

GAO

Report to the Administrator, National  
Aeronautics and Space Administration  
and the Secretary of the Air Force

August 1986

# SPACE SHUTTLE

## NASA's Procurement of Solid Rocket Booster Motors



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**National Security and  
International Affairs Division****B-223785**

August 26, 1986

The Honorable James C. Fletcher  
Administrator, National Aeronautics  
and Space Administration

The Honorable Edward C. Aldridge, Jr.  
The Secretary of the Air Force

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

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**Competition**

In 1973 NASA selected the Thiokol Chemical Corporation (now Morton Thiokol, Incorporated) to develop, qualify, and produce the motors. The selection was made after a competitive solicitation involving Aerojet Corporation; Lockheed Propulsion Company; and United Technologies, Chemical Systems Division. Since that time, Thiokol has been the sole supplier of the shuttle rocket motors.

As early as 1974, NASA began formulating plans to develop a second production source for parts of the motor manufacturing operation. The plan, however, was never implemented because of slippage in the shuttle development schedule. In 1978 NASA developed another plan for establishing a second source but this plan also was not implemented because, according to NASA officials, budget priorities precluded funding for the qualification of a second source producer.

Interest and activity in dual sourcing the motor production was reactivated at the initiative of several potential suppliers in early 1984. By this time, NASA had successfully completed a number of shuttle flights. The motor design had essentially stabilized and, according to NASA, no significant design problems were apparent.

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Contractors, in a number of meetings with NASA management, asserted that millions of dollars in motor production costs could be saved with dual source competition.

On January 21, 1986, NASA announced its intention to establish a second production source under the provisions of section 2723(a)(1) of the Competition in Contracting Act of 1984 (Public Law 98-369). The objectives were to enhance national security and increase the production base for large solid rocket motors. The announcement contained the conditions or ground-rules under which the second source initiative would continue. The potential second source contractors expressed concerns that several of the ground-rules would inhibit competition. These included NASA's decision not to fund the second source qualification program and its decision to reserve 50 percent of the production quantities for Thiokol. Following the Challenger accident on January 28, 1986, the agency suspended its second sourcing plans until the causes of the accident could be determined.

In acting on NASA's fiscal year 1986 urgent supplemental appropriation, the Congressional Conference Committee, in June 1986, directed that NASA make available sufficient funds to study an alternative solid rocket booster design such as one using a unitary case or single cast propellant. The studies are to be completed by December 31, 1986, and results forwarded to the Committees on Appropriations. The Conference Committee further directed that when a final design is selected, NASA issue a request for proposal for a second source if the agency determines that such an approach can be adopted with available resources. In July 1986 the Administrator stated that when the redesign studies are completed, he will determine what second source approach can be taken.

We believe that this is a reasonable approach. However, we also believe that the guidelines established by NASA in January 1986 might not have fostered competition in the motor procurement. Some of these would have required specific justifications under the Competition in Contracting Act.

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## Quality Control and Safety

While we did not make an in-depth review of quality control and safety issues at Thiokol, documents available to us indicate significant and potentially serious problems. Further, these documents indicate that neither the contractor nor the government was giving the problems the management attention they deserved. NASA and the Air Force's plant representative at Thiokol oversee the contractor's quality control and

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safety systems. A part of the problem has been insufficient staff to perform the necessary oversight.

When the government becomes dependent on a sole source of supply for a critical subsystem on a large and long-term program such as the shuttle, the contractor may not have the incentive to identify and correct problems in areas such as quality control and safety. The government does not have maximum leverage to ensure correction of problems. The chance of winning a government contract or the threat of losing it provides a key incentive for greater efficiency and effectiveness.

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## Recommendations

Given its previous difficulties in developing a second source for shuttle motor production, including the January 1986 ground-rules which might not have fostered competition, we recommend that following the redesign decision, the NASA Administrator prepare, and provide to the Congress, a comprehensive acquisition strategy and plan for continued procurement of the motors. This plan should address (1) NASA's decision about upgrading the motor design, (2) alternatives for establishing and maintaining competition in future procurements, and (3) the costs and benefits of each alternative.

We further recommend that before motor production resumes, the NASA Administrator and the Secretary of the Air Force determine the number and types of government personnel needed to adequately ensure quality control in motor manufacturing operations and to acquire the needed staff. We also recommend that, before resuming production, NASA identify any other mechanisms, including possible contractual incentives or penalties, needed to ensure that the controls are properly implemented and enforced.

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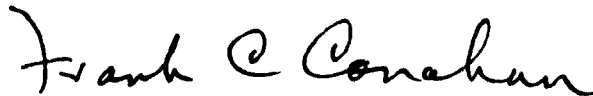
We examined documents and records prepared by NASA Headquarters, the Marshall Space Flight Center, and Morton Thiokol, Incorporated. We also held discussions with officials of NASA, the Air Force; Morton Thiokol; Aerojet Strategic Propulsion Company; Atlantic Research Corporation; Hercules, Incorporated, and United Technologies Corporation, Chemical Systems Division.

We did not obtain agency comments on this report, but we did discuss its contents with officials of both NASA and the Department of Defense. Our work was performed in accordance with generally accepted government auditing standards from May through July 1986.

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The head of a federal agency is required by 31 U.S.C. 720 to submit a written statement on actions taken on our recommendations to the House Committee on Government Operations and the Senate Committee on Governmental Affairs not later than 60 days after the date of the report and to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of the report.

We are sending copies of this report to the Chairmen of the above Committees. Copies are also being sent to the Chairmen, House Committee on Science and Technology and the Senate Committee on Commerce, Science, and Transportation; and the Director, Office of Management and Budget.



Frank C. Conahan  
Assistant Comptroller General



# Testimony on NASA's Shuttle Booster Rocket Motor Procurement

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UNITED STATES GENERAL ACCOUNTING OFFICE  
WASHINGTON, D.C. 20548

For release on delivery  
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STATEMENT OF  
MILTON SOCOLAR  
SPECIAL ASSISTANT TO THE COMPTROLLER GENERAL  
OF THE UNITED STATES  
BEFORE THE  
LEGISLATION AND NATIONAL SECURITY SUBCOMMITTEE  
COMMITTEE ON GOVERNMENT OPERATIONS  
HOUSE OF REPRESENTATIVES  
ON  
NASA'S SHUTTLE BOOSTER ROCKET MOTOR PROCUREMENT



Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE:

I AM PLEASED TO APPEAR BEFORE THE SUBCOMMITTEE TO TESTIFY ON OUR REVIEW OF NASA'S PROCUREMENT OF SPACE SHUTTLE SOLID ROCKET MOTORS (SRMs). THIS REVIEW WAS CONDUCTED AT YOUR REQUEST AND WE CONCENTRATED ON

(1) THE CIRCUMSTANCES SURROUNDING NASA'S SECOND SOURCE INITIATIVE FOR PROCURING SRMs;

(2) NASA'S PLANS TO:

--REDESIGN THE SRM TO RESOLVE PROBLEMS IDENTIFIED BY THE PRESIDENTIAL COMMISSION ON THE SPACE SHUTTLE CHALLENGER ACCIDENT AND

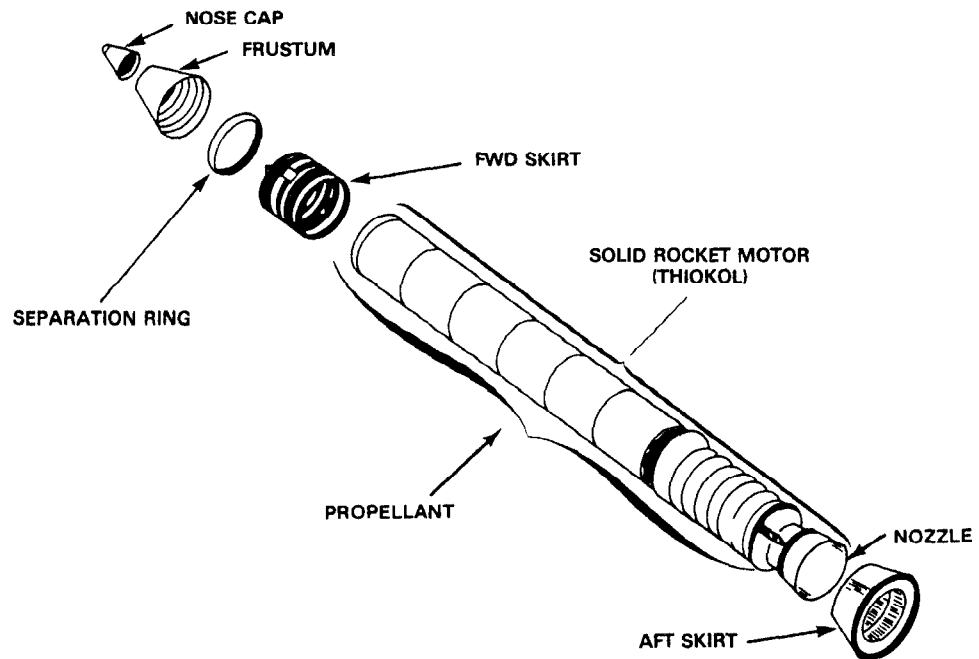
--DEVELOP AND MAINTAIN MULTIPLE PRODUCTION SOURCES; AND

(3) QUALITY CONTROL AND SAFETY AT THE MORTON THIOKOL SRM MANUFACTURING FACILITY.

**BACKGROUND**

SRMs, 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 ROCKETS EXHAUST THEIR FUEL. EXPLOSIVES SEPARATE THE BOOSTERS FROM THE REST OF THE SHUTTLE. THE BOOSTERS THEN FALL INTO THE OCEAN TO BE RECOVERED. PARTS OF THE BOOSTERS, INCLUDING PARTS OF THE MOTORS, ARE RETRIEVED AND REFURBISHED FOR USE IN FUTURE FLIGHTS. THE SRM IS THE LARGEST U.S. SOLID ROCKET MOTOR EVER FLOWN AND THE ONLY ONE DESIGNED FOR REUSE. THE FOLLOWING CHART ILLUSTRATES A SHUTTLE SOLID ROCKET BOOSTER, INCLUDING THE SRM PORTION.

## SOLID ROCKET BOOSTER SYSTEM WITH SOLID ROCKET MOTOR



IN 1973 NASA SELECTED THE THIOKOL CHEMICAL CORPORATION (NOW MORTON THIOKOL, INCORPORATED) TO DEVELOP, QUALIFY, AND PRODUCE THE MOTORS. THE SELECTION WAS MADE AFTER A COMPETITIVE SOLICITATION INVOLVING AEROJET CORPORATION; LOCKHEED PROPULSION COMPANY; AND UNITED TECHNOLOGIES, CHEMICAL SYSTEMS DIVISION.

Procurement plan

THE ORIGINAL SRM PROCUREMENT PLAN DIVIDED DEVELOPMENT AND PRODUCTION INTO THE FOLLOWING THREE INCREMENTS.

INCREMENT I: DEVELOPMENT, DEMONSTRATION, TESTING,  
AND PRODUCTION OF 12 MOTORS.

INCREMENT II: PRODUCTION OF 108 MOTORS.

INCREMENT III: PRODUCTION OF AN ADDITIONAL 770  
MOTORS.

THE INITIAL CONTRACT WITH THIOKOL WAS FOR INCREMENT I, WITH AN UNPRICED OPTION FOR INCREMENT II. NASA NEVER EXERCISED THE INCREMENT II OPTION. BECAUSE THE SHUTTLE DEVELOPMENT SCHEDULE SLIPPED AND THE PLANNED FLIGHT RATE DECREASED, THE PROCUREMENT APPROACH WAS CHANGED FROM LARGE INCREMENTS TO SMALLER BLOCK BUYS.

IN APRIL 1978, NASA AMENDED THE DEVELOPMENT CONTRACT TO PROVIDE FOR THE FIRST PRODUCTION BUY OF 18 MOTORS. IN DECEMBER 1982, NASA MODIFIED THE CONTRACT AGAIN TO PROVIDE FOR THE SECOND PRODUCTION BUY FOR AN ADDITIONAL 46 MOTORS. THE MOTOR WHICH FAILED, CAUSING THE CHALLENGER ACCIDENT, CAME FROM THIS PRODUCTION BUY. AT THE TIME OF THE ACCIDENT, NASA WAS NEGOTIATING A THIRD BUY OF BETWEEN 120 AND 180 MOTORS.

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Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

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IMMEDIATELY FOLLOWING THE ACCIDENT, NASA ISSUED AN ORDER TO STOP PRODUCTION PENDING THE OUTCOME OF THE ACCIDENT INVESTIGATION AND SUSPENDED ONGOING NEGOTIATIONS FOR THE THIRD BUY.

CIRCUMSTANCES SURROUNDING NASA'S  
SECOND SOURCE INITIATIVE

AS EARLY AS 1974, NASA BEGAN FORMULATING PLANS TO DEVELOP A SECOND PRODUCTION SOURCE FOR THE SRM NOZZLE AND PROPELLANT LOADING EFFORT. THE PLAN WAS NEVER IMPLEMENTED BECAUSE OF SLIPPAGE IN THE SHUTTLE DEVELOPMENT SCHEDULE BUT WAS RESURRECTED IN 1978. ACCORDING TO A MEMORANDUM SIGNED BY THE ASSOCIATE ADMINISTRATOR FOR SPACE TRANSPORTATION SYSTEMS, A REVIEW BY HIS OFFICE HAD CONFIRMED THAT COMPETITION COULD LOWER OPERATIONAL COSTS AND ALSO PROTECT AGAINST SINGLE SOURCE PRODUCTION DELAYS AND STOPPAGES. THE ASSOCIATE ADMINISTRATOR SPECIFIED THAT A REQUEST FOR PROPOSAL FOR AN ALTERNATE SOURCE BE ISSUED IN FISCAL YEAR 1980 AND AN "EDUCATIONAL BUY" TO QUALIFY THE SECOND SOURCE WOULD COMMENCE IN FISCAL YEAR 1981.

AT NASA'S DIRECTION, THIokol, IN 1979, COMPLETED DELIVERY OF A TECHNICAL DATA PACKAGE FOR THE PLANNED COMPETITION. HOWEVER, THE COMPETITION WAS NEVER HELD BECAUSE, ACCORDING TO NASA OFFICIALS, BUDGET PRIORITIES PRECLUDED FUNDING FOR THE QUALIFICATION OF A SECOND SOURCE.

Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

INTEREST AND ACTIVITY IN DUAL SOURCING THE SRM PRODUCTION WAS REACTIVATED AT THE INITIATIVE OF SEVERAL POTENTIAL SUPPLIERS IN EARLY 1984. BY THIS TIME, NASA HAD SUCCESSFULLY COMPLETED A NUMBER OF SHUTTLE FLIGHTS. THE SRM DESIGN HAD ESSENTIALLY STABILIZED AND, ACCORDING TO NASA, NO SIGNIFICANT DESIGN PROBLEMS WERE APPARENT. CONTRACTORS, IN A NUMBER OF MEETINGS WITH NASA MANAGEMENT, ASSERTED THAT THEY COULD SAVE MILLIONS OF DOLLARS IN SRM PRODUCTION COSTS WITH DUAL SOURCE COMPETITION.

1984 sources sought announcement

TO DETERMINE IF SAVINGS COULD IN FACT BE REALIZED WITH A DUAL SOURCE, THE NASA ADMINISTRATOR DIRECTED THAT A FORMAL ASSESSMENT BE CONDUCTED. A "SOURCES SOUGHT ANNOUNCEMENT" WAS PLACED IN THE COMMERCE BUSINESS DAILY IN NOVEMBER 1984 TO DETERMINE INDUSTRY INTEREST. THE ANNOUNCEMENT REQUESTED INTERESTED VENDORS TO SUBMIT INFORMATION OUTLINING THE FACILITY LOCATIONS WHERE THEY WOULD MANUFACTURE THE MOTORS, IDENTIFY MAJOR TOOLING AND EQUIPMENT NEEDED, OUTLINE A QUALIFICATION TEST PROGRAM, PROVIDE AN OVERALL SCHEDULE FOR COMPLETING THE QUALIFICATION PROGRAM AND IDENTIFY THE TOTAL COSTS INCLUDING FACILITIES, QUALIFICATION, AND RECURRING PRODUCTION COSTS.

THE ANNOUNCEMENT LIMITED THE SCOPE OF ANY SECOND SOURCE EFFORT TO (1) THE MANUFACTURE OR SUPPLY OF EXPENDABLE NOZZLES AND NOZZLE EXTENSIONS AND ASSEMBLY OF THE NOZZLES WITH GOVERNMENT-

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Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

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FURNISHED GIMBAL BEARINGS, (2) PROPELLANT LOADING AND CASTING OPERATIONS USING GOVERNMENT-FURNISHED MOTOR CASES, (3) FINAL MOTOR ASSEMBLY USING GOVERNMENT-FURNISHED SYSTEM TUNNELS AND IGNITERS, AND (4) TRANSPORTATION OF THE COMPLETE MOTORS AND NOZZLE EXTENSIONS ON RAIL CARS FURNISHED BY OTHERS. THE SECOND SOURCE WOULD NOT BE PERMITTED TO MANUFACTURE OR REFURBISH REUSABLE COMPONENTS OF THE MOTOR.

FOUR FIRMS RESPONDED TO THE SOLICITATION--AEROJET STRATEGIC PROPULSION COMPANY; UNITED TECHNOLOGIES CORPORATION, CHEMICAL SYSTEMS DIVISION; ATLANTIC RESEARCH CORPORATION; AND HERCULES, INCORPORATED. DURING 1985 NASA CONDUCTED FURTHER DISCUSSIONS WITH THE COMPANIES, EVALUATED THE DATA SUPPLIED, AND CONCLUDED THAT ALL FOUR COMPANIES HAD OR COULD ACQUIRE THE CAPABILITY TO PRODUCE THE SRM. WHILE NASA CONCLUDED THAT THERE WERE NO CLEAR INDICATIONS THAT DEVELOPING AN ALTERNATE PRODUCTION SOURCE WOULD RESULT IN SIGNIFICANT SAVINGS TO THE GOVERNMENT, IT DECIDED TO PROCEED WITH THE INITIATIVE IN ORDER TO BROADEN THE INDUSTRIAL BASE FOR LARGE SOLID ROCKET MOTOR PRODUCTION AND ENHANCE NATIONAL SECURITY. NASA STATED IT HOPED THAT ECONOMIC BENEFITS WOULD DEVELOP AS THE SECOND SOURCING PROGRAM MATURED.

Ground-rules

ON JANUARY 21, 1986, NASA ANNOUNCED ITS INTENTION TO PURSUE ESTABLISHMENT OF A SECOND SOURCE UNDER THE PROVISIONS OF SECTION

Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

2723(a)(1) OF THE COMPETITION IN CONTRACTING ACT OF 1984 (PUBLIC LAW 98-369). THE ANNOUNCEMENT ADVISED THE FOUR FIRMS OF THE CONDITIONS OR GROUND-RULES UNDER WHICH THE INITIATIVE WOULD CONTINUE.

FOLLOWING THE CHALLENGER ACCIDENT ON JANUARY 28, 1986, NASA SUSPENDED ITS SECOND SOURCING PLANS UNTIL THE CAUSES OF THE ACCIDENT COULD BE DETERMINED. IF NASA DECIDES TO RESUME ITS SECOND SOURCE INITIATIVE, IT MAY USE DIFFERENT GROUND-RULES.

THE MORE SALIENT OF THE JANUARY 1986 GROUND-RULES WERE:

--NASA WOULD NOT PROVIDE UP-FRONT FUNDING OF SECOND SOURCE FACILITIES, TOOLING, OR QUALIFICATION.

--TOTAL COSTS FOR THE PRODUCTION BY BOTH SOURCES WOULD BE LIMITED TO NASA'S SRM OPERATIONS BUDGET.

--QUALIFICATION OF THE SECOND SOURCE AND INITIAL PRODUCTION OF AT LEAST EIGHT MOTORS WOULD COINCIDE WITH THE LAST DELIVERY BY THIokol OF MOTORS FROM THE THIRD PRODUCTION BUY.



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**Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement**

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--UPON SUCCESSFUL QUALIFICATION, AND CONTINGENT ON BUDGET AVAILABILITY, NASA WOULD CONTRACT WITH THE SECOND SOURCE FOR A PRODUCTION QUANTITY OF 40 MOTORS TO BE DELIVERED AT A RATE OF NOT LESS THAN 8 A YEAR.

--NASA WOULD AWARD AT LEAST 50 PERCENT OF THE FOURTH BUY QUANTITIES TO THIOKOL BUT THE SECOND SOURCE WOULD BE PERMITTED TO COMPETE FOR THE REMAINING SRMs PLANNED FOR THE FOURTH BUY. THE DECISION TO PROCURE ANY MOTORS ABOVE THE INITIAL 40 FROM THE SECOND SOURCE, HOWEVER, WOULD BE PREDICATED ON THE TOTAL COSTS INVOLVED COMPARED TO THE BUDGET AVAILABLE FOR SRM PROCUREMENT.

--THE SECOND SOURCE WOULD BE EXPECTED TO OBTAIN THE SRM NOZZLE ASSEMBLY THROUGH A DIRECTED PROCUREMENT FROM THIOKOL, BUT NASA WOULD CONSIDER ALTERNATIVES TO THIS APPROACH.

--ANY SRM REQUIREMENTS SUBSEQUENT TO THE FOURTH PRODUCTION BUY WOULD BE COMPETED BETWEEN THE TWO SOURCES AND THE SPLIT WOULD BE WEIGHTED TOWARD OVERALL LOWEST COST TO THE GOVERNMENT.

NASA INVITED INTERESTED FIRMS TO SUBMIT ANY QUESTIONS THEY HAD REGARDING THESE GROUND-RULES BY FEBRUARY 12, 1986, AND REQUIRED THAT THE FIRMS PROVIDE A LETTER OF INTENT TO RESPOND TO ANY SECOND SOURCE REQUEST FOR PROPOSAL BY MARCH 12, 1986. THE FIRMS SUBMITTED QUESTIONS AND EXPRESSED THEIR CONCERNS ABOUT THE GROUND-RULES IN FEBRUARY. ON MARCH 3, 1986, NASA ACKNOWLEDGED RECEIPT OF THE QUESTIONS, INFORMED THE CONTRACTORS THAT IT WOULD PROVIDE ANSWERS TO THE QUESTIONS AT A LATER DATE, AND RELIEVED THE REQUIREMENT FOR THE CONTRACTORS TO PROVIDE LETTERS OF CONTINUING INTEREST BY THE ESTABLISHED DATE OF MARCH 12, 1986.

GAO assessment

WE BELIEVE THAT NASA'S DECISION TO INTRODUCE COMPETITION INTO THE SRM PROGRAM BY DEVELOPING ALTERNATE PRODUCTION SOURCES WAS APPROPRIATE. COMPETITION IS A NATIONAL POLICY AND FOR GOOD REASON. IT CAN LEAD TO INCREASED TECHNICAL PERFORMANCE, ENCOURAGE IMPROVEMENTS IN QUALITY, REDUCE ACQUISITION COSTS, AND ENHANCE THE INDUSTRIAL BASE.

NASA'S STATED OBJECTIVES IN THIS CASE WERE TO ENHANCE NATIONAL SECURITY, EXPAND THE PRODUCTION BASE, AND CAPITALIZE ON ANY POSSIBLE ECONOMIC BENEFITS. WE BELIEVE THAT COMPETITION WOULD SUPPORT THESE OBJECTIVES. IN OUR OPINION, HOWEVER, THE GROUND-RULES INITIALLY ESTABLISHED BY NASA FOR THE SECOND SOURCING INITIATIVE WOULD REQUIRE SPECIFIC JUSTIFICATIONS UNDER

THE COMPETITION IN CONTRACTING ACT (PUBLIC LAW 98-369) AND MIGHT NOT ADEQUATELY FOSTER COMPETITION. WHILE THE POTENTIAL SUPPLIERS HAD NOT ANNOUNCED THEIR DECISION ON COMPETITION, THEY EXPRESSED SERIOUS CONCERNS TO US ABOUT THE GROUND-RULES AND THEIR WILLINGNESS TO COMPETE UNDER THOSE CONDITIONS.

National security and  
enhanced production base

CONFIDENCE IN A SOLE SOURCE OF SUPPLY FOR THE SRMs WAS AFFECTED NOT ONLY BY THE CHALLENGER ACCIDENT BUT ALSO BECAUSE OF A NUMBER OF SAFETY RELATED INCIDENTS IN THIOKOL'S PRODUCTION FACILITY. IN THE PAST 2 YEARS, THIOKOL HAS EXPERIENCED EXPLOSIONS AND FIRES RESULTING IN THE LOSS OF PRODUCTION FACILITIES IN THE SRM CASTING BUILDING, PROPELLANT MIXER BUILDING, AND PROPELLANT GRINDING FACILITIES AS WELL AS TWO FIRES RESULTING IN THE LOSS OF FACILITIES IN THEIR COMMERCIAL OPERATIONS AREAS.

LOSS OF PRODUCTION CAPABILITY DID NOT AFFECT MEETING SRM DELIVERY REQUIREMENTS IN SUPPORT OF NASA'S FLIGHT SCHEDULES BECAUSE OF EXCESS CAPACITY AT THE MANUFACTURING PLANT. HAD NASA ACHIEVED ITS PROJECTED LAUNCH RATE OF 24 FLIGHTS A YEAR, HOWEVER, THE FIRES COULD HAVE ADVERSELY AFFECTED NASA'S ABILITY TO LAUNCH.

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**Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement**

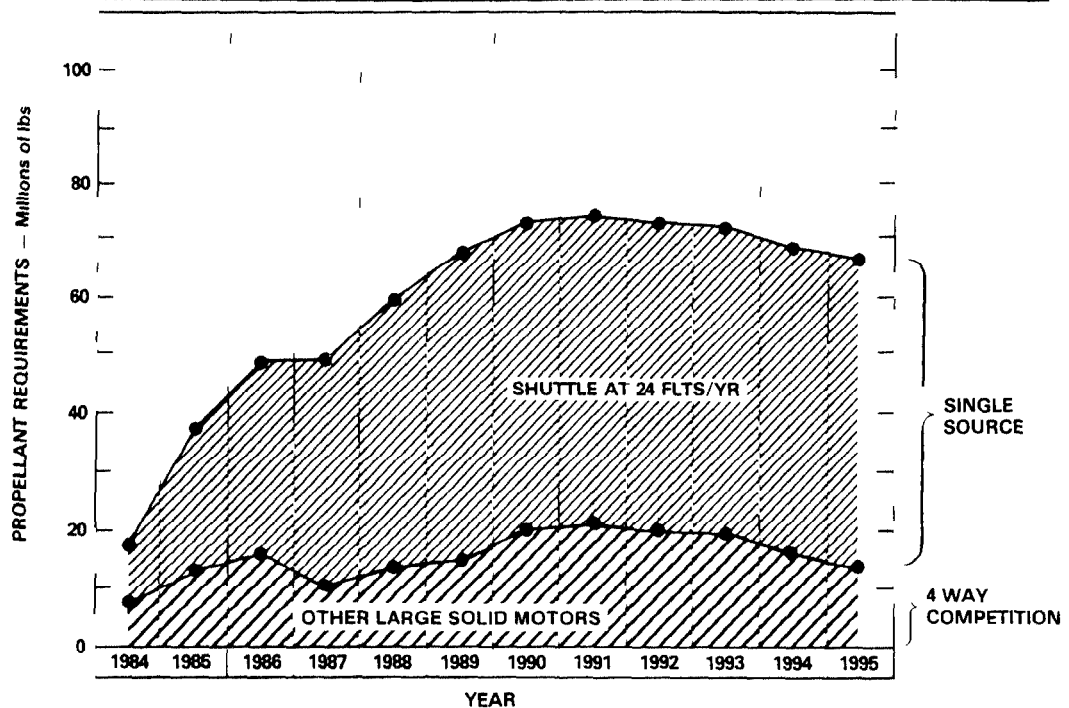
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MULTIPLE PRODUCTION SOURCES WOULD PROVIDE PROTECTION NOT ONLY AGAINST LOSS OF PRODUCTION DUE TO SUCH ACCIDENTS, WHICH ARE AN INHERENT RISK IN EXPLOSIVE PROPELLANT OPERATIONS, BUT WOULD ALSO PROVIDE A BUFFER AGAINST OTHER POTENTIAL DISRUPTIONS SUCH AS THOSE CAUSED BY LABOR DISPUTES.

THERE ARE FIVE MAJOR SOLID ROCKET MOTOR MANUFACTURERS IN THE UNITED STATES: AEROJET STRATEGIC PROPULSION COMPANY, ATLANTIC RESEARCH CORPORATION, HERCULES CORPORATION, THIOKOL CORPORATION, AND UNITED TECHNOLOGIES CORPORATION'S CHEMICAL SYSTEMS DIVISION. WITH THE EXCEPTION OF HERCULES, WHICH IS BUILDING A NEW MOTOR MANUFACTURING FACILITY IN MAGNA, UTAH, THESE COMPANIES' FACILITIES FOR MOTOR PRODUCTION WERE BUILT IN THE 1960s.

IN 1984, THE SHUTTLE SRM ACCOUNTED FOR WELL OVER HALF OF THE UNITED STATES' LARGE SOLID MOTOR MANUFACTURING. AS NASA BUILT UP TO ITS PLANNED 24 SHUTTLE FLIGHTS A YEAR, THE PERCENTAGE WAS EXPECTED TO INCREASE SIGNIFICANTLY. THE RELATIONSHIP BETWEEN THE SHUTTLE AND OTHER LARGE MOTORS, SUCH AS THOSE USED IN THE MINUTEMAN AND TRIDENT SYSTEMS, IS SHOWN IN THE FOLLOWING CHART PROVIDED BY THE AEROJET STRATEGIC PROPULSION COMPANY.

## SHUTTLE SRM/AND OTHER LARGE SOLID ROCKET MOTOR PROPELLANT REQUIREMENTS



SOURCE AEROJET STRATEGIC PROPULSION COMPANY

UP TO THIS POINT, THE SHUTTLE MOTOR PRODUCTION HAS BEEN ACCOMPLISHED BY A SINGLE SOURCE, WHILE MOTORS FOR THE OTHER LARGE SYSTEMS IS SHARED BY FOUR CONTRACTORS, INCLUDING THIOKOL. BECAUSE THE SHUTTLE MOTOR PRODUCTION ACCOUNTS FOR SUCH A LARGE PERCENTAGE OF THE TOTAL, IT IS THE KEY TO EXPANDING THE U.S. PRODUCTION BASE FOR LARGE SRMs. THE FOUR MOTOR CONTRACTORS WHICH

RESPONDED TO NASA'S EARLIER MARKET SURVEY ALL PROPOSED TO EXPAND AND MODERNIZE THEIR PRODUCTION FACILITIES TO ACCOMPLISH THE WORK.

Cost savings

NASA'S ANALYSIS CONCLUDED THAT THERE WERE NO CLEAR INDICATIONS OF COST SAVINGS RESULTING FROM THE SECOND SOURCING INITIATIVE. HOWEVER, THE AGENCY EXPRESSED A HOPE THAT ECONOMIC BENEFITS WOULD DEVELOP AS THE PROGRAM MATURES.

WE MADE ONLY A LIMITED REVIEW OF NASA'S COST ANALYSIS AND FOUND NO OBVIOUS ERRORS OR SIGNIFICANT OMISSIONS. NASA'S 1978 ANALYSIS, WHICH SHOWED COST SAVINGS FROM DEVELOPING A SECOND PRODUCTION SOURCE, WAS BASED ON A TOTAL PRODUCTION RATE OF 120 MOTORS A YEAR. IN 1985, WHEN NASA ANALYZED THE COST EFFECTIVENESS OF DEVELOPING A SECOND SOURCE, THE EXPECTED PRODUCTION RATE HAD DROPPED TO 48 A YEAR.

NASA'S HOPE THAT FUTURE ECONOMIC BENEFITS MIGHT RESULT FROM COMPETITION AMONG MULTIPLE PRODUCTION SOURCES IS SUPPORTED BY OUR 1984 STUDY OF DUAL SOURCING IN THE DEPARTMENT OF DEFENSE AND SIX CIVIL AGENCIES, INCLUDING NASA.<sup>1</sup> THAT STUDY FOUND THAT ALTHOUGH PRICE COMPETITION WAS NOT A PRIMARY OBJECTIVE IN ANY OF THE DUAL SOURCE PROCUREMENTS, OVER HALF OF THE ALTERNATIVE SUPPLIERS FOR

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<sup>1</sup>Cost Effectiveness of Dual Sourcing for Production Price Competition is Uncertain, NSIAD-84-111, August 31, 1984

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Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

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THE ITEMS IN OUR SAMPLE WERE ABLE TO ACHIEVE A LOWER PRICE THAN THE ORIGINAL SUPPLIERS EVEN THOUGH THEY HAD PRODUCED THE ITEMS AN AVERAGE OF 2 YEARS LESS THAN THE ORIGINAL SUPPLIERS.

Ground-rules and the  
Competition in Contracting Act

SECTION 2723(a)(1) OF THE COMPETITION IN CONTRACTING ACT AUTHORIZES AN AGENCY TO EXCLUDE A PARTICULAR SOURCE (IN THIS CASE THIOKOL) FROM A PROCUREMENT IN ORDER TO ESTABLISH OR MAINTAIN AN ALTERNATIVE SOURCE OF SUPPLY IF THE AGENCY HEAD DETERMINES THAT TO DO SO WOULD (1) INCREASE OR MAINTAIN COMPETITION AND LIKELY RESULT IN REDUCED OVERALL COSTS, (2) BE IN THE INTEREST OF NATIONAL DEFENSE BY HAVING MULTIPLE SOURCES IN THE EVENT OF A NATIONAL EMERGENCY OR INDUSTRIAL MOBILIZATION, OR (3) BE IN THE INTEREST OF NATIONAL DEFENSE BY ESTABLISHING OR MAINTAINING AN ESSENTIAL ENGINEERING, RESEARCH, OR DEVELOPMENT CAPABILITY OF AN EDUCATIONAL OR OTHER NONPROFIT INSTITUTION OR A FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTER.

UNDER THIS PROVISION, NASA COULD EXCLUDE THE INCUMBENT PRODUCER FROM THE 40 MOTORS IT PLANNED TO RESERVE TO AN ALTERNATE PRODUCER. THE CONTRACT FOR THESE MOTORS WAS TO BE A PART OF THE FOURTH PRODUCTION BUY.

Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

TO PREDETERMINE THAT 50 PERCENT OF THE QUANTITY IN THE PLANNED FOURTH BUY WOULD BE GIVEN TO THE INCUMBENT, HOWEVER, WOULD AMOUNT TO A SOLE-SOURCE AWARD. NASA WOULD HAVE TO JUSTIFY THIS AWARD UNDER ONE OF THE SEVEN EXCEPTIONS TO FULL AND OPEN COMPETITION PROVIDED IN THE ACT. THIS JUSTIFICATION WOULD HAVE TO BE BASED ON A FORMAL FINDING BY NASA.

NASA OFFICIALS TOLD US THAT THE DECISION TO RESERVE 50 PERCENT OF THE FOURTH BUY QUANTITIES TO THE INCUMBENT AND ANY QUALIFIED SECOND SOURCE A QUANTITY OF 8 MOTORS A YEAR WAS NOT BASED ON ANY ECONOMIC OR COST ANALYSIS. THESE OFFICIALS TOLD US THEY DID NOT BELIEVE IT WOULD BE PRACTICAL TO EXPECT A SECOND SOURCE TO BEGIN PRODUCTION AT A RATE OF 48 MOTORS A YEAR. THE OFFICIALS TOLD US THAT THEY CONSIDERED A MAXIMUM OF A 50/50 SPLIT OR PRODUCTION OF 24 MOTORS A YEAR BY EACH OF THE TWO SOURCES REASONABLE.

SINCE THE SPLIT WAS NOT BASED ON AN ECONOMIC ANALYSIS OF THE RELATIVE COSTS OF THE TWO SOURCES, THE GROUND-RULE RESERVING 50 PERCENT OF THE FOURTH BUY QUANTITY FOR THIOKOL COULD RESULT IN AN OVERALL HIGHER COST TO THE GOVERNMENT FOR THE SRMs IF ONE OF THE POTENTIAL ALTERNATIVE SOURCES IS ABLE TO ACHIEVE A COST LOWER THAN THAT PROPOSED BY THIOKOL.

SINCE THE INCUMBENT WOULD BE GUARANTEED 50 PERCENT OF THE PROCUREMENT QUANTITIES, UNDER NASA'S PROPOSED GROUND-RULES, THAT



Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

CONTRACTOR THEORETICALLY COULD PRICE ITS PROPOSAL IN SUCH A WAY AS TO VIRTUALLY ASSURE THAT IT RECEIVED ALL BUT THE 40 MOTORS RESERVED TO THE SECOND SOURCE. THIS COULD BE DONE BY PROPOSING A HIGH PRICE FOR THE GUARANTEED 50 PERCENT AND A MUCH LOWER PRICE FOR THE REMAINING QUANTITIES. BECAUSE OF THE POTENTIAL FOR PROVIDING AN UNFAIR ADVANTAGE TO THE INCUMBENT, NASA WOULD HAVE TO STRUCTURE ITS EVALUATION TO PREVENT SUCH UNBALANCED PRICING AND ENSURE THAT THE COMPETITION WAS FAIR.

NASA OFFICIALS INFORMED US THAT THE REASONS FOR ELIMINATING THE NOZZLE COMPONENT MANUFACTURE AND ASSEMBLY FROM THE SCOPE OF THE SECOND SOURCING INITIATIVE WERE

--TECHNICAL PROBLEMS WHICH RESULTED IN A NEAR "BURN-THROUGH" OF THE NOZZLE ON A PREVIOUS FLIGHT, AND

--TIGHT MANUFACTURING PROCESS CONSTRAINTS IMPLEMENTED TO HELP RESOLVE THE PROBLEM.

NASA OFFICIALS SAID THAT, ALTHOUGH IT MIGHT HAVE BEEN POSSIBLE FOR THEM TO PREPARE PERFORMANCE SPECIFICATIONS AND REQUIREMENTS FOR MANUFACTURE OF THE NOZZLE, THAT EFFORT WOULD BE A HIGHER RISK THAN OTHER PARTS OF THE SECOND SOURCE SCOPE. THE GROUND-RULES SPECIFICALLY STATE THAT ALTERNATIVES TO THE DIRECTED PROCUREMENT FROM THIOKOL WOULD BE CONSIDERED.

Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

IN OUR OPINION, THE FACT THAT TIGHT MANUFACTURING PROCESS CONSTRAINTS ARE ESSENTIAL TO THE NOZZLE MANUFACTURE IS NOT NECESSARILY ADEQUATE JUSTIFICATION FOR EXCLUDING THAT EFFORT FROM THE COMPETITION SINCE ANY SECOND SOURCE WOULD HAVE TO TEST AND QUALIFY ANY NOZZLES PRODUCED. IN FACT, WE NOTED THAT THE INCUMBENT WAS PLANNING CHANGES IN THE NOZZLE MANUFACTURING PROCESS UNDER AN INDUSTRIAL MODERNIZATION IMPROVEMENT PROGRAM WHICH WOULD HAVE BEEN IMPLEMENTED IN CONJUNCTION WITH THE THIRD PRODUCTION BUY.

ELIMINATING THE NOZZLE MANUFACTURE AND ASSEMBLY COULD FURTHER INCREASE THE FINANCIAL RISK FOR THE SECOND SOURCE. ACCORDING TO BOTH NASA AND CONTRACTOR ESTIMATES, THIS EFFORT ACCOUNTS FOR ABOUT 30 PERCENT OF THE RECURRING COST ASSOCIATED WITH THE SECOND SOURCE EFFORT.

NASA'S DECISION NOT TO PROVIDE UP-FRONT FUNDING OF SECOND SOURCE QUALIFICATION COSTS COULD ALSO INHIBIT A VIABLE COMPETITION. ACCORDING TO NASA OFFICIALS, THIS DECISION RESULTED FROM BUDGET CONSTRAINTS. THESE OFFICIALS SAID THAT NASA'S BUDGET WAS NOT SUFFICIENT TO FUND THE QUALIFICATION COSTS.

DIRECT AGENCY FUNDING OF ALTERNATIVE SOURCE QUALIFICATION COSTS, WHILE NOT REQUIRED BY THE COMPETITION IN CONTRACTING ACT, IS NORMAL IN MAJOR SYSTEM ACQUISITIONS. IN THIS REGARD, WE NOTED THAT IN ITS EARLIER SECOND SOURCE PLANNING, NASA CONCLUDED THAT

AGENCY FUNDING OF THE QUALIFICATION PROGRAM WOULD BE ESSENTIAL TO ESTABLISHING A VIABLE COMPETITION.

THE FOUR FIRMS RESPONDING TO NASA'S SOLICITATION ESTIMATED THAT THE QUALIFICATION COSTS WOULD RANGE BETWEEN \$52 AND \$101 MILLION AND WOULD REQUIRE SUBSTANTIAL ADDITIONAL INVESTMENT IN FACILITIES AND TOOLING. NASA'S DECISION NOT TO FUND THE QUALIFICATION COSTS MEANT THAT THE CONTRACTORS WOULD HAVE TO RECOVER THESE COSTS THROUGH THEIR PRODUCT PRICE. THIS WOULD NOT BE TRUE FOR THIOKOL SINCE THE GOVERNMENT PAID THE QUALIFICATION COSTS FOR THAT CONTRACTOR DURING THE SRM DEVELOPMENT PROGRAM. ACCORDING TO THE CONTRACTORS, THE DECISION TO GUARANTEE ANY SECOND SOURCE A PRODUCTION QUANTITY OF ONLY 40 MOTORS WOULD INTRODUCE A HIGH RISK THAT THE WINNING FIRM WOULD NOT BE ABLE TO COMPLETELY RECOVER ITS INVESTMENT AND AN ACCEPTABLE RATE OF RETURN ON THAT INVESTMENT.

WHILE THE POTENTIAL SUPPLIERS HAD NOT ANNOUNCED THEIR DECISION ON COMPETITION, THIS FINANCIAL RISK COULD HAVE INHIBITED SOME FIRMS FROM COMPETING.

NASA'S STRATEGY FOR FUTURE  
SRM PROCUREMENT

BEFORE THE INVESTIGATION INTO THE CHALLENGER ACCIDENT WAS COMPLETED, NASA AND THIOKOL BEGAN PRELIMINARY REDESIGN OF SRM

PARTS. RECOGNIZING THAT THE CHALLENGER ACCIDENT WOULD AFFECT ITS PLANS FOR SECOND SOURCING SRM PRODUCTION, NASA OFFICIALS ALSO BEGAN REASSESSING THESE PLANS.

SRM redesign plan

ON FEBRUARY 3, 1986, PRESIDENT REAGAN ANNOUNCED THE FORMATION OF A COMMISSION TO REVIEW THE CIRCUMSTANCES SURROUNDING THE ACCIDENT TO ESTABLISH ITS PROBABLE CAUSE OR CAUSES AND TO DEVELOP RECOMMENDATIONS FOR CORRECTIVE ACTION. THE COMMISSION'S REPORT, PUBLISHED JUNE 6, 1986, CONCLUDED THAT THE CHALLENGER LOSS WAS CAUSED BY A FAILURE IN THE JOINT BETWEEN THE TWO LOWER SEGMENTS OF THE RIGHT SRM.

THE SPECIFIC FAILURE WAS THE DESTRUCTION OF SEALS OR "O-RINGS" THAT ARE INTENDED TO PREVENT HOT GASES FROM LEAKING THROUGH THE JOINT DURING THE PROPELLANT BURN OF THE ROCKET MOTOR. THE COMMISSION STATED THAT THE FAULTY MOTOR JOINT AND SEAL MUST BE CHANGED BEFORE SHUTTLE FLIGHTS RESUME. THIS COULD BE ACCOMPLISHED BY A NEW DESIGN ELIMINATING THE JOINT OR A REDESIGN OF THE CURRENT JOINT AND O-RINGS. THE REPORT RECOMMENDS THAT NO DESIGN OPTIONS BE PREMATURELY PRECLUDED BECAUSE OF SCHEDULE, COST, OR RELIANCE ON EXISTING HARDWARE AND SPECIFIED CRITERIA THAT SHOULD BE MET IN ANY REDESIGN.

**Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement**

THE COMMISSION ALSO RECOMMENDED THAT THE ADMINISTRATOR OF NASA REQUEST THE NATIONAL RESEARCH COUNCIL TO FORM AN INDEPENDENT SOLID ROCKET MOTOR DESIGN OVERSIGHT COMMITTEE TO IMPLEMENT THE COMMISSION'S DESIGN RECOMMENDATIONS AND OVERSEE THE DESIGN EFFORT.

THE COMMISSION FURTHER RECOMMENDED THAT NASA REVIEW THE DESIGNS OF ALL CRITICAL COMPONENTS OF BOTH THE MOTOR AND OTHER SHUTTLE SYSTEMS. THEREFORE, THE REDESIGN EFFORT ENCOMPASSES OTHER CHANGES TO THE MOTOR. FOR EXAMPLE, NASA OFFICIALS TOLD US THAT THE SEALS BETWEEN THE NOZZLE AND MOTOR CASE HAD EXPERIENCED MORE EROSION ON PAST FLIGHTS THAN THE CASE JOINT O-RINGS. THESE SEALS ARE ALSO BEING REDESIGNED.

NASA OFFICIALS SAID THAT THEIR BASIC APPROACH TO THE REDESIGN EFFORT IS TO HOLD THIOKOL CONTRACTUALLY RESPONSIBLE FOR FIXING THE DEFECTS IN THE MOTOR DESIGN, AND THIOKOL HAS ESTABLISHED A REDESIGN TEAM TO ACCOMPLISH THIS EFFORT. TO ENSURE A BACKUP DESIGN AND TO ENABLE THE AGENCY TO ADEQUATELY ASSESS THIOKOL'S REDESIGN PROPOSALS, NASA ALSO ESTABLISHED AN IN-HOUSE REDESIGN TEAM AT MARSHALL SPACE FLIGHT CENTER. THE TWO TEAMS ARE WORKING INDEPENDENTLY BUT IN PARALLEL. NASA DID NOT INITIALLY PLAN TO SOLICIT REDESIGN PROPOSALS FROM OTHER MAJOR SOLID MOTOR MANUFACTURERS.

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**Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement**

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ACCORDING TO NASA OFFICIALS, THIS APPROACH WOULD ENABLE THE AGENCY TO RESUME SAFE FLIGHT AT THE EARLIEST POSSIBLE TIME AND TO MAKE MAXIMUM USE OF HARDWARE ALREADY PRODUCED. THE OFFICIALS TOLD US THAT THEY RECOGNIZED THIS APPROACH WOULD NOT NECESSARILY COMPLY WITH THE PRESIDENTIAL COMMISSION RECOMMENDATION SINCE THAT APPROACH DID NOT ADDRESS ALL POTENTIAL REDESIGN ALTERNATIVES.

AT THE COMPLETION OF OUR FIELD WORK, NASA STILL HAD NOT FORMALLY SOLICITED INDUSTRY PROPOSALS FOR THE REDESIGN ALTHOUGH WE UNDERSTAND THAT THE AGENCY HAS RECENTLY INVITED OTHER MOTOR MANUFACTURERS TO SUBMIT THEIR IDEAS. IN APRIL 1986, ONE SOURCE SUBMITTED AN UNSOLICITED PROPOSAL FOR AN ALTERNATE DESIGN FOR THE SRM, BUT NASA WAS NOT EVALUATING THE TECHNICAL MERITS OF THIS PROPOSAL PENDING A REASSESSMENT OF PLANS FOR FUTURE SRM PROCUREMENT.

THE DIRECTOR OF MARSHALL SPACE FLIGHT CENTER'S REDESIGN TEAM ASKED OTHER MOTOR MANUFACTURERS TO PROVIDE INFORMATION ON THEIR EXISTING CASE JOINT AND SEAL DESIGNS. IN ADDITION, THIS OFFICIAL ESTABLISHED AN ADVISORY TEAM COMPRISED OF INDUSTRY AND OTHER GOVERNMENT OFFICIALS TO PROVIDE ADVICE ON THE REDESIGN EFFORT. THE CENTER'S TEAM DIRECTOR TOLD US, HOWEVER, THAT THIS ADVISORY GROUP DID NOT INCLUDE OFFICIALS OF THE OTHER MAJOR MOTOR MANUFACTURERS BECAUSE OF THIOKOL'S RELUCTANCE TO HAVE THEIR POTENTIAL COMPETITORS INVOLVED IN THE REDESIGN EFFORT.

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Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

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AT THE RECOMMENDATION OF THE PRESIDENTIAL COMMISSION, NASA ALSO CHARTERED THE NATIONAL RESEARCH COUNCIL TO PROVIDE AN INDEPENDENT REVIEW AND OVERSIGHT OF THE REDESIGN PROCESS. THE FIRST MEETING OF THE RESEARCH COUNCIL PANEL WAS HELD ON JUNE 20, 1986. WE WERE ADVISED THAT THE PANEL IS VERY SENSITIVE TO THE PRESIDENTIAL COMMISSION'S RECOMMENDATION THAT NO REDESIGN OPTIONS BE PRECLUDED. ACCORDINGLY, THE PANEL MET ON JULY 7 AND 8 WITH REPRESENTATIVES FROM THREE OF THE COMPANIES INVOLVED WITH THE SECOND SOURCE INITIATIVE. THE PURPOSE OF THIS MEETING WAS TO OBTAIN OPINIONS AND ALTERNATIVES FOR THE SRM JOINT REDESIGN.

BEFORE THE CHALLENGER ACCIDENT, NASA WAS CONSIDERING SOME OTHER CHANGES TO THE MOTOR DESIGN. FOR EXAMPLE, THE MOTOR CASE LINERS AND INSULATORS IN THE CURRENT DESIGN ARE MADE FROM ASBESTOS. BECAUSE OF THE HEALTH HAZARDS OF USING ASBESTOS IN THE MANUFACTURING PROCESS, THE AGENCY WAS STUDYING POSSIBLE CHANGES IN THE INSULATOR AND LINER MATERIALS. ALTHOUGH RECOGNIZING THAT THE CASE LINERS AND INSULATION WILL LIKELY HAVE TO BE REDESIGNED IN THE NEAR FUTURE, NASA OFFICIALS TOLD US THAT THIS CHANGE IS NOT BEING PURSUED IN THE CURRENT REDESIGN EFFORT.

Competition planning

FOLLOWING THE CHALLENGER ACCIDENT, NASA OFFICIALS DEFINED ALTERNATIVE APPROACHES FOR DEALING WITH THE ISSUE OF MULTIPLE SRM SOURCES. THEY WERE

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Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

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--TERMINATE THE SECOND SOURCE INITIATIVE IMMEDIATELY  
WITH NO FURTHER PLANNED FUTURE ACTION;

--CONTINUE THE SECOND SOURCE INITIATIVE USING EITHER  
THE GROUND-RULES ESTABLISHED EARLIER OR CHANGING SOME OR  
ALL OF THE CONDITIONS AND GROUND-RULES;

--POSTPONE A DECISION ON THE SECOND SOURCE INITIATIVE  
UNTIL AFTER THE SRM SEAL AND JOINT REDESIGN IS QUALIFIED  
AND CERTIFIED, AND THEN RESUME THE INITIATIVE USING EITHER  
THE GROUND-RULES ESTABLISHED EARLIER OR CHANGING SOME OR  
ALL OF THE GROUND-RULES; OR

--TERMINATE THE CURRENT INITIATIVE BUT AWARD STUDY  
CONTRACTS FOR ANOTHER, MORE BASIC REDESIGN OF THE MOTOR  
(REFERRED TO AS A BLOCK II MOTOR).

INHERENT IN ALL OF THE OPTIONS WOULD BE FIXING THE CURRENT JOINT  
AND SEAL DESIGN DEFICIENCY AND RESUMING SRM PRODUCTION BY THIOKOL  
BUT AT A LOWER PRODUCTION RATE THAN ORIGINALLY PLANNED.

IN ACTING ON NASA'S FISCAL YEAR 1986 URGENT SUPPLEMENTAL  
APPROPRIATION, THE CONGRESSIONAL CONFERENCE COMMITTEE, IN JUNE  
1986, DIRECTED THAT NASA MAKE AVAILABLE SUFFICIENT FUNDS TO STUDY  
AN ALTERNATIVE SOLID ROCKET BOOSTER DESIGN SUCH AS ONE USING A  
UNITARY CASE OR SINGLE CAST PROPELLANT. THE STUDIES ARE TO BE



Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

COMPLETED BY DECEMBER 31, 1986, AND RESULTS FORWARDED TO THE COMMITTEES ON APPROPRIATIONS. THE CONFERENCE COMMITTEE FURTHER DIRECTED THAT WHEN A FINAL DESIGN IS SELECTED, NASA ISSUE A REQUEST FOR PROPOSAL FOR A "SECOND SOURCE" IF THE AGENCY DETERMINES THAT SUCH AN APPROACH CAN BE ADOPTED WITH AVAILABLE RESOURCES.

AT THE COMPLETION OF OUR FIELD WORK, NASA INFORMED US THAT THEY PLANNED TO PROCEED WITH A COMMERCE BUSINESS DAILY ANNOUNCEMENT SOLICITING CONCEPTS FOR A "BLOCK II SRM." ACCORDING TO A MEMORANDUM FROM NASA'S ASSOCIATE ADMINISTRATOR FOR SPACE FLIGHT DATED JULY 18, 1986, THE BLOCK II DESIGN CHANGES SHOULD INCLUDE ELIMINATION OF ASBESTOS FILLED INSULATION AND COULD INCLUDE OTHER CHANGES SUCH AS ALTERNATE CASE AND PROPELLANT DESIGNS.

THE ONLY DESIGN LIMITATION WOULD BE THAT THE OUTSIDE GEOMETRY OF THE MOTOR SHOULD NOT AFFECT THE INTERFACES WITH OTHER SHUTTLE ELEMENTS NOR ALTER THE AERODYNAMIC AND DYNAMIC CHARACTERISTICS OF THE SHUTTLE VEHICLE. NASA EXPECTS THE CONCEPTUAL STUDIES TO BE COMPLETED BY MID-DECEMBER 1986. THE AGENCY INDICATED THAT, AT THAT TIME, IT WILL ALSO DETERMINE WHAT SECOND SOURCE APPROACH CAN BE TAKEN WITHIN AVAILABLE RESOURCES.

GAO assessment

WE BELIEVE THAT THIS IS A REASONABLE APPROACH. ONCE THE DESIGN IS SELECTED, HOWEVER, WE BELIEVE THAT NASA SHOULD PREPARE A COMPREHENSIVE, LONG-TERM ACQUISITION STRATEGY AND PLAN FOR MOTOR PRODUCTION. THE PLAN SHOULD ADDRESS THE AGENCY'S DECISION ABOUT UPGRADING THE MOTOR DESIGN, ALTERNATIVES FOR ESTABLISHING AND MAINTAINING COMPETITION IN FUTURE PROCUREMENTS, AND THE COSTS AND BENEFITS OF EACH ALTERNATIVE.

QUALITY ASSURANCE AND SAFETY

AT MORTON THIOKOL PLANT

THE BASIC RESPONSIBILITY FOR QUALITY ASSURANCE AND MANUFACTURING SAFETY RESTS WITH THE CONTRACTOR. THIOKOL HAS ESTABLISHED ELABORATE SYSTEMS OF QUALITY AND SAFETY CONTROLS AT ITS WASATCH, UTAH, PLANT. NASA APPROVED THIOKOL'S QUALITY ASSURANCE AND SAFETY PLANS. NASA HAS DELEGATED AUTHORITY FOR OVERSEEING THE CONTRACTOR'S QUALITY ASSURANCE TO THE AIR FORCE'S PLANT REPRESENTATIVE AT THE THIOKOL FACILITY.

WHILE WE DID NOT MAKE AN INDEPTH REVIEW OF QUALITY CONTROL AND SAFETY ISSUES AT THIOKOL, DOCUMENTS AVAILABLE TO US INDICATE SIGNIFICANT AND POTENTIALLY SERIOUS PROBLEMS. FURTHER, THESE DOCUMENTS INDICATE THAT NEITHER THE CONTRACTOR NOR THE GOVERNMENT WAS GIVING THE PROBLEMS THE MANAGEMENT ATTENTION THEY DESERVED.

WHEN THE GOVERNMENT BECOMES DEPENDENT ON A SOLE SOURCE OF SUPPLY FOR A CRITICAL SUBSYSTEM ON A LARGE AND LONG TERM PROGRAM SUCH AS THE SHUTTLE, THE CONTRACTOR MAY NOT HAVE THE INCENTIVE TO IDENTIFY AND CORRECT PROBLEMS IN AREAS SUCH AS QUALITY CONTROL AND SAFETY. THE GOVERNMENT DOES NOT HAVE MAXIMUM LEVERAGE TO ENSURE CORRECTION OF PROBLEMS. THE CHANCE OF WINNING A GOVERNMENT CONTRACT OR THE THREAT OF LOSING IT PROVIDES A KEY INCENTIVE FOR GREATER EFFICIENCY AND EFFECTIVENESS.

Quality Control Problems

IN THE FALL OF 1984, MARSHALL SPACE FLIGHT CENTER PERSONNEL CONDUCTED ITS ANNUAL RELIABILITY AND QUALITY ASSURANCE SURVEY AT THIOKOL. THE SURVEY TEAM IDENTIFIED 23 DISCREPANCIES AND 12 OBSERVATIONS, MORE THAN IN ANY OF THE THREE PREVIOUS YEARS.<sup>2</sup> SEVENTY PERCENT, OR 15, OF THE DISCREPANCIES HAD BEEN REPORTED IN AT LEAST ONE OF THE THREE PRIOR YEARS' SURVEYS. THE SURVEY REPORT ALSO NOTED THAT MANY OF THESE PROBLEMS HAD ALREADY BEEN IDENTIFIED BY THIOKOL'S OWN QUALITY ASSURANCE AUDIT PERSONNEL BUT THAT CORRECTIVE ACTION EITHER HAD NOT BEEN TAKEN OR WAS INEFFECTIVE.

<sup>2</sup>A discrepancy is a deficiency which violates provisions of the contract. An observation is an irregularity not specifically controlled by the contract but the correction of which would improve reliability and quality assurance.

Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

NO QUALITY CONTROL SYSTEM IS PERFECT. MARSHALL SPACE FLIGHT CENTER OFFICIALS ADVISED US THAT NO STANDARDS EXIST FOR DETERMINING THE EXPECTED NUMBER OF DEFICIENCIES IN A CONTRACTOR'S QUALITY CONTROL SYSTEM. THEY SUGGESTED THAT A REVIEW OF OTHER CONTRACTORS' SYSTEMS MIGHT REVEAL SIMILAR DEFICIENCIES. IT IS IMPORTANT TO REMEMBER, HOWEVER, THAT THE SRMs WERE BUILT FOR USE ON A MANNED VEHICLE AND A STANDARD OF EXCELLENCE IN QUALITY CONTROL IS ESSENTIAL.

SOME OF THE DISCREPANCIES IDENTIFIED IN THE 1984 SURVEY HAD POTENTIALLY SERIOUS CONSEQUENCES. FOR EXAMPLE, THE SURVEY TEAM FOUND THAT MOTOR NOZZLE COMPONENTS WHICH HAD BEEN DETERMINED TO BE UNACCEPTABLE FOR FLIGHT HAD NOT BEEN TAGGED AS SCRAP. THE FAILURE TO TAG THE COMPONENTS INCREASED THE CHANCES THAT THEY COULD HAVE BEEN RETURNED TO THE MANUFACTURING PROCESS AND USED ON A FLIGHT MOTOR.

IN ANOTHER INSTANCE, THE SURVEY TEAM FOUND THAT MATERIAL WHOSE SHELF LIFE HAD EXPIRED WAS STORED IN THE SAME AREA AS ISSUABLE MATERIAL. IF THE EXPIRED MATERIAL HAD INADVERTENTLY BEEN ISSUED, THE CONSEQUENCES DURING FLIGHT COULD HAVE BEEN SERIOUS, ACCORDING TO A MARSHALL SPACE FLIGHT CENTER SOLID ROCKET QUALITY ASSURANCE SPECIALIST.

MARSHALL SPACE FLIGHT CENTER SURVEYED THIOKOL'S RELIABILITY AND QUALITY ASSURANCE PROCEDURES AGAIN IN 1985. THE TEAM

CONCLUDED THAT THE CONTRACTOR HAD MADE IMPROVEMENTS SINCE 1984. FOR EXAMPLE, ONLY THREE OF THE DISCREPANCIES FROM THE 1984 SURVEY WERE NOTED AGAIN IN 1985. STILL, THE TOTAL NUMBER OF DISCREPANCIES INCREASED FROM 23 IN 1984 TO 33 IN 1985. THE SURVEY TEAM ALSO NOTED A GENERIC PROBLEM: CONTRACTOR PERSONNEL SIMPLY WERE FAILING TO COMPLY WITH APPROVED PLANS AND PROCEDURES IN THE MANUFACTURING PROCESS. THE 1984 SURVEY REPORT HAD POINTED OUT THAT THE CONTRACTOR WAS SIGNIFICANTLY BEHIND SCHEDULE IN CONDUCTING "PROCESS AUDITS" TO DETERMINE IF ACTUAL MANUFACTURING OPERATIONS COMPLIED WITH WRITTEN PLANS, PROCEDURES, AND INSTRUCTIONS.

AS A PART OF THE INVESTIGATION OF THE CHALLENGER ACCIDENT, THE AIR FORCE PLANT REPRESENTATIVE'S OFFICE AND THIOKOL PERSONNEL JOINTLY REVIEWED THE CONTRACTOR'S QUALITY CONTROLS AS THEY RELATED TO THE SPECIFIC RIGHT HAND SRM WHICH CAUSED THE CHALLENGER ACCIDENT. THE REVIEW DID NOT UNCOVER ANY EVIDENCE THAT THE LACK OF ADEQUATE CONTROLS CONTRIBUTED TO THE ACCIDENT, BUT IT IDENTIFIED 2,075 POSSIBLE QUALITY CONTROL PROBLEMS. BECAUSE OF TIME CONSTRAINTS, THE TEAM DID NOT RESOLVE ALL OF THE PROBLEMS AND SOME MAY NOT BE SIGNIFICANT ENOUGH TO WARRANT CORRECTIVE ACTION. HOWEVER, THE TEAM CONCLUDED THAT EACH OF THE PROBLEMS WARRANTED CONSIDERATION FOR CORRECTIVE ACTION OR IMPROVEMENTS IN THIOKOL'S AND ITS SUPPLIERS' SYSTEMS, PROCEDURES, AND PRACTICES. MARSHALL SPACE FLIGHT CENTER OFFICIALS INFORMED US THAT THE CONTRACTOR IS CURRENTLY STUDYING THE TEAM'S REPORT

AND PREPARING A CORRECTIVE ACTION PLAN. HOWEVER, AT THE CONCLUSION OF OUR FIELD WORK THE CONTRACTOR HAD NOT COMPLETED THIS REVIEW.

THE TEAM IDENTIFIED 76 POSSIBLE DEFICIENCIES IN THE GOVERNMENT INSPECTIONS OF THE MOTOR. FOR EXAMPLE, THE TEAM FOUND THREE OF SEVEN MANDATORY GOVERNMENT INSPECTIONS ON THE CRITICAL O-RINGS WHICH CAUSED THE CHALLENGER DISASTER WERE NOT CONDUCTED. THIOKOL HAD DELETED THE THREE GOVERNMENT INSPECTIONS FROM THE INSPECTION PLANS WITHOUT GOVERNMENT AUTHORIZATION. AS A RESULT, THIOKOL PERSONNEL DID NOT NOTIFY THE AIR FORCE'S PLANT REPRESENTATIVE THAT THE INSPECTIONS WERE SCHEDULED.

ONE OF THE INSPECTIONS DELETED WAS TO DETECT IMPERFECTIONS OR VOIDS SUCH AS BUBBLES IN THE O-RINGS. IN ADDITION TO THE GOVERNMENT INSPECTION, THIOKOL HAD ALSO DELETED ITS OWN INSPECTION OF THE O-RINGS FOR THESE KINDS OF DEFECTS. SUBSEQUENT INVESTIGATION CONVINCED NASA THAT IT WAS IMPROBABLE THAT A DEFECT IN THE O-RINGS PRIOR TO MOTOR ASSEMBLY CAUSED THE ACCIDENT. ACCORDING TO A MEMBER OF THE INVESTIGATION TEAM, SUCH DEFECTS HAVE THE POTENTIAL FOR CAUSING A MISSION FAILURE.

Safety problems

IN ADDITION TO THE NASA RELIABILITY AND QUALITY ASSURANCE SURVEYS, THE AIR FORCE CONTRACT MANAGEMENT DIVISION CONDUCTS

Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

PERIODIC REVIEW OF CONTRACTORS' MANAGEMENT SYSTEMS SUCH AS QUALITY ASSURANCE, SAFETY, PRODUCT INTEGRITY, AND ENGINEERING. THE 1984 REVIEW AT THE WASATCH MANUFACTURING FACILITY RATED THIOKOL'S OPERATIONS AS MARGINAL IN FIVE OF EIGHT AREAS. THE MARGINAL AREAS WERE PRODUCT INTEGRITY, QUALITY ASSURANCE, ENGINEERING, SUBCONTRACT MANAGEMENT, AND SAFETY.

THE CONTRACTOR OPERATIONS REVIEW TEAM CONCLUDED THAT THIOKOL DID NOT SATISFACTORILY ENFORCE ESTABLISHED SAFETY RULES AND REGULATIONS. ACCORDING TO THE REPORT, THIOKOL WAS UNABLE OR RELUCTANT TO IDENTIFY OR CORRECT EASILY RECOGNIZABLE SAFETY VIOLATIONS. MANY OF THE VIOLATIONS IDENTIFIED BY THE REVIEW TEAM HAD ALSO BEEN FOUND IN PREVIOUS REVIEWS BUT HAD NOT BEEN SATISFACTORILY CORRECTED.

IN MARCH 1984, THERE WAS A FIRE IN THE CASTING PIT AREA AT THE WASATCH FACILITY. THE FIRE DESTROYED OVER \$11 MILLION WORTH OF FACILITIES AND EQUIPMENT, INCLUDING ABOUT \$8.6 MILLION OF GOVERNMENT-OWNED PROPERTY. THE NASA TEAM WHICH INVESTIGATED THE FIRE PINPOINTED INADEQUATE SAFETY AND QUALITY CONTROL PROCEDURES AS CONTRIBUTING FACTORS. THE INVESTIGATION BOARD ALSO NOTED THAT EVEN THE EXISTING 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 FIXING SAFETY PROBLEMS.

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**Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement**

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BECAUSE OF ITS INCREASING CONCERNS ABOUT THIOKOL'S SAFETY RECORD, NASA, IN 1984, RECOMMENDED THAT THE CONTRACTOR DEVELOP A FORMAL ANALYSIS PROGRAM THAT WOULD SYSTEMATICALLY IDENTIFY AND TRACK ALL POTENTIAL SAFETY HAZARDS. THIOKOL RESPONDED TO THE RECOMMENDATION BY HIRING AN INDIVIDUAL TRAINED IN HAZARD ANALYSIS TECHNIQUES AND ESTABLISHED A BRANCH IN THEIR SAFETY OFFICE TO IMPLEMENT THE ANALYSIS PROGRAM. THIOKOL WAS TRAINING OTHER INDIVIDUALS, DEVELOPING PROCEDURES, AND PERFORMING INITIAL STUDIES WHEN, IN JUNE 1985, ANOTHER FIRE OCCURRED IN ITS PROPELLANT MIX HOUSE.

AS A RESULT OF NASA'S CONCERN ABOUT THE STATUS OF THE HAZARD ANALYSIS EFFORT, THE AGENCY DIRECTED THIOKOL TO OBTAIN CONTRACTUAL ASSISTANCE IN ANALYZING HAZARDS FOR THE MOST CRITICAL FACILITIES AND OPERATIONS. IN THE SPRING OF 1986, THIOKOL SELECTED FIVE CONTRACTORS TO PERFORM THE FIRST PHASE OF THIS ANALYSIS EFFORT. ONE OF THESE CONTRACTORS IS CURRENTLY ANALYZING THE REMAINING HAZARDOUS OPERATIONS. AFTER COMPLETION OF THIS ANALYSIS, THIOKOL PLANS A CONTINUING IN-HOUSE HAZARDS ANALYSIS PROGRAM. NASA IS CLOSELY MONITORING THE STATUS OF THIS PROGRAM AND CONSIDERS THIOKOL'S ACTIONS TO DATE TO BE RESPONSIVE TO THEIR CONCERNS.



Management action

THE NASA TEAM WHICH PERFORMED THE 1984 RELIABILITY AND QUALITY ASSURANCE SURVEY AT THIOKOL ATTRIBUTED THE LARGE NUMBER OF REPEAT DEFICIENCIES NOTED IN THAT SURVEY TO A LACK OF THIOKOL MANAGEMENT ATTENTION TO THE PROBLEMS AND A TENDENCY ON THE PART OF THE CONTRACTOR TO USE PARTS WHICH WERE MANUFACTURED BASED ON UNAPPROVED AND UNOFFICIAL EXTENSIONS OF ENGINEERING TOLERANCES.

THIOKOL'S CORRECTION OF QUALITY ASSURANCE AND SAFETY PROBLEMS HAS BEEN SLOW AND INCOMPLETE. FOR EXAMPLE, AS LATE AS MARCH 1986, THE AIR FORCE'S PLANT REPRESENTATIVE DESCRIBED THIOKOL'S IMPLEMENTATION OF ACTIONS TO CORRECT THE PROBLEMS NOTED IN NASA'S 1985 RELIABILITY AND QUALITY ASSURANCE SURVEY AS "DISMAL." ACCORDING TO THE PLANT REPRESENTATIVE, THERE APPEARED TO BE A BREAKDOWN BETWEEN THIOKOL'S PROMISE OF CORRECTIVE ACTION TO NASA AND COMMUNICATION OF THOSE ACTIONS TO THE CONTRACTOR PERSONNEL RESPONSIBLE FOR IMPLEMENTING THEM.

A MARSHALL SPACE FLIGHT CENTER OFFICIAL INFORMED US THAT AS OF JULY 8, 1986, ALL BUT 8 OF THE 52 FINDINGS FROM THE 1985 RELIABILITY AND QUALITY ASSURANCE SURVEY HAD BEEN CORRECTED AND THE CONTRACTOR HAD SUBMITTED A PLAN FOR THOSE EIGHT. MARSHALL'S QUALITY CONTROL PERSONNEL ARE ASSESSING THE CONTRACTOR'S PROPOSED ACTION PLAN FOR THE EIGHT FINDINGS.

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Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

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IN JUNE 1986, NASA AND THE AIR FORCE JOINTLY CONDUCTED A REVIEW OF OPERATIONS AT THE WASATCH PLANT. THE REVIEW RATED THIOKOL'S OPERATIONS SATISFACTORY IN ALL AREAS EXCEPT ENGINEERING AND SAFETY. THE REVIEW TEAM NOTED THAT SIGNIFICANT SAFETY PROBLEMS WHICH HAD BEEN PREVIOUSLY IDENTIFIED STILL EXISTED. ACCORDING TO THE DRAFT REVIEW REPORT, INADEQUATE ATTENTION HAD BEEN PAID TO EMPLOYEE COMPLIANCE WITH PROCEDURES FOR POTENTIALLY HAZARDOUS OPERATIONS. THE REVIEW TEAM ALSO NOTED THAT THIOKOL MANAGEMENT HAD NOT UNIFORMLY APPLIED THE DISCIPLINARY ACTION NEEDED TO ENSURE COMPLIANCE. FOR EXAMPLE, APPROPRIATE DISCIPLINARY ACTION WAS TAKEN BY THIOKOL SUPERVISORS IN ONLY 5 OF 50 INSTANCES OF NONCOMPLIANCE NOTED BY THE REVIEW TEAM. THE NATURE OF MANY SOLID ROCKET MOTOR MANUFACTURING OPERATIONS IS SUCH THAT PROCEDURAL COMPLIANCE IS VITAL TO AVOID INJURY OR DAMAGE.

BASED IN PART ON THE FINDINGS OF THE 1984 SURVEY TEAM REPORT, MARSHALL SAFETY AND QUALITY ASSURANCE PERSONNEL REQUESTED THE AIR FORCE'S PLANT REPRESENTATIVE TO ADD THREE QUALITY CONTROL ENGINEERS TO HIS STAFF. UP TO THIS TIME, THE PLANT REPRESENTATIVE'S STAFF INCLUDED ONLY ONE QUALITY CONTROL ENGINEER WHO HAD DEVOTED AN AVERAGE OF ONLY HALF OF HIS TIME TO THE SRM PROGRAM. IN ADDITION TO THE ENGINEER, THE PLANT REPRESENTATIVE'S STAFF INCLUDED ABOUT 34 QUALITY INSPECTORS DEVOTED ALMOST EXCLUSIVELY TO THE MOTOR PRODUCTION. ACCORDING TO MARSHALL QUALITY ASSURANCE PERSONNEL, HOWEVER, THESE INSPECTORS, WHO ARE

NOT TRAINED ENGINEERS, ARE NOT QUALIFIED TO MAKE THE ENGINEERING JUDGMENTS NECESSARY TO ENSURE THAT THE CONTRACTOR'S QUALITY ASSURANCE PROGRAM IS ADEQUATE AND IS BEING PROPERLY IMPLEMENTED.

CITING STAFFING CONSTRAINTS AND EXPRESSING THE BELIEF THAT ENGINEERS WERE NOT NEEDED, THE PLANT REPRESENTATIVE REJECTED MARSHALL'S REQUEST. AFTER REVIEWING THE PLANT REPRESENTATIVE'S RESPONSE, MARSHALL SAFETY AND RELIABILITY PERSONNEL DECIDED NOT TO PURSUE THE REQUEST FURTHER. FOLLOWING THE CHALLENGER ACCIDENT, HOWEVER, NASA RENEWED ITS EFFORTS TO PERSUADE THE PLANT REPRESENTATIVE TO HIRE QUALITY ENGINEERS. WE UNDERSTAND THAT NASA AND THE AIR FORCE REACHED A TENTATIVE AGREEMENT IN LATE JUNE TO PROVIDE THE ENGINEERS. HOWEVER, THE NUMBER AND TYPES OF PERSONNEL NEEDED HAVE NOT YET BEEN DETERMINED.

GAO assessment

NEITHER THIOKOL NOR THE GOVERNMENT HAS BEEN SUFFICIENTLY AGGRESSIVE IN RESOLVING SIGNIFICANT AND POTENTIALLY SERIOUS QUALITY CONTROL AND SAFETY PROBLEMS AT THE THIOKOL MOTOR MANUFACTURING FACILITY. THE PLANNED INCREASE IN QUALITY CONTROL ENGINEERS ON THE AIR FORCE PLANT REPRESENTATIVE'S STAFF MAY HELP. HOWEVER, THE DIFFICULTY HAS NOT BEEN ONE OF IDENTIFYING PROBLEMS BUT RATHER OF ASSURING THAT EFFECTIVE CORRECTIVE ACTIONS ARE TAKEN. THEREFORE, WE BELIEVE THAT THE MARSHALL SPACE FLIGHT CENTER SHOULD CONSIDER OTHER ACTIONS, INCLUDING POSSIBLE CONTRACT

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Appendix I  
Testimony on NASA's Shuttle Booster Rocket  
Motor Procurement

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INCENTIVES OR PENALTIES, NEEDED TO ASSURE ADEQUATE QUALITY CONTROL IN SRM MANUFACTURING.

RECOMMENDATIONS

WE BELIEVE NASA'S CURRENT APPROACH TO COMPETITION IS A REASONABLE ONE. HOWEVER, GIVEN ITS PREVIOUS DIFFICULTIES IN DEVELOPING A SECOND SOURCE, INCLUDING THE JANUARY 1986 GROUND-RULES WHICH MIGHT NOT HAVE FOSTERED COMPETITION, WE ARE RECOMMENDING THAT FOLLOWING THE REDESIGN DECISION THE NASA ADMINISTRATOR PREPARE, AND PROVIDE TO THE CONGRESS, A COMPREHENSIVE ACQUISITION STRATEGY AND PLAN FOR CONTINUED PROCUREMENT OF MOTORS. THIS PLAN SHOULD ADDRESS (1) THE AGENCY'S DECISION ABOUT UPGRADING THE MOTOR DESIGN, (2) ALTERNATIVES FOR ESTABLISHING AND MAINTAINING COMPETITION IN FUTURE PROCUREMENTS, AND (3) THE COSTS AND BENEFITS OF EACH ALTERNATIVE.

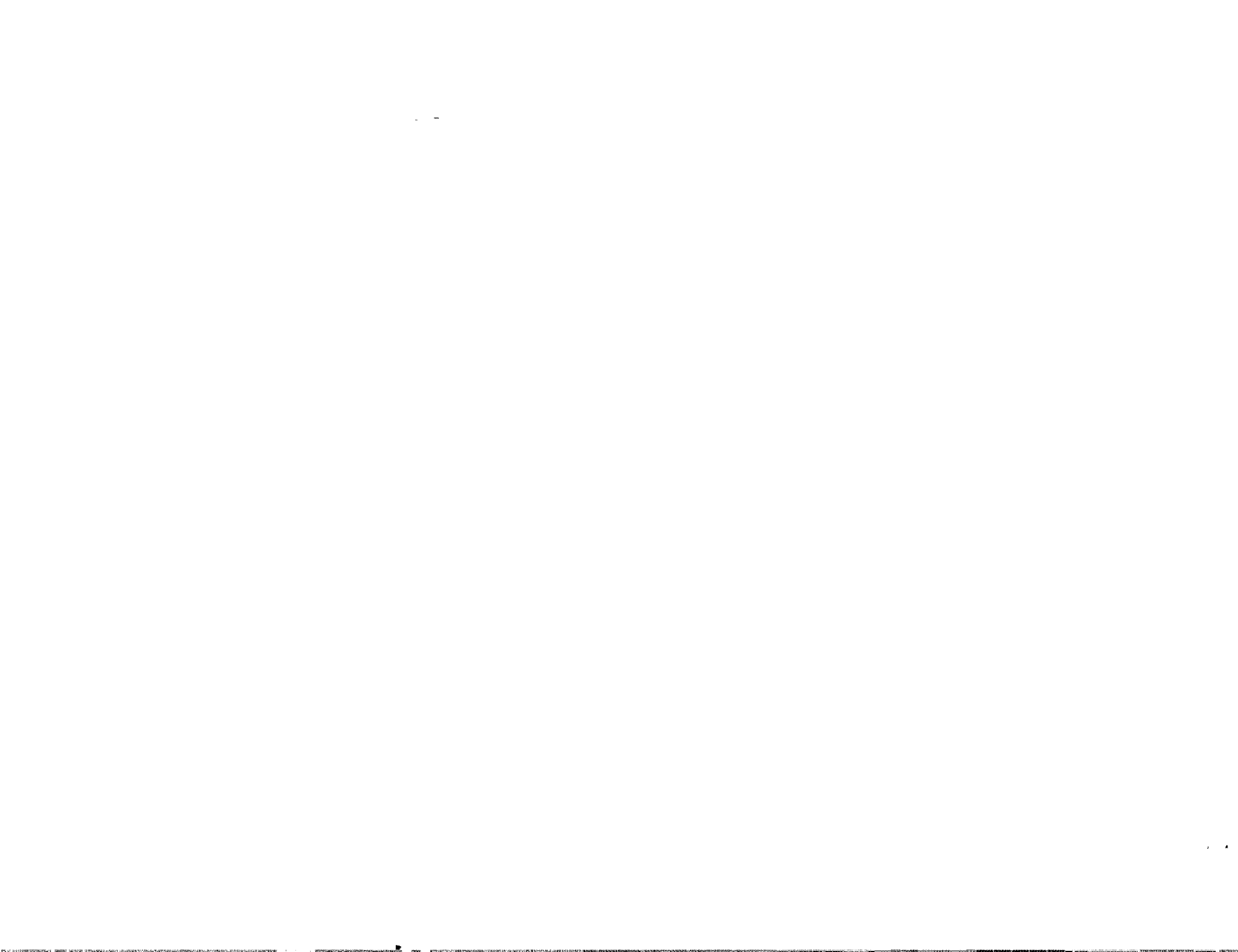
WE ARE FURTHER RECOMMENDING THAT BEFORE MOTOR PRODUCTION RESUMES THE ADMINISTRATOR AND THE SECRETARY OF THE AIR FORCE DETERMINE THE NUMBER AND TYPES OF GOVERNMENT PERSONNEL NEEDED TO ADEQUATELY ENSURE QUALITY CONTROL IN MOTOR MANUFACTURING OPERATIONS AND TO ACQUIRE THE NEEDED STAFF. ALSO, WE BELIEVE THAT, BEFORE RESUMING PRODUCTION, NASA SHOULD IDENTIFY ANY OTHER MECHANISMS, INCLUDING POSSIBLE CONTRACTUAL INCENTIVES OR PENALTIES, NEEDED TO ENSURE THAT THE CONTROLS ARE PROPERLY IMPLEMENTED AND ENFORCED.

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**Appendix I**  
**Testimony on NASA's Shuttle Booster Rocket**  
**Motor Procurement**

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MR. CHAIRMAN, THIS CONCLUDES MY FORMAL TESTIMONY. I WOULD  
BE PLEASED TO RESPOND TO ANY QUESTIONS YOU OR MEMBERS OF THE  
SUBCOMMITTEE MAY HAVE.



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