Appendix D
The Defense Science Board Report on NASP[1]

Among the most thorough outside technical reviews of the X-30 program to date is that of the Defense Science Board Task Force on NASP. The DSB task force, composed of eminent aerospace experts, was asked to evaluate the degree to which the technology base could support a decision for NASP to advance to Phase III—the design, fabrication, and flight test of a selected engine and airframe configuration.

Most of DSB's work was performed in the first half of 1987, although the study was not released publicly until October 1988. NASP officials believe some parts of the DSB study are now out of date and note that the DSB report occurred while airframe and engine configurations were still in a very preliminary design stage. In particular, vehicle designs being examined by the DSB closely resembled initial concepts that came from the Copper Canyon study of 1986. These concepts have been abandoned by NASP as overly demanding of near-term technology.

The DSB found that NASP was a vitally important national program and affirmed decisions to focus the program around the objective of achieving single-stage-to-orbit. However, the DSB also noted that, "early estimates of vehicle size, performance, cost, and schedule were extremely optimistic. " The DSB concluded that NASP's Technology Maturation Program was inadequate to support NASP's schedule with an acceptable degree of risk.

In response to the DSB report and internal evaluations, NASP officials modified their schedule; focused their program on a small number of vehicle and engine options; established an elaborate risk-closure plan based on the achievement of a specific series of technical objectives or milestones; and combined the five major engine and airframe contractors in a novel Materials Consortium. NASP believes rapid progress has been made in the key enabling technologies of the X-30 since the DSB performed their study. A brief review of some of the DSB's conclusions and NASP's response is given below. Space allows only a cursory review of the many areas of technical concern.

In aerodynamics DSB found the greatest uncertainty in predicting the point at which air flowing smoothly over the vehicle (laminar flow) becomes turbulent. Lift decreases, drag increases, and heat transfer rates change when airflows become turbulent. Thus, predicting the location of this "boundary layer transition" has a profound effect on vehicle design. For example, the DSB noted that location of the transition point could affect the design vehicle take-off gross weight by a factor of two or more

As noted earlier, progress has been made in the ability of computational fluid dynamics to characterize the boundary layer transition since the DSB report. Furthermore, X-30 designers believe that a vehicle designed with ''conservative' assumptions about the boundary transition-such as assuming laminar flow only between Mach 4 and Mach 15, and only over part of the forebody-would still allow a vehicle design that would meet the primary objective of single-stage-to-orbit. Nevertheless, until an X-30 undergoes flight testing there will be uncertainty regarding the adequacy of computational predictions.

In propulsion DSB expressed a large number of concerns including: the integration of a low-speed propulsion system with a ramjet/scramjet; the potential effect of combustion instabilities, transients, or even flameout during acceleration; engine performance at high Mach numbers; and the adequacy of knowledge of thermal loads (influenced by uncertainties in the boundary layer problem noted above). The DSB called for increased experimental verification to improve understanding of the complex NASP design. In particular, they suggested NASP consider performing fully integrated engine tests in a variable Mach wind tunnel.

To address these concerns, NASP officials plan to conduct over 20,000 hours of wind tunnel testing in Phase II of the program. These tests would include near full-scale wind tunnel tests at Mach 8, Additional Phase III engine qualification and certification tests are also being planned. Officials have rejected recommendations to improve hypersonic test facilities beyond what is already planned because of their cost (hundreds of millions of dollars) and long developmental lead times, Nevertheless, a recent National Research Council Air Force Studies Report considered the development of new hypersonic test facilities an urgent requirement.

NASP officials also believe that, based on their latest analysis and ground tests, the problem of large engine thrust changes or flameout (here collective y referred to as ''unstarts") will not occur outside the range of Mach 2 to 8. To control engine unstarts within this region, NASP contractors are planning to implement engine designs that could survive the unstart condition, control the unstart,

[1] Report of the Defense Science Board Task Force on the National Aerospace Plane (NASP), (Washington DC: Office of the Under Secretary of Defense for Acquisition, September 1988).

and be relit.[2] Safe mission aborts are also being designed. However, not all experts appear satisfied that the issue of combustion instabilities has been resolved.[3]

Some of the details of the NASP propulsion system are classified, preventing a complete discussion here. NASP has reduced the number of potential engine types to two and will select one (along with one airframe) in late 1990. At least in principle, the problem of designing a propulsion system that can accelerate a candidate X-30 airframe from a standing start to Mach 25 has been solved. How well theoretical expectations match up to experimental performance would be demonstrated in a flight test program.

In addition to its concern with the pace of materials development, DSB was concerned with the lack of knowledge characterizing the behavior of potential materials when fashioned into aircraft structures-some of which would be subjected simultaneously to severe aerodynamic and aerothermal stresses. The large uncertainties in theoretical predictions, and the lack of an adequate experimental data base appeared especially worrisome given the design requirement to minimize structural weight. In fact, the DSB stated that the knowledge base at the time of their report was such that a decision to proceed to Phase 111 ''is considered an unacceptable risk to program success and in fact could impose serious flight safety risks. "

NASP officials have stated that if the technology is not sufficiently mature to support a decision to begin Phase III they will not do so, but will continue technology development until a positive decision can be made. Furthermore, there are contingency plans in most of the technical risk areas identified by JPO. For example, in the structures and materials program, a heavier material closer to availability may be substituted for a less mature material. The increased weight could be accommodated at a cost in payload; an increase in vehicle size, weight, and cost; or the substitute of rocket propulsion for scramjet propulsion (which in turn will lower payload or increase the vehicle's gross weight). The tradeoff process is an ongoing one. Since the time of the DSB report, several higher risk materials have been eliminated from consideration for use in the X-30 and the Phase III decision has been delayed 1 year to provide additional time to mature key technologies.

[2] Between about Mach 1 and Mach 2 a shock wave must pass through the engine inlet without causing the engine to fl ameout. Changes in air flow patterns that cause a sudden loss of thrust must also be avoided. In addition, steady flow conditions must be maintained as engine operation is transformed from ramjet to scramjet mode. Unstarts can result in hazardous asymmetrical thrust conditions unless corrected quickly. They were a problem in early flights of the Au Free's high-altitude, Mach 3+, SK-71 "Blackbird" reconnaissance aircraft, but are now routinely controlled. In briefings and letters to OTA, Pratt & Whitney and Rocketdyne officials prowled details of their methods to avoid and control thrust instabilities. Both contractors supported the NASP JPO contention that instabilities would not be a severe problem despite the reservations expressed in the DSB report, and more recently by the Air Force Studies Board Report.

[3] For example, see *Hypersonic Technology for Military Applications*. . . . op. cit, footnote [4]