

August 1988

# SPACE SHUTTLE

## Changes to the Solid Rocket Motor Contract



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**National Security and  
International Affairs Division**

B-229005

August 5, 1988

The Honorable Bill Nelson  
The Honorable Robert G. Torricelli  
House of Representatives

In February 1987 you asked us to determine the extent to which the Space Shuttle solid rocket motor (SRM) contract was changed after a Presidential Commission concluded that the SRM caused the January 1986 Challenger accident (Space Shuttle mission 51-L). The National Aeronautics and Space Administration (NASA) and Morton Thiokol, Incorporated, signed a Memorandum of Understanding (MOU) in February 1987 outlining the principles under which they would renegotiate the contract. We reviewed the MOU and briefed your representatives on April 2, 1987. At that time, we agreed to delay our formal report until the parties completed negotiations and signed a contract modification. They signed the modification restructuring the contract on May 9, 1988.

The restructured contract included some significant changes as a result of the accident, and other contract changes are still being negotiated. The amount of work to be done increased significantly due to redesigning the motor joints, making other design changes to enhance the motor's safety and reliability, and incorporating the changes into 13 sets of motors.<sup>1</sup> The estimated contract costs increased by \$772.9 million, from \$594.1 million to \$1,367 million. After additional contract changes are negotiated, the costs are expected to increase even further to about \$1,816.6 million, according to an April 1988 Thiokol estimate.

Under the restructured contract, the maximum amount of available fee or profit increased from \$84.4 million to \$86 million, even after Thiokol voluntarily took a \$10 million fee reduction. Thiokol agreed to the fee reduction on the condition that NASA agreed not to formally conclude that the contractor was responsible or liable for the accident. After other changes are negotiated, the maximum fee will increase further to \$109.2 million, according to the April 1988 Thiokol estimate. In addition, the basis for determining the amount of fee to be paid was changed from specific cost and performance incentives to more subjective evaluations by NASA of Thiokol's performance in areas such as quality assurance, cost control, and project management.

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<sup>1</sup>There are two motors in each set.

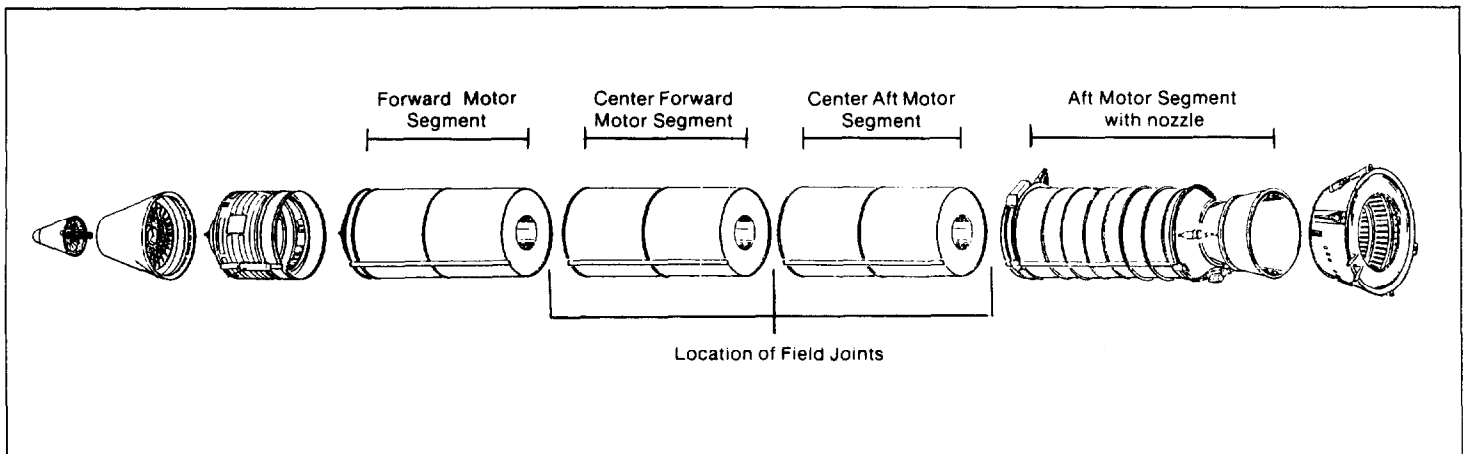
## Background

The SRM is the primary subsystem of the Space Shuttle's solid rocket booster. It is the largest U.S. solid rocket motor ever flown and the only one designed to be reused. Two SRMs 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 downrange, the SRMs exhaust their fuel. Explosives separate the boosters from the rest of the Shuttle. The boosters then fall into the ocean so they can be recovered. Once recovered, much of the hardware can be cleaned up and used again. For example, the steel motor cases may be used as many as 20 times.

Each SRM is fabricated and shipped to the Kennedy Space Center in four segments, as shown in figure 1. The four segments are "mated," or stacked together, at the launch site. The points at which the segments join are called field joints; each motor has three field joints.

**Figure 1: Solid Rocket Booster**



## Contract Status

In June 1974, NASA contracted with the Thiokol Chemical Corporation (now Morton Thiokol, Inc.) to develop, qualify, and produce the SRMs. NASA's Marshall Space Flight Center (MSFC) managed the contract. At the time of the Challenger accident, the contract consisted of four schedules; NASA considered each schedule to be a separate contract.<sup>2</sup> The work under Schedule A had an estimated value of about \$391.6 million and

<sup>2</sup>The contract values shown include both estimated cost and fee.

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included the development and qualification of the motor and manufacture of the first six sets of flight motors. The work under Schedule B was estimated at \$403.5 million and provided for the manufacture of nine motor sets. The work under these schedules was essentially complete in January 1986.

Schedule C provided for the development of a lighter-weight case to enhance the motor's lift capability for flights from Vandenberg Air Force Base, California, and was valued at about \$214.9 million. Schedule D included the manufacture of 23 motor sets and procurement of long-lead time hardware and materials for a future production buy and was valued at about \$626.6 million at the time of the accident.

NASA had accepted and flown 10 sets of SRMs under Schedule D, including the motor that caused the accident. Thiokol had also delivered or had in process additional motor segments equivalent to 6-1/2 motor sets.

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## Presidential Commission Findings

The Presidential Commission, which was established shortly after the accident to determine its cause, concluded that the accident had resulted from the failure of the pressure seal in one of the field joints of the SRM on the right side of the Shuttle. According to the Commission's June 1986 report, the failure was due to a faulty joint design that was unacceptably sensitive to a number of factors, such as temperature.

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## Settling the Claims

On February 4, 1986, before the cause of the accident was known, NASA ordered Thiokol to suspend motor production work to conserve resources. NASA and Thiokol had recognized the need to improve the motor field joint as well as the joint between the motor case and nozzle—the case-to-nozzle joint—even before the accident. Early reviews of the launch films and recorder data led NASA officials to conclude that the accident was probably caused by a failure in one of the motor joints, and in April 1986 the contractor submitted a plan for redesigning and testing the field joint and the case-to-nozzle joint. In May 1986 NASA issued a technical directive requiring the contractor to implement the redesign plan.

According to the Deputy Director of MSFC's Procurement Office, the use of a technical directive rather than a contract change order meant that NASA believed the original joint design did not meet contract specifications and should be corrected under the contract's "inspection and correction of defects" clause. Under this clause, the government could

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reimburse the cost of correcting the defective design but would not pay any additional fee for the redesign work.<sup>3</sup>

Thiokol considered that the redesign effort was outside the original contract scope and that a change order adjusting both the estimated cost and fee was needed to incorporate the redesign and recovery work into the contract. After numerous discussions, NASA and Thiokol representatives agreed to proceed with the technical directive and negotiate the cost and fee issues later.

NASA considered a number of possible rights or remedies under various provisions of the contract. These included (1) declaring that the defective joint design had caused a category I mission failure<sup>4</sup> and reducing Thiokol's fee by \$10 million under the contract's incentive fee provisions, (2) requiring Thiokol to redesign the motor joints at no additional fee, and (3) requiring Thiokol to replace, at no cost to the government, the hardware such as the boosters and/or the Shuttle orbiter, which were destroyed in the accident.

NASA also had to decide whether to assert the government's rights in litigation or to negotiate a settlement. At a minimum, NASA concluded it would have to show that the joint design did not meet contract specifications, according to an analysis by MSFC's Chief Counsel.

MSFC's Chief Counsel and the Manager of the Solid Rocket Booster Systems Management and Integration Office told us they believed that NASA could show that the joint design did not operate satisfactorily under all temperature conditions required by the contract specifications. However, the Chief Counsel recognized that Thiokol would likely assert that the temperature specifications were ambiguous or that NASA operated the motor outside the limits of the temperature requirements on the day of the accident. Thiokol might also claim that NASA had waived the specifications by accepting the Thiokol design. Even before the accident, NASA was both reimbursing costs and paying a fee for Thiokol to redesign the joint. Finally, Thiokol might assert that NASA had exercised economic duress to obtain Thiokol's recommendation to launch the Challenger on

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<sup>3</sup>The contract clause also provides that the government could require the contractor to correct the defect without reimbursing any cost if the contractor's failure to comply with specifications resulted from fraud, lack of good faith, or willful misconduct on the part of its directors, officers, managers, superintendents, or other equivalent representatives.

<sup>4</sup>A category I mission failure is one in which lives and/or the Shuttle vehicle are lost.

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January 28, 1986. At that time, NASA and Thiokol were negotiating the terms and conditions of another production contract.

NASA ultimately decided to pursue a negotiated settlement because of the uncertainty associated with litigation and the possible adverse impact of a protracted court action on the space program.

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## Memorandum of Understanding

In February 1987 NASA and Thiokol signed an MOU establishing the principles for the negotiated settlement. These principles were as follows:

- Thiokol would voluntarily take a \$10 million reduction in the contract fee, but NASA would not reach a formal conclusion as to Thiokol's responsibility or liability for the accident;
- NASA would reimburse costs and pay a fee for work performed before the accident under the original contract provisions;
- NASA would reimburse costs associated with the redesign and recovery effort but would not pay a fee for this work; and
- Thiokol would perform the work to complete the contract, including some NASA-directed safety and reliability enhancements in the motor nozzle, igniter, and system tunnel under a cost-plus-award fee arrangement.

Modification number 985 incorporated the MOU agreement into the contract on May 9, 1988. The modification restructured and continued the work under Schedule D. It requires Thiokol to complete delivery of the 13 remaining motor sets in the redesigned configuration, provide support for the next 13 Shuttle launches, and perform other studies and tasks as required.

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## Changes in Work Scope

The modification does not change the basic scope of Schedule D—the quantities of motors to be produced or the number of flights to be supported. However, it did increase the amount of work to be done, primarily due to

- redesigning and testing the motor field joint and case-to-nozzle joint;
- designing and testing changes in motor igniter, nozzle, and system tunnel to enhance SRM safety and reliability;
- incorporating the design changes into 13 motor flight sets;
- replacing manufacturing tooling as needed to produce the redesigned SRM; and
- providing increased support for the remaining 13 Shuttle flights.

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## Changes in Estimated Cost

The modification increased estimated costs for Schedule D by \$772.9 million, from \$594.1 million to \$1,367 million. The primary reasons for the increase were the cost of redesigning and testing the new motor joints and incorporating the design changes into the remaining 13 motor sets.

The \$1,367 million estimate includes \$415.6 million for work performed before the accident, \$505.1 million for the redesign and recovery effort, and \$446.3 million for the other NASA-directed design changes and completion of the contract.

The \$415.6 million estimate was based on information from Thiokol's accounting system as of January 26, 1986, 2 days before the accident. It primarily covers the cost of the motor sets and the support for the first 10 Shuttle flight sets in Schedule D.

The \$505.1 million estimate covers the costs of (1) designing and testing all case joints, including the case-to-nozzle joint, (2) investigating the accident, (3) retaining certain critical skills during the stop work period, (4) replacing the motor hardware, which was either destroyed by the accident, consumed in redesign testing, or made obsolete by the redesign, (5) modifying or replacing the production tools and test support equipment made obsolete by the redesign, and (6) reworking the 6-1/2 motor sets that were in process at the time of the accident.

The \$446.3 million estimate covers the costs of (1) manufacturing the remaining 6-1/2 motor sets, (2) refurbishing reusable hardware for 13 flight sets, (3) providing flight support for the next 13 Shuttle flights, (4) engineering and testing changes in the nozzle, igniter, and system tunnel designs, (5) purchasing some additional reusable hardware such as the redesigned case segments needed for the new joint, (6) acquiring long lead time hardware and materials for 16 motor sets to be procured in a follow-on contract, and (7) performing special studies.

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## Changes in Fee

Under the modification, Thiokol voluntarily agreed to accept a reduction of \$10 million from the fee earned on work before the accident. However, the maximum amount of fee available under the contract increased from about \$84.4 million to about \$86 million. The \$86 million fee for the restructured contract is the net of \$47.8 million for work completed before the accident, the \$10 million voluntary fee reduction, and \$48.2 million for completing the contract. No fee is to be paid for the redesign and recovery work.



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The \$47.8 million fee for work prior to 51-L included about \$38 million for the basic work, a fixed fee of \$0.5 million for the launch support effort, and incentive fees of \$9.3 million. The incentive fees included \$6.9 million for the contractor's share of a projected cost underrun and \$2.4 million for successful performance of the first 7 motor sets delivered under Schedule D.

The modification also changed the manner in which NASA determines the amount of fee to be paid for work subsequent to the accident. Schedule D was originally a cost-plus-incentive fee contract. The contract specified a target fee, but the target could be increased or decreased, within certain specified limits, based on Thiokol's performance in meeting specific goals—primarily controlling costs. If actual cost were less than the target established in the contract, Thiokol would retain 60 percent of the underrun, subject to a maximum fee limitation.<sup>5</sup> In addition, Thiokol's fee would increase by an additional 12.5 percent if all of the motors performed successfully.<sup>6</sup> The maximum fee that Thiokol could earn, including the incentives, was 15 percent of the total contract cost.

The restructured contract provides for more subjective determinations of the amount of fee to be earned by Thiokol. Under the restructured contract, NASA paid Thiokol a fixed fee of \$10.5 million for fee-bearing work performed between January 29, 1986, and October 31, 1987. In addition, NASA will pay a base fee of \$11.3 million in monthly installments based on the percentage of work completed, and an additional \$26.4 million will be available to be paid based on NASA's periodic evaluation of Thiokol's performance.<sup>7</sup>

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 of the motor sets. NASA will base the other half of the award fee on its evaluations of Thiokol's performance in more general areas such as cost control and

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<sup>5</sup>Similarly, the contractor's target fee could be reduced by up to 40 percent of any cost overrun.

<sup>6</sup>For incentive fee purposes the 23 flight motor sets were divided into three blocks of 7 or 8 motor sets each. The contractor would be entitled to a portion of the performance incentive when all of the motors within a block were successfully flown.

<sup>7</sup>The MOU specified that all fee-bearing work performed after January 28, 1986, would be on an award-fee basis. However, because NASA and Thiokol had not completed negotiations, including agreeing on an award fee plan, NASA paid a fixed fee for work from January 29, 1986, through October 31, 1987. The fixed fee of \$10.5 million was about 6.2 percent of the fee-bearing costs incurred during that period.

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quality assurance and reliability. The award fee plan has a "roll-forward" feature, which provides that, if Thiokol earns less than the full amount of fee available in any award period, NASA may carry forward half of the unearned fee and award it in a future period if warranted.

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.

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## Fines

You specifically asked us to identify any changes in contract terms and condition related to fines. There is no provision for NASA fining Thiokol for the accident.<sup>8</sup> Thiokol agreed to a voluntary fee reduction of \$10 million; in return NASA agreed not to formally conclude that Thiokol was responsible or liable for the accident.<sup>9</sup> In addition, the parties agreed that Thiokol would perform an estimated \$505 million worth of redesign and recovery effort at no additional fee.

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## Other Contract Changes

The \$1,367 million estimated cost for the modification covers the contract work scope as it was defined on December 31, 1986. Since then, NASA has issued 21 additional contract change orders. For example, in March 1987 NASA directed Thiokol to conduct a flight support motor test program. The test program will provide two full-scale SRM test firings each year beginning in 1989 to ensure the continued integrity of the motor design. NASA and Thiokol have not yet negotiated a price for these additional changes, but on April 20, 1988, Thiokol estimated the changes would increase contract costs by about \$450 million to \$1,816.6 million. Thiokol also estimated its fees would increase by about \$23.2 million to \$109.2 million as a result of the changes.

In a separate action, the Contracting Officer has determined that the incentive fee paid for the cost underrun before the accident should be

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<sup>8</sup>According to MSFC's Chief Counsel, the contract does not contain any provision under which NASA could "fine" the contractor; rather, it contains a negative incentive under which NASA could reduce Thiokol's fee by \$10 million for a category I mission failure provided that NASA could sustain that Thiokol's joint design did not meet contract specifications.

<sup>9</sup>According to NASA officials, NASA concluded that Thiokol was culpable, and it sustained that position throughout the negotiations; however, NASA was not required to implement its conclusion through the terms of the contract.

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reduced by \$1,054,007 due to defects in the original contract pricing. At the time of the accident, Thiokol had projected that it would underrun the contract's target cost by about \$18 million. Under the terms of contract, Thiokol would retain 60 percent of this underrun. Since the contract was about 65 percent complete at the time of the accident, the modification included an incentive fee of \$6.9 million for the cost underrun.

According to a January 1987 Defense Contract Audit Agency report, the \$18 million cost underrun forecast by Thiokol in January 1986 was partly due to defects in the original contract price. The audit concluded that Thiokol overstated the original price by about \$5.2 million because it submitted inaccurate, incomplete, or outdated pricing data. The Contracting Officer subsequently reviewed the audit report and Thiokol's response and concluded that Thiokol overstated the costs by only about \$2.2 million.

Since the cost underrun was partly due to an overstatement in the original contract price, NASA is entitled to recover a portion of the \$6.9 million incentive fee paid for the cost underrun. In March 1988 the Contracting Officer prepared a modification reducing Thiokol's fee by \$1,054,007 because of the defective pricing. However, at the completion of our review, Thiokol had not accepted the modification.

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## Objective, Scope, and Methodology

Our objective was to identify changes made in the terms and conditions of the SRM production contract as a result of the Challenger accident. We examined contract files, negotiating records, and correspondence. We also discussed the negotiations with officials of NASA's Solid Rocket Booster Project Office and MSFC's Procurement Office and Office of General Counsel. As requested, we did not obtain official agency comments on this report. However, we discussed the results of our work with officials responsible for the SRM program and contract, and we considered their comments as we prepared this report.

As arranged with your Offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 10 days after its issue date. At that time, we will send copies to the Chairmen, House Committee on Government Operations; Senate Committee on Governmental Affairs; House Committee on Science, Space, and Technology;

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Senate Committee on Commerce, Science, and Transportation; and House and Senate Committees on Appropriations. Copies will also be sent to the Administrator, NASA; the Director, Office of Management and Budget; and other interested parties.



Frank C. Conahan  
Assistant Comptroller General





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