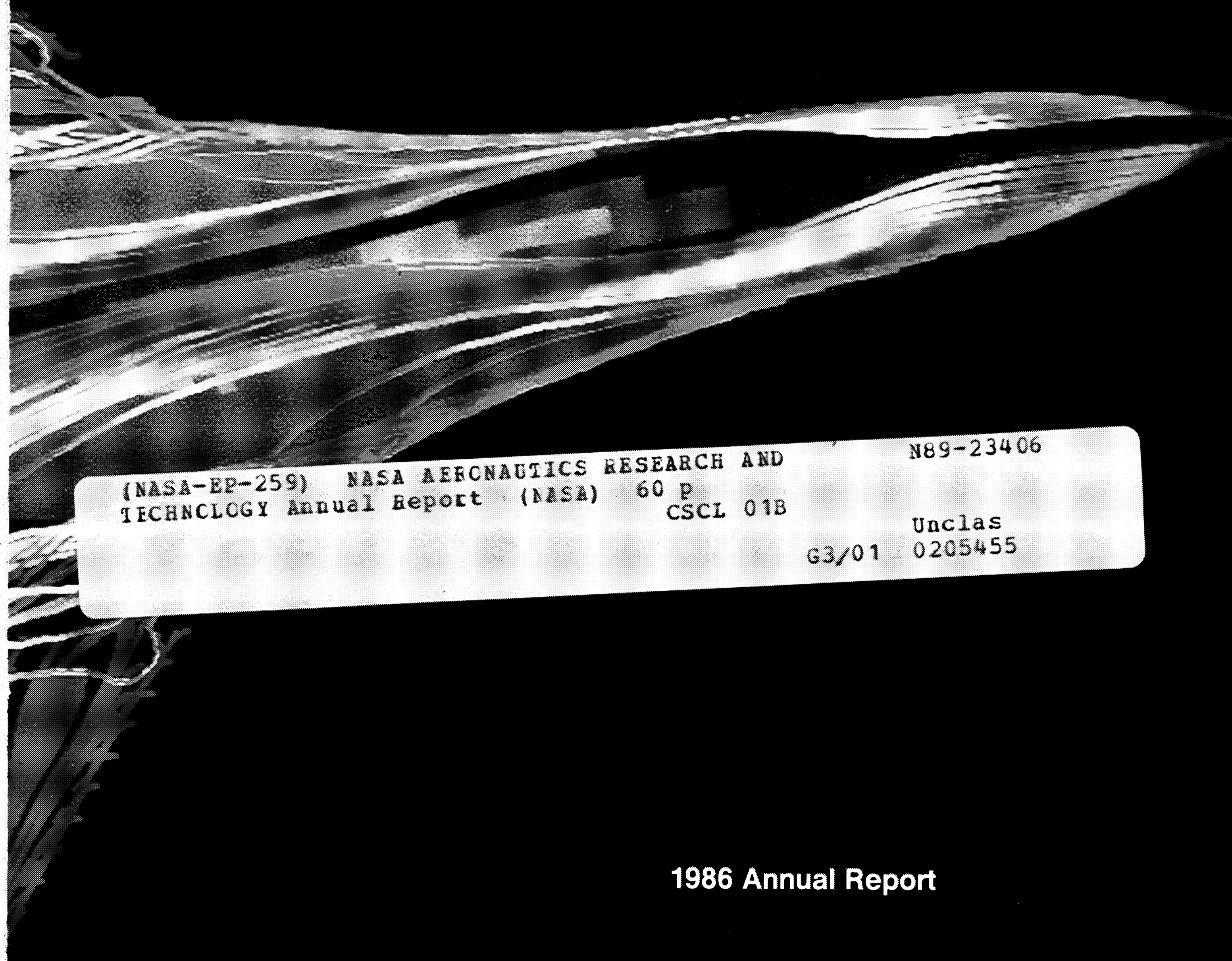
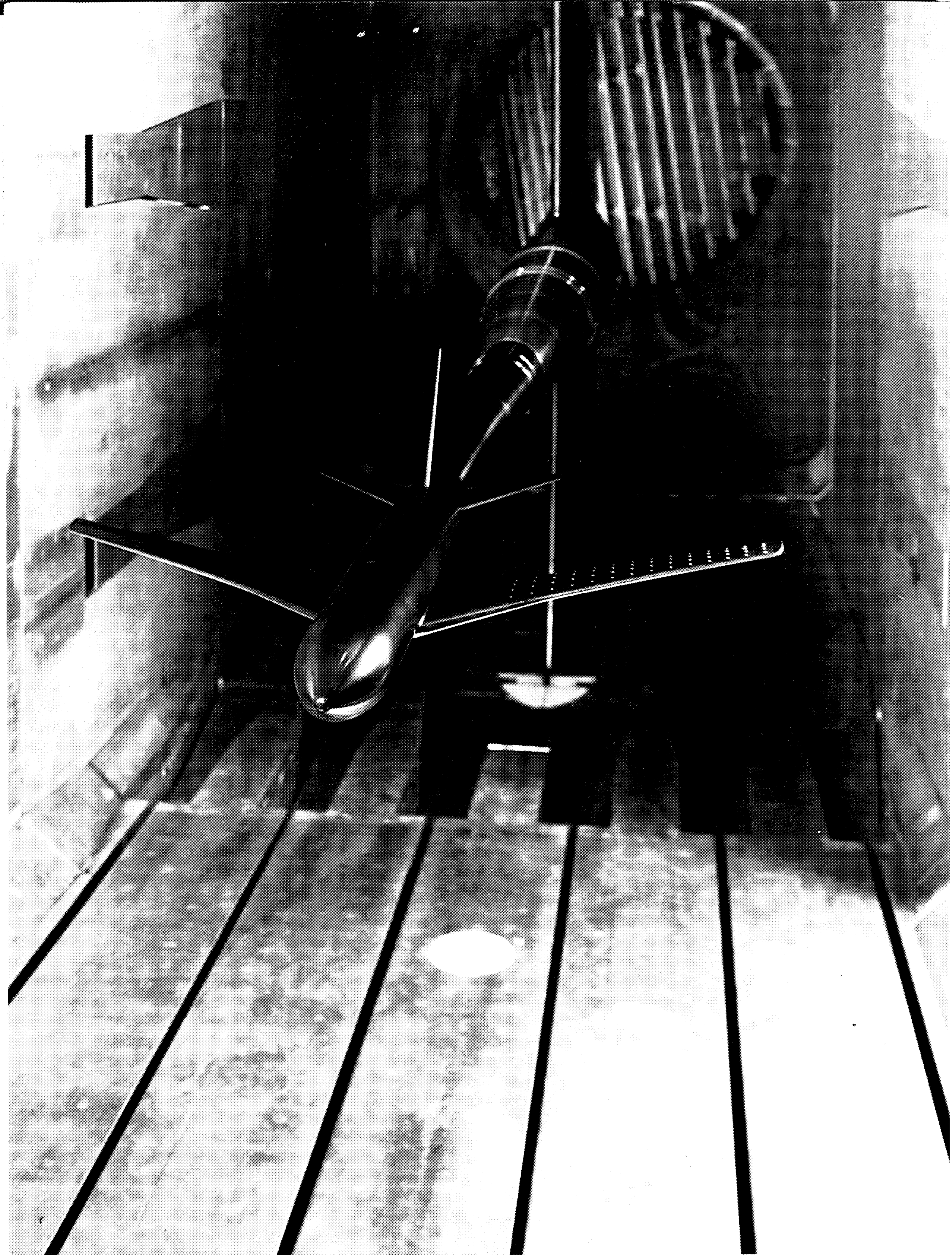
NASA AERONAUTICS
RESEARCH AND TECHNOLOGY



1986 Annual Report



Foreword

Aviation in the United States occupies a unique position with its contribution to trade, its coupling with national security and its symbolism of American technological might. Since the beginning of manned flight, the United States has been the world leader in aviation. This world leadership is founded on a strong national research and technology base and the innovative application of advanced technologies to new concepts and missions.

NASA contributions over the past 70 years have been a major factor in establishing and maintaining United States preeminence in aviation. The Agency is committed to continuing an assertive, leadership role in developing the knowledge base in emerging areas from which important new advances and breakthroughs in U.S. aircraft capability can flow.

The recently established National Aeronautical R&D Goals outline opportunities for significant advances in technology that will reshape civil and military aviation by the turn of the century. The sequel report *National Aeronautical R&D Goals: Agenda for Achievement*, released by the President's Science Advisor in February 1987, presents a national strategy and eight concrete actions for preserving America's leadership and achieving the National Goals. They provide a sound roadmap for addressing the exciting future possibilities in aeronautics which are as great now, if not greater, than at any time in the history of aviation.

The 1986 Annual Report on the NASA Aeronautics Research and Technology Program features the technical accomplishments and research highlights of the past year and offers a glimpse of the exciting possibilities for future research as we focus our program in new directions.

Office of Aeronautics and Space Technology

Pathfinder model in the National Transonic Facility

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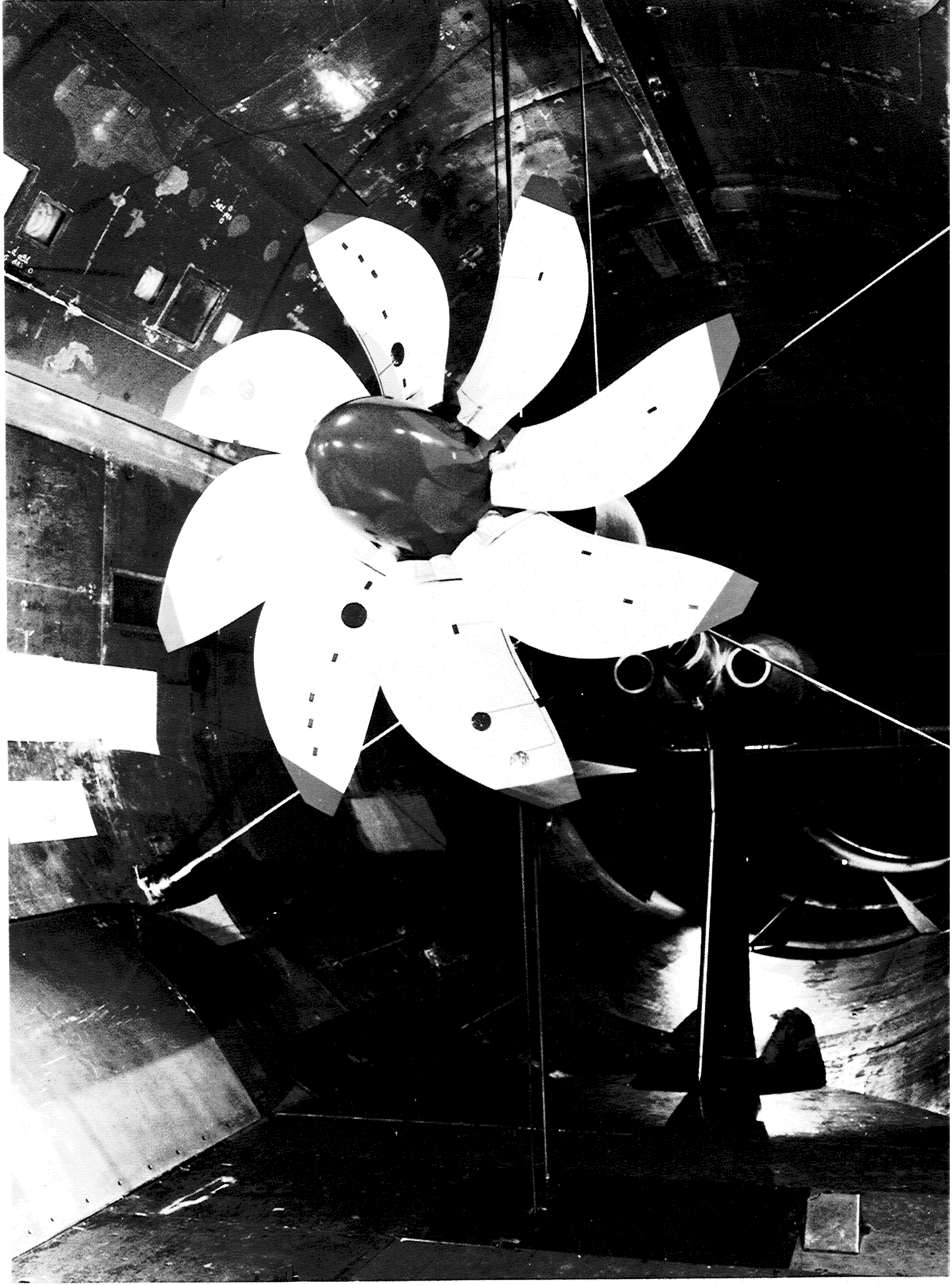


Introduction

For the greater part of this century, NASA and its predecessor, NACA, have pioneered advanced technology for superior U.S. aircraft. This technological superiority in aeronautics has been attained through independent, far-term, fundamental research. The products of this research have significantly benefitted the nation. In addition to making a positive contribution to the trade balance and a secure national defense, American aeronautics is a symbol of this country's technological strength.

While U.S. aircraft still maintain a broad technology advantage, the margin of that advantage has narrowed dramatically in recent years. In a growing number of aircraft related areas, foreign technical capabilities are now comparable, if not superior, to those of the U.S. The implications of this change are important to the nation.

For the U.S. to retain world leadership in aviation into the next century, the nation must aggressively pursue those technological opportunities which will enable dramatic advances in aircraft performance and capability. NASA, with the technical expertise of its cadre of internationally acclaimed researchers and its unique aeronautical facilities, will have a pivotal role in developing these emerging technologies.

In recognition of the serious challenge to America's world leadership in aviation, NASA has maintained a strong commitment to aeronautics research and technology. The goal of the NASA program is to conduct effective and productive aeronautics research and technology development which contributes materially to the enduring preeminence of U.S. civil and military aviation. This goal is supported by comprehensive program objectives which acknowledge and strengthen NASA's central role in aeronautics research and technology development, and focus the research efforts on emerging technological opportunities.

The first objective of the program is to maintain the excellence of NASA's Aeronautical Research Centers by repairing and replacing aging facilities, as well as developing additions and improvements; advancing scientific and engineering computational capabilities; and enhancing staff competence through the selection of highly qualified personnel and providing them with challenging career opportunities.

The second objective is to identify and concentrate on those emerging technologies with potential for order-of-magnitude advances in aircraft capability and performance. These revolutionary advances require a broad program of fundamental research that focuses on critical technologies and accelerates technology readiness for future vehicles.

The third objective is to ensure timely and efficient transition of research results to the U.S. aerospace community through reports, conferences, workshops and active participation of industry in contractual and cooperative programs.

The fourth objective is to provide technical expertise and facility support to the Department of Defense, other government agencies and U.S. industry for major aeronautical programs.

The fifth objective is to ensure strong university involvement in NASA's program to broaden the base of technical expertise and innovation.

A number of comprehensive studies in recent years have endorsed the

Wind tunnel test of advanced turboprop

need for a dynamic and positive thrust in Aeronautics, and identified conceptual vehicles which serve to focus technology development. The Office of Science and Technology Policy (OSTP) chaired a multi-agency study group in 1982 whose detailed review of U.S. aeronautical R&T policies reiterated the importance of aeronautics to the nation, strongly emphasized the necessity for a research and technology base to support the development of superior U.S. aircraft, and reconfirmed the roles of government agencies in aeronautics.

The Aeronautics and Space Engineering Board of the National Research Council conducted a workshop in 1984 that projected the state of knowledge and capability in aeronautical technology areas through the year 2000. This activity also provided vehicle concepts and applications into the next century based on technology and system advances.

In 1985, OSTP established the National Aeronautical R&T Goals which outlined numerous opportunities for dramatic advances in technology that could reshape civil and military aviation by the beginning of the next century. The U.S. Air Force's Forecast II Study, released in 1986, reiterated the importance of a strong commitment to pursue technologies that could enable a leapfrog of current military aircraft capability.

These recent studies have provided a vision of new generations of advanced civil and military aircraft that could supercede all current aircraft by the turn of the century. NASA's Aeronautics Research and Technology Program is focused on those emerging technologies that will make these vehicles possible. Potential vehicle applications are described below and the key or enabling technologies are identified. In addition to vehicle specific technologies, strong emphasis is being placed on fundamental disciplinary research that addresses major technological opportunities which are broadly applicable to all classes of aircraft or which will enable entirely new systems or aircraft not yet defined.

Hypersonic Cruise/Transatmospheric Vehicles: Fully reusable manned vehicles with horizontal takeoff and landing capability, able to cruise and maneuver into and out of the atmosphere and to provide rapid, long-range transport between intercontinental earth destinations. The key to these missions is development of air-breathing propulsion system technology providing horizontal takeoff, acceleration through the transonic and supersonic speed range, and sustained operation at hypersonic speeds. Other crucial technology challenges include actively cooled thermal structures for peak and sustained heat loads, revolutionary concepts for highly integrated airframe and propulsion systems, and advanced computational methods to address the complex flow, structures and integration phenomena associated with very high speed vehicles.

Long Range Supersonic Cruise: Passenger aircraft that feature transpacific range at cruise speeds of two-to-four times the speed of sound. The critical technology challenges include variable cycle propulsion providing noise levels acceptable to the community and with a substantial reduction in fuel consumption and extended-life at high sustained engine operating temperatures; reduction in airframe structures weight fraction; and increasing cruise lift/drag through improved aerodynamics including supersonic laminar flow.

Supermaneuverable Aircraft: Tactical aircraft capable of supersonic cruise and maneuver throughout the speed range with short take-off and vertical landing (STOVL) capability. The key technology challenges involve STOVL capability with minimum performance penalty, supersonic maneuverability, and effective low-speed control at up to 90 degrees angle-of-attack.

Transcentury Transport: An entirely new generation of fuel efficient, affordable, technically superior subsonic transport aircraft. The key technology challenges involve reduction of fuel consumption with advanced turboprop propulsion systems; reduction of viscous drag with laminar flow and turbulence control; reduction of structural weight with advanced composite materials and concepts; and fully integrated flight controls and operating systems that interface with a flexible and modernized National Airspace System.

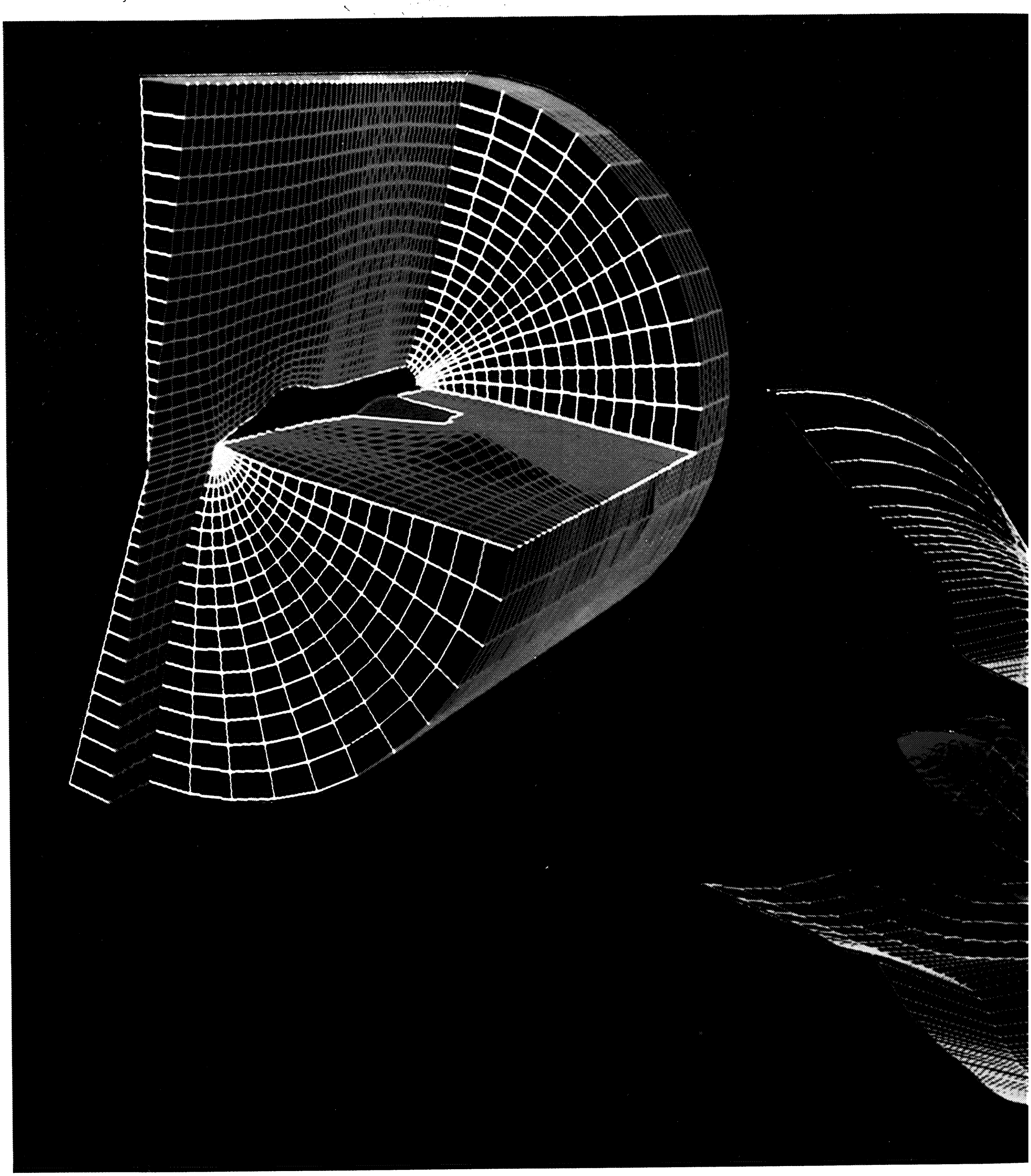
Next Generation Rotorcraft: Quiet, jet smooth, highly automated helicopters and revolutionary new rotorcraft with unprecedented high speed capabilities for both military and civil roles. The technology challenges include reduction of external noise and airframe vibrations through validated prediction and design methods; reduction of crew workload in performing complex piloting tasks through cockpit automation and emerging concepts in man-machine interfaces; and integrating new enabling technologies in materials, controls, and aerodynamics into innovative configurations which combine the utility of the low disk loading rotor with the high speed capability of a fixed wing.

Fundamental Disciplinary Research: Technology areas with broad application to safety, efficiency and performance of a broad range of aircraft types or that have the potential to enable entirely new aircraft systems. Goals for this research include:

- Validate computational methods for analysis and prediction of complex external and internal flows, structural mechanics, control theoretics and their interactions to enable confident, practical application for aircraft and engine design.
- Provide design and validation methods for highly reliable, integrated, and interactive control of aerodynamics, structures, and propulsion for optimum configuration.

Laser illumination of leading edge vortices

Computer generated spatial grid system
for vehicle aerodynamic flow calculations



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- Develop technology for human error tolerant and computer-aided piloting systems and for windshear modeling and detection.

- Develop methodologies to design sophisticated, intelligent automated systems to enhance crew performance of complex tasks and provide dramatic advances in vehicle performance and agility.

- Develop design methodologies and life prediction modeling techniques for advanced high temperature materials such as ceramics, ceramic composites, carbon carbon and metal matrix composites to enable their application in high-performance, uncooled turbine engines.

- Enhance aeronautical facility capability by improving productivity and integrity of major facilities and extending capability in critical areas.

The far-term focus of the NASA Aeronautics Research and Technology Program is intended to provide results well in advance of specific applications and to provide long-term, independent research and technology which is not driven by the development and operational pressures often encountered by the DoD and industry. Fundamental research in the traditional aeronautical disciplines is emphasized in addition to research directed at interaction among disciplines, components, and subsystems. Ongoing and planned research in the redirected program will provide the technological foundation for securing and maintaining world leadership in aeronautics for the United States.

The 1986 Annual Report focuses on key technical accomplishments and research highlights of the NASA Aeronautics Research and Technology Program. The Report is divided into two principal sections—vehicle technology and discipline research. The vehicle technology section includes activities that are focused on, or clearly applicable to, a particular class of vehicles. Frequently, this research involves the testing of innovative systems in a realistic environment. Aeronautical discipline research includes activities in the traditional areas of aerodynamics, propulsion, materials and structures, information sciences and human factors, and flight systems and safety. This research is aimed at establishing and maintaining a solid foundation of technology, embracing all of the relevant disciplines to provide a wellspring of ideas, concepts and emerging technologies to catalyze new advancements in aeronautics. Brief descriptions of NASA's organizational structure, unique facilities, university program, and the Aeronautics Advisory Committee are presented in the concluding section of the report.

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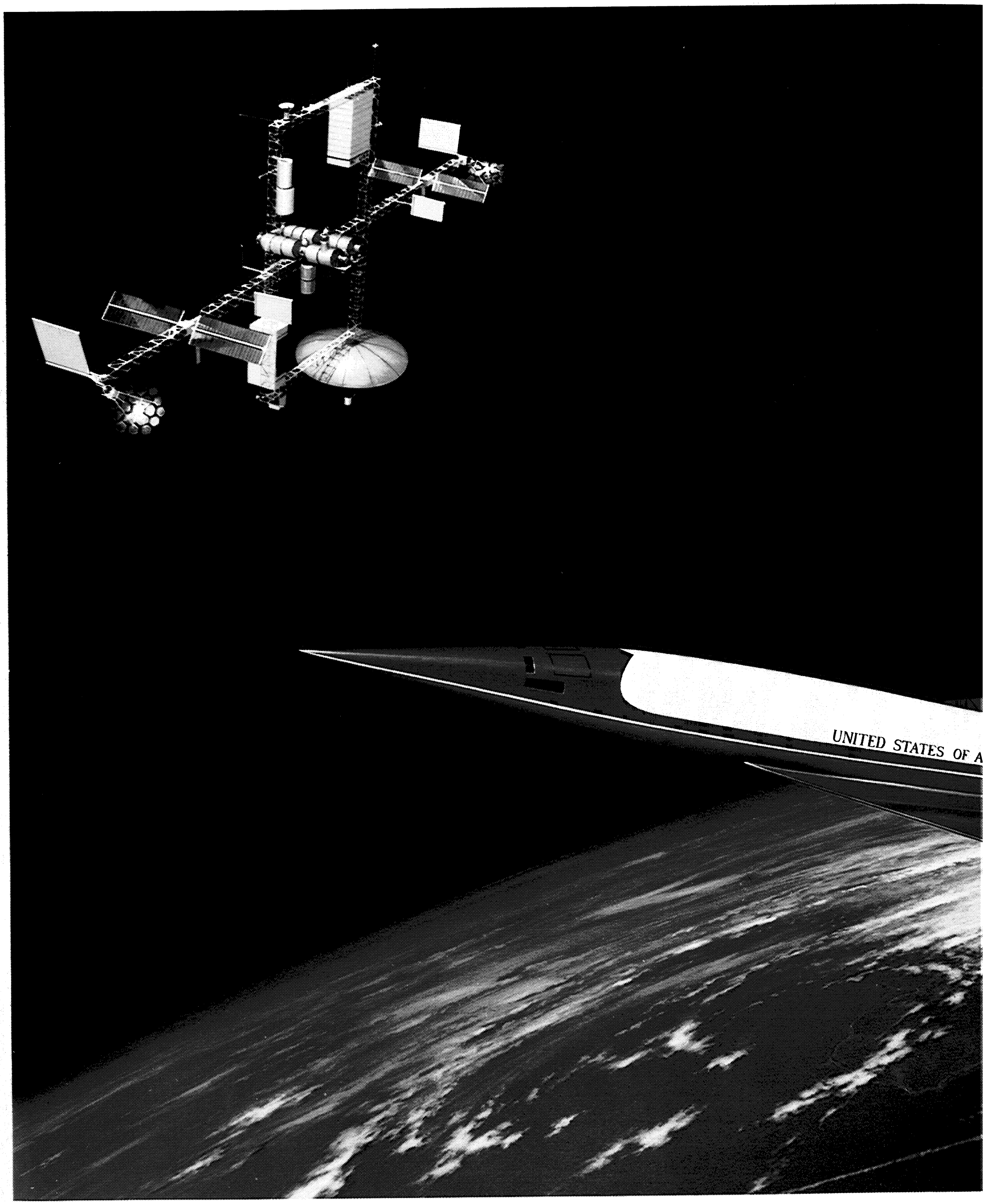

HYPERSONIC

Hypersonic Technology

One of the key technology thrusts of the aeronautics program being pursued by NASA is the technology foundation for hypersonic vehicles. The program focuses on vehicle configuration studies, propulsion, and materials and structures. Recent accomplishments in these areas, combined with earlier progress in hypersonic research, established the foundation for the National Aero-Space Plane (NASP) program. The NASP program, which is jointly funded by DoD and NASA, focuses technology development toward a flight research vehicle, the X-30, which will be used to validate and demonstrate the successful merging of aeronautics and space technologies across the speed range from takeoff to orbital velocities.

This merging of aeronautics and space technologies into an aerospace vehicle powered by an airbreathing propulsion system, provides the potential for an entirely new class of vehicles for the next century, ranging from hypersonic aircraft to a single-stage-to-orbit space transportation system. These vehicles would have the ability to take off from and land on conventional runways, sustain hypersonic cruise flight in the atmosphere, or accelerate into space. The trans-atmospheric capability made possible by this technology will greatly enhance the operational potential of both military and civil aircraft and significantly cut the cost of delivering payloads to orbit.

National Aero-Space Plane concept

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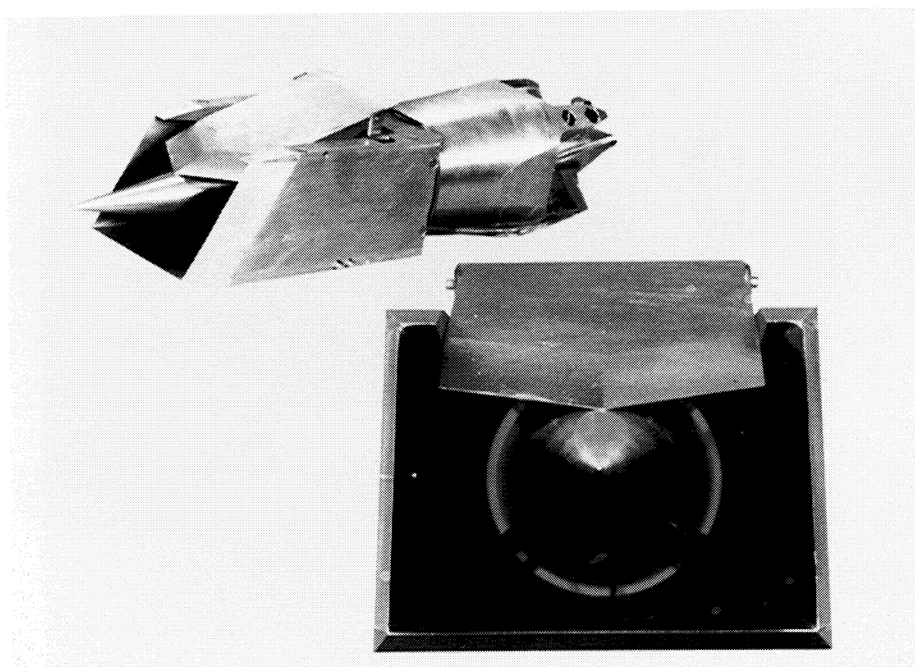
Variable geometry SCRAMJET engine inlet



The technical challenges of an aerospace plane are formidable and the list of essential technologies is long. During 1986, NASA addressed a number of the major technology issues with significant accomplishments in propulsion, high temperature structures, and computational fluid dynamics.

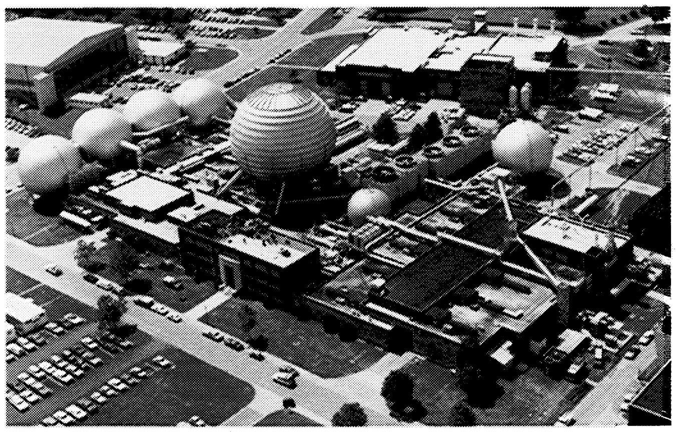
One of the key enabling technologies for an aerospace plane is in the area of hypersonic propulsion. Testing in the Langley Research Center wind tunnels has demonstrated that measured thrust levels of a supersonic combustion ramjet (SCRAMJET) engine module, the system required for airbreathing propulsion above Mach 6, agreed well with theoretical predictions for airframe integrated SCRAMJET engines. Using these ground facility data, projections made to flight indicated that thrust significantly greater than vehicle drag can be achieved at both Mach 4 and Mach 7.

Successful experimental and analytical progress on variable geometry SCRAMJET configurations was achieved with the successful testing of the variable geometry inlet configuration at Mach 4. Companion analytical progress was achieved with the development of a Navier-Stokes flow analysis for the transition section of the engine combustion section for cross-section changes from square to circular. A square inlet configuration would permit integration with the vehicle contours while a circular combustion section would reduce structural complexity at high pressures. This configuration reduces the complex integration problems associated with SCRAMJET propulsion systems which use the underside of the vehicle for airflow compression prior to entering the inlet. These 1986 accomplishments are significant steps in achieving a hypersonic propulsion system that can be operated over a broad range of speed-altitude combinations.

In related engine structures research, an advanced technology fuel injection strut for the SCRAMJET engine was fabricated in 1986 using a complex brazing process. Two shortened versions of a full-size flight-weight article were successfully assembled. This effort demonstrated the feasibility of this design approach and preparations are now underway to test the strut assembly with burning fuel in the Langley Research Center propulsion test facilities.

Accomplishments in aerothermal airframe structures also included progress with a promising concept under investigation for the fabrication of load-carrying honeycomb panels of high-temperature super-alloys. A panel array of super-alloy honeycomb material was successfully tested in 1986 in the Langley Research Center High Temperature Tunnel under hypersonic flow conditions.

The development of an optimum integrated vehicle design through the integration of a hypersonic propulsion system with the airframe demands unprecedented technological sophistication. NASA's Numerical



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Hypersonic Facilities Complex, Langley Research Center

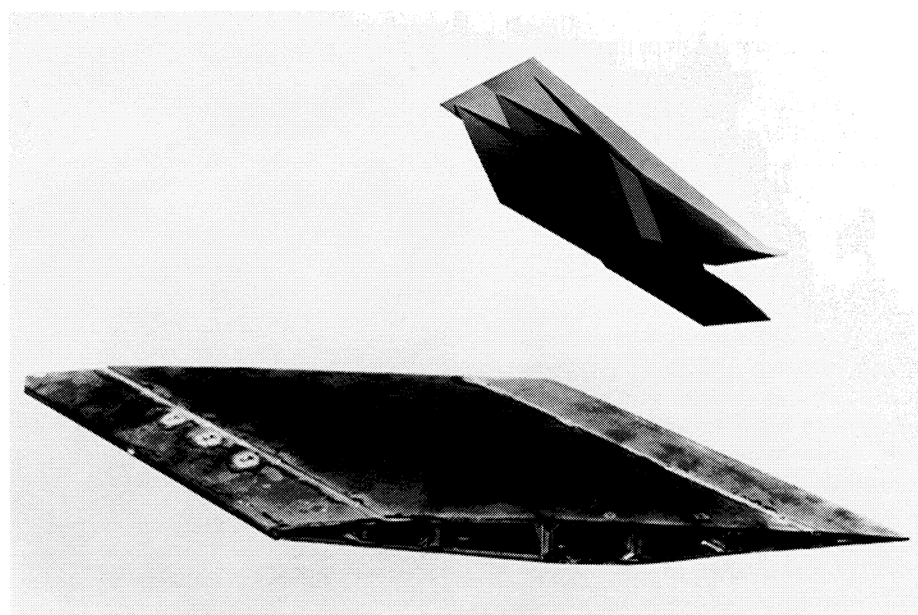
Aerodynamic Simulation capability, now in operation, provided vital support to the technology development program by enabling the calculation of the complex flow fields for various aerospace plane configurations. This capability to provide solutions of Navier-Stokes equations that define the air flow around NASP configurations at high Mach numbers allows analysis and prediction of vehicle aerodynamic loadings and aero-thermodynamic interactions at Mach numbers beyond the capability of existing ground test facilities.

Hypersonic Facilities

NASA hypersonic facilities represent a major, and unique, national asset. These facilities range in Mach Number capability from Mach 6 to Mach 20. The Hypersonic Facilities Complex at Langley Research Center includes the Hypersonic CF 4 (tetraflouromethane) Tunnel with a Mach 6 capability, the Mach 6 High Reynolds Number Tunnel, the 20-inch Mach 6 Tunnel, the Mach 8 Variable Density Tunnel, the 31-inch Mach 10 Tunnel, the Hypersonic Nitrogen Tunnel (Mach 17), and the Hypersonic Helium Tunnel and its open jet leg (Mach 20). Key hypersonic facilities at the Ames Research Center include the 3.5 Foot Tunnel, arcjets, and High Enthalpy Facility.

These NASA hypersonic test facilities are used to study the aerodynamic and aerothermal phenomena associated with the development of advanced aerospace transportation systems, including trans-atmospheric and hypersonic transport vehicle concepts. In addition, the facilities are used to perform basic fluid mechanics studies, to establish data bases for verification of computer codes, and to develop measurement and testing techniques. The research in aerothermodynamics, structures, and propulsion technologies requires unique facilities that simulate the high energy environment of hypersonic flight. Small-scale tests for screening potential propulsion system component designs are performed in a Mach 4 blowdown tunnel. In addition, the Mach 4 and the Mach 7 SCRAMJET Test Facilities at the Langley Research Center provide free-jet tunnel flow for subscale SCRAMJET engine tests.

Two major facilities are also being modified to expand NASA's hypersonic testing capabilities: the 8-foot High Temperature Tunnel at the Langley Research Center for aerothermal structures testing and for large-scale and multi-module airframe-integrated SCRAMJET tests, and the Propulsion Systems Laboratory (PSL) at the Lewis Research Center for subsonic and supersonic propulsion systems tests.



Fuel injection strut for SCRAMJET engine

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SUPERSONIC

It has been 24 years since the 1962 Anglo-French agreement to build the Concorde was signed. On January 21st of 1986, the Concorde fleet completed 10 years of active commercial service. Ten years is long enough for the novelty to have worn off, yet it is evident that there is a steady demand for high speed transportation, even at premium fares.

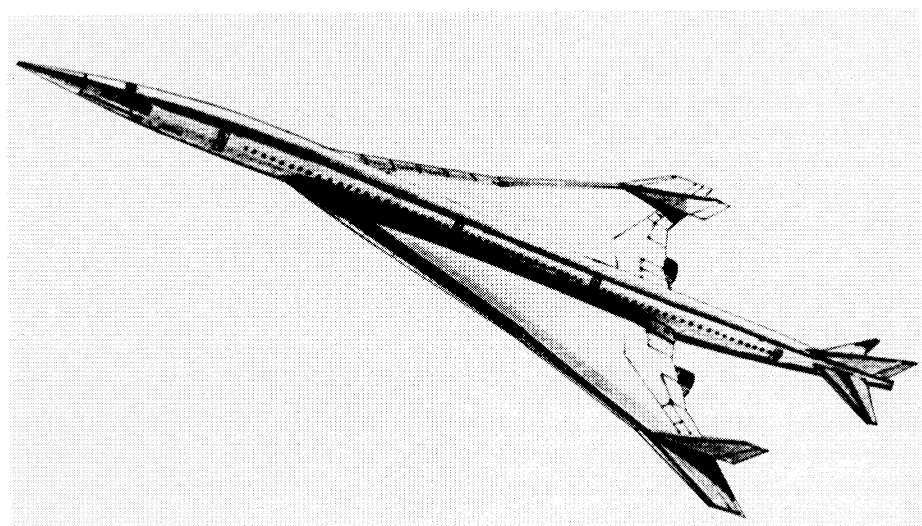
During 1986 NASA continued several technology efforts that are applicable to supersonic aircraft. These include research in aerodynamics, materials and structures, propulsion, and systems.

In aerodynamics, much of the applicable research was focused on reducing drag to provide more efficient sustained supersonic cruise capability for military aircraft. This involves tailoring the configuration to reduce wave drag, interference drag, and induced drag and surface changes to reduce friction drag and reduce surface heating. Increased effort is being aimed at determining the feasibility for laminar boundary layer flow retention at supersonic speeds. During the past year, the first exploratory flight tests were conducted on an F-106 aircraft at Langley Research Center to develop instrumentation for research on skin friction drag reduction.

In materials and structures, research efforts have concentrated on the development of advanced composite and ceramic materials for the high-temperature environment in the engines and on the airframes of high speed vehicles. Studies are underway that indicate major improvements are possible for supersonic aircraft engines by the application of advanced high-temperature materials. In propulsion, research efforts have been initiated to investigate the feasibility for supersonic fans in future supersonic aircraft turbofan engines.

In systems, research efforts are underway to develop automation technology incorporating artificial intelligence to improve the operational efficiency and safety of all aircraft. This can be particularly valuable for future high-speed transport aircraft because of their large fuel and relatively small payload fractions.

This year, in order to better focus NASA's technology efforts, two major contracted studies were initiated with Boeing and McDonnell-Douglas to examine the opportunities for new high-speed civil transport aircraft. These studies will evaluate conceptual designs ranging in speed capability from new supersonic transports to "Orient Express" hypersonic transports. The studies will evaluate the technical feasibility and economic viability of these conceptual designs and identify the critical technology requirements.



Supersonic cruise transport aircraft concept

F-111 Mission Adaptive Wing (MAW) aircraft

HIGH PERFORMANCE

NASA's high performance aircraft research program is an integral and critical part of the overall aeronautics program that is structured to develop and mature technologies that have important military and civil applications. NASA and the military, historically, have worked closely together to identify and develop aeronautical technologies which require flight research to fully explore, validate, and mature the technologies for application in a military aircraft. These technology programs are carefully selected to demonstrate a significant improvement in performance or to show a new capability that potentially has high payoff.

NASA has also traditionally had a role in applying its knowledge, people and facilities to assist the military in solving challenges encountered with operational aircraft. Finally, it should be recognized that certain synergies exist between the military and civil technology developments. The military strives to expand the performance envelope while the civil sector tends to concentrate on lower production costs, maintainability, and high reliability. This in turn results in military aircraft being more affordable and civil aircraft having increased performance.

Mission Adaptive Wing

The joint NASA/Air Force Mission Adaptive Wing program has produced results in 1986 which will directly enhance military and civil aircraft capabilities. The variable camber wing technology offers the potential for significant aerodynamic improvements when compared with current fixed-airfoil technology. Increased range of up to 25 percent, increased operating ceiling by 15 percent, and increased sustained maneuver capability of 20 percent are achievable. The F-111 aircraft, one of a number of high performance military testbed aircraft on loan to NASA, was modified to incorporate a flexible wing surface structure allowing the implementation of the variable camber wing concept.

Supporting ground based research and analytical studies indicated that if a wing's airfoil shape could be adapted to a wide range of mission flight conditions, a significant overall improvement in performance could be achieved. Phase I flight tests of the manual flight control system with the Advanced Fighter Technology Integration (AFTI/F-111) aircraft have been completed. The next phase of testing is now underway using automatic, in-flight adjustment of variable camber based on measured flight conditions.

The Phase I flight tests cleared the flight envelope to Mach 1.3 at an altitude of 40,000 feet. Performance data were obtained which agreed with predictions. In addition, airfoil pressure distribution measurements were obtained and they compare well with wind tunnel data. The initial checkout of a deflection measurement system, which is used to measure the shape of the wing in flight, was accomplished. Structural load distribution charateristics have also been determined and compared with analytical predictions.

High angle-of-attack free flight model in 30-by 60-foot Wind Tunnel

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Supermaneuverability

In 1986, high angle-of-attack flight technology for high performance aircraft was accelerated. The area of interest was the behavior of these aircraft configurations at angles-of-attack approaching 90 degrees (also referred to as high-alpha flight). Achieving stable and controllable flight at these angles to the free stream airflow offers the potential for dramatic payoffs in agility, performance, and safety. Collectively the technology is referred to as "supermaneuverability."

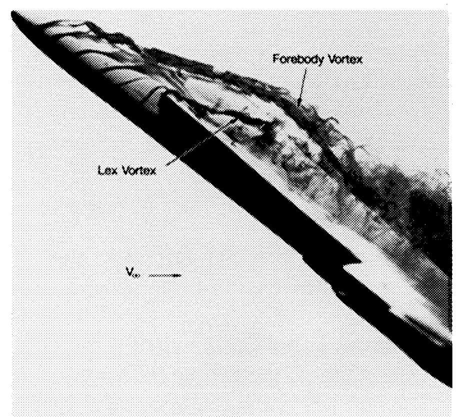
Unprecedented high angle-of-attack, or "high-alpha," capabilities utilizing propulsive control concepts were demonstrated with free-flying models and simulation studies. The key to this achievement was the advancement in propulsive flight control technology that couples the propulsion system and flight control in a quick response, integrated system.

Free flight model tests in the Langley Research Center 30- by 60-foot Wind Tunnel using an F-18 with propulsive flight control confirmed the ability to achieve incredibly stable performance and full maneuverability at an 80-degree nose-up angle-of-attack relative to the oncoming airstream.

The wind tunnel model and simulation investigations were complemented by experimental and computational analyses of forebody flows and vortex flows to study the aerodynamics of high-alpha flight. Water tunnel model tests of the F-18 configuration conducted at the Ames Research Center, Dryden Flight Research Facility confirmed that, by making flow injections in the airstream near the nose of the aircraft, the vortex flow over the vehicle can be altered to achieve favorable aerodynamic changes and overall drag reduction.

Additional flow investigations were carried out in July 1986 in the Langley Research Center 4-by 7-Meter Wind Tunnel. Oil flow patterns on an F-18 model illustrated that the inherent aerodynamic flow asymmetry in the region of the tip of the aircraft nose at high angle-of-attack plays a key role in the loss of control. Further research in the understanding and control of this flow characteristic will offer significant payoff in the ability to design for high-alpha flight.

Preparations are now underway to conduct a full-scale flight research program utilizing a modified Navy F-18 aircraft. Initial flights began in the fall of 1986 with the emphasis on acquiring aerody-



F-18 model water tunnel flow studies

Oil flow studies of F-18 at high angle-of-attack in 4- by 7-Meter Tunnel

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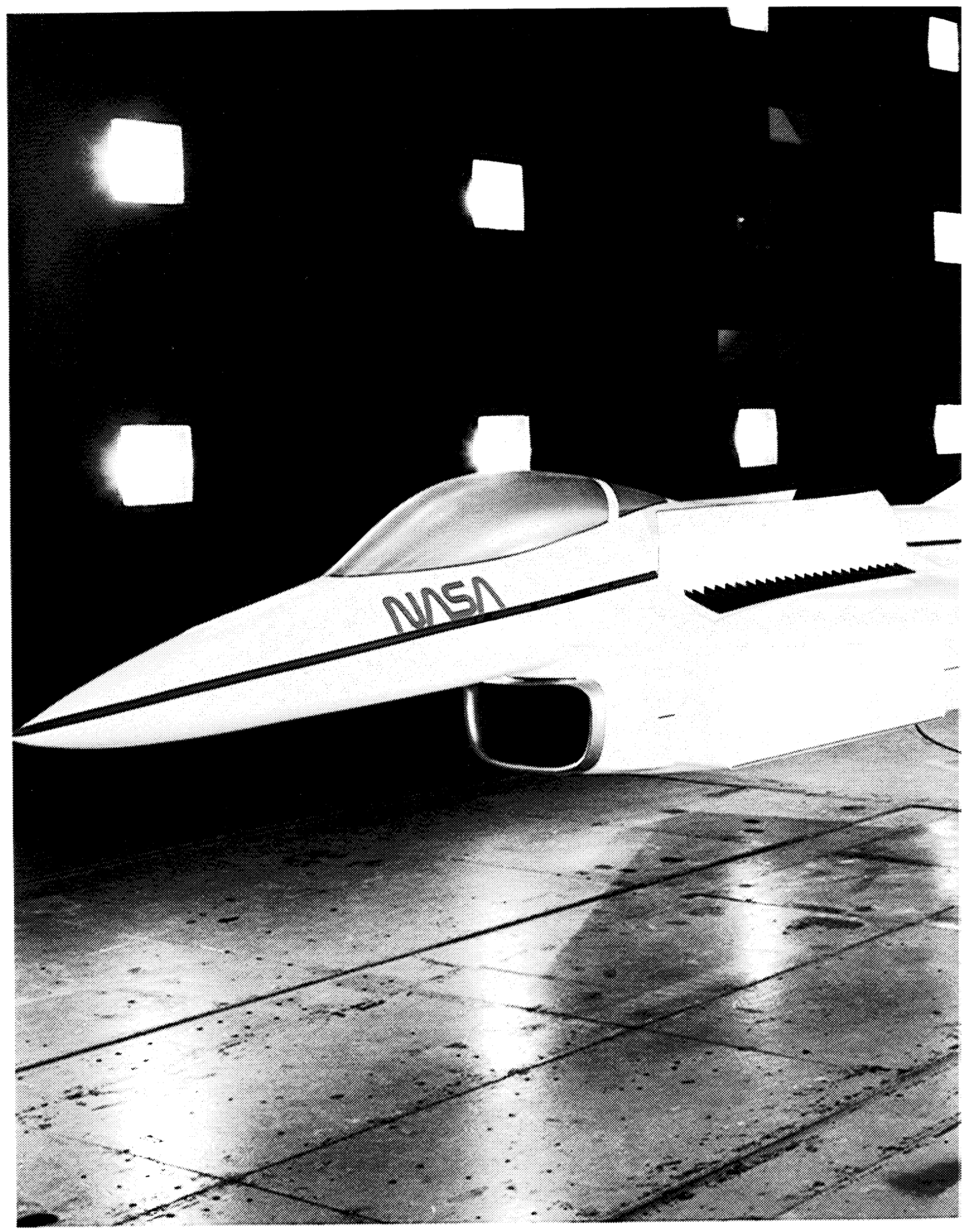
namic data for correlation with wind tunnel results. Next, conceptual designs will be tested for a thrust vectoring system for the F-18 research vehicle. Modification of the research aircraft with such a system will allow full-scale flight verification of wind tunnel results.

Vertical and Short Take Off and Landing Technology

Advances in propulsion system thrust-to-weight ratios, propulsive lift control, and the understanding of low speed aerodynamics combine to open new opportunities for state-of-the-art advances in vertical and short take off and landing (V/STOL) aircraft technology, as well as for new short take off and vertical landing aircraft (STOVL) concepts.

The United States and the United Kingdom signed a joint research agreement in 1986 to foster collaboration in the development of advanced STOVL (ASTOVL) technologies aimed at reducing the technological risk associated with potential ASTOVL aircraft development. The two countries have agreed upon a conceptual evaluation model to be used to assess different concepts. During 1986, NASA performed an internal evaluation of four aircraft configurations: vectored thrust, ejector augmentation, tandem fan and remote augmented lift propulsion. In a related 1986 activity, NASA entered into an agreement with Canada to build and test a full-scale STOVL wind tunnel model. The model, an E-7 transonic aircraft configuration, utilizes an ejector thrust augmentation system for low speed STOVL operations.

As part of the continuing V/STOL technology program, the Ames Research Center conducted wind tunnel tests of a 1/10 scale E-7 V/STOL fighter at Mach numbers ranging from 1.6 to 2.2. The generally favorable agreement of predic-



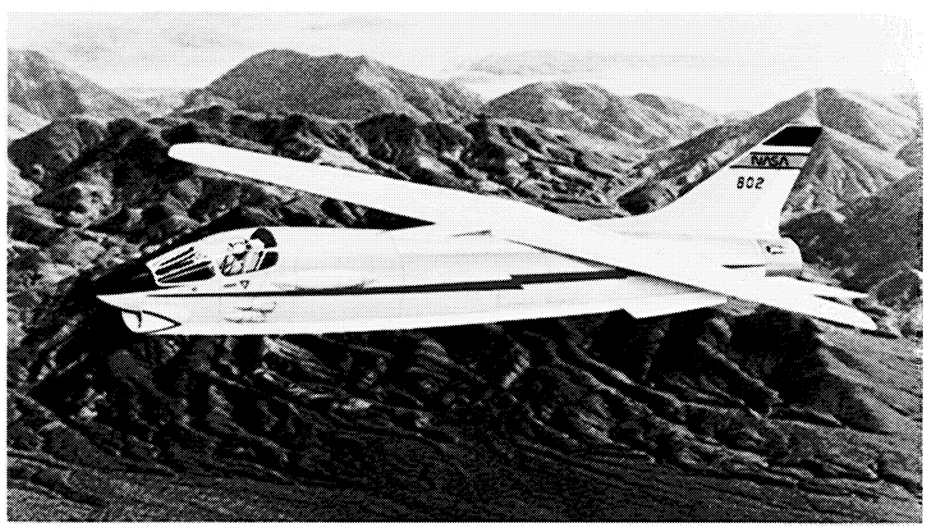
E-7 V/STOL aircraft wind tunnel model

tions and high speed test results for the E-7 confirmed the aerodynamic viability of the design as a high performance fighter aircraft. The tests also resolved many uncertainties and established a large, comprehensive design base for realistic V/STOL configurations.

Oblique Wing Technology

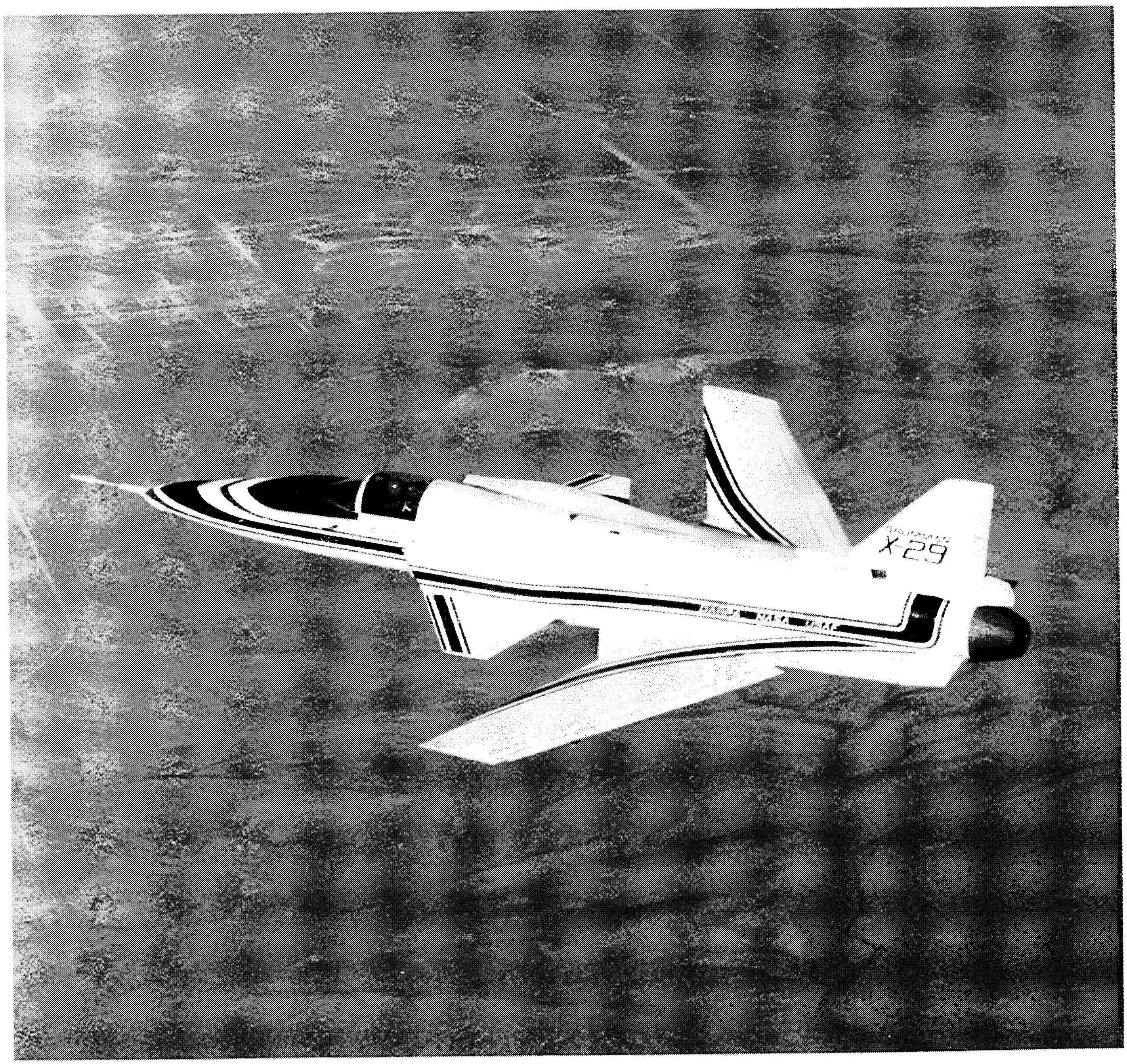
Achieving efficient flight performance at both high and low speed has been a challenge to aircraft designers. The oblique wing concept offers the promise of meeting this challenge for high performance aircraft. The concept, first envisioned over 40 years ago, incorporates a wing that pivots in to form oblique angles with the airplane's fuselage in high speed flight forming a low aspect ratio wing configuration to minimize drag. The wing is positioned in a high aspect ratio position at right angles to the fuselage during take off and landing and low-speed flight.

Precursor research, analytical studies, wind tunnel investigations, and preliminary flight tests with the low speed AD-1 research aircraft have provided the confidence and data base required to construct and flight test a full scale vehicle based on the NASA F-8 flight research aircraft in a joint NASA/Navy program. In 1986 the preliminary design was completed for a 300 square-foot aeroelastically tailored



F-8 oblique wing technology demonstrator aircraft illustration

X-29 Forward Swept Wing aircraft



wing for the F-8 oblique wing demonstration. The subsequent detail design, fabrication and aircraft modification will lead to flight validation of the concept at supersonic speeds.

Forward Swept Wing Technology

In 1980, NASA, Air Force and the Defense Advanced Research Projects Agency embarked on designing, building and testing a forward swept wing fighter class aircraft. This design was projected to offer both performance advantages and a new option in configuration integration. At the same time, the opportunity was seized to test several other emerging technologies of high potential. These included relaxed static stability; three surface longitudinal control; aeroelastically tailored, composite, thin supercritical wing; close coupled wing and canard; and digital flight control system. The successful integration of these technologies was demonstrated in 1986 as the flight envelope expansion program was completed.

During the envelope expansion flight program, preliminary research data were acquired that validated the performance predictions at the design flight conditions. Detailed engineering data have been collected by each of the engineering disciplines for correlation, comparison and improvement of prediction methodology. Major new test and analysis techniques were developed including the ability to do detailed flight controls analysis in real time and the ability to extract stability and control derivatives from a highly unstable aircraft. Predictions of structural loads were verified throughout the flight envelope which included high speed, high dynamic pressure, operating conditions.

Improvement of Operational Aircraft

Frequently, at the direct request of the military services, the expertise and facilities of NASA are utilized to solve technical problems and develop improvements for operational military aircraft.

In 1986, at the request of the Navy, NASA developed and tested aerodynamic modifications that provide options for significant improvement in the safety and effectiveness of the EA-6B aircraft. As the EA-6B configuration evolved from the 1960's, A-6 aircraft weight increased from the original 36,000 pounds to 55,000 pounds without a corresponding increase in wing area. This degradation in maneuver margin has contributed to the aircraft's high accident rate.

NASA completed wind tunnel studies of the EA-6B configuration in the Langley Research Center National Transonic Facility. The results of the tests in this unique facility formed the basis for recommended configuration modifications which include the addition of a small vertical tail extension, addition of a wing root/body strake, and an airfoil leading and trailing edge modification. These modifications improve the EA-6B lift at low speed and increase the directional stability at high angles of attack, thus reducing stall/spin tendencies. The Navy is currently initiating an EA-6B test program to evaluate the recommended modifications in flight prior to incorporating them into the aircraft fleet.

SUBSONIC

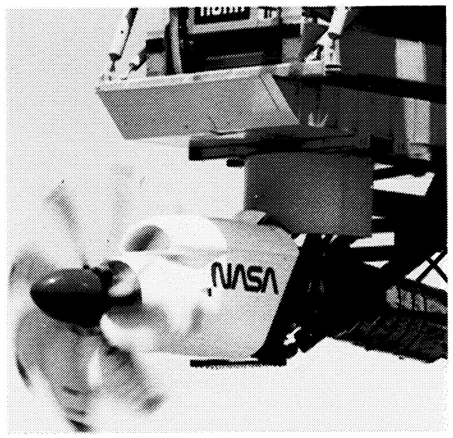
NASA works closely with manufacturers, airlines, and the Federal Aviation Administration to advance the technology for subsonic transport aircraft. This close relationship is essential to the timely introduction of new technology to assure the United States retains its preeminent position in this important world market. The research activities in the subsonic program are coupled directly to technology application programs in industry. In this way the timely transfer of research results to new aircraft developments is enhanced in keeping with current aeronautical research and technology policy.

A major goal of the subsonic transport program is to establish the technology that will enable the doubling of the fuel efficiency of today's best transport aircraft, while substantially increasing their productivity and affordability.

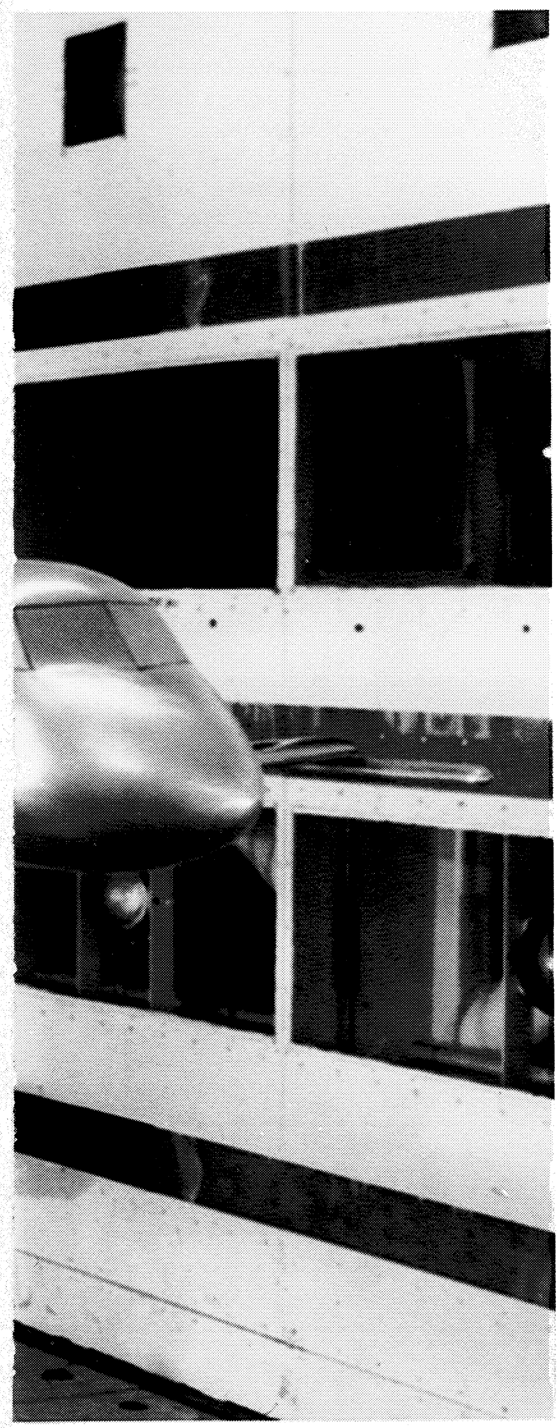
Advanced Turboprop Program

A number of accomplishments in advanced turboprop research directed to the improvement of subsonic transport propulsion system efficiency were realized in 1986. Earlier analysis and wind tunnel studies clearly showed the potential to use 15 to 30 percent less fuel while maintaining cruise speed, cabin comfort and noise levels of current comparable turbofan transports. Lewis Research Center augmented both analytical and experimental propfan research in support of increased industrial activity in the advanced turbo-

Propfan Test Assessment (PTA) aircraft
model in the 4- by 7-Meter Wind Tunnel



Large scale propfan ground test



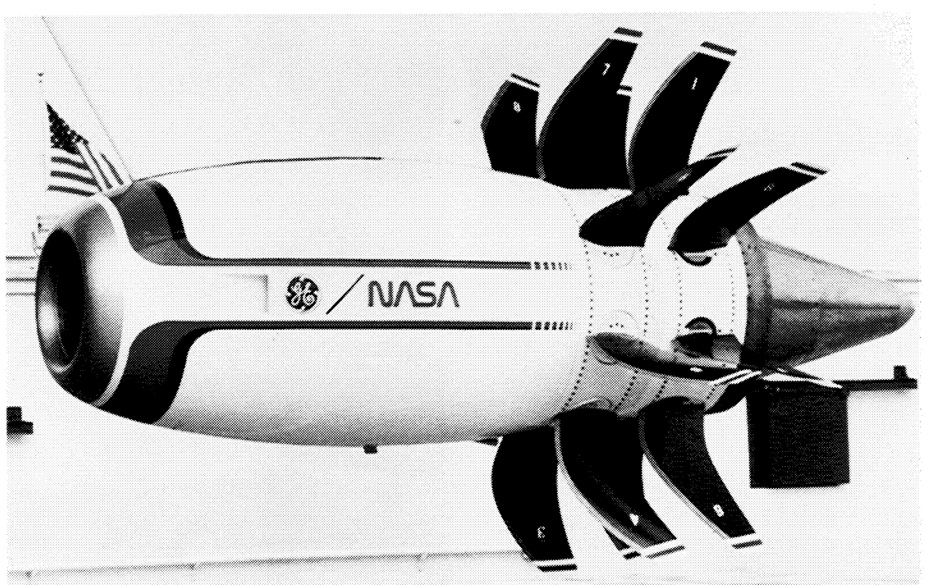
prop area in 1986. This effort included both counter-rotating propellers and drive systems. Full scale advanced turbo-prop propulsion system ground testing and flight demonstration activities were begun by NASA and industry in 1986.

The objective of the NASA Propfan Test Assessment (PTA) program is to conduct flight tests to verify blade structures, aerodynamics, and acoustics prediction capability. In preparation for the flight test project, a 1/9-scale model of the PTA aircraft configuration was tested in the Langley Research Center 4- by 7-Meter Wind Tunnel during August, 1986. The wind tunnel data verify the safety-of-flight aerodynamics and that theoretical design and analysis methods predict the nacelle and nacelle/slipstream flow with sufficient accuracy for design purposes.

The PTA wind tunnel results also defined the extent to which the installation of a propfan on a complete aircraft configuration affects the aerodynamic performance. In addition, the speed/altitude capability and buffet margins were defined for the PTA aircraft. The analytical code for predicting aircraft flutter characteristics was also verified in high speed wind tunnel testing.

Ground testing of a large scale (nine-foot diameter) propfan was also completed in 1986. The aerodynamic results were close to those predicted, thus satisfying ground testing requirements prior to flight evaluation of the structural and aerodynamic characteristics of the propfan installation on a Gulfstream II twinjet transport.

During 1986 significant progress was achieved in the joint NASA/General Electric Unducted Fan (UDF) program. This advanced turboprop concept incorporates two unducted, counter-rotating fans with eight highly swept blades on each fan. Studies have shown that two counter-ro-



Unducted Fan (UDF) turboprop propulsion system

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Flight test of UDF on modified Boeing 727 aircraft

tating fans can totally eliminate the wake swirl that exists in single fan designs. The swirl elimination results in an 8 percent increase in propulsion system efficiency. The UDF system was successfully ground tested in preparation for flight testing. The 100-hour ground test demonstrated thrust levels of over 25,000 pounds with acceptable engine vibration and propfan stress levels.

Both near-field and far-field noise measurements—taken over a range of tip speeds, power settings, and blade sweep-indicated that significant noise reductions were achievable, and projections indicate that the counter-rotating propeller designs should meet community noise level requirements.

First flight tests of the UDF on a modified Boeing 727 were completed successfully in August, 1986. In-flight performance and acoustics evaluations were conducted. Currently, General Electric, in conjunction with McDonnell Douglas, is preparing for additional flight evaluation on a modified McDonnell Douglas MD 80 aircraft.

Aircraft Drag Reduction

Reducing viscous drag caused by skin friction is a key objective in aerodynamics research since it accounts for roughly one-half of an aircraft's total drag when flying at normal cruise speed. Laminar boundary layer flow and turbulence control techniques can significantly reduce viscous aerodynamic drag, thereby contributing to overall aircraft drag reductions of up to 40 percent.

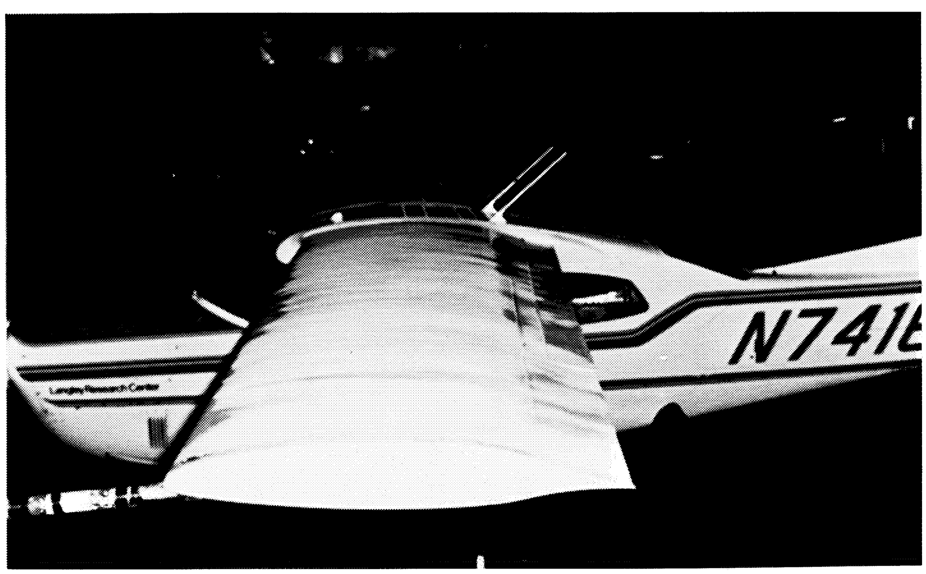
Laminar Flow: A promising approach to achieving reduced drag is to sustain smooth, non-turbulent (laminar) flow in the layer of air in contact with the aircraft airfoil and fuselage surfaces. Non-turbulent flow over airfoils can be achieved by a favorable pressure gradient stabilization known as natural laminar flow (NLF), or by a small amount of surface suction known as laminar flow control (LFC), or a combination of these known as hybrid laminar flow control (HLFC). The technical challenge is to devise a means for maintaining the smooth flow as far along the surfaces as possible and delaying the tendency for the flow to transition from laminar to turbulent flow. During 1986, these laminar-flow concepts were investigated with promising results.

Recent NLF airfoil research in the Langley Research Center Low-Turbulence Pressure Tunnel (LTPT) demonstrated that extensive natural laminar flow can be maintained over properly designed airfoil surfaces at design lift conditions, resulting in profile drag reductions of 33 percent.

A full size proof-of-concept wing incorporating the new NLF airfoil was designed by the Langley Research Center and fabricated by Cessna. Wind tunnel and flight tests in 1986, utilizing a Cessna 210 aircraft, confirm that the airfoil achieves natural laminar flow over 70% of the upper and lower surfaces over a broad range of operating conditions. The aircraft cruise speed increased 14 knots at the same power setting, which is the ultimate demonstration of improved aerodynamic efficiency.

Another NLF accomplishment in 1986 was the successful flight testing of a contoured glove installed on the wing of a Boeing 757 aircraft in the region of intense acoustic radiation from the turbofan engine. The flight tests confirmed that the desired laminar flow can be maintained not only in a quiet environment but also in close proximity to engine noise.

Recent NASA research in laminar flow



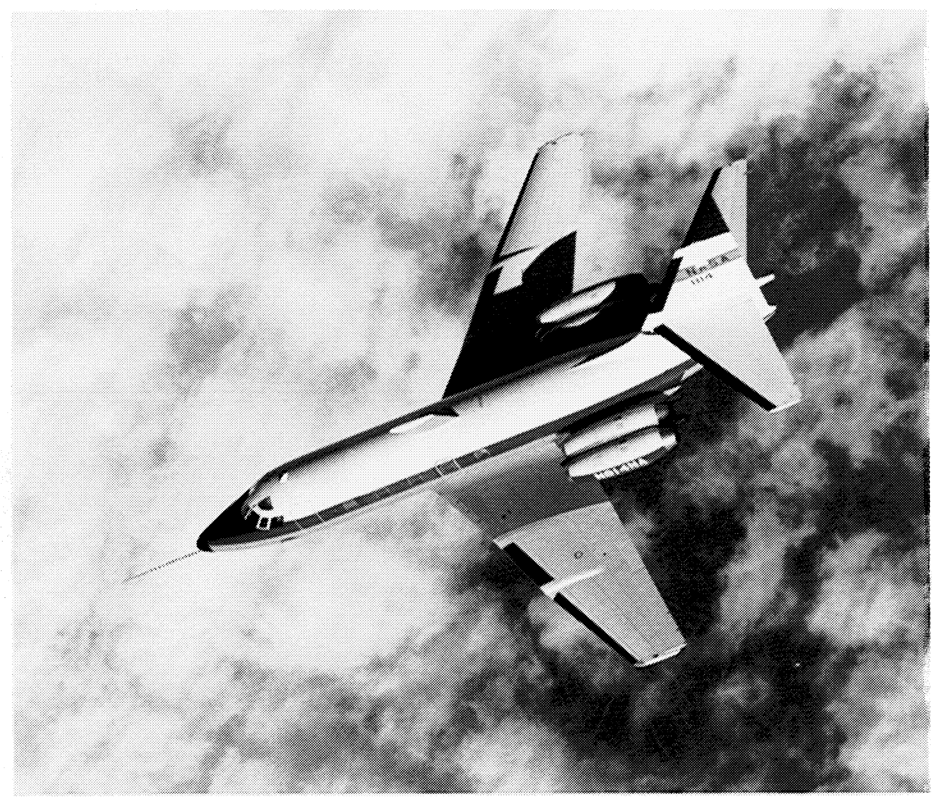
Full scale natural laminar flow (NLF) wing installed on Cessna 210 aircraft

Laminar flow control (LFC) installation on Jetstar wing

control (LFC) indicated that significant amounts of laminar flow may be sustained on wing surfaces having a moderate sweep angle, typical of commercial transports. In order to verify this potential in flight, laminar flow control gloves with suction through tiny slots or perforations were installed on the leading edge of the wings of a JetStar aircraft to investigate their effectiveness. The 1986 flight testing confirmed the technique and demonstrated that laminar flow over the critical leading edge of the wing could be achieved without undue maintenance burden while operating in a typical airline environment. This was particularly noteworthy because of earlier concerns that insect and other airborne debris might degrade the suction surfaces of the laminar control system.

Laminar flow control research accomplishments in 1986 set the stage for the next phase of research which will concentrate on hybrid laminar flow control—combining the best features of active laminar flow control and natural laminar flow—to achieve significant drag reduction with less system complexity.

Turbulent Flow: Research in turbulence control encompasses techniques such as large eddy break-up (LEBU) devices and riblets, whose small streamwise grooves inhibit the lateral spread of small turbulent eddies. These concepts have the potential of reducing turbulent skin-friction-drag on surfaces where laminar flow is difficult to achieve. These techniques have progressed through the laboratory development phase to the point of being ready for flight validation. In 1986 wind tunnel tests the drag reduction associated with LEBU devices and riblets was demonstrated to be additive. Also, computational fluid dynamic codes were developed to predict the flow physics of both devices.



JetStar aircraft with laminar flow control (LFC) wing glove installed for flight investigation

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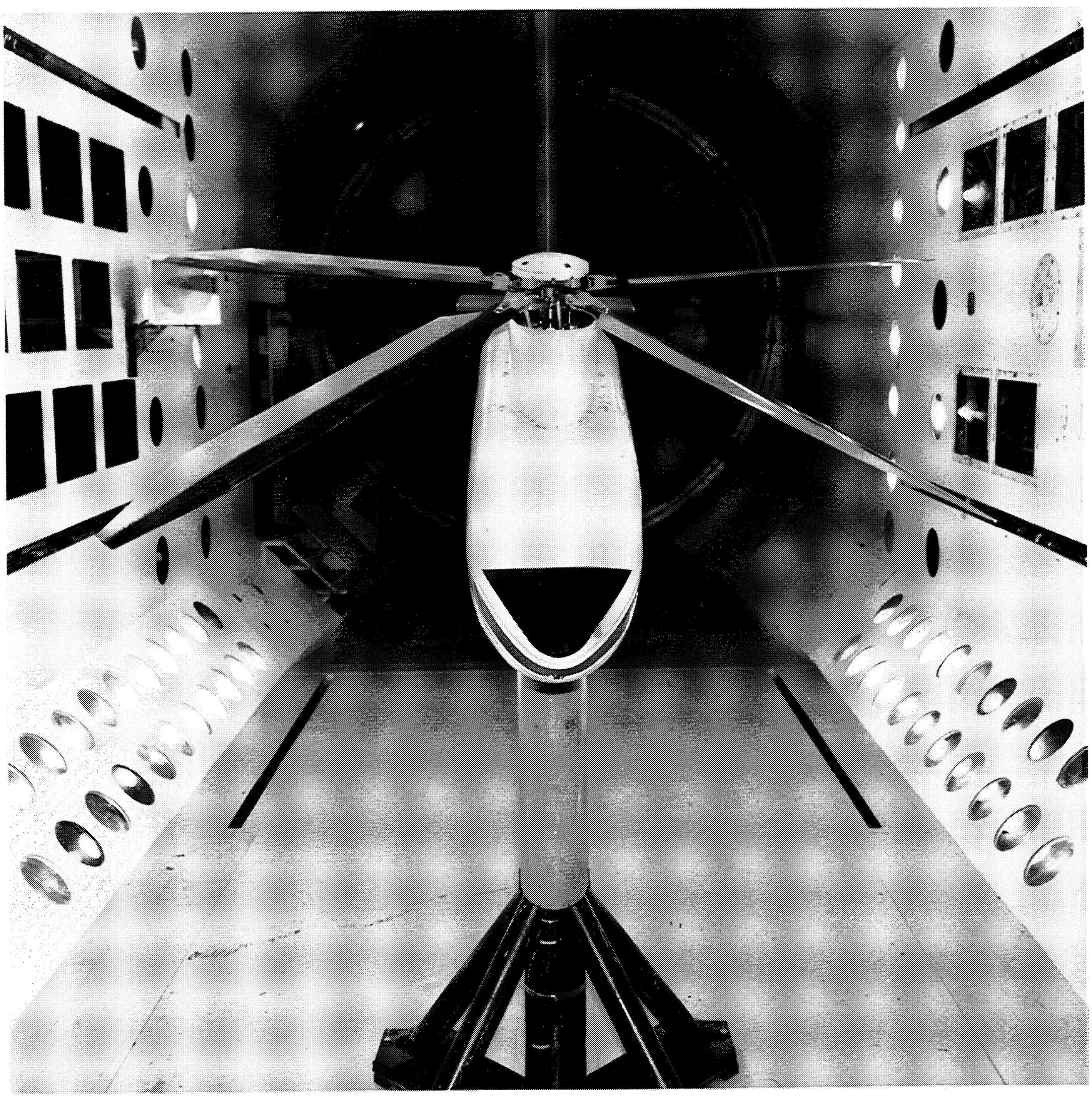

ROTORCRAFT

The nation's continued leadership in military and civil rotary wing technology depends on a strong and broad-based research program. NASA, in cooperation with other government agencies and industry, carries out a rotorcraft program that addresses fundamental research in aerodynamics, structural dynamics, acoustics, guidance, stability and control, propulsion and drive, and human factors. This research is conducted through analytical and experimental programs which focus on critical areas of technological need in order to exploit the full potential of this unique vehicle class.

The U.S. Army and NASA work hand-in-hand on rotorcraft research. This is made possible by an arrangement of collocated Army laboratories at the NASA aeronautical research centers. Joint programs with the Defense Advanced Research Projects Agency (DARPA), the Federal Aviation Administration, and the U.S. helicopter industry result in a constructive and closely coordinated national research effort in rotorcraft technology.

In 1986 there were a number of significant accomplishments in the areas of reduced noise, improved rotor performance, enhanced flying qualities, and high speed performance. Reducing rotorcraft noise is essential to secure community acceptance and to reduce military detectability. Noise reduction has received special emphasis with the research cooperation achieved by NASA, the United States rotorcraft industry (under the umbrella of the American Helicopter Society), the U.S. Army, the Federal Aviation Administration, and the Helicopter Association International. As a result of this unique cooperative program a new helicopter total system noise prediction code called ROTONET has been developed and made available to industry in its initial operational phase.

A major rotor system noise experiment was completed in 1986. The experiment measured rotor broadband noise systematically over a range of conditions in a controlled environment for the first time. The results of this broadband test are being included in ROTONET. In addition, comprehensive blade-vortex interaction (BVI) data were obtained that will enable the development of a semi-empirical BVI noise methodology.

A promising tool for significantly reducing the internal noise caused by helicopter transmission was developed. This tool is a computer program for gear tooth contact analysis and determination of gear cutting machine parameters that will provide spiral bevel gears with zero kinematic error. Transmission gears produced with this code will operate with less vibration, leading to more reliable, longer life and quieter transmission designs.

A major rotor system improvement was demonstrated in 1986 with the use of an advanced rotor blade design tested on a scale model UH-60 rotor. The model blade utilized advanced airfoils, a unique planform shape, a high degree of twist and aeroelastic tailoring to increase rotor performance and reduce vibration. The wind tunnel tests showed such a significant performance improvement, especially at high altitude, that the U.S. Army is seriously evaluating this blade design as a product improvement for the UH-60 Blackhawk helicopter.

In the area of flying qualities, a cooperative program with the U.S. Army utilizing the CH-47 variable stability research helicopter and ground based simulators has resulted in a major update to the outdated military specifications for rotorcraft flying qualities with a focus on the Army's light helicopter (LHX) program. This research will continue with a goal of completely redefining flying qualities criteria for new helicopters.

Increased forward flight speed is a technology focus which leads to new and innovative configurations such as the Tilt Rotor and the X-Wing. By converting from a pure helicopter mode to a more efficient wing-lift mode, it is possible to double, or even triple, rotorcraft cruise speeds, thereby vastly improving the productivity of rotorcraft. Other benefits of higher speed wing-borne flight include reduced noise and vibration, and enhanced military effectiveness.

Scale model UH-60 rotor in Transonic Dynamics Tunnel

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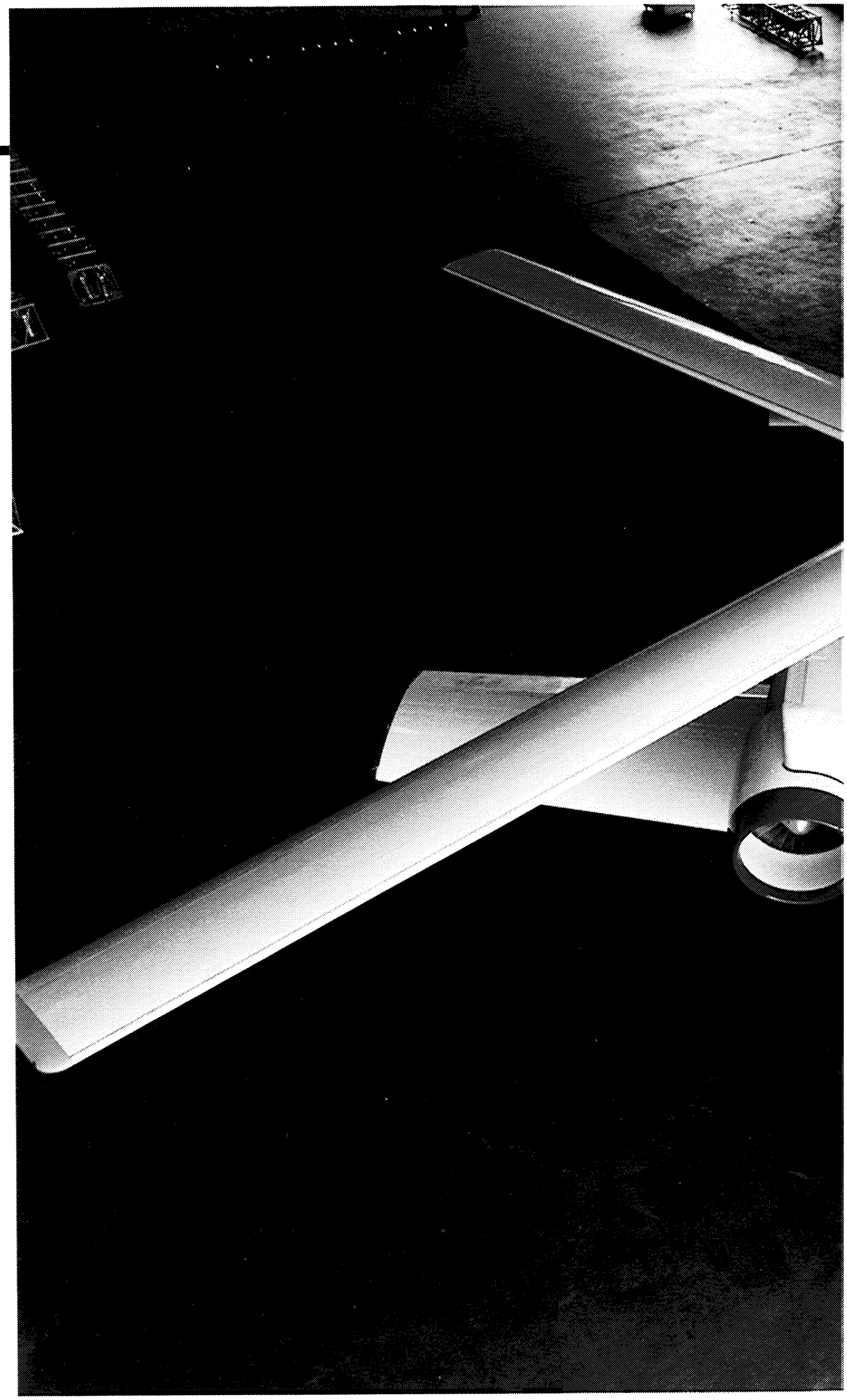
RSRA/X-Wing flight research aircraft



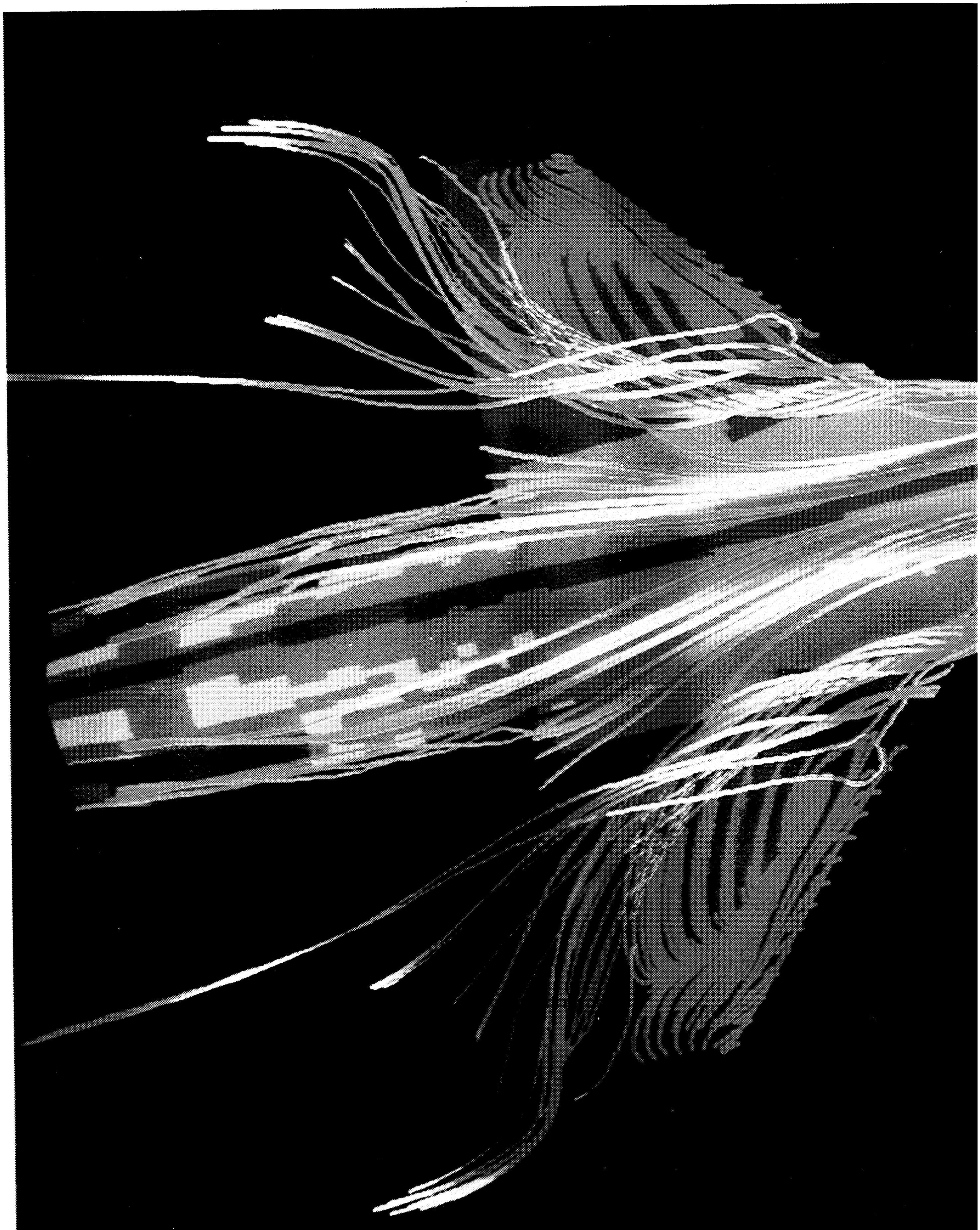
A significant advancement was made in tilt rotor research in 1986. An experiment was conducted applying circulation control to the trailing edge of a tilt rotor wing which was enmeshed in the downward flow from the hovering proprotors. The results verified analytical calculations that the downward force on the wing can be reduced by 25%, making possible promising design alternatives for future tilt rotor aircraft which will enable more efficient higher forward flight speeds.

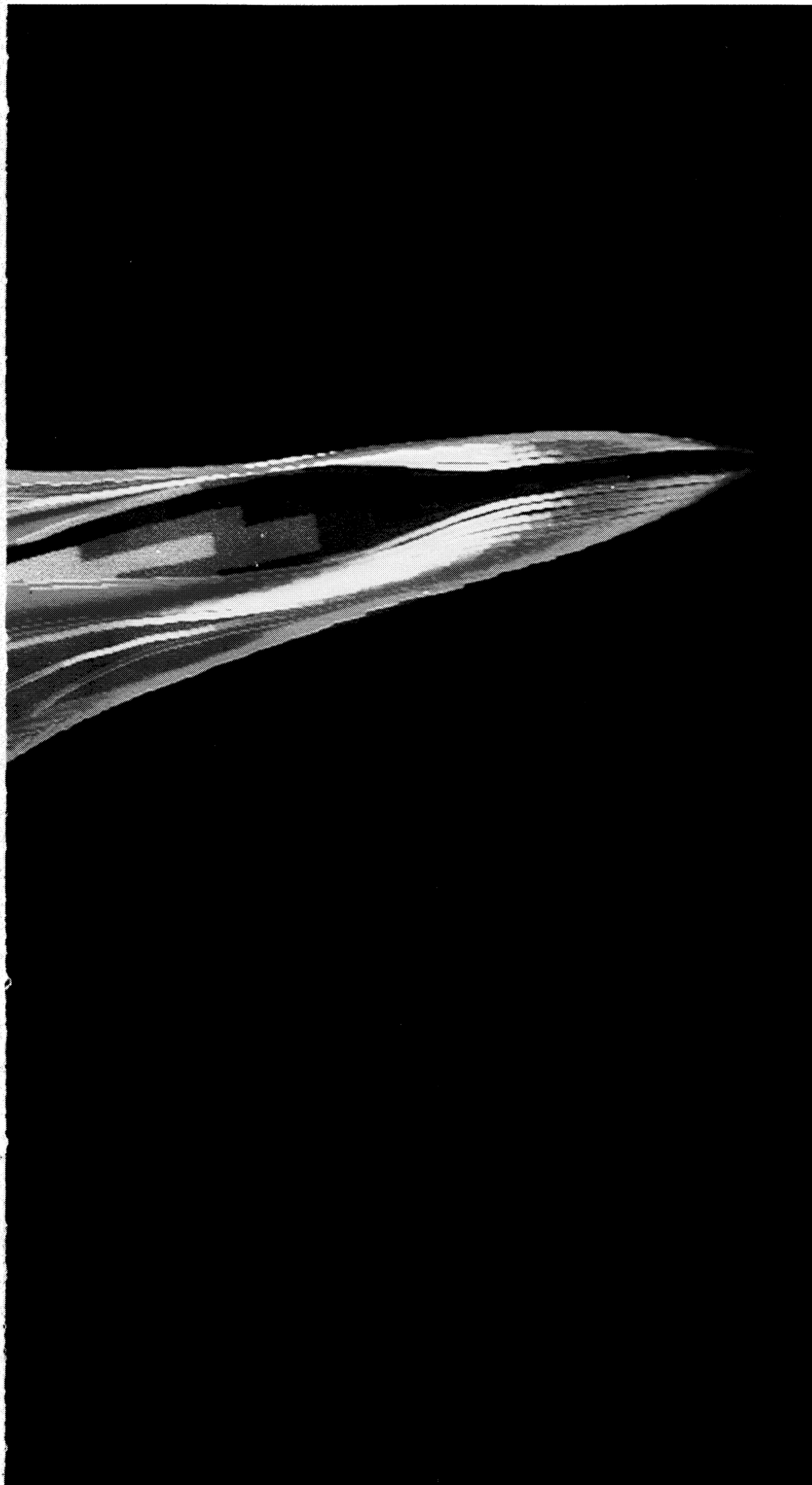
An important rotorcraft milestone was reached in August 1986 with the completion of the fabrication and assembly of the Rotor Systems Research Aircraft RSRA/X-Wing research vehicle. The X-Wing rotor is a four-bladed, extremely stiff, rotor system utilizing circulation control aerodynamics for lift and control. In hover and low speed flight the rotor system rotates as a conventional helicopter rotor. In high speed forward flight the rotor rotation is stopped and a fixed X-Wing configuration results. The RSRA/X-Wing vehicle was shipped to Dryden Flight Research Facility at Edwards Air Force Base, California to begin preparation for flight research.

This joint DARPA/NASA program continues the effort to advance the state of technology in high speed rotorcraft flight and in several other key technology areas. The X-Wing rotor is a fully composite rotor/wing which incorporates the thickest load bearing composite structure ever built. In addition, the quadraplex flight control system has over 60 control effectors controlling complex pneumodynamics, and circulation control aerodynamics.

The potential national benefits of tilt rotor technology are being assessed in a joint study initiated in 1986 by NASA with the Department of Transportation and the Department of Defense. The study will document economic factors related to civil tilt rotor development, the effect on the industrial base of the V-22 and follow-on tilt rotor programs, emerging applications and potential designs to accommodate them, and the effects on the National Airspace System.

XV-15 Tilt Rotor Research Aircraft flight demonstration in New York City





AERODYNAMICS

The increased emphasis on technology thrusts that are responsive to new aeronautical opportunities and national needs has led to the pursuit of aerodynamics research tasks that focus on innovative analytical techniques, unconventional aircraft configurations, new operating regimes, and more sophisticated instrumentation and testing techniques.

The NASA disciplinary research in aerodynamics is a tightly interwoven program of theoretical analyses, numerical simulation, wind-tunnel testing, instrumentation and where necessary, flight research. The basic, on-going, research underlies and enables the advancement of aeronautical vehicles through the application of new technology.

Major emphasis is being placed on the development and application of computational fluid dynamics for the prediction of complex aerodynamic phenomena. This is made possible by the rapidly growing supercomputer capabilities now available.

Computational Fluid Dynamics

With the increasing availability of supercomputers, the discipline of computational fluid dynamics (CFD) is now providing powerful analytical, simulation, and predictive tools to address the basic physics of aerodynamic flow fields. New CFD tools are being used to advance the understanding of the complex flow environment of advanced aircraft configurations and to permit aerodynamic optimization of the new aircraft designs.

During 1986, significant progress was achieved in CFD techniques. Computations are now possible for three-dimen-

Computer generated flow stream trace lines over F-16 aircraft configuration sional, viscous compressible flows containing separated flow regions whereas, previously, only simple aerodynamic flows for complex configurations were solvable.

Thus, the computation of flow over realistic wing-body combinations are now possible. As an example, the new techniques were used at the Ames Research Center to calculate the streamlines over an F-16 high performance aircraft configuration utilizing a new 3-D grid scheme. This accomplishment marked the first complete flow field solution for viscous 3-D flows around an actual aircraft configuration.

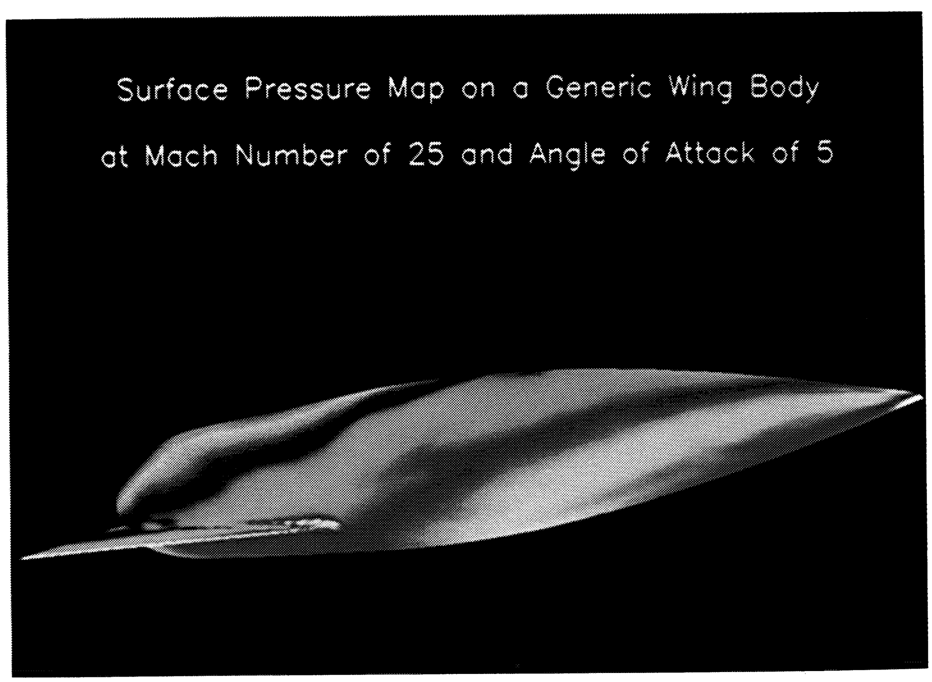
The new CFD techniques were also used in 1986 in support of the National Aero-Space Plane (NASP) effort. Baseline CFD calculations of pressure contours on the vehicle surfaces and in the surrounding flow field were performed. Achieving the solution of Navier-Stokes equations at high Mach number forms the base for future analysis and prediction efforts in support of NASP. This is especially important in the investigation of vehicle aerodynamics and aerothermodynamics where ground test facilities are currently inadequate.

Successful computations of hypersonic wing/body surface pressure contours were also performed in 1986. These CFD calculations were carried out for a flight environment of Mach 25, a 5 degree angle of attack and a 3000 degree R wall temperature.

The rapid advances in supercomputer technology are directly responsible for the new progress in CFD. A major 1986 milestone in CFD supercomputer capability was the opening of the Numerical Aerodynamic Simulation (NAS) facility at the Ames Research Center on July 21. The new facility will be fully operational in March of 1987. The NAS currently utilizes a Cray-2 supercomputer having a memory of 256 million words. Future plans at NAS are to continue its pathfinding role in state-of-the-art computer systems as a requisite for pioneering aerodynamics research and development. Combined DoD/NASA programs requiring secure processing are also planned.

In a related activity, a complete end-to-end, high-speed mainframe computer networking subsystem, utilizing the Program Support Communications Network (PSCN) as the communications medium, was implemented in 1986. In addition to providing access to the Ames supercomputers, the PSCN provides a general purpose network to allow center users to interface with the computer mainframes as a total system. The Computer Networking Subsystem (CNS), which is one of PSCN's services, is designed to exchange large bulk files between large mainfame computer facilities located at Ames Research Center, Dryden Flight Research Facility, Langley Research Center, and Lewis Research Center. The CNS is intended to improve the effectiveness and productivity of large mainframe computers in support of the aeronautics research and technology program.

The CNS began operation in March of 1986 at the transmission rate of 56 kilobaud and has been upgraded to its current 224 kilobaud rate. During the ongoing development the satellite network is being heavily used to provide Langley Research Center with access to the Cyber 205 located at the Ames Research Center.



Numerical simulation of hypersonic aircraft configuration surface pressure map

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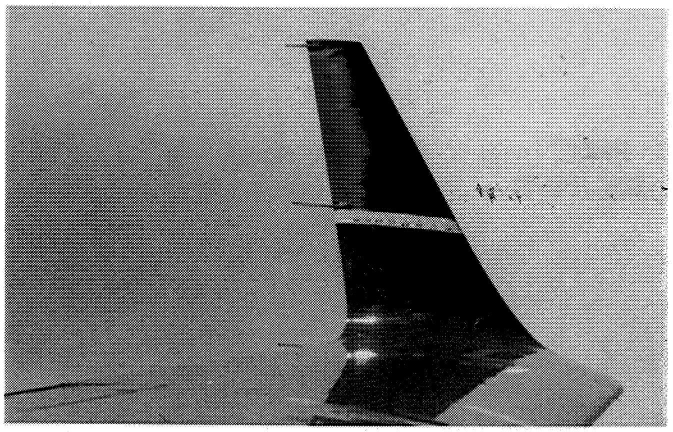
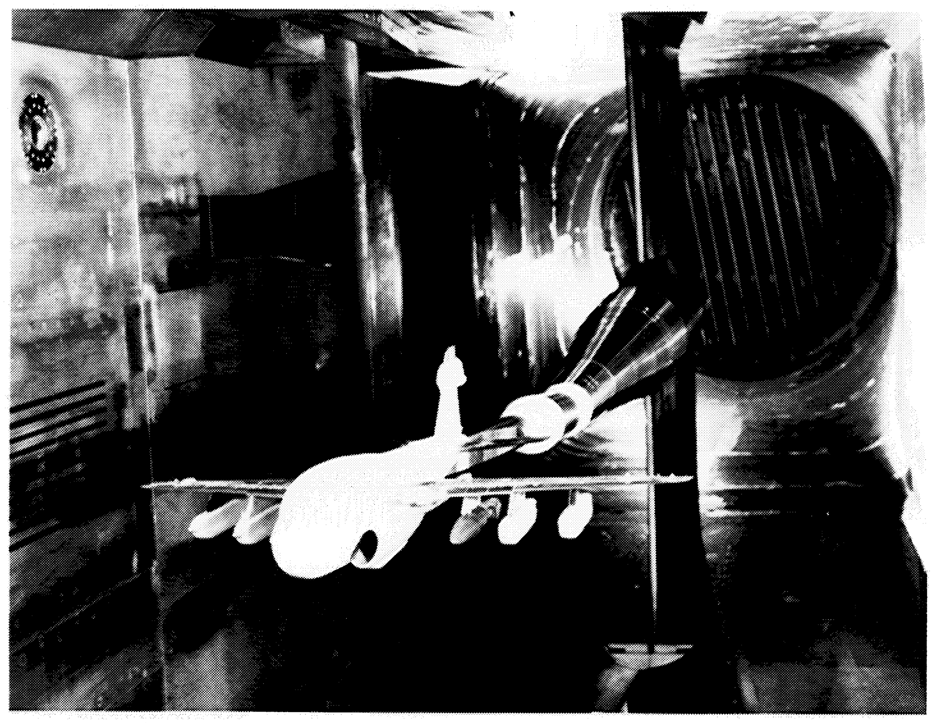


In-flight winglet boundary layer investigation utilizing liquid crystal technique

Experimental Aerodynamics and Test Techniques

The National Transonic Facility (NTF) at the Langley Research Center plays an important role in experimental aerodynamics. This cryogenic wind tunnel facility allows true simulation of full-scale flight Reynolds number. This capability makes possible the independent investigation of compressibility, viscosity and aeroelasticity effects—a powerful new tool in validating new computational codes. The NTF has been utilized in "problem-solving" testing as well as research investigations. Extensive tests were conducted on an EA-6B aircraft model where low speed stability and lift were improved significantly. This tunnel has also provided data which aided in the validation of existing CFD codes. An example of this was the favorable comparison of data taken on the Pathfinder I generic transport model with a shock wave prediction code.



EA-6B aircraft model in National Transonic Facility (NTF) cryogenic wind tunnel

The recent completion of the Fluid Mechanics Laboratory at the Ames Research Center is a major new capability for the experimental aerodynamics program. This laboratory contains a number of small research facilities that are used for fundamental fluid physics investigations. Theory and experiment are being closely integrated in this environment in studies in turbulence modeling, vortex flow, high angle-of-attack flows, and other complex fluid phenomena. This facility will promote cooperative activities with the university community, the aerospace industry, and with other government research organizations.

Another advancement in experimental test techniques was achieved in 1986 with the initiation of operations of the adaptive wall pilot wind tunnel at Langley Research Center. The adaptive wall tunnel has greatly improved transonic wind tunnel test fidelity by eliminating wall disturbances which would otherwise propagate toward the model, distorting test conditions, and compromising test accuracy. Three airfoils were tested in 1986—a calibration airfoil (NACA 0012), and two advanced airfoils developed by Boeing.

The application of laser holography advanced significantly in 1986. Using several laser beams focused at a point, the first non-intrusive detailed measurement of a rotor flow field was made. Using this technique and automatically scanning the flow under a helicopter model in the Langley Research Center 4-by 7-Meter Tunnel, the first comprehensive measurement of the rotor downwash was achieved. This database is an important contribution to the understanding and prediction of rotor loads, noise, and vibration.

Important progress was also achieved in the use of liquid crystal coatings to study boundary layer behavior in flight. The key to the technique is the tendency of the liquid crystal to change color in response to changes in shear stress and temperature. In 1986 a Learjet 28/29 was used to successfully develop the liquid crystal technique for in flight boundary layer investigations. Using liquid crystal coatings, the boundary layer transition on a winglet of the Learjet was displayed in flight at 300 knots and 50,000 ft. altitude. The significance of this achievement was that it demonstrated the first method for high-al-titude, cold temperature boundary layer behavior visualization.

PROPULSION

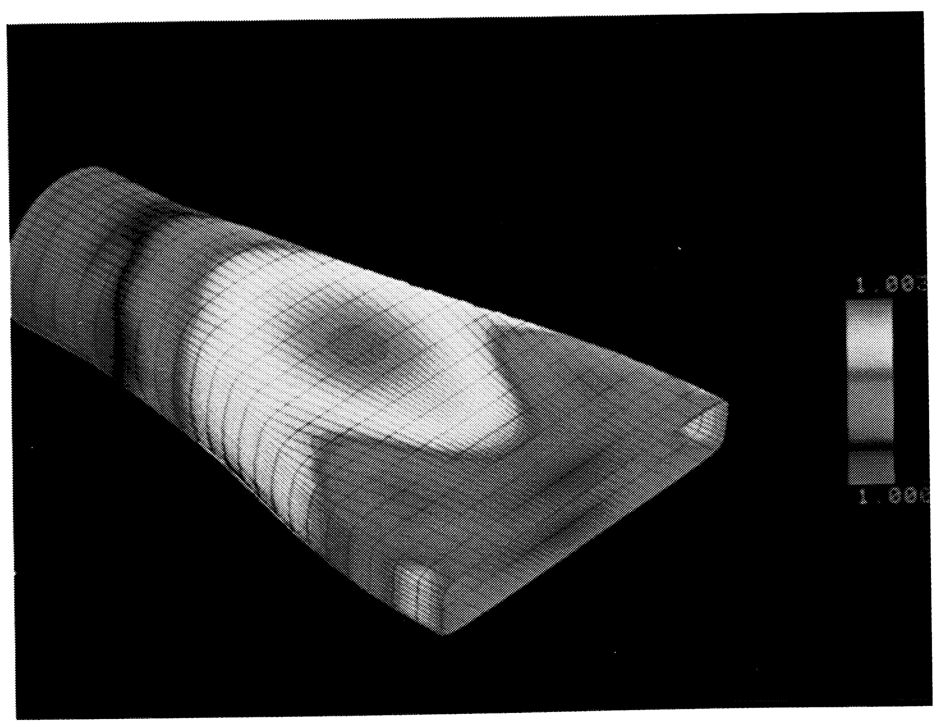
Advanced propulsion technology is the key to achieving order of magnitude improvements in new aeronautical vehicle concepts. For example, hypersonic flight is critically dependent on new propulsion systems, advancements in supersonic cruise and subsonic transport performance are dependent on more efficient propulsion systems, and the successful achievement of high speed rotorcraft operation requires new, innovative propulsion system concepts.In each instance the new propulsion system technology must be built upon a solid base of research in the areas of internal computational fluid mechanics, advanced control concepts, and new instrumentation techniques.

Specific propulsion concepts which are being investigated at both a component and system level at the Lewis Research Center include small turbine engines, powered lift concepts in support of advanced short take-off and vertical landing aircraft configurations, propulsion for supersonic cruise aircraft and for hypersonic aircraft. Rotary cycle engines and unique propulsion systems for high speed rotorcraft applications are also elements of the current aeropropulsion program. Combining these research areas with focused discipline research in areas such as new high temperature materials enables advances in propulsion systems technologies which are critical to the successful development of new vehicle concepts.

Internal Fluid Mechanics

Discipline research in internal fluid mechanics (IFM) is providing the analytical tools to describe the complex flow in turbomachinery, high speed inlets, exhaust nozzles and ducts, and chemically reacting flows in combustors. The ability to describe the flow in more than one stage of turbomachinery was recently demonstrated with a new code developed by the Lewis Research Center. The code uses an average-passage approach to describe the extremely complex flow field while also reducing computer calculation time to a manageable level using the highest speed computers currently available. In addition to code development, it is necessary to perform experiments to validate the complex phenomena predicted by the codes. A recent experiment used a sophisticated laser measurement system to develop a unique data set describing the structure of a normal shock interacting with a boundary layer and the flow field downstream of the shock.

Computer graphic display of stress distribution on turbine engine exhaust duct



Instrumentation

Laser velocimetry has become a valuable technique for acquiring detailed turbomachinery internal flow field measurements. By combining an interferometer and a conventional laser velocimeter into a single optical system, the system is capable of measuring three velocity components using two laser beams and requires only single port optical access to the internal flow field. The system was first used successfully in 1986 to measure radial velocity components as small as one percent of the axial velocity component. The system is currently being used to investigate the flow field within a turbine vane annular cascade in which flowpath convergence generates large radial velocity components. Results of these experiments compare favorably with analytical predictions.

Laser velocimeter instrumentation system for measuring turbo-machinery internal flow fields

High temperature electronics technology is a key element in achieving successful advances in propulsion system technology. Silicon carbide, because of its wide temperature capability for electronic devices and because of its wide range of frequency output, is an ideal instrumentation material for use in aeropropulsion experimental rigs and in operational aircraft engines. These characteristics also make silicon carbide a potential candidate for use in spacecraft where heat dissipation is of critical concern. Significant progress was made in 1986 in high temperature transistor technology with the demonstration of the ability of silicon carbide devices, manufactured at the Lewis Research Center from silicon carbide crystals grown there, to retain diode characteristics up to 300 degrees C.

In addition, the first successful demonstration of plasma etching was accomplished on silicon carbide crystals to form high quality semi-conductor device geometries. It was also discovered that antiphase boundaries in the crystals alters the electronic structure and thus affects device characteristics, particularly as temperatures increase. This discovery points the way to the production of improved silicon carbide crystals for integrated sensors for aerospace propulsion control systems capable of operation above 600 degrees C.

Intermittent Combustion Technology

Intermittent combustion engines offer inherently low cost for general aviation and commuter applications but have been restricted to the use of aviation gas which has become more difficult to obtain and thus expensive. Research is currently underway on stratified charge rotary engines which have the capability to operate on several different fuels, including jet fuel, as well as offer improved efficiency and power relative to current engines.

The intermittent combustion research program is structured to improve power densities and efficiencies for stratified charge rotary engines. A major accomplishment of the NASA/Deere and Co. stratified charge rotary engine program was the attainment of 160 Horsepower (HP) from a 40 cubic inch single rotor engine, the highest power density ever achieved in this type of engine. Using a high speed electronic fuel control system

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Assembly of stratified charge rotary engine test hardware

and jet fuel, a fuel consumption was achieved comparable with today's general aviation engines. The ultimate goal is to reduce fuel consumption by approximately 30% using optimized fuel control and ignition systems in conjunction with design improvements developed on the basis of validated analytical airflow modeling codes. Turbocompounding, adiabatic components, lightweight rotors, and reduced friction schemes are also being investigated. The first laser holographic visualization of airflow in the combustion chamber of a rotary engine was successfully obtained in 1986 and will be used along with other methods of determining airflow to validate a multi-dimensional airflow model for a rotary internal combustion engine.

Small Turbine Engine Technology

The primary objective of the small turbine engine program is to raise the performance level of small turbine engines to more nearly match that of large engines. Work continues to be focused on providing fundamental experimental data to enable an understanding of the design parameters that affect component performance as size is reduced. Small engine component technology studies were completed which determined that high temperature materials, such as ceramics for the hot section; improved aerodynamics; and advanced cycles, including recuperators, have the potential of reducing fuel use by 20-50% with a corresponding reduction in direct operating costs of 12-20%. A scaled centrifugal compressor program was completed demonstrating that the effects of tip clearance, blade thickness, and surface roughness could be properly accounted for, leaving the effect of aerodynamic scaling as the fundamental cause of efficiency change.

A new structural analysis code was completed in 1986 which predicts fast fracture probability for ceramic turbine components. Also, experimental evaluation of an advanced ceramic matrix combustor liner provided a 300 degree F increase in turbine inlet temperature yet eliminates film cooling requirements. An analytical model for predicting flow fields velocity and temperature trends in the turns of a reverse flow combustor was developed under contract to industry.

STOVL Technologies

The advanced short take-off and vertical landing (ASTOVL) program at the Lewis Research Center is providing a technology base in the area of propulsive lift systems, attitude control systems, light weight deflecting and vectoring nozzles, and integrated flight and propulsion controls for application to advanced military supersonic powered lift aircraft configurations. The 1986 completion of the Powered Lift Test Rig, which can provide adequate air flow rates and pressure ratios to simulate typical engine performance, will make possible the full scale assessment of various lift augmentation systems. The rig is capable of measuring axial thrust up to 30,000 lbs., vertical thrust to 20,000 lbs., and lateral thrust up to 3,000 lbs.

Convertible fan/shaft turbine engine ground test installation

Convertible Engine

The completion of the convertible engine program in 1986 at the Lewis Research Center has successfully demonstrated that this type of propulsion system is viable for future advanced rotorcraft concepts such as the X-wing, folding tilt rotor, and advancing blade concept configurations. The joint NASA/DARPA program used a TF34 engine, with variable fan inlet guide vanes for thrust modulation, to evaluate improved fan hub design and map the steady state and transient performance and stability of this concept over the full range of engine operation. The variable guide vane engine system was found to be inherently stable and controllable in all modes of operation. Utilizing this type of propulsion concept to provide power in either a forward or vertical mode will enable a 20 percent reduction in direct operating costs compared to using separate engines to achieve the two flight modes. The application of this technology is now underway and the General Electric Company expects to make available a flight-rated, convertible engine demonstrator in the early 1990s.

Transmission Technology

The rotorcraft transmission program achieved several significant accomplishments in FY86. The first rigorous analytical study of transmission dynamic load effect on gear pitting fatigue life was completed which showed that operating speed and contact ratio significantly affect component life. A 3600 HP split torque helicopter transmission design study was completed which provides a 15 percent weight reduction, improved reliability, a 9 percent reduction in power losses, and approximately a 35 percent reduction in noise. This design provides for a possible replacement of the Blackhawk helicopter transmission and includes growth potential from 3000 HP to 4500 HP.

In addition, a life and reliability computer program was completed which will serve as a valuable tool for evaluating preliminary designs and for evaluating competing helicopter transmission designs. Using inputs such as transmission configuration, load, and speed, the expected life of transmission components and systems can thus be predicted. The program also provides information which can be used to support fleet operations to plan spare parts requirements based upon the predicted life of the components.

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MATERIALS AND STRUCTURES

Significant improvements in the performance, durability and economy of future civil and military aircraft requires that advancements in the technology base in materials and structures be achieved. To meet the national goal in hypersonics alone, new materials and structural concepts must be developed that can withstand high aerothermal loading cycles in airframes that are lightweight and incorporate complex intersecting structural surfaces.

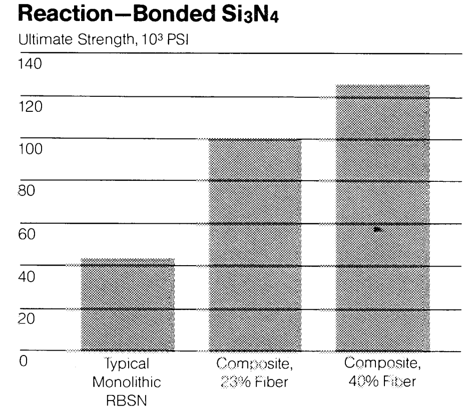
In addition, the development of new, validated analytical prediction methods for complex, lightweight, high temperature structures has resulted in increased emphasis on computational structural mechanics (CSM), optimization techniques, and integrated active control concepts for flutter suppression, relaxed static stability, gust load alleviation and maneuver load control.

High Temperature Structural Materials

Ceramics are attractive high temperature structural materials because of their strength, low density, environmental resistance and net shape fabricability. However, the brittle nature of ceramics makes these materials sensitive to minute flaws and defects. Enhancement of ceramic toughness, via the addition of particles or whiskers to deflect and arrest cracks and toughening and strengthening of ceramics by fabrication of continuous ceramic filament reinforced ceramics, can permit ceramic parts to be more forgiving of flaws and to exhibit tensile behavior more comparable to ductile metals.

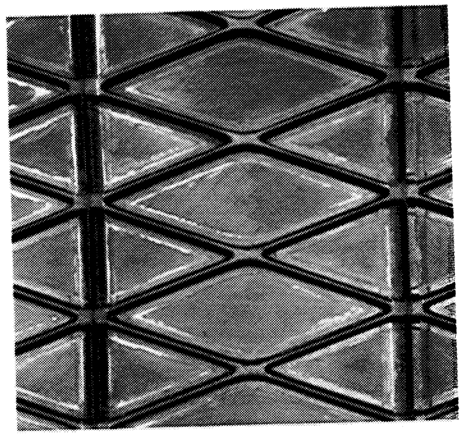
Significant progress in ceramic toughness technology was accomplished in 1986 with the Lewis Research Center development of an approach to strong, tough, high temperature ceramic-ceramic composites that utilize continuous silicon carbide fibers to reinforce reaction bonded silicon nitride matrices. The high fiber content in the ceramic composite impacts improved fracture toughness and ultimate strength over state-of-the-art monolithic materials. The most important aspect of this accomplishment is that a failure in this new ceramic composite occurs in a more stable, progressive manner than the catastrophic fracture of monolithic materials.

SiC Fibers Strengthen and Toughen Reaction—Bonded Si_3N_4

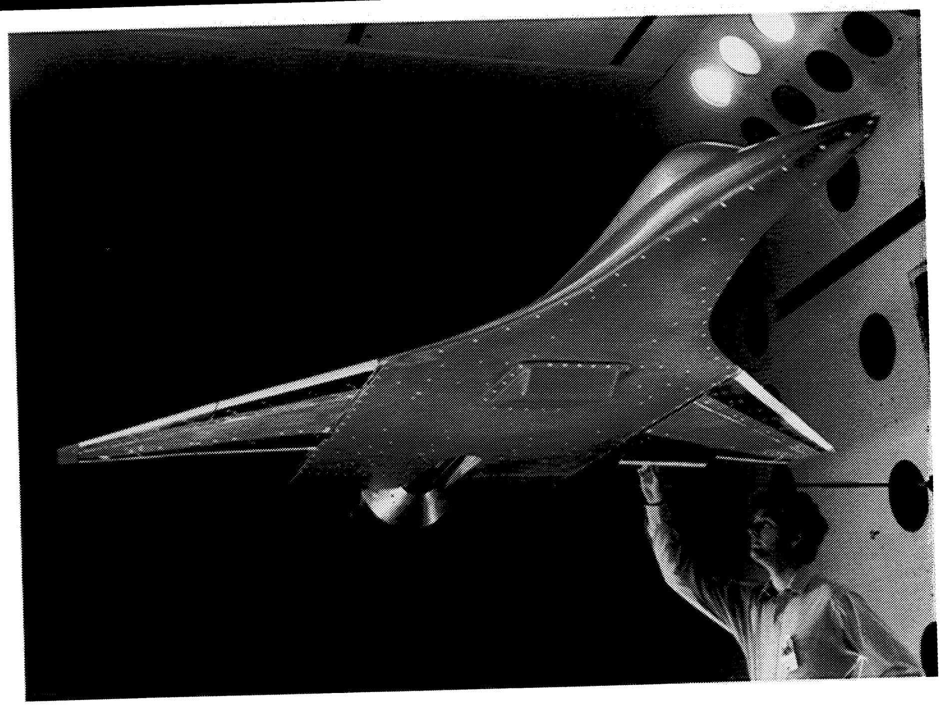


Fiber content effect on ceramic composite strength

High temperature test of ceramic material turbine vane



Composite structure geodesic stiffened compression panel



Aeroelastic model of "active flexible wing" aircraft in Transonic Dynamics Tunnel

Composite Structures

Composite materials are finding increased use in current and future airframe designs because they are lighter and stiffer than conventional metallic aircraft structural materials. The composite program is directed toward the development of new polymeric systems and concepts for innovative structures for large wings and fuselages with improved toughness, fabricability, consistency of properties, and weight/cost reductions.

One example of the breakthroughs in composite structures research in 1986 is the development of the geodesic stiffened compression panel with isogrid construction geometry. This structural concept, developed at the Langley Research Center, has resulted in major steps towards producing cost effective, damage tolerant airframe designs. The geodesic orthogrid wall panel concept provides 30% lower weight than a corresponding skin/stringer aluminum structure, and is over 40% lower in cost. Current design practice with conventional layup techniques results in double the cost of aluminum structures with only equivalent weight savings.

Computational Structural Mechanics

NASA has initiated a focused multicenter activity in computational structural mechanics (CSM) with the key objectives of (1) developing accurate, efficient and innovative computational methods for very large and complex aerospace structures and, (2) exploiting the newest and most powerful computers available. A significant 1986 accomplishment of CSM is the detailed analysis of an advanced, uncooled turbomachinery turbine blade. This component is subjected to severe cyclic thermal and mechanical loading, and the blade material characteristics become highly nonlinear in critical locations during normal operation. A detailed analysis of this problem is beyond the scope of traditional analytical methods on conventional computers. Advanced computational methods are demonstrating the capability to significantly reduce solution time with improved accuracy. These methods are currently being used on a state-of-the-art CRAY XMP vector processing supercomputer, but are being installed on a more powerful CRAY 2 supercomputer.

Aeroelasticity

NASA is a leader in the study of aircraft aeroelasticity, including the phenomena of divergenece and flutter. Structural deformations of the aircraft can couple with the aerodynamic forces acting on it to produce unstable conditions in which the deformations grow excessively large. This condition can lead to the destruction of the aircraft. The avoidance or control of these unstable aeroelastic phenomena are critical to the successful flight of advanced aircraft configurations.

An innovative scheme was recently proposed to the Air Force by Rockwell International in which the flexibility of the wing would be used di-

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rectly to control aeroelastic response. This involves elastically deforming the wing shape instead of just moving control surfaces. The approach has the potential of saving several thousand pounds of structural weight.

A model of an "active flexible wing" was successfully tested in the Transonic Dynamics Tunnel (TDT) at Langley Research Center in 1986. Initial testing has been completed and a valuable database obtained to validate the predicted advantages of the concept. Rolling moment coefficients, which correlated well with predictions, were experimentally determined. Additional testing will be conducted in the TDT to support the development of a complete control system for aeroelastic tailoring.

INFORMATION SCIENCES AND HUMAN FACTORS

Increasing emphasis is being placed on the significant payoffs that can occur from the infusion of the disciplines of information sciences and human factors into the process of applying advanced technology to future generations of aeronautical vehicles. The research challenges range from the basic understanding of new computational concepts to the theoretical basis for reliable fault-tolerant systems, from the exploitation of new control and guidance concepts to the definition of readily adaptable artificial intelligence concepts, and from reliable workload prediction techniques to sophisticated techniques for analytically modeling the behavior of human pilots in high workload cockpit environments.

These challenges are the drivers that establish the priorities of the research efforts in NASA's information sciences and human factors program. The enabling technologies emerging from this rapidly expanding field of science will provide the key to understanding, applying, and controlling a new family of aeronautical vehicles such as rotorcraft that can fly nap-of-the-earth in all weather, high perfor-

Numerical Aerodynamics Simulation facility computer complex

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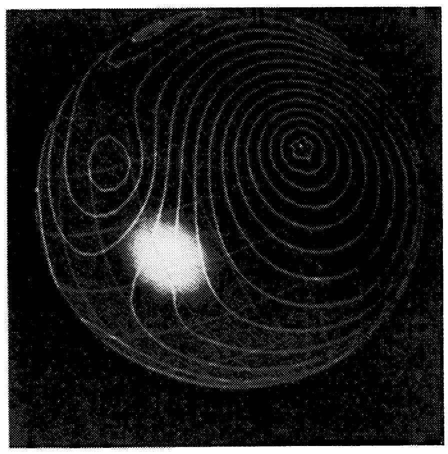
mance aircraft that can maneuver at 90 degree angle of attack, transports that can fly more safely in the National Airspace System, or transatomspheric vehicles that can operate routinely across the boundaries of the atmosphere and space.

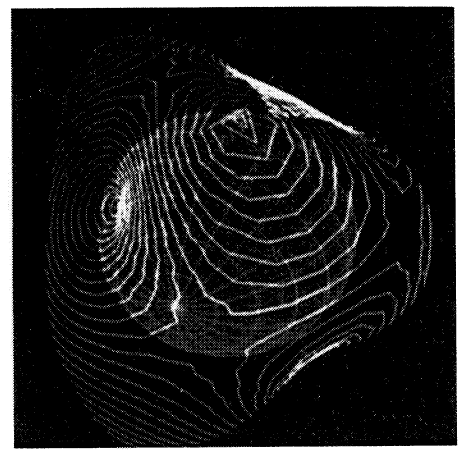
Computer Science

Significant accomplishments in computer science took place in 1986 that provide the leading edge technology necessary to aggressively and effectively realize the tremendous computational potential of the National Aerodynamic Simulation (NAS) facility and the Computer Networking Subsystem (CNS).

During 1986, a concurrent processor test bed became operational at the Research Institute for Advanced Computer Science (RIACS) at Ames Research Center. Among the equipment in the test bed are a main timesharing system that supports 20 users, an Intel Hypercube that supports concurrent programming research, and an IRIS 1500 work station that supports Numerical Aerodynamic Simulation Graphics tasks and RIACS graphics. Research is being conducted in architectures for computational physics and in graphics for computational and experimental physics.

Initial demonstrations were successfully accomplished in 1986 using a new special purpose computer. A parallel architecture computer for simulating flows governed by the Navier-Stokes equations is being developed by Professor Nosenchuck of Princeton University under a grant from Langley Research Center. This computer is capable of peak processor speeds of 960 Mflops.





Computational science mathematical representation of surfaces on spheres

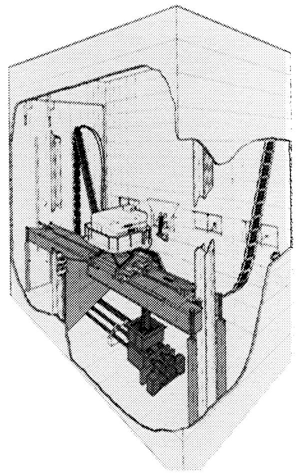
Significant progress was achieved in finding improved techniques for visualizing depth in three-dimensional computer graphics images. A new stereo imaging capability has been developed and demonstrated on an IRIS workstation. In addition, IRIS can now be used for interactive viewing of Cray 2 simulations utilizing a direct Cray 2-IRIS interconnect scheme.

Other 1986 computer science accomplishments include improved mapping of mathematical functions on the surfaces of spheres. This achievement evolved from research in dynamic displays of data on closed surfaces carried out under sponsored research at the University of Arizona. Related display research at the University of Utah resulted in high quality 3-D solid modeling techniques and computer generated "transparent" displays showing hidden surfaces.

Controls and Guidance

Controls and guidance research is providing advanced technology enabling the exploitation of new avionics concepts to dramatically improve the operational capabilities of new civil and military aircraft. Major advances in aircraft control design methodologies, reliability validation techniques, and guidance and display concepts are taking place that will increase the efficiency and effectiveness of the next generation of aircraft and rotorcraft.

Important progress was made in the critical area of fault tolerant data management system concepts. In 1986 an Advanced Information Processing System (AIPS) design was developed that provides triplex, duplex, and simplex processing capability. Corollary efforts addressing sensors and effectors were combined with the AIPS development to achieve a total systems level approach to fault tolerance.



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Vertical Motion Simulator (VMS) and computer generated visual display system

NASA is supporting the FAA's activities to explore the viability of automated terminal control functions enabling more efficient management of aircraft operating into, within or out of an airport area. During 1986, an evolutionary time-based terminal area flow control concept was developed for use in the Ames Research Center ATC simulation system. The simulation algorithm is designed to investigate new techniques for fully utilizing runway capacity and improve fleet operational efficiency while enhancing operational safety within the National Airspace System.

Significant progress was made in utilizing the power of new aerodynamic computational methods to analyze the low altitude wind shear hazard. This atmospheric phenomenon, characterized by rapid changes in wind magnitude and direction, is a potential hazard to all aircraft during takeoff and landing.

During 1986, a wind shear computer model was developed and applied to several wind shear accidents to provide improved understanding of the phenomenon and to provide insight and a data base for future investigations. The wind patterns derived from these computations were also demonstrated to be valuable in developing forecasting models and wind shear models for simulators used in aircraft detection system development and pilot training.

Human Factors

The failure to properly integrate the human pilot into advanced aircraft systems can impede the orderly progress of aviation. During 1986 research in human factors and automation explored the potential of artificial intelligence (AI) computer systems and radically different methods of control to enable humans and automated machines to work together successfully.

A primary example of the progress in the area of man-machine integration is the Army-NASA Aircrew Integration program underway at the Ames Research Center. This exploratory program is focused on the development of predictive methodology for helicopter cockpit system design. In 1986 an initial version of an advanced integrated workstation was developed that generates predictive methodologies for systems design based on mission requirements and pilot training levels. Primitive human performance models were also incorporated.

In related man-machine research, two simulations were successfully performed in the Vertical Motion Simulator (VMS) during 1986 to compare the workload and performance of pilots flying in a combat environment with twenty different levels of automation in both one-and-two-pilot configurations. Different combinations of pilot-selectable features were provided and mission management requirements and communications were imposed to introduce realistic workload levels. Results showed that workload was high for a single pilot and only one configuration was satisfactory for single-pilot nap-of-the-earth operations.

The cross-coupling of rotorcraft

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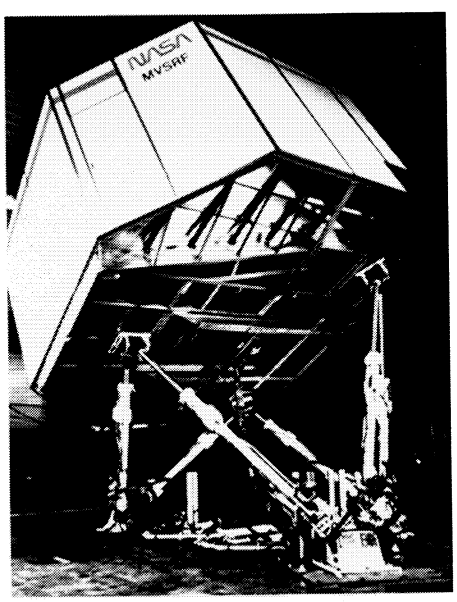
pitch and roll control has a direct influence on the handling qualities of rotorcraft. Research accomplished at the Ames Research Center on the Vertical Motion Simulator in 1986 quantified the effects of varying levels of cross-coupling on handling qualities. Preliminary findings demonstrate that coupling pitch response to roll control inputs has less significant impact on handling qualities than coupling roll response to pitch control inputs. The validation of selected VMS results using the Variable Stability Helicopter at the Ames Research Center is scheduled for early 1987.

The Man-Vehicle Systems Research Facility (MVSRF) is now fully operational at the Ames Research Center. This facility is devoted entirely to research in aeronautical system human factors. The facility incorporates advanced experimental display formats, control logic and systems interaction techniques in a realistic operational environment utilizing both fixed-base and moving-base simulation concepts.

During 1986, side-stick controller handling qualities evaluations were accomplished on the MVSRF. The controllability of several different modes of coupling and control priority were examined as a precursor to determining pilot preference for various levels of coupling between side-stick controllers and auto-pilot systems.



Man-Vehicle Systems Research Facility (MVSRF) moving base simulator

727 Cockpit Simulator in MVSRF

FLIGHT SYSTEMS/ SAFETY

In each discipline area; such as aerodynamics, structures, flight controls, and propulsion; there exists a need to validate the research progress through actual flight testing of new components and systems using advanced instrumentation techniques. In some instances, aeronautical research can only be performed or validated in flight. This in-flight validation is frequently accomplished by utilizing high performance aircraft as test beds. These aircraft are often provided by agencies of the Department of Defense under long standing agreements with NASA in connection with one element of the NASA charter, which is to support military aviation technology development. NASA utilizes these aircraft primarily in flight systems research programs conducted at the Ames Research Center-Dryden Flight Research Facility.

While the NASA aeronautical research and technology program places major emphasis upon new vehicle technology and the fundamental disciplines that provide the base for new technology, an important aspect of the program is the investigation of phenomena critical to the operational safety of civil and military aircraft. This research is focused on the understanding and prediction of the natural and man-made environment that impact upon the operational safety of existing and future aircraft. Areas of special concern include storm haz-

Highly Integrated Digital Electronic Control (Hi DEC) F-15 flight research aircraft

ards, such as lightning, gusts, turbulence, and rain effects, icing, and wind shear encounter. In accordance with NASA's charter, the safety related research is conducted in support of, and in very close coordination with the FAA, which has the primary responsibility for aircraft safety.

HiDEC Program

The Highly Integrated Digital Electronic Control (HiDEC) program is designed to flight validate the technology for integrating engine and flight controls. The program is conducted jointly between NASA, the Air Force and industry. A highly integrated digital engine controller has been flight tested on one engine of a F-15 aircraft. The control technology allows the automatic adjustment of engine operating parameters as a function of flight conditions. In 1986, a breakthrough in performance was demonstrated, which included a 12% thrust increase. This achievement translates into either a 12% increase in climb performance or a 14% reduction in specific fuel consumption, or reduced acceleration times.

This promising technology in integrated flight/propulsion control has wide application to advanced civil, as well as military, aircraft designs. The application to advanced rotorcraft and V/STOL aircraft is especially beneficial due to the critical importance of precise, efficient control of thrust and aircraft motion at hover and low forward speed.

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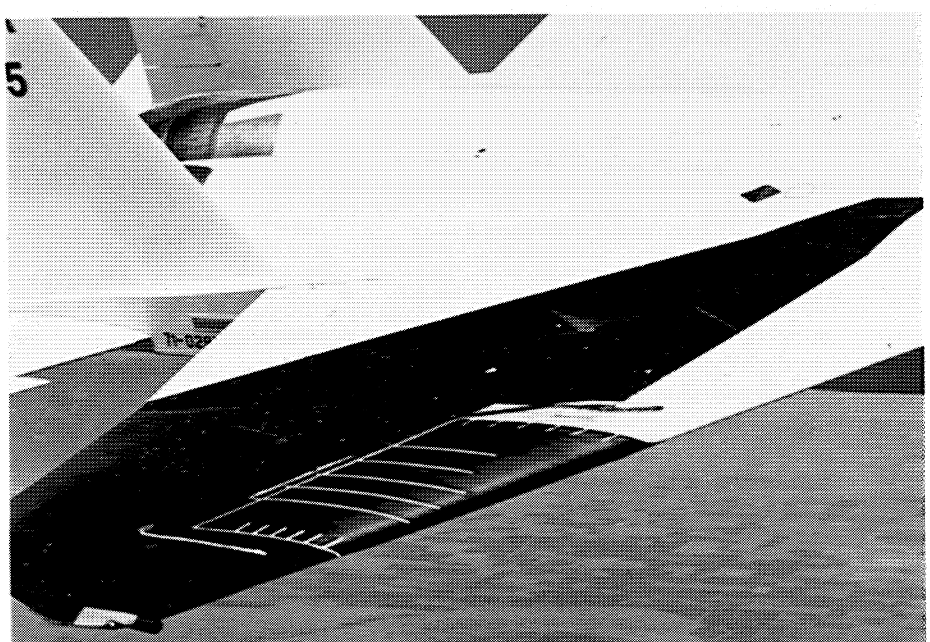
Flight Test Instrumentation

The objectives of the flight test instrumentation and techniques activity are to significantly improve the efficiency of flight testing, increase the accuracy of information (data) obtained in flight, and develop techniques for acquiring information previously unobtainable in flight. Existing aircraft are used as test beds for evaluation of new flight test techniques and instrumentation, which results in the fast implementation and rapid analysis and assessment of new techniques. The real flight environment provides the exact "simulation" of the environment that will be encountered in he eventual application. Variables such as temperature, pressure, density, viscosity, and Reynolds number are involved in a particular combination, and flight testing is the only way of duplicating the combination of these variables representative of real atmospheric flight conditions.

A new technique was developed to determine boundary layer transition for subsonic and supersonic speeds with hot film anemometers and flow visualization chemicals. During 1986 this technique was successfully demonstrated on the F-104, F-14, and F-15 research test aircraft. In addition, a smoker-type flow visualization system was demonstrated in flight with an F-104 aircraft.



Flow visualization chemical used in determining boundary layer transition location

Flight Safety

Improving flight safety through research into the operating environment is viewed by NASA as vital and is being addressed with research related to natural phenomena as well as operational flight systems. Storm hazards research concentrates on lightning and rain effects while NASA's Aircraft Icing Program is directed against the problems caused by aircraft icing.

The Storm Hazards Research Program is intended to improve the capability for detecting and avoiding severe storm hazards and to provide a knowledge base for protecting aircraft against hazards that cannot be avoided. Current airplanes are protected by their aluminum skins, which are natural conductors; however, future aircraft may have skins of less conductive materials. Records indicate that transport aircraft are struck by lightning about twice a year; this susceptibility to lightning damage may be of greater concern to aircraft of the future. Future aircraft will also have digital electronic controls which are potentially more sensitive to lightning damage than today's controls.

The Storm Hazards Program includes research on heavy rain effects. Heavy rain can momentarily blur airfoil shapes, which can degrade airplane performance, possibly severely enough to affect safety. In 1986, tests were conducted in the Langley Research Center 4- by 7-Meter wind tunnel using a wing section model to investigate the effect of rain on airplane aerodynamics. The tests were run at simulated landing speeds. The data revealed that the maximum lift

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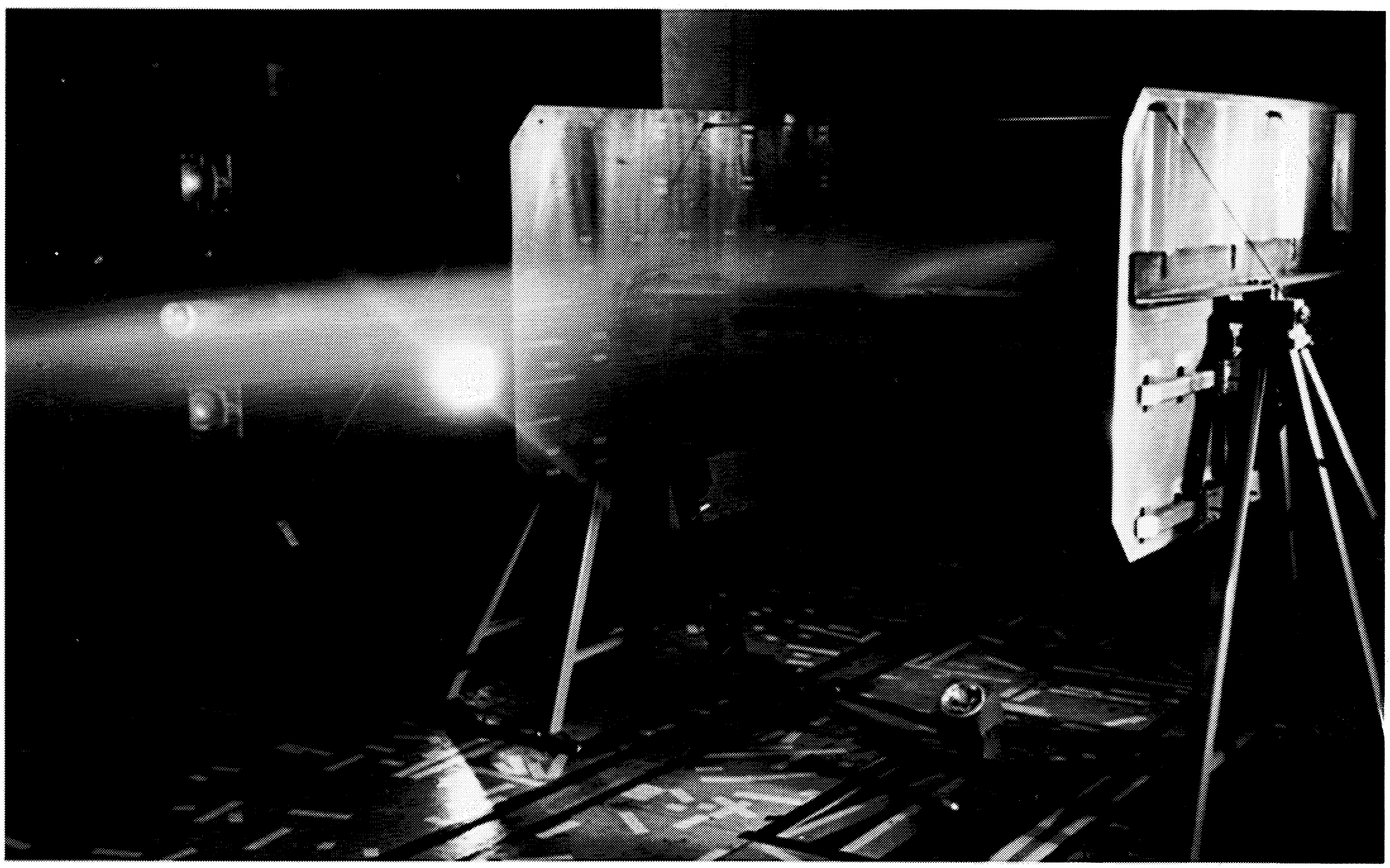
Heavy rain effects investigation in 4- by 7-Meter Wind Tunnel

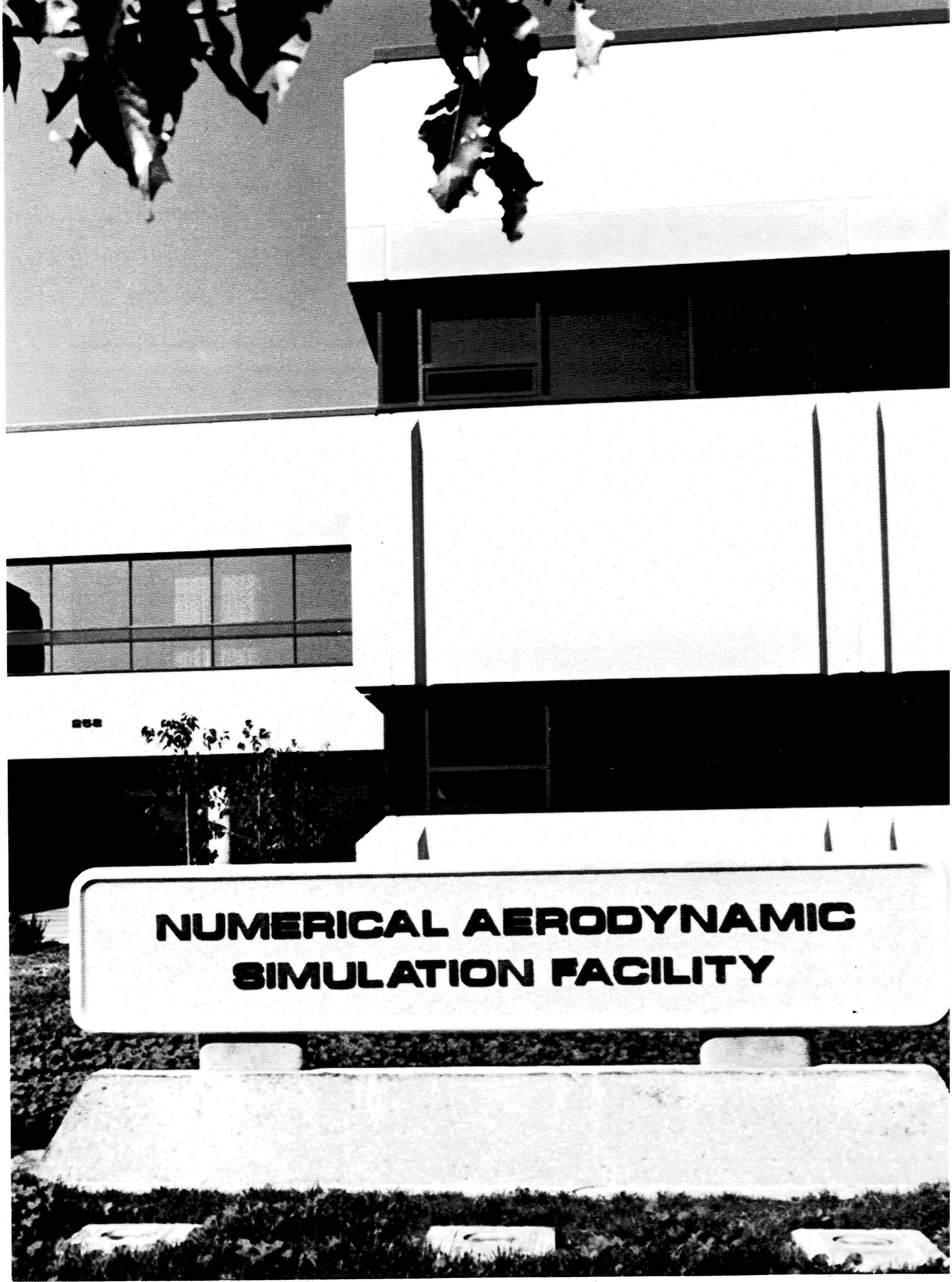


capacity was reduced by 20 percent during periods of very heavy rainfall. Further tests will be conducted on a larger scale wing section mounted on an outdoor moving carriage facility, which will be modified to include an overhead spray system for rain simulation.

The NASA Icing Research Program is focused on the development of analytical and experimental methods to determine the changes in handling qualities of an aircraft due to icing. This technology will have direct application in the following areas: (1) the design of aircraft; (2) the design of advanced flight control systems for relaxed stability aircraft; (3) the analysis of failure effects modes; (4) the development of simulator software for pilot training; (5) the determination of aircraft certification criteria for improved operational safety; and (6) the development of deicing systems. Little or no quantitative data has previously existed that would be useful for engineering analyses.

In 1986, two flight test programs were conducted at the Lewis Research Center using a deHavilland DHC6 Twin Otter NASA research aircraft, to start acquiring an icing research data base. Clear air flight tests were conducted using artificial ice shapes attached to the horizontal tail of the Twin Otter to measure changes in the static stability margin of the aircraft.

The "double-horned" ice shape characteristic of glaze ice caused the greatest reduction in static stability margin, while the surface roughness produced by rime (granular) ice shapes showed negligible deviation from the baseline. Pilot longitudinal control deteriorated with the light and moderate glaze shapes and some tail buffet was experienced.


NUMERICAL AERODYNAMIC
SIMULATION FACILITY

Organization and Installations

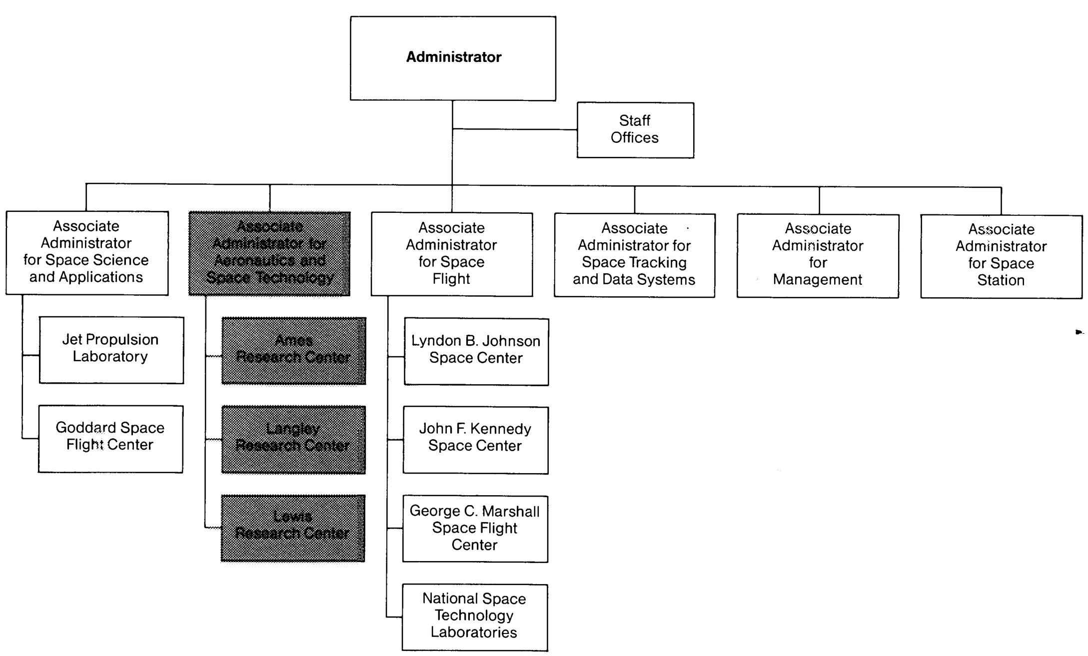
AERONAUTICS ORGANIZATION

The NASA Aeronautics Research and Technology program is carried out under the direction of the Associate Administrator for Aeronautics and Space Technology. The Office of Aeronautics and Space Technology (OAST) is responsible for the planning, direction, execution and evaluation of projects and research activities concerned with aeronautics and space technology, in addition to providing line institutional management of Ames, Langley and Lewis Research Centers.

Within OAST, the Director for Aeronautics has responsibility for overall aeronautics strategy, long-range program and facility planning and oversight to insure proper focus of the aeronautics program. In addition, the Director for Aeronautics determines overall program budgeting, establishes subprogram budget allocations to the Discipline Divisions, and is the principal OAST external interface on aeronautics with Congress, advisory committees, DoD, FAA, and other government agencies. He discharges these duties through interaction and coordination with the Director for Space on synergistic research activities that have application to both Aeronautics and Space; and with the Director for Institutions on Research Center institutional planning and budgeting, management and advocacy of facilities, and administrative functions in OAST.

In collaboration with the Director for Aeronautics, the Division Directors establish discipline program strategy, plans and objectives, and determine facility requirements consistent with overall program strategy and long-range directions. The Discipline Divisions are also responsible for budget allocation to the program element level for implementation of the discipline research programs and flight projects through the Research Centers and for assessing and reporting on the discipline program. The Research Centers implement and manage the ongoing aeronautics programs, and participate jointly with

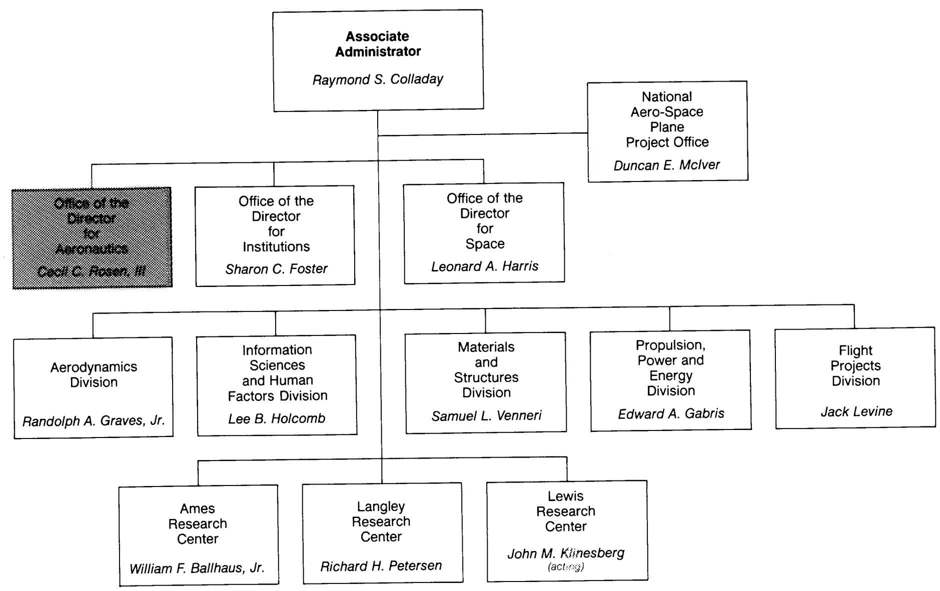
NASA Organization



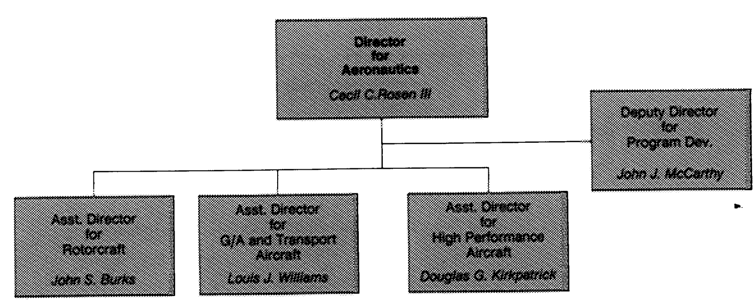
OAST in developing strategic plans and in establishing future research and facility requirements.

The Director for Aeronautics is supported by a Deputy Director for Program Development and by three Assistant Directors for the specific vehicle classes of General Aviation and Transport Aircraft, Rotorcraft, and High-Performance Aircraft. The Deputy Director for Program Development is responsible for overall program development, strategic planning, and policy development. For each vehicle class, the respective Assistant Director defines R&T requirements based on user needs and evolving opportunities, ensures the proper balance of vehicle related research, develops vehicle long range plans, and is the principal OAST external interface with industry, DoD, and other government agencies.

Office of Aeronautics and Space Technology



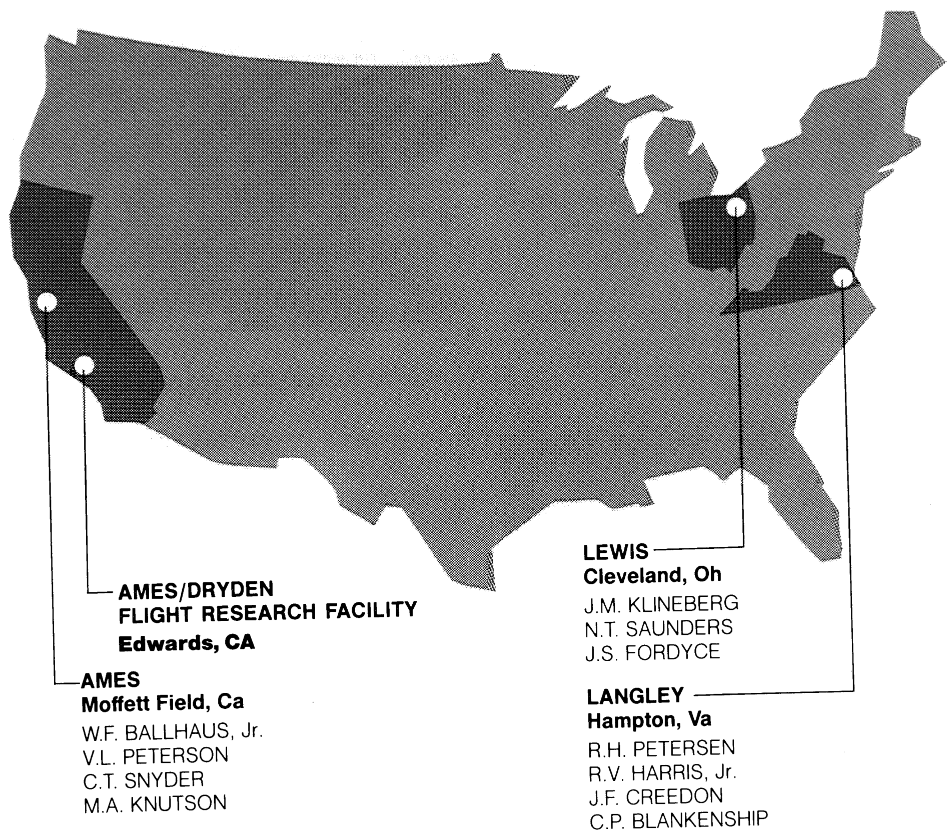
Office of Aeronautics



NASA RESEARCH CENTERS

The NASA Aeronautics Research and Technology program is conducted at NASA research centers located in California, Ohio, and Virginia. The accompanying map shows the locations of each aeronautical research center together with a listing of the Center Director and key aeronautical managers. Each center has unique facilities and research staff expertise that provide a significant national resource for the pursuit of new advancements in aeronautical technology. Each center conducts extensive in-house research utilizing special facilities and equipment. In addition, each center conducts research in close coordination with other government research organizations, universities and industry. The university research is supported through various grant programs and the industry research is carried out through numerous cooperative research projects and through direct contracted research with industry and private research organizations.

NASA/OAST Research Centers



Ames Research Center (ARC)

The Ames Research Center areas of aeronautical excellence include technology expertise and unique facility capability in computational fluid dynamics and computer science applications which focus on the development of new analytical methods using the growing power of advanced computers. The Center has unique facilities in aerodynamic testing and flight simulation for the purpose of validating the analytical methods and conducting research investigations of both small and large scale aeronauti-

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cal vehicle configurations. This ground test capability is complemented by the extensive flight research capability of the Dryden Flight Research Facility (DFRF). The Ames Research Center is also a center of excellence in flight simulation research, human factors, aircraft automation, flight dynamics, guidance and digital controls research. Key systems technology areas at the two Centers include:

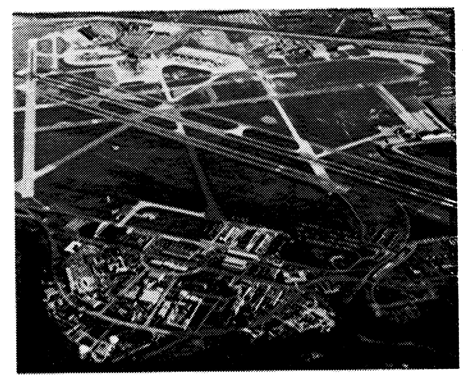
- Propulsion/Airframe Integration.
- Powered Lift Technology.
- Rotorcraft Aeromechanics.

Dryden Flight Research Facility

Langley Research Center (LaRC)

The Langley Research Center areas of aeronautical excellence include technology expertise and unique facility capabilities in fundamental aerodynamics and fluid dynamics, computer science, unsteady aerodynamics and aeroelasticity. Aerodynamic testing to support the research in each of these areas is a major focus of the Center. In addition, the Center is a leader in structures and materials research with a primary focus on structural analysis development and validation and airframe metallic and composite materials research. The Center also conducts fundamental research on fault tolerant electronic systems and flight control. Special areas of research include:

- Simulation and Evaluation of Advanced Operational Aircraft Systems.
- Acoustics and Noise Prediction and Reduction.
- Propulsion/Airframe Integration.



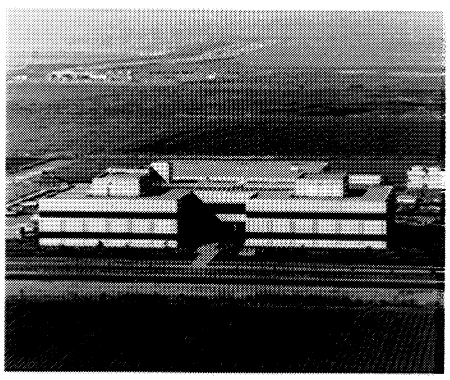
Lewis Research Center (LeRC)

The Lewis Research Center features aeronautical excellence in propulsion. Technology expertise and unique facility capabilities focus on internal fluid dynamics, computational science and applications, unsteady aerodynamics and aeroelasticity of propulsion systems with analytical studies, wind tunnel tests, and propulsion system testing. Research in engine materials, structures, and dynamics complements the aerodynamic research with a special emphasis on high temperature materials research. Special areas of emphasis include:

- Small Turbine Engine Research.
- Rotary Engine Research.
- Engine Instrumentation.
- Inlet, Nozzle, Engine System Integration.
- Icing/Deicing Research and Testing.

NEW FACILITIES

Several new facilities have been added to NASA's overall capability that will greatly increase both the scope and output of aeronautical R&T activities.

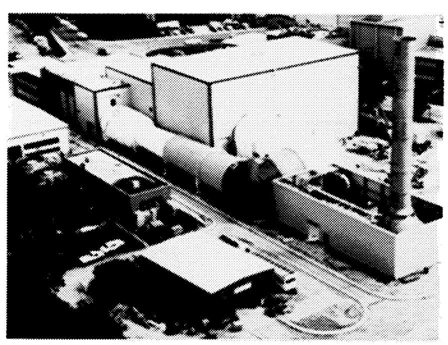


Numerical Aerodynamic Simulation Facility

The Numerical Aerodynamic Simulation (NAS) capability now coming on line at the Ames Research Center is the world's premier scientific computational facility for aeronautical research and development. This new capability greatly accelerates the rate of progress in computational fluid dynamics as well as in other important computationally intensive disciplines such as structures, materials, and chemistry. It represents the key enabling technology for the development of new hypersonic and transatmospheric vehicles.

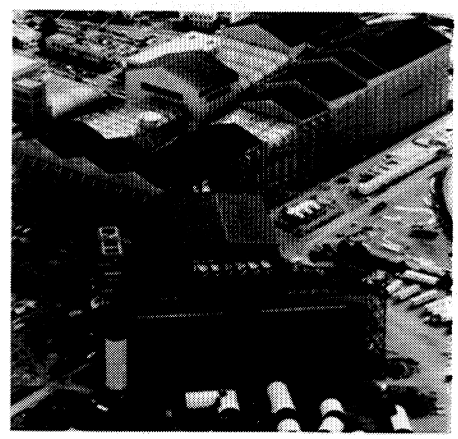
The heart of the NAS is the Cray 2 supercomputer. The NAS machine is currently the world's largest and most powerful scientific computer, containing more memory than all of the 100 computers that Cray Research has delivered in the past. The NAS is capable of achieving one billion computational operations each second. The NAS is designed to accommodate the most advanced computational equipment as it becomes available in the future.

The advanced NAS capabilities are becoming available just in time to support the the analysis and design activities for the National Aero-Space Plane program. The NAS facility and other large supercomputers will provide the necessary flow interactions of airbreathing propulsion systems and external configuration aerodynamics in operating conditions where existing ground test facilities are inadequate.



National Transonic Facility

The National Transonic Facility at Langley Research Center is now operational providing the most advanced transonic test capability in the world. Its 8- by 8-foot test section permits nearly exact simulation of flight conditions of the world's largest aircraft at near-sonic flight speeds and realistic altitudes. This new capability is achieved through the use of nitrogen as a test medium in the continuous flow, closed circuit, pressurized test facility.



Expanded Wind Tunnel Capability

A major new aeronautical research facility is now coming on line to provide the nation with a unique capability for testing full-sized rotorcraft and V/STOL aircraft and large scale models of new concepts such as the National Aero-Space Plane to investigate low speed characteristics. The original 40- by 80-Foot Wind Tunnel has been modified with the addition of a new 80-by 120-foot test leg that shares the same upgraded drive system. This new test facility complex is the largest wind tunnel in the free world and will be used to conduct powered lift research, full scale/large scale propulsion system research at speeds to 300 knots in the 40- by 80-foot test section, and research on highlift devices for takeoff and landing of conventional aircraft at low forward speeds below 100 knots in the 80- by 120-foot leg.

UNIVERSITY PROGRAM

About ten percent of NASA's aeronautics program is devoted to the Nation's universities to conduct long-range, high-risk research, to develop innovative, creative approaches and ideas, and to produce trained professionals. The major portion of this university program is for **Basic Research Grants** to individual universities to extend the mainstream aeronautical base research program. There is an accompanying element at each Research Center called the **Fund for Independent Research** to support the universities in addressing innovative, high-risk concepts that are not clearly aligned with the mainstream research program.

The **Research Institutes** located at the Research Centers are for strengthening specific capabilities within the program by bringing in leading university researchers on a temporary basis to work with NASA personnel on specific applications and to utilize the unique facilities at the Centers.

Research Center	*Research Institute*
Ames Research Center	Research Institute for Advanced Computer Science
Langley Research Center	Institute for Computer Applications in Science and Engineering
Lewis Research Center	Institute for Computational Mechanics in Propulsion

Centers of Excellence have been established at specific universities to develop a unique expertise and to accelerate progress in new/emerging fields. At the university there is a critical mass of key faculty established to conduct research, to train students, and to foster interdisciplinary interactions between the universities, the Research Centers, DoD, and industry.

Discipline	*University*
Composite Materials	Rensselaer Polytechnic Institute
Ceramics	University of Michigan
Computer Science	University of Illinois
Computer Science	Stanford University
Material Science	Virginia Polytechnic Institute and State University

The **Joint Institutes** established at the Research Center are to promote an active NASA/university interchange in the mainstream cooperative, innovative research areas.

Research Center	*Joint Institute*
Ames Research Center	Joint Institute for Aeronautics and Acoustics
Dryden Flight Research Facility	Joint Institute for Flight Research
Langley Research Center	Joint Institute for Advancement of Flight Science
Lewis Research Center	Joint Institute for Aeronautical Propulsion and Power

In FY 1986 NASA initiated a pilot undergraduate program with six universities in **Aeronautical Systems Design Studies** to develop an understanding of and appreciation for systems design/analysis at the universities, surface new innovative ideas that have potential payoff and promote enthusiasm in students and professors for aeronautical systems.

Research Center	*University*
Ames Research Center	University of California, Los Angeles
	California Polytechnic University
Langley Research Center	University of Kansas
	Purdue University
Lewis Research Center	Case Western Reserve University
	Ohio State University

Because the National Aero-Space Plane is arising as a vehicle for the future and because of the increased interest in hypersonic flight, in 1986 NASA, with help from the Navy and Air Force, established **Training Grants in Hypersonics** with three universities to develop a graduate-level curriculum and to conduct basic research in hypersonics.

Universities
Stanford University
State University of New York
University of Texas at Austin

In FY 1987 there are plans to establish hypersonic training grants at three additional universities.

The **Graduate Program in Aeronautics** sponsors research that is relevant to both NASA and the university, encouraging new graduates to pursue advanced degrees in aeronautics. The program involves over 100 students at about 50 institutions.

The **NASA/National Research Council Resident Research Associateship Program** sponsors postdoctoral scientists and engineers of unusual promise and ability to perform research at the centers for one year with consideration for a one-year extension.

The **American Society for Engineering Education Summer Faculty Fellowship Program** provides the opportunity for university professors to do research at NASA's centers during the summer for the purpose of furthering the knowledge of engineering and science faculty, stimulating the exchange of ideas between NASA and university personnel, enriching the research and training activities of the participants' institution, and contributing to NASA's research objectives.

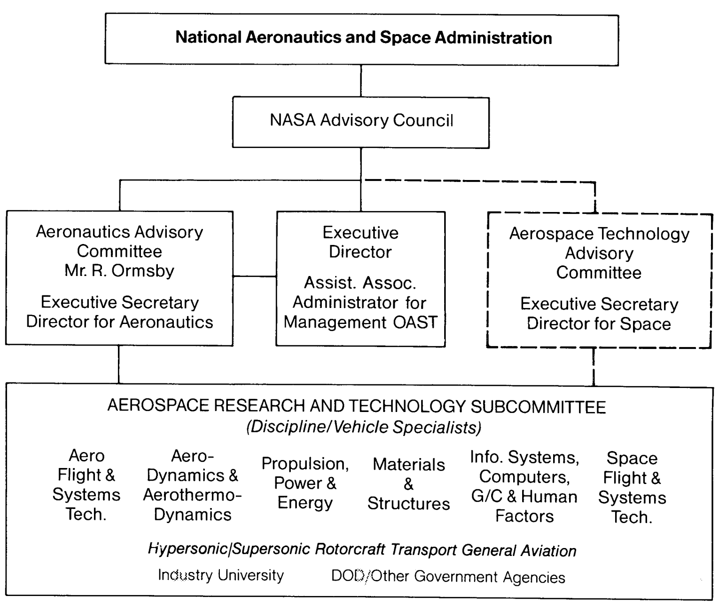
The **NASA Graduate Students Research Program** has the objective of increasing the number of highly-trained aerospace scientists and engineers and sponsoring thesis/dissertation research in areas of interest to NASA. In FY 1986 there were 240 participants in the program.

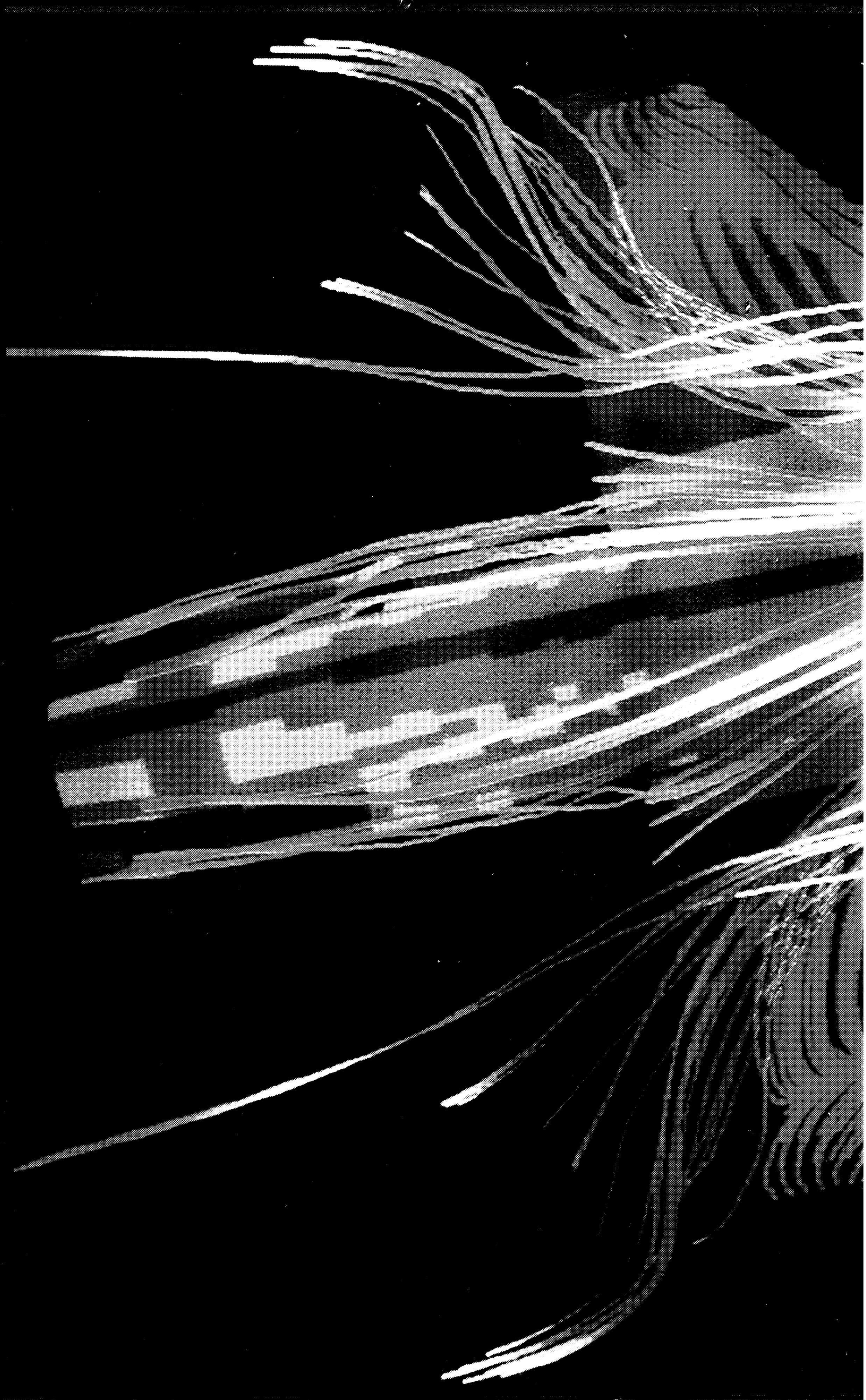
AERONAUTICS ADVISORY COMMITTEE

NASA receives valuable guidance and technical advice regarding aeronautics research and technology programs from external sources. A primary mechanism for interacting with the external technical community of aeronautics experts is the Aeronautics Advisory Committee (AAC) of the NASA Advisory Council. The AAC makes recommendations based upon periodic reviews of NASA's technical plans, research priorities and program progress. This advisory function provides NASA with critical guidance in planning, coordinating, and assessing the aeronautics program, and expeditiously transferring technology to the nation's aerospace industry.

The AAC consists of 15 to 20 members from industry, academia and government selected for their expertise in specific technical areas of aeronautics. Supporting the AAC is a larger group of discipline and vehicle specialists who make up the Aerospace Research and Technology Subcommittee (ARTS). The AAC defines specific topics of interest or concern that require in-depth review. Technical specialists from the ARTS are selected, based on their expertise in the topical area, to conduct a detailed assessment and to develop recommendations for AAC consideration.

Because of the rapidly changing nature of aeronautics, the role of the AAC is critical to maintaining an aggressive and productive aeronautics research and technology program. The continuous interface and dialogue between OAST and the AAC assist NASA in prioritizing research efforts to meet the nation's aeronautical technology needs.





NASA
National Aeronautics and
Space Administration

NASA Headquarters
Office of Aeronautics
and Space Technology
Washington, D.C. 20546

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