Apparently, the future belongs to the National Aerospace Plane—but the immediate problem is a backlog of payloads in the wake of the Shuttle disaster.

Mastering the Transatmosphere

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THE United States has made its first major move toward mastering space and the transatmosphere for military and civilian pursuits in the twenty-first century.

It has gone beyond dabbling in concepts for an incredibly swift and versatile aircraft/spacecraft that would make such mastery possible and has now set up shop to design and build one. A prototype could be flying within ten years.

The National Aerospace Plane (NASP) program at Wright-Patterson AFB, Ohio, is the seat of the action.

With strong White House backing, the NASP program teams the Department of Defense and the National Aeronautics and Space Administration in what is shaping up as the most technologically and operationally tantalizing aerospace project ever undertaken.

Breaking the sound barrier, breaching lower space with rocket-powered aircraft, going to the moon, and flying and landing the Space Shuttle may come to pale alongside the multifaceted feats in prospect for the manned, X-series flying machine to which the NASP program aspires.

Given its allure, the aerospace plane is fast becoming regarded as the bright hope of the future for the US space program.

By and large, that program is well conceived and well executed. Its satellites do many marvelous things, and will do more, to enhance the prowess of US military forces and of US commercial enterprises.

The space program is increasingly costly, however, and has suffered some recent setbacks.

For one, USAF's program for developing and testing antisatellite (ASAT) rockets for high-flying F-15 fighters is in deepening political trouble in Congress. Plans to deploy an ASAT force to counter the heightening Soviet threat in space have already been scaled down. There is growing concern in Pentagon circles that such deployment may never happen.

Even more sobering, perhaps, is the dire impact that the Space Shuttle *Challenger* disaster of last January 28 has had—and will continue to have—on US space-launching capabilities and prospects. This setback has been compounded by recent failures of Titan and Delta space-launching rockets.

The aerospace plane now on the drawing board does not present itself as a near-term solution to such problems currently besetting the

Artist's concept of a hypersonic National Aerospace Plane (NASP) heading for space straight from an airfield, where three others wait on the ramp. INSET: A rocket-powered X-15 is released by a B-52 to explore manned flight at the fringe of space. The X-15 program of the late 1950s and early 1960s helped show the way to the NASP.


X-15
NORTH AMERICAN AVIATION INC.

space program. It is too far off for that, even though the development of its technologies may well teach some lessons that can be applied to the space program relatively soon.

Potential Space Superstar

However, the aerospace plane's mind-boggling potential as an all-purpose superstar in space and the new national commitment to bring it into being if at all possible serve to infuse the currently bedeviled space program with optimism that would otherwise be lacking.

As planned, the experimental (X-30) aerospace plane will be capable of runway takeoff, hypersonic single-stage entry into space and/or flight in the transatmosphere, and runway landing.

NASP officials acknowledge that all this will take some doing. They express confidence, however, that now—for the first time since the idea of an aerospace plane first surfaced in the early 1960s—it can be done.

"If we didn't think so, we wouldn't be in business," declares Air Force Brig. Gen. Kenneth E. Staten, who is the director of the NASP program.

General Staten describes the aerospace plane as "revolutionary, not evolutionary." To him, the NASP program is "an adventuresome, pioneering step—the kind of thing that Americans are good at and that established America's leadership in the world."

The going will be precarious. There are great expectations but no guarantees that the extremely sophisticated and demanding technologies needed for the aerospace plane can be brought to fruition and formed into a thoroughly integrated whole.

General Staten categorizes those technologies in "three main sets—propulsion, advanced materials, and computation." The latter means computers and software.

"The computational state of the art supports our requirement," the General says. "The breakthroughs that gave us confidence to proceed were in propulsion and materials."

As a key to the ultimate success of the NASP program, the clear-cut national need for an aerospace plane may be as important as the maturation of its technologies.

The US military sector is heavily and increasingly dependent on such satellites as those for communications, navigation, warning, weather forecasting, and surveillance. The US civilian sector also sets store by space assets. Both sectors will make much greater demands on space in the years ahead.

Thus, the US will need spacecraft that will enable it to take advantage of space for military and civilian purposes much more flexibly, efficiently, and inexpensively than is possible with Shuttles and with rocket boosters in existence or under construction.

"If we're going to exploit space, we're going to have to make space cheaper and easier to exploit," asserts Gilbert H. Rye, President of COMSAT Government Systems Inc. and former director of space programs, as an Air Force colonel, on the National Security Council staff.

Wide Range of Tasks

US space planners covet the aerospace plane in this regard. They see it as a machine of many potential uses and forms.

Big aerospace planes could take heavy, bulky satellites into space or could even serve as such satellites. Platforms for lasers or rockets of the sorts being worked up in the Strategic Defense Initiative (SDI) program come to mind.

Smaller aerospace planes could be used to service and to repair satellites and could ferry people, supplies, and mail to and from the space station that NASA is planning to have assembled in space around the mid-1990s.

On the military side, varieties of aerospace planes could perform such missions as reconnaissance, global interdiction, and interception of attacking forces in space and in the air.

As General Staten puts it, "The military has a need for quickly gaining access to anywhere in the world, and this [NASP] program would give us a vehicle that could do that."

Hopes for the aerospace plane as a relatively inexpensive means of boosting payloads into space rest on the airplane-like operational mode foreseen for it.

It is not expected to require anywhere near the logistical support needed by Shuttles or by space-boosting rockets. Moreover, aerospace planes could be launched on short notice from dispersed and readily accessible runways, giving them great advantages of security and flexibility.

"It offers strategic force survivability," says Gen. Lawrence A. Skantze, Commander of Air Force

The aerospace-plane idea has been around a long time, as witness this 1965 McDonnell Douglas artist's concept of an aerospace plane that is strikingly similar to NASP configurations now being explored. The US abandoned its aerospace-plane program of the early 1960s because key technologies, now ripe for testing, were lacking back then.

Systems Command. "A fleet could sit alert like B-52s."

At an Air Force Association symposium on military space late last year, General Skantze discussed the aerospace plane in the context of USAF's Project Forecast II, a study of important new technologies and of their future impact on the Air Force. The aerospace plane gets big play in that study.

General Skantze pointed out that it "responds to a wide range of Strategic Air Command, Tactical Air Command, Military Airlift Command, and unified Space Command needs.

"We're talking about the speed of response of an ICBM and the flexibility and reliability of a bomber packaged together in a plane that can scramble, get into orbit, and *change* orbit so [that] the Soviets can't get a reading accurate enough to shoot at it," General Skantze explained.

Cheaper Way into Space

He emphasized, however, that the aerospace plane's "paramount importance" lies in its potential for "low-cost, reliable access to space—precisely what's needed to open up the space frontier to routine operations."

Getting a Shuttle off the ground is too costly and too cumbersome. It requires an elaborate and expensive launch complex. About 6,000 people are involved in the operation.

Moving the Shuttles between landing points and launching points also eats up money, as does their heavy maintenance, much of it on the protective tiles. They also depend on a single carrier aircraft, which itself needs maintaining.

These are the main reasons why it costs up to $3,000 to put just one pound of payload into space aboard a Shuttle.

The aerospace plane would dispense with most of this and would carry payloads into space at one-tenth or less of the Shuttle system's cost, officials estimate.

If this turns out to be anywhere near the mark, there will be no stopping the NASP program—providing that its technologies pan out.

"We've got to get the cost of space launches down," asserts Secretary of the Air Force Edward C. Aldridge, Jr. "If the aerospace plane can cut the cost by a factor of 100, wonderful. If it can cut it by a factor of ten, we would all be elated. But if it can't cut the cost at all, then we'll have a problem with the [NASP] program."

In any case, the aerospace plane will probably not be ready to take over from the Shuttle at the time that the Shuttle needs to be replaced as the workhorse of the US space program. That time is expected to come no later than the mid-1990s.

At this writing, the Air Force and NASA were jointly studying the requirements for a post-1995, next-generation Space Transportation System (STS) of manned or unmanned launchers, or of both. The big players in determining these requirements are the Strategic Defense Initiative Organization (SDIO) and NASA's space station planners.

The space station and SDI weapons satellites and command control communications and intelligence (C^3I) satellites are expected to need launch vehicles capable of lifting much heavier payloads into space much more cost-effectively and at much higher rates than will be possible with the Shuttles or with the Titan 34D-7 Complementary Expendable Launch Vehicles (CELVs) now under construction for USAF.

The Shuttles, the CELVs, and

The US space program has been jolted by the Challenger disaster and recent failures of Titan 34D boosters. This 34D is off to a flying start.

other, smaller expendable launch vehicles (ELVs) will suffice to boost non-SDI military payloads into space through the mid-1990s.

For example, the vital Global Positioning System (GPS) navigation satellites can go into space on Shuttles or ELVs. The equally imperative Milstar communications satellites, which will be prime-choice military assets, can be launched, starting in 1988, on Shuttles or on CELVs.

However, all US military and civilian satellites have now run into a problem that has nothing to do with the one of going beyond the Shuttles, the CELVs, and the ELVs as launchers in the coming decade.

The Shortfall in Capacity

The problem is one of a severe shortfall in US space-launching capacity right now and for years to come. It was created by the loss of the Shuttle *Challenger.*

The *Challenger* disaster postdated both the NASA-DoD study of a new, post-Shuttle STS in the nearer term and the establishment of the DoD-NASA program for an aerospace plane in the farther term. It was obviously not the motivation for either endeavor, but it served to underscore the importance of both.

It did this by dramatizing how dangerously in arrears the loss of a single Shuttle leaves the US space program—consigning to limbo the previously scheduled launchings of many military satellites—and by demonstrating that the US will have to attend to its space-launching capabilities more assiduously than it has in the past.

"We must build a space-launch posture that is stronger and more robust than that which existed before," Secretary Aldridge asserts. "Restoring the *status quo* should not be our goal. The *status quo* was too thin."

At this writing, the timetable for resuming Shuttle flights was still uncertain, even though NASA had indicated that such flights may begin again next year.

Even if they do, the problem will still remain severe. The STS will have only three Shuttle orbiters, and only two of those—*Discovery* and *Atlantis*—are capable of flying the heavier loads that DoD missions require.

Moreover, the heavy-lift Titan 34D-7 CELVs that the Air Force had the foresight to begin ordering prior to the *Challenger* disaster will not begin coming into play until late 1988.

Once the Shuttles are back in action, they will fly less frequently than scheduled prior to the *Challenger* accident. This will exacerbate a backlog of launches that is already building.

If the STS is shut down one year, ten DoD payloads will have been put off. If it is down two years, more than thirty-five Shuttle missions will have been canceled, and "DoD would have serious problems with twenty-one high-priority payloads waiting on the launchpad," Secretary Aldridge told Congress.

Moreover, he testified, "There would be a heavy impact on NASA missions, because many of the backlogged DoD missions must take priority when the flights are reinstituted."

The Air Force has encouraged Congress to approve the construction of a replacement Shuttle orbiter at an estimated cost of $2.8 billion. It also has indicated that it will need more CELVs than the ten now authorized.

Not even these moves would alleviate the problem of space-launch shortfalls in the near term, however. A new Shuttle orbiter put into construction right now would not begin flying until 1990. Adding to the number of CELVs would not hasten their advent, which is more than two years in the offing.

These days, in the wake of the *Challenger* tragedy, the appearance of undue haste is something devoutly to be avoided in the US space program.

Meanwhile, the Air Force must resort to its ELVs—such rockets as Atlas, Delta, converted Titan II, and Titan 34D. All are either too scarce or too small to handle the numbers and the masses of the payloads for which DoD requires Shuttles and CELVs.

The Manned Alternative

Some officials believe that the aerospace plane could be ready in time to succeed the Shuttle and that an interim vehicle or vehicles will not be needed.

Secretary Aldridge, for one, doubts it. "The earliest we see the aerospace plane becoming available is the very late 1990s, around the year 2000," he says, "so there would be a discrepancy of eight to ten years between the time we need a new orbiter and the time we could have the aerospace plane."

Still and all, the aerospace plane is said to figure as an outside possibility in the Air Force-NASA study of the future STS to succeed the Shuttle, and a paper associated with USAF's Project Forecast II also identifies the aerospace plane as such.

If the aerospace plane is not ready, it is possible that two varieties of stopgap spacecraft will be built to take over from the Shuttles. One would be an unmanned vehicle, parts of which would perhaps be recoverable, for lifting heavy payloads. The other would be smaller and manned and supply the space station and service satellites. The smaller one "could use derivative technology" from the NASP program, Secretary Aldridge speculates.

That program, off and running, involves the Air Force, the Navy, the Army, the Defense Advanced Research Projects Agency (DARPA), SDIO, and NASA. Each is committed to share in financing the program's two phases.

The first phase, running through mid-1989, is expected to cost $600 million. It will deal with designing the airframe, developing and testing propulsion modules, getting all technologies in hand, and testing some key components.

DARPA is the leading agency in this phase. In fact, DARPA and the White House Office of Science and Technology Policy (OSTP) are given much of the credit for the technological developments and the political influence, respectively, that gave life to the NASP program.

If all goes well in its first phase, the program will proceed into its second phase, expected to cost about $3 billion. The X-series prototype aerospace plane will be built during this phase and begin flying in the mid-1990s. USAF will have charge of this part of the endeavor.

The NASP program has a $68 million budget in the current fiscal year and is slated to receive $212 million in FY '87, which will begin next October 1.

Industry competition for the aerospace plane began in earnest last April. Airframe design contracts went to Boeing, General Dynamics, Lockheed, McDonnell Douglas, and Rockwell International. Propulsion contracts were awarded to General Electric and Pratt & Whitney.

Most of these contractors had taken part in concept studies of a Transatmospheric Vehicle (TAV) that were managed by AFSC's Aeronautical Systems Division at Wright-Patterson. That program and another at AFSC's Space Division were forerunners of the NASP program.

As conceived, the aerospace plane will be capable of flight in two modes—single stage into low-earth orbit and hypersonic (Mach 12 to Mach 25) cruising in the transatmosphere at altitudes between 100,000 feet and 350,000 feet.

The first of these modes addresses the payload-launching aspect of the US space program and is the one in which SDIO, as a prime player in the NASP program, is chiefly interested.

The NASP and SDI

SDIO's portion of the NASP program budget is \$9 million in the current fiscal year and has been set at \$30 million in FY '87.

Several SDI experimental projects have prospered well enough to make its goal of directed-energy weapons, kinetic-energy weapons, and C^3I systems for space (if the decision is made someday to deploy them there) more tangible and nearer at hand. This lends impetus to the NASP program.

Air Force Lt. Gen. James A. Abrahamson, SDIO director, recently told Congress that the program "may be able to cut more than a decade" from its original timetable for fruition and testing of some key technologies.

The need to plan ahead for SDI space deployment figures heavily in considerations of heavy-lift launch vehicles, such as possible aerospace-plane variants.

SDI officials have recently indicated that they now emphasize the development of ground-based lasers over that of space-based lasers. They have by no means given up on the latter, however, and even the ground-based lasers would need to be teamed with beam-reflecting mirrors and with sensors, battle-management systems, and C^3I systems in space to do their job of intercepting enemy missiles in post-boost and midcourse flight.

Ground-based lasers for firepower in space have been made possible by stunning SDI successes in "adaptive optics" experiments to overcome the problem of laser beams dissipating as they pass through the atmosphere into space.

To counter atmospheric distortion of the beam, a sensor in space monitors atmospheric characteristics and continuously sends down atmosphere-calibration data to a computer that is part of the laser-weapon system.

The computer keeps adjusting a "deformable mirror" in the laser system that skews its beam to compensate for the atmospheric aberrations. The result is that the deformed beam, in penetrating and interacting with the atmosphere, reacquires its original form and its intended coherency.

The SDI project also involves promising experiments in weapons that would attack enemy ICBMs from space with hypervelocity projectiles and neutral particle beams, which could also be used as sensing devices.

For ground-based systems that will intercept the reentry vehicles of such ICBMs in their "terminal" phase, Lockheed is working up the exoatmospheric reentry-vehicle interceptor subsystem (ERIS) for SDIO, and McDonnell Douglas is developing a test-bed missile for the program's High Endoatmospheric Defense Interceptor (HEDI) system. Both seem well in hand.

None of this comes cheap. However, the costs that concern SDIO officials as much as any are those of launching SDI payloads into space for testing and—if it comes to that—deployment.

Cumbersome logistics involved in preparing a Shuttle for liftoff contribute heavily to the Shuttle program's high payload-launching costs. Here, USAF works with the original Shuttle* Enterprise *in preparing its Vandenberg AFB, Calif., Shuttle-launching complex for eventual action.

General Abrahamson has said that the single most important cost parameter in the SDI program is that of launching such payloads.

The NASP program could be a lifesaver in this regard.

"Our initial calculations," declares the program's General Staten, "show that we will be able to go single stage to orbit with payloads at between one percent and twenty-five percent of the expense of doing it with the Shuttle."

Getting from Here to 1995

First off, however, there must *be* an aerospace plane.

Developing the propulsion system and integrating it with the airframe will be the hardest part of making the aerospace plane happen.

It is already being referred to as "a flying engine," because, says DARPA Director Dr. Robert Duncan, "the whole airframe plays a part in the propulsion system."

This means, says DARPA Deputy Director Dr. James A. Tegnelia, that "the fuselage forebody is an integral part of the engine inlets and the fuselage afterbody is an integral part of the engine nozzles."

The aerospace plane's multiple powerplants will have to operate efficiently from zero velocity at the start of the takeoff roll, which is expected to be short, to Mach 25 at the point of orbital insertion.

"We believe we have achieved some breakthroughs in propulsion that will enable us to use air-breathing technology for most of our velocity," General Staten asserts.

This means scramjets (supersonic-combustion ramjets) powered by liquid hydrogen. They will require a supersonic flow of compressed air through their combustion chambers. Regulating such a flow at hypersonic speeds to prevent shock waves and to keep the engine-ignition process stable and efficient will be extremely difficult.

The aerospace plane will have to take off from a standing start, a capability that airflow-driven scramjets cannot provide. It also will need to accelerate to, and fly at, hypersonic speeds of 4,000 to 8,000 miles an hour and then drop down to subsonic speeds for approach and landing.

To manage all this, the aircraft/spacecraft could well embody hybrid powerplants that combine takeoff-power rockets with scramjets and subsonic-combustion ramjets.

The machine may also need to carry air onboard as a means of oxygenating its propulsion system to maneuver in airless space and to come back down into the atmosphere. It could restore its air supply by dipping into atmosphere.

Propulsion technologies and all others for the aerospace plane will be closely held.

"Our country has invested a quarter of a century of its money and some of its very best talents in developing these key technologies, and it would be irresponsible to compromise them until the nation has had the opportunity to capitalize on them," General Staten declares.

Even though the aerospace plane project of the early 1960s was aborted because the technologies were just not there, work on those technologies continued.

NASA, says General Staten, has been "the big champion of research in hypersonics."

The success of "Copper Canyon," a DARPA project on hydrogen-powered scramjets and ramjets, was the key to forging a virtual consensus in the US aerospace community that the aerospace-plane concept has come of age.

Some Doubt Remains

Some knowledgeable officials and observers caution against overconfidence in the NASP program's ability to master the required technologies even now, however.

One is Under Secretary of Defense for Research and Engineering Dr. Donald A. Hicks, who warns against "pretending we have something we don't have" and against "overselling" the NASP program.

"But let me not put a damper on it," Dr. Hicks continues. "I'm optimistic about the research turning out well, and I'd love to see the aerospace plane happen. It could be terribly important to us, even critical."

Another is Gen. Robert T. Marsh, USAF (Ret.), former commander of Air Force Systems Command, which itself played a major role in nurturing many aerospace-plane technologies.

General Marsh believes that the NASP program is a "sensible" one, with prudently timed and probably attainable goals.

"I'm enthusiastic about the program," he declares. "It has tremendous potential for military and civilian access to, and capability in, space. It deserves a major national push.

"But there are gaps in our understanding of hypersonics and in our experience in hypersonics. It's very complicated."

One "very challenging undertaking" that General Marsh sees in store for the NASP program is that of removing moisture from the propulsion air-liquefaction system and disposing of the water.

It would have to be done to perfection, he says, "to keep from having a flying ice cube on your hands."

In broader terms, "Propulsion is the hardest challenge of all," General Marsh continues. "It's not just engines. In hypersonics, there's a very intimate connection between propulsion and aerodynamics. What you must have is a totally integrated aerodynamic and propulsion capability, a total system that uses the externals of the vehicle to shape the airflow."

In keeping with the "high degree of streamlining" that hypersonic vehicles require, General Marsh believes that the aerospace plane's engine inlets will need "knife-edge lips. This will exacerbate the temperature problem," he asserts.

That problem is a huge one. Hypersonic flight will induce metal-melting temperatures on the airframe. The airframe will have to be built of advanced materials capable of withstanding them (Shuttle-style tiles are out of the question), and it will probably need an exotic system of fluid coolants and/or pipes to draw heat away from critical areas.

The aerospace plane's materials must also be much stronger and lighter than any ever fabricated for a flying machine—given the demands to be made on its propulsion system and on its payload-toting capability.

Breakthroughs in materials technology now make all this possible, NASP officials claim.

The supercomputers, such as NASA's Cray II, provide the computational prowess that designers need in order to figure out the aerospace plane's fluid dynamics, or the flows of air and of energy around it and into it. Such computers can simulate various airframe-engine configurations under many different airflow conditions.

Such data must be validated in flight, however, and "there's great uncertainty out there beyond Mach 6 or Mach 8," says General Marsh. "We need a lot of empirical data on hypersonic flow."

In Phase I of the NASP program, engine modules will be built and tested up to Mach 8, which is the speed limit of wind tunnels for engine tests. It will be up to the pilots of the prototype aerospace plane to find out for sure what happens beyond Mach 8—providing Phase I culminates in a decision to go forward with the prototype.

Despite its obvious risks, the aerospace plane is widely regarded in US aerospace circles as ripe for the trying. Its commercial potential may rival its military potential as the reason for this.

"I believe that it will fly and that we won't be too many years into the twenty-first century before it will be as common as Boeing 727s are today," declares an influential Administration official.

Dr. Karl G. Harr, President of the Aerospace Industries Association of America, says that the aerospace plane's "implications for future space operations, particularly the commercial development of space, are stunning."

Dr. Harr sees the aerospace plane as "dropping the cost of delivering payloads to orbit from several thousand dollars a pound to tens of dollars a pound."

Moreover, he says, its development promises to "provide a technology base that could sharply reduce the time and the cost of developing the companion commercial hypersonic transport—and that's a very big factor, because most experts have felt for years that economic feasibility has been a greater barrier than technical feasibility to faster-than-sound passenger transportation." ■