Testing the Limits at Mach 25

The $3.3-billion program to build a hypersonic aerospace plane is facing major technical hurdles; air transport industry shows little interest

In a mid-April speech to the Electronic Industry Association, President Reagan reiterated the technological challenge first issued in his 1986 State of the Union address, urging that America break "the bounds of Earth-bound imagination" by pursuing the hypersonic National Aerospace Plane (NASP). "We will be capable of taking off from Dulles Airport . . . leaping into space, and docking with the space station, almost like taking off from Washington to London," Reagan said.

In his State of the Union speech only 2 years earlier, interestingly, the NASP was not touted principally as a quick-turnaround taxi to the planned space station. Rather, Reagan then referred to "a New Orient Express that could, by the end of the next decade, take off from Dulles Airport and accelerate up to 25 times the speed of sound, attaining low Earth orbit or flying to Tokyo within 2 hours."

The intriguing New Orient Express concept, not surprisingly, has captured the bulk of the ink that has been spilled about the ambitious program since it first soared into public view in early 1986. Not that there has been all that much public debate and discussion about the NASP, aside from an initial flurry of articles and editorials—a striking degree of relative obscurity considering that the project has already consumed almost $500 million of an estimated $3.3 billion-budget through 1995.

But, a widespread public impression to the contrary notwithstanding, the air transport industry has no real interest in a Mach 25 airliner. Instead, the primary applications for the NASP's hypersonic technology would be to slash launch costs dramatically and to provide a speedy new weapons and surveillance platform for the military.

Moreover, the actual deployment of NASP technology lies much farther in the future than suggested by Reagan 2 years ago. First flight for the two NASP demonstrators that will be built, designated the X-30, is not scheduled until 1995; until recently, the target date was 1993. "People sometimes lose sight that we are currently in Phase II of the program, technology development, leading to an X-30, which is a flight research vehicle that will look nothing like any follow-on prototype or NASP-derived vehicle," stressed Duncan E. McIver, director of NASA's National Aerospace Plane Office. The NASP is a joint project of NASA and the Defense Department, with the latter agency slated to pony up about 80% of the total budget.

In the beginning, at least, military "applications will clearly be the predominant utilization of the NASP technologies," with the first operational follow-on to the X-30 not likely to be available until sometime early in the 21st century, the Air Force told the Senate Appropriations Committee last year. "Civil applications for the NASP technologies are probably 5 to 10 years later in time than the military applications."

Duncan McIver. *"There are a lot of questions that we must answer in flight."*

Before any deployment, military or civil, can take place, of course, it must first be proven that a vehicle can, in fact, take off like a conventional airliner and achieve orbital escape velocity—Mach 25, or 25 times the speed of sound, or roughly 16,000 miles per hour—burning atmospheric oxygen. The fastest that a piloted aircraft has ever flown before, in a 1967 test of the rocket-assisted X-15 flight demonstrator, was Mach 6.7—or some 4400 miles per hour. The only U.S. aircraft that routinely operates at high supersonic speeds is the Mach 3.2 SR-71 spy plane. Air Force Secretary Edward C. Aldridge, therefore, has likened the space plane development challenge to the "advent of the automobile and the internal combustion engine."

The unique pitfall posed by the NASP project, however, is that there is no way to determine the feasibility of a plane speeding eight times faster than the SR-71 without actually building one and giving it a go.

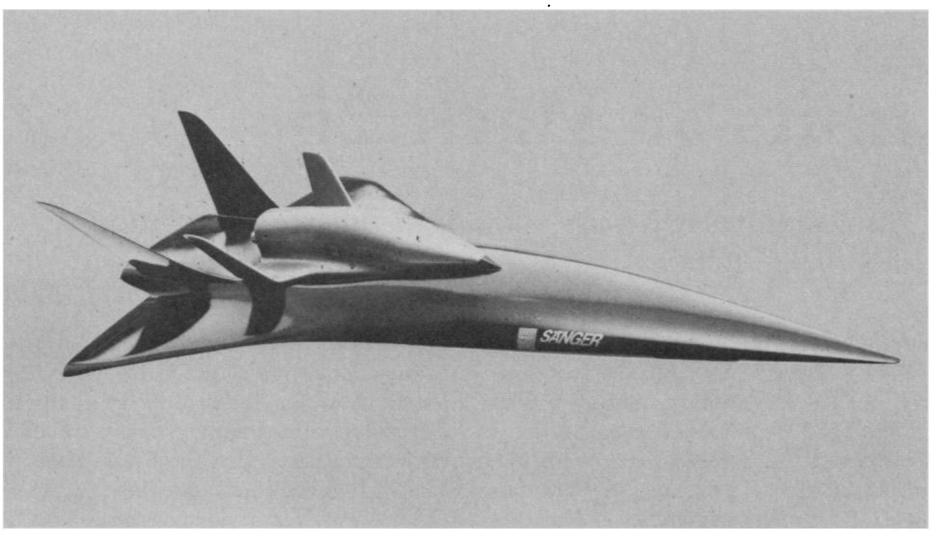
Some work can be done on the ground, of course. Advances in computational fluid dynamics, for instance, have contributed greatly to NASP researchers' understanding of hypersonic flow physics. "This program pushes U.S. supercomputer technology probably as hard as any program in the United States," former NASP program manager Robert M. Williams of the Defense Advanced Research Projects Agency (DARPA) said in a speech late last year. Even on one of the ten Cray II supercomputers that are laboring on NASP problems, which can perform 250 million operations per second, more complex individual calculations can take as long as 9 hours.

Similarly, sophisticated NASA wind tunnels and shock tubes are being put into service for the NASP project. But, said McIver, "Our ground facilities are limited in testing a full-scale engine at about Mach 8, so we will have to end up flying to really get answers. There are a lot of questions that we must answer in flight."

Some of those questions promise to be real posers. In a new report, the General Accounting Office (GAO) cites the potential payoffs from the NASP program, but adds that it also "faces substantial technological, programmatic and financial risks."

Among the technological risks: Fabricating exotic materials—ceramics, carbon-carbons, and aluminum-titanium alloys made with rapid solidification technology—that can stand up to friction heat as searing as 3000°F; designing a complex active cooling system that can circulate liquid hydrogen fuel to the hottest leading edges; and devising an equally complex hybrid engine that can operate as a turbojet for takeoffs and landings, switch to supersonic combustion ramjet (scramjet) for hypersonic cruise—Mach 6 and above—and then use limited rocket power in space.

Two contractors—United Technologies Corp.'s Pratt and Whitney subsidiary and Rockwell International Corp.'s Rocketdyne



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Foreign competition. *A model of the German Sänger hybrid hypersonic plane and rocket orbiter. France, Japan, and Britain are also interested in the technology.*

Division—were awarded $85 million apiece last September to design the X-30's propulsion system. In October, Rockwell, the McDonnell Douglas Corp., and the General Dynamics Corp. were given $25.5 million each to design airframes. The extreme degree of airframe-engine integration demanded by the X-30 introduces another level of complexity. Each of the airframers, for instance, must collaborate closely with each of the engine designers, meaning that the program managers will actually have six designs to chose from when they select an X-30 prototype to build when the project moves into Phase III in late 1990.

The degree of technological challenge posed by the NASP "is all in the eyes of the beholder," contended Colonel David W. Milam, a deputy program manager in the NASP office at Wright-Patterson Air Force Base. "This is 100 times more difficult than the X-15," Milam said, but in those times "they didn't have computational fluid dynamics and the wind tunnels and the things that we have now. The X-15 was an unbelievable job in its day, but we've certainly come a long way."

Even the most avid NASP boosters concede, however, that it may simply prove impossible in practice to push an air-breathing vehicle all the way up to Mach 25. According to Scott A. Crossfield, the first test pilot to break Mach 2 and now a consultant to the House Science, Space and Technology Committee, "there's nothing that says the aerospace plane has to be an air-breather all the way to orbital speeds. There may well be a rocket boost at the end of flight because it makes more sense. Above Mach 20, it is more efficient to go to rocket." At very high velocities, shock waves impede the flow of air into engine inlets.

The prospect of substantial rocket assistance, however, raises a warning flag for some NASP skeptics. "If they start talking about using combined propulsion systems, it is the kiss of death," contended a Pentagon aerodynamics expert. "A combined propulsion system works in one regime but not the other, and then you end up with a lot of dead weight."

The programmatic risks inherent in the NASP program revolve around what the GAO terms the "ambitious" goal to have an X-30 demonstrator in the air by 1995. The current NASP schedule is "probably overoptimistic for the hurdles that have to be overcome," agreed former DARPA director Robert S. Cooper, under whose tenure the NASP germinated between 1982 and 1985 in its Phase I incarnation as a $5.5-million project code named Copper Canyon. Predicting that the first flight will have to be pushed out into "the more ambitious future," he said he hoped that "a focus on engine testing and materials technology will continue at a high rate and that the preponderance of funding will continue to be invested in those tall technology poles."

Others associated with the project are less pessimistic. The NASP program affords a far wider "time window than we've had on other airplanes," said General Dynamics' NASP program director, Max E. Waddoups. "We built the B-58, F-111, and YF-16 in 2 years after go-ahead, and this program is looking at 3 to 4 years. So, in our view, we have a margin of safety of 2 years for NASP."

The financial risks identified by the GAO are easily grasped at a time when the Pentagon is struggling to cope with the new downward slope of its previously skyrocketing spending trajectory. "Programs that are in the embryonic stage are either being stretched out or canceled outright," noted Paul H. Nisbet, vice president for research at Prudential Bache Securities Inc. "Anything else will have to be secondary in a tight budget environment, certainly including this aircraft."

Sure enough, the Senate Appropriations Committee almost succeeded last December in halving the Air Force's fiscal 1988 request for NASP research, arguing that the space plane's "hypothetical, far-distant benefits" ran a poor second to programs with "demonstrated, near-term military payoffs."

Timely intervention by, among others, Raytheon Corp.'s Joseph F. Shea, who chairs a Defense Science Board task force on the NASP, succeeded in holding down the budget cuts levied by the final appropriations conference to only $53 million out of the Air Force's requested $236 million, and only $13 million out of NASA's $84-million request. If not as dire as threatened, those cuts still hurt, as did a $62 million drop, down to $350 million, in the previously planned Pentagon-NASA fiscal 1989 request for NASP.

NASA's relatively limited budget share of the NASP, roughly one-fifth of the $3.3 billion total, has been a continuing issue for some lawmakers. For 2 years running, Congress has fenced in half of the NASP appropriation, pending certification that NASA has upped its ante. NASA contends, and GAO confirms, that the agency has boosted its share of the Phase II costs, between fiscal years 1986 and 1990, from 20.2% to 28.2%.

Asked if his company was worried whether the funding stream for NASP could be maintained, General Dynamics' Waddoups replied that "we're following it on an hourly basis; at this hour, we're okay. But it is still a question and we're concerned." As well they might be. According to the Pentagon, industry's own contribution to NASP research, over and above contracts awarded, will total $727 million during Phase II, an investment that could come to naught if the program succumbs to fiscal erosion.

A decision to transfer overall management of the NASP program from DARPA to the Air Force Systems Command this year, 2 years ahead of earlier plans—ostensibly to smooth the transition into Phase III in 1990—has also aroused funding concerns among those who fret that the management change portends a lessening of NASA's role.

Likewise, some observers wonder precisely to what use this $3.3-billion technology investment will be put to. "This thing is as expensive as the superconducting supercollider," said Federation of American Scientists space specialist John E. Pike. "I think when you get into that ballpark you've got have a better explanation of why you want to do it than what they've come up with."

"We have perhaps overstated and overblown the potential applications," conceded former DARPA director Cooper. "But the technology we are pursuing is worthwhile. Even if we can only do half the goal that has been represented, there will be marvelous applications in military and civil aviation."

A hypersonic New Orient Express for nonmilitary use would not seem to be one of those applications—at least not directly—however, for the contractors working on NASA's High Speed Civil Transport study are now focusing strictly on supersonic birds. The NASP and the high-speed transport programs "are two entirely separate and distinct projects," said J. Roger Fleming, senior vice president for technical services with the Air Transport Association of America. "Basically, the airlines have stated a design goal of a 6500-nautical-mile range, speed in the Mach 2.5 to Mach 5 range, and the ability to carry passengers at 'seat-mile' costs roughly equivalent to today's 'seat-mile' costs," Fleming said. Noting that a hypersonic jetliner would also require liquid hydrogen fuel, Fleming added wryly, "You saw the appeal the [fueled space shuttle] Challenger might have had to airline passengers."

Nonetheless, NASP research—into heat-resistant materials, for instance—should contribute to future high-speed commercial aircraft, NASA's McIver said, adding that "it depends on where the numbers come down how much of the NASP technology will be applicable."

Because the X-30 will be a technology demonstrator, not an operational vehicle, defense officials have been reluctant to discuss exactly what uses they envision for it. Asserting that a study under way of prospective NASP applications was classified, Colonel Milam said only: "You can let your imagination run wild as to the variety of things that you could do with it."

The GAO report noted that aerospace planes based at only six facilities around the world could be deployed to anywhere on the planet in only 45 minutes to carry out missions as bombers, airlifters, or intelligence collectors. But, the accounting office adds, "existing or planned subsonic or supersonic aircraft . . . may be more cost-effective than an operational aerospace plane for some missions." No official price tag for a fleet of operational space planes has yet been issued, but it would likely run into the tens of billions of dollars.

Clearly, the most compelling utilization for a NASP-based vehicle—and the original raison d'etre for the program—is as a potentially cheap and reliable avenue into space. Today, it costs about $3000 to $4000 to insert a pound of payload into orbit. Part of the reason that the fare is so expensive is that 75% of the space shuttle's lift-off weight is fuel, four-fifths of which is liquid oxygen. Yet the shuttle climbs through an atmosphere filled with oxygen—a phenomenon some have compared to a fish carrying a canteen. Simply by largely eliminating the need for on-board oxygen, an air-breathing space plane could garner enormous savings.

The space shuttle is a balky beast, too, demanding that 6000 technicians dance attendance to check out thousands of components, many of which must be replaced or refurbished after every flight. For their part, expendable boosters require 600 launch technicians and, of course, are used up entirely. Because the space plane is supposed to have operational characteristics approaching that of an airliner, program officials hope that it will cut launch costs by at least 90%.

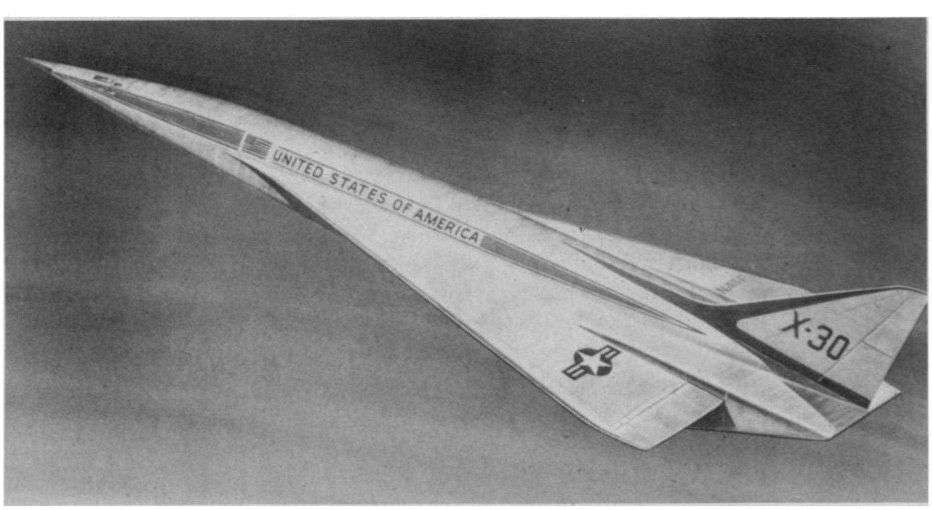
Because of urgent need for cheaper access to space, former Defense Department under secretary for research and engineering Richard D. DeLauer—like Cooper, a member of the Defense Science Board's NASP task force—is unhappy that the X-30 will be a piloted aircraft. "What we really need is to get the unmanned booster payload costs down," DeLauer said. "I think it should be an evolutionary program, getting the propulsion system and heat transfer [problems solved], using it as an unmanned booster and then man-rate it at a later date." NASP program officials respond that a manned research vehicle provides more flexibility and obviates the need to develop a globe-spanning automatic control system.

Undeniably, a measure of technological nationalism sparked by potential overseas competition is one sharply emerging motivation for proceeding full speed ahead with space plane research. "If another country demonstrates NASP-type technology first, the risks to the nation from both an economic and national security perspective could be staggering," the Pentagon told Congress in a plea last year for full funding of the NASP.

The United Kingdom, for one, is working on the HOTOL (horizontal takeoff and landing) space plane. Launched from a trolley, HOTOL would soar to Mach 5 before climbing into orbit on pure rocket power. British Aerospace Inc. estimates that a roughly $9-billion investment could get the HOTOL into the air by the year 2000. West Germany is also designing a space plane. Called the Sänger II, its first stage—the prototype for a hypersonic transport—would take off from a runway and climb to Mach 7 before launching a small rocket plane into low earth orbit. France, Japan, and the Soviet Union, too, have all expressed a keen interest in hypersonic space plane technology.

Decrying the apparent post-Challenger disaster scramble to make a splash in space, congressional aide and NASP booster Crossfield argued that "we don't have to show off this country one damned bit. What we ought to do is devote our efforts to the ongoing business of keeping our technology up to the way that we want to live as a nation."

But, the former test pilot complained, "We haven't been doing that when we're just flying 707s and their shiny sisters after 30 years. I first went Mach 2 in 1953, and that's the best that we can do since then, except for the SR-71. And that's a sad commentary for the nation of the Wright brothers." ■ **David C. Morrison**



Rockwell International

Rockwell's entry. *McDonnell Douglas and General Dynamics are also working on airframes, while Rockwell and United Technologies have engine contracts.*

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