

**AUDIT  
REPORT**

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**X-34 TECHNOLOGY DEMONSTRATOR**

**March 30, 2000**

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National Aeronautics and  
Space Administration

**OFFICE OF INSPECTOR GENERAL**

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## **Acronyms**

FY	Fiscal Year
GAO	General Accounting Office
GPRA	Government Performance and Results Act
ISTP	Integrated Space Transportation Plan
NPD	NASA Policy Directive
NPG	NASA Policy Guidance
OIG	Office of Inspector General
OMB	Office of Management and Budget
RLV	Reusable Launch Vehicle
TRL	Technology Readiness Level

W

March 30, 2000

TO: A/Administrator

FROM: W/Inspector General

SUBJECT: INFORMATION: Audit of the X-34 Technology Demonstrator  
Report Number IG-00-029

The NASA Office of Inspector General has completed an audit of the X-34 Technology Demonstrator, one of NASA's faster, better, cheaper projects. The audit was completed prior to the current X-34 replanning effort, which NASA initiated in early 2000 to improve X-34 risk mitigation. We reviewed the status of the X-34 Technology Demonstrator Project in meeting technology requirements for the next-generation Reusable Launch Vehicle (RLV), and, as necessary, reviewed strategic planning for Space Transportation and the role of the X-34. We concluded that the Agency needs to improve management of Space Transportation technologies at the Agency, Enterprise, Center, and program/project levels. Specifically, NASA has not adequately performed strategic planning for the Space Transportation mission and needs to better state the next-generation RLV technology requirements. The Office of Aero-Space Technology has not issued an Enterprise Strategic Plan for the Space Transportation mission. Also, the Marshall Space Flight Center (Marshall) has not established mission-specific requirements for each of the 27 currently planned X-34 flights, nor properly documented, with a cost/benefit analysis, the requirement for these flights or the numerous changes to the proposed flight test program. Finally, basic program documentation for the X-34 Project Plan and the Future-X/Pathfinder Program has not been finalized and approved in a timely manner.

Without adequate strategic planning, NASA has less assurance that the technologies resulting from the X-34 Project will effectively support RLV needs. This deficiency also may extend the time required to develop needed technology, delaying realization of the launch savings anticipated from the next-generation RLV. Unless flight test requirements are properly documented there is no assurance the appropriate number of test flights are planned or that the test program content is the most cost-effective way to meet project objectives. Also, delays in preparing program documentation can adversely impact Agency management of technologies needed to reduce the cost of access to space and delay establishing approved program/project objectives and concepts to be used to manage these high-priority, costly programs.

## Background

The next-generation RLV concept is an attempt to reduce the cost of access to space. The original RLV was the Space Shuttle. NASA is now looking towards a second-generation RLV to reduce launch costs. The X-34 Project is one of the three original “stepping stones” (DC-XA, X-34, and X-33) in Marshall’s RLV Program and is the first in a series of planned *Pathfinder*<sup>1</sup> class technology demonstrators managed by Marshall’s new Future-X/ Pathfinder Program Office. Marshall manages the X-34 as part of its responsibility as the Lead Center for Space Transportation. The NASA Headquarters Office of Aero-Space Technology manages the overall Agency Space Transportation mission. The estimated cost of the present X-34 Project (including the \$18.6 million cost of the Fastrac engine<sup>2</sup> and approximately \$2 million in experiments) totals about \$186 million as of November 1999, including the option exercised in January 1999 for 25 additional flights. Project costs may increase further as a result of the current replanning effort.

During our review, NASA continued to work on a Space Transportation Architecture Study, including the latest phase, the Integrated Space Transportation Plan. Study results should be incorporated into the Aero-Space Technology Enterprise Strategic Plan. This study is being done in response to 1996 and 1997 Office of Management and Budget concerns regarding how NASA planned to reduce launch costs. Enterprise officials told us that during fiscal year 2000, they will perform extensive Space Transportation systems analyses to continue establishing the technology requirements for the next-generation RLV.

## Recommendations

We recommended that the Agency correct deficiencies in the Agency Strategic Plan and issue an Enterprise Strategic Plan and Lead Center Implementation Plan addressing space transportation that defines technology requirements, establishes an implementing strategy including technology metrics, and implements an appropriate cost/benefit analysis process. We recommended that Marshall revalidate X-34 flight test requirements to include the number and type of flights and the number of engines, delete any unneeded flights or engines, cancel plans for the expanded flight test program, and properly document X-34 management decisions. We also recommended that NASA place added emphasis on (1) compliance with Agency program documentation requirements to include promptly completing X-34 and Future-X/Pathfinder documentation and (2) on establishment of internal control procedures to ensure the timely preparation of future program documentation.

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<sup>1</sup> *Pathfinder* class technology demonstrators are technology-focused flight vehicle projects within the Future-X/Pathfinder Program and generally cost less than \$100 million each.

<sup>2</sup> Marshall is developing the Fastrac engine in-house, with contractor support, using currently available technology. Initiated in 1996, separately from the X-34 Project, Fastrac is to reduce launch costs by providing a low-cost booster for small payloads. Fastrac will be the main propulsion for the X-34 vehicle.

**Management's Response and OIG Evaluation**

Management concurred with all 16 recommendations, agreeing to implement recommended actions, which should significantly improve the overall effectiveness of Agency management of Space Transportation programs and projects. The actions should also help ensure that Agency and Enterprise Strategic Plans comply with Agency directives and more effectively address required technologies, that flight programs cost-effectively meet X-34 needs, and that basic program documentation is promptly finalized and approved. A summary of the status of all the recommendations is in the Executive Summary of the report.

**[Original signed by]**

Roberta L. Gross

Enclosure

Final Report on the Audit of the X-34 Technology Demonstrator

**FINAL REPORT**  
**AUDIT OF THE X-34 TECHNOLOGY DEMONSTRATOR**

W

March 30, 2000

TO: R/Associate Administrator for Aero-Space Technology  
DA01/Director, Marshall Space Flight Center

FROM: W/Assistant Inspector General for Auditing

SUBJECT: Final Report on the Audit of X-34 Technology Demonstrator  
Assignment Number A-HA-98-050  
Report Number IG-00-029

The subject final report is provided for your information and use. Please refer to the Executive Summary for the overall audit results. Our evaluation of your response is incorporated into the body of the report. The corrective actions taken or planned for recommendations 1 through 7, 9, 10, 11, 13, 14, and 15 were responsive, but the recommendations will remain open for reporting purposes until corrective action is completed. Please notify us when corrective action has been completed on these recommendations, including the extent of testing performed to ensure corrective actions are effective. The corrective actions completed on recommendations 8, 12, and 16 were responsive, and those recommendations are considered closed for reporting purposes.

If you have questions concerning the report, please contact Ms. Karen VanSant, Audit Program Director, Aero-Space Technology Audits, at (256) 544-1149, or Mr. Jim Linville, Auditor-in-Charge, at (256) 544-0971. We appreciate the courtesies extended to the audit staff. The final report distribution is in Appendix J.

**[Original signed by]**

Russell A. Rau

Enclosure

cc:

B/Chief Financial Officer

B/Comptroller

BF/Director, Financial Management Division

G/General Counsel

JM/Director, Management Assessment Division



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# NASA Office of Inspector General

IG-00-029  
A-HA-98-050

March 30, 2000

## X-34 Technology Demonstrator

### Executive Summary

**Background.** The next-generation Reusable Launch Vehicle (RLV) concept is an attempt to reduce the cost of access to space. The original RLV was the Space Shuttle. NASA is now looking towards a second-generation RLV to reduce launch costs. The X-34 Project is one of the three original “stepping stones” (DC-XA, X-34, and X-33) in Marshall Space Flight Center’s (Marshall’s) RLV Program and is the first in a series of planned *Pathfinder*<sup>3</sup> class technology demonstrators managed by Marshall’s new Future-X/Pathfinder Program Office. Marshall manages the X-34 as part of its responsibility as the Lead Center for Space Transportation. The NASA Headquarters Office of Aero-Space Technology manages the overall Agency Space Transportation mission. The estimated cost of the present X-34 Project (including the \$18.6 million cost of the Fastrac engine<sup>4</sup> and approximately \$2 million in experiments) totals about \$186 million as of November 1999, including the option exercised in January 1999 for 25 additional flights. Marshall is contemplating additional experiments and vehicle tests.

**Objectives.** The overall objective was to assess the status of the X-34 Technology Demonstrator Project, through fiscal year (FY) 1999, in meeting technology requirements for the next-generation RLV. To evaluate NASA’s planned use of X-34 technologies, it was necessary that our review also address strategic planning for Space Transportation and the role the X-34 was expected to play in meeting Agency Space Transportation technology requirements. Appendix A contains details on the objectives, scope, and methodology used for this audit.

**Results of Audit.** Management of Space Transportation technologies needs improvement at the Agency, Enterprise, Center, and program/project levels as illustrated below:

**Strategic Planning.** NASA has not adequately performed strategic planning for the Space Transportation mission. Specifically, improvements are needed at all

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<sup>3</sup> *Pathfinder* class technology demonstrators are technology-focused flight vehicle projects within the Future-X/Pathfinder Program and generally cost less than \$100 million each.

<sup>4</sup> Marshall is developing the Fastrac engine in-house, with contractor support, using currently available technology. Initiated in 1996, separately from the X-34 Project, Fastrac is to reduce launch costs by providing a low-cost booster for small payloads. Fastrac will be the main propulsion for the X-34 vehicle.

levels in preparing effective strategic plans and in procedures for managing those technologies (including the X-34) needed to develop the next-generation RLV and to reduce launch costs. Strategic planning deficiencies may result in the Agency not receiving technology benefits from the X-34 Project and may extend the time required to develop needed technology, delaying realization of launch savings anticipated from the next-generation RLV (see Finding A).

**Flight Test Requirements.** Marshall has not established mission-specific requirements for each of the 27 currently planned X-34 flights, including the option exercised prematurely by Marshall for 25 additional flights. Marshall has not properly documented, with a cost/benefit analysis, the requirement for these flights or the numerous changes to the proposed flight test program. Similarly, Marshall also has not justified the need for an additional 7-10 flights proposed as an expanded flight test program. In the absence of necessary documentation, there is no assurance the appropriate number of test flights are planned or that the test program content is the most cost-effective way to meet project objectives. Canceling the additional flights will save \$7 to 10 million (see Finding B).

**Program Documentation.** Basic program documentation (to include the X-34 Project Plan and the Future-X/Pathfinder Program Commitment Agreement and Program Plan), which is required prior to program implementation, had not been finalized and approved, although the Project and Program were initiated in 1995 and 1997, respectively. Drafts of the program documentation lacked necessary information to effectively implement Agency strategic plans. This delayed establishing approved program/project objectives and concepts to be used to manage these high-priority, costly programs and delayed formally defining the roles and responsibilities of NASA officials. Delays in preparing program documentation can adversely impact Agency management of technologies needed to reduce the cost of access to space, a key NASA goal (see Finding C).

**Recommendations.** NASA management should:

- Correct deficiencies in the Agency Strategic Plan and issue an Enterprise Strategic Plan and Lead Center Implementation Plan addressing space transportation that defines technology requirements, establishes an implementing strategy including technology metrics, and implements an appropriate cost/benefit analysis process.
- Revalidate X-34 flight test requirements to include the number and type of flights and the number of engines. Delete any unneeded flights or engines, cancel plans for the expanded flight test program, and properly document X-34 management decisions.
- Place added emphasis (1) on compliance with Agency program documentation requirements to include promptly completing X-34 and Future-X/ Pathfinder

documentation, and (2) on establishment of internal control procedures to ensure timely preparation of future program documentation.

**Management's Response.** Management concurred with all 16 recommendations, agreeing to implement recommended actions, which should significantly improve the overall effectiveness of Agency management of Space Transportation programs and projects. The actions should help ensure that Agency and Enterprise Strategic Plans comply with Agency directives and more effectively address required technologies, that flight programs cost-effectively meet X-34 needs, and that basic program documentation is promptly finalized and approved.

**Evaluation of Management's Response.** Management actions taken and planned are responsive to all of the recommendations.

## Introduction

The X-34 Project is part of the Future-X/Pathfinder Program within NASA's Space Transportation mission. The Headquarters Aero-Space Technology Enterprise and Marshall share responsibility for preparing strategic plans for the Space Transportation mission. The strategic planning process establishes the long-term direction for this mission and includes a vision of the future, goals, objectives, and implementing strategies.<sup>5</sup> During our review, NASA continued to work on a Space Transportation Architecture Study, including the latest phase, the Integrated Space Transportation Plan. Study results should be incorporated into the Aero-Space Technology Enterprise Strategic Plan when completed. This study is being done in response to 1996 and 1997 Office of Management and Budget (OMB) concerns regarding how NASA planned to reduce launch costs. Enterprise officials told us that during FY 2000 they will perform extensive Space Transportation systems analyses to continue establishing the technology requirements for the next-generation RLV. Additional background information is in Appendix B.

In 1995, Marshall selected and awarded a cooperative agreement<sup>6</sup> to the team of Orbital Sciences Corporation (Orbital) and Rockwell International, Inc., to design, build, and fly the X-34 unmanned test vehicle. The proposed vehicle was to be an orbital spacecraft that could be put into commercial production upon completion of the demonstration program. However, in early 1996 the industry partners withdrew from the partnership due to a number of factors including changes in the projected business profitability. Shortly thereafter, on March 27, 1996, Marshall issued NASA Research Announcement 8-14<sup>7</sup> and subsequently awarded Orbital a firm-fixed-price contract for a smaller, suborbital X-34 vehicle that is similar in some respects to Orbital's *Pegasus* expendable launch vehicle, but incorporates new technologies. The basic contract provided for a test article (A1), one flight vehicle (A2), and only two flights at a total cost of about \$50 million, excluding the cost of the Fastrac engine.<sup>8</sup> However, in January 1998, NASA exercised options for a Characterization and Validation effort<sup>9</sup> and a third flight test vehicle (A3).<sup>10</sup> Subsequently, in January 1999, Marshall exercised an option for an additional flight program (25 more flights).

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<sup>5</sup> NASA's long-term goal to provide safe and affordable space travel to enable research and human expansion relies on the development of a reusable launch vehicle and/or significant improvements to the Space Shuttle.

<sup>6</sup> Under the terms of the cooperative agreement partnership, NASA and the industry partners would each provide half (50/50) of the \$150 million estimated cost.

<sup>7</sup> The NASA Research Announcement solicited proposals for applied research that offered new and innovative solutions to enhance key technologies applicable to future RLV's. The proposals could address a demonstrator vehicle, technology test bed, or RLV technology flight experiments.

<sup>8</sup> Marshall developed the Fastrac engine in-house for small payload launchers.

<sup>9</sup> The Characterization and Validation Effort is intended to provide risk mitigation to the X-34 Project. It provides for additional hardware, including a second powered vehicle, permitting early validation of critical X-34 systems and demonstration of vehicle performance and maturity.

<sup>10</sup> The first X-34 vehicle, A1, was originally a test article and was not scheduled to fly. However, modified as the A1A vehicle, it will be used for ground tests, including tow tests, and will perform the unpowered portion of the X-34 flight tests using the wing and other components "borrowed" from the A3 vehicle.

The X-34 Project will demonstrate technologies necessary for a next-generation RLV. The present X-34 vehicle is a suborbital, rocket-powered, Mach-8-capable flight demonstrator testbed intended to enhance U.S. commercial space launch competitiveness through the development and demonstration of key technologies applicable to future RLV's. The X-34 will demonstrate flexible integration capability and operability to include a high-flight rate,<sup>11</sup> autonomous flight operations, safe abort capability, landing in cross winds up to 20 knots, flights through rain and fog, and a recurring flight cost of about \$500,000.<sup>12</sup>

Several aspects of the X-34 have undergone change since the X-34 Project (formerly "Program") was initiated in 1995. These continual changes have had a significant effect on the X-34 Project's cost, schedule, and potential results. For example, although the X-34 first flight (current project) was to have occurred on November 21, 1998, the first flight is now planned for March 2000 or later. The proposed X-34 flight test program was still undergoing change (flight trajectories, etc.) as of November 1999. It is anticipated there will be still more changes in the Project.

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<sup>11</sup> The flight rate is equivalent to 25 flights per year and 2 flights within 24 hours.

<sup>12</sup> The \$500,000 does not include NASA in-house costs, range costs, or certain contractor costs. Actual cost is estimated to be more than \$1 million per flight.

## **Findings and Recommendations**

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### **Finding A. Strategic Planning for Space Transportation**

NASA has not adequately performed strategic planning for the Agency's Space Transportation mission, which includes the X-34 Project. Specifically, the Office of Aero-Space Technology and Marshall have not: (1) defined technology requirements qualitatively and quantitatively for the next-generation RLV; (2) established appropriate implementing strategies to include metrics, performance indicators, and an evaluation process for measuring and reporting technology progress; (3) routinely performed cost/benefit analyses of Space Transportation technology initiatives and alternatives; or (4) prepared essential strategic planning documents. Neither the Office of Aero-Space Technology nor Marshall adequately followed Agency requirements regarding strategic planning. Strategic planning deficiencies may result in the Agency receiving technology from the X-34 Project that will not be used and may extend the time required to develop needed technology and/or delay realization of the launch savings anticipated from the next-generation RLV.

#### **Federal and Agency Requirements**

**Government Performance and Results Act.** The Government Performance and Results Act (GPRA), passed by Congress in 1993, requires Federal agencies including NASA to develop an agency 5-Year Strategic Plan and update it at least every 3 years and to prepare an annual agency Performance Plan and submit an agency Performance Report. NASA prepared the Agency's first GPRA Performance Plan in September 1998 (for FY 1999). NASA's first annual GPRA Performance Report (for FY 1999) is due to the President and Congress on March 31, 2000. A key GPRA requirement is that performance plans include appropriate performance targets that are measurable for the fiscal year reported. Details on GPRA requirements are in Appendix C.

**NASA Strategic Management Handbook.** NASA's Strategic Management Handbook (NASA Procedures and Guidelines (NPG) 1000.2), dated October 1996, documents the Agency's policies, processes, guidelines, and responsibilities for strategic management as required by GPRA. The Handbook requires that all Agency strategic plans, the NASA Strategic Plan, Enterprise Strategic Plans, and lower level strategic planning documents include specific elements to ensure consistency and meet GPRA requirements. Agency strategic plans articulate what NASA does, who its customers are, NASA's goals, and how it will achieve them. Agency strategic plans should have mission-critical but achievable goals, specific and measurable objectives, implementing strategies describing how the goals and objectives will be achieved, performance targets and appropriate metrics for measuring progress. The Handbook states that Enterprise strategic plans must be reviewed annually and updated as necessary. Lower level strategic planning documents such as Center Implementation Plans, supported by program/project plans and Center of Excellence or Lead Center Plans, should prescribe milestones, resource requirements, schedules, and performance criteria at both the program and task level. Details on the NASA Strategic Management Handbook are in Appendix C.



## NASA Strategic Planning

At the Agency, Enterprise, and Center levels, strategic planning documents for the Agency's Space Transportation mission did not adequately comply with Agency requirements, and some key Enterprise and Lead Center plans had not been prepared. There has been continuing congressional, OMB, and General Accounting Office concerns regarding the adequacy of NASA's strategic plans for Space Transportation. (See Appendix D for additional details on these concerns.) The NASA Strategic Management Handbook states that "NASA must be able to monitor its success in achieving each objective." Space Transportation technology management extensively involves the development of hardware (engines, composite structures, composite/cryogenic fuel tanks, thermal protection systems, avionics, etc.) for new boosters/launchers. NASA has been performing hardware research and development for 4 decades. Therefore, the Aero-Space Technology Enterprise and Marshall should have established more definitive strategic plans that included specific data on the technologies required to reduce launch costs and appropriate metrics to measure technology progress. The NASA Technology Plan, dated December 1998, did include some broad technology requirements and technology "challenges" for the Space Transportation mission. However, they were not included in the strategic plans.

The handbook establishes requirements for strategic planning documents and requires roadmaps,<sup>13</sup> specific objectives, and implementing strategies to include performance targets as well as metrics and an evaluation process to assess progress towards meeting objectives. However, strategic planning documents for Space Transportation do not include specific information on the technology requirements, including the technology "gap",<sup>14</sup> necessary to significantly reduce launch costs or appropriate metrics to measure technology progress. Appropriate metrics and an evaluation process for measuring and reporting annual progress are not established and reflected in strategic plans for Space Transportation. It is essential that appropriate technology metrics be established for each RLV core technology<sup>15</sup> requirement. Although existing planning documents frequently use the term "technology," none used the standard NASA metric, "Technology Readiness Level,"<sup>16</sup> to identify current technology status, to define the needed technology requirement, or to report technology progress. (Additional information on metrics is in Appendix E). NASA's Space Science and Earth Science Enterprises used the term Technology Readiness Level (TRL) in their Technology Strategy documents for 1998 or 1999. Although the Office of Aero-Space Technology did not use TRL's in strategic planning documents for Space Transportation, it did use TRL's as a metric in managing aviation technologies in the Level II Plan for the Advanced Air Transportation Technologies Project, dated May 1999.

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<sup>13</sup> The Handbook requires that NASA and Enterprise strategic plans include a one page "Strategic Roadmap." Roadmaps are to show how NASA plans to attain goals, objectives, and milestones.

<sup>14</sup> Difference between current technology capability and the more advanced technology requirement.

<sup>15</sup> RLV core technologies include avionics, composite structures, composite/cryogenic tanks, thermal protection systems, propulsion, and aircraft-like operations.

<sup>16</sup> Per the NASA Technology Plan, dated December 1998, the metric Technology Readiness Level specifies the maturity of a technology from 1 (not mature) through 9 (mature).

Deficiencies in the Agency, Enterprise, and Center strategic planning documents included the following:

- Objectives in the 1998 and 1999 strategic plans generally meet the criteria of the handbook, but were not measurable due to the lack of appropriate implementing strategies.
- Implementing strategies did not:
  - state how the goals and objectives will be achieved,
  - provide an investment strategy that addressed resource requirements, and
  - provide metrics that identify performance indicators or the evaluation process to be used to measure progress.

As a result of the deficiencies, NASA is unable to adequately monitor its success overall and the contribution of the X-34 Project was not clear.

**Agency Level.** NASA Strategic Plans for FYs 1996, 1998,<sup>17</sup> and 1999,<sup>18</sup> and the NASA FY 1999 Performance Plan did not adequately define the role of the X-34 in meeting Space Transportation technology requirements for the next-generation RLV. The Plans, prepared by the Office of Aero-Space Technology, do not state how, when, or if the technologies addressed by the X-34 Project will be used to satisfy Space Transportation technology needs. The Agency's FY's 1998 and 1999 strategic plans for Space Transportation did not provide appropriate implementing strategies stating how goals and objectives would be achieved and did not include appropriate implementing strategies with performance indicators and an evaluation process to measure progress and to address resource requirements. The plans state goals, objectives, and related activities, but these related activities (that is, the X-33 and X-34) also are not readily measurable. The FY 1999 NASA Performance Plan contains goals, objectives, and performance targets. However, the performance targets were not in quantified, measurable metrics, and the specific contribution of the X-34 and other Space Transportation programs/ projects to goals and objectives was not clear. Deficiencies in the Agency strategic plans adversely affected the strategic planning process at all levels. Additional details on specific weaknesses in the Space Transportation (access to space) portion of the Agency's FY's 1998 and 1999 Strategic Plans and FY 1999 Performance Plan are provided in Appendix F.<sup>19</sup>

**Enterprise Level.** The Office of Aero-Space Technology did not issue an Enterprise Strategic Plan addressing the Space Transportation mission pursuant to the NASA Strategic Management Handbook. The Enterprise was assigned responsibility for the Space Transportation mission in February 1997, but had not issued an Enterprise strategic plan on this high-priority mission as of November 1999, more than 2 years later. The Enterprise last issued a Strategic Plan in April 1995. The Office of Space Access and Technology, which was previously responsible for

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<sup>17</sup> There was no 1997 plan.

<sup>18</sup> The FY 1999 Plan is the FY 1998 Plan with 1999 Interim Adjustments.

<sup>19</sup> The NASA Strategic Management Handbook, dated October 1996, implements GPRA; we used the handbook as audit criteria to evaluate the NASA FY 1998 and FY 1999 Strategic Plans.

NASA's Space Transportation mission from 1994 to 1997, also did not issue an Enterprise strategic plan on Space Transportation. As a result, there has been no Enterprise strategic plan on the critical Space Transportation mission in at least 5 years.

Enterprise officials acknowledged they had not issued a specific Enterprise Strategic Plan since 1995, but stated three documents issued in 1997 and 1998, cumulatively, would satisfy requirements for a Plan.<sup>20</sup> Our review of the three strategic planning documents issued by the Aero-Space Technology Enterprise showed that together, they would not adequately serve as an Enterprise Strategic Plan. The NASA handbook states that Enterprise Strategic Plans must elaborate on their respective missions and goals, as presented in NASA's Strategic Plan, by providing more detailed objectives, implementing strategies, and a description of the key elements, programs, and/or processes. Documents the Enterprise issued did not adequately meet these criteria.

For example, Enterprise documents should have provided specifics and details for achieving the Agency objective to "Complete research and development (during the period 1998 thru 2002) to enable U.S. industry to launch to Low Earth Orbit at \$1,000 /lb." as stated in the NASA 1998 Strategic Plan. Enterprise plans also should have established an implementing strategy for achieving this objective to include appropriate metrics (performance indicators) and should have defined an evaluation process for monitoring and reporting research and development progress on needed technologies over the 5-year period. Enterprise documents did neither. Details not provided by the Enterprise include specifics on the required technologies, including current status and the technology "gap" of each technology being pursued by research and development; and the metric (such as TRL's) for monitoring technology progress as well as cost/benefit data -- the benefit to be provided by each of the Enterprise's initiatives. Enterprise documents did not make clear the contribution (benefit) of the X-34 toward this objective.

**Center Level.** Consistent with the Agency's decentralization of program/project management, the Associate Administrator for Aeronautics (now Aero-Space Technology) and the Associate Administrator for Space Flight jointly designated Marshall the Lead Center for Space Transportation in February 1997. The Associate Administrators directed that Marshall "will develop a long-range technology plan that fully utilizes the capabilities of other NASA Centers, other Government agencies, academia, and industry. The plan will be developed consistent with Headquarters program and investment strategies and guidance." However, as of November 1999, Marshall, as the Lead Center, had not prepared the required implementation plan.

Although Enterprise officials told us we would find the details and specifics missing from the Agency and Enterprise strategic planning documents at the Center level, existing Center-level documents prepared by Marshall including the Center Implementation Plans and Annual Reports for FY's 1996 through FY 1999 also lacked such details. Necessary detail implementing the NASA and Enterprise Strategic Plans, such as approximate qualitative and quantitative technology requirements, technology "gaps" that the program/project would address, or appropriate implementing strategies including performance indicators, metrics, and an evaluation

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<sup>20</sup> The three Enterprise strategic planning documents reviewed were "Three Pillars and 10 Goals," "Roadmaps to the Future," and "Progress Report for 1997-1998."

process for measuring and reporting technology progress were missing from the Future-X/Pathfinder Program Plan (draft) and the X-34 Project Plan (draft). (See Finding C for details.)

### **Cost/Benefit Analyses**

The Aero-Space Technology Enterprise strategic planning process for Space Transportation does not include appropriate use of cost/benefit analyses to support management decisions, help prioritize technology requirements, and ensure resources are utilized in the most cost-effective manner. The NASA handbook assigns the Enterprise Associate Administrator responsibility to develop an Enterprise Strategy, to include a Long-Term Investment Strategy. Similarly, NPG 7120.5A, "NASA Program and Project Management Processes and Requirements," dated April 3, 1998, tasks Enterprise Associate Administrators to formulate programs and allocate resources. The NPG requires that a system analysis and life-cycle costing analysis be performed during program formulation to produce feasible concepts and explore a wide range of implementation options. The value of a Space Transportation technology roadmap, depicting how NASA will attain Space Transportation goals, depends heavily on the extent to which it effectively links the cost of a given initiative or alternative to the technology benefit expected to be received. However, the Enterprise's strategic planning process for Space Transportation does not include an effective process for routinely identifying, measuring, and documenting the technology benefit to be provided by each initiative. The Enterprise should use cost/benefit analyses to prioritize technology requirements and ensure cost-effective use of resources in attaining technology benefits, to produce feasible concepts and explore options, and to develop an appropriate investment strategy for Space Transportation.

Enterprise officials acknowledged they have not routinely used cost/benefit analyses to document support for Space Transportation technology management decisions. Instead, they used a "facilitated expert judgment"<sup>21</sup> process to support management decisions. However, Enterprise officials did not provide documentation on that process or on specific process results for Space Transportation, stating the process was largely undocumented. While actions such as the "facilitated expert judgment" process may contribute to management of Space Transportation technologies, the basis for management decisions should be properly documented. Further, the evaluation process inherent in a cost/benefit analysis can contribute significantly to the validity of decisions for prioritizing technology requirements. However, the existing, undocumented process does not adequately implement the requirements of NPG 7120.5A. As a result, Strategic planning documents generally do not identify the specific technology contribution, in quantitative or qualitative terms, to be provided by elements of the RLV Program such as the X-34 Technology Demonstrator. Enterprise plans for Space Transportation would be improved by using an appropriate, documented cost/benefit analysis to prioritize technology needs and to help ensure that scarce Agency resources are utilized in the most effective manner. The lack of an effective, documented cost/benefit analysis process further undermines validity of the Agency strategic planning process for Space Transportation.

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<sup>21</sup> The process was defined by Office of Aero-Space Technology officials as a roundtable dialogue at meetings attended by NASA, industry, and other interested parties.

The Enterprise, with Marshall assistance, drafted a “Space Transportation Investment Strategy” document, dated September 1997, in response to OMB direction that NASA submit a launch plan. This document acknowledged the lack of an appropriate investment strategy for Space Transportation, stating “Up to now, the agency has not had a systematic approach to defining, prioritizing and implementing technology development that addresses both (Shuttle and new RLV) needs as well as other future technology requirements.” However, this strategy document generally addressed Space Transportation alternatives only at a high level (that is, Shuttle upgrades as opposed to new RLV technology or other options) and unfortunately did not result in the Enterprise establishing an appropriate cost/benefit analysis process at the technology level. In September 1999, Marshall officials stated NASA was considering a proposed process for determining (1) the “goodness” of a technology product produced within each Enterprise and (2) the extent of progress toward strategic goals. The proposed process, which includes the use of Technology Readiness Levels, may eventually be utilized by the Enterprise and Marshall to provide improved management of space transportation resources.

### **Contributing Factors to Strategic Planning Problems**

**Waiting on Industry.** NASA’s effort to purchase commercially available space goods and services from the private sector, in compliance with the National Space Transportation Policy, has contributed to the lack of identified technology requirements. Specifically, because NASA anticipates being a customer and buying space launch services from the private sector, NASA officials deferred to the private sector to define specifications and requirements, including technology requirements, for the next-generation RLV. As a result, NASA’s implementation of the National Space Transportation Policy focused on private industry requirements and did not properly recognize Agency requirements for access to space.<sup>22</sup>

We believe NASA’s implementation of the Space Transportation Policy<sup>23</sup> guidance in 1994 placed too much dependence on industry to identify requirements and insufficient recognition of the Agency’s needs to carry out assigned missions in science and human exploration of space. The Policy tasked NASA to “... be the lead agency for technology development and demonstration for next generation reusable space transportation systems...” As the Lead Government Agency responsible for civil Space Transportation, NASA should, with industry input, take the lead in defining technology requirements for the next-generation RLV, recognizing both industry and NASA requirements.

**Consensus.** NASA officials told us a major stumbling block to Agency preparation of an acceptable strategic plan for Space Transportation in recent years has been a lack of consensus within the Agency and between NASA and private industry on the future of Space Transportation and the specific solution to high launch costs. The officials stated some elements of the Agency were not receptive to anything less than a Shuttle-derived, next-generation RLV. Marshall officials told us that the Space Transportation Architecture Study became bogged down in the

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<sup>22</sup> Our prior audit of the X-33 Advanced Technology Demonstrator (OIG Audit Report IG-99-001, “X-33 Funding Issues,” dated November 3, 1998) determined NASA’s failure to properly recognize Agency requirements as bona fide needs was a contributing factor to significant financial management deficiencies on the X-33 program.

<sup>23</sup> President Clinton issued the National Space Transportation Policy on August 5, 1994.

second quarter of calendar year 1999, during our review, due to a lack of consensus within NASA regarding the future plans for Space Transportation. One difficulty was reaching agreement on the extent to which Agency launch requirements, as opposed to industry requirements should be recognized. As a result, OMB officials, who had been asking NASA for an appropriate Space Transportation strategic plan (launch plan) for more than 2 years, advised NASA that unless the Agency submitted an acceptable plan for Space Transportation, the \$1.2 billion funding “wedge”<sup>24</sup> for FY’s 2001 through 2004 would not be included in the Agency’s Space Transportation budget. The possible loss of more than \$1 billion in Space Transportation funding, if NASA did not provide OMB an acceptable strategic plan, precipitated additional effort by NASA and Marshall to initiate improvements in Space Transportation strategic plans. The results of the ongoing Space Transportation Architecture Study (and the current study phase, the Integrated Space Transportation Plan) may provide more definitive technology requirements and “roadmaps” for NASA’s Space Transportation requirements. (Additional information on the ongoing Space Transportation Architecture Study is in Appendix G).

## **Recommendations, Management's Response, and Evaluation of Response**

**The Associate Administrator for Aero-Space Technology, in coordination with the Marshall Center Director, should:**

- 1. Improve Agency strategic planning documents to ensure they comply with requirements of the NASA Strategic Management Handbook and GPRA. At a minimum, specify goals that support mission statements; results oriented, measurable objectives; and implementing strategies that articulate how the goals and objectives will be achieved, including metrics to be used as performance indicators and a process for evaluating results.**

**Management’s Response.** Concur. Agency strategic planning for space transportation has been significantly enhanced with the development of the Integrated Space Transportation Plan (ISTP). The specific goals, roadmaps, and implementing strategies that were defined through the ISTP development process will be reflected, as appropriate, in future versions of agency documentation. Specific performance metrics that contribute to the objective and provide a meaningful measure of progress toward meeting the safety, reliability, and affordability objectives will be identified and included in the annual NASA Performance Plan. These changes will be reflected in the next Agency plan, scheduled for release in the fall of 2000. The complete text of the comments is in Appendix I.

**Evaluation of Management’s Response.** The actions taken and planned by management are responsive to the recommendation. The recommendation is resolved, but will remain undispositioned and open until agreed-to corrective actions are completed.

- 2. Prepare an Enterprise strategic plan, in compliance with the NASA Strategic Management Handbook and GPRA, and establish procedures to review the plan**

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<sup>24</sup> Separate budget line item for Future Space Launch Development.

**annually, and update it as required. The plan should identify technology requirements, as well as an implementing strategy, to include metrics and evaluation processes to measure technology progress.**

**Management's Response.** Concur. The Enterprise is developing a detailed strategic plan that will include the space transportation goal, objectives, performance metrics, and implementing strategies. The Enterprise plan will be released in conjunction with the Agency plan in the fall of 2000. The plan will be reviewed on an annual basis and updated as required (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management are responsive to the recommendation. The recommendation is resolved but will remain undispositioned and open until agreed-to corrective actions are completed.

- 3. Implement an appropriate cost/benefit analysis process to support and document the rationale for management decisions on Space Transportation, and develop an investment strategy to implement Space Transportation strategic plans and to help ensure effective use of resources.**

**Management's Response.** Concur. The ISTP development process implemented a rigorous and thorough method of defining and understanding requirements and of evaluating and recommending investment options. Through this process, NASA consolidated technology requirements from industry, as well as the Agency, and prioritized them based on the importance of improving safety, followed by cost and applicability to multiple industry concepts. The ISTP process implemented an analytical hierarchy methodology of evaluating technology investment options that was based on architecture-level economic metrics. Each technology was subjected to a cost/benefit analysis. Each technology was also ranked based on potential payoff to cost, safety, and technical risk. The results of the integration and analysis process served as the foundation of a series of roadmaps that illustrate the development needed to advance the TRL's of key technologies (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management are responsive to the recommendation. Subsequent to receipt of management's comments, we requested and management agreed to provide us an ISTP update status briefing and copies of additional pertinent documentation. The recommendation is resolved but will remain undispositioned and open until agreed-to corrective actions are completed.

- 4. Define technology requirements for the next-generation RLV using metrics that will facilitate measuring and reporting incremental progress. Consideration should be given to using Technology Readiness Levels as one Space Transportation metric.**

**Management's Response.** Concur. As stated in the response to Recommendation 3, NASA has, through the ISTP development process, performed a comprehensive and detailed analysis of RLV concept requirements and has established a bottoms-up development approach as demonstrated by its integrated roadmap structure. Each roadmap illustrates a path to develop the necessary technology from its existing TRL to at least a flight demonstration TRL (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management are responsive to the recommendation. As stated earlier, management agreed to provide us an ISTP update status briefing and copies of additional pertinent documentation. The recommendation is resolved but will remain undispositioned and open until agreed-to corrective actions are completed.

- 5. The Marshall Center Director should issue a Lead Center Implementation Plan on Space Transportation. The plan should identify requirements, objectives, and implementing strategies that are specific and measurable and should identify metrics that include performance targets and the evaluation process for measuring annual performance.**

**Management's Response.** Concur. The Marshall Space Transportation Directorate has created an integrated strategic plan to implement its charter and accomplish its programmatic assignments. The "Space Transportation Directorate 2010: Corporate Strategy" Volume I, March 2000, is a 10-year, integrated plan designed to focus the Directorate on the critical activities as Marshall and its partners proceed to accomplish NASA's goals of enabling future safe, reliable, and affordable access to space. The plan is intended to provide guidance and direction for the decisions and actions of the Space Transportation Team. To ensure that the Space Transportation Directorate successfully accomplishes this strategy, specific action plans will be developed for each of the core strategies. Each action plan will include a statement of measurable and qualitative outcomes, significant partners, key decisions and actions, responsible personnel, and a timetable for completion. The action plans will be focused on the next 3 to 5 years and will be updated at least annually. Upon completion in June 2000, these plans will be included as Volume II of the Corporate Strategy (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management are responsive to the recommendation. The recommendation is resolved but will remain undispositioned and open until agreed-to corrective actions are completed.



## **Finding B. X-34 Project Flight Test Requirements**

Marshall had neither established mission-specific requirements for each X-34 flight test nor properly documented, with a cost/benefit analysis, a requirement for the 27 flights currently on contract. Additionally, Marshall has not properly documented the rationale for substantial changes, including the proposed addition of 7 to 10 more flights, to the X-34 flight test program. This condition exists because Marshall and the Office of Aero-Space Technology established the number of X-34 flights without performing a cost/benefit analysis and have not revalidated flight test requirements. Consequently, 25 flights do not adequately support Project objectives and NASA has no assurance that the appropriate number of test flights are planned or that test program content (number of X-34 vehicles, sites, powered vs. unpowered flights, etc.) is the most cost-effective to meet Project objectives. Each flight test costs NASA about \$1 million.

### **Agency Guidance**

Neither NASA nor Marshall has issued specific guidance on the conduct of X-vehicle flight test programs such as the X-34. However, the NASA Systems Engineering Handbook, SP-6105, dated June 1995, provides "... a generic description of systems engineering as it *should* be applied throughout NASA"<sup>25</sup> [emphasis added] and includes guidance on the methods and techniques, including testing, that can be used to verify that project requirements have been met. This engineering handbook defines verification as "... the process of confirming that deliverable ground and flight hardware and software are in compliance with functional, performance, and design requirements. The verification process, which includes planning, requirements definition, and compliance activities, begins early and continues throughout the project life cycle."

NPG 7120.5A, "NASA Program and Project Management Processes and Requirements," dated April 3, 1998, establishes definitive requirements for managing Agency programs and projects such as the X-34. The NPG contains requirements that program/project managers properly document management decisions. For example, the NPG states "A system for documentation and tracking of risk decisions shall be implemented." The NPG also establishes certain requirements for managing risk.

### **Flight Tests Requirements**

The X-34 contract requires a Basic Flight Test Program of two flights. However, on January 22, 1999, Marshall exercised contract Option 1, Optional Flight Test Program for 25 additional flights at a cost of \$10,095,798. This increased the total number of flights under contract to 27. In accordance with NASA Research Announcement 8-14 and the X-34 contract, the parameters for X-34 flight tests include altitudes up to 250,000 feet and speeds up to Mach 8. In addition to testing RLV technologies embedded in the X-34 vehicle and a variety of experiments, the project

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<sup>25</sup> The Handbook states, "The objective of systems engineering is to see to it that the system is designed, built, and operated so that it accomplishes its purpose in the most *cost-effective* way possible, considering performance, cost, schedule, and risk." [emphasis added]

is to demonstrate “aircraft like” operability,<sup>26</sup> that is, quick turnaround averaging 2 weeks between flights, with a “surge” capability of 2 flights in 24 hours as defined in the draft X-34 Project Plan. As of October 1999, Marshall had separated the 27 flight X-34 flight test program into four segments: unpowered flight segment (5 flights), first powered envelope expansion<sup>27</sup> segment (7 flights), operability segment (7 flights including one contingency flight), and a final maximum envelope expansion segment, with experiments, (8 flights).

**Mission-Specific Requirements.** The X-34 contract statement of work requires that the contractor<sup>28</sup> develop requirements compliance verification methodologies, which permit the linking of NASA mission requirements to each test flight and to the verification process. However, the contractor has not yet completed verification methodologies or flight software on the Optional Flight Test Program because NASA has not yet established the mission-specific requirements for each flight test.

Because Marshall had not determined the mission-specific requirements of the additional 25 flights, they were all identical 2.5 mach flights without additional speed, altitude, or other performance mission requirements. The 25 “baseline” flights did not meet Project objectives, which include testing the X-34 at speeds up to mach 8 and altitudes up to 250,000 feet. On November 14, 1996, Marshall negotiated modification No. 2 to the X-34 contract which added a pool of 100,000 labor hours to the contract in anticipation of the additional contractor effort that would be required to develop necessary flight control software and to perform additional tasks to support mission requirements, once Marshall identified them. As of November 1999, Marshall still had not established the mission-specific requirements for each flight.

**Contingency Flights.** During our audit, Marshall officials acknowledged that the 27 test flights include 1 or 2 “contingency”<sup>29</sup> flights. A draft X-34 flight test schedule identified at least one contingency flight to support the 24-hour turn around (two flights in 24 hours) portion of the existing “operability” flight test segment, in the event the first attempt is not successful. The need for this contingency flight does not appear warranted because the six-flight “operability” segment of the flight test program offers other opportunities to attempt a 24-hour turnaround. Until Marshall reviews and revalidates all X-34 flight test requirements, the Center should not include such contingency flights in the X-34 flight test program.

**X-34 Testbed for Space Transportation Experiments.** The X-34 Project objectives include use of the X-34 vehicle as a testbed to flight test Space Transportation technologies. In addition to soliciting proposals for the X-34 test vehicle, NASA Research Announcement 8-14 also solicited proposals for experiments to fly on the X-34 vehicle. Marshall has approved at least 10 experiments that it will fund<sup>30</sup> and has identified a requirement for 15 flights to carry out these

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<sup>26</sup> “Aircraft like” operability is defined in the X-34 Project Plan as a quick turnaround averaging 2 weeks between flights, with a “surge” capability of 2 flights in 24 hours.

<sup>27</sup> Envelope expansion refers to gradual increases in vehicle performance (speed and altitude) in each subsequent flight.

<sup>28</sup> The contractor is Orbital Sciences Corporation.

<sup>29</sup> A contingency flight is an additional, back-up flight in the event the first attempt is not successful.

<sup>30</sup> Marshall had an initial \$2 million budget for the experiments, but more funding will be needed to support the composite tank experiment.

experiments. Multiple experiments can be satisfied concurrently by a single flight. However, the current flight test plan of 27 flights will satisfy only about 3 or 4 of the 15 required experiment flights because the speed and altitude on many of the 27 flights is not sufficient to meet experiment requirements. Marshall hopes the initial X-34 flight tests will generate interest within the U. S. launch community to use the X-34 to fly additional experiments.

**Fastrac Engine Requirements.** Requirements for the Marshall-developed Fastrac<sup>31</sup> engine used on the X-34 vehicles are dependent on the number of X-34 flights required to meet X-34 Project objectives. Marshall has contracted for 4 engines to satisfy the planned<sup>32</sup> 22 powered flights,<sup>33</sup> at a total of more than \$10 million.<sup>34</sup> Because Marshall has not yet revalidated the number of powered flights needed, and further engine testing is planned, Marshall should reassess the number of needed engines.

**Changes in Proposed X-34 Project Flight Test Program.** Since the contract was awarded in FY 1996, the proposed X-34 Project flight test program has undergone continuous change as a result of both internal and external factors. Some of the changes Marshall made are illustrated below:

- Twenty-five flights were added in the optional flight test program.
- The number of unpowered flights increased from 1 to 5 from August 1996 through August 1999. Although the X-34 Flight Test Planning Group determined in 1998 that a total of three unpowered flights were required, Marshall now plans to have five unpowered flights. The increase in unpowered flights is primarily related to a U.S. Air Force decision that the X-34 powered flights could not be made at White Sands Missile Range. As the number of unpowered flights increased, the number of powered flights decreased from 27 to 22.
- Twenty X-34 tow test runs<sup>35</sup> using the A1A vehicle were added. The tow tests are considered risk mitigation and are intended to demonstrate vehicle landing gear, steering, etc. are acceptable prior to actual flight.
- Marshall has decreased the number of flights needed to demonstrate the “operability” of the X-34, from 25 flights in 12 months, to only 6 flights in 3 months.

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<sup>31</sup> Marshall is developing the Fastrac engine in-house, with contractor support, using currently available technology. Initiated in 1996, separately from the X-34 Project, Fastrac is to reduce launch costs by providing a low cost booster for small payloads. Fastrac will be the main propulsion for the X-34 vehicle.

<sup>32</sup> Per current plans, five of the 27 flights are to be unpowered.

<sup>33</sup> The number of required engines depends on the number of flights and the expected life of the engine. Marshall estimated that each engine may be used for about seven flights.

<sup>34</sup> Marshall officials told us the 4 flight engines cost about \$1 million each and that the 18 engine refurbishments totaled about \$6 million. The engines generally must be refurbished after each use.

<sup>35</sup> The first X-34 vehicle assembled, A1, will be used for the tow tests. A1 will be towed across the White Sands Missile Range to verify functioning of components including the landing gear and steering.

- There originally was to be a test article (A1) and one flight vehicle (A2). This requirement changed, incrementally, to three flight vehicles (A1A, A2, and A3). A1A will be used only for tow tests and the five unpowered flights.

Marshall's X-34 Project Office did not properly document the rationale for such changes. Specifically, Marshall did not document the available alternatives or options to meet X-34 requirements, including their benefits and disadvantages or the rationale for the options Marshall selected. Substantial changes such as these should also be supported by cost/benefit analyses. In the absence of adequate support for the proposed X-34 flight test program, NASA has no assurance that all 27 flights are needed. Each flight will cost NASA about \$500,000<sup>36</sup> under the fixed-price contract.

**Expanded Flight Test Program.** Marshall has proposed an expanded flight test program, which will add up to 10 flights to the planned 27 X-34 flight tests. Marshall identified FY 2001-2003 funding requirements for 7 to 10 additional flights at about \$1 million each. Marshall officials told us these flights are needed to support the flight requirements of the 10 experiments identified thus far using the X-34 vehicle as a flight testbed. Marshall has scheduled eight flights for the A3 vehicle<sup>37</sup> on which the experiments will fly. However, Marshall officials stated that it is likely only three to five of the eight A3 flights will attain the speed and/or altitude needed to support the experiments. For this reason, Marshall has identified the need for additional flights under the expanded flight test program. Marshall should cancel the proposed expanded flight test program, until a reassessment of all X-34 flight test requirements has been completed. Canceling the proposed 7 to 10 additional flights would save up to \$10 million. The extent of any savings is contingent on the results of Marshall's reassessment of X-34 flight test requirements.

**Use of Other Flight Test Vehicles.** Marshall does not plan to use the A2 vehicle, which is expected to fly 14 flights, to support the experiments. The limited speed (up to mach 5) planned for the A2 vehicle may be sufficient to benefit some of the experiments. Therefore, Marshall should give consideration to also using the A2 vehicle to support the experiments. This alternative should be addressed as part of the reassessment of overall flight test requirements.

## **Recommendations, Management's Response, and Evaluation of Response**

**The Marshall Center Director should:**

- 6. Establish mission-specific requirements for X-34 flight tests, determine the minimum number of flights required to satisfy X-34 Project objectives, and delete from the X-34 contract those flights that are not justified.**

**Management's Response.** Concur. In January 2000, Marshall provided mission-specific flight test requirements to Orbital Sciences Corporation. As each flight is planned, minor adjustments

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<sup>36</sup> This amount reflects Orbital contractor costs only and does not include in-house Agency costs, range costs, etc.

<sup>37</sup> The third X-34 vehicle is designated the A3 and will be the only vehicle on which the experiments will be installed.

may be made for the individual mission flight software. The X-34 Project Plan identifies the requirement for a project controlled Flight Test Plan that documents the requirement for 27 test flights. The X-34 Project Manager will ensure that, as part of the ongoing replanning activity, flight requirements will be appropriately revalidated (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management are responsive to the recommendation. The recommendation is resolved but will remain undispositioned and open until agreed-to corrective actions are completed.

**7. Implement internal controls to appropriately document management decisions, including changes to the proposed flight test program.**

**Management's Response.** Concur. A project configuration control process has been put in place to manage changes to documentation such as the flight test program and to better document management decisions (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management are responsive to the recommendation. However, X-34 Project Office officials did not provide us data on their configuration control process and, after receipt of the comments, stated the process is not yet totally in place. Therefore, the recommendation is resolved but will remain undispositioned and open until agreed-to corrective actions are completed.

**8. Cancel the proposed expansion of the flight test program until justification for the existing 27 flight test program has been reassessed and the total number of flights needed to meet Project objectives have been determined and revalidated. The reassessment should consider using the A2 vehicle to support experiments.**

**Management's Response.** Concur. Currently, there are no budget or contractual actions planned for an expanded flight program beyond the existing 27-flight test program (see Appendix I).

**Evaluation of Management's Response.** The actions taken by management are sufficient to disposition and close the recommendation for reporting purposes.

**9. Reassess the number of Fastrac engines required to support the X-34 Project based on results of the reassessment of test flight requirements for the X-34 and on engine reliability tests, and eliminate any unneeded engines from the contract.**

**Management's Response.** Concur. The X-34 Project Office will reassess the number of Fastrac engines required to support the Project and, based on this assessment, will eliminate any unneeded engines from the contract (see Appendix I).

**Evaluation of Management's Response.** The actions planned by management are responsive to the recommendation. The recommendation is resolved but will remain undispositioned and open until agreed-to corrective actions are completed.



## **Finding C. Documentation for Space Transportation Programs/Projects**

NASA has not finalized and approved the X-34 Project Plan or the program commitment agreement and program plan for the Future-X/Pathfinder Program, which includes the X-34 Project. This condition exists because Marshall and the Office of Aero-Space Technology have not complied with Agency directives, have not placed sufficient emphasis on timely preparation of program documentation, and have not established appropriate internal controls to ensure such documentation is prepared prior to granting approval for program/project implementation. As a result, delays occurred (1) in obtaining senior Agency approval for the program management concepts and the internal control functions to be used in managing these high-priority, costly programs, and (2) in defining the roles and responsibilities of NASA officials for managing them. Delays in preparing program documentation can also adversely affect the Agency's management of technology needed to reduce the cost of access to space.

### **Agency Guidance on Program Documentation**

Agency directives on program/project management require that both a program commitment agreement and a program/project plan be prepared early, in the formulation phase, prior to actual implementation of the program or project. NASA Policy Directive (NPD) 7120.4A, "Program/Project Management," dated November 14, 1996, requires that the plans be in place prior to the start of project implementation. NPG 7120.5A, "NASA Program and Project Management Processes and Requirements," dated April 3, 1998, defines the requirements that managers must meet in formulating, approving, implementing, and evaluating programs and projects. (Additional information on program documentation requirements is in Appendix H).

**Compliance with Agency Directives.** Marshall and the Office of Aero-Space Technology have not finalized and approved X-34 program documentation. In February 1998, more than 3 years after the original X-34 Program was initiated, Marshall prepared a Draft X-34 Program Plan. However, neither the Marshall Center Director nor NASA Headquarters approved the plan. In February 1999, when NASA Headquarters redesignated the X-34 a "Project" within the Future-X/Pathfinder Program, the draft plan was to be rewritten as a Project Plan; however as of November 1999, Marshall and the Office of Aero-Space Technology have not completed and approved it.

As of November 1999, Marshall and the Office of Aero-Space Technology also did not have an approved Program Commitment Agreement or Program Plan for the Future-X/Pathfinder Program. Although both documents have been drafted, they have not yet been approved by NASA Headquarters. Marshall initiated funding/budgets for the Future-X/Pathfinder Program in 1997, requesting that initial funding be provided in FY 1999. NASA Headquarters approved the funding requests, constituting program implementation, and funds were included in the Agency budget for FY 1999. We attribute the noncompliance with Agency directives primarily to a lack of emphasis by Marshall and the Office of Aero-Space Technology on program documentation requirements.

**Compliance with Procurement Notices.** On February 22, 1999, NASA’s Associate Deputy Administrator issued a letter, subject “Integration of Acquisition Planning with NPG 7120.5A, NASA Program and Project Management Processes and Requirements,” to the Associate Administrator for Procurement. The letter emphasized the importance of complying with applicable Agency directives and directed the Associate Administrator for Procurement not to process solicitations initiated by Agency programs/projects if program documentation was incomplete. To ensure compliance with the Associate Deputy Administrator’s guidance, the Associate Administrator for Procurement issued Procurement Information Circular 99-6, “NPG 7120.5 Approvals and Requirements for the Release of Solicitations,” dated March 26, 1999; and Procurement Notice 97-28, “NASA Internal Programmatic Approval Documentation,” dated March 26, 1999. The Notice and Circular both prohibit Center Procurement Officers from issuing solicitations on Agency programs and projects for which program documentation is incomplete. The Circular and Notice require a new certification to accompany all purchase requests, stating that all program documentation has been completed and approved.

Marshall issued a Request for Offer for the Fastrac engines on April 20, 1999. Marshall subsequently awarded contract NAS8-99103 valued at \$11.3 million on July 30, 1999, for the Fastrac engines to support the X-34 flight test program. When the Request for Offer was issued and the contract was awarded, program documentation for both the X-34 Project and the Future-X/Pathfinder Program had not been completed and approved by NASA Headquarters. The Marshall Contracting Officer provided us a copy of a letter from the X-34 Project Office stating, “This confirms prior verbal certification that all required documentation under NPG 7120.5 for X-34 is current and approved.” The X-34 Project Office officials stated they certified that all X-34 documentation was complete because they did not think the requirement in the Circular and Notice applied to the X-34 since the project had been previously approved for implementation (upon funding approval) by NASA Headquarters.

We do not agree that the X-34 Project is exempt from requirements in Procurement Notice 97-28. The Procurement Notice clearly states the “Purpose” is “To ensure that no affected solicitation is released prior to the approval of key programmatic documentation required by NPG 7120.5, NASA Program and Project Management Processes and Requirement.”

**Program Documentation Content.** Agency Space Transportation programs and projects respond to the goals, objectives, and requirements specified in NASA and Enterprise strategic plans. The NASA Strategic Management Handbook requires increasing detail at lower levels of program documentation. Program documentation should provide full details for implementing strategic plans. Aero-Space Technology Enterprise officials stated that the specific, quantified technology requirements and metrics missing from Agency and Enterprise strategic plans (see Finding A) would be provided in Center-level, program and project documents. However, Marshall’s draft plans for Future-X/Pathfinder and X-34 do not provide adequate levels of detail on the Space Transportation technologies that are to be addressed. Specifically, Future-X/Pathfinder and X-34 are technology development/demonstration initiatives, however:

- The draft program/project plans did not comply with NPG 7120.5A and address the technology readiness levels of either those technologies embedded in the X-34 vehicle or



the experiments to be flown as part of the X-34 flight test program. NPG 7120.5A requires a Technology Requirements Synthesis at both program and project levels which identifies and establishes the status of all technologies required. A Technology Requirements Synthesis is performed to "...examine project concepts and assess technology requirements for feasibility, availability, technology readiness, opportunities for leveraging research, and new technologies."

- The draft X-34 plan did not adequately address flight test objectives, specify the procedures to be used to analyze test results, or effectively identify processes to validate/verify embedded RLV technologies (see Finding B for details on flight tests).
- The draft X-34 plan also did not indicate specifically how X-34 technology results would be used by NASA (see Finding A for details).
- The draft program/project plans did not adequately identify the metrics or processes for evaluating technology results.
- The draft program/project plans did not establish a requirement to input results of the X-34 Project or other Future-X/Pathfinder projects into the Agency technology database.

The lack of appropriate strategic plans at the Agency and Enterprise levels (see Finding A) may be a contributing factor to the untimely and deficient program and project documentation for Space Transportation initiatives identified by this and prior NASA Office of Inspector General audits of Space Transportation. Complete and accurate strategic planning documents at Agency and Enterprise levels would facilitate the preparation and maintenance of current program documentation.

## **Recommendations, Management's Response and Evaluation of Response**

**The Associate Administrator, Office of Aero-Space Technology, and the Marshall Center Director should:**

- 10. Finalize all required program documentation for the X-34 and Future-X/Pathfinder as required by NPD 7120.4A, "Program/Project Management," and NPG 7120.5A, "NASA Program and Project Management Processes and Requirements."**

**Management's Response.** Concur. The Marshall Future-X/ Pathfinder Program Office is working with the Office of Aero-Space Technology to complete the Future-X/Pathfinder Program Commitment Agreement and Program Plan and the X-34 Project Plan at the earliest possible date (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management are responsive to the recommendation. The recommendation is resolved but will remain undispositioned and open until agreed-to corrective actions are completed.

- 11. Revise the existing draft program commitment agreement and draft program/project plans for the Future-X/Pathfinder and X-34 Project to better define approximate technology requirements and expected results (benefits), and establish performance metrics and an evaluation process to evaluate results.**

**Management's Response.** Concur. The Future-X Pathfinder Program Commitment Agreement and Program Plan and X-34 Project Plan are being updated, and management will ensure that appropriate technology requirements, expected results, and performance metrics are included. The Pathfinder Program Office and the Office of Aero-Space Technology will work together to complete these documents at the earliest possible date (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management are responsive to the recommendation. The recommendation is resolved but will remain undispositioned and open until agreed-to corrective actions are completed.

**The Associate Administrator, Office of Aero-Space Technology, should:**

- 12. Establish internal control procedures within the Enterprise's Programs Division to ensure that responsible Centers submit required program/project documentation during the program formulation process.**

**Management's Response.** Concur. The Office of Aero-Space Technology Headquarters Office Work Instruction for "Program Project Formulation and Approval (HOWI: 7100-ROO7B, September 1999)" established procedures for the preparation of documentation during the program formulation phase. Management will continue to ensure that responsible Centers submit required program/project documentation during the program formulation process (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management are sufficient to disposition and close the recommendation for reporting purposes.

- 13. Discontinue the practice of approving programs and projects for which Program Commitment Agreements and program/project plans are not yet prepared or approved, and place added emphasis on compliance with program documentation requirements specified in Agency directives NPD 7120.4A and NPG 7120.5A.**

**Management's Response.** Concur. Management will ensure that all Enterprise programs and projects will be in compliance with and have the proper documentation specified in NPD 7120.4A and NPG 7120.5A (see Appendix I)

**Evaluation of Management's Response.** Management's original response was only partially responsive because management did not identify specific corrective actions. However, on March 27, 2000, the Office of Aero-Space Technology provided additional comments that identified planned actions as follows:

Since development of the documentation is a shared responsibility, we [Headquarters and Marshall] are putting special emphasis and working with the Chief Engineer's Office to ensure that

the X-34 program is in compliance with the NPD. Additionally, the Office will lead a Headquarters-Center team to coordinate the review and update, as appropriate, of ISO [International Organization for Standardization] 9000 Office Work Instructions to ensure these procedures cover all requirements of and contain appropriate emphasis on compliance with the NPD 7120.4A and NPG 7120.5A.

Based on the additional comments, we consider the recommendation resolved but undispositioned and open until agreed-to corrective actions are completed.

**14. Require responsible Centers to clearly identify in program documentation the approximate technology requirements, expected results (benefits), and performance metrics for evaluating actual results and to establish internal control procedures to ensure that the documentation effectively implements Enterprise strategic plans.**

**Management's Response.** Concur. Management has recognized this deficiency. The documentation for the two major programs (Aviation Safety and Ultra Efficient Engine Technology) initiated in FY 2000 identifies the expected requirements, benefits, and metrics (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management that were included in their original response were only partially responsive because management did not identify specific corrective actions. As stated above, we received additional comments that identified planned actions as follows:

The wide variety of programs managed by this Office (flight programs, focused research and basic research) precludes a set standard for the metrics as they vary from program to program. As noted in the original response, the Office is improving the documentation and the Office is in the process of establishing internal controls by modifying appropriate OWI's [Office Work Instructions] to ensure all future documentation, as submitted by the centers and approved by the Office clearly defines technology requirements and effectively implements strategic plans.

Based on the additional comments, we consider the recommendation resolved but undispositioned and open until agreed-to corrective actions are completed.

**The Marshall Center Director should:**

**15. Establish internal controls to ensure solicitations are not issued on programs/projects for which program documentation is not complete as required by Procurement Notice 97-28 and Procurement Information Circular 99-6.**

**Management's Response.** Concur. Internal controls have now been established to ensure compliance with the policy. The Automated Procurement Request System at Marshall has been revised to include mandatory fields regarding applicability and compliance with NPD-7120 documentation requirements. Procurement requests cannot be processed without completing the mandatory fields (see Appendix I).

**Evaluation of Management's Response.** The actions taken and planned by management are responsive to the recommendation. However, we requested additional clarification of corrective

actions to determine their effectiveness, which disclosed the need for further actions. On March 28, 2000, Marshall officials agreed to take additional actions to further strengthen internal controls and to ensure that the revisions to the Automated Procurement Request System are effective.

The recommendation is resolved but will remain undispositioned and open until agreed-to corrective actions are completed.

**16. Place added emphasis on compliance with program documentation requirements specified in Agency Directives NPD 7120.4A and NPG 7120.5A, and ensure that programs and projects prepare documentation in a timely manner.**

**Management's Response.** Concur. Marshall has established a Systems Management Office that has charter responsibility for ensuring that Center programs and projects comply with NPD 7120.4A and NPG 7120.5A. The Systems Management Office conducts independent evaluations (as required by NPG 7120.5A) of Marshall programs and projects (Microgravity and Space Transportation) that report to the Marshall Project Management Council and Marshall Lead-Center Program Management Councils. If the Systems Management Office or the Directorate program/project review process had been in place previously, the X-34 Project's noncompliances would have been identified and corrected in a timely manner.

**Evaluation of Management's Response.** The actions taken and planned by management are responsive to the recommendation. Management actions are sufficient to disposition and close the recommendation for reporting purposes.

## **Appendix A. Objectives, Scope, and Methodology**

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### **Objectives**

The overall objective was to assess the status of the X-34 Demonstrator Project in meeting technology requirements for the next generation RLV. Specifically, we determined whether:

- Orbital Sciences Corporation was fulfilling its obligations under the contract,
- key technologies were being identified and tested in accordance with milestones, and
- NASA's process for transferring X-34 technology was effective.

To evaluate NASA's planned use of X-34 technologies, we reviewed the management of Space Transportation technology requirements by the Aero-Space Technology Enterprise and Marshall in view of the significant role Marshall has as Lead Center for Space Transportation. We also reviewed the interrelationship of the X-34 technology to overall Space Transportation technology requirements.

### **Scope and Methodology**

We performed audit work at Marshall; NASA Headquarters; and the Orbital Sciences Corporation, Dulles, Virginia, facility.

- To determine whether Orbital Sciences Corporation was fulfilling its obligations under the contract, we reviewed contractor compliance with various contract requirements to include meeting milestone due dates, cost and schedule targets, and deliverable requirements.
- To determine whether key technologies were being identified and tested in accordance with milestones, we reviewed the contractor's record of completion of technology milestones under the X-34 contract.
- To determine whether NASA's process for transferring X-34 technology was effective, we reviewed NASA's operation of the Agency's technology database to include the extent of input from the X-34 Project as well as the number of queries by database users. We also reviewed the adequacy of Agency guidance on technology management.
- To determine how NASA planned to use the technologies developed on the X-34 Project, we reviewed Future-X/Pathfinder and X-34 Program/Project documentation and NASA, Marshall, and Aero-Space Technology Enterprise strategic planning documents, and we evaluated adequacy of the overall process established to acquire the technologies needed to reduce launch costs.

We examined the policies, procedures, and practices NASA and the Aero-Space Technology Enterprise used in preparing strategic planning documents for Space Transportation. We reviewed the limited documentation on the rationale and support for the proposed X-34 flight test program. We also reviewed the current program status for the X-34. We interviewed personnel involved in preparing program documentation, flight test plans, and strategic planning documents. Our interviews included Aero-Space Technology officials, Marshall personnel, and personnel at the Orbital Sciences Corporation headquarters facility at Dulles, Virginia. We did not assess the scientific requirements underlying the X-34 flight requirements.

**Management Controls Reviewed.** We reviewed NASA’s policies on program/project management and strategic planning. Specifically, we reviewed NPD 7120.4A, “Program/Project Management”; NPG 7120.5A, “NASA Program and Project Management Processes and Requirements”; and NPG 1000.2, “NASA Strategic Management Handbook.” Management controls regarding strategic planning for Space Transportation, flight test plans, and program documentation should be improved, as discussed in the findings.

**Computer-Processed Data.** We used computer-processed reports from NASA Headquarters, Marshall, and Orbital Sciences Corporation to assess the status of the X-34 Project and to evaluate the proposed X-34 flight test program. We reviewed and tested selected data but did not verify the overall validity of the reports. The lack of verification did not affect our audit results.

**Prior Audit Coverage.** There has been no prior audit coverage on the X-34. However, we issued the following reports on the X-33 Advanced Technology Demonstrator, a “sister” program of the X-34 under the Marshall-managed RLV Program:

On March 29, 1999, we issued audit report IG-99-019, “X-33 Cooperative Agreement,” which states that NASA’s use of a cooperative agreement contributed to deficiencies in program management processes including planning and execution, resource management, and property control. The report made recommendations to improve these processes.

On November 3, 1998, we issued audit report IG-99-001, “X-33 Funding Issues,” which discusses NASA’s lack of properly recognizing Agency requirements as bona fide needs which contributed to significant financial management deficiencies on the X-33 program. This approach not only did not properly recognize Agency requirements, but also may have made it more difficult for NASA to reach a consensus on RLV technology requirements.

In August 1999, the General Accounting Office (GAO) issued Audit Report Number NSIAD-99-176: “Space Transportation – Status of the X-33 Reusable Launch Vehicle Program,” which identifies problems in NASA’s strategic planning for Space Transportation. Specifically, the report states that NASA’s Fiscal Year 2000 Performance Plan does not include performance targets that establish a clear “growth path leading from the X-33 flight test vehicle to an operational SSTO [Single-Stage-To-Orbit] vehicle.” The GAO report points out that the

## Appendix A

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NASA Advisory Council has also voiced similar concerns. GAO recommended “the NASA Administrator include in the agency’s Fiscal Year 2001 Performance Plan performance targets for the X-33 Program that establish a clear path leading from the X-33 flight-test vehicle to an operational RLV and show progress toward meeting the agency’s objective of significantly reducing launch costs.” NASA management concurred with the recommendation.

**Audit Field Work.** During February through December 1999, we conducted field work at Marshall; NASA Headquarters; and Orbital Sciences Corporation Headquarters, Dulles, Virginia. We performed the audit in accordance with generally accepted government auditing standards.

## Appendix B. Background

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Since the 1970's, NASA has searched for a cheaper launch vehicle, which led to the decision to build the Space Shuttle. Although the original intent of the Space Shuttle Program was to significantly reduce NASA's cost of access to space, the Shuttle has not come close to the flight rates (as high as 57 flights annually) anticipated early in the program. The Shuttle fleet is currently able to sustain only about seven or eight flights per year, and the maximum flights in any year was nine (1985). As a result, the Shuttle has proven expensive to launch (about \$300 - \$500 million per launch depending on the number of flights launched annually), and NASA has spent much of the last decade looking for a way to reduce launch costs. NASA's original goal of reducing the launch cost from \$10,000 per pound to \$1,000 per pound by 2006 may not be realized until 2010–2011 or later.

NASA's Access to Space study in 1993 determined that an RLV offered advantages over use of an expendable launch vehicle. Specifically, while the development and production costs of an expendable launch vehicle primarily determine launch costs, the cost of launching an RLV is determined mainly by the number of times the RLV can be used. A higher flight rate for an RLV allows better amortization of the development costs, resulting in a lower overall launch cost per flight.

The fact that the Shuttle has not been successful in significantly reducing launch costs has led to increased concern by Congress and OMB (see Appendix D) that NASA find a solution. NASA expected to make a decision before December 31, 2000, on an RLV to replace the Shuttle. Under the original RLV/*Venture Star*<sup>38</sup> timetable, NASA and industry partners had hoped the X-33 Program would permit them to make a decision on *Venture Star* by the end of 1999. The decision on a next-generation RLV involves several decisions addressing what the next generation RLV will look like, when it can be operational, how it will be phased in to replace the existing Shuttle, and who will own and operate it. According to a NASA in-house study completed in February 1999, "Not enough knowledge is available today to commit to a Shuttle replacement." NASA simply does not have the technology(s) at this time to support the decision. It is unlikely that NASA can make the decision prior to 2002 or 2003 at the earliest, and it may be the middle of the next decade before an informed decision can be made.

As the Lead Center for Space Transportation, Marshall has extensive responsibility for implementing the Agency's Space Transportation mission managed by NASA's Office of Aero-Space Technology. Marshall's responsibility includes participating in strategic planning for the Space Transportation mission area.

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<sup>38</sup> *Venture Star* is a next-generation RLV concept proposed by Lockheed Martin Skunk Works.



## Appendix B

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The Center's Space Transportation Directorate has responsibility for various Space Transportation elements including the following:

- The Advanced Space Transportation Program Office is responsible for developing, maturing, and performing ground testing of the technologies needed to meet NASA's unique mission requirements and for reducing space transportation costs to enable commercial development of space.
- The Future-X /Pathfinder Program Office has responsibility for the X-34 and X-37 Projects and is responsible to demonstrate advanced space transportation technologies through the use of flight experiments and experimental vehicles.
- The X-33 Program is a one-half scale size advanced technology demonstrator and is an integral part of the RLV Program, which NASA hoped would lead to a commercially owned and operated RLV --- the *Venture Star*. While *Venture Star* is still an option for the next-generation RLV, NASA's ongoing Integrated Space Transportation Plan does not identify *Venture Star* as the likely successor to the Space Shuttle.

The X-34 Project is subject to oversight by several groups, internal and external to NASA. Marshall's Program Management Council, a senior-management group chaired by the Deputy Center Director, has primary oversight of the X-34 Project.<sup>39</sup> Additionally, the Space Transportation Council, the NASA Advisory Council, and the Aero-Space Technology Advisory Council all provide Space Transportation expertise. Independent reviews such as the Non-Advocate Reviews<sup>40</sup> and Independent Annual Reviews<sup>41</sup> provide the Program Management Council with objective evaluations of Project conformance to plans and objectives.

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<sup>39</sup> NPG 7120.5A permits certain projects to have Center-level oversight.

<sup>40</sup> The Non-Advocate Review team performs its reviews during program formulation phases as input to the program approval process; the reviews include the verification of life-cycle cost estimates.

<sup>41</sup> The Independent Annual Review is an analysis of the status of commitments (performance, cost, and schedule) as compared to the program/project baseline and established thresholds.

## Appendix C. Federal and Agency Requirements

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The Government Performance and Results Act (GPRA), passed by Congress in 1993, requires Federal agencies including NASA to accomplish the following:

- Develop an Agency 5-year Strategic Plan, setting forth NASA's mission, long-term goals, objectives, implementing strategies, and associated resource requirements. Initial submission to the OMB and Congress was September 30, 1997, with updates at least every 3 years.
- Prepare annual Agency Performance Plans that establish performance goals, measurable objectives, and associated resource requirements needed to achieve long-term goals. The initial plan, for FY 1999, was to be submitted to OMB by September 1997. As part of the Performance Plans, agencies may request that OMB grant managerial waivers on personnel levels, salaries, and budget constraints for programs indicating improved performance within program funding.
- Submit annual Agency Performance Reports that will measure goal achievement and/or identify reasons for failure in goal achievement. The initial report is to be submitted to the President and Congress by March 31, 2000, for FY 1999.

NPG 1000.2, "NASA Strategic Management Handbook," documents the Agency's management policies, processes, guidelines, and responsibilities for strategic management as required by GPRA. Specifically, the handbook delineates the processes, schedules, and management responsibilities for the following:

- Integrating Strategic Planning with the budget process
- Developing detailed Implementation Plans and strategies
- Managing the execution of strategies through programs and processes
- Evaluating performance and assessing and reporting results

The handbook requires that the NASA Strategic Plan and the Enterprise Plans include specific elements to ensure consistency and meet GPRA requirements. The specific elements should include broad vision and mission statements, identification of customers and applicable environments, as well as appropriate goals, objectives, and implementing strategies.

- **Goals** elaborate on the mission statement and constitute a specific set of policy, programmatic, or management outcomes for the programs and operations covered in the strategic plan.

## Appendix C

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- **Objectives** are specific milestones and target levels of near-term outputs that are to be achieved during strategic implementation. Objectives should be:
  - Specific - reflect the accomplishments to be achieved
  - Measurable – either quantifiable or verifiable
  - Aggressive, but attainable
  - Results-oriented – focused on the desired outputs and outcomes
  - Time-bound – achieved within a specific time frame
- **Implementing Strategies** should include a description of how the goals and objectives will be achieved. Each strategy should have details addressing:
  - Key elements, programs, processes, values, and culture
  - Metrics to include performance indicators, and an evaluation process to determine progress and indicate how evaluations are to be used to establish or revise goals
  - Resource requirements with an investment strategy

The handbook states that annual Performance Plans required by GPRA are to establish performance goals, measurable objectives, and associated resource requirements needed to achieve long-term goals. The handbook also requires that Enterprise Strategic Plans, which flow down from, and must align with, the NASA Strategic Plan be reviewed and updated, as required, annually. The plans are to include performance goals and metrics for the Enterprise as well as top-level resource requirements. NASA's annual GPRA Performance Plan presents the integration of the performance planning inputs provided by the Agency's Strategic Enterprises. Consistent with GPRA requirements, this plan should include the following:

- Quantifiable performance goals
- Level of performance to be achieved during the budget year
- Human, capital, or other resources required to meet performance goals
- Specific nonprogrammatic actions planned within the time frame and fiscal scope of the proposed budget
- Metrics to be used as performance indicators

The NASA Strategic Management Handbook and the NASA strategic plans assign Marshall the mission area of Space Transportation Systems.

## Appendix D. Congressional, OMB, and GAO Concerns

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Congress, OMB, and the GAO have expressed concern about NASA's strategic planning for Space Transportation. Other NASA external oversight elements have also voiced concerns. In response to congressional concerns in the early 1990's over the continued high cost of launching payloads into space, NASA performed the Access to Space Study in 1993. This study concluded that a Single Stage to Orbit RLV offered the most potential for significantly reducing the cost of access to space, but at substantial risk. NASA's X-33 Program continues to pursue the Single Stage to Orbit RLV concept, although numerous difficulties have been encountered.

### OMB Concerns

OMB expressed concern over the adequacy of NASA's strategic planning for replacing the Shuttle and lowering launch costs. In November 1996, OMB stated in its Passback<sup>42</sup> guidance:

NASA's budget assumes about \$4B over 5 years for a variety of technologies, upgrades and development activities related to space launch (e.g., X-33, X-34, ASTP [Advanced Space Transportation Program], Shuttle upgrades, CRV [Crew Return Vehicle], Hyper-X). Yet it is difficult to understand the strategy that will enable a decision on a future space transportation architecture for NASA. OMB requests that the appropriate offices within NASA and NASA's Independent Program Assessment Office coordinate to create a strategic plan that outlines: (1) the Agency's space launch requirements; (2) current investments in technology, development, and operations of space launch vehicles; and, (3) the objectives, strategy, budget and key decisions that will enable a future space transportation architecture for NASA. OMB also requests that the RLV criteria documents be incorporated in such a plan, the decision criteria for Phase 3 be updated to reflect the X-33 award, and the criteria be independently reviewed as earlier agreed to by NASA. NASA should submit the launch plan to OMB no later than September 1997.

OMB was concerned about the adequacy of NASA Strategic Plans for acquiring the technology needed to develop a next-generation RLV. Agency efforts for strategic planning in response to this 1996 OMB Passback were not sufficient, and OMB again expressed concern about NASA's plans for reducing launch costs in the 1997 Passback guidance:

The President's 1994 National Space Transportation Policy calls for an end-of-the-decade decision on the development of an operational launch system to reduce NASA's launch costs. ... OMB ... recommends that before decisions are made on the allocation of funds, NASA present options developed by the private sector to OMB and OSTP [Office of Science and Technology Policy] on how they could lower NASA's overall launch costs through either existing, planned, or new vehicles. Industry inputs could be accomplished through an RFP [Request for Proposal] with appropriate Terms of reference for the studies.

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<sup>42</sup> OMB's feedback/comments to NASA on previously submitted budget.

## Appendix D

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As a result of OMB concerns, NASA initiated the Space Transportation Architecture Study in 1998, and initiated phase III of the study, the Integrated Space Transportation Plan, in July 1999 to ensure NASA's access to space requirements and industry requirements were appropriately addressed.

### GAO Concerns

Based on its recent audit<sup>43</sup> of the X-33, a sister program of the X-34 within NASA's RLV Program, GAO concluded that NASA Strategic Plans for Space Transportation need improvement. GAO reported that NASA's FY 2000 Performance Plan for Space Transportation does not contain sufficient metrics for measuring performance. GAO reported that NASA's Fiscal Year 2000 Performance Plan does not include performance targets that establish a clear "growth path leading from the X-33 flight test vehicle to an operational SSTO [Single Stage to Orbit] vehicle." GAO recommended that "the NASA Administrator include in the agency's Fiscal Year 2001 Performance Plan performance targets for the X-33 Program that establish a clear path leading from the X-33 flight-test vehicle to an operational RLV and show progress toward meeting the Agency's objective of significantly reducing launch costs." NASA management concurred with the recommendation and will include performance targets in the FY 2001 Performance Plan.

### Oversight Organization Concerns

NASA oversight committees that are responsible to provide Space Transportation expertise have also expressed concerns regarding NASA's strategic planning for Space Transportation. In an August 26, 1997, report to the Aero-Space Technology Advisory Committee, the Space Transportation Subcommittee indicated its concern that NASA's space technology programs (X-34, Advanced Space Transportation Program, Hyper-X, Future-X/Pathfinder, etc.) are somewhat unfocused across a wide range of future technologies, while the immense, near-term challenge of achieving an operational RLV by 2012 was underfunded. Similarly, the NASA Advisory Council indicated that the strategic path for the X-33 was not clear and that the goals and expectations appear to be overstated and unrealistic. One of the members of the NASA Advisory Council added that "... the strategic plan for Aero-Space Technology is in shambles."

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<sup>43</sup>Report Number NSIAD 99-176, Status of the X-33 Reusable Launch Vehicle Program, dated August 1999.

## Appendix E. Metrics for Acquiring Needed Technologies

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To be effective, strategic planning should involve significant use of metrics. The NASA Strategic Management Handbook requires that strategic planning documents include objectives that are “quantifiable” or “measurable,” and states “NASA must be able to monitor its success in achieving each objective.” The Handbook further requires that strategic planning include implementing strategies, to include performance indicators, metrics, and a program evaluation process to determine progress. Space Transportation technology management extensively involves the development of hardware (engines, composite structures, composite/cryogenic fuel tanks, thermal protection systems, avionics, etc.) for new boosters/launchers. NASA has been performing hardware research and development for 4 decades; therefore, the Agency should be able to establish measurable goals and metrics for Space Transportation. However, as stated in Finding A, strategic planning documents do not clearly identify specific technology objectives, requirements, and implementing strategies with appropriate metrics in quantitative and/or qualitative terms to permit measurement and reporting of incremental progress. Additionally, the plans do not identify how NASA will attain the critical goal of reducing launch costs. Agency, Enterprise, and Marshall strategic planning documents do not indicate how the X-34 will contribute to the needed technology for the next-generation RLV.

The technology requirement for each of the six core technologies<sup>44</sup> needed for the next-generation RLV should be clearly specified in quantitative and qualitative terms, to the extent possible, that can be used to measure and report annual progress toward each requirement. For example, if a better Thermal Protection System is needed for the next generation RLV, criteria for defining the technology requirement might include:

- Temperature endurance capability
- Penetration (hardness) resistance to space debris
- Durability, maintainability (replacement) and operability

Specific requirement criteria should be established for all six RLV core technologies.

Achieving reduced cost of access to space is dependent on NASA’s successful maturing of several core technologies that could be used on the next-generation RLV. In this endeavor, NASA must identify the required technology in meaningful, measurable terms that include metrics for reporting incremental progress over time. A comparison of current status with the requirement identifies the existing “technology gap.” However, NASA has not yet identified an acceptable method/metric for stating the technology requirement or for measuring progress.

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<sup>44</sup> Technologies to be demonstrated are reusable cryogenic tankage, composite structures, durable thermal protection systems, advanced avionics, reliable propulsion systems, and aircraft-like operations.

## Appendix E

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Space Transportation strategic planning documents at all levels use the term “technology” extensively, but do not use the term Technology Readiness Level to identify Space Transportation technology requirements and technology status or to report progress. According to the NASA Technology Plan, dated December 1998, the metric TRL specifies the maturity of a technology, incrementally, from 1 (not mature) through 9 (mature). Therefore, TRL's can be used to identify the incremental change in each Space Transportation technology as it matures (from TRL 1 to 2 to 3, etc.). The TRL metric is “quantitative” (1 – 9), but the definition of each TRL level may also add a “qualitative” aspect to this metric. The absence of an appropriate Space Transportation technology metric can adversely affect the Space Transportation strategic planning function, including the ability to effectively specify technology requirements, technology status, and technology progress. Without a means to effectively identify, measure, and report technology progress, strategic planning documents do not adequately serve their main purpose as planning tools. We believe the use of TRL's can be a useful metric in carrying out NASA's technology management task for Space Transportation. Other Enterprises and the Aeronautics element of the Office of Aero-Space Technology already use the TRL metric. However, other metrics may also be appropriate. Regardless of which metric(s) is chosen, NASA must determine the appropriate metrics to support Agency Space Transportation strategic planning.

## Appendix F. Agency Strategic and Performance Plans

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### Strategic Plans

The NASA Strategic Management Handbook, NPG1000.2, requires a strategic plan to have goals, objectives, and implementing strategies. Goals elaborate on the mission statement and need not be in a quantitative or measurable form, but they must be expressed in a manner that allows a future assessment of whether each is being achieved.

Objectives are specific milestones and target levels of near-term outputs that are to be achieved during strategic implementation. Objectives should be specific, measurable (either quantifiable or verifiable to allow NASA to monitor success in achieving each objective), results oriented, and time phased. Implementing strategies should include a description of how the goals and objectives will be achieved. The Space Transportation objectives in the FY 1998 Strategic Plan related to X-33 and X-34 are to:

- Complete research and development to enable U.S. industry to launch to Low Earth Orbit at \$1,000 /lb. (1998 – 2002)
- Revolutionize space launch capabilities – reduce the payload cost to low earth orbit by an order of magnitude (\$1,000 per pound to orbit) (2003 – 2009)
- Revolutionize space launch capabilities – reduce the payload cost to low earth orbit by an order of magnitude (hundreds of dollars per pound to orbit). (2010 – 2023)

The objectives for the FY 1999 Strategic plan for Space Transportation are similar to those for FY 1998, but do not include dollar values for reduced launch costs. The time-phased objectives in the FY 1999 Strategic Plan are to:

- Complete R&D [research and development] to enable US industry to significantly reduce cost of launches to Low Earth Orbit (LEO) [1998 – 2002];
- Reduce the payload cost to Low Earth Orbit by an order of magnitude. [2003 – 2009]; and
- Reduce the payload cost to LEO by an additional order of magnitude. [2010 – 2023].

### Performance Plans

Our review of the objectives and performance measures in the FY 1999 NASA Performance Plan included a comparison of strategic planning data for the Aero-Space Technology Enterprise's Aeronautics and Space Transportation missions. Our comparison showed Aeronautics objectives and performance measures were more specific and more readily related to the Aeronautics goals than the objectives and performance measures for Space Transportation. The Space Transportation goal in the Enterprise's FY 1999 Performance Plan is "Enable the full commercial potential of space research and exploration," and the objective is "Revolutionize space launch capabilities." The two performance measures are:



## Appendix F

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- Continue the X-33 vehicle assembly in preparation for flight testing
- Complete vehicle assembly and begin flight-testing of the X-34

Assuming these performance measures were met (neither the X-33 nor X-34 flew in FY 1999), such objectives and performance measures do not readily provide meaningful metrics to measure progress toward the goal. Appropriate metrics are needed to measure progress in acquiring needed technologies and in moving toward the Agency goal of reduced Space Transportation launch costs.

An example of one Aeronautics goal is “Enable U.S. leadership in global civil aviation through safer, cleaner, quieter, and more affordable air travel.” An objective is “Contribute to aviation safety by reducing the aircraft accident rate.” The performance measures for these objectives are:

- Characterize the Super-cooled Large Droplets (SLD) icing environment, determine its effects on aircraft performance, and acquire and publish data to improve SLD forecasting confidence.
- For the aviation safety areas of Controlled Flight into Terrain, runway incursion, and loss of control, identify the contributing causes to be addressed, potential solutions using current capabilities, and gaps that require technology solutions.

These Aeronautics performance measures clearly contribute to the objective and ultimately to the goal. Performance measures for Space Transportation should likewise clearly contribute to the objective and goal stated in the Performance Plan.

## Appendix G. Space Transportation Architecture Study

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In response to OMB direction in the FY 1999 budget passback guidance, NASA is performing a Space Transportation Architecture Study. On July 20, 1998, NASA Headquarters issued a Request for Offer to obtain industry input on the architecture study. The purpose of the study is for industry to develop architecture options to meet NASA's future space transportation requirements with significant reductions in costs. Industry will compete its options for award, and OMB will include the selected architecture in the President's FY 2001 budget. The Space Transportation Architecture Study called for up to nine architecture scenarios.<sup>45</sup> The study is being implemented in multiple phases including an initial phase to develop a detailed study approach (completed in 1998) and one or more additional follow-on phases to fully develop proposed space launch architectures with sufficient levels of detail to support decisions regarding NASA budget.

In February 1999, in the second phase of the study, NASA received six proposed architectures from private industry and the results of the NASA in-house study team. The Chief Engineer's Office briefed the Aeronautics and Space Engineering Board in June 1999. The study results proposed alternative scenarios for keeping the Shuttle and/or for replacing it. Based on the study, NASA initially proposed upgrading the Shuttle through 2008 and phasing it out by 2011 and postponing the decision on specific criteria for the 2<sup>nd</sup> generation RLV until 2000.

However, in July 1999, NASA began Phase three of the architecture study because the NASA Administrator was not satisfied with the Agency-identified Space Transportation requirements, which were the baseline for the study. The Administrator considered the first set of requirements too narrow in scope, because they addressed only currently planned Agency missions and did not include other potential missions (space flights). NASA officials told us the Administrator wanted another study (Phase 3) performed that considers the requirements not only for planned missions, but also for missions not yet planned, such as satellite recovery, space exploration, and building platforms in space. Human-rated missions<sup>46</sup> and vehicles will be highlighted in the Phase 3 study. NASA provided an initial briefing to OMB on October 5, 1999, with preliminary recommendations on a Space Transportation architecture plan. NASA plans to give OMB a final, more detailed briefing later in FY 2000.

NASA's original goal of reducing launch costs to \$1,000 per pound by 2006 probably will not be met. Preliminary results of the current Space Transportation Architecture Study move the goal beyond 2007 because a decision on the next-generation RLV cannot be made before 2002 or 2003 at the earliest and may be delayed until 2005.

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<sup>45</sup> Each scenario addresses various new vehicle options and/or Shuttle upgrades.

<sup>46</sup> NASA space flight missions that have humans on board.

## Appendix H. Program Documentation Requirements

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NASA Policy Directive (NPD) 7120.4A, "Program/Project Management," dated November 14, 1996, requires that program documentation, to include program commitment agreements and program/project plans, be in place prior to the start of project implementation. Paragraphs 1.b.(6) and (b) state:

- The Agency commitment to execute the program will be documented in the Program Commitment Agreement which forms the basis for program implementation and evaluation plans.
- Signature on the Program Commitment Agreement by the Administrator and the Enterprise Associate Administrator formalizes Agency approval of the program.
- In order to ensure that all supporting organizations and entities understand and commit to providing the required support defined in the Program Commitment Agreement, all such agreements/commitments must be represented in Program and Project Plans. **These plans must be in place prior to the start of implementation.** [Emphasis added.]

NPG 7120.5A, "NASA Program and Project Management Processes and Requirements," dated April 3, 1998, defines the requirements for formulating, approving, implementing, and evaluating programs and projects and states: "The disciplined approach of program and project management is now being applied to **technology development programs** to enable future Agency missions." [emphasis added]

NPD 7120.4A, "NASA Program/Project Management," dated November 14, 1996, establishes the management system by which NASA shall formulate, approve, implement, and evaluate all programs and projects established for development and operation of aeronautical and space ground and flight systems and technologies. The process for approval of projects within a program varies, depending on the size, nature, and criticality of the project. The specific process for each program should be specified in the Program Commitment Agreement.

NPG 7120.5A, "NASA Program and Project Management Processes and Requirements," dated April 3, 1998, establishes the management system for processes, requirements, and responsibilities for implementing NPD 7120.4A. This management system governs the formulation, approval, implementation, and evaluation of all Agency programs and projects established to Provide Aero-Space Products and Capabilities. It is intended to support accomplishment of the NASA programs and projects, consistent with established Agency strategic planning, on schedule, and within budget, while satisfying the requirements of multiple stakeholders and customers. The NPG provides the basic processes and requirements for the life cycle of all programs and projects. The NPG shall be used specifically for programs/projects that provide aerospace products or capabilities, that is, provide space and aeronautics, flight, and ground systems, technologies, and operations satisfying the requirements of multiple stakeholders and customers.

The NPG requires that program commitment agreements and program/project plans be prepared in the formulation stage, prior to approval of the program/project. In fact, approval of the agreement and plans constitutes Agency approval of the program/project. The NPG also stipulates that program/project documentation should be consistent with and provide details for implementing Agency and Enterprise strategic plans.

## Appendix I. Management's Response

National Aeronautics and  
Space Administration  
**Headquarters**  
Washington, DC 20546-0001



MAR 24 2000

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Reply to...

TO: W/Inspector General  
FROM: R/Associate Administrator for Aero-Space Technology  
SUBJECT: Response to Draft Report on the Audit of X-34 Technology Demonstrator  
(Assignment No. A-HA-98-050)

We are forwarding to you the reply on this draft report of the audit of the X-34 Technology Demonstrator (Assignment No. A-HA-98-050). The Office of Aero-Space Technology and the Marshall Space Flight Center coordinated the responses to all the recommendations.

Any questions should be directed to Terry Hertz at 202/358-4636 or Phil Sumrall at 358-4474, the Point of Contact for this audit.

A handwritten signature in black ink, appearing to read "Samuel L. Venneri".  
Samuel L. Venneri

Enclosure

**RESPONSE TO THE OIG DRAFT REPORT ON THE  
AUDIT OF THE X-34 TECHNOLOGY DEMONSTRATOR  
ASSIGNMENT NO. A-HA-98-050**

**GENERAL COMMENTS:**

**Finding A Strategic Planning for Space Transportation**

With the creation of the Integrated Space Transportation Plan (ISTP), NASA has defined a single, integrated investment strategy for all of its diverse space transportation efforts. The ISTP, which was approved by the NASA Administrator and accepted by OMB in October 1999, has resulted in the creation of the Administration's Space Launch Initiative and contributed to a significant increase in NASA's budget for space transportation systems.

The ISTP strengthens NASA's Strategic Plan by:

- Focusing on safety, reliability, cost, and NASA mission requirements while making maximum use of US aerospace industry capabilities and commercial market leverage,
- Ensuring the continued safe access to space through the Space Shuttle Safety Upgrades until a replacement alternative has been demonstrated,
- Enabling a competitive environment and the development of a 2<sup>nd</sup> Generation Reusable Launch Vehicle (RLV) architecture at an acceptable level of risk by 2005,
- Securing NASA's future through investments in 3<sup>rd</sup> Generation RLV technologies for Earth-to-orbit and in-space applications, and
- Providing near-term alternate access to the International Space Station.

The ISTP establishes a framework within which Agency strategies can be defined and investment priorities established. It will be the basis on which NASA and industry contributions can be effectively evaluated and integrated and future decisions regarding the development of 2<sup>nd</sup> Generation RLV can be made. The ISTP contains detailed investment options that encompass what industry participants have indicated is necessary to close their business cases, as well as investments required to meet NASA-unique missions for years to come. The ISTP provides the plan by which the Agency will meet its commitment of enabling safe, affordable, and reliable access to space for the Nation. NASA will continue to build upon the success and progress of on-going programs, including the X-33, X-34, and X-37, to further reduce the technical and programmatic risks.

**Finding B X-34 Project Flight Test Requirements**

As a result of a number of independent reviews addressing risk mitigation and the Fastrac engine, a replanning effort of the X-34 Project is currently ongoing. This replanning activity could result in a number of changes to the Project and will provide an opportunity to reassess the flight requirements.

### **Finding C Documentation for Space Transportation Programs/Projects**

The Pathfinder Program Office is actively working the Program Commitment Agreement (PCA), the Program Plan, and the X-34 Project Plan. The existing draft documents will be updated to better define, as appropriate, technology requirements and expected results. Steps will be taken to ensure that required documentation for future projects will be completed in an appropriate and timely manner.

#### **SPECIFIC COMMENTS:**

Page 7, **Cost/Benefit Analyses**, 1<sup>st</sup> paragraph (p), 1<sup>st</sup> sentence. It is extremely difficult to perform cost benefit analyses of individual technologies because of the vehicle system interactions (a lighter material, for example, leads to reduced thrust and Isp (specific impulse) requirements which leads to less propellant loading which leads to networks of still other derivative benefits. MSFC has work underway which will improve the analytical ability to assess individual technologies, but these techniques require continued development. However, the architecture level studies have repeatedly shown that in aggregate, the suite of technologies, once implemented into future space transportation architectures, have an economic payoff.

Page 12, **Agency Guidance**. 2<sup>nd</sup> p. NPG 7120.5A and NPD 7120.4A were not in existence when the project was started. Compliance with these documents has required the project to develop additional documentation.

Page 13, **Contingency Flights**. 1<sup>st</sup> p. The audit report identifies contingency flights in the X-34 flight test program. As of September 1999, the project did have contingency flights in this plan. However, with the change of scope, the project currently has no plans for any contingency flights in the 27 flights that are on contract.

#### **RESPONSES TO THE RECOMMENDATIONS:**

**OIG Recommendation 1:** The Associate Administrator for Aero-Space Technology, in coordination with the Marshall Center Director, should improve Agency strategic planning documents to ensure they comply with requirements of the NASA Strategic Management Handbook and GPRA. At a minimum, specify goals that support mission statements; results oriented, measurable objectives; and implementing strategies that articulate how the goals and objectives will be achieved, including metrics to be used as performance indicators and a process for evaluating results.

**Response: Concur.** Agency strategic planning for space transportation has been significantly enhanced with the development of the Integrated Space Transportation Plan. The specific goals, roadmaps and implementing strategies that were defined through the ISTP development process will be reflected, as appropriate, in future versions of agency documentation. Consistent with NPG 1000.2 "NASA Strategic Management Handbook",

the general goal for achieving the Agency's mission related to enabling future space transportation capability will continue to be included in the Strategic Plan. Objectives that more clearly relate to the goal will be identified and stated in the plan. Specific performance metrics that contribute to the objective and provide a meaningful measure of progress toward meeting the safety, reliability and affordability objectives will be identified and included in the annual NASA Performance Plan. These changes will be reflected in the next Agency plan, scheduled for release in the fall of 2000.

**IG Recommendation 2:** The Associate Administrator for Aero-Space Technology, in coordination with the Marshall Center Director, should prepare an Enterprise strategic plan, in compliance with the NASA Strategic Management Handbook and GPRA, and establish procedures to review the plan annually, and update it as required. The plan should identify technology requirements, as well as an implementing strategy, to include metrics and evaluation processes to measure technology progress.

**Response: Concur.** The Enterprise is in the process of developing a detailed strategic plan, which will include the space transportation goal objectives, performance metrics and implementing strategies. The plan will reflect, as appropriate, the ISTP. The plan will reflect at a top-level technology requirement and the process for developing detailed technology requirements. The plan will also describe the processes for measuring technology progress and measuring impact against the objectives. The Enterprise plan will be released in conjunction with the Agency plan in the fall of 2000. The plan will be reviewed on an annual basis and updated as required.

**OIG Recommendation 3:** The Associate Administrator for Aero-Space Technology, in coordination with the Marshall Center Director, should implement an appropriate cost/benefit analysis process to support and document the rationale for management decisions on Space Transportation, and develop an investment strategy to implement Space Transportation strategic plans and to help ensure effective use of resources.

**Response: Concur.** The ISTP development process implemented a rigorous and thorough method of defining and understanding requirements, and evaluating and recommending investment options. Through this process, NASA consolidated technology requirements from industry, as well as the Agency, and prioritized them based upon the importance of improving safety, followed by cost and applicability to multiple industry concepts. The ISTP process implemented an analytical hierarchy methodology of evaluating technology investment options. Each technology was subjected to a cost/benefit analysis and ranked based on potential payoff to cost, safety and technical risk. All analyses were based on architecture-level economic metrics. The focus areas for the ISTP economic analysis included, technology prioritization, incentive evaluation, sanity checks, architecture optimization, and architecture evaluation. The results of the integration and analysis process served as the foundation of a series of roadmaps that illustrate the development required to advance the Technology Readiness Levels (TRL) of key technologies.



While the ISTP provided critical information necessary to define NASA's space transportation strategy, increased fidelity and understanding of safety, reliability, affordability and mission requirements is also required prior to initiating new investments in 2001. Therefore, NASA plans to implement and maintain a rigorous systems engineering and requirements definition focus throughout the 2<sup>nd</sup> Generation RLV Risk Reduction Program. As stated in the "2<sup>nd</sup> Generation RLV Program Strategy", the integrated systems engineering process will develop detailed technical and programmatic requirements necessary to link technology and other risk reduction efforts. It will be used as the basis of critical decisions regarding architecture options and system characteristics to assure proper integration of the overall program. The initial phase of the 2<sup>nd</sup> Generation Program will be focused on developing specific and detailed requirements. The second phase will be an integral element of the 2<sup>nd</sup> Generation RLV Program and will maintain the integrated requirements for the overall program. We will also analyze overall technology impacts against the strategic goals and objectives for both 2<sup>nd</sup> and 3<sup>rd</sup> generation space transportation systems. NASA will also develop an integrated approach for implementing Intelligent Synthesis Environment (ISE) and other critical tool development needs in the 2<sup>nd</sup> Generation RLV Risk Reduction Program and 3<sup>rd</sup> Generation RLV technology programs. Additional tools and upgrades to the existing inventory will be incorporated, as they become available.

Consistent with the "2<sup>nd</sup> Generation RLV Program Strategy", this program will include investments in risk reduction that will be driven by the efforts of industry and NASA and will be based on the direction of competing industry concepts per the precedents established in the X-33, X-34, and X-37 programs. These activities may include business development and planning, technology investments, advanced development activities, and flight demonstrations or experiments. It is expected that NASA will initiate a wide range of risk reduction activities during the first two years. A focusing of risk reduction efforts to the most promising areas will occur throughout the program to assure a competition of at least two architecture options by 2005. Decision milestones have been identified in the program schedule to stop or change projects, as needed, to assure overall program success. The 2<sup>nd</sup> Generation Program Strategy can be located at the following URL and contains a more detailed description of the strategy and management process defined by this program; <http://std.msfc.nasa.gov/spacelaunch.html>.

Based on the corrective actions already taken to date, it is requested that this recommendation be closed upon issuance of the final report.

**OIG Recommendation 4:** The Associate Administrator for Aero-Space Technology, in coordination with the Marshall Center Director, should define technology requirements for the next-generation RLV using metrics that will facilitate measuring and reporting incremental progress. Consideration should be given to using Technology Readiness Levels as one Space Transportation metric.

**Response: Concur.** As stated in the response to Recommendation 3, NASA has, through the ISTP development process, performed a comprehensive and detailed analysis of RLV concept requirements and has established a bottoms-up development approach as demonstrated by its integrated roadmap structure. Each road map illustrates a path to develop the necessary technology from its existing TRL to at least flight demonstration TRL. The top-level technology drivers for next generations of RLV's have been identified and include, but are not limited to, the following: crew escape and survival; operable, long-life liquid hydrogen / liquid oxygen (H<sub>2</sub>/O<sub>2</sub>), and RP/liquid oxygen (RP/O<sub>2</sub>) engines; long-life, lightweight integrated airframes; advanced thermal protection systems (TPS), integrated vehicle health monitoring (IHVM) systems, vehicle operability; and the cutting edge technologies of ejector ramjet and Slender Hypervelocity Aerothermodynamic Research Probe (SHARP) leading edges. NASA expects that these priorities will remain the key focus of 2<sup>nd</sup> Generation technology efforts and is anticipated to be the basis of the program's risk reduction activities. Technologies that may be required for orbital operations risk reduction will also be addressed in coordination with the 2nd generation RLV needs. Each technology will be evaluated on its contribution to the Agency's safety, cost and reliability goals.

Based on the corrective actions already taken to date, it is requested that this recommendation be closed upon issuance of the final report.

**OIG Recommendation 5:** The Marshall Center Director should issue a Lead Center Implementation Plan on Space Transportation. The plan should identify requirements, objectives, and implementing strategies that are specific and measurable and should identify metrics that include performance targets and the evaluation process for measuring annual performance.

**Response: Concur.** We concur with the intent of this recommendation. The Space Transportation Directorate has created an integrated strategic plan to implement its charter and successfully accomplish its programmatic assignments. The Space Transportation Directorate has been designated by MSFC to be the Agency focal point for the Space Transportation Systems Development Mission Area and Center of Excellence in Space Propulsion. The Space Transportation Directorate has also been established as the MSFC Directorate to execute the lead center assignments for the Aero-Space Technology Enterprise's programs, including, X-33 Advanced Technology Demonstrator Program, Future X Pathfinder Program, and Advanced Space Transportation Program. Additionally, the Directorate supports the Human Exploration and Development of Space Enterprise through the development of propulsion capabilities, specifically, upper stages for the Space Shuttle, De-orbit Propulsion Stage for the ISS Crew Return Vehicle, and the ISS Propulsion Module. The Space Transportation Directorate also supports the HEDS mission by providing support to the Expendable Launch Vehicle Program and the Next Generation Launch Services effort.

The "Space Transportation Directorate 2010: Corporate Strategy" is a 10-year, integrated plan designed to focus the Directorate on the critical activities as MSFC and it's partners proceed to accomplish NASA's goals of enabling future safe, reliable, and affordable

## Appendix I

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access to space. The plan is intended to provide guidance and direction for the decisions and actions of the Space Transportation Team. As such, it will be a living document and will be reviewed and revised, as appropriate, on a regular basis.

Volume I of this plan includes the vision and mission of the Directorate, core strategies and metrics, technology portfolio and strategic priorities. Additionally, the authority and enabling guidance provided to MSFC and the Space Transportation Directorate through the National Space Policy, NASA, and its Enterprises is described in this volume.

To ensure that the Space Transportation Directorate successfully accomplishes this strategy, specific action plans will be developed for each of the core strategies. Each action plan will include a statement of measurable and qualitative outcomes, significant partners, key decisions and actions, champions and a timetable for completion. The action plans will be focused on the next 3 to 5 years and will be updated at least annually. Upon completion in June 2000, these plans will be included as Volume II of the Corporate Strategy.

Consistent with the NPG 1000.2, "NASA Strategic Management Handbook", and the Space Transportation Directorate is in the process of creating an implementation plan for MSFC's Center of Excellence in Space Propulsion (COE) assignment. The existing draft of the implementation plan will be modified to be consistent with the Directorate Strategic Plan. It is anticipated that the COE Implementation Plan will be complete and approved by October 2000.

<b>Corrective Action Officer:</b>	<b>TD15/Garry Lyles</b>
<b>Corrective Action Closure Official:</b>	<b>DE01/Sidney Saucier</b>
<b>Projected Closure Date:</b>	<b>10/31/2000</b>

**OIG Recommendation 6:** The Marshall Center Director should establish mission requirements for X-34 flight test requirements, determine the minimum number of flights required to satisfy X-34 Project objectives, and delete from the X-34 contract those flights that are not justified.

**Response: Concur.** In January 2000, MSFC provided mission-specific flight test requirements to OSC. As each individual flight is planned, minor adjustments may be made for the individual mission flight software. The software is the responsibility of the vehicle contractor. The X-34 Project Plan identifies the requirement for a project controlled Flight Test Plan which documents the requirement for 27 test flights. These 27 flights represent an even balance of unpowered tests, initial powered tests at lower Mach numbers, powered tests to achieve an appropriate operational tempo, powered flights to expand the Mach and altitude performance envelope, and powered tests to evaluate a host of carry-on experiments. The X-34 Project Manager will ensure that, as part of the ongoing replanning activity, flight requirements will be appropriately revalidated.

**Corrective Action Officer:** TD14/Michael Allen  
**Corrective Action Closure Official:** DE01/Sidney Saucier  
**Projected Closure Date:** 9/30/2000

**OIG Recommendation 7:** The Marshall Center Director should Implement internal controls to appropriately document management decisions, including changes to the proposed flight-test program.

**Response: Concur.** A project configuration control process has been put in place to manage changes to documentation such as the flight test program and to better document management decisions.

Based on this information, it is requested that this recommendation be closed upon issuance of the final report.

**OIG Recommendation 8:** The Marshall Center Director should cancel current plans for the extended flight test program until justification for the existing 27 flight test program has been reassessed and the total number of flights needed to meet Project objectives have been determined and revalidated. The reassessment should consider using the A2 vehicle to support experiments.

**Response: Concur.** Currently, there are no budget or contractual actions planned for an expanded flight program beyond the existing 27-flight test program.

Based on this information, it is requested that this recommendation be closed upon issuance of the final report.

**OIG Recommendation 9:** The Marshall Center Director should reassess the number of Fastrac engines required to support the X-34 Project based on results of the reassessment of test flight requirements for the X-34 and on engine reliability tests, and eliminate any unneeded engines from the contract.

**Response: Concur.** The number of engines is based on the contractor's requirement to support the project. The project requirement to support the operational flights at KSC dictates that an engine must be on-dock to replace the engine that has just completed a flight. This requirement along with the time to replace the nozzles from flown engines aids in the establishment of the number of engines required. The X-34 Project Office will reassess the number of Fastrac engines required to support the Project and, based on this assessment, will eliminate any unneeded engines from the contract.

**Corrective Action Officer:** TD14/Michael Allen  
**Corrective Action Closure Official:** DE01/Sidney Saucier  
**Projected Closure Date:** 9/30/2000

**OIG Recommendation 10:** The Associate Administrator, Office of Aero-Space Technology, and the Marshall Center Director should finalize all required program documentation for the X-34 and Future-X/Pathfinder as required by NPD 7120.4A, "Program/Project Management," and NPG 7120.5A, "NASA Program and Project Management Processes and Requirements."

**Response: Concur.** The X-34 project has submitted the project plan for approval in accordance with the appropriate NASA documents. The Future-X Pathfinder Program Commitment Agreement (PCA) and the Future-X Pathfinder Program Plan are currently being worked with the Office of Aero-Space Technology. The Pathfinder Program Office and the Office of Aerospace Technology will work together to complete these documents at the earliest possible date.

**OIG Recommendation 11:** The Associate Administrator, Office of Aero-Space Technology, and the Marshall Center Director should revise the existing draft program commitment agreement and draft program/project plans for the Future-X/Pathfinder and X-34 Project to better define approximate technology requirements and expected results (benefits), and establish performance metrics and an evaluation process to evaluate results.

**Response: Concur.** The Future-X Pathfinder PCA and Program Plan and X-34 Project Plan are being updated and we will ensure that appropriate technology requirements, expected results, and performance metrics are included. An evaluation process is being developed that will assess whether technologies, which are candidates to be flown on the X-34, address the stated requirements. This process will also evaluate the overall results from these flights. As noted above, the Pathfinder Program Office and the Office of Aerospace Technology will work together to complete these documents at the earliest possible date.

**OIG Recommendation 12:** The Associate Administrator, Office of Aero-Space Technology, should establish internal control procedures within the Enterprise's Programs Division to ensure that responsible Centers submit required program/project documentation during the program formulation process.

**Response: Concur.** The Office of Aero-Space Technology headquarters office work instruction for Program Project Formulation and Approval (HOWI: 7100-ROO7B, Sept 1999) established procedures for preparation of documentation during formulation. The Office will continue to ensure responsible Centers submit required program/project documentation during the program formulation process.

**OIG Recommendation 13:** The Associate Administrator, Office of Aero-Space Technology, should discontinue the practice of approving programs and projects for which Program Commitment Agreements and program/project plans are not yet prepared or approved, and place added emphasis on compliance with program documentation requirements specified in Agency directives NPD 7120.4A and NPG 7120.5A.

**Response: Concur.** We will make sure that all of our programs and projects will be in compliance with and have the proper documentation specified in the Agency directives NPD 7120.4A and NPG 7120.5A.

**OIG Recommendation 14:** The Associate Administrator, Office of Aero-Space Technology, should require responsible Centers to clearly identify in program documentation the approximate technology requirements, expected results (benefits), and performance metrics for evaluating actual results and to establish internal control procedures to ensure that the documentation effectively implements Enterprise strategic plans.

**Response: Concur.** The Office has recognized this deficiency and in the documentation for the two major programs initiated in FY00 (Aviation Safety and Ultra Efficient Engine Technology) the expected requirements, benefits and metrics have been identified.

**OIG Recommendation 15:** The Marshall Center Director should establish internal controls to ensure solicitations are not issued on programs/projects for which program documentation is not complete as required by Procurement Notice 97-28 and Procurement Information Circular 99-6.

**Response: Concur.** Internal controls have now been established to ensure compliance with the policy. The Automated Procurement Request System (APRS) at MSFC has been revised to include mandatory fields regarding applicability and compliance with NPD 7120 documentation requirements. Procurement requests cannot be processed without completing the mandatory fields.

Based on this information, it is requested that this recommendation be closed upon issuance of the final report.

**OIG Recommendation 16:** The Marshall Center Director should Place added emphasis on compliance with program documentation requirements specified in Agency Directives NPD 7120.4A and NPG 7120.5A, and ensure that programs and projects prepare documentation in a timely manner.

**Response: Concur.** MSFC has established a Systems Management Office (SMO) that has charter responsibility for ensuring Center programs and projects comply with NPD

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7120.4A and NPG 7120.5A. The SMO conducts independent evaluations (per NPG 7120.5A) of MSFC programs and projects that report to the MSFC Project Management Council and MSFC Lead-Center Program Management Councils (Microgravity and Space Transportation). In addition to providing a monthly evaluation of programs/projects to the Center Director, the SMO conducts Non-Advocate Reviews and Independent Annual Reviews consistent with NPG 7120.5A. The SMO is currently organizing the first round of these program/project reviews. Finally, Product Line Directorates at the Center have been directed to begin reviewing the status, at least quarterly, of all programs and projects under their management. We believe that if the SMO or the Directorate program/project review process had been in place previously, the X-34 Project's NPD 7120.4A and NPG 7120.5A non-compliances would have been identified and corrected in a timely manner.

Based on this information, it is requested that this recommendation be closed upon issuance of the final report.

## **Appendix J. Report Distribution**

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### **National Aeronautics and Space Administration (NASA) Headquarters**

A/Administrator  
AE/Chief Engineer  
AI/Associate Deputy Administrator  
B/Chief Financial Officer  
B/Comptroller  
BF/Director, Financial Management Division  
G/General Counsel  
H/Associate Administrator for Procurement  
J/Associate Administrator for Management Systems  
JM/Director, Management Assessment Division  
R/Associate Administrator for Aero-Space Technology  
RG/Director, Goals Division  
RP/Director, Programs Division

### **NASA Center Directors**

Director, George C. Marshall Space Flight Center  
Chief Counsel, Kennedy Space Center

### **Non-NASA Federal Organizations and Individuals**

Assistant to the President for Science and Technology Policy  
Deputy Associate Director, Energy and Science Division, Office of Management and Budget  
Branch Chief, Science and Space Programs Branch, Energy and Science Division, Office of Management and Budget  
Associate Director, National Security and International Affairs Division, Defense Acquisition Issues, General Accounting Office  
Professional Assistant, Senate Subcommittee on Science, Technology, and Space

### **Chairman and Ranking Minority Member - Congressional Committees and Subcommittees**

Senate Committee on Appropriations  
Senate Subcommittee on VA, HUD, and Independent Agencies  
Senate Committee on Commerce, Science, and Transportation  
Senate Subcommittee on Science, Technology, and Space  
Senate Committee on Governmental Affairs  
House Committee on Appropriations  
House Subcommittee on VA, HUD, and Independent Agencies  
House Committee on Government Reform



**Chairman and Ranking Minority Member - Congressional Committees and Subcommittees  
(Cont.)**

House Subcommittee on Government Management, Information, and Technology

House Subcommittee on National Security, Veterans Affairs, and International Relations

House Committee on Science

House Subcommittee on Space and Aeronautics

**Congressional Member**

Honorable Pete Sessions, U.S. House of Representatives

# NASA Reader Survey

## Assistant Inspector General for Auditing

### Reader Survey

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Report Title: X-34 Technology Demonstrator \_\_\_\_\_

Report Number: \_\_\_\_\_ Report Date: \_\_\_\_\_

*Circle the appropriate rating for the following statements.*

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A
1. The report was clear, readable, and logically organized.	5	4	3	2	1	N/A
2. The report was concise and to the point.	5	4	3	2	1	N/A
3. We effectively communicated the audit objectives, scope, and methodology.	5	4	3	2	1	N/A
4. The report contained sufficient information to support the finding(s) in a balanced and objective manner.	5	4	3	2	1	N/A

*Overall, how would you rate the report?*

Excellent  
Very Good  
Good

Fair  
Poor

*If you have any additional comments or wish to elaborate on any of the above responses, please write them here. Use additional paper if*

*necessary.* \_\_\_\_\_  
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***How did you use the report?*** \_\_\_\_\_

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***How could we improve our report?*** \_\_\_\_\_

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***How would you identify yourself? (Select one)***

Congressional Staff

NASA Employee

Private Citizen

Government: \_\_\_\_\_ Federal: \_\_\_\_\_ State: \_\_\_\_\_ Local: \_\_\_\_\_

Media

Public Interest

Other: \_\_\_\_\_

***May we contact you about your comments?***

**Yes:** \_\_\_\_\_

**No:** \_\_\_\_\_

**Name:** \_\_\_\_\_

**Telephone:** \_\_\_\_\_

Thank you for your cooperation in completing this survey.

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