United States General Accounting Office 146378

GAO

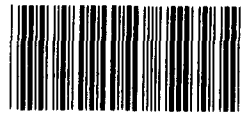
Testimony

Before the Subcommittee on Technology and Competitiveness, Committee on Science, Space, and Technology, House of Representatives

March 31, 1992

NATIONAL AERO-SPACE PLANE

Key Issues Facing the Program



146378

Statement for the Record by
Nancy R. Kingsbury
Director, Air Force Issues
National Security and International Affairs Division

Mr. Chairman and Members of the Subcommittee:

As you requested, I am submitting this statement as part of the record of the Subcommittee's authorization hearing on aeronautical research and technology, including the National Aero-Space Plane (NASP) Program. This statement provides our interim assessment of the NASP Program and addresses four key questions currently facing the program:

- Will the NASP Program include single-stage-to-orbit flight testing?
- How much will the NASP Program cost?
- How have changes affected the NASP Program's schedule?
- How much progress has been made in developing key technologies?

RESULTS IN BRIEF

Since its inception in December 1985, the NASP Program has undergone significant evolutionary changes. Its cost estimates have increased dramatically and some key schedule milestones may be delayed up to 11 years. While the program has achieved technical progress, it has also encountered problems with its weight and propulsion system. These problems, in conjunction with budget constraints and increasing costs, have resulted in various options being explored to reduce program costs and technical risks. As a part of this assessment, the primary goal of the program--to conduct single-stage-to-orbit flight testing of the X-30--is being reconsidered.

Even without additional technical problems, potential cost increases and budget constraints are likely to be significant contributors to future schedule delays in the NASP Program. Furthermore, determining how much funding is needed and when, focusing development activities on needed technologies, and

developing achievable long-range plans are complicated by the lack of a determination of whether the X-30 will conduct single-stage-to-orbit flight testing. For these reasons, we believe that a timely decision on this issue is critical.

The Joint Program Office's recent proposal to concentrate on the X-30's propulsion system in the near term and defer a decision to build the X-30 until 1996 would likely reduce the program's near-term technical risk. Nevertheless, testing of several critical components and an analysis of the test results are not expected to occur until after the scheduled Phase III go-ahead decision in September 1993.

OVERVIEW

The NASP Program is a joint Department of Defense (DOD)/National Aeronautics and Space Administration (NASA) technology development and demonstration program to build and test the X-30, a manned experimental flight vehicle. The program's goal is to provide the technological basis for future space launch and hypersonic flight vehicles by developing critical or enabling technologies. These technologies include an air-breathing propulsion system using a supersonic combustion ramjet (scramjet); advanced materials that are high strength, lightweight, and able to withstand high temperatures; a fully integrated engine and airframe; computational fluid dynamics (advanced computer programs) and supercomputers to be used for aerodynamic, structural, and propulsion system design; and hydrogen that can be efficiently used as a fuel and a coolant to actively cool the airframe and engines.

The X-30 is expected to validate enabling technologies by demonstrating single-stage-to-orbit space launch and hypersonic cruise capability. The X-30 is being designed to take off horizontally from a runway, reach hypersonic speeds of up to Mach

25 (25 times the speed of sound), attain low earth orbit, and land on a runway.

Public perception of the NASP Program has been confused by images of follow-on, operational aerospace vehicles or unrealistic, low-risk vehicle concepts. Since the X-30 is planned as an experimental research vehicle, it is not being designed to meet specific operational missions or requirements. It will not be a prototype or operational vehicle and will not carry passengers or payload except for two crew members and test instrumentation. While the NASP Program is intended to lay a technological foundation for future operational aerospace vehicles, it is not intended to develop or build them. Such vehicles would require an additional development effort and would be separately justified and funded.

The NASP Program is both technologically challenging and high risk. No vehicle has ever flown single-stage-to-orbit using either air-breathing or rocket propulsion. The X-30 is being designed to fly about 5 times faster and higher within the atmosphere than any previous air-breathing aircraft, such as the SR-71 strategic reconnaissance aircraft. To date, the United States has not flight tested a scramjet engine.

The NASP Program, managed by the NASP Joint Program Office, is being conducted in three phases. Phase I (1982 to 1985), which preceded the formal beginning of the program, defined the technical concept for an aerospace plane. The program is currently in Phase II (1985 to 1994), concept validation, which includes developing critical technologies; developing production processes; building and testing structural articles and components; testing a subscale concept demonstration engine; and developing an initial concept design. Phase II consists of several consecutive segments, the most recent of which began in 1991 and is referred to as Phase IID.

In 1991, the Joint Program Office and the NASP National Contractor Team--a consortium of five major aerospace companies executing the program--established four basic exit criteria to demonstrate satisfaction of Phase II objectives and measure the program's readiness to enter Phase III. These criteria included (1) demonstration of the engine concept, (2) development of an integrated air vehicle/engine design, (3) demonstration of materials and structures, and (4) determination of the various properties of slush hydrogen as a fuel.

The NASP Joint Program Office is currently analyzing options which would extend Phase II and restructure Phase III. Under this proposal, Phase III would begin in 1994 and continue at least through 2006. This period would include designing, building, and flight testing the X-30. A considerable amount of work would be required during this phase, especially in designing the X-30. For example, the X-30's preliminary design review, which is to establish the technical adequacy of the selected design approach and its ability to meet performance requirements, would not be scheduled until 1997.

UNCERTAINTIES REGARDING SINGLE-STAGE-TO-ORBIT FLIGHT TESTING

According to NASP Program officials, the most important and technically challenging X-30 design goal is to achieve single-stage-to-orbit capability using air-breathing propulsion. However, program officials are exploring options to reduce program costs and minimize technical risks. Some of these options do not include single-stage-to-orbit flight testing of the X-30 vehicle. No clear consensus exists as to whether it is necessary to actually go single-stage-to-orbit to demonstrate the technologies needed to do so.

Since the program's inception in 1985, demonstrating single-stage-to-orbit capability has been its primary objective. Program officials believed that demonstrating this capability offered the highest potential payoff of any NASP technology, noting that such a capability in an operational system could lead to more reliable and less costly access to space compared with the space shuttle and other launch systems. To demonstrate this capability, the X-30's aerodynamics, thermal control, propulsion system, and structures must be fully integrated. Since adequate ground test capabilities and facilities to test the X-30 above Mach 8 for sustained periods do not exist, the X-30 is envisioned as a "flying test bed" to validate requisite technologies between Mach 8 and 25.

Some NASP Program officials have indicated that demonstrating many of the technologies necessary to achieve single-stage-to-orbit space launch capability may be possible without the X-30 actually achieving single-stage-to-orbit. They noted that the X-30's scramjet could be demonstrated within the atmosphere up to Mach 16. They also stated that the X-30's final ascent maneuver into orbit, which would use rocket propulsion, is based on known technology and is not as demanding as demonstrating an air-breathing propulsion system using a scramjet. Although some specific technical questions might be answered without going single-stage-to-orbit, total integrated vehicle design questions (such as demonstrating that the vehicle could carry enough propellent to go all the way to orbit) cannot.

U.S. Air Force Space Command and Strategic Air Command--two primary military users of potential future operational aerospace vehicles--believe that demonstrating single-stage-to-orbit is an essential part of the NASP Program. During 1991, these commands reiterated their position that the NASP Program needs to address operational questions during its flight test program and that the test program must be structured to achieve single-stage-to-orbit. They stated that without such testing, a follow-on technology demonstration

program would be necessary before initiating a program to develop an operational vehicle. Command officials said they did not believe a second technology demonstration program was affordable given projected budget constraints. Command representatives told us that the commands' support for the NASP Program would be jeopardized if it were not planned for the X-30 to demonstrate single-stage-to-orbit capability.

Although single-stage-to-orbit still remains the NASP Program's ultimate goal, the Joint Program Office has been directed to explore ways to reduce cost and technical risk. Estimates of the cost, risk, and value associated with a series of program options will be presented to senior DOD and NASA leadership (in their capacity as members of the NASP Steering Group) and the National Space Council. Several of these options do not include single-stage-to-orbit. Some DOD officials believe single-stage-to-orbit may ultimately have to be achieved through incremental steps. No decision has been made regarding whether to eliminate the capability to conduct single-stage-to-orbit flight testing in the NASP Program. However, program officials emphasized that current efforts remain focused on developing the technologies necessary to achieve single-stage-to-orbit.

INCREASING PROGRAM COSTS

The Air Force has no current official cost estimate of how much developing, building, and testing the X-30 will cost, but preliminary information indicates that program costs may be more than five times the 1986 estimate of $3.1 billion. The projected cost of the NASP Program has increased significantly since 1986. In 1991, the Acting Under Secretary of Defense (Acquisition) reported to Congress that total program costs for two single-stage-to-orbit experimental flight vehicles could be about $10 billion. This estimate more than tripled the 1986 estimate of $3.1 billion. Although a more current official cost estimate is not expected

until May 1992, initial National Contractor Team estimates for Phase III alone indicate that further increases in projected program costs are expected. The National Contractor Team estimated that building and flight testing two X-30 test vehicles capable of single-stage-to-orbit flight--the baseline NASP Program--could cost between $13.2 billion and $15.1 billion. When coupled with the more than $1.9 billion that is expected to be spent on Phase II activities through fiscal year 1994, NASP Program costs could total as much as $17 billion--more than five times the original estimate.

The NASP Joint Program Office is expected to complete a revised cost estimate in May 1992. This estimate will rely heavily on a parametric analysis, a typical cost-estimating methodology used for programs in an early stage of development. Our preliminary analysis indicates that the Joint Program Office may be using overly optimistic assumptions and may not be reflecting all costs typically included in such estimates. For example, flight test costs are estimated only through the first single-stage-to-orbit flight test, although several additional years of testing are likely. Additionally, the cost estimate assumes a gross takeoff weight of 325,000 pounds, although current estimates indicate that even if weight reduction measures are successfully implemented, the vehicles's gross takeoff weight is likely to be about 450,000 pounds. Program officials noted that by using the heavier weight, estimated program costs could increase from 10 to 20 percent. Once the official NASP cost estimate is released, we plan further work to assess its reasonableness.

The various program options currently being explored by the Joint Program Office are based on decreasing the number, size, or capability of the X-30. These options include building either

- one full-scale, single-stage-to-orbit-capable vehicle;
- one full-scale, suborbital vehicle; or
- one subscale, suborbital vehicle.

Initial figures provided by the National Contractor Team indicate that these options may reduce the Phase III baseline cost estimate (between $13.2 billion and $15.1 billion) by $2.5 billion to $6.5 billion. However, technical risks would increase if only one test vehicle is built, and the suborbital options represent a significant departure from the program's original goal of conducting single-stage-to-orbit flight testing using the X-30.

DELAYS IN PROGRAM SCHEDULE

Since its inception in 1985, the NASP Program has encountered several schedule delays that have been attributed to a combination of funding constraints and slower-than-expected technical progress. The Joint Program Office is again revising the program's schedule to reflect current and future funding constraints and the need to reduce technical risk. These efforts will again stretch the program's schedule. However, meeting the NASP Program's revised schedule may be challenging, since the program will be competing with other space and defense programs for increased funding in a constrained budget environment. On the other hand, the NASP Program offers high potential to increase the U.S. aerospace technology base--a factor which many believe is critical in light of increasing international competition.

Under a 1987 schedule, the program plan called for completing Phase II efforts by 1989 and beginning flight testing in 1993. By 1988, these efforts had been delayed by several months to reflect reduced funding and slower-than-expected technical progress. In 1989, the newly formed National Space Council reviewed the NASP Program and further extended Phase II by 2-1/2 years until early 1993.

Consequently, the first single-stage-to-orbit flight test was scheduled for 1999.

Joint Program Office representatives cited decreased funding levels as the primary reason for restructuring the current phase. They also expected some delays due to technical problems and the need to reduce technical risk. When the Phase IID program began in January 1991, program officials anticipated that total funding for fiscal years 1992 and 1993 would be $607 million. However, congressional budget actions in fiscal year 1992 and a lower-than-expected fiscal year 1993 budget request may reduce this funding to about $460 million.

The NASP Program's Phase III efforts are also being revised by the Joint Program Office to reflect future funding constraints and decrease some of the technical risk associated with the previous acquisition strategy. Under the previous plan, annual funding requirements between fiscal years 1994 and 1996 were expected to be $1 billion or more, and both the airframe and engine were to be developed and produced concurrently. The NASP Steering Group was expected to meet in April 1993 to approve initiation of Phase III activities.

NASP Program officials now propose to divide Phase III into two efforts to limit annual funding requirements through fiscal year 1996 to less than $600 million and to reduce some of the technical risks included in the previous acquisition plan. The first effort, Phase IIIA, would focus on developing and testing the X-30's propulsion system. The NASP Steering Group is expected to meet in September 1993 to determine whether sufficient progress has been made to proceed into Phase IIIA. Under the revised program plan, building and flight testing the X-30 would be deferred until the proposed second effort, Phase IIIB, which would begin in 1996.

Under the revised plan, program officials anticipate additional delays in both the first suborbital flight and the first single-stage-to-orbit flight. This proposal would slip the X-30's first flight to 2004, and its first single-stage-to-orbit flight until 2006. In total, the proposed revisions to the flight test schedule represent about an 11-year delay from a 1987 schedule.

Future Budget Constraints Could Further Affect Proposed Phase III Schedule

The proposed Phase III schedule may not be met, even in the absence of any major technical problems. To a large degree, meeting this schedule is dependent on DOD and NASA funding. Despite efforts to limit near-term funding needs, the NASP Program's annual funding requirements are still expected to increase from the current level of about $260 million to about $600 million in fiscal year 1996 and to as much as $2 billion by the late 1990s. During this period, DOD and NASA are planning to fund other significant programs such as the F-22 Advanced Tactical Fighter, B-2 Stealth Bomber, Strategic Defense Initiative, National Launch System, space shuttle, and space station. Meeting these commitments in an era of fiscal constraints will be difficult for both DOD and NASA.

DOD, which has funded about 74 percent of the NASP Program's Phase II development costs through fiscal year 1992, is expected to incur a significant decline in its overall budget through fiscal year 1997 as the United States adjusts to a changing threat environment. How DOD plans to implement these reductions among the services and between its development and procurement budgets is not yet clear. However, the Congressional Budget Office reported in December 1991 that, based on the administration's February 1991 plans, by fiscal year 1997, funding for the Air Force's research and development activities could be less than 55 percent of its fiscal year 1992 level when expressed in real terms.

Similarly, the availability of adequate NASA funding is questionable. We reported in March 1992[1] that NASA's preliminary projected funding requirements through fiscal year 1997 are likely to exceed available funding by $13 to $21 billion.

PROGRESS AND PROBLEMS IN DEVELOPING KEY TECHNOLOGIES

Through March 1992, the National Contractor Team made progress in varying degrees toward meeting several broad technical criteria established to measure the program's readiness to enter Phase III. Resolving the weight and ramjet-cycle engine performance problems, combined with restructuring of the Phase II program, will likely delay efforts to demonstrate satisfaction of all four exit criteria. Preliminary schedules indicate that some critical tests will be delayed past September 1993, when the NASP Steering Group is scheduled to assess the program's readiness to enter Phase III.

Significant Revisions Expected to Air Vehicle and Engine Concept Designs

Projected increases in the X-30's gross takeoff weight have delayed the National Contractor Team's efforts to establish an integrated air vehicle design. This problem became evident in November 1991 at the conclusion of the second of four Phase IID design cycles. According to program officials, the National Contractor Team limited the X-30's gross takeoff weight to its design goal of about 350,000 pounds. However, program officials estimated that carrying sufficient fuel to fly single-stage-to-orbit, the X-30 would weigh at least 550,000 pounds--more than 50 percent heavier than the National Contractor Team's goal and more than 25 percent heavier than the program's weight threshold (the maximum acceptable weight

---

[1]NASA Budget: Potential Shortfalls in Funding NASA's 5-Year Plan (GAO/T-NSIAD-92-18, Mar. 17, 1992).

without requiring a program review to reassess program objectives and success criteria).

NASP Program officials consider the X-30's projected weight problem to be significant, but caution that current weight estimates may overstate the problem. Program officials pointed out that efforts are under way to reduce vehicle weight. If successful, these efforts could reduce the X-30's weight to about 450,000 pounds.

Ramjet-cycle engine performance (between about Mach 3 and 6) has also been unsatisfactory. Results from initial subscale engine test runs in mid-1991 indicate that the current engine design would not allow a sufficient amount of fuel to be burned in the engine's combustor. As a result, the X-30 would not be able to accelerate past Mach 3. Joint Program Office representatives said resolving the ramjet-cycle engine performance problem could require changes to the low-speed (Mach 0 to about 3) and scramjet (Mach 6 to about 16) engine designs. Program officials report that performance in the scramjet mode has generally been successful. Tests of subscale engine and components at Mach 8 have demonstrated scramjet combustion efficiencies of between 80 and 95 percent of maximum theoretical performance. Tests of the low-speed design were completed in February 1992 and the Joint Program Office is still evaluating test results.

The National Contractor Team has formed two special troubleshooting teams to determine what design changes are needed to reduce the X-30's weight and improve engine performance. Developing an integrated solution for these problems is essential, since the underside of the X-30's airframe serves as the engine's air inlet and exhaust nozzle, while changes to the engine design could increase the vehicle's weight. The National Contractor Team is expected to report its initial findings in April 1992.

Progress in Developing Materials

Demonstration of another Phase II exit criteria--the development of materials, structural design, and production processes necessary to build the X-30--is proceeding in a two-pronged effort. Efforts to define the properties of these baseline and other more advanced materials will continue through 1993.

The Joint Program Office approved the initial selection of materials for the airframe and engine in March 1991. Program officials told us the baseline materials were selected because their characteristics were more readily understood than other more advanced materials being studied. They noted that to a large degree, these decisions were based on previous plans to begin fabrication of the X-30 vehicle in 1993. Program officials believe that program restructuring may allow more time to develop some of the advanced materials, which in turn could replace the baseline materials and help decrease the X-30's weight.

A concurrent effort is underway to determine various methods to fabricate both baseline and alternative materials into usable components for the X-30. Much of the testing conducted thus far on these materials has been performed in laboratories using small samples. A large-scale model of the fuel tank, a major component, has been fabricated from baseline materials. This tank has successfully met test objectives by containing liquid hydrogen at a temperature of -423 degrees Fahrenheit while subjected to external heat of 1,300 degrees Fahrenheit. Program officials considered the test a significant accomplishment. Other tests of components fabricated from baseline materials are expected to begin soon. For example, testing to demonstrate the ability to join several large panels made of Beta 21S--a titanium matrix compound designated as the primary airframe material--is to begin in April 1992. However, due to funding constraints, most other structural tests have been postponed until fiscal year 1993.

Status of Slush Hydrogen Production Efforts

NASP Program researchers have made considerable progress in demonstrating the capability to produce slush hydrogen (a mixture of liquid and frozen hydrogen that is denser than liquid hydrogen), the fourth Phase II exit criteria. NASP Program officials hope to store slush hydrogen rather than liquid hydrogen in the X-30's fuel tank, since slush hydrogen's greater density allows more fuel to be carried in a given space. The goal was to achieve a ratio of 55 percent frozen hydrogen to 45 percent liquid hydrogen. Tests in 1990 achieved the required results, and subsequent tests in 1991 exceeded the requirements. For example, 41 of the 75 tests conducted in 1991 achieved a ratio of over 60 percent.

Some Critical Tests and Design Reviews Postponed Until After the Planned Phase III Go-Ahead Decision

As of March 1992, the Joint Program Office had not yet determined what effect restructuring would have on demonstrating the Phase II exit criteria or in meeting interim program milestones. However, several critical tests will not be completed until after the NASP Steering Group is scheduled to meet in September 1993 to consider the program's readiness to enter Phase III.

For example, the concept demonstration engine test, which is scheduled for November 1993, is designed to evaluate a subscale ramjet/scramjet engine at various speeds up to Mach 8. This test is considered essential to demonstrate the viability of the engine concept. The testing of large-scale active cooling panels is scheduled for December 1993. These tests are expected to more accurately represent the hypersonic flight environment, whereas earlier tests of smaller-scale panels are to be tested under less rigorous conditions. Finally, the fourth and final Phase IID design cycle is not scheduled until February 1994. This design cycle is intended to produce and document an X-30 design that meets

the Phase II exit criteria and is sufficiently detailed to enter Phase III.

In February 1992, the Director of Defense Research and Engineering tasked the Defense Science Board, in part, to determine if (1) the current Phase II exit criteria are adequate to justify a decision to proceed to Phase III and (2) the completed and planned technical efforts are likely to satisfy the current Phase II exit criteria or the exit criteria needed to justify a decision to proceed to Phase III. The Board is expected to report its findings in June 1992.

- - - - -

We will continue to explore these issues as a part of our ongoing evaluation of the NASP Program and expect to issue a report in the summer of 1992.

(392620)

Ordering Information

The first copy of each GAO report and testimony is free. Additional copies are $2 each. Orders should be sent to the following address, accompanied by a check or money order made out to the Superintendent of Documents, when necessary. Orders for 100 or more copies to be mailed to a single address are discounted 25 percent.

U.S. General Accounting Office
P.O. Box 6015
Gaithersburg, MD 20877

Orders may also be placed by calling (202) 275-6241.

United States
General Accounting Office
Washington, D.C. 20548

Official Business
Penalty for Private Use $300

First-Class Mail
Postage & Fees Paid
GAO
Permit No. G100