue damage, dynamic stress on the airframe, crew and passenger discomfort, and reduction of the pilot's ability to control the aircraft during ground operations. One potential method

for improving operational characteristics of aircraft on the ground is the application of active control technology to the landing gears to reduce ground loads applied to the airframe. An experimental investigation was conducted which simulated the landing dynamics of a light airplane to determine the feasibility and potential of a series hydraulic active control main landing gear. The experiments involved a passive gear and an active control gear. Results of this investigation show that a series hydraulically controlled gear is feasible and that such a gear is very effective in reducing the loads transmitted by the gear to the airframe during ground operations.

90. McWithey, Robert R.; and Royster, Dick M.: **Mechanical Property Characterization of Borsic®/Aluminum Laminates at Room and Elevated Temperatures.** NASA TP-1761, 1980.

Six Borsic/aluminum laminate orientations exposed to a braze temperature cycle were tested in tension, compression, and shear to determine tangent modules, maximum stress and strain, and Poisson's ratio of the laminates at room and elevated temperatures. Mechanical properties in tension were determined from flat tensile and sandwich beam tests. Room temperature flat tensile tests were performed on laminates in the as-received condition to compare with specimens exposed to a braze temperature cycle. Sandwich beam tests were also used to determine mechanical properties in compression. Shear properties were determined from biaxially loaded, picture frame shear specimens. Results are presented by using functional relations between stress and strain and tangent modulus and strain and in tables by indicating maximum stress and strain and Poisson's ratio.

91. Murrow, Harold N.; McCain, William E.; and Rhyne, Richard H.: **Power Spectral Measurements of Clear-Air Turbulence to Long Wavelengths for Altitudes up to 14 000 Meters.** NASA TP-1979, 1982.

Measurements of three components of clear air atmospheric turbulence were made with an airplane incorporating a special instrumentation system to provide accurate data resolution to wavelengths at approximately 12 500 m (40 000 ft). Flight samplings covered an altitude range from approximately 500 to 14 000 m (1500 to 46 000 ft) in various meteorological conditions. Individual autocorrelation functions and power spectra for the three turbulence components from 43 data runs, taken primarily from mountain wave and jet stream encounters, are presented. The flight location (Eastern or Western United States), date, time, run length, intensity level (standard deviation), and values of statistical degrees of freedom for each run are provided in tabular form. The data presented should provide adequate information for detailed meteorological correlations. Some time histories which contain predominant low-frequency wave motion are also presented.

92. Poe, C. C., Jr.; and Sova, J. A.: **Fracture Toughness of Boron/Aluminum Laminates With Various Proportions of 0° and ± 45° Plies.** NASA TP-1707, 1980.

The fracture toughness of boron/aluminum laminates was measured on sheet specimens containing central slits of various lengths that represent cracks. The specimens were loaded axially and had various widths. The sheets were made with five laminate orientations. Fracture toughness was calculated for each laminate orientation. Specimens began failing at the ends of the slit with what appeared to be tensile failures of fibers in the primary load-carrying laminae. A general fracture toughness parameter independent of laminate orientation was derived on the basis of fiber failure in the principal load- carrying laminae. The value of this parameter was proportional to the critical value of the stress intensity factor. The constant of proportionality depended only on the elastic constants of the laminates.

93. Poe, C. C., Jr.: **A Single Fracture Toughness Parameter for Fibrous Composite Laminates.** NASA TM-81911, 1981.

A general fracture-toughness parameter Q_c was previously derived and verified to be a material constant, independent of layup, for centrally cracked boron aluminum composite specimens. The specimens were made with various proportions of 0 and ± 45° plies. A limited amount of data indicated that the ratio Q_c/ϵ_{tuf}, where ϵ_{tuf} is the ultimate tensile strain of the fibers, might be a constant for all composite laminates, regardless of material and layup. In that case, a single value of Q_c/ϵ_{tuf} could be used to predict the fracture toughness of all fibrous composite laminates from only the elastic constants and ϵ_{tuf}. Values of Q_c/ϵ_{tuf} were calculated for centrally cracked specimens made from graphite/polyimide, graphite/epoxy, E-glass/epoxy, boron/epoxy, and S-glass graphite/epoxy materials with numerous layups. Within ordinary scatter, the data indicated that Q_c/ϵ_{tuf} is a constant for all laminates that did not split extensively at the crack tips or have other deviate failure modes.

94. Royster, Dick M.; McWithey, Robert R.; and Bales, Thomas T.: **Fabrication and Evaluation of Brazed Titanium-Clad Borsic®/Aluminum Compression Panels.** NASA TP-1573, 1980.

Processes for brazing Borsic/aluminum composite materials that eliminate diffusion of braze alloy constituents into the aluminum matrix have been developed at the NASA Langley Research Center. One brazing study led to the development of a hybrid composite which combines high strength Borsic/aluminum and ductile titanium to form a material identified as titanium-clad Borsic/aluminum. The titanium foil provides the Borsic/aluminum with a durable outer surface and serves as a diffusion barrier which alleviates fiber and matrix degradation during brazing.

Titanium-clad Borsic/aluminum skin panels were joined to titanium-clad Borsic/aluminum stringers by brazing and were tested in end compression at room and elevated temperatures. The data include failure strength, buckling strength, and the effects of brazing on the material properties. Predicted buckling loads are compared with experimental data.

95. Royster, Dick M.; Bales, Thomas T.; and Shuart, Mark J.: **Superplastic Forming/Weld-Brazing of Titanium Compression Panels.** SPF/DB Titanium Technology, Thomas T. Bales, ed., NASA CP-2160, 1980, pp. 237–244.

The use of titanium on high-performance aircraft is increasing. However, the limitations of conventional titanium forming methods often require the use of heavier alternate alloys, a larger number of parts, or expensive components machined from thick plates or bars. The manufacture of complex parts from titanium sheet metal using conventional forming methods poses distinct manufacturing limitations. Superplastic forming is a viable method for improving fabricability of titanium alloys. Complex parts can be readily superplastically formed and diffusion bonded or superplastically formed and then joined together using a secondary process. This talk describes the NASA LaRC in-house program to study the superplastic forming/weld-brazing (SPF/WB) of compression panels for a SCR environment. The design, tooling, and fabrication of 10-in-long titanium stringers by SPF and the joining of these stringers to titanium skins by weld-brazing will be discussed. Preliminary results from end compression tests on the panels will be shown along with predicted local buckling strengths. The effects of SPF and brazing on the properties of titanium will also be discussed. The findings will be substantiated by photomicrographs of the titanium microstructure. Following evaluation of the 10-in-long, single stringer panels, the SPF/WB process will be scaled-up to fabricate 36-in. by 26-in. multistringer panels.

96. Ruhlin, Charles L.; and Pratt-Barlow, Charles R.: **Transonic Flutter Study of a Wind-Tunnel Model of an Arrow-Wing Supersonic Transport.** NASA TM-81962, 1981.

A 1/20-size, low-speed flutter model of the SCAT-15F complete airplane was tested on cables to simulate a near free-flying condition. Only the model wing and fuselage were flexible. Flutter boundaries were measured for a nominal configuration and a configuration with wing fins removed at Mach numbers from 0.76 to 1.2. For both configurations, the transonic dip in the wing flutter dynamic pressure boundary was relatively small and the minimum flutter dynamic pressure occurred near Mach 0.92. Removing the wing fins increased the flutter dynamic pressure about 14 percent and changed the flutter mode from symmetric to antisymmetric. Vibration and flutter analyses were made using a finite-element structural representation and subsonic kernel-function aerodynamics. For the nominal configuration, the analysis (using calculated modal data) predicted the experimental flutter dynamic pressure levels within 10 percent but did not predict the correct flutter mode at the higher Mach numbers. For the configuration without wing fins, the analysis predicted 16 to 36 percent unconservative (higher than experimental) flutter dynamic pressure levels and showed extreme sensitivity to mass representation details that affected wing tip mode shapes. For high subsonic Mach numbers, empennage aerodynamics had a significant effect on the predicted flutter boundaries of several symmetric modes.

97. Willis, Conrad M.: **Fluctuating Loads Measured on an Over-the-Wing Supersonic Jet Model.** NASA TP-1366, 1979. (N79-16641)

A test was conducted to measure fluctuating pressure loads on the wing and flap of an over-the-wing supersonic jet model. The model was tested statically and at a Mach number of 0.1 in a small free jet to simulate forward speed. Test parameters were impingement angle, nozzle height, and flap deflection. Load levels as high as 170 dB were measured at the center of the impingement region during static tests. Forward speed reduced the loading about 1 dB. Load level increased with increasing impingement angle and decreasing nozzle height above the wing. The effect of flap deflection was small. When scaled to full-size aircraft conditions, the maximum amplitude of the one-third-octave fluctuating pressure spectra was about 154 dB at about 160 Hz.

98. Yates, E. Carson, Jr.; Cunningham, Herbert J.; Desmarais, Robert N.; Silva, Walter A.; and Drobenko, Bohdan: **Subsonic Aerodynamic and Flutter Characteristics of Several Wings Calculated by the SOUSSA P1.1 Panel Method.** NASA TM-84485, 1982.

The SOUSSA (Steady, Oscillatory, and Unsteady Subsonic and Supersonic Aerodynamics) program is the computational implementation of a general potential-flow analysis (by the Green's function method) that can generate pressure distributions on complete aircraft having arbitrary shapes, motions, and deformations. This paper presents results of some applications of the initial release version of this program to several wings in steady and oscillatory motion, including flutter. The results are validated by comparisons with other calculations and experiments. Experiences in using the program as well as some recent improvements are described.

NASA Contractor Reports

99. *Arvin, G. H.; Israeli, L.; Stolpestad, J. H.; and Stacher, G. W.: **Evaluation of Superplastic Forming and Co-Diffusion Bonding of Ti-6Al-4V Titanium Alloy Expanded Sandwich Structures.** NASA CR-165827, 1981.

One of the outstanding new design and fabrication technologies applicable to airframe structures is the superplastic forming/diffusion bonding (SPF/DB) process, which in the field of titanium structures has already shown significant reductions in weight and fabrication cost. The program reported herein is a continuation of previous NASA programs oriented toward the application of the SPF/DB

process to supersonic cruise research. This program verifies the capability of an SPF/DB titanium structure to meet the structural requirements of the inner wing area of the NASA arrow-wing advanced supersonic transport design and consists of selection of structural concepts and their optimization of minimum weight, SPF/DB process optimization, fabrication of representative specimens, and specimen testing and evaluation. The structural area used for this research includes both upper and lower wing panels, where the upper wing panel is used for static compression strength evaluation and the lower panel, in tension, is used for fracture mechanics evaluations. The individual test specimens, cut from 6 large panels, consist of 39 static specimens, 10 fracture mechanics specimens, and 1 (each) full-size panel for compression stability and fracture mechanics testing. Tests are performed at temperatures of -54°C (-65°F), room temperature, and 260°C (500°F).

*Rockwell International Corp., contract NAS1-15788.

100. *Borland, Christopher J.: **Aeroelastic Loads Prediction for an Arrow Wing, Task I—Evaluation of R. P. White's Method.** NASA CR-3640, 1983.

The accurate prediction of loads on flexible, low-aspect-ratio wings is critical to the design of reliable and efficient aircraft. The conditions for structural design frequently involve nonlinear aerodynamics. Two separated-flow computer programs and a semiempirical method for incorporating the experimentally measured separated-flow effects into a linear aeroelastic analysis were evaluated under this contract. These three tasks are documented separately. This report describes the evaluation of R. P. White's (RASA Division of Systems Research Laboratories, Inc.) separated-flow method (Task I). This method was developed for moderately swept wings with multiple, constant-strength vortex systems. The flow on the highly swept wing used in this evaluation is characterized by a single vortex system of continuously varying strength. The data comparisons show, as currently formulated, that this method does not predict the pressure distribution on this highly swept wing. The evaluation of The Boeing Company's three-dimensional leading-edge vortex (LEV) code (Task III) is presented in NASA CR-3642. The development and evaluation of a semiempirical method to predict pressure distributions on a deformed wing from an experimental data base (Task II) is described in NASA CR-3641. These evaluations were based on a large experimental data base (for three wing shapes), which was obtained under previous NASA contracts NAS1-12875, NAS1-14141, and NAS1-14962. Linear theoretical methods were also evaluated under these contracts.

*Boeing Commercial Airplane Co., contract NAS1-15678.

101. *Del Mundo, Alhedo R.; McQuilkin, Fred T.; and Rivas, René R.: **SPF/DB Primary Structure for Supersonic Aircraft (T-38 Horizontal Stabilizer).** NASA CR-163114, 1981.

Key words: stabilizers, fluid dynamics, superplasticity, supersonic cruise aircraft research, titanium alloys, aircraft structures, diffusion welding, finite element method, and structural design criteria.

*Rockwell International Corp., contract NAS4-2651.

102. *Doble, G. S.: **Fabrication of Boron/Aluminum Fan Blades for SCR Engines.** NASA CR-165294, 1981. (X83-10114)

Some F-404 SCR Prototype first stage boron/aluminum fan blades were fabricated by rapid air bonding of fully dense monotapes. The F-404 configuration is representative of a low-aspect-ratio advanced design blade with supersonic capability. Dovetail pull tests of this geometry, which substituted boron/aluminum for titanium, suggested that excessive shear stresses were present in the root. A redesigned blade, incorporating a titanium tang and root, was fabricated by hot isostatic pressing (HIP). Blades appeared well bonded but the airfoil contained sizable areas of deformation and indentation from the alumina grain used as a pressure transmitting medium. The use of HIP with a formed steel encapsulator should eliminate this problem.

*TRW, Inc., contract NAS3-20360.

103. *Dusto, Arthur R.; and Epton, Michael A.: **An Advanced Panel Method for Analysis of Arbitrary Configurations in Unsteady Subsonic Flow.** NASA CR-152323, 1980. (N80-26270)

An advanced method is presented for solving the linear integral equations for subsonic unsteady flow in three dimensions. The method is applicable to flows about arbitrary, nonplanar boundary surfaces undergoing small-amplitude harmonic oscillations about their steady mean locations. The problem is formulated with a wake model, wherein unsteady vorticity can be convected by the steady mean component of flow. The geometric location of the unsteady source and doublet distributions can be located on the actual surfaces of thick bodies in their steady mean locations. The method is an outgrowth of a recently developed steady flow panel method and employs the linear source and quadratic doublet splines of that method.

*Boeing Commercial Airplane Co., contract NAS2-7729.

104. *Garber, D. P.: **Tensile Stress-Strain Behavior of Graphite/Epoxy Laminates.** NASA CR-3592, 1982.

The tensile stress-strain behavior of a variety of graphite/epoxy laminates was examined. Longitudinal and transverse specimens from 11 different layups were monotonically loaded in tension to failure. Ultimate strength, ultimate strain, and stress-strain curves were obtained from four replicate tests in each case. Polynomial equations were fitted by the method of least squares to the stress-strain data to determine average curves. Values of Young's modulus and Poisson's ratio, derived from polynomial coefficients, were compared with laminate analysis results. While the polynomials appeared to accurately fit the stress-strain data in most cases, the

use of polynomial coefficients to calculate elastic moduli appeared to be of questionable value in cases involving sharp changes in the slope of the stress-strain data or extensive scatter.

*Kentron International, Inc., contract NAS1-16000.

105. *Goree, James G.: **Preliminary Investigation of Crack Arrest in Composite Laminates Containing Buffer Strips.** NASA CR-3000, 1978.

The mechanical properties of some hybrid buffer strip laminates and the crack arrest potential of laminates containing buffer strips were determined. The hybrid laminates consisted of graphite with either S-glass, E-glass, or Kevlar. Unnotched tensile coupons and center-cracked fracture coupons were tested. Elastic properties, complete stress/strain curves, and critical stress intensity values are given. The measured elastic properties compare well with those calculated by classical lamination theory for laminates with linear stress/strain behavior. The glass hybrids had more delamination and higher fracture toughness than the all-graphite or the Kevlar hybrid.

*Clemson University, grant NSG-1297.

106. *Goree, James G.; and Gross, Robert S.: **Stresses in a Three-Dimensional Unidirectional Composite Containing Broken Fibers.** NASA CR-158986, 1978.

Key words: fibers, stress analysis, three-dimensional composites, numerical analysis, partial differential equations, shear stress.

*Clemson University, grant NSG-1297.

107. *Goree, James G.; Dharani, Lokeswarappa R.; and Jones, Walter, F.: **Mathematical Modeling of Damage in Unidirectional Composites.** NASA CR-3453, 1981.

A review of some approximate analytical models for damaged, fiber-reinforced composite materials is presented. Using the classical shear lag stress displacement assumption, solutions are presented for a unidirectional laminate containing a notch, a rectangular cut-out, and a circular hole. The models account for longitudinal matrix yielding and splitting as well as transverse matrix yielding and fiber breakage. The constraining influence of a cover sheet on the unidirectional laminate is also modeled.

*Clemson University, grant NSG-1297.

108. *Hill, S. G.; Peters, P. D.; and Hendricks, C. L.: **Evaluation of High Temperature Structural Adhesives for Extended Service.** NASA CR-165944, 1982. (N82-29460)

The evaluation, selection, and demonstration of structural adhesive systems for supersonic cruise research applications and establishment of environmental durability of selected systems for up to 20 000 hours is described. Ten candidate adhesives were initially evaluated. During screening and evaluation, these candidates were narrowed to three of the most promising for environmental durability testing. The three adhesives were LARC-13, PPQ, and NR056X. The LARC-13 was eliminated because of a lack of stability at 505 K. The NR056X was removed from the market. The LARC-TPI was added after preliminary evaluation and an abbreviated screening test. Only PPQ and LARC-TPI remained as the reasonable candidates late into the durability testing. Large-area bond panels were fabricated to demonstrate the processability of the selected systems. Specifications were prepared to assure control over critical material and process parameters. Surface characterization concentrated primarily upon titanium surface treatments of 10-V chronic acid anodize, 5-V chromic acid anodize, and PASA-JELL. Failure analysis was conducted on lap shear adhesive bond failures which occurred in PPQ and LARC-13 test specimens after 10 000 hours at 505 K.

*Boeing Aerospace Co., contract NAS1-15605.

109. *Kerr, J. R.; and Haskins, J. F.: **Time-Temperature-Stress Capabilities of Composite Materials for Advanced Supersonic Technology Application—Phase I.** NASA CR-159267, 1980. (N80-33496)

Advanced composites will play a key role in the development of the technology required for the design and fabrication of future supersonic vehicles. However, implementation of the material into vehicle usage is contingent upon accelerating the demonstration of service capacity and design technology. Because of the added material complexity and lack of extensive service data, laboratory replication of the flight service will provide the most rapid method of documenting the airworthiness of advanced composite systems. A program is in progress to determine the time-temperature-stress capabilities of several high-temperature composite materials. Tests included in this study are thermal aging, environmental aging, fatigue, creep, fracture, tensile strength, and real-time flight simulation exposure. The program has two parts. The first includes all the material property determinations and aging and simulation exposures up through 10 000 hours. The second continues these tests up to 50 000 cumulative hours. This report presents the results of the 10 000-hour phase, which has now been completed.

*General Dynamics Corp., contract NAS1-12308.

110. *Manro, Marjorie E.: **Aeroelastic Loads Prediction for an Arrow Wing. Task III—Evaluation of the Boeing Three-Dimensional Leading-Edge Vortex Code.** NASA CR-3642, 1983.

Two separated-flow computer programs and a semiempirical method for incorporating the experimentally measured separated-flow effects into a linear aeroelastic analysis were evaluated under this contract. These three tasks are documented separately. This report describes the evaluation of The Boeing Company's three-dimensional leading-edge vortex (LEV) code (Task III). This code is an improved panel method for three-dimensional inviscid flow over a wing with leading-edge vortex separation. The governing equations are the linear-flow differential

equations with nonlinear boundary conditions. The solution is iterative; the position as well as the strength of the vortex is determined. Cases for both full- and partial-span vortices were executed. The predicted pressures are good and adequately reflect changes in configuration. The evaluation of R. P. White's (RASA Division of Systems Research Laboratories, Inc.) separated-flow method (Task I) is presented in NASA CR- 3640. The development and evaluation of a semiempirical method to predict pressure distributions on a deformed wing from an experimental data base (Task II) is described in NASA CR-3641. These evaluations were based on a large, experimental data base (for three wing shapes), which was obtained under previous NASA contracts NAS1-12875, NAS1-14141, and NAS1-14962. Linear theoretical methods were also evaluated under these contracts.

*Boeing Commercial Airplane Co., contract NAS1-15678.

111. *Mark, William D.: **Characterization, Parameter Estimation, and Aircraft Response Statistics of Atmospheric Turbulence.** NASA CR-3463, 1981.

A non-Gaussian, three-component model of atmospheric turbulence is postulated that accounts for readily observable features of turbulence velocity records, their autocorrelation functions, and their spectra. Methods for computing probability density functions and mean exceedance rates of a generic aircraft response variable are developed using non-Gaussian turbulence characterizations readily extracted from velocity recordings. A maximum likelihood method is developed for optimal estimation of the integral scale and intensity of records possessing von Karman transverse of longitudinal spectra. Formulas for the variances of such parameter estimates are developed. The maximum likelihood and least-squares approaches are combined to yield a method for estimating the autocorrelation function parameters of a two component model for turbulence.

*Bolt Beranek and Newman Inc., contract NAS1-14837.

112. *McQuilkin, Fred T.: **Feasibility of SPF/DB Titanium Sandwich for LFC Wings.** NASA CR-165929, 1982.

This program, conducted by the North American Aircraft Operations of Rockwell International for NASA Langley Research Center, has demonstrated the feasibility of fabricating SPF/DB titanium structures of sufficient smoothness to be used for laminar flow wing surfaces. Two methods of fabricating panels which meet the surface smoothness criteria have been demonstrated. The first consists of superplastically forming/diffusion bonding a panel using steel dies and then machining the surface to the required flatness and finish after forming. This approach, however, has been estimated to be more costly than the second approach, in which the panel is formed against ceramic platens which produce the desired surface smoothness without subsequent finishing. The acceptable surface quality, as well as feasibility, of the Rockwell-developed laminar flow control (LFC) surface design, in which separate strips incorporating the boundary-layer bleed provisions are bonded into slots on the surface, has also been demonstrated. Recommendations for future work are presented, including continued study on additional smoothness concerns, scale-up to larger wing panels, fabrication of separate LFC strips, and the application of the technology to military aircraft.

*Rockwell International Corp., contract NAS1-16236.

113. *Sakata, I. F.; Davis, G. W.; and Cox, J. M.: **Advanced Hybrid Structural Concepts Development—Technology Study for Advanced Supersonic Cruise Vehicles.** NASA CR-3728, 1983.

A feasibility study was performed by the Lockheed-California Co. to assess the applications of advanced hybrid designs to a structural component of a representative supersonic cruise vehicle (SCV). The component selected for investigation was an upper spar cap of an arrow-wing configuration SCV with a multispar structural arrangement. The two designs included in this investigation were (1) a hexagonal-shaped Ti-6Al-4V spar cap reinforced with unidirectional silicon carbide (SCS-6) filament in a titanium matrix and (2) a more conventional tee-shaped Ti-6Al-4V spar cap reinforced with unidirectional boron carbide coated boron (B_4C-B) in an aluminum matrix. Both of these design studies included design, fabrication, testing, and performance evaluation phases. For the testing phase, this included an evaluation of the basic metal matrix composite (MMC) system and of the final structural component. Studies were conducted to evaluate the impact of each of these designs on the weight and performance of the representative SCV. Reported herein are the results of these studies and a discussion of the significant findings.

*Lockheed-California Co., contract NAS1-16048.

114. *Wald, G. G.: **Supersonic Cruise Vehicle Technology Assessment Study of an Over/Under Engine Concept—Advanced Aluminum Alloy Evaluation.** NASA CR-165676, 1981.

This report describes the work completed by Lockheed during the FY 1979. NASA Langley Research Center Supersonic Cruise Vehicle Technology Assessment studies in the area of advanced aluminum alloy evaluations for supersonic cruise applications. Alloys are being developed for cruise temperatures between 394 K (250°F) and 450 K (350°F) using powder metallurgy and mechanical alloying techniques. Development work was conducted by the Aluminum Co. of America (ALCOA) and the International Nickel Co. (INCO) under subcontract to the Lockheed-California Co.

*Lockheed-California Company, contract NAS1-14625, 1981.

115. *Wery, Andre C.; and Kulfan, Robert M.: **Aeroelastic Loads Prediction for an Arrow Wing. Task II—Evaluation of Semi-Empirical Methods.** NASA CR-3641, 1983.

Two separated-flow computer programs and a semiempirical method for incorporating the experimentally measured separated flow effects into a linear aeroelastic analysis were evaluated under this contract. These three tasks are documented separately. This report describes the development and evaluation of a semiempirical method to predict pressure distributions on a deformed wing by using an experimental data base in addition to a linear potential-flow solution (Task II). The experimental data account for the effects of aeroelasticity by relating the pressures to a parameter which is influenced by the deflected shape. Several parameters were examined before the net leading-edge suction coefficient was selected as the best. The evaluation of R. P. White's (RASA Division of Systems Research Laboratories, Inc.) separated-flow method (Task I) is described in NASA CR-3640. The evaluation of The Boeing Company's three-dimensional leading-edge vortex (LEV) code (Task III) is presented in NASA CR-3642. These evaluations were based on a large experimental data base (for three wing shapes) obtained under previous NASA contracts NAS1-12875, NAS1-14141, and NAS1-14962. Linear theoretical methods were also evaluated under these contracts.

*Boeing Commercial Airplane Co., contract NAS1-15678.

Articles, Meeting Papers, and Company Reports

116. Doble, Gordon S.: **Fabrication of Filamentary Reinforced Titanium Composites.** Metal Matrix Composites II, NASA CP-2252, 1982, pp. 69–77.

117. Jurey, L. F.; and Radovcich, N.: **Integrated Active Controls Impact on Supersonic Cruise Vehicle Structural Design.** SAE Paper 801210, Oct. 1980. (A81-34218)

118. Kaneko, R. S.; Davis, G. W.; Woods, C. A.; and Royster, D. M.: **Low Cost Fabrication of Sheet Structure Using a New Beta Titanium Alloy, Ti-15V-3Cr-3Al-3Sn.** Materials Overview for 1982, Volume 27 of National SAMPE Symposium and Exhibition, Soc. Advance. Mater. & Process Eng., May 1982, pp. 589–604.

119. Kennedy, John M.: **Fracture Behavior of Hybrid Composite Laminates.** AIAA-83-0804, May 1983.

120. Kerr, J. R.; and Haskins, J. F.: **Effects of 50,000 Hours of Thermal Aging on Graphite/Epoxy and Graphite/Polyimide Composites.** A Collection of Technical Papers—Part I: Structures and Materials—AIAA/ASME/ASCE/AHS 23rd Structures, Structural Dynamics and Materials Conference, May 1982, pp. 101–108. (Available as AIAA-82-0657.)

121. LeLand, T. J. W.; McGehee, J. R.; and Dreher, R. C.: **Studies of Some Unconventional Systems for Solving Various Landing Problems.** 1980 Aircraft Safety and Operating Problems, NASA CP-2170, Part 2, Joseph W. Stickle, compiler, 1981, pp. 569–582.

122. McWithey, Robert R.; Camarda, Charles J.; and Weaver, Gerald G.: **Design Considerations for Compression Panels at Elevated Temperature.** Graphite/Polyimide Composites, NASA CP-2079, 1979, pp. 319–337.

123. Morris, David L.; and McGehee, John R.: **Experimental and Analytical Investigation of Active Loads Control for Aircraft Landing Gear.** Shock & Vib. Bull., Bull. 53, Pt. 2, U.S. Dep. Def., May 1983, pp. 79–89.

124. Poe, C. C., Jr.: **A Unifying Strain Criterion for Fracture of Fibrous Composite Laminates.** Eng. Fract. Mech., vol. 17, no. 2, 1983, pp. 153–171. (A83-13340)

125. Poe, C. C., Jr.; and Kennedy, J. M.: **An Assessment of Buffer Strips for Improving Damage Tolerance of Composite Laminates.** J. Compos. Mater. Suppl., vol. 14, 1980, pp. 57–70.

126. Royster, Dick M.; Bales, Thomas T.; and Wiant, H. Ross: **Superplastic Forming/Weld-Brazing of Titanium Skin-Stiffened Compression Panels.** Materials Overview for 1982, Volume 27 of National SAMPE Symposium and Exhibition, Soc. Advance. Mater. & Process Eng., 1982, pp. 569–582.

127. Weaver, G. G., II; and Vinson, J. R.: **Minimum-Mass Designs of Stiffened Graphite/Polyimide Compression Panels.** Modern Developments in Composite Materials and Structures, J. R. Vincent, ed., American Soc. Mech. Eng., c.1979, pp. 215–233.

SCR AERODYNAMIC PERFORMANCE

NASA Formal Reports

128. Coe, Paul L., Jr.; Huffman, Jarrett K.; and Fenbert, James W.: **Leading-Edge Deflection Optimization for a Highly Swept Arrow-Wing Configuration.** NASA TP-1777, 1980.

An experimental investigation has been conducted to determine the influence of an optimized leading-edge deflection on the low-speed aerodynamic performance of a configuration with a low-aspect-ratio, highly swept wing. Tests have also been conducted to determine the sensitivity of the lateral-stability derivative C_{l_β} to geometric anhedral. The optimized leading-edge deflection was developed by aligning the leading edge with the incoming flow along the entire span. Owing to the spanwise variation of upwash, the resulting optimized leading edge was a smooth, continuously warped surface. For the particular configuration studied, levels of leading-edge suction on the order of 90 percent were achieved with the smooth, continuously warped leading-edge contour. The results of tests conducted to determine the sensitivity of C_{l_β} to geometric anhedral indicate values of $\partial C_{l_\beta}/\partial \Gamma$ which are in reasonable agreement with estimates provided by simple vortex-lattice theories.

129. Hess, R. W.; Wynne, E. C.; and Cazier, F. W., Jr.: **Static and Unsteady Pressure Measurements on a 50 Degree Clipped Delta Wing at M = 0.9.** NASA TM-83297, 1982.

Pressures were measured with Freon as the test medium. Data taken at Mach 0.9 are presented for static and oscillatory deflections of the trailing-edge control surface and for the wing in pitch. Comparisons of the static measured data are made with results computed using the Bailey-Ballhaus small disturbance code.

130. Mercer, Charles E.; and Carson, George T., Jr.: **Transonic Aerodynamic Characteristics of a Supersonic Cruise Aircraft Research Model With the Engines Suspended Above the Wing.** NASA TM-80145, 1979.

An investigation was conducted in the Langley 16-Foot Transonic Tunnel to determine the influence of upper-surface nacelle exhaust flow on the aerodynamic characteristics of a supersonic cruise aircraft research configuration over a range of Mach numbers from 0.60 to 1.20. The arrow-wing transport configuration with engines suspended over the wing was tested at angles of attack from -4° to 6° and jet total-pressure ratios from 1 to approximately 13. Wing-tip leading-edge flap deflections of -10° to 10° were tested with the wing-body configuration. Various nacelle locations (chordwise, spanwise, and vertical) were tested over the ranges of Mach numbers, angles of attack, and jet total-pressure ratios.

131. Rhyne, Richard H.: **Accuracy of Aircraft Velocities Obtained From Inertial Navigation Systems for Application to Airborne Wind Measurements.** NASA TM-81826, 1980.

An experimental assessment was made of two commercially available inertial navigation systems with regard to their inertial-velocity measuring capability for use in wind, wind shear, and long-wavelength atmospheric turbulence research. The assessment was based on 52 sets of postflight measurements of velocity (error) during a "Schuler cycle" (84 minutes) while the inertial navigation system (INS) was still operating but the airplane was motionless. Four INS units of one type and two units of another were tested over a period of two years after routine research flights similar to airline- type operations of from 1 to 6 hours duration. The maximum postflight error found for the 52 cases had a root-mean-square value of 2.82 m/s with little or no correlation of error magnitude with flight duration in the 1- to 6-hour range.

132. Robins, A. Warner; Carlson, Harry W.; and Mack, Robert J.: **Supersonic Wings With Significant Leading-Edge Thrust at Cruise.** NASA TP-1632, 1980. (N80-21279)

Experimental-theoretical correlations are presented which show that significant levels of leading-edge thrust are possible at supersonic speeds for certain planforms which match the theoretical thrust-distribution potential with the supporting airfoil geometry. The new analytical process employed provides not only the level of leading-edge thrust attainable but also the spanwise distribution and/or that component of full theoretical thrust which acts as vortex lift. Significantly improved aerodynamic performance in the moderate supersonic speed regime is indicated.

NASA Contractor Reports

133. *Bangert, L. H.; Feltz, E. P.; Godby, L. A.; and Miller, L. D.: **Aerodynamic and Acoustic Behavior of a YF-12 Inlet at Static Conditions.** NASA CR-163106, 1981. (N81-21079)

An aeroacoustic test program was performed with a YF-12 aircraft at ground static conditions. The objective was to collect acoustic and aerodynamic data that could determine the cause of YF-12 inlet noise suppression observed earlier. Data were obtained over a wide range of engine speeds; with the spike in forward, midway, and aft positions; with the forward bypass open or closed; and with the spike bleed open or closed. Acoustic measurements were made in the far field and aerodynamic and acoustic measurements were made inside the YF-12 inlet. The J58 test engine was also removed from the aircraft and tested separately with a bellmouth inlet. The test results showed that the far-field noise level was significantly lower for the YF-12 inlet than for the bellmouth inlet at engine speeds above about 5500 rpm. The differences varied from about 5 PNdB to about 11 PNdB, depending on engine speed and on YF-12 inlet configuration. There was no evidence that YF-12 inlet noise suppression was caused by flow choking. The spectral peak near the blade passing frequency disappeared in the region of the spike support struts at engine speeds between 6000 and 6600 rpm, however. Also, multiple pure tones were significantly reduced in the region of the spike support struts.

*Lockheed-California Co., contract NAS1-14625.

134. *Carlson, Harry W.; and Walkley, Kenneth B.: **A Computer Program for Wing Subsonic Aerodynamic Performance Estimates Including Attainable Thrust and Vortex Lift Effects.** NASA CR-3515, 1982.

This report describes numerical methods which have been incorporated into a computer program to provide estimates of the subsonic aerodynamic performance of twisted and cambered wings of arbitrary planform with attainable thrust and vortex lift considerations taken into account. The computational system is based on a linearized theory lifting-surface solution which provides a spanwise distribution of theoretical leading-edge thrust in addition to the surface distribution of perturbation velocities. In contrast to the commonly accepted practice of obtaining linearized theory results by simultaneous solution of a large set of equations, the approach used here relies on a solution iteration. The method also features a superposition of independent solutions for a cambered and twisted wing and a flat wing of the same planform to provide, at little additional expense, results for a large number of angles of attack or lift coefficients. A previously developed method is employed to assess

the portion of the theoretical thrust actually attainable and the portion that is felt as a vortex normal force.

*Kentron International, Inc., contract NAS1-16000.

135. *Carlson, Harry W.: **Application of an Aerodynamic Analysis Method Including Attainable Thrust Estimates to Low Speed Leading-Edge Flap Design for Supersonic Cruise Vehicles.** NASA CR-165843, 1982. (X83-10271)

A study of low-speed leading-edge flap design for supersonic cruise vehicles has been conducted. Wings with flaps were analyzed with the aid of a newly developed subsonic wing program which provides estimates of attainable leading-edge thrust. Results indicate that the thrust actually attainable can have a significant influence on the design and that the resultant flaps can be smaller and simpler than those resulting from more conventional approaches.

*Kentron International, Inc., contract NAS1-16000.

136. *Dusto, Arthur R.; and Epton, Michael A.: **An Advanced Panel Method for Analysis of Arbitrary Configurations in Unsteady Subsonic Flow.** NASA CR-152323, 1980. (N80-26270)

An advanced method is presented for solving the linear integral equations for subsonic unsteady flow in three dimensions. The method is applicable to flows about arbitrary, nonplanar boundary surfaces undergoing small amplitude harmonic oscillations about their steady mean locations. The problem is formulated with a wake model, wherein unsteady vorticity can be convected by the steady mean component of flow. The geometric location of the unsteady source and doublet distributions can be located on the actual surfaces of thick bodies in their steady mean locations. The method is an outgrowth of a recently developed steady-flow panel method and employs the linear source and quadratic doublet splines of that method.

*Boeing Commercial Airplane Co., contract NAS2-7729.

137. *Kerr, J. R.; and Haskins, J. F.: **Time-Temperature-Stress Capabilities of Composite Materials for Advanced Supersonic Technology Application—Phase I.** NASA CR-159267, 1980. (N80-33496)

Advanced composites will play a key role in the development of the technology required for the design and fabrication of future supersonic vehicles. However, implementation of the material into vehicle usage is contingent upon accelerating the demonstration of service capacity and design technology. Because of the added material complexity and lack of extensive service data, laboratory replication of the flight service will provide the most rapid method of documenting the airworthiness of advanced composite systems. A program is in progress to determine the time-temperature-stress capabilities of several high-temperature composite materials. Tests included in this study are thermal aging, environmental aging, fatigue, creep, fracture, tensile strength, and real-time flight simulation exposure. The program has two parts. The first includes all the material property determinations and aging and simulation exposures up through 10 000 hours. The second continues these tests up to 50 000 cumulative hours. This report presents the results of the 10 000-hour phase, which has now been completed.

*General Dynamics Corp., contract NAS1-12308.

138. *Lan, C. Edward; and Mehrotra, Sudhir C.: **An Improved Woodward's Panel Method for Calculating Leading-Edge and Side-Edge Suction Forces at Subsonic and Supersonic Speeds.** NASA CR-3205, 1979.

Woodward's panel method for subsonic and supersonic flow was improved by employing control points determined by exactly matching two-dimensional pressure at a finite number of points. The results show great improvement in the predicted pressure distribution of a flapped airfoil. With the paneling scheme of cosine law in both chordwise and spanwise directions, the method is shown to accurately predict leading-edge and side-edge suction forces of various configurations in subsonic and supersonic flow.

*Kansas University, Center for Research, Inc., grant NSG-1046.

139. *Manro, Marjorie E.: **Transonic Pressure Measurements and Comparison of Theory to Experiment for Three Arrow-Wing Configurations, Volume I: Experimental Data Report—Basic Data and Effect of Wing Shape.** NASA CR-165701, 1981.

Wind tunnel tests of arrow-wing body configurations consisting of flat, twisted, and cambered-twisted wings, as well as a variety of leading- and trailing-edge control-surface deflections, have been conducted at Mach numbers from 0.4 to 1.05 to provide an experimental pressure data base for comparison with theoretical methods. Comparisons of the predictions of current state-of-the-art and advanced attached-flow methods to the detailed experimental pressure distributions have been made to delineate conditions under which these theories are valid for these wings. This volume presents the basic experimental results and the effect of wing shape—twist, camber, and combined camber and twist. The effects of full- and partial-span trailing-edge control-surface deflection and a wing fin are presented in NASA CR-165702. NASA CR-165703 presents detailed comparisons of the predictions of attached-flow methods to experimental results. NASA CR-3434 summarizes the results of this entire investigation. These reports supplement those from earlier test programs using this model which cover a range of Mach numbers from 0.40 to 2.50. Only the flat wing and the twisted wing were available for these earlier test programs. These data have been reported in NASA CR-2610, NASA CR-132727, NASA CR-132728, NASA CR-132729, and NASA CR-145046.

*Boeing Commercial Airplane Co., contract NAS1-14962.

140. *Manro, Marjorie E.: **Transonic Pressure Measurements and Comparison of Theory to Experiment for Three Arrow-Wing Configurations, Volume II: Experimental Data Report—Effect of Trailing-Edge Control Surface Deflection and a Wing Fin.** NASA CR-165702, 1981.

This volume presents the effects of full- and partial-span trailing-edge control-surface deflection and a wing fin. NASA CR-165701 presents the basic experimental results and the effect of wing shape—twist, camber, and combined camber and twist. Detailed comparisons of the prediction of attached-flow methods to experimental results are presented in NASA CR-165703. NASA CR-3434 summarizes the results of this entire investigation. These reports supplement those from earlier test programs using this model which cover a range of Mach numbers from 0.40 to 2.50. Only the flat wing and the twisted wing were available for these earlier test programs. These data have been reported in NASA CR-2610, NASA CR-132727, NASA CR-132728, NASA CR-132729, and NASA CR-145046.

*Boeing Commercial Airplane Co., contract NAS1-14962.

141. *Manro, Marjorie E.: **Transonic Pressure Measurements and Comparison of Theory to Experiment for Three Arrow-Wing Configurations, Volume III: Data Report—Comparison of Attached-Flow Theories to Experiment.** NASA CR-165703, 1981.

This volume presents detailed comparisons of the predictions of attached-flow methods to experimental results. NASA CR-165701 presents the basic experimental results and the effect of wing shape—twist, camber, and combined camber and twist. The effects of full- and partial-span trailing-edge control-surface deflection and a wing fin are presented in NASA CR-165702. NASA CR-3434 summarizes the results of this entire investigation. These reports supplement those from earlier test programs using this model which cover a range of Mach numbers from 0.40 to 2.50. Only the flat wing and the twisted wing were available for these earlier test programs. These data have been reported in NASA CR-2610, NASA CR-132727, NASA CR-132728, NASA CR-132729, and NASA CR-145046.

*Boeing Commercial Airplane Co., contract NAS1-14962.

142. *Manro, Marjorie E.: **Transonic Pressure Measurements and Comparison of Theory to Experiment for Three Arrow-Wing Configurations—Summary Report.** NASA CR-3434, 1982.

Wind tunnel tests of arrow-wing body configurations consisting of flat, twisted, and cambered-twisted wings, as well as a variety of leading- and trailing-edge control-surface deflections, have been conducted at Mach numbers from 0.4 to 1.05 to provide an experimental pressure data base for comparison with theoretical methods. Comparisons of the predictions of current state-of-the-art and advanced attached-flow methods to the detailed experimental pressure distributions have been made to delineate conditions under which these theories are valid for these wings. This report summarizes the results of the entire program. NASA CR-165701 presents more detailed results of the experimental phase of the program for the basic data and comparison of the effect of wing shape—twist, camber, and combined camber and twist. The effects of trailing-edge control-surface deflection and of the wing fin are presented in NASA CR-165702. NASA CR-165703 presents in more detail the comparisons of the predictions of attached-flow theory to experimental data. These reports supplement those from earlier test programs using this model which cover a range of Mach numbers from 0.40 to 2.50. Only the flat wing and the twisted wing were available for these earlier test programs. These data have been reported in NASA CR-2610, NASA CR-132727, NASA CR-132728, NASA CR-132729. and NASA CR-145046.

*Boeing Commercial Airplane Co., contract NAS1-14962.

143. *Martin, Glenn L.; and Walkley, Kenneth B.: **Aerodynamic Design and Analysis of the AST-204, -205, and -206 Blended Wing-Fuselage Supersonic Transport Configuration Concepts.** NASA CR-159223, 1980.

The aerodynamic design and analysis of three blended wing-fuselage supersonic cruise configurations providing four-, five-, and six-abreast seating was conducted using a previously designed supersonic cruise configuration as the baseline. The five-abreast configuration was optimized for wave drag at a Mach number of 2.7. The four- and six-abreast configurations were also optimized at Mach 2.7, but with the added constraint that the majority of their structure be common with the five-abreast configuration. Analysis of the three configurations indicated an improvement of 6.0, 7.5, and 7.7 percent in cruise lift-drag ratio over the baseline configuration for four, five, and six abreast.

*Kentron International, Inc., contract NAS1-16000.

144. *Middleton, W. D.; and Lundry, J. L.: **A System for Aerodynamic Design and Analysis of Supersonic Aircraft. Part 1—General Description and Theoretical Development.** NASA CR-3351, 1980.

An integrated system of computer programs has been developed 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. The description of the design and analysis system is broken into four parts, covered in four separate documents:

Part 1—General description and theoretical development (NASA CR-3351)

Part 2—User's manual (NASA CR-3352)

Part 3—Computer program description (NASA CR-3353)

Part 4—Test cases (NASA CR-3354)

This part contains a general description of the program and a description of the theory used. These four documents

supersede NASA CR-2715, CR-2716, and CR- 2717, which describe an earlier version of the system.

*Boeing Commercial Airplane Co., contract NAS1-15534.

145. *Middleton, W. D.; Lundry, J. L.; and Coleman, R. G.: **A System for Aerodynamic Design and Analysis of Supersonic Aircraft. Part 2—User's Manual.** NASA CR-3352, 1980.

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 were included in the system to display or edit input and to permit monitoring and read out of program results.

*Boeing Commercial Airplane Co., contract NAS1-15534.

146. *Middleton, W. D.; Lundry, J. L.; and Coleman, R. G.: **A System for Aerodynamic Design and Analysis of Supersonic Aircraft. Part 3—Computer Program Description.** NASA CR-3353, 1980.

The computer program documentation for the design and analysis of supersonic configurations is presented. Schematics and block diagrams of the major program structure together with subroutine descriptions for each module are included.

*Boeing Commercial Airplane Co., contract NAS1-15534.

147. *Middleton, W. D.; and Lundry, J. L.: **A System for Aerodynamic Design and Analysis of Supersonic Aircraft. Part 4—Test Cases.** NASA CR-3354, 1980.

An investigated system of computer programs was developed 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. Representative test cases and associated program output are presented.

*Boeing Commercial Airplane Co., contract NAS1-15534.

148. *Moretti, Gino: **Calculation of Three-Dimensional, Inviscid Supersonic, Steady Flows.** NASA CR-3573, 1982.

A numerical technique is described for the calculation of three-dimensional, inviscid, supersonic, steady flows over wing-body configurations. A high degree of accuracy without increasing the number of computational nodes is obtained by means of a powerful conformal mapping technique. Results are presented for some simple body configurations and for a more complex arrow-wing airframe. The numerical results show good agreement with experimental measurements.

*Polytechnic Inst. of New York, grant NSG-1248.

149. *Morino, Luigi: **Steady, Oscillatory, and Unsteady Subsonic and Supersonic Aerodynamics—Production Version (SOUSSA-P 1.1). Volume I—Theoretical Manual.** NASA CR-159130, 1980. (N80-26269)

A review and summary of recent developments of the Green's function method and the computer program SOUSSA (Steady, Oscillatory, and Unsteady Subsonic and Supersonic Aerodynamics) are presented. Applying the Green's function method to the fully unsteady (transient) potential equation yields an integro- differential-delay equation. With spatial discretization by the finite-element method, this equation is approximated by a set of differential-delay equations in time. Time solution by Laplace transform yields a matrix relating the velocity potential to the normal wash. Premultiplying and postmultiplying by the matrices relating generalized forces to the potential and the normal wash to the generalized coordinates, one obtains the matrix of the generalized aerodynamic forces. The frequency and mode-shape dependence of this matrix makes the program SOUSSA very useful for multiple frequency and repeated mode-shape evaluations. The program SOUSSA is general, flexible, easy to use, and accurate. Applications to aerodynamic design are also discussed. The user/programmer manual for SOUSSA-P 1.1 is presented in Volume 2 of this report (NASA CR-159131).

*Aerospace Systems, Inc., contract NAS1-14977.

150. *Page, G. S.; Cunningham, E. J.; and Welge, H. R.: **Supersonic Aerodynamic Wind Tunnel Test Results of an Advanced 2.2 Mach Cruise Transport Configuration.** NASA CR-165933, 1982.

A cooperative McDonnell Douglas-NASA wind tunnel test of a McDonnell Douglas Mach 2.2 advanced supersonic transport configuration was conducted in the Langley 4 x 4 Foot Supersonic Wind Tunnel. The purposes of the test were to verify refined aerodynamic analysis procedures and to verify the performance of the refined wing design designated wing W_4. Comparisons of experimental data with theoretical estimates show good agreement over the test Mach number range of 1.8 to 2.86. Performance of the refined W_4 wing configuration shows a 0.92 improvement in lift-drag ratio L/D from the previous test configuration for a trimmed, full-scale L/D of 9.75 at Mach 2.2. The configuration also achieves a favorable nacelle interference for the wing/nacelle integration technique used. The experimental data show the W_4 wing configuration does not present any lateral-directional stability problems at cruise. Data analysis indicates the W_4 wing configuration did not produce the predicted pitching moment increment due to nacelle addition. A further L/D improvement is available by recambering the wing for the measured nacelle pitching moment.

*McDonnell Douglas Corp., contract NAS1-14624.

151. *Smolka, Scott A.; Preuss, Robert D.; Tseng, Kadin; and Morino, Luigi: **Steady, Oscillatory, and Unsteady Subsonic and Supersonic Aerodynamics—**

Production Version 1.1 (SOUSSA-P 1.1). Volume II—User/Programmer Manual. NASA CR-159131, 1980.

The theoretical formulation upon which the program is based is described in a companion manual, NASA CR-159130. The overall objective in designing the program was to provide accurate and efficient evaluation of steady and unsteady loads on aircraft having arbitrary shapes and motions, including structural deformations. The SOUSSA-P 1.1 program was therefore designed to be modular, computationally efficient, user oriented, general, accurate, and simple. These design goals were in part achieved through the incorporation of the data handling capabilities of the SPAR finite-element structural analysis computer program. As a further result, SOUSSA-P 1.1 possesses an extensive checkpoint/restart facility. The programmer's portion of this manual includes the following: overlay/subroutine hierarchy, logical flow of control, definition of SOUSSA-P 1.1 FORTRAN variables, and definition of SOUSSA-P 1.1 subroutines. The user-oriented portion of the manual describes the following: purpose of the SOUSSA-P 1.1 modules, input data to the program, output of the program, hardware/software requirements, error detection and reporting capabilities, job control statements, a summary of the procedure for running the program, and two test cases including input and output listings.

*Aerospace Systems, Inc., contract NAS1-14977.

152. *Syberg, J.; and Turner, L.: **Supersonic Test of a Mixed-Compression Axisymmetric Inlet at Angles of Incidence.** NASA CR-165686, 1981.

A large-scale model of a supersonic inlet has been tested in the Lewis 10 x 10 Foot Supersonic Wind Tunnel to obtain generalized data on the internal flow characteristics of supersonic inlets operating at angle of incidence. This report describes and analyzes the test results and provides a data bank index that will facilitate future, more extensive studies of the data.

*Boeing Commercial Airplane Co., contract NAS1-16150.

153. *Woodward, F. A.: **Development of the Triplet Singularity for the Analysis of Wings and Bodies in Supersonic Flow.** NASA CR-3466, 1981.

A supersonic triplet singularity was developed which eliminates internal waves generated by panels having supersonic edges. The triplet is a linear combination of source and vortex distributions which gives directional properties to the perturbation flow field surrounding the panel. The theoretical development of the triplet singularity is described, together with its application to the calculation of surface pressures on wings and bodies. Examples are presented comparing the results of the new method with other supersonic methods and with experimental data.

*Analytical Methods, Inc., contract NAS1-15792.

154. *Yetter, Jeffrey A.; and Evelyn, George B.: **Nozzle Installation Effects for Supersonic Cruise Configurations.** NASA CR-165835, 1982.

A wind tunnel test has been conducted to evaluate exhaust nozzle-airframe interactions at transonic speeds for a representative supersonic cruise vehicle with an underwing nacelle installation. The purpose of the test was threefold: (1) to establish and validate a test approach from which the nozzle performance, nozzle drag, power sensitive boattail effects, and nozzle-airframe interactions could be evaluated; (2) to determine the magnitude of the nozzle installation effects for use in related NASA supersonic cruise technology system studies; (3) to provide a data base for validation of analytical codes. The test results indicate that the test approach does permit evaluation of nozzle-airframe interactions and the performance assessment of candidate nozzle concepts for development of low-drag supersonic exhaust system installations. Favorable installation effects were found to be significant at high subsonic cruise Mach numbers. A 3-D linearized potential flow analysis provided qualitative results that aided in interpretation of the test data.

*Boeing Military Airplane Co., contract NAS1-16150.

Articles, Meeting Papers, and Company Reports

155. Kandil, Osama A.: **State of Art of Nonlinear, Discrete-Vortex Methods for Steady and Unsteady High Angle of Attack Aerodynamics.** High Angle of Attack Aerodynamics, AGARD-CP-247, Jan. 1979, pp. OD5-1–OD5-5.

156. Kandil, Osama A.: **Numerical Prediction of Vortex Cores of the Leading and Trailing Edges of Delta Wings.** ICAS Paper No. 80-14.2, Oct. 1980. (A81-14475)

157. Kandil, Osama A.; Chu, Li-Chuan; and Tureaud, Thomas: **Steady and Unsteady Nonlinear Hybrid Vortex Method for Lifting Surfaces at Large Angles of Attack.** AIAA-82-0351, Jan. 1982.

158. Tseng, Kadin; and Morino, Luigi: **Fully Unsteady Subsonic and Supersonic Potential Aerodynamics of Complex Aircraft Configurations for Flutter Applications.** Proceedings—AIAA/ASME/SAE 17th Structures, Structural Dynamics, and Materials Conference, May 1976, pp. 626-638.

SCR STABILITY AND CONTROL

NASA Formal Report

159. Oehman, Waldo I.: **Stability and Control of a Supersonic Transport Airplane During Landing Approach.** NASA TM-84659, 1983.

Previous simulator studies have shown that a proposed supersonic transport airplane exhibits undesirable lateral motions during landing approach. Large adverse sideslip excursions and large peak lateral acceleration at

the pilot's station occurred during rolling maneuvers of the unaugmented airplane. In this study, modal control theory has been applied to determine feedback gains that provide desirable stability characteristics and satisfactory transient response to aileron deflection input. However, the peak value of lateral acceleration at the pilot's station does not satisfy a proposed criterion during a rolling maneuver. Optimal regulator theory was then applied to the closed loop design provided by the modal procedure in an attempt to reduce the acceleration peak. However, this did not provide a significant reduction of the peak lateral acceleration. Subsequent experimentation with various open loop rudder and aileron control inputs provided the desired bank angle (30°) with the desired roll rate (10 deg/sec) and provided a satisfactory level of lateral acceleration. However, a large adverse sideslip angle was required.

NASA Contractor Reports

160. *Anderson, D. L.; Connolly, G. F.; Mauro, F. M.; and Reukauf, P. J.: **YF-12 Cooperative Airframe/Propulsion Control System Program—Volume I.** NASA CR-163099, 1980. (N81-13044)

Several YF-12C airplane analog control systems were converted to a digital system. Included were the air data computer, autopilot, inlet control system, and autothrottle systems. This conversion was performed to allow assessment of digital technology applications to supersonic cruise aircraft. The digital system was composed of a digital computer and a specialized interface unit. A large-scale mathematical simulation of the airplane was used for integration testing and software checkout. The general objective was accomplished with some minor deviations which could have been corrected during a full development program. The system was flown for approximately 23 hours.

*Lockheed-California Co.

161. *Ashkenas, I. L.; Magdaleno, R. E.; and McRuer, D. T.: **Flight Control and Analysis Methods for Studying Flying and Ride Qualities of Flexible Transport Aircraft.** NASA CR-172201, 1983. (X84-10010)

Methods and treatment of flight control problems related to flying and ride qualities of a flexible, supersonic cruise transport aircraft are systematically addressed. General aspects of flexible vehicle control and system design requirements and desires are first formulated in order to better define the problem(s), a necessary precursor to the selection/development of a pertinent methodology. The available methodology is then considered and evaluated in the light of its adequacy, efficiency, and insight development relative to flexible-aircraft flying and ride-quality flight control. The basic control methodology selected comprises conventional, classical, multivariable, frequency-domain analysis techniques. The efficient application of these techniques to the design of a suitable flexible-aircraft flight control system requires approximating the full modal equations of motion, including unsteady aerodynamics, with one or more reduced-order models, depending on the bandwidths of interest. The considerations involved in and the progressive development of these models are given in detail. Ride-quality considerations demand a fairly high bandwidth of interest and dictate the final model selected for flight control design, which is accomplished according to the considerations previously set forth. The resulting flight-control-augmented aircraft characteristics are assessed against a number of flying and ride-quality criteria and considerations. Specific areas worthy of piloted simulation and additional analysis are delineated.

*Systems Technology, Inc., contract NAS1-16847.

162. *Govindaraj, K. S.; Lyons, J. R.; and Chalk, C. R.: **Evaluation of Handling Qualities of Flexible Aircraft. Phase 1: Model Procedures.** NASA CR-165822, 1981. (X82-10039)

Modeling procedures were developed to evaluate the handling qualities of large, flexible aircraft. The modeling procedure used consisted of two steps: (1) obtain reduced-order transfer function models of the aircraft, including the important flexible mode responses and the unsteady aerodynamic effects from the frequency response data; and (2) convert the transfer function models obtained in step (1) to time domain equations of motion or, equivalently, to a state space representation. The computer programs for performing the two steps involved in the modeling procedure were also developed.

*Calspan Corp., Advanced Technology Center, NASA Order L-75228A and contract AF-F33615-79-C-3618.

163. *Govindaraj, K. S.; and Chalk, C. R.: **Evaluation of Handling Qualities of Flexible Aircraft. Phase 2: Development of Simulation Model.** NASA CR-166014, 1982. (X83-10003)

The objective of this study was to develop time domain simulation models from frequency response data. The modeling procedure developed in phase 1 of the study was used for simulation model development. The data, which include the effects of flexible modes and unsteady aerodynamics, were computed by Boeing Aircraft Co. using complex mathematical models for the frequency range from 0.01 to 10 Hz. The data in the frequency range from 0.01 to 4 Hz were selected for model development. The data have five symmetric and six antisymmetric structural modes in this frequency range. Transfer functions were first estimated and then converted to time domain equations. With the inclusion of the rigid body modes, the longitudinal model is 14th order and the lateral model is 16th order. These models define the responses at the center of gravity station. Auxiliary equations are defined to compute the responses at other stations. The final simulation model includes the nonlinear kinematic and inertial coupling terms, but treats the aerodynamics linearly.

*Calspan Corp., Advanced Technology Center, NASA Order L-75228A and contract AF-F33615-79-C-3618.

164. *Levison, William H.; and Rickard, William W.: **Analytical and Simulator Study of Advanced Transport Handling Qualities.** NASA CR-3572, 1982.

An analytic methodology, based on the optimal-control pilot model, was demonstrated for assessing longitudinal-axis handling qualities of transport aircraft in final approach. Calibration of the methodology is largely in terms of closed-loop performance requirements, rather than specific vehicle response characteristics, and is based on a combination of published criteria, pilot preferences, physical limitations, and engineering judgment. Six longitudinal-axis approach configurations were studied covering a range of handling quality problems, including the presence of flexible aircraft modes. The analytical procedure was used to obtain predictions of Cooper-Harper ratings, a solar quadratic performance index, and root-mean-square excursions of important system variables.

*Bolt Beranek and Newman, Inc., contract NAS1-16410.

165. *Matthew, John R.: **Developing, Mechanizing and Testing of a Digital Active Flutter Suppression System for a Modified B-52 Wind-Tunnel Model.** NASA CR-159155, 1980. (N80-19566)

A study was conducted to develop and mechanize a digital flutter suppression system for a significantly modified version of the 1/30-scale B-52E aeroelastic wind tunnel model. A model configuration was identified that produced symmetric and antisymmetric flutter modes that occur at 2873 N/m^2 (60 psf) dynamic pressure with violent onset. The flutter suppression system, using one trailing-edge control surface and two accelerometers on each wing, extended the flutter dynamic pressure of the model beyond the design limit of 4788 N/m^2 (100 psf). The hardware and software required to implement the flutter suppression system were designed and mechanized using digital computers in a fail-operate configuration. The model equipped with the system was tested in the Transonic Dynamics Tunnel at NASA Langley Research Center, and results showed the flutter dynamic pressure of the model was extended beyond 4884 N/m^2 (102 psf).

*Boeing Military Airplane Co., contract NAS1-14031.

166. *Ross Irving; and Edson, Ralph: **An Electronic Control for an Electrohydraulic Active Control Landing Gear for the F-4 Aircraft.** NASA CR-3552, 1982.

A controller for an electrohydraulic active-control landing gear was developed for the F-4 aircraft. A controller was modified for this application. Simulation results indicate that during landing and rollout over repaired bomb craters the active gear effects a force reduction, relative to the passive gear, of approximately 70 percent.

*Hydraulic Research Textron, contract NAS1-16420.

167. *Weingarten, Norman C.; and Chalk, Charles R.: **In-Flight Investigation of the Effects of Pilot Location and Control System Design on Airplane Flying Qualities for Approach and Landing.** NASA CR-163115, 1982.

The handling qualities of large airplanes in the approach and landing flight phase were studied. The primary variables were relative pilot position with respect to center of rotation, command path time delays and phase shifts, augmentation schemes, and levels of augmentation. It is indicated that the approach and landing task with large airplanes is a low-bandwidth task. Low equivalent short-period frequencies and relatively long time delays are tolerated only when the pilot is located at a considerable distance forward of the center of rotation. The control problem experienced by the pilots, when seated behind the center of rotation, tended to occur at low altitudes when they were using visual cues of rate of sink and altitude. A direct lift controller improved final fight-path control of the Shuttle-like configurations.

*Calspan Corp., Advanced Technology Center, contract AF-F33615-79-C- 3618.

Articles, Meeting Papers, and Company Reports

168. Govindaraj, K. S.; Eulrich, B. J.; and Chalk, C. R.: **Modeling Procedures for Handling Qualities Evaluation of Flexible Aircraft.** Paper presented at IEEE 19th Annual Allerton Conference on Communication, Control, and Computing (Monticello, Illinois), Sept.–Oct. 1981. (A82-13968)

169. Levison, William H.: **A Model-Based Technique for Predicting Pilot Opinion Ratings for Large Commercial Transports.** A Collection of Technical Papers—AIAA Atmospheric Flight Mechanics Conference, Aug. 1980, pp. 166–174. (Available as AIAA-80-1573.)

170. Nissim, E.; and Lottati, I.: **Active Controls for Flutter Suppression and Gust Alleviation in Supersonic Aircraft.** J. Guid. & Control, vol. 3, no. 4, July–Aug. 1980, pp. 345–351.

171. Poopaka, S.: **Handling Qualities of Large Flexible Aircraft.** Ph. D. Thesis, Oklahoma State Univ., 1980. (N81-28081)

172. Schwanz, Robert C.; and Grimes, Gary L.: **Parameter Identification of B-52E CCV Flight Test Data Including Aeroelastic Effects.** A Collection of Technical Papers—AIAA Atmospheric Flight Mechanics Conference, Aug. 1980, pp. 662–676. (Available as AIAA-80-1635.)

173. Sliwa, Steven M.: **Impact of Longitudinal Flying Qualities Upon the Design of a Transport With Active Controls.** A Collection of Technical Papers—AIAA Atmospheric Flight Mechanics Conference, Aug. 1980, pp. 133–141. (Available as AIAA-80-1570.)

174. Weingarten, Norman C.; and Chalk, Charles R.: **In-Flight Investigation of Large Airplane Flying Qualities for Approach and Landing.** AFWAL-TR-81-3118, U.S. Air Force, Sept. 1981. (N83-16332) (Available from DTIC as AD A120 202.)

AUTHOR INDEX

INDEX OF NASA REPORT NUMBERS

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA RP-1117		

4. Title and Subtitle	5. Report Date
BIBLIOGRAPHY OF SUPERSONIC CRUISE RESEARCH (SCR) PROGRAM FROM 1980 TO 1983	July 1984
	6. Performing Organization Code 505-43-43-01
7. Author(s) Sherwood Hoffman	8. Performing Organization Report No. L-15740
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665	10. Work Unit No.
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546	13. Type of Report and Period Covered Reference Publication
	14. Sponsoring Agency Code

15. Supplementary Notes

Bibliography for 1972 to mid-1977 is published as NASA RP-1003 and bibliography for 1977 to mid-1980 is published as NASA RP-1063.

16. Abstract

This report is the third and final bibliography for the Supersonic Cruise Research (SCR) and Variable-Cycle Engine (VCE) Programs. Prior bibliographies (NASA RP-1003 and RP-1063) cover the reporting time period from 1972 to mid-1980. The reports and articles published in 1980 to 1983 are listed herein, and all publications that were received by the end of 1983 are included. The total number of contractors and grantees at the close of the program was 105. The studies they performed, plus those undertaken by the NASA research centers during a decade of work, produced approximately 690 formal reports and about 340 articles. This final paper presents an annotated bibliography for the last 123 formal reports and a listing of titles for 44 articles and presentations. The studies identified technologies for producing efficient supersonic commercial jet transports for cruise Mach numbers from 2.0 to 2.7.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Supersonic transports Propulsion Materials and structures Aerodynamic performance Stability and control	Unclassified—Unlimited Subject Category 02

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	55	A04

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