NASA RESEARCH TOWARDS VERY HIGH SPEED TRANSPORTS

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Introduction

About two years ago the White House Office of Science and Technology Policy published the U.S. "National Aeronautical R&D Goals", which recognized the major advances in aircraft performance that remain to be achieved and defined specific high-payoff technology areas in which to focus U.S. research and technology efforts. In NASA we have incorporated the National Goals into our long-range planning and strategy and will do our part in pursuing the enabling technologies for achieving the National Goals, especially the long-term and high-risk research and technology. The potential aeronautical improvements that can be achieved with advanced technology are impressive for all classes of aircraft. However, one of the most exciting areas involves the development of technology for hypersonic cruise and transatmospheric vehicles.

In his State of the Union address to the Congress a year ago the President referred to research under way in the joint NASA/DOD National Aero-Space Plane (NASP) Program that will provide the technology for a revolutionary leap in U.S. capability that could reshape military and civil aviation near the turn of the century. This entirely new class of aerospace vehicle, powered by airbreathing propulsion, would have vastly superior performance to anything flying today. Conceptually these vehicles would takeoff from an airport runway, fly at six or more times the speed of sound at altitudes of 20 miles or more. Two hours or less after departure, it would roll to stop at an airport on another continent half way around the earth, or instead, fly from the runway directly to orbit, work in space, and then return for a conventional airport landing. The extreme altitude and speed capability of this vehicle could make our military aircraft far less vulnerable to attack, and initial indications are that such transatmospheric vehicles could significantly reduce the cost of delivering payloads to orbit.

The renewed interest in an aerospace plane is a direct result of advances and breakthroughs made during the past two decades in NASA's and DOD's ongoing aeronautics and space research and technology (R&T) base programs.

Goals and Objectives of Transatmospheric R&T

The transatmospheric goal blurs the traditional line of demarcation between aeronautics and space. It represents the first real convergence of aeronautics and space technology.

Rapid point-to-point intercontinental travel and routine low-cost access to space are two key goals critical to maintaining U.S. economic and defensive preeminence. Technology advances over the last decade now provide an opportunity to address both of these goals in a new class of vehicle with the potential to revolutionize both air and space travel. The transatmospheric R&T program, a part of the NASA/DOD National Aero-Space Plane program, will greatly accelerate development of the technology required to provide aerospace vehicles as an option by the turn of the century.

The objective of the National Aero-Space Plane program is to demonstrate aerospace vehicle technologies for horizontal takeoff from and landing on a airport runways, sustained hypersonic cruise and maneuver in the atmosphere, and acceleration to orbit and return. These technologies will be integrated into an experimental research airplane, the X-30, which should begin validation in actual flight by the early 1990s. These technologies could then be optimized for specific military or civil hypersonic cruise applications or single-stage-to-orbit applications, or perhaps some combination of the two. The technical challenges are certainly formidable, and the list of key technologies is long, but at this time we see nothing insurmountable.

Underlying Technology

Although most ongoing hypersonic research and technology was terminated in the early 1970s, NASA sustained its effort in the most critical and enabling technologies for hypersonic vehicles. The current opportunity for NASP is the result of breakthroughs and advances in the NASA hypersonic research program over the past decade that provide the basis for developing the enabling technologies and the confidence that the goal is feasible.

During the past decade, technology has been pursued for hydrogen-fueled supersonic combustion ramjet (SCRAMJET) engines. Langley Research Center has conducted more than 1100 tests of fixed-geometry sub-scale SCRAMJET engine modules at simulated flight conditions in the ground test facility to Mach 7. The measured performance levels achieved are sufficient to propel a large aircraft at hypersonic speeds. This effort has produced the initial technology base on the internal design, combustion processes, and fuel-mixing techniques needed to design an efficient SCRAMJET engine. A variable geometry SCRAMJET model utilizing a square two-dimensional inlet is part of the effort to develop a practical design that can operate over a wide Mach number Range (4-20+). The square inlet permits easy integration with the vehicle while the circular combustor reduces structural complexity at high pressures.

Substantial advances have been made in the strength, stiffness, durability, and reusability of a number of high temperature materials. Advanced carbon-carbon materials development, begun in the late 1970s, now has achieved two to three times the strength and stiffness of currently used reinforced carbon-carbon plus a reusable coating that provides a tenfold to twentyfold improvement in oxidation resistance. Oxide-stabilized superalloys, with Angstrom-thin ceramic coatings, are performing successfully under arcjet testing to 2200°F, making them candidates for hypersonic airframe and engine primary structures. In addition, continuing research in metal matrix and organic composites, such as graphite-aluminum and graphite-polyimide, hold the promise of high-strength, lightweight applications. Research will be conducted on the technology for active cooling in areas of high thermal loads, such as occur on the leading edges and other surfaces of a hypersonic vehicle, using cryogenic hydrogen fuel as the coolant.

Current fabrication technologies, such as superplastic forming, diffusion bonding and brazing of thermal structural systems, now make possible more geometrically efficient, lighter-weight structures. In addition, fabrication procedures developed during the last decade for foil-gage structures, such as honeycomb and multiwall structures, now provide the capability to fabricate the lightweight efficient insulating thermostructural systems concepts needed for hypersonic vehicles. Structural design and fabrication has been completed of a fuel-injection side strut for a SCRAMJET using a complex three-step brazing process. This concept will be tested with burning fuel in 1987.

A major change has occurred over the last decade in computational capability as a result of advances in computer memory and speed and the current development of codes.

Today, the use of Navier-Stokes and Euler methods for analyzing very complicated internal and external flowfields, including boundary layers, for complex configurations is an integral part of the design process. Colors indicate surface pressure contours computed on the Ames Research Center Numerical Aerodynamic Simulation (NAS) in August 1986. The capability in three-dimensional Navier-Stokes computations is now sufficiently advanced to address internal flow fields of propulsion systems, such as ramjets and SCRAMJETS.

The Ames Research Center NAS supercomputer capabilities are now available to support the analysis and design activities for the NASP program. The NAS, with its 264 million words of memory and sustained operational speed of 250 million floating-point operations per second, plus our other large computers will provide the power required to handle the challenge of integrating the complex internal and external flow interactions of configuration aerodynamics and airbreathing propulsion systems.

NASP Program

The NASP program is a three-phase program consisting of a Phase I Feasibility Study conducted by DARPA with NASA; Phase II Technology Development under a joint effort with the DOD and the U.S. industry; and a proposed Phase III Flight Research Demonstration in cooperation with DOD. Phase II provides for the development of critical technologies as a precursor to a future decision on Phase III. Phase II includes major contracts with industry amounting to approximately $600 million for five for airframe manufacturers and two engine companies. If Phase II is successful, a Phase III flight research program would go forward to demonstrate, by the mid 1990s, transatmospheric vehicle technologies on a research vehicle over the entire flight regime from takeoff to orbital speed. This demonstration will validate the necessary technology base for very-high-speed U.S. aerospace vehicles with initial operational capability in the 2000 to 2010 time period.

The NASP program will concentrate on the critical technologies in the Phase II program through a combination of computational efforts and ground-based experiments. The challenging conditions projected for the X-vehicle flight research envelope require the application of the most advanced analysis and prediction techniques available to determine the aerodynamic and aerothermodynamic characteristics of the many potential airframe and engine configurations. These predictions will be validated in ground-based facilities. In addition, we have studies under way on the need for selected flight experiments which could be conducted as needed, on a small, specially instrumented research vehicle to validate the predictions for high speed and altitude conditions that cannot be adequately simulated in ground facilities.

Major emphasis is being placed on the design and experimental determination of the performance level and efficiency of several airbreathing propulsion system cycles, including low-speed cycles, ramjets, and SCRAMJETS operation from takeoff to near-orbital speeds; integration of a small rocket will also be required for on-orbit and deorbit operations. Both passively and actively cooled high-temperature engine and airframe structures, combined with cryogenic tankage structures, as appropriate, are being designed for repeated exposure to combinations of extreme peak heating during ascent and long-duration heat loads during cruise. These component designs will be fabricated, and their performance as reusable, lightweight/high-strength structures will be tested under simulated flight loading conditions. Analyses of propulsion system/airframe integration characteristics, including the major controls challenge, will be conducted continually throughout the program in order to define a high-performance, minimum-weight configuration.

In addition, we are currently modifying two of our major facilities: the 8-foot High Temperature Tunnel at Langley Research Center for testing of large structural components in high-quality aerothermal flow and for propulsion testing of large-scale and multiple-module SCRAMJET models; and the Propulsion System Laboratory at Lewis Research Center for subsonic to supersonic engine system tests. We have also reactivated the 3.5-foot Hypersonic Tunnel at Ames Research Center for aerodynamic testing of inlet configurations at high Mach numbers.

The progressive and continual output of these efforts will be integrated into the design, development, and testing of preliminary concepts for propulsion system modules and airframe components for the X-vehicle.

Extending research from experiments in the laboratory to flight has long been recognized as a necessity for the development and validation of hypersonic-transatmospheric technology, since ground test facilities alone are inadequate in simulating that regime. Notable examples began with the development and flight test of the X-15 in the 1950s, the Lifting Body program in the 1960s, and most recently the Space Shuttle. This is particularly true for an aerospace plane, where integration of the highly interdependent airframe and the propulsion system plus vehicle performance validation throughout this broad flight envelope require experimental flight investigation and validation with the NASP X-vehicle. A major technology readiness assessment will be conducted in FY 1989 to determine if sufficient progress has been made in the NASP Phase II program to approve proceeding to the design and fabrication of the X-vehicle. If Phase III can begin at that time, initiation of an extensive flight research program could be possible as early as FY 1992.

High Speed, Civil Air Transport Study

Separate from the National Aero-Space Plane program, NASA has awarded two contracts for high-speed, civil air transport studies, one to Boeing Commercial Airplane Company and one to McDonnell-Douglas Corporation.

The companies are to take into consideration the international growth and economic development into the next century that is expected to create a significant market for high-speed, long-range air transportation. Further, the need to conduct business in areas such as the Pacific basin will place emphasis on minimizing trip time and increasing productivity. Either a hypersonic transport, based in large part on aerospace plane technology, or an advanced supersonic cruise airplane that incorporates emerging technologies could prove to be an attractive and economically competitive vehicle for this market.

The studies will evaluate expected technology advances from the National Aero-Space Plane program and from continued research in high-speed aircraft, in general, to satisfy two major objectives. The first objective is to identify the most promising concepts for future long-range, high-speed, civil transport aircraft. The second is to provide information needed to guide NASA planning of technology development.

The two contractors will conduct work in three phases. The first phase will consist of an initial assessment of potential vehicle concepts, of relevant nonvehicle technologies, and commercial value, i.e. economics, scheduling, and marketing. The second phase will produce a prioritized list of vehicle concepts. The final phase will focus on one or two of the more promising vehicle concepts per contract.

This work requires an understanding of the economics, flight speeds, size, range, fuel type, and technology levels required for the proposed vehicles to become successful major elements in the international air transportation system.

Conclusion

Synthesizing advanced technology into a transportation concept for the 21st century is a difficult, complex task that requires timely availability of vast amounts of data, engineering and management expertise, skilled personnel, and major investments in facilities. This is a high-technology area that requires long lead times and substantial, timely investments in R&D on the part of the aviation community and the government.

With the potential for major revolution in transportation based on these technologies, we are on the threshold of an opportunity to assure U.S. air and space leadership well into the 21st century. NASA's research is providing, and will continue to provide, a solid foundation from which the country can proceed effectively in directions it selects on the basis of national goals and priorities.