August 2000

SPACE SHUTTLE

Human Capital and Safety Upgrade Challenges Require Continued Attention

GAO

Accountability ★ Integrity ★ Reliability

Contents

Abbreviations

NASA   National Aeronautics and Space Administration

B-285463

August 15, 2000

The Honorable John McCain
Chairman, Committee on Commerce, Science,
 and Transportation
United States Senate

Dear Mr. Chairman:

The National Aeronautics and Space Administration's (NASA) space shuttle program is at a critical juncture as three key factors converge: its workforce has declined significantly since 1995, its flight rate will have to double over that of recent years to support assembly of the International Space Station, and costly safety upgrades are being planned to enhance the space shuttle's safe operation until at least 2012.

As agreed with your office, we examined workforce and safety issues facing NASA and its shuttle program. Specifically, we assessed the impact of workforce reductions on the shuttle program, the challenges NASA faces in addressing workforce issues, and the status of planned shuttle safety and supportability upgrades.

Results in Brief

Several internal NASA studies have shown that the shuttle program's workforce has been affected negatively by the downsizing, much of which occurred after 1995. Since 1995, the shuttle workforce has decreased by more than one-third to about 1,800 full-time equivalent employees.[1] The shuttle program has identified many key areas that are not sufficiently staffed by qualified workers, and the remaining workforce shows signs of overwork and fatigue. For example, indicators on forfeited leave, absences from training courses, and stress-related employee assistance visits are all on the rise. Moreover, the program's demographic shape has changed. For example, throughout the Office of Space Flight, which includes the shuttle program, there are more than twice as many workers over 60 years old than under 30 years old. This jeopardizes the program's ability to hand off

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[1]Full-time equivalent is a measure of staff hours equal to those of an employee who works 40 hours per week in 1 year.

leadership roles to the next generation and achieve a higher flight rate to support assembly of the International Space Station. In addition, according to NASA, it poses significant shuttle program flight safety risks.

NASA has recognized the need to revitalize its workforce. For example, in December 1999, it terminated shuttle program downsizing plans and initiated efforts to begin hiring new staff. In addition, NASA and the Office of Management and Budget have begun an overall workforce review to examine personnel needs, barriers to achieving proper staffing levels and skill mixes, and potential reforms to help address the agency's long-term requirements. NASA human resource officials told us that they are now using a draft checklist we recently published as a guide[2] in ongoing workforce planning and in discussions with the Office of Management and Budget. The checklist includes a five-part framework: strategic planning, organizational alignment, leadership, talent, and performance culture. The guide should help NASA to more clearly establish a linkage between human capital programs and the agency's mission, goals, and strategies.

In addition, the Government Performance and Results Act requires a performance plan that describes how an agency's goals and objectives are to be achieved.[3] These plans are to include a description of the (1) operational processes, skills, and technology and (2) human, capital, information, and other resources required to meet goals and objectives. In reviewing NASA's fiscal year 2000 annual performance plan, we found that the plan does not adequately describe how the agency's strategies and human capital resources will help it achieve performance goals.[4] NASA's fiscal year 2001 plan, however, addresses at least some human capital issues in that it includes an objective to improve workforce health monitoring. In addition, in June 2000, the President directed the heads of all executive branch federal agencies to integrate human resource management into planning, budgeting, and mission evaluation processes. The directive requires each agency to include specific human resource management goals and objectives in its strategic and annual performance plans beginning October 1, 2000.

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[2]*Human Capital: A Self-Assessment Checklist for Agency Leaders* (GAO/GGD-99-179, Sept. 1999).

[3]Section 4(b) of Public Law 103-62, Aug. 3, 1993, 31 U.S.C. 1115.

[4]*Observations on the National Aeronautics and Space Administration's Fiscal Year 2000 Performance Plan* (GAO/NSIAD-99-186R, July 20, 1999).

Concerning safety issues, over the next 5 years, NASA plans to develop and begin equipping the shuttle fleet with a variety of safety and supportability upgrades, at an estimated cost of about $2.2 billion. The potential safety upgrades are estimated to cost $1.6 billion and are expected to enhance shuttle system safety significantly.[5] Improvements could include an electric auxiliary power unit, improved orbiter avionics, and main engine modifications. However, to implement the program successfully, NASA will have to overcome a number of programmatic and technical challenges, such as a demanding schedule and undefined design and workforce requirements. During the summer of 2000, NASA plans to independently review the shuttle program's safety upgrade strategy to assess how funding can be used most effectively to improve space shuttle safety. NASA also has an ongoing supportability upgrade program that is intended to address the effects of aging components on the system. NASA estimates that it will spend about $630 million through fiscal year 2005 to develop and incorporate the supportability upgrades, which include the electronic assembly in the solid rocket booster and insulation of the external tank.

While the President's June 2000 directive provides further emphasis on the need to integrate human capital requirements with the strategic planning process, continued management emphasis will be critical to the success of NASA's human capital planning. In addition, NASA will need to take steps to ensure it has the right people to manage the shuttle program.

Because the President has now directed NASA and all other executive branch agencies to include human capital goals and objectives in their strategic and annual performance plans, we are not making recommendations in this report. We will monitor NASA's progress in establishing and achieving its human capital goals as part of our annual performance plan assessments. NASA reviewed a draft of this report but provided no comments.

Background

The space shuttle is the world's first reusable space transportation system. It consists of a reusable orbiter with three main engines, two partially reusable solid rocket boosters, and an expendable external fuel tank. Since it is the nation's only launch system capable of carrying people to and from space, the shuttle's viability is important to other space programs, such as

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[5]NASA has not yet fully approved the set of upgrades it will include in the program.

the International Space Station. NASA operates four orbiters in the shuttle fleet.

NASA budget data shows that from fiscal year 1995 through fiscal year 1999, the space shuttle's workforce shrank from about 3,000 to about 1,800 full-time equivalent employees. A major element of this workforce reduction was the transfer of shuttle launch preparation and maintenance responsibilities from the government and multiple contractors to a single private contractor. NASA believed that consolidating shuttle operations under a single contract would allow it to reduce the number of engineers, technicians, and inspectors directly involved in the day-to-day oversight of shuttle processing, and it restructured its organization accordingly. However, the agency now recognizes that it has shortages of required personnel to perform in-house activities and maintain adequate oversight of the contractor. In December 1999, NASA terminated its shuttle program downsizing efforts and initiated efforts to begin hiring new staff.

Space systems are inherently risky because of the technology involved and the complexity of their activities. For example, thousands of people perform about 1.2 million separate procedures to prepare a shuttle for flight. NASA's top priority for the shuttle program is safety. Since the shuttle's first flight in 1981, the program has developed and incorporated many modifications to improve performance and safety. These include a super lightweight external tank, cockpit display enhancements, and main engine safety and reliability improvements. In 1994, NASA stopped approving additional upgrades pending the potential replacement of the shuttle with another reusable launch vehicle. NASA now believes that it will have to maintain the current shuttle fleet until at least 2012 and has established a development office to identify and prioritize upgrades to maintain and improve shuttle operational safety.

Human Capital Needs for the Space Shuttle Program Require Continued Attention

According to recently completed internal NASA studies, workforce reductions are jeopardizing NASA's ability to safely support the shuttle's planned flight rate. Various assessments, one completed as recently as March 2000, provide evidence that the current shuttle civil service workforce is stretched thin and overworked. In addition, studies of launch vehicle failures[6] cited workforce concerns similar to those experienced by the shuttle program. Recognizing that in-house workforce reductions had gone too far, NASA discontinued its downsizing and has begun addressing critical staffing needs. However, it faces several human capital challenges, including that of successfully attracting and retaining employees with critical skills. NASA officials have begun using our draft human capital self-assessment checklist, which provides a structured approach to identifying and addressing human capital issues.

Recent Studies and NASA's Actions Highlight Shuttle Workforce Problems

Over the past several years, NASA and its Aerospace Safety Advisory Panel have studied the shuttle program civil service workforce.[7] The studies concluded that the workforce suffered significantly from the downsizing, much of which occurred since 1995. The studies found that stress levels have reached the point of creating an "unhealthy" workforce. According to NASA's Associate Administrator for the Office of Space Flight, the agency faces significant safety and mission success risks as a result of the downsizing. The safety panel concluded that workforce problems could potentially impact flight safety as the shuttle launch rate increases to meet its demands.

In addition, NASA has concluded that the shuttle program's workforce is showing signs of overwork and fatigue as a result of the downsizing.[8] For example, indicators on forfeited leave, absences from training courses, and

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[6]Between August 1998 and May 1999, there were five government/commercial expendable launch vehicle failures. NASA, the Department of Defense, and private industry use expendable launch vehicles to place satellites in orbit when human presence is not required.

[7]Several workforce studies have been completed since 1996. The most recent include *Independent Assessment of the Shuttle Processing Directorate Engineering and Management Processes,* NASA Human Exploration and Development of Space Independent Assessment Office (Nov. 4, 1999); *Annual Report for 1999,* Aerospace Safety Advisory Panel (Feb. 2000); and *Report to Associate Administrator, Office of Space Flight,* Space Shuttle Independent Assessment Team (Mar. 7, 2000).

[8]*Space Shuttle: Human Capital Challenges Require Management Attention* (GAO/T-NSIAD-00-133, Mar. 22, 2000).

stress-related employee assistance visits are all on the rise. Moreover, the program's demographic shape and skill mix jeopardizes the program's ability to hand off leadership roles to the next generation. For example, throughout the Office of Space Flight, which includes the shuttle program, there are more than twice as many workers over 60 years old than under 30 years old.

NASA has also identified areas in which it believes the shuttle program is experiencing critical skill shortages (see app. I). In December 1999, NASA completed an internal workforce assessment focusing on its Office of Space Flight. That assessment identified work in which NASA is experiencing skill shortfalls. These areas include avionics, mechanical engineering, computer systems, and software assurance engineering. More recently, the Space Shuttle Independent Assessment Team Report, completed in March 2000 and chaired by NASA's Ames Research Center Director, concluded that the shuttle program should determine the size of the workforce, skill levels, and experience needed to maintain and operate the shuttle at the anticipated higher flight rates. The shuttle program flew four flights each in fiscal year 1998 and 1999. However, the number of flights is projected to increase substantially over the next 5 years.

In response to the studies, NASA has begun taking actions to address its shuttle workforce problems. It has terminated downsizing plans and expects to add 95 full-time equivalent employees to the shuttle program in fiscal year 2000 to address many critical skill shortages. In its fiscal year 2001 budget request, NASA is seeking authority to add another 278 full-time equivalent employees to the shuttle's workforce. NASA believes the stress-related indicators highlighted by the studies constitute critical evidence supporting the need to increase its workforce.

In October 1999, NASA's Administrator directed the agency's highest-level managers to consider ways to reduce workplace stress. NASA subsequently included improved health monitoring as an objective in its fiscal year 2001 performance plan. The Government Performance and Results Act of 1993 requires agencies to prepare annual performance plans. The purpose is to improve the efficiency of all federal agencies, with the goals of improving management, effectiveness, and public accountability; improving congressional decision-making on where to commit the nation's fiscal and human resources; and improving citizens' confidence in the government's performance.

According to its fiscal year 2001 performance plan, NASA intends to develop and implement supervisor-specific and individual training to identify, manage, and cope with stress in the workplace. Also, in May 2000, the Administrator announced the creation of a new office to increase the agency's emphasis on health and safety.

In addition, NASA has undertaken a joint review with the Office of Management and Budget to identify its overall future workforce needs. According to the NASA Administrator, this review will assess potential tools for and approaches to overall agency personnel management. NASA expects this effort to examine the process used to determine resource needs, the barriers to achieving proper staffing levels, and potential reforms that may help the agency address long-term human capital requirements. NASA and the Office of Management and Budget plan to complete the study in time for consideration during the fiscal year 2002 budget process.

Expendable Launch Vehicle Studies Offer Ways to Address Workforce Issues

NASA, the Department of Defense, and the private sector have carried out a number of studies on the causes of expendable launch vehicle failures. The studies can provide additional insights into how NASA's shuttle program can address workforce issues.[9] These studies, completed in late 1999, include assessments by the Lockheed Martin and Boeing companies and a review by the Department of Defense that encompass previous and ongoing studies and included NASA's participation. In general, the studies address a range of issues, including the effects of hardware problems and the need to improve launch processes, establish accountability for mission success, and enhance government and industry cooperation. The studies also emphasize the importance of human resources by discussing the effects of employee burnout, the need for a proper skill mix, the alignment of staff with program goals, the potential effects of critical skill losses, and the need for long-term human capital planning.

Shuttle officials believe that they can apply the lessons learned from the expendable launch vehicle studies, particularly in the areas of establishing accountability when transferring work to a private contractor and mitigating the effects of downsizing. Over the next several years, NASA expects to seek improvements in these areas by (1) responding to the study

[9]The studies prompted a number of investigations by the Department of Defense, NASA, and the private sector to identify the root causes and potential corrective actions.

completed in March 2000 by NASA's shuttle independent assessment team, (2) developing cost and accountability criteria for completing the next phase of the transfer of responsibilities to the shuttle processing contractor, and (3) establishing resource levels during the current budget preparation cycle.

Structured Approach Can Help NASA Face Its Human Capital Challenges

In dealing with its workforce issues, NASA shuttle program officials will have to deal with a number of complicating challenges. These include (1) meeting increased training needs deriving from higher workforce levels, (2) ensuring adequate staffing levels for its safety upgrade program, (3) attracting and retaining employees with critical skills, and (4) achieving a higher projected flight rate compared with rates of recent years. A structured approach can help NASA resolve its human capital challenges.

NASA's shuttle independent assessment team report notes that although hiring and training new personnel are logical steps in making up for the loss of critical skills, these are slow processes and initially add to the workload of existing personnel. For example, according to another NASA study, training new engineers can take 2 or more years, but the shuttle's current workload leaves little time for training.[10]

Also, the shuttle program is undertaking a 5-year safety upgrade initiative involving modifications to increase the safety of all major vehicle components. Although the workforce requirement for the upgrade program is still undefined, Johnson Space Center officials believe the program could require more than 200 engineers. Moreover, NASA Headquarters officials told us that people with some critically needed skills, such as software engineering, will be hard to attract and retain.

NASA's downsizing coincided with a decreased number of shuttle flights: eight flights in fiscal year 1997, but only four each in fiscal years 1998 and 1999. However, the number of flights is projected to increase substantially as the International Space Station assembly schedule accelerates. For example, NASA plans nine flights in fiscal year 2001.

[10]*Independent Assessment of the Shuttle Processing Directorate Engineering and Management Processes,* NASA's Human Exploration and Development of Space Independent Assessment Office (Nov. 4, 1999).

Our Comptroller General has made improved human capital management throughout the federal government one of his top priorities. In testimony on March 9, 2000, he stated that

"human capital management recognizes that employees are a critical asset for success, and that an organization's human capital policies and practices must be designed, implemented, and assessed by the standard of how well they support the organization's mission and goals." [11]

In September 1999, we published a draft human capital self-assessment checklist that provides a systematic approach to identifying and addressing human capital issues. This checklist allows agency managers to quickly determine whether their approach to human capital supports their vision of who they are and what they want to accomplish and to identify those policies that are in particular need of attention. The checklist follows a five-part framework that includes strategic planning, organizational alignment, leadership, talent, and performance culture. The guide helps to establish a linkage between human capital programs and an agency's mission, goals, and strategies.

Our Standards for Internal Control in the Federal Government also address human capital management issues and state that

"only when the right personnel for the job are on board and are provided the right training, tools, structure, incentives, and responsibilities is operational success possible." [12]

In addition, the Government Performance and Results Act requires a performance plan that describes how an agency's goals and objectives are to be achieved. These plans are to include a description of the (1) operational processes, skills, and technology and (2) human, capital and information resources required to meet those goals and objectives. In reviewing NASA's fiscal year 2000 annual performance plan, we found that

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[11]Testimony was given before the Subcommittee on Oversight of Government Management, Restructuring, and the District of Columbia, Senate Committee on Governmental Affairs; *Human Capital: Managing Human Capital in the 21st Century* (GAO/T-GGD-00-77). Also on March 9, 2000, we testified on similar human capital concerns related to the Department of Defense. This testimony was given at a joint hearing involving the Subcommittee on Military Readiness, House Committee on Armed Services, and the Subcommittee on Civil Service, House Committee on Government Reform; *Human Capital: Strategic Approach Should Guide DOD Civilian Workforce Management* (GAO/T-GGD/NSIAD-00-120).

[12]*Standards for Internal Control in the Federal Government* (GAO/AIMD-00-21.3.1, Nov. 1999).

the plan does not adequately describe how the agency's strategies and human capital resources will help it achieve performance goals.[13]

The President recently underscored the importance of linking human capital requirements with an agency's strategic planning processes. On June 9, 2000, he directed the heads of all executive branch federal agencies to "fully integrate human resources management into (each) agency's planning, budgeting and mission evaluation processes, and clearly state specific human resources management goals and objectives in (the) organization's strategic and annual performance plans."

NASA human resource officials told us that the agency is using our checklist as a guide in ongoing workforce planning and discussions with the Office of Management and Budget. For example, they provided a draft of a Human Resources and Education Functional Leadership Plan that addresses NASA's approach to (1) recognizing employees as the agency's most important resource by creating a safe, challenging, and satisfying work environment; (2) attracting and retaining a skilled and diverse workforce; (3) establishing a continuous learning environment; and (4) ensuring that the agency's human resources professionals have the knowledge, skills, abilities, and tools to carry out their responsibilities.[14] NASA plans to develop feedback surveys to measure its success in achieving these goals.

Safety and Supportability Upgrade Programs

Over the next 5 years, NASA plans to develop and begin equipping the shuttle fleet with a variety of shuttle safety and supportability upgrades, at an estimated cost of about $2.2 billion. While safety upgrades have been identified, NASA plans to independently review the shuttle program's safety upgrade strategy to assess how funding can most effectively be used to improve space shuttle safety. To implement the safety program successfully, a number of programmatic and technical challenges will have to be overcome. NASA also plans to incorporate system supportability upgrades to mitigate the effects of aging components and outdated technologies.
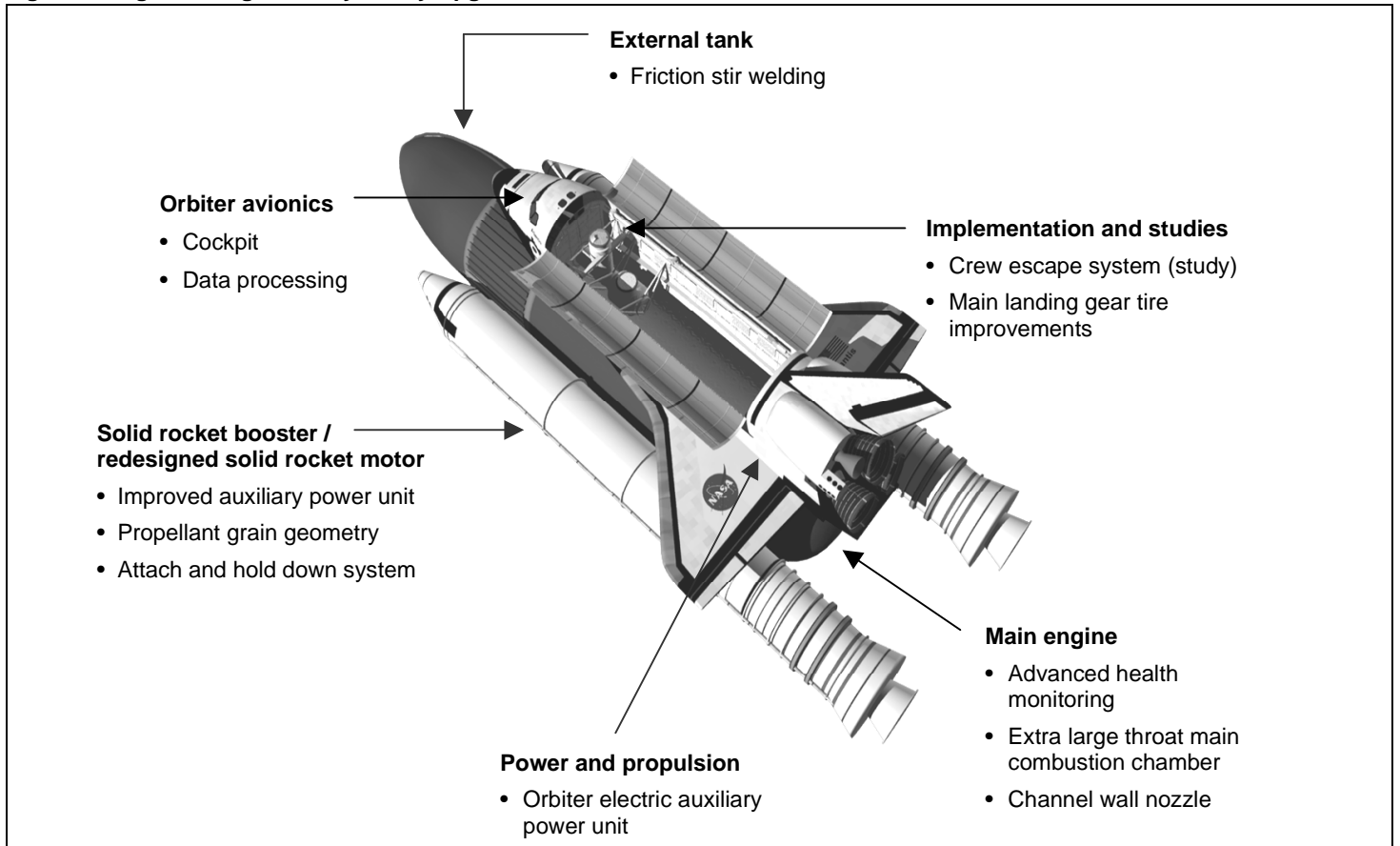
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[13] *Observations on the National Aeronautics and Space Administration's Fiscal Year 2000 Performance Plan* (GAO/NSIAD-99-186R, July 20, 1999).

[14] The Functional Leadership Plan establishes the human resource strategies necessary to achieve the agency's missions and goals.

Safety Upgrades Identified but Currently Under Evaluation

Between fiscal year 2000 and 2005, NASA plans to develop and begin equipping the shuttle fleet with safety upgrades affecting every major aspect of the system, at an estimated cost of $1.6 billion. For example, the plan includes potential improvements to the orbiter, the external tank, the main engine, and the solid rocket booster (see fig. 1). NASA's time frame for completing these improvements is based on its current plans to operate the shuttle fleet until at least 2012. A general description of each potential upgrade is provided in appendix II.

Figure 1: Figure 1: High-Priority Safety Upgrades

External tank
- Friction stir welding

Orbiter avionics
- Cockpit
- Data processing

Implementation and studies
- Crew escape system (study)
- Main landing gear tire improvements

Solid rocket booster / redesigned solid rocket motor
- Improved auxiliary power unit
- Propellant grain geometry
- Attach and hold down system

Main engine
- Advanced health monitoring
- Extra large throat main combustion chamber
- Channel wall nozzle

Power and propulsion
- Orbiter electric auxiliary power unit

Source: Space Shuttle Program Office.

NASA has undertaken two independent reviews of the safety upgrade program. One review, begun in April 2000, will deal with specific cost and technical issues related to each project; the other, begun in June 2000, will concentrate on the overall program strategy. As individual projects are approved for implementation, NASA's Independent Program Assessment Office will evaluate the upgrades to determine whether (1) requirements are well defined, (2) design and implementation risks are acceptable, and (3) cost-effectiveness has been appropriately considered.

In addition, in February 2000 the Associate Administrator for Space Flight asked NASA's Space Flight Advisory Committee to assess the agency's strategy and priorities for the planned safety upgrades. The Committee is expected to determine whether NASA has defined the right upgrade program and has adopted a sound approach. It also expects to incorporate the results of the review by the Independent Program Assessment Office into its work, currently scheduled to be completed by late summer 2000.

NASA Faces Challenges in Successfully Completing Safety Upgrade Program

NASA and the shuttle program will have to overcome many programmatic and technical challenges to implement the safety upgrade program successfully. Specifically, the agency has not yet fully approved the set of upgrades it will include in the program or the associated workforce requirements. Assuming the shuttle will be replaced by 2012, the upgrade program must be implemented on schedule to achieve maximum benefit. Addressing potential development problems while meeting a demanding flight schedule will make cost containment a major challenge. Programmatic and technical challenges include the following:

- Several major safety upgrade projects are not fully approved, creating program uncertainty. For example, the avionics upgrade is to increase hardware reliability and improve cockpit information for the crew. The breadth of information to be provided and the means to do so have not yet been fully determined. In addition, replacing the auxiliary power unit in the solid rocket booster will require additional studies to determine the best alternative. Also, NASA is still assessing potential safety upgrades such as crew escape and thermal protection systems.

- While NASA has begun to establish a dedicated shuttle safety upgrade workforce, it has not fully determined its needs in this area. Johnson Space Center officials estimate that the program could require more than 200 engineers dedicated specifically to the safety upgrades. NASA Headquarters officials believe the planned workforce increase in fiscal

year 2000 and 2001 will be sufficient to cover upgrade workforce needs. However, neither organization was able to provide a firm estimate. Also, it is important to note that the planned workforce increase as currently portrayed is supposed to address all shuttle program workforce needs, not just those of the upgrade program.

- NASA currently plans to operate the shuttle until at least 2012. Thus, it is important that the safety upgrades be developed by 2005 to ensure that the program provides maximum benefit. The upgrade schedule coincides with the peak assembly period of the International Space Station. During this period, the shuttle will have to double its flight rate over those of recent years. NASA officials acknowledge that it will be a challenge to accommodate both schedules.

- Historically, major hardware and software development efforts have encountered unforeseen technical problems. The planned safety upgrade program could require developing and integrating at least nine major improvements in 5 years. As such, it may be the most aggressive modification effort ever undertaken by the shuttle program. Because the technical requirements for the program are not yet fully defined and the schedule for implementation is very success oriented, it is likely that cost pressures will develop.

Supportability Upgrades to Mitigate Effects of Aging Components

In addition to the safety improvements, NASA plans to incorporate a number of supportability upgrades over the next 5 years at an estimated cost of $630 million. This effort is designed to combat the obsolescence of vehicle and ground systems. Through this program, NASA hopes to mitigate the effects of aging components and outdated technologies.

The most expensive supportability upgrade is the Checkout and Launch Control System. This system is to replace the launch processing system that has been used since the 1970s at the Kennedy Space Center. In 1997, the new system was estimated to cost about $200 million, with a completion date in fiscal year 2001. The estimate was later increased to about $230 million, with completion in fiscal year 2003. According to a program official, additional substantial cost and schedule increases are under review but will not be fully determined until fiscal year 2001. Other supportability upgrades involve improvements to the vehicle itself, including the solid rocket booster and external tank.

Conclusions

Over the last several years, NASA's strategic human capital planning was inadequate. While the agency was emphasizing workforce reductions, various NASA studies were showing that the shuttle workforce was being negatively impacted by the reductions. In the wake of analyses of workforce shortages agencywide over the past couple of years, NASA recognized that it had serious problems. The shuttle program was entering a critical phase in which it had to prepare for a doubling of its current flight rate to assemble the International Space Station while at the same time developing and incorporating numerous safety upgrades. NASA is now taking a number of important steps to address the effects of workforce reductions and to ensure that a proper skill mix and staffing level for the shuttle program is achieved and maintained. While the President's June 2000 directive provides further emphasis on the need for integrating human capital requirements with the strategic planning process, continued NASA management emphasis on human capital planning will be critical to continued safe shuttle operations in an environment of increasing flight rates.

Agency Comments

NASA reviewed a draft of this report but provided no comments.

Scope and Methodology

To assess the impact of workforce reductions on the shuttle program and the challenges NASA faces in addressing workforce issues, we reviewed the agency's workforce reduction goals, recent shuttle workforce studies, budget documentation, internal indicators of workplace stress, recruitment and hiring strategies, and workforce trends related to skill mix and age. In addition, we reviewed internal briefings and recent launch vehicle studies and interviewed program officials, study participants, members of NASA's Aerospace Safety Advisory Panel, and officials in the Expendable Launch Vehicle Office to gain further insights.

To assess the program's plans to incorporate safety upgrades, we reviewed development plans, budget documentation, internal briefings, and risk assessments. In addition, we compared cost estimates to budgetary projections. We interviewed officials in the shuttle program development office, NASA's Office of Safety and Mission Assurance, and the Aerospace Safety Advisory Panel.

We conducted our review from September 1999 through June 2000 in accordance with generally accepted government auditing standards.

Unless you publicly announce its contents earlier, we plan no further distribution of this report until 14 days from its issue date. At that time, we will send copies to the Honorable Ernest Hollings, Ranking Minority Member, Senate Committee on Commerce, Science, and Transportation; the Honorable Daniel Goldin, NASA Administrator; the Honorable Jacob Lew, Director, Office of Management and Budget; and other interested parties. We will also make copies available to others on request.

Please contact me at (202) 512-4841 if you or your staff have any questions about this report. Key contacts for and contributors to this report are listed in appendix III.

Sincerely yours,

Allen Li
Associate Director
Defense Acquisitions Issues

Space Shuttle Program Skill Shortfall Areas

In December 1999, NASA completed an internal workforce assessment focusing on its Office of Space Flight, which includes the shuttle program. That assessment identified work areas in which NASA was experiencing skill shortfalls. At our request, NASA provided a listing of shuttle program skill shortages. The areas the agency identified follow:

- Program/project management/project engineering
- Aerospace vehicle design and mission analysis
- Avionics
- Guidance, navigation, and control systems
- Materials analysis
- Mechanical engineering
- Thermal control
- Structural dynamics
- Vehicle dynamics
- Aircraft ground systems
- Human factors
- Environmental controls
- Robotic systems
- Computer systems
- Fluids (liquid propulsion systems)
- Information technology security
- Aerospace systems test engineering
- Software (applications and systems)
- Sensors and transducers
- Electrical engineering
- Software assurance engineering
- Flight assurance
- Quality engineering
- Reliability engineering
- Safety engineering
- Flight controls

Space Shuttle Upgrades

NASA has identified a set of potential shuttle upgrades to be incorporated by fiscal year 2005. The program includes potential improvements to every major area of the shuttle system. A breakout of the planned modifications is shown in table 1.

Table 1: Potential Space Shuttle Upgrades

Dollars in millions

Upgrade area	Purpose of upgrade	Estimated cost
Electric auxiliary power Unit	Eliminates use of hazardous fuel and high-speed equipment to generate power for the orbiter's hydraulic system	$224.0
Space shuttle main engine advance health monitoring	Provides real-time information to the crew on engine performance	108.1
Orbiter avionics	Reduces flight crew workload and improves situational awareness	380.0
Space shuttle main engine	Improves engine operating environment, thereby increasing reliability	400.0
Solid rocket booster auxiliary power unit	Eliminates the use of hazardous fuel in the solid rocket booster thrust vector control auxiliary power unit	208.0
Solid rocket booster attach/hold-down hardware	Reduces the potential for human error and improves reliability	5.0
Redesigned solid rocket motor propellant	Improves the solid propellant and safety of ground personnel	10.0
External tank friction stir welding	Improves reliability, supportability, and manufacturing process control	20.0
Implementation and additional studies	Vehicle installation, system integration, studies, and maintainability	232.9
Subtotal		**$1,588.0**
Supportability upgrades	Checkout and Launch Control System and mandatory supportability shuttle upgrades	$630.0
Total		**$2,218.0**

GAO Contact and Staff Acknowledgments

GAO Contact

Allen Li (202) 512-4841

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