Special Report:
Advanced Aircraft Research, Planning

T-tail, variable-geometry supersonic model at Langley
Wide-ranging program, including work on propulsion, materials, ecology, controls and aerodynamics, aimed at data by 1980s

Hampton, Va.—Advanced Supersonic Technology (AST) program, which the National Aeronautics and Space Administration hopes will provide the data necessary for the U.S. to compete with Soviet and European civil aircraft producers during the rest of this century, is focusing on three concepts of varying degrees of complexity.

But recent funding cuts by Congress have slowed the program to the point where it may not be able to generate the necessary data any time for any of the three approaches to be translated into an economically viable aircraft within a competitive time.

The AST program was initiated after the Supersonic Transport Development program—which was terminated by the Transportation Dept.—was terminated by Congress in 1971 (AW&ST Mar. 29, 1971, p. 14).

Goal of the AST, according to NASA officials, is not to design any particular type of supersonic aircraft—fighter, bomber or transport—but to “keep the technological powder dry” so that the nation will have the continuing capability of producing advanced supersonic aircraft of any type.

In order to do this, it has been necessary to identify the types of problems that have to be solved and this means, in practical terms, that some type of supersonic flight vehicle conceptual design is needed to permit researchers to focus on specific problems.

The three concepts on which the AST program has settled are:

- **Near-term supersonic transport concept.** This is basically a continuing refinement of the basic Scat 15F design, from which came the original arrow wing concept (AW&ST Jan. 17, 1972, p. 39). Near-term, in this case, is used by NASA to define the amount of work necessary to permit the start of development of such an aircraft, rather than in a chronological sense.

- **Intermediate configuration,** an advanced variable-geometry supersonic aircraft employing such concepts as a hard stability augmentation system (HSAS) in order to compensate for low-speed instability.

- **Long-term configuration,** an idealized supersonic transport with long-range, an advanced propulsion/control system, the ability to operate overland without creating a disturbing sonic boom, and embodying advanced materials, materials processes and structures methodology in order to permit the use of a blended wing/fuselage design.

First wind tunnel model for such a vehicle now is under construction.

But development of this concept is a long-term project, at least 15-20 years off, according to A. Warner Robins, head of the supersonic mechanics section of Langley's full-scale research division.

These concept configuration studies are only one phase of the total AST program, but they tend to bring into focus the status of technology today and the advances required before aircraft development could begin.

The total AST program consists of five areas of research, including:

- **Propulsion—Identification of promising powerplant concepts and improved methods of fabricating major components.**
- **Stratospheric emission impact—Support for the Transportation Dept.'s Climatic Impact Assessment Program (AW&ST July 16, p. 33) by providing measurements of atmosphere/wake interaction processes.**
- **Structures and materials—Development of improved materials and determination of analytic tools.**

This includes the study of new structural design concepts and new materials to permit lighter, more durable and more efficient assemblies; development of improved materials, such as fuel tank sealants or high-temperature titanium alloys; definition of loads induced by atmospheric turbulence at operational altitudes; improved methods of flutter prediction and analysis and modeling of active control systems.

- **Stability and controls—Development of improved methods for analyzing flexible aircraft, better definitions of handling qualities criteria and minimum requirements and studies of improved controls concepts.**

The last includes methods of control mechanization, active loads suppression...
and integrated cooperative control systems.

Aerodynamics performance—Study of new supersonic transport configuration concepts for improved performance over the entire speed range and development of more accurate analysis and design tools. This area of research also includes a major effort exploration of methods for reducing sonic shock wave-induced overpressures.

In conjunction with this work, which is being done largely in-house at the various NASA research centers, four open-ended technology integration contracts have been let to Boeing, Lockheed, McDonnell Douglas and Rockwell International. Aim of these systems studies is to identify research needs, goals and possible trade-offs involved in putting the technology to use, as well as to study integration of the various segments and to assess the economic viability of aircraft that might be based on the technology developed in the AST program.

Initially, three one-year contracts were awarded, with Boeing getting $460,400, McDonnell Douglas $405,800 and Lockheed-California $377,000 for systems studies, each involving about 16,000 man-hours.

Subsequently, a fourth contract was issued to Rockwell International for $137,000 to fund the study of an unsolicited proposal by the company involving a multi-mode integrated propulsion system.

This study will conclude in the spring of 1974.

The three earlier contracts were to expire this month, but all are expected to be extended, on a somewhat reduced basis, for another year. The addition will involve 5,000-10,000 man-hours per contractor and will center on the problems of propulsion integration.

"These studies are becoming the glue which is holding the AST program together," according to D. G. Stone, AST program manager at Langley.

But, he added, it may not be possible, because of the budget action by Congress, to keep the studies going beyond September, 1974.

The studies, he pointed out, rely on technology generated by NASA. NASA in turn uses the data provided by the studies to help it focus its technology research efforts on the most critical areas.

With the research budget now at only $11.7 million for Fiscal 1974, it may not be possible to generate enough new technology to provide any basis for the continuation of the studies.

This level of funding is insufficient to keep up technological study levels in all disciplines and is not sufficient to permit the purchase of materials for test in even one discipline, NASA program planners said.

AST programs officials at present are "chopping the program up and trying it in different ways to see what we can get [for the money available]."

Among the areas, other than the contractor studies, that may feel the pinch first are sonic boom reduction research and terminal area noise suppression.

"If we have to cut back that far," Stone said, "we'll concentrate on engines and configuration concepts."

Next in priority would be structures and materials, but this would be hampered because funding would be needed soon to purchase these to permit their testing in the environment in which a supersonic aircraft would operate.

The supersonic configuration study that seems nearest to being ready for potential development—the so-called arrow wing concept—primarily is faced with structural rather than aerodynamics problems.

The arrow wing concept requires a low wing-unit-weight structure, and at present the fatigue life of such a structure cannot be guaranteed to 50,000 hr.

This is compounded by other problems, including those of thermal effects. Range potentials of 4,200 naut. mi. are considered possible now for an arrow wing concept transport aircraft and, with a good deal of development work, it is anticipated that this could be stretched to 6,800-7,000-naut.-mi. range.

Some of the performance gains are being predicted because of recent work in drag reduction, which has indicated that significant advances can be made.

Also, a series of three different wind tunnel models now is being built to test different concepts of the effect of leading edge radius on the aircraft's performance.

A large model of the NASA-developed Scat 15F-9898, which originally was used in the now-canceled supersonic transport development program, is being refurbished and will be placed back into the 40 X 80 ft. low-speed tunnel at Ames Research Center.

Despite the potential advantages of the arrow wing concept and its advanced state of aerodynamic development, there are some doubts beginning to form in the minds of AST researchers as to whether the structural problems inherent in the concept can ever be solved satisfactorily.

As a backup in case this proves correct, the so-called intermediate-term supersonic concept—an advanced, T-tail, variable-geometry aircraft—is getting much of the attention now being devoted to specific configurations at Langley.

The variable-sweep concept is dependent on hard stability augmentation systems for any hope of success and consequently much of the present research centers on control configured vehicle (CCV) technology.

Variable-sweep transport aircraft have trim and stability problems that change with wing sweep, and the present version is unstable with the wings fully forward.

NASA's solution is to rely on the HSAS for stability when the wings are fully forward, as in landing and slow flight, and, possibly, to install an attitude limiting system for use at low speeds.

"We will really be taking advantage of active controls," Robins said, noting that active controls also could be used for loads and gust alleviation.

As a means of reducing trim drag to acceptable proportions, NASA researchers

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have hit upon the plan of using the tail surfaces for control only and doing all the trimming with flaps and wing sweep.

With the wings swept only a modest degree, the aircraft becomes stable and can be flown subsonically in this mode. By designing the wings so that they flex and change shape as the sweep and speed combination changes, NASA believes it is possible to make the wings into efficient trim instruments.

Another possibility being explored is the use of interaction between the propulsion and control systems for improved control efficiency at certain speeds and in certain flight regimes. This idea is not as far advanced as in the concept of using the wing sweep and shape for trim control, but basically it envisions the deflection of engine nozzles and wing flaps in unison to get the most advantageous airflow over the lifting and control surfaces.

This would be an advantage mostly during takeoff.

NASA researchers at present envision the HSAS as an item without which the aircraft could not operate. Present work is centered on developing aerodynamics and operational procedures so that favorable trade-offs can be realized. Tests thus far with wind tunnel models have been designed to get basic low-speed data for this purpose and transonic testing is next on the schedule.

The variable-geometry concept is not as susceptible to weight and balance problems caused by engine mass as is the arrow wing concept, and for this reason it conceivably could use a straight turbojet engine easier than could an arrow wing aircraft.

Ultimate Concept

Ultimate supersonic aircraft concept, NASA now believes, will be an advanced version of the arrow wing concept, but with these basic differences from the so-called near-term arrow wing:

- Wing and fuselage will be blended into one structure, providing significant aerodynamic benefits, but also requiring structures that are today beyond the state of the art. This will require an integrated lifting surface and pressure vessel and may require a lower wing-unit-weight than even the near-term arrow wing concept.

- Integrated propulsion and control surfaces, in which the engines would provide a portion of the control power for the aircraft, will be used rather than the just aerodynamic surfaces, as in the near-term arrow wing.

- A variable cycle engine that possibly will use something other than JP-type fossil-based fuel will provide power. The variable cycle engine is generally considered the best for both noise reduction and operational efficiency.

- An aerodynamic design will reduce sonic shock wave overpressures sufficiently to permit overland flight.

Unconventional viewing and emergency egress systems will be used in a windowless aircraft. Only apertures now expected in such a structure would be those needed by the flight crew.

Active control systems studies are working to establish new criteria on the impact of such systems on basic airflow stability and control, according to William Kemp, head of the active controls systems studies at Langley.

When stability requirements are relaxed, control power becomes of critical importance. This in turn opens new criteria assessments. Langley studies now are centering on:

- Increasing the data base on the aerodynamic control effectiveness for arrow wing designs in order to select control surface types.

- Development of low-speed control surfaces.

- High-speed research work, centering around the 8-ft. unitary tunnel at Langley.

High-speed research includes such things as the effect of engine failure at supersonic speeds.

"If you lose an engine in supersonic flight," Kemp noted, "it's more significant than in subsonic flight. It changes the flow field over the entire airframe." This fact, coupled with the fact that in flexible airframes, as any advanced supersonic aircraft is certain to be, asymmetric loading can bend or warp the aircraft to produce adverse airflow patterns, and, consequently affect cruise performance, drag or other economically sensitive areas.

NASA is seeking to develop analytical tools in a number of different research fields in order to get optimum tradeoffs in a reasonable period of time and also to develop a high degree of confidence in any resulting answer. This is critical because even with advanced designing techniques it often takes 6-12 months to redesign an airplane if one parameter is found to be incorrect.

Structures and materials research is one of the areas in which the AST program is obviously suffering from a funding shortage. This area and the engine development area are considered to be the two items that will regulate the pace of any future aircraft development.

Although a great many studies are now under way or planned, hardware demonstration is keyed directly to future funding, according to Richard R. Heldenfels, assistant director for structures at Langley. At the present funding level of $11.7 million annually, such demonstration tests would be confined to structural elements only and these probably would be limited to "tabletop sizes."

The AST program's structures and materials effort is seeking to develop structural concepts for future high-speed aircraft, to provide advanced design data tools and to advance the state of the art in materials application.

Studies are under way at NASA research centers and by contractors to determine which materials and structural concepts appear best.

AST researchers hope to be able to go into considerable depth in determining the best design and structural arrangement for an aircraft that would operate at speeds up to Mach 2.7, getting into such things as the structural arrangement (for example, spar locations), structural parameters (such as wing thickness) and materials and manufacturing processes (such as the relative merits in different situations of aluminum, titanium, and various composites). A similar design profile for a Mach 3.2 aircraft then could be done in somewhat less detail.

Aluminum materials, NASA researchers tend to believe, are limited to an absolute speed of Mach 2.2 and more likely to speeds lower than Mach 2 until some still-existing thermal problems are solved.

Titanium materials would permit speeds up to Mach 2.7.

At speeds over Mach 2.7, many of the other materials now used or planned for use in advanced aircraft begin to fail, necessitating development of improved transparencies, seals, bonds and other hardware. Composite materials show considerable promise in weight saving, but little is yet known about their ability to resist such high-speed-environmental factors as thermal or sonic stress.

Savings Sacrifice

It may be necessary to sacrifice some of the potential weight savings offered by various composites in order to increase their environmental resistance and to get the cost down.

Weldenfels said this would require a "long, hard development program—not less than 8-10 years."

Seven composites now are being studied, including boron and graphite with epoxy, boron and graphite with polyimides, boron with aluminum, boron with copper and aluminum oxide with alumina. In addition, high temperature polyimides are to be studied under two contracts, one to General Electric Research Laboratories and one to a team of Avco and Boeing.

Fatigue test procedures for metals are also being studied with a goal of determining what thermal cycling does to conventional test procedures. Boeing has a contract to determine if fatigue testing with thermal cycling can be done on a compressed basis.

Some materials applications testing will be done by Lockheed's Skonk Works under a NASA contract. Two different titanium structures—one embodying honeycomb sandwich and one with conventional skin/stringer construction but using a weld braze technique—are to be built and flown on a YF-12.

Aviation Week & Space Technology, September 17, 1973