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GAO

Report to the Chairman, Committee on Government Operations, House of Representatives

May 1989

SPACE SHUTTLE

Follow-up Evaluation of NASA's Solid Rocket Motor Procurement

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

National Security and
International Affairs Division

B-223785

May 23, 1989

The Honorable John Conyers, Jr.
Chairman, Committee on Government
Operations
House of Representatives

Dear Mr. Chairman:

As requested, we performed a follow-up review of the National Aeronautics and Space Administration's (NASA) solid rocket motor procurement. Specifically, we reviewed NASA's plans to establish and maintain competition in the future procurement of shuttle solid rocket motors and the quality assurance and industrial safety programs at Morton Thiokol's solid rocket motor manufacturing plant.

The report contains recommendations to conduct an economic analysis of the requirements for additional redesigned solid rocket motors and review the need for additional government safety inspection personnel at the Thiokol plant. NASA's acquisition plan for the advanced solid rocket motor provides for full and open competition in the initial contract award. However, because of the difficulty in competing follow-on production of a major system, the Congress may wish to consider obtaining periodic status reports from NASA on its efforts to maintain competition in the program.

As requested, we did not obtain official agency comments on this report. However, we sought the views of directly responsible officials during our work, and we included their comments in our report where appropriate. Unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after its issue date. At that time we will send copies to the Administrator, National Aeronautics and Space Administration; the Secretary of the Air Force; appropriate congressional committees; and other interested parties upon request.

This report was prepared under the direction of Harry R. Finley, Director, Air Force Issues. Other major contributors are listed in appendix I.

Sincerely yours,

Bill W. Thurman
for Frank C. Conahan
Assistant Comptroller General

Executive Summary

Purpose

In August 1986 GAO reported on the National Aeronautics and Space Administration's (NASA) unsuccessful attempts to reestablish competition in the procurement of space shuttle solid rocket motors and on problems relating to quality assurance and safety at the Morton Thiokol plant, which manufactures the motors.

The former Chairman, House Committee on Government Operations, asked GAO to perform a follow-up review on these issues. Specifically, the Chairman asked GAO to determine whether NASA planned to establish and maintain competition in future shuttle motor procurement and whether NASA, the Air Force, and Thiokol had improved quality assurance and industrial safety at the Thiokol plant.

Background

Solid rocket motors provide most of the thrust needed for lift-off and during initial phases of shuttle flight. Morton Thiokol, Incorporated, has been the sole supplier of the motors since it won the contract in 1973. After the Challenger accident on January 28, 1986, Thiokol redesigned the motors and resumed production. At about the same time, NASA began studies to define concepts for an advanced solid rocket motor. The Fiscal Year 1988 NASA Authorization Act requires the NASA Administrator to issue a request for proposals for competitive development of an advanced motor by the time the President submits the fiscal year 1990 NASA budget request. The act further directs the Administrator to consider constructing a government-owned, contractor-operated production facility and providing for a dual source of supply for the advanced motor. NASA issued the request for proposals for advanced solid rocket motor development in August 1988. As a part of the program, new motor manufacturing facilities are to be constructed on government property.

Results in Brief

NASA's Acquisition Plan for the advanced solid rocket motor provides for full and open competition in the initial contract award and protects NASA's option to compete future contracts for advanced motor production. Government ownership of the manufacturing plant is a key element of NASA's strategy for maintaining competition in the program. Government ownership of the plant should facilitate future competition, but experience has shown that it does not always guarantee continued competition.

Until the advanced motor is available in sufficient quantities to support all flights, NASA will have to continue procuring redesigned motors on a sole-source basis from Thiokol. NASA's objective is to purchase the minimum number of redesigned motors needed to make a transition to the advanced motor program, but it may have overestimated the number of redesigned motors it will need.

NASA and Thiokol have taken steps to enhance quality assurance and reduce industrial safety hazards at the motor manufacturing plant. Both NASA and the Air Force Plant Representative Office, which monitors Thiokol's performance for NASA, believe that quality assurance has improved and that Thiokol management needs to devote more attention to industrial safety. GAO agrees, but believes that NASA needs to improve its monitoring of Thiokol's safety program.

GAO's Analysis

Competition

NASA allowed all interested and qualified firms to compete for the contract to develop and produce advanced solid rocket motors. In May 1988 NASA advertised its requirement for the advanced motor development and initial production. The announcement specified that the contractor would be selected through full and open competition. To help ensure that none of the proposed contract provisions or specifications would restrict competition, NASA also circulated a draft of the request for proposals to all interested firms.

Experience has shown that maintaining competition in the follow-on production of a major system can be time-consuming and costly to ensure that another contractor is qualified to produce the system with the needed quality. The government and initial development contractor normally invest large sums in facilities and equipment to develop, test, and produce a system. Maintaining competition has often meant duplicating these expenditures to qualify another contractor for the competition.

To protect the option to compete any future production, either the advanced motor is to be developed, built, and tested in government-owned facilities, or, if the facilities are privately financed, the contract is to provide for transfer of ownership of the facilities to the government or another contractor if NASA selects one. Also, the advanced motor contractor will be required to (1) document all technical and procedural data and software under government ownership, (2) assist potential competitors to become familiar with advanced motor manufacturing processes and procedures, and (3) include agreements in all subcontracts providing for subcontract transfer to any successor contractor.

Government ownership of the manufacturing plant does not guarantee continued competition. The Army has not always sought competition for contracts to operate its ammunition plants. Also, NASA decided not to seek competition for contracts to produce the shuttle's external fuel tank. In 1987 NASA decided to purchase additional external tanks on a sole-source basis from Martin Marietta partly because of its past performance record. Circumstances surrounding the external tank procurement are similar in many ways to those planned for the advanced solid rocket motor production. The external tank is manufactured in a government-owned facility, and competition would not have been precluded by either a lack of data or the existence of proprietary manufacturing processes.

In 1989 NASA plans another sole-source procurement for 142 redesigned motors from Thiokol at an estimated cost of $2.3 billion. The motor quantity was based on a projected shuttle flight rate of up to 14 launches a year. However, according to a National Research Council study, NASA's flight rate projection may be optimistic. NASA did not perform an economic analysis to determine whether purchasing a smaller quantity may be prudent. NASA told GAO that it will update its requirements during contract negotiations to eliminate any over- or under-buy to the extent possible.

Quality Assurance

Both NASA and Thiokol have reorganized and centralized their quality assurance functions. Thiokol has improved some quality control methods and increased its quality assurance audits. Also, both Thiokol and the Air Force Plant Representative Office have substantially increased the number of quality assurance inspections and inspectors. In addition, NASA has changed Thiokol's contract to an award fee arrangement—with quality assurance as one of the criteria for determining the amount of fee to be paid to Thiokol.

According to both NASA and the Air Force Plant Representative Office, quality assurance has improved. For example, a March 1988 NASA audit concluded that Thiokol's quality assurance organization was operating in an excellent manner.

Industrial Safety

Since 1986 Thiokol also has undertaken initiatives to improve industrial safety at the motor manufacturing plant. However, both NASA and Air Force evaluations continue to identify safety hazards and violations. For example, the Air Force concluded that Thiokol's failure to take prompt and effective corrective action after a near accident while building Peacekeeper motors may have set the stage for an explosion in December 1987. NASA and the Air Force have applied financial penalties as an incentive for Thiokol to resolve recurring safety problems.

The Air Force Plant Representative Office, NASA's Safety Assessment Center contractor, and Thiokol do not always agree on the safety data to be reported and tracked. NASA has not analyzed the reported safety incidents to detect trends, identify the underlying causes of safety problems and determine where best to focus attention. The Air Force also has not performed all needed independent safety inspections of shuttle motor manufacturing facilities due to a lack of personnel.

Matter for Consideration

GAO concluded that NASA's advanced solid rocket motor acquisition strategy provides for full and open competition in the initial contract award and protects the option to compete future contracts. However, GAO recognizes that maintaining competition in the follow-on production of a major system has proven difficult in practice, and, therefore, the Congress may wish to obtain periodic status reports from NASA on its efforts to maintain competition in the program.

Recommendations

GAO recommends that the NASA Administrator require the Director, Marshall Space Flight Center, to prepare an economic analysis as part of its efforts during contract negotiations to update requirements for redesigned solid rocket motors.

GAO further recommends that the Administrator and the Secretary of the Air Force determine safety inspection staffing requirements at the Thiokol plant.

Agency Comments

As requested, GAO did not ask NASA to comment officially on a draft of this report. However, the views of responsible officials were sought during the course of GAO's work and are included in the report where appropriate.

Contents

Abbreviations

GAO	General Accounting Office
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration

Introduction

Solid rocket motors, which are a subsystem of the strap-on solid rocket boosters, provide 80 percent of the total thrust needed by the shuttle at lift-off and during the initial phases of flight. Roughly 2 minutes after lift-off and 24 miles down range, the solid rocket motors exhaust their propellant, and the boosters separate from the rest of the shuttle and fall into the ocean. Parts of the boosters, including parts of the motors, are retrieved and refurbished for use in future flights. The shuttle motors are the largest U.S. solid rockets ever flown and the only ones designed for reuse.

Procurement History

In 1973 the National Aeronautics and Space Administration (NASA) competitively selected the Thiokol Chemical Corporation (now Morton Thiokol, Incorporated) to develop, qualify, and produce solid rocket motors for the space shuttle program. Since that time, Thiokol has been the sole supplier of the motors. NASA's Marshall Space Flight Center (MSFC) has primary responsibility for managing the shuttle solid rocket motor program.

As early as 1974, NASA began formulating plans to develop a second production source for selected portions of the solid rocket motor manufacturing effort. However, the plans were never implemented because of schedule delays, budget constraints, and the Challenger accident on January 28, 1986. The accident, according to the Presidential Commission, was caused by the failure of a pressure seal in one of the joints of the right hand motor. The failure was due to a faulty design that was unacceptably sensitive to a number of factors such as the effects of temperature. After the accident, Thiokol redesigned the solid rocket motor to prevent a recurrence of the problem and resumed production of the redesigned motors in August 1987.

Acting on NASA's fiscal year 1986 urgent supplemental appropriation, the congressional conference committee, in June 1986, directed that NASA make sufficient funds available to study an alternative solid rocket booster design, such as one using a unitary case or single cast propellant. The studies were to be completed by December 31, 1986, and results forwarded to the House and Senate Committees on Appropriations. The conference committee also directed that after NASA selects a final design, it should issue a request for proposals for a second source if it determines that such an approach could be adopted with available resources.

GAO's 1986 Testimony and Report

On July 31, 1986, we testified before the Legislation and National Security Subcommittee, House Committee on Government Operations, on NASA's procurement of solid rocket motors. Our testimony focused on (1) the circumstances surrounding NASA's second source initiative for procuring solid rocket motors, (2) NASA's plans to redesign the motor to resolve problems identified by the Presidential Commission on the Challenger accident and to develop and maintain multiple production sources, and (3) quality assurance and safety at the Thiokol solid rocket motor manufacturing facility.

Subsequently, we reported[1] on these matters and recommended that the NASA Administrator prepare and provide to the Congress a comprehensive acquisition strategy and plan for continued procurement of the motors that addressed (1) NASA's decision about upgrading the motor design, (2) alternatives for establishing and maintaining competition in future procurement, and (3) the costs and benefits of each alternative. We also recommended that before motor production resumed, the NASA Administrator and the Secretary of the Air Force determine the number and types of government personnel needed to ensure that quality in motor manufacturing operations is adequate and acquire the needed staff. Finally, we recommended that, before resuming production, the NASA Administrator identify mechanisms, including possible contractual incentives or penalties, needed to ensure that the controls were properly implemented and enforced.

Objectives, Scope, and Methodology

The former Chairman, House Committee on Government Operations, asked us to follow up on our 1986 review on NASA's solid rocket motor procurement and quality assurance and safety. Specifically, the Chairman asked us to determine if NASA planned to establish and maintain competition in the future procurement of shuttle solid rocket motors and if NASA, the Air Force, and Thiokol had improved quality assurance and industrial safety programs at the solid rocket motor manufacturing plant.

To assess competition in future motor procurements, we reviewed NASA's proposed solid rocket motor acquisition strategy and plan, the advanced solid rocket motor acquisition plan, the Request for Proposals for advanced motor development and initial production, and other documents related to the planned procurement. We discussed the advanced

[1] Space Shuttle: NASA's Procurement of Solid Rocket Booster Motors (GAO/NSIAD-86-194, Aug. 26, 1986).

motor procurement plans with officials at MSFC, NASA Headquarters, and the potential advanced motor contractors. We also reviewed NASA's plan for continued procurement of redesigned solid rocket motors. We reviewed NASA's experience with the development and production of solid rocket boosters and shuttle external tanks that are produced in government-owned facilities and the Army's experience with government-owned, contractor-operated ammunition plants.

To assess improvements in Thiokol's quality assurance and industrial safety programs, we reviewed audit, inspection, investigation, and other reports prepared by NASA, Thiokol, the Air Force Plant Representative Office, and the Occupational Safety and Health Administration. We also discussed quality and safety improvements with appropriate officials at MSFC, Thiokol, and the Plant Representative Office.

We performed our work from January 1988 to January 1989 in accordance with generally accepted government auditing standards. As requested, we did not ask NASA, the Air Force, or Thiokol to review and comment officially on a draft of this report. However, we sought the views of directly responsible officials during our work, and we included their comments in our report where appropriate.

Competition in Solid Rocket Motor Procurement

Competition in the procurement of public goods and services is a national policy that is embodied in the Competition in Contracting Act of 1984. Competition can lead to increased technical performance, encourage improvements in quality, reduce acquisition costs, and enhance the industrial base. The chance of winning a government contract or the threat of losing one provide a key incentive for greater efficiency and effectiveness.

A key element of NASA's strategy for maintaining the ability to compete future advanced motor production contracts is government ownership of the manufacturing plant. Although government ownership of the plant will facilitate competition, experience has shown that it does not guarantee that competition will be maintained.

Until the advanced motor is available in sufficient quantities, NASA will continue procuring redesigned solid rocket motors on a sole-source basis from Thiokol. According to NASA, it would not be cost effective to develop competition for the redesigned motor, since this motor is to be phased out and replaced by the advanced motor beginning in fiscal year 1994. In 1989 NASA plans to contract with Thiokol for an additional 142 redesigned motors at an estimated cost of $2.3 billion. However, NASA may have overestimated the number of redesigned motors.

Past Efforts to Maintain Competition Were Unsuccessful

In 1986 we reported on NASA's unsuccessful attempts to maintain competition in the procurement of shuttle solid rocket motors. Thiokol has been the sole producer of these motors since it won the original development competition contract in 1973. Plans that NASA formulated in the 1970s to develop alternate motor production sources were never implemented because of changes in the shuttle development schedule and funding constraints. In January 1986 NASA announced another plan to develop a second source for shuttle motor production. However, this plan was suspended a few days later because of the Challenger accident. We found that this plan contained restrictions on competition that were questionable and that would have required specific justifications under the Competition in Contracting Act. As a result, the plan might not have fostered competition, even if it had been implemented.

After the Challenger accident, NASA officials decided to reintroduce competition into shuttle motor procurement through the development of an advanced motor. On March 31, 1987, the NASA Administrator provided the Congress with a comprehensive acquisition strategy and plan for the continued procurement of solid rocket motors. The plan addressed motor design decisions, alternatives for establishing and maintaining competition in future procurement, and costs and benefits of each alternative. It identified the following options for the continued procurement of shuttle motors: (1) continuing single source procurement of the redesigned motor, (2) developing an alternate source for the redesigned motor, and (3) competitively developing an advanced solid rocket motor.

Decision to Develop Advanced Solid Rocket Motor

NASA concluded that the third option—competitive development of an advanced motor—would best satisfy its objectives. This option was expected to provide improved reliability and flight safety, procurement competition, and enhanced flight performance. According to the plan, this option should also result in building a high technology solid rocket motor facility that would enhance quality assurance, reduce operational hazards, and decrease labor costs. NASA said it was prepared to proceed with the definition and preliminary design studies of the advanced motor using already available fiscal year 1987 and 1988 funding if the Congress approved the plan.

During the fiscal year 1988 budget authorization process, the Congress approved NASA's decision to develop and produce the advanced motor and reemphasized the need for competition. Section 121 of the NASA Authorization Act of 1988 (P.L. 100-147) states that, "It is the sense of Congress that the solid rocket motor project of the space shuttle program would benefit from competition, and that an advanced solid rocket motor would enhance the margin of safety, reliability, and performance of the space shuttle."

The act requires the NASA Administrator to issue a request for proposals for competitive development of the advanced motor by the time the President submits the fiscal year 1990 NASA budget request. The act also requires the Administrator to consider ways to improve quality assurance, decrease operational hazards, decrease costs, increase competition, and enhance manufacturing processes. The act directs the Administrator to consider constructing a government-owned and contractor-operated production facility and providing for a dual source of supply of the advanced motor.

Although development of the advanced motor will reintroduce competition into solid rocket motor procurement, the primary program goals are to increase shuttle performance and enhance flight safety, according to NASA. NASA and the potential contractors estimated that the advanced motor could increase the shuttle's weight-carrying capability by 17 percent, or about 12,000 pounds per flight. With the increased performance, fewer flights would be required to transport a given set of payloads. For example, according to the Chief of NASA's Shuttle Propulsion Division, five to six fewer flights would be needed to transport and assemble the Space Station using the advanced motor. The advanced motor is expected to improve shuttle flight safety by eliminating up to one-half of the potential failure causes. For example, the advanced motor would eliminate the need to throttle the shuttle's liquid-fueled main engines during a critical ascent phase, thereby eliminating or reducing about 175 potential failure modes, according to NASA.

According to NASA officials, achieving the needed increase in flight safety will require improvements in quality and reproducibility during the motor manufacturing process. To achieve the high quality and reproducibility needed, NASA has concluded that a substantially new motor manufacturing facility, incorporating a high degree of automation and robotics, is needed. NASA also expects that the process automation and production controls will reduce motor costs.

Advanced Solid Rocket Motor Acquisition Strategy Promotes Competition

The request for proposals for development and initial production of the advanced motor was issued in August 1988, and it provides for full and open competition. It also protects NASA's ability to maintain competition in the program by competing contracts for future production.

NASA intends to award two contracts to the successful bidder in the advanced motor program. One contract will be to design, develop, and test the motor. It will also provide for delivery of 6 sets of flight motors and include an option for the manufacture of up to 44 additional motor sets. The other contract will be to acquire the motor manufacturing and test facilities, which are to be constructed on government land. The manufacturing facilities are to be located in Yellow Creek, Mississippi, and the static test facilities will be located at Stennis Space Center, near Bay St. Louis, Mississippi.

The bidders were required to propose two methods of financing the facilities—direct government financing and private financing. NASA will decide which method to use based on its evaluation of the proposals. The bidders also were permitted to submit another proposal for privately owned facilities at other sites.

Initial Contract Award to Be Based on Full and Open Competition

The Competition in Contracting Act specifies that as an agency prepares for the procurement of property or services, it shall (1) specify its needs and solicit bids or proposals in a manner designed to achieve full and open competition, (2) use advanced procurement planning and market research, and (3) develop specifications in such a manner as is necessary to obtain full and open competition with regard to the nature of the property or services to be acquired. In our opinion, the procurement processes NASA followed were sufficient to identify and eliminate any specifications or provisions that might unnecessarily restrict competition.

Competition to develop the advanced motor began in 1986 when NASA awarded contracts to define alternative motor design concepts.[1] Contracts were awarded to all five of the major U.S. solid rocket motor manufacturing firms[2] through an open competitive procurement. In August 1987 NASA selected these same five firms through a follow-on competition to further define the advanced motor concepts and needed facilities.

In May 1988 NASA advertised its requirement for advanced motor development and initial production in the Commerce Business Daily. The announcement specified that the development contractor would be selected through a full and open competition.

MSFC conducted an industry briefing on May 19, 1988, to familiarize potential contractors with the details of the planned procurement and answer questions. NASA also circulated a draft of the request for proposals to potential contractors to help identify any provision or specification that might unnecessarily restrict competition.

We asked the five potential contractors for their views on the advanced motor competition. Four contractors told us that the procurement plan provides for full and open competition. According to officials of these firms, the government-owned, contractor-operated manufacturing facility was the key to achieving a fair competition. According to Thiokol officials, the solid rocket motor industry has an excellent history of investing capital in facilities to meet market needs. However, they believed that future industrial base expansion might be discouraged by

[1]These contracts are referred to as phase A or block II studies.

[2]The five firms are Aerojet Solid Propulsion Company; Atlantic Research Corporation; Hercules, Incorporated; Morton Thiokol, Incorporated; and United Technologies Corporation, Chemical Systems Division.

the potential for competing with a government-owned, contractor-operated facility. Also, according to these officials, there is minimal evidence of continued competition where systems are produced in government-owned, contractor-operated facilities. Thiokol subsequently announced that it would not compete for the advanced motor development.

NASA Removes Barriers to Competition in Future Contracts

Maintaining competition in the follow-on production of a major system can be difficult. It can be time-consuming and costly to ensure that another firm is qualified to produce the system with the needed quality. The government and initial development contractor normally invest large sums in facilities and equipment to develop, test, and produce a system. Maintaining competition has often meant duplicating these expenditures to qualify another contractor for the competition. For example, in 1986 NASA estimated that it would cost between $60 million and $100 million to establish and qualify a second production source for solid rocket motors, depending on the contractor selected. Also, development contractors have sometimes used proprietary information or processes in the manufacturing operations, making it difficult, if not impossible, to transfer operations to a successor.

In the advanced motor program, NASA has made a concerted and successful attempt to identify and remove many of the barriers to follow-on competition. The advanced motor procurement plan specifies that the development contract must not restrict the government's ability to compete future advanced motor procurement. The request for proposals instructs potential contractors to structure their proposals to allow for the timely and economical competition of contracts for future work. According to the request for proposals, competition planning is to be a factor in the selection of the advanced motor development contractor.

The procurement plan provides that the government will own or be permitted to acquire the facilities and tooling used by the original contractor to develop, test, and manufacture the advanced motor. NASA's preferred approach is to provide government-owned, contractor-operated facilities. The request for proposals permits bidders to propose privately owned facilities but specifies that the selected contractor must be willing to transfer the facilities to the government or any successor contractor to facilitate competition in follow-on work.

To further protect the government's ability to compete follow-on work, the request for proposals specifies that bidders must (1) cooperate by helping potential competitors to become familiar with advanced motor manufacturing processes and procedures, (2) document all technical and procedural data and software that are under government ownership, and (3) include agreements in all subcontracts providing for the transfer of the subcontracts to the government or any successor contractor. According to the request for proposals, the selected contractor will have to agree to assist in an orderly and efficient transition to any successor contractor chosen by NASA. At the direction of the government, the development contractor may be required to train a successor to manufacture and test the advanced motor and operate the facilities. The contractor also will have to provide potential competitors with access to all program data, documentation, information, and facilities.

The request for proposals also specifies that it is essential that all technical and procedural data and software be thoroughly documented, current, in a usable form, and under government ownership or access. A successor contractor would need access to all technical and manufacturing data to understand the manufacturing processes and procedures as well as manage the facilities. According to the request for proposals, the contractor and its subcontractors will have to obtain the contracting officer's approval before using any proprietary data or computer software to develop or manufacture the advanced motor. If the contracting officer grants such approval the contractor will have to agree to license the data or software to either the government or a successor contractor.

The contract also will provide for the orderly transfer of subcontracts or leases to another contractor. According to the request for proposals, all subcontracts or leases that have been awarded in performance of the contract or that are necessary for the continued operation of the manufacturing and test facilities must contain a special provision granting the government or a successor contractor the right to assume the subcontracts or leases. This will avoid the cost of terminating and renegotiating subcontracts if NASA selects another contractor.

According to the manager of the Advanced Solid Rocket Motor Task Team, the production option to be included in the development contract also was structured to facilitate future competition. The request for proposals provides that the development contract will require delivery of 6 sets of flight motors and contain an option for the production of up to another 44 sets of flight motors. According to the task team manager, the optional production quantity was chosen to provide NASA the time to arrange for future competition of the advanced motor production and supply NASA's needs during that period. NASA estimates that about

3 years would be needed to conduct a new competition and bring a successor contractor on line.

Government-Owned Plant Will Facilitate but Not Guarantee Continued Competition

Although NASA plans to maintain the ability to compete future advanced motor contracts, it has not prepared a detailed plan showing how and when any future competitions will be held. According to the task team manager, conducting a future competition and qualifying another motor production contractor would cost about $50 million and would take about 3 years. Thus, NASA would have to issue a request for proposals in fiscal year 1995 to compete the next production contract if the development and initial production remain on schedule. NASA also will have to plan and budget for the competition well in advance of issuing the request for proposals.

Government ownership of the manufacturing plant is a key element in NASA's strategy to maintain competition. Government ownership of the plant will facilitate but not guarantee that follow-on contracts are awarded competitively. For example, in 1988 we reported that the Army was renewing most of the contracts for the operation of government-owned, contractor-operated ammunition plants without competition.[3] Contracts for operation of the plants generally covered a 5-year period (1 base year, with 4 option years). The Army devised a procedure for selecting 2 of the 24 contracts to be awarded competitively. Decisions of which contracts to compete were based partly on the incumbent contractors' performance in a number of areas such as safety, quality, and cost. We reported that the Army was not complying with the Competition in Contracting Act in its selection of two ammunition plant contracts for competition because the act mandates that competitive procedures be used in awarding all contracts unless one of seven circumstances (exceptions) set forth in the act is met. Lack of staff, resources, and expertise—reasons that the Army cited for awarding contracts without competition—are not among the exceptions.

We also inquired into NASA's experience with the development and production of other major systems in government-owned facilities. We found that such facilities are used in the refurbishment and assembly of solid rocket boosters and the production of external tanks.

[3] Army Procurement: Contracting for Management and Operation of Government-Owned Ammunition Plants (GAO/NSIAD-88-72, Mar. 8, 1988).

NASA conducted a new competition for the booster refurbishment and assembly work in 1983. The incumbent contractor won the competition and was awarded a new contract in January 1985. However, NASA has not competed the external tank effort since the original development contract was competitively awarded to Martin Marietta Corporation in September 1973. NASA decided not to seek further competition for external tank production partly because it was satisfied with Martin Marietta's cost, schedule, and technical performance.

In December 1988 we reported[4] on NASA's actions to award two sole-source contracts to Martin Marietta for the continued production of the shuttle external fuel tanks. We stated that NASA had not justified this procurement as prescribed by the Competition in Contracting Act and that it was questionable whether NASA could currently justify a noncompetitive award to Martin Marietta.

The competitive environment for the external tank program is similar in many respects to that planned for the advanced motor program. The tank is manufactured in a government-owned, contractor-operated facility. Also, NASA had taken steps to maintain a competitive environment in the external tank program. According to the external tank project manager, all of the data that would be needed by competing firms are available.

Under the terms of the contract, NASA requires Martin Marietta to maintain a data package to facilitate future competition. Furthermore, according to the project manager, provision could be made to transfer materials and parts purchased by Martin Marietta for use in manufacturing the tanks to another contractor. Additionally, according to the external tank project manager, no proprietary processes that might preclude competition are used in manufacturing the tanks.

[4] Space Shuttle: External Tank Procurement Does Not Comply With Competition in Contracting Act (GAO/NSIAD-89-62, Dec. 28, 1988).

Procurement Options for the Redesigned Motor Should Be Based on a Thorough Economic Analysis

To support projected shuttle flights through the advanced motor development and initial production period, NASA will continue to procure redesigned motors on a sole-source basis from Thiokol. NASA concluded that it would not be worthwhile to establish a competitive source for the redesigned motors. According to NASA, it would take about 4 years to conduct a second source competition and qualify another contractor to produce redesigned motors. The cost of facilities and equipment needed by a second source contractor would range from $80 million to $200 million. Since the redesigned motor is expected to be phased out and replaced by the advanced motor design beginning in fiscal year 1994, the cost of qualifying another source would likely exceed the savings that might result from competition.

In 1989 NASA plans to procure an additional 142 redesigned motors in a single contract or "block buy" from Thiokol at an estimated cost of $2.3 billion.[5] However, the planned contract may not provide the flexibility needed to respond to possible reductions in the projected shuttle flight rate or changes in the advanced motor development schedule or production build-up rate. As a result, NASA may be faced with a choice of either (1) renegotiating or terminating the redesigned motor contract and incurring additional costs or (2) procuring more redesigned motors on a sole-source basis than are needed to transition to the advanced motor program.

NASA officials told us they had considered a number of alternative procurement strategies to provide more flexibility. They concluded that the best approach was a block buy of 142 motors to take advantage of the economies of scale in both labor and materials. However, NASA officials could not provide any documentation indicating that they had performed an economic analysis of the various options. Although NASA procurement regulations do not require that an economic analysis be performed, Air Force regulations suggest that an economic analysis be prepared when deciding to commit resources of over $1 million. An economic analysis is an aid in making a rational choice among competing alternatives. It is not intended to replace the judgment of the decisionmaker, but rather to aid the decisionmaker. An economic analysis provides the means to reach conclusions about the soundness of an acquisition strategy through the systematic assessment of both monetary and non monetary costs and benefits of various alternatives.

[5]The plan includes 132 operational motors (66 flight sets) and 10 test motors, for a total of 142 redesigned motors.

Basis for Estimate of Redesigned Motor Quantity

NASA estimated that it would need about 79 sets of redesigned motors for use on shuttle flights from fiscal year 1988 to fiscal year 1997 when the advanced motor contractor would begin producing enough motors to support all planned flights. Of the 79 sets, 13 sets are to be delivered under the current contract, and 66 are to be delivered under another contract to be awarded. NASA's estimate of the number of sets of redesigned motors was based on the following assumptions:

- NASA would resume shuttle flights in fiscal year 1988 and gradually build up to a maximum rate of 14 flights a year by fiscal year 1994;
- the first advanced motor would be delivered in fiscal year 1993 and the first advanced motor flight would occur in fiscal year 1994; and
- the advanced motor contractor would gradually increase the production rate from 2 sets in fiscal year 1993 to 14 sets in fiscal year 1997.

Any of the assumptions are subject to change as NASA gains more experience both with shuttle flights and the advanced motor development program. For example, NASA does not yet have sufficient post-Challenger experience to predict future shuttle flight rates with confidence.

According to the National Research Council's "Post-Challenger Assessment of Space Shuttle Flight Rates and Utilization," NASA may not be able to achieve the flight rates it predicted for the shuttle.[6] According to the Council's report, the maximum safe shuttle flight rate will be between 8 and 10 flights per year with three orbiters and between 9 and 12 flights per year with 4 orbiters. If these estimates are correct and the projected advanced motor development and production schedules do not change, NASA will need from 4 to 18 fewer sets of redesigned motors than it currently plans to procure.

NASA has already reduced its estimate of the number of shuttle flights to be accomplished during fiscal years 1988 through 1993. In August 1988 NASA revised its shuttle flight manifest or projection of shuttle flights to be accomplished during this time frame. The revised manifest included four fewer flights than the one used to estimate the number of additional redesigned motors to be procured. The revised manifest reflects NASA's more current estimate of the rate at which shuttle flights can be resumed in fiscal year 1989. According to the Executive Assistant to the

[6] At the request of the House Committee on Appropriations, NASA contracted with the National Research Council to study shuttle flight rates and utilization after the Challenger accident.

Director of MSFC, NASA will update its requirements during contract negotiations to eliminate any over- or under-buy situation to the extent possible.

According to NASA, the primary purpose of purchasing additional redesigned motors on a sole-source basis from Thiokol is to support shuttle flights until advanced motors become available. The number of redesigned motors may be further reduced if the advanced motor contractor is able to increase production at a faster rate than NASA has predicted. Potential contractors told us they may be able to build up to the maximum production rate faster than NASA projects if NASA provides adequate funding. According to the task team manager, the request for proposals permits contractors to propose production build-up rates different from those NASA used in computing redesigned motor requirements.

A supervisory procurement analyst in NASA Headquarters told us that NASA intends to replace the redesigned motor with the advanced motor as soon as possible. According to this official, NASA's objectives are to minimize the number and cost of redesigned motors while still meeting flight requirements before the advanced motor is introduced. The procurement analyst told us that because of potential uncertainties in the total requirement for redesigned motors before the introduction of the advanced motor, NASA considered a number of alternative procurement strategies, including contracting for a lower quantity of redesigned motors, for example, 36 flight sets with 3 options for 10 additional flight sets each. According to this official, NASA concluded that a block buy of 66 flight sets was the best alternative because Thiokol would be in the best position to obtain reasonable subcontract prices and take advantage of economies of scale in both material and labor. However, if a smaller quantity is needed, NASA will have to (1) renegotiate or terminate the contract and possibly incur additional costs or (2) procure the redesigned motors and use them instead of the potentially more capable, more reliable advanced solid rocket motors. The latter approach would require NASA to maintain two production contractors and fly two different configurations of motors over a longer period, which would likely increase both procurement and launch costs.

Conclusions

NASA plans to reintroduce competition into the procurement of shuttle solid rocket motors through the competitive development and procurement of an advanced motor. NASA's plan provides for full and open competition for the advanced motor development and initial production contract. The plan also protects NASA's option to maintain competition in any follow-on procurement of the motors. Government ownership of the manufacturing plant is a key element of NASA's strategy for maintaining competition in the advanced motor production. Although government ownership of the plant will facilitate competition, experience has shown that it does not guarantee that follow-on contracts will be competitively awarded.

NASA plans to contract on a sole-source basis with Thiokol for another 142 redesigned motors to support shuttle flights until the transition to advanced motors is made in fiscal year 1997. However, the quantity of redesigned motors that will be required is based on several assumptions; for example, the need for 142 motors is partly based on NASA's achieving a shuttle flight rate of 14 per year. In circumstances in which requirements are uncertain and based on assumptions, an economic analysis would provide a means of systematically assessing both monetary and non monetary costs and benefits of each procurement alternative. Although NASA officials advised us that they considered a number of alternate procurement strategies to provide more contract flexibility, they did not have any documentation to indicate that they had quantified the costs of the various options.

Matter for Consideration

We concluded that NASA's advanced solid rocket motor acquisition strategy provides for full and open competition in the initial contract award and protects the option to compete future contracts. However, we recognize that maintaining competition in the follow-on production of a major system has proven difficult in practice, and, therefore, the Congress may wish to obtain periodic status reports from NASA on its efforts to maintain competition in the program.

Recommendation

We recommend that the NASA Administrator require the Director, MSFC, to prepare an economic analysis as part of its efforts during contract negotiations to update requirements for redesigned solid rocket motors.

Improvements in Solid Rocket Motor Quality Assurance Program

In 1986 we reported on indications of significant and potentially serious quality assurance problems at Thiokol's solid rocket motor facility. Neither the contractor nor the government was giving the problems the managerial attention they deserved. Since then the government and Thiokol have taken steps to enhance solid rocket motor quality assurance. NASA and Thiokol have reorganized and centralized their quality assurance functions and increased the number of inspectors and inspections. In addition, Thiokol has enhanced quality assurance techniques, developed a plan to improve quality audits and better ensure compliance with procedures, and established measurable goals for producing defect-free hardware. Furthermore, NASA has restructured the motor production contract to provide Thiokol financial incentives for improving its quality assurance program.

The effectiveness of the improvements cannot be fully assessed at this time because Thiokol is producing motors at a low rate; however, both NASA and Air Force quality assurance personnel believe Thiokol's quality assurance program has improved.

Previous Quality Problems

In 1986 we found a number of indications of quality assurance problems in the manufacture of solid rocket motors at the Thiokol plant. For example, we reported that, as a part of the Challenger accident investigation, a team of government and contractor personnel had reviewed the contractor's quality controls as they related to the right-hand motor, especially the O-rings that caused the accident. The review identified over 2,000 possible quality control problems. Some of these had potentially serious consequences. For example, three of seven mandatory government inspections on the critical O-rings had been deleted by Thiokol from inspection plans without government authorization. We also found that neither the contractor nor the government were giving quality assurance problems the managerial attention they deserved. For example, as of March 1986, Thiokol had not corrected all of the deficiencies identified in a 1985 NASA survey of the contractor's reliability and quality assurance program. The Air Force Plant Representative described Thiokol's implementation of corrective actions from the NASA survey as "dismal."

The problems we noted were caused in part by insufficient government quality assurance personnel and by Thiokol's lack of incentives to correct quality problems. We recommended that the NASA Administrator and the Secretary of the Air Force determine the number and types of government personnel needed to ensure that quality is adequate and acquire the needed staff before resuming motor production. We also recommended that the NASA Administrator identify any other mechanisms, including possible contractual incentives or penalties, to ensure that quality controls were properly implemented and enforced.

NASA Provides Better Visibility Over Quality

Before the Challenger accident, the Chief Engineer at NASA Headquarters had overall responsibility for shuttle safety, reliability, and quality assurance. According to the Presidential Commission that investigated this accident, the Chief Engineer's ability to manage NASA's safety program was restricted by the organizational structure and limited staffing.[1] The Chief Engineer's staff included only one person who spent 25 percent of the time on shuttle maintainability, reliability, and quality assurance and another who spent 10 percent of the time on these vital functions.

At MSFC, the Director of Reliability and Quality Assurance reported to the Director of Science and Engineering, who was responsible for overseeing the development of shuttle hardware. The Presidential Commission concluded that this arrangement resulted in a lack of independence from the producer of hardware and was compounded by reductions in staff. According to the Commission's report, as the shuttle flight rate increased, the MSFC safety, reliability, and quality assurance work force decreased, adversely affecting mission safety.

The Commission recommended that NASA establish an Office of Safety, Reliability, and Quality Assurance to be headed by an Associate Administrator, reporting directly to the NASA Administrator. In July 1986 NASA created this office and appointed an Associate Administrator who reports directly to the NASA Administrator.

In March 1987 MSFC reorganized and consolidated its safety, reliability, maintainability, and quality assurance functions under one director who reports to the MSFC Director. The new organization was designed to provide more independence and better visibility of quality assurance issues and problems to top NASA management.

At the same time, MSFC increased the personnel allocated to safety, reliability, and quality assurance functions by absorbing the personnel who

[1] "The Silent Safety Program," Report of the Presidential Commission on the Space Shuttle Challenger Accident, June 6, 1986, pp. 152-162.

had been in the science and engineering directorate and hiring new people. According to the Director of MSFC's Safety, Reliability, Maintainability, and Quality Assurance Office, the number of people assigned to these functions increased from 102 to 185.

In addition to increasing the number of civil service personnel, MSFC hired a mission support contractor to assist MSFC in-house staff by performing services in areas of safety, reliability, maintainability, and quality assurance. Services include evaluating the quality assurance and safety plans of MSFC contractors, such as Thiokol, and participating in surveys and reviews of contractor compliance with quality assurance and safety program requirements. As of December 1988, the mission support contractor had 123 employees assigned to the contract, including 26 quality assurance personnel.

MSFC also increased the quality assurance staff at the resident office at the Thiokol manufacturing plant in 1986 from two to four people. This staff is the primary interface between the contractor and the Air Force Plant Representative Office for safety, reliability, and quality assurance issues. It determines the level of inspection required to ensure quality and participates in acceptance and readiness reviews.

Increased Oversight by Air Force Plant Representative Office

Since our 1986 review, the Air Force Plant Representative Office has increased not only the inspections performed but the number of personnel to perform these inspections. The Plant Representative Office, which had been delegated primary authority for overseeing Thiokol's quality assurance program by NASA, inspects all critical parts and processes in motor manufacturing and evaluates the contractor's quality assurance program.

In 1986 we reported that the Plant Representative Office was not adequately staffed. The staff included only 1 quality control engineer, who was devoting an average of only one-half of the time to the solid rocket motor program, and about 34 quality inspectors dedicated to the shuttle program. However, according to MSFC quality assurance personnel, these inspectors were not trained engineers and not qualified to make the engineering judgments necessary to ensure that the contractor's quality assurance program was adequate and being properly implemented.

The Plant Representative Office now has 7 aerospace engineers to help oversee quality assurance on the solid rocket motor and 58 inspectors for the shuttle program. Also, the number of government inspection points for each motor has been increased from 1,733 in January 1986 to 2,619 in September 1988.

Changes in Thiokol's Quality Assurance Program

Since our 1986 review, Thiokol has undertaken initiatives to improve quality assurance. These include (1) reorganizing the safety, reliability, maintainability, and quality assurance functions and increasing the number of personnel performing these functions, (2) instituting more systematic audits to detect and eliminate quality problems, (3) enhancing techniques for detecting hardware defects, and (4) establishing measurable goals for improving motor quality.

Contractor Reorganization

In January 1987 Thiokol reorganized its safety, reliability, and quality assurance functions under a single director. In July 1988 the Director was elevated to the level of Vice President, placing the safety, reliability, and quality assurance organization on an equal status with engineering, production, and program management. The Vice President for Safety, Reliability, and Quality Assurance reports directly to the Vice President of Space Operations.[2] This new organization, according to Thiokol management, will (1) internally improve communication and coordination by providing a single point of administration and shortening communication lines, (2) provide greater consistency in administration of quality assurance policies and philosophies, (3) increase efficiency and effectiveness through better use of resources, and (4) enhance communication with NASA.

Thiokol also substantially increased the number of personnel assigned to quality assurance from 329 in January 1986 to 549 in March 1988. This included an increase in quality assurance inspectors from 199 to 272, or about 37 percent. In addition, the contractor increased the number of inspection points for each motor from 78,560 to 105,600, or about 34 percent, to ensure hardware quality.

[2]Thiokol's manufacturing facility encompasses three divisions. Space Operations is responsible for the shuttle solid rocket motors; Strategic is responsible for the Peacekeeper and other strategic missiles; and Tactical is responsible for military tactical missiles.

Validation and Compliance Audits

In August 1988 Thiokol instituted a plan for systematically conducting building compliance and process validation audits. The purpose of these audits is to provide independent assurance that employees are complying with approved procedures and performing work according to specifications, drawings, and other official documents.

The building compliance audit team is to review each manufacturing building once a month. The team will inspect all work areas within a building by looking for both quality assurance and safety problems and documenting compliance and noncompliance to approved procedures. The team is to review its findings with the building manager and help identify corrective actions for any problems. During the next audit, the team will do a follow-up review to ensure that corrective actions have been implemented.

The purpose of a process validation audit is to verify that motor hardware is being manufactured according to approved procedures, specifications, and drawings. Audit teams are to review the manufacturing plan to ensure that it accurately reflects current engineering specifications and verify that work is being performed according to the plan. Thiokol's intent is to validate annually every process used to manufacture the motors.

Enhanced Inspection Techniques

Thiokol uses evaluation methods and techniques, such as radiography (x-ray), ultrasonic testing, and laser measurements to help identify hardware defects and better ensure quality. Since 1986 Thiokol has added a number of improved nondestructive evaluation techniques and increased the amount of nondestructive testing. According to both NASA and the Plant Representative Office, the new testing should significantly enhance Thiokol's ability to detect hardware defects.

For example, Thiokol is constructing a contamination control laboratory to improve testing for contamination in bonding processes such as those used to bond insulation to motor case segments. The laboratory, which Thiokol projects will be fully operational by May 1989, is to include state-of-the-art optical scanning and infrared systems that will identify contamination and determine the cleanliness of bonding surfaces.

The contractor has improved its inspection of O-rings. A laser micrometer has been added to provide additional and more precise information on various O-ring dimensions. Also, criteria for visual inspection of O-ring surface conditions have been tightened. In addition, larger

O-rings are now x-rayed to ensure that subsurface conditions comply with design requirements.

The amount of x-ray inspection of loaded motor segments has increased from about 25 percent of the segments produced to all segments. Loaded motor segments are x-rayed to detect anomalies such as failures in the bond between the propellant and liner, loose material in flap openings, or foreign objects in the propellant.

Improvement Goals

In October 1987 Thiokol established goals for improving the quality of motor hardware. The objective is to reduce and eventually eliminate all nonconformances in solid rocket motor production.[3]

When quality assurance personnel determine that material or a part to be used in the motor does not conform to all engineering requirements, they withdraw it from the manufacturing process and prepare a discrepancy report. If the cause of the nonconformance and the corrective action can be determined at the time the report is prepared, that information is entered on the report and is reviewed and approved by a Material Review Board.[4] If the cause of the problem cannot be determined or the corrective action cannot be implemented right away, the Board prepares a corrective action request. The responsible supervisor or subcontractor must then prepare a corrective action plan, which specifies actions to be taken to prevent recurrence of the problem and milestones for implementing the corrective action.

Thiokol's long-term goal is to have no new nonconformances by the time it manufactures the 25th set of redesigned motors in 1991.[5] According to Thiokol's Vice President for Safety, Reliability, and Quality Assurance, the only way to produce defect-free hardware is to identify and eliminate the causes of the nonconformances. To accomplish this, the contractor has also established a short-term goal of improving actions to correct quality problems once they are identified.

[3]A nonconformance is a failure to conform to specified engineering requirements for any quality characteristic.

[4]When a nonconformance is identified, a Material Review Board determines if the hardware can be used, must be reworked, or scrapped. The Board consists of representatives from Thiokol's engineering and quality assurance organizations and includes a NASA representative if the nonconformance could affect the safety of the crew or success of the mission.

[5]Since some of the hardware is reused, some defects that the Board has previously determined do not degrade safety or performance may remain.

The short-term goal was to have no more than 100 discrepancy reports and 100 corrective action requests open, or unresolved, by January 1, 1988. To achieve this goal, Thiokol quality assurance management assigned goals to each functional organization and hardware component team within the Space Operations Division. Management also posted charts on bulletin boards showing progress against the goals.

Although the contractor did not achieve the short-term goal by January 1988, Thiokol has made progress in reducing the number of unresolved problems. The number of open discrepancy reports decreased from 253 in October 1987 to 71 in November 1988. The number of open corrective action requests also decreased from 251 to 110 during this time period. Also, the contractor has reported a reduction in the number of new nonconformances in production. The number of new nonconformances decreased from 725 for the first set of redesigned motors to 484 for the third set.

Restructured Contract Provides Incentives to Maintain Motor Quality

In 1986 we concluded that neither Thiokol nor the government had been sufficiently aggressive in resolving significant and potentially serious quality control problems. A part of the problem was that the government did not have sufficient incentives to force the contractor to provide the attention needed to correct problems. We recommended that NASA consider instituting contract incentives or penalties to help ensure adequate quality control in the motor manufacturing.

As we stated in our August 1988 report,[6] NASA revised the motor contract in May 1988 by changing its pricing structure from a cost-plus-incentive fee to a cost-plus-award fee arrangement. The original contract specified a target fee that could be increased or decreased, within certain specified limits, based on Thiokol's performance in meeting specific goals—primarily controlling costs. The revised contract provides for more subjective determinations of the amount of fee to be earned by Thiokol. Beginning with the award fee period that ended July 31, 1988, quality assurance performance was one of the criteria used to determine the amount of fee to be paid to the contractor.

NASA will base half of the award fee on evaluations of the quality and timeliness with which Thiokol performs certain specified "key events," such as the critical design review or the delivery of each motor set. NASA will base the other half of the award fee on its evaluations of Thiokol's

[6] Space Shuttle: Changes to the Solid Rocket Motor Contract (GAO/NSIAD-88-203, Aug. 5, 1988).

performance in more general areas, such as safety, reliability, maintainability, and quality assurance. NASA managers will rate quality assurance using criteria such as the identification and correction of hardware discrepancies, procurement controls, training, responsiveness to and effectiveness in correcting problems, and compliance with plans and procedures. The ratings will help determine the amount of fee to be paid to the contractor for each 6-month evaluation period.[7]

According to the contracting officer, the contract was changed to an award fee structure so that NASA would have more flexibility to influence Thiokol's performance. Under the award fee arrangement, NASA can change the performance areas being emphasized from time to time and provide an incentive for Thiokol to make improvements in any areas found to be deficient.

At the completion of our review in January 1989, NASA had evaluated Thiokol's performance for the first two evaluation periods. The evaluation for the first period—November 1987 through January 1988—was based on the contractor's accomplishment of two key events and cost control criteria. The key events were timely and successful completion of a static motor test and timeliness and completeness of the critical design review package and support to the critical design review. The evaluation for the second period—February through July 1988—was based on accomplishment of five key events, such as delivery of the first two flight sets of redesigned motors, as well as more subjective evaluations of the contractor's performance in the areas of safety, reliability, maintainability, and quality assurance; schedule; cost control; project management; and technical performance. According to MSFC's Assistant Director for Policy, during the second evaluation period, 20 percent of the fee was determined by Thiokol's safety, reliability, maintainability, and quality assurance performance. During the next period, 30 percent of the fee will be allocated to safety, reliability, maintainability, and quality assurance.

[7]The first and last evaluation periods cover 3 and 8 months, respectively.

Recent Assessments Indicate Thiokol's Quality Assurance Has Improved

According to the Director of MSFC's Quality Assurance Office, it is difficult to assess Thiokol's overall quality at this time because of the redesign of the motor and the low rate of production. The Air Force began a contractor operations review[8] at the Thiokol plant in January 1989, but the review results were not available at the completion of our work. However, both NASA and the Air Force told us that the contractor's quality assurance program had improved.

In February and March 1988 NASA conducted a recertification audit at Thiokol. The purpose of the audit was to evaluate the quality of all shuttle elements before flights resumed, which was planned for October 1988. The audit included a review of the quality assurance program and the procedures used in the manufacture of the motors to be used on the first shuttle flight after the Challenger accident. The audit team, which was chaired by NASA's Deputy Associate Administrator for Safety, Reliability, and Quality Assurance, concluded that Thiokol's quality assurance organization was performing its assigned duties and responsibilities "in an excellent manner." According to the audit report, the manufacturing procedures used to build the hardware were in compliance with the released drawings; quality assurance processes were adequate to prevent discrepancies from going unnoticed and unresolved; quality assurance audit controls were effective and efficient; and Thiokol's system for correcting discrepancies was adequate. The audit team also concluded that Thiokol's controls for ensuring that quality requirements were included in purchase orders and in procedures for inspecting purchased parts and materials were commendable.

Although the audit team concluded that the contractor's quality assurance organization was performing well, it cited 17 findings relating to quality assurance in its report. For example, a pressure gauge was overdue for calibration, and there was no checklist for use in leak testing the joint between the motor case and the nozzle. The audit team concluded that although these findings did not have a harmful effect on the use of the motors on shuttle flight, they warranted corrective action. According to the Director of MSFC's Quality Assurance Office, all but three of the findings had been corrected by January 1989, and MSFC and Thiokol were working together to expedite closure of the three findings.

[8]These reviews are periodic and are conducted by the Air Force Contract Management Division to assess the adequacy of contractor management systems, such as quality assurance, safety, product integrity, and engineering.

According to the Director, improvements have been made in Thiokol's quality. Thiokol management is now clearly communicating expectations to its workers and believes that it can build defect-free hardware, according to this official. As a result, for the first time some manufacturing tasks have been completed without any defects. For example, the Director said that in 1988 Thiokol manufactured 12 motor igniters and completed the lining and casting of 3 motor segments with no defects.

In December 1988 MSFC's Performance Evaluation Board assessed Thiokol's safety, reliability, maintainability, and quality assurance performance to help determine the amount of award fee to be paid the contractor for the period of February through July 1988. The Board considered (1) overall safety, reliability, maintainability, and quality assurance management, (2) the identification and correction of discrepancies, (3) development of the capability to ensure hardware integrity, (4) minimization of handling and transportation anomalies, and (5) compliance with system and industrial safety requirements. The Board concluded in its report that Thiokol's performance was "better than standard," all segments of the first flight set of redesigned motors conformed to design and manufacturing requirements and specifications, and the overall quality of the second set of flight motors was excellent.

The Board's report did not provide a separate rating for quality assurance, but it cited both strengths and weaknesses in Thiokol's quality assurance performance. Strengths included improvements in the capability to ensure the integrity of the hardware and reductions in the number of open discrepancy reports and corrective action requests. Weaknesses included frequent changes in the quality assurance plan, which made government review and approval of the plan difficult.

The Chief of Quality Assurance, Air Force Plant Representative Office, also told us that Thiokol's quality assurance program had improved. She explained that the contractor was taking more timely action to correct problems. For example, she said that as of December 1988 there were no open contractor deficiency reports relating to quality assurance.[9] She also cited progress in quality inspection techniques and the increase in the number of inspection points as evidence of recent improvements.

[9]The Air Force Plant Representative Office prepares contractor deficiency reports when it identifies significant management system deficiencies.

Conclusions

NASA, the Air Force Plant Representative Office, and Thiokol have taken steps to enhance quality assurance in the solid rocket motor program. Steps include reorganizing quality assurance organizations at both NASA and Thiokol to provide a greater degree of independence and more visibility to top management, providing more quality assurance inspections and inspectors, adopting improved inspection techniques, and developing a plan to improve quality audits and better ensure compliance with established procedures. Also, NASA has restructured the motor production contract to provide financial incentives for Thiokol to maintain high quality. Because Thiokol is producing motors at a low rate, it is difficult to assess the effect of these changes on motor quality at this time. However, both NASA and the Air Force believe the changes have enhanced quality assurance. A 1988 audit by NASA concluded that the contractor's quality assurance organization was performing in an excellent manner.

Industrial Safety at Morton Thiokol Needs Further Improvement

Manufacturing solid rocket motors is a hazardous process. Insufficient guidelines or failure to conform to rules, especially when working with the explosive materials used to manufacture the motors, can have fatal consequences. Thiokol is directly responsible for ensuring plant safety, but NASA and the Air Force are also responsible for overseeing Thiokol's safety program to ensure that government property is properly protected.

In our 1986 review, we reported that, according to NASA and the Air Force, Thiokol was not satisfactorily enforcing industrial safety rules and regulations. Since 1986 Thiokol has undertaken several initiatives to improve its industrial safety program. However, NASA and the Air Force believe that further improvements are needed, and both have applied financial penalties as an incentive for Thiokol to improve its safety practices.

We also found that NASA and the Air Force still do not have an effective program for monitoring Thiokol's industrial safety performance in the shuttle motor program. NASA's safety incident tracking program is not fully effective because safety incident data are not consistently reported and NASA is not adequately analyzing the data. Also, the Air Force Plant Representative Office has not performed all needed safety inspections due to a lack of personnel.

Previously Reported Safety Problems

We reported previously that NASA and the Air Force had identified safety problems at the Thiokol manufacturing facility. Contractor operations reviews conducted by the Air Force and NASA in 1984 and 1986 rated Thiokol's safety program as "marginal" and concluded that Thiokol did not satisfactorily enforce safety rules and regulations. According to the 1984 review report, Thiokol was unable or reluctant to identify or correct easily recognizable safety violations. Many of the violations identified in 1984 had been found in previous reviews but had not been satisfactorily corrected.

In March 1984 a fire in the casting pit area at the Thiokol facility destroyed over $11 million worth of facilities and equipment, including about $8.6 million of government-owned property. The NASA team that investigated the fire pinpointed inadequate safety procedures as contributing factors. The team also noted that even the inadequate procedures were ignored by Thiokol personnel performing the casting operations. NASA attributed the accident in part to a lack of contractor management involvement in correcting safety problems.

Thiokol Industrial Safety Initiatives

To improve its industrial safety program, Thiokol has conducted safety hazard analyses, reorganized its safety functions, and initiated a system of safety audits and inspections to ensure that employees comply with safety procedures. Despite these initiatives, problems still remain in Thiokol's safety program.

Hazard Analyses

Because of its increasing concerns about Thiokol's safety record, NASA recommended in 1984 that Thiokol develop a program to identify and track all potential safety hazards. Thiokol responded to the recommendation by hiring a hazards analysis specialist and establishing a branch to implement the program. The purpose of the analysis program is to identify and correct safety hazards before they result in accidents. After the 1984 fire in the casting pit area, NASA directed Thiokol to obtain contractual assistance in analyzing hazards for the most critical facilities and operations. In spring 1986 Thiokol selected five contractors to perform the analyses.

Between January 1986 and February 1988, the 5 contractors performed hazards analyses of 20 critical facilities and operations in Thiokol's Space Division. The analyses disclosed 3,647 potential safety hazards that were classified according to their seriousness. The classifications ranged from "imminent danger" to "negligible consequences." We found that Thiokol had closed out 3,397, or about 93 percent, of the hazards by August 1988, indicating that corrective actions had been taken or the hazards did not warrant correction. Thiokol was still studying the corrective actions needed to avoid the remaining hazards.

Both NASA and the Air Force Plant Representative Office monitor the hazard analysis program. In March 1988 the Plant Representative Office reported that all Space Operations Division hazard analyses performed since 1987 were considered satisfactory. However, the Director of MSFC's Institutional Safety Office concluded in September 1988 that the hazard analyses received during the period of February through July 1988 were generally inadequate.[1]

According to the Director, some hazards were overlooked, and others were closed out without verification of acceptable control. For example,

[1]The Director's assessment was a part of NASA's evaluation of Thiokol's safety, reliability, maintainability, and quality assurance performance to help determine the amount of fee to be paid to Thiokol for the period of February through July 1988.

a December 1987 hazard analysis on an item of ground support equipment identified the possibility of a hazardous condition and recommended corrective action that might have prevented a subsequent mishap that caused damage to some components of a test motor. Thiokol did not implement the corrective action, stating that it was the responsibility of another shuttle contractor. In addition, according to the Director, Thiokol had not submitted analyses of the hazards in handling and transporting shuttle motor hardware.

Reorganization

In August 1986 Thiokol reorganized its safety, reliability, maintainability, and quality assurance functions to provide greater independence and improve managerial attention on problem areas. The reorganization created separate safety offices in Thiokol's three manufacturing divisions.

In February 1988 the Air Force Plant Representative issued a contractor deficiency report that cited inadequacies in the new organization, which resulted in a fragmentation of responsibilities. These inadequacies include the following.

- Specific program responsibilities, authorities, and lines of communication had not been thoroughly outlined in policies and procedures after the reorganization.
- Only two Aerospace Group[2] policies had been published; neither of them adequately addressed the responsibilities and authorities necessary to implement the various division safety programs.
- There was no safety guidance from the corporate level, and no personnel were assigned to the Aerospace Group to oversee the safety programs of the operating divisions.
- For the most part, the various division safety office responsibilities were by word-of-mouth rather than written.

According to the Plant Representative, the failure to clearly define safety program responsibilities, authorities, and lines of communication had resulted in employees not complying with procedures, discipline problems, serious safety hazards, and an increased risk to government personnel and property.

[2]The Aerospace Group consists of the three manufacturing divisions at the Wasatch, Utah, plant and five divisions at other U.S. locations.

In response to the deficiency report, the Aerospace Group president hired a safety director to oversee safety programs in all of the Group's operating divisions, transferred responsibility for performing safety audits to the group safety director's office, and doubled the size of the audit staff. In addition, the Group issued a safety directive establishing a safety standard for the Utah divisions. Furthermore, Thiokol prepared a detailed plan of action to correct the inadequacies identified in the deficiency report. In June 1988 the Plant Representative reported that the plan was acceptable and that his office would continue to monitor Thiokol's implementation of the plan.

Safety Audits and Inspections

Numerous investigations, reviews, and audits have shown that safety problems at Thiokol frequently result from employees failing to comply with safety procedures. For example, Thiokol investigations show that of the 31 safety incidents reported to NASA in 1987, 25 were caused in part by a failure to comply with procedures.

Before August 1988 Thiokol's Space Operations Division did not have a program for systematically inspecting shuttle motor manufacturing facilities and operations to identify and correct noncompliance and safety violations. However, as discussed in chapter 3, in August 1988 Thiokol implemented a building compliance audit plan that outlines steps to be taken to ensure that work areas comply with rules and procedures, Occupational Safety and Health Administration policies, and NASA regulations.

In addition to the building compliance and process validation audits, Thiokol's Aerospace Group conducts safety audits. Safety audits were conducted before our 1986 review, but since that time Thiokol has reorganized the safety audit function and increased the number of auditors. For example, in August 1988 Thiokol increased the number of safety auditors from four to eight. According to the manager of the Safety Audit organization, the increased staffing may result in more audits of shuttle motor facility and operations in the future. However, most of the increase will be devoted to safety audits in other Aerospace Group operating divisions. Between July 1986 and March 1988, the Aerospace Group's safety audit staff performed 13 audits of shuttle solid rocket motor facilities and operations that disclosed 135 findings.

We reviewed 6 of the 135 findings, which we believe to be among the more significant, to determine if recommended corrective actions were implemented in a timely manner. Our review showed that corrective actions were initiated within established time frames.[3] In all six cases, corrective action requests were issued within 2 weeks of the audit reports, and responsible individuals responded to the action requests on or before the suspense dates. Time required to complete the corrective actions ranged from 1 to 9 months, depending upon their complexity.

Government Reviews Show That Further Improvements Are Needed

According to NASA and the Air Force, Thiokol's safety program needs further improvement. NASA and Air Force reports and correspondence show that Thiokol management and supervisors have not given adequate attention to safety in the manufacturing operations. Thus, to provide Thiokol an incentive to improve its safety program, the Air Force reduced progress payments to Thiokol under its contract for Peacekeeper motors, and NASA reduced the amount of award fee under the shuttle motor contract.

Multifunctional zone evaluations[4] conducted by the Plant Representative Office in 1987 and 1988 identified numerous safety-related problems in the Space Operations Division, where shuttle motors are manufactured, and in the Strategic Operations Division, where Peacekeeper motors are built. For example, an evaluation conducted from April through May 1987 rated Thiokol's in-plant handling of hardware as marginal and noted a lack of compliance with established systems and planning such as movement of shuttle motor cases without proper authorization. The evaluation also found a number of unsafe conditions resulting from poor housekeeping practices. According to a report on the evaluation, the contractor had good safety policies and procedures, but a lack of supervisory accountability and responsibility for implementing the safety program had eroded its effectiveness. The report stated that the prevailing attitude was to correct specific deficiencies, not their underlying causes. Thus, Thiokol's emphasis was not on preventing further recurrence.

Similarly, a March 1988 evaluation of Thiokol test operations identified 54 findings related to safety. Because of the many findings, the team performing the evaluation concluded that there appeared to be a safety system breakdown. Proper control of hazardous materials and handling equipment needed management's immediate attention, according to the evaluation report.

[3] We based our assessment on time frames established by the contractor for each finding.

[4] This evaluation is a vehicle for assessing and reporting on contractor operations during a specific time period.

According to MSFC's Director of Institutional Safety, Thiokol has proper safety policies and procedures, but they are poorly executed. Management controls must be implemented to ensure that all operations are conducted in a safe manner.

One problem with the industrial safety program is that Thiokol does not always take timely action to correct safety problems or the corrective action is not broad enough to prevent a recurrence of the problem. Some recent incidents, which are listed below, illustrate this problem.

Peacekeeper Incidents

In 1987 Thiokol experienced two incidents while personnel removed core fixtures[5] from Peacekeeper motors. The first incident was only a near miss, but the second resulted in a catastrophic explosion, which killed five employees. After the first incident, Thiokol agreed to implement a number of corrective measures. The investigative report of the second incident concluded that its probable causes were similar to those of the earlier incident and that many of the recommendations resulting from the earlier incident had not been fully implemented.

On May 20, 1987, Thiokol employees were extracting the core from Peacekeeper motor number 303 when a flash occurred followed by a loud popping sound, smoke, and fumes. This apparently resulted from the ignition of a small piece of propellant. Fortunately, the spark did not spread to the rest of the propellant in the motor.

After this near miss, Thiokol agreed to implement a number of corrective actions to prevent the occurrence of a similar incident or minimize damage in the event it did. The most important change was to require operators to perform the core removal process from a remote location. Other actions were to install a video system in the curing facility to assist the operators in removing the core by remote control and establish grounding paths for the equipment to reduce the risk of electrostatic discharge.

On December 29, 1987, Thiokol employees were extracting the core from Peacekeeper motor number 322 when a catastrophic explosion occurred. The motor ignited, destroying the curing facility and killing five people.

[5]Uncured propellant is poured between the motor cases and a core fixture and then cured or baked. Once the curing process is completed, the core must be removed to leave an empty hole through which hot gases escape as the motor burns in flight.

After this explosion, an Air Force Safety Investigation Board performed an extensive review and analysis to determine its cause.

The Board was unable to determine the exact cause of the explosion but concluded that it could have resulted from friction or electrostatic discharge. The five employees were killed because, according to the investigation report, they were performing the core extraction from within the curing facility rather than the remote location established after the earlier incident. The Board found that (1) Thiokol had been slow to implement many of the recommendations from the earlier incident, (2) the remote controls had been installed in a patchwork manner, and (3) the video installation was only partially complete and not effective. Also, according to the Occupational Safety and Health Administration's investigation report on this incident, Thiokol had not taken effective action to ensure that mechanical devices were properly grounded. Although none of the actions or inactions involving the recommendations from the earlier incident could be directly related to the accident, failure to implement corrective action effectively and in a timely manner may have set the stage for the accident, according to the Air Force Plant Representative.

Overpressurization Incidents

In 1988 Thiokol personnel incorrectly connected pressurizing equipment to shuttle motor test articles on two separate occasions. The first incident resulted in minor damage to test hardware. The second incident did not damage hardware, but it caused a costly delay in completing the test. According to the Director of MSFC Institutional Safety, both incidents could have been prevented if Thiokol had taken effective action.

On June 28, 1988, Thiokol test personnel were attempting to check out the thrust vector control subsystem on a test motor.[6] This procedure required employees to apply hydraulic pressure to two locations in the subsystem. The employees accidentally applied high pressure to the low pressure side of the system, causing a reservoir to rupture and damage a number of motor components. The estimated cost of the damage was $30,000.

On July 9, 1988, a similar incident occurred. While conducting a leak test of the field joint on the same test motor, contractor personnel again reversed high and low pressure lines, allowing 1,000 pounds of pressure

[6]The thrust vector control subsystem controls the motor nozzle position, which provides the force for guiding the shuttle.

to enter an O-ring cavity that is normally pressurized to only 100 pounds. As a result, the affected joint had to be disassembled and inspected for damage. Although the joint was not damaged, the cost of disassembling and reassembling the motor was estimated to be $600,000, and the incident caused a 2-week delay in performing the test.

The NASA board that investigated the second incident concluded that the causes of the two incidents were common and that recommendations should be directed toward a redress of the system process rather than be confined to the specific incident. According to MSFC's Director of Institutional Safety, the second incident might have been avoided if Thiokol had addressed the system problems after the first incident.

This official also told us that even the first incident could have been avoided if Thiokol had taken appropriate action after conducting a hazard analysis on the ground support equipment used to pressurize the subsystem. The hazard analysis report, dated December 1987, identified the possibility that pressure lines could be reversed on the subsystem and made several recommendations. According to NASA, Thiokol closed out that analysis without implementing a recommendation that could have prevented the first incident. The pressurization equipment was designed by another contractor and provided to Thiokol as government furnished equipment. According to Thiokol, the other contractor was responsible for implementing the recommendation, since that contractor had designed the pressure equipment used in the test.

Air Force and NASA Apply Financial Penalties

To provide an incentive for Thiokol to make safety improvements, in September 1988 the Air Force reduced progress payments to Thiokol for the Peacekeeper motor contract. According to the Air Force Plant Representative, the reduction was based on (1) Thiokol's failure to ensure that employees follow operating procedures and (2) a general deterioration of housekeeping practices that affected safety. Reviews and audits by the Air Force Ballistic Missile Office and the Plant Representative Office had documented evidence of the deficiencies over the previous 6 months. According to the Air Force, successful resolution of the problems that led to the reduction would also benefit other programs, such as the shuttle motor program.

Also, NASA considered safety program deficiencies in its recent evaluation of the amount of award fee to be paid to Thiokol for the period of February through July 1988. The Performance Evaluation Board rated Thiokol's overall performance in the safety, reliability, maintainability, and quality assurance area as "better than standard" and did not separately rate Thiokol's industrial safety performance. However, during deliberations MSFC's Director of Institutional Safety characterized the contractor's industrial safety performance during this period as "poor." Thiokol will not receive the maximum fee for the evaluation period partly due to this rating.

NASA and Air Force Monitoring Should Be Improved

MSFC is responsible for overseeing Thiokol's safety program to ensure that government property is adequately protected. MSFC tracks reports of safety incidents at the Thiokol plant through a Safety Issue Assessment Center, which is operated by an MSFC contractor, but has delegated responsibility for on-site monitoring and inspection of Thiokol's safety performance to the Plant Representative.

We found that the MSFC contractor for the Assessment Center, which is responsible for assessing safety incidents, had not analyzed reported safety incidents to detect trends, as required by its contract, and it had not updated estimates of damage resulting from safety incidents. Also, MSFC had not adequately defined safety reporting criteria for the Thiokol plant. Furthermore, the Plant Representative and Thiokol were not consistently interpreting the report criteria, and the Assessment Center was not always updating data on the cost of safety incidents.

According to the Plant Representative, the Air Force was not performing all of the needed safety inspections at Thiokol because of a lack of personnel.

Inadequately Defined Reporting Criteria

After the August 1984 casting pit fire at Thiokol, MSFC established a Safety Issue Assessment Program to track non-flight mishaps and safety issues involving shuttle hardware, equipment, and facilities. The objectives of the program are to screen and track safety incidents and issues, ensure that appropriate actions are taken to resolve the problems, and assess the safety performance of MSFC organizations and MSFC shuttle contractors. All MSFC shuttle contractors and plant representatives are required to report safety incidents to the Assessment Center.

The Assessment Center classifies reported safety incidents as "problems" or "non-problems" based on its judgment as to whether flight critical hardware was affected. Incidents that do not directly affect flight critical hardware are classified as non-problems and are not subject to managerial follow-up or further tracking by the Assessment Center.

Examples of incidents categorized as non-problems included trash on a rail car, wires and cords scattered all over the floor, and propellant on the floor. According to the contract statement of work, the contractor for the Assessment Center also is supposed to use the database of problem history to develop systems that will allow prediction of problem areas, analyze trends in safety problems, and perform special studies. The purpose of trend analyses is to recommend actions that will prevent problems from recurring.

We found that the Assessment Center does not always update damage cost estimates. Documents from the Assessment Center showed that some incidents had been closed out before the final damage cost estimates were prepared. Since incidents are categorized according to cost, accurate damage cost information is important. In two of the six incidents we reviewed, the difference between the Assessment Center's and Thiokol's damage cost estimates was sufficient to change the mishap category.

Thiokol and the Plant Representative do not agree on the importance of certain safety issues, and, thus, the Plant Representative reports safety data that Thiokol does not. We compared the Assessment Center's and Thiokol's databases for July 1, 1986, through March 31, 1988, and found the Assessment Center tracked 99 safety issues; however, Thiokol recognized only 64 as reportable. All of the incidents reported by the Plant Representative were unsafe practices such as poor housekeeping. According to Thiokol, such incidents are outside the contractual criteria for mishap reporting because they did not result in damage to government property. However, according to the Plant Representative, housekeeping practices should be reported and tracked because they can cause accidents and may be symptomatic of a larger problem.

According to the Deputy Plant Representative, although these safety issues did not directly affect critical solid rocket motor hardware, they were serious industrial safety concerns because they might have caused accidents. He also stated that they represented the type of housekeeping problems the Plant Representative Office cited when it withheld progress payments under the Peacekeeper contract.

MSFC recognizes that incident reporting criteria needs to be more clearly defined and trend analyses need to be performed. MSFC is preparing new data reporting requirements for both Thiokol and the Plant Representative to achieve consistency in safety issue reporting. MSFC also is considering ways of tracking and analyzing safety incidents to prescribe more efficient use of existing data systems. The revised approach will divide responsibility for tracking and analyzing safety issues between the Assessment Center's system and another NASA-wide safety reporting system. According to the Director of Institutional Safety, the NASA-wide system may be used to track accidents or near misses involving shuttle hardware, equipment, and facilities, and the Assessment Center would be limited to tracking and analyzing other safety problems, such as poor housekeeping practices. To accomplish this, reporting criteria and responsibilities for the two systems will be revised. However, specific responsibilities and reporting criteria had not been defined and implemented at the completion of our work in January 1989.

MSFC officials also told us that in January 1989 they tasked the Plant Representative to provide monthly reports of his office's industrial safety activities in Thiokol's Space Operations Division. The reports are to include information on safety assurance program surveys and audits, meetings attended, documents reviewed, activities monitored, generic problems identified, safety incident costs, evidence of contract non-conformance and significant accomplishments.

MSFC officials told us that they recognize that the lack of industrial safety trend analysis is a problem and that action is underway to increase visibility in this area by highlighting potential safety issues in a newly established Safety, Reliability, Maintainability, and Quality Assurance Data Center. Data will focus on trends for mishap experience, controls implemented, results of recurrence control analyses, and comparative analyses with other programs.

Lack of Inspections

According to the Director of MSFC Institutional Safety, the Plant Representative does not have sufficient staff to adequately monitor Thiokol's safety performance. In January 1989 the Plant Representative Office had only two people who monitored safety performance in three Thiokol operating divisions. As a result, the Plant Representative Office staff performed only three safety inspections in the Space Operations Division in 1988. According to the Plant Representative Office's safety manager, adequate monitoring of Thiokol's safety performance would include independent government inspections that would help ensure that facilities, operations, and activities meet applicable safety standards.

In 1986 the Plant Representative Office performed 17 safety inspections in the Space Operations Division, and in 1987 it performed 10 safety inspections. As of July 1988, the Plant Representative Office had not performed any safety inspections in the Space Operations Division. A new Plant Representative was assigned in August 1988, and he instituted a program of "walk through" inspections. During these inspections the Plant Representative and Thiokol management, together with contractor and government safety personnel, walk through buildings that the Plant Representative has selected and identify safety hazards and violations. The Plant Representative conducted three walk through inspections from August through December 1988. The Plant Representative also performed two special audits using safety personnel from plant representative offices at other locations and a multifunctional zone evaluation of inert operations (those operations that do not involve propellants) in the Space Operations Division in August 1988. However, the Plant Representative stated that he is still unable to perform fire protection inspections at the plant due to a lack of personnel.

The Plant Representative is authorized three industrial safety positions—one manager and two occupational safety and health specialists. However, one of the specialist positions has been vacant since May 1988. According to the Plant Representative, he has been unable to attract a qualified person to fill the position. The other specialist primarily monitored the Peacekeeper program.

The Director of MSFC Institutional Safety told us he believes that the Plant Representative Office needs additional safety personnel. According to the Director, three people are not sufficient for monitoring all Air Force and NASA programs at the plant. However, the Plant Representative told us he believes the three authorized positions would be sufficient if all three were filled. He pointed out that quality assurance specialists also identify and document safety hazards and violations. For example, he said that the quality assurance staff had documented over 100 safety hazards and violations in the Space Operations Division during 1988.

Also, through December 1988 MSFC's resident office at the Thiokol plant did not include an industrial safety specialist position. However, at the completion of our work in January 1989, the Director of MSFC Safety, Reliability, Maintainability, and Quality Assurance informed us that he had added a safety engineer to the resident staff. The safety engineer will be MSFC's principal interface with both Thiokol and the Plant Representative for industrial safety matters.

Conclusions

Since 1986 Thiokol has undertaken a number of initiatives to strengthen its industrial safety program. However, according to both NASA and the Air Force, Thiokol's safety program is still not adequate. NASA and Air Force safety officials believe the contractor has adequate safety policies and procedures, but that they are poorly executed. Independent reviews, such as the Air Force's multifunctional zone evaluations, continue to identify numerous safety-related problems. Both the Air Force and NASA have applied financial penalties to encourage Thiokol to improve its safety practices. Improvements are needed in the government's monitoring of Thiokol's shuttle program safety performance. Safety incident data are not consistently reported or adequately analyzed, and the Director of MSFC Institutional Safety and the Air Force Plant Representative do not agree on the number of government safety inspection staff required.

Recommendation

We recommend that the NASA Administrator and the Secretary of the Air Force determine safety inspection staffing requirements at the Thiokol plant.

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