

National Aeronautics and
Space Administration

Office of Inspector General
Washington, D.C. 20546-0001



Reply to Attn of: W

September 28, 2004

TO: MSFC/MP41/Manager, Solid Rocket Booster Project Office

FROM: Assistant Inspector General for Auditing

SUBJECT: Final Memorandum on Government Mandatory Inspections for Solid Rocket Booster Bolt Catchers
Assignment Number A-04-003-00
Number IG-04-024

The Office of Inspector General is reviewing NASA's plans for implementing the Columbia Accident Investigation Board (CAIB) recommendation to test and qualify flight hardware bolt catchers (Recommendation 4.2-1). The CAIB concluded that the bolt catchers on the Solid Rocket Booster (SRB) could not be definitively excluded or included as a potential cause of left wing damage to the Space Shuttle Columbia during STS-107. The CAIB investigation also identified problems with certification, quality assurance, and safety margins. Failure to fully implement the recommendation of the CAIB regarding the bolt catchers could prevent NASA from safely returning the Space Shuttle to flight.

Executive Summary

As part of our ongoing review, we are evaluating the Agency's quality assurance plans for the bolt catcher to determine whether those plans will ensure product compliance for the redesigned bolt catcher. To date, the SRB Project Office and its prime contractor, United Space Alliance (USA), have made significant progress toward redesigning, testing, and flight certifying a redesigned bolt catcher. However, our review of records for bolt catchers manufactured from 1995 through 1998 identified several deficiencies in addition to those identified by the CAIB.

We found that the Defense Contract Management Agency (DCMA) did not perform mandatory hardware inspections on bolt catchers used in Space Shuttle operations. Specifically, we found that DCMA Quality Assurance Representatives (QAR) either (a) removed the requirement for mandatory inspections without obtaining NASA's authorization or approval, or (b) gave final approval for manufactured bolt catchers although not all inspections required throughout the bolt catcher manufacturing process were performed. When inspections were performed, however, we found that DCMA

QARs were not always adequately trained to perform the types of inspections delegated. We also found that NASA relied entirely on DCMA to provide surveillance of bolt catcher manufacturing without the oversight that NASA regulations required.

Because of the flawed inspection process, DCMA should have rejected all of the bolt catchers manufactured from 1995 to 1998, including those used on Columbia during STS-107. We made recommendations to management to improve the redesigned bolt catcher quality assurance process as well as NASA oversight of functions delegated to DCMA. Management concurred with each recommendation and has either taken or planned responsive corrective actions.

Background

A total of four separation bolts connect each SRB to the External Tank. The bolts include three at the bottom and a larger one at the top. The larger bolt weighs approximately 65 pounds. About 2 minutes after launch, the firing of pyrotechnic charges breaks each forward separation bolt into two pieces, allowing each SRB to separate from the External Tank. The two bolt catchers on the External Tank each trap the upper half of a fired separation bolt, while the lower half of the bolt stays attached to the SRB. As a result, both halves are kept from flying free of the assembly and potentially hitting the Space Shuttle Orbiter. The two halves of the upper bolts and their respective catchers stay connected to the External Tank, which burns up on reentry, while the lower halves stay with the SRBs that are recovered from the ocean.

The CAIB's August 2003 report on the cause of the Columbia accident identifies problems with mandatory X-ray and inspection of welds. As a result of the CAIB recommendation to test and qualify the flight hardware bolt catchers, USA selected Summa Technologies (Summa), manufacturer of the bolt catchers that flew on Columbia, to produce the redesigned bolt catchers. USA also selected a second manufacturer, General Products, to produce the redesigned bolt catchers. Although it manufactures other Space Shuttle related items for USA as well as NASA, General Products did not previously produce bolt catchers. In order for both manufacturers to benefit from lessons learned, we focused our efforts on identifying and researching the causes for breakdowns in the quality assurance process for the previous bolt catchers.

NASA Procedural Requirements (NPR) 8735.2, "Management of Government Safety and Mission Assurance Surveillance Functions for NASA Contracts," dated August 15, 2000, states that issuance of a proper Letter of Delegation prevents confusion in the operations of delegated agency personnel and contributes to effective utilization of delegated agency and NASA personnel. Section 1.3.4 states that the NASA Safety and Mission Assurance (S&MA) Lead is the technical expert in the safety and mission assurance disciplines. Section 1.3.4 further states that the S&MA Lead is appointed by the Center to support the program or project manager and contracting officer in determining the appropriate level and type of safety and mission assurance surveillance applied to the program or project. The NASA S&MA Lead also monitors the performance and effectiveness of the safety and mission assurance surveillance over the course of the program or project.

In November 1996, NASA delegated the quality oversight for bolt catchers that Summa manufactured to the DCMA. The Letter of Delegation, issued approximately 1 year after Summa received the initial bolt catcher purchase order, required that DCMA (1) perform Government source inspections (commonly referred to as Government Mandatory Inspection Points [GMIPs]), (2) identify manufacturing deficiencies and necessary corrective actions, and (3) maintain official inspection records. For the Summa-manufactured bolt catchers, NASA originally required GMIPs for material certification, heat treatment, dye penetrant, weld X-ray, and final inspection. With respect to GMIPs, the contractor is responsible for notifying the DCMA QAR when mandatory inspection and approval is required. The DCMA QARs document that they have performed the mandatory inspections by stamping the inspection documents for each individual item (such as a bolt catcher) with the QARs unique stamp.

Quality Assurance Deficiencies Identified at Summa

We examined the inspection records that were available for the 60 bolt catchers Summa manufactured between November 1995 and September 1998 to determine if quality assurance problems existed in addition to those the CAIB identified. The bolt catchers that flew on Columbia during STS-107 were among the 60 Summa manufactured during that period. The inspection records DCMA provided were incomplete and in some instances had to be obtained from the contractor. Breakdowns occurred in the quality assurance and inspection process in addition to those the CAIB identified.

Unauthorized Removal of GMIPs. On at least 12 separate occasions, DCMA QARs removed from the bolt catcher inspection process without NASA's authorization or approval GMIPs that were required by the NASA Letter of Delegation. Specifically, DCMA QARs annotated inspection documents with the statement "no mandatory inspection required." The inspection documents did not indicate why the required inspections were removed. We also found no evidence that DCMA notified the NASA S&MA Office representative at the Marshall Space Flight Center (Marshall) (responsible for monitoring DCMA work) about why QARs removed the required GMIPs or why DCMA did not request approval to remove the GMIPs in accordance with NPR 8735.2. Further, the DCMA liaison at Marshall could not explain the actions of the QAR.

GMIPs Not Performed. Documentation DCMA provided showed that the QARs should have performed 258 GMIPs for the 60 bolt catchers Summa manufactured. The inspection records that were available showed that DCMA QARs documented performing only 99 (38 percent) of the 258 required inspections. Consequently, less than half of the required inspections were documented as performed. DCMA representatives did not agree with our summary of the inspections performed and stated that multiple inspections, for example, material certification, heat treatment, and X-ray, could have been performed and stamped (accepted) when a final inspection was completed. However, if performing multiple inspections during the final inspection was the norm, the supporting inspection records should have been annotated accordingly. We found no

evidence that supported the DCMA position. Further, from the records that were available, we could not identify any instances where DCMA notified NASA that the GMIPs were not performed.

GMIPs Performed by Either Untrained or Unqualified QARs. We found that for 99 of 258 required GMIPs DCMA performed, 77 (78 percent) were performed by QARs who lacked the necessary training or qualifications to perform the GMIPs. Based on our review of available training records for DCMA QARs assigned to the Summa facility, the required training the QARs most often lacked was a familiarization course on NASA inspection requirements. However, we also found that some of the QARs who performed inspections for critical processes such as dye penetrant, X-ray, and heat-treatment, lacked appropriate training and certification in those areas. Specifically, QARs who were either untrained or unqualified performed 37 critical mandatory inspections that included 21 X-ray, 13 dye penetrant, and 3 heat-treatment inspections.

Lack of Oversight Contributed to Problems

The quality assurance problems at Summa were the result of a lack of oversight by NASA and DCMA during the manufacturing and inspection process, a failure to impose Government source inspections until long after the manufacturing process began, and unclear inspection requirements. Our review of files at the Marshall S&MA Office for the bolt catchers Summa manufactured showed a lack of documentation and notification of inspection problems made to the office. Further, no evidence existed that the NASA SRB Project Office was alerted to the problems until the office and USA performed a joint process audit of Summa in March 2003. NASA also did not delegate the inspection requirements to DCMA for more than 1 year after Summa accepted the original purchase order to manufacture the bolt catchers.

NASA's Letter of Delegation to DCMA also did not contain the detail and level of inspection required by NPR 8735.2. (Although NPR 8735.2 was not in effect at the time NASA made this Letter of Delegation to DCMA, the guidance that was in effect, NASA Handbook 5300.4 [2B-2], "Management of Government Quality Assurance Functions for NASA Contracts," April 1993, contains identical provisions concerning Letters of Delegation.) For example, the CAIB report indicates that NASA believed its delegation for the bolt catchers called for an interpretation of the adequacy of welds based on analysis of the X-ray data. Conversely, DCMA believed the Letter of Delegation only required that the QARs ensure that Summa perform X-rays of the bolt catcher welds.

While the CAIB report addresses quality problems with Summa-manufactured bolt catchers (serial numbers 1 and 19), other significant problems existed with the quality assurance process which increased the risk that NASA accepted sub-standard bolt catchers. Because of the problems cited above, we believe that NASA did not receive the level of quality required or the assurance needed for the acceptance of this flight hardware. As a result, DCMA should have rejected all of the bolt catchers manufactured from 1995 to 1998, including those that flew on the Space Shuttle Columbia during STS-107. To avoid the quality assurance problems previously encountered, the

manufacturers of the redesigned bolt catchers should use the information in this memorandum as lessons learned. In coordination with the Marshall S&MA Office, the SRB Project Office should ensure that the appropriate quality assurance processes are in place for the redesigned SRB bolt catchers and that the end product complies with the requirements of the NASA Space Shuttle Program for safety and mission assurance.

Recommendations for Corrective Action:

The Manager, SRB Project Office, in coordination with the Marshall S&MA Office, should direct that initial quality assessments for critical processes for the redesigned bolt catchers ensure that:

1. DCMA Letters of Delegation for the redesigned bolt catchers provide detailed inspection requirements in accordance with NPR 8735.2.

Management's Response: Concur. The sub-delegation form within DCMA has been revised to ensure the requirements of NPR 8735.2 are met. Detailed inspection requirements were clearly defined in the sub-delegations and USA purchase orders. Sub-delegations and purchase order requirements were also formally communicated to and reviewed by DCMA. Actual incorporation of the GMIP into production work orders was verified during preproduction reviews at General Products but remains open relative to production at Summa.

Evaluation of Management's Response: The actions taken and planned by management are responsive to the intent of the recommendation. The recommendation is resolved but will remain undispositioned and open for reporting purposes until corrective actions have been completed.

2. The Marshall S&MA Office provides oversight for the bolt catchers in accordance with NPR 8735.2 for the quality surveillance delegated to DCMA to include ensuring inspections are performed as required and that DCMA QARs are trained and qualified.

Management's Response: Concur. A USA Product QAR was assigned full-time to provide oversight from qualification through first production hardware builds. DCMA will provide NASA oversight for all production builds and will report monthly to the Marshall S&MA Office on the actual required inspections performed. DCMA will retain inspection records and certify that the required procurement quality assurance actions have been accomplished and that the personnel performing the inspections are adequately trained and certified.

Evaluation of Management's Response: The actions taken and planned by management are responsive to the intent of the recommendation. The recommendation is resolved but will remain undispositioned and open for reporting purposes until corrective actions have been completed.

3. DCMA provide appropriate notification to the Marshall S&MA Lead for any inspection problems and maintain all required documentation to include inspection records in accordance with its Letter of Delegation.

Management's Response: Concur. DCMA shall provide notification of inspection problems with bi-weekly and monthly vendor reports to NASA S&MA. In addition, real-time reports, as needed, will be provided to the Marshall S&MA Office and prime contractor QAR.

Evaluation of Management's Response: The actions taken and planned by management are responsive to the intent of the recommendation. The recommendation is resolved but will remain undispositioned and open for reporting purposes until corrective actions have been completed.

[original signed by]

David M. Cushing

Enclosures

cc:

Administrator

Deputy Administrator

Associate Deputy Administrator for Systems Integration

General Counsel

Associate Administrator for Space Operations Mission Directorate

Chief of Safety and Mission Assurance

Director, Management Systems Division

JSC/AA/Director, Lyndon B. Johnson Space Center

JSC/MA/Manager, Space Shuttle Program

KSC/AA/Director, John F. Kennedy Space Center

MSFC/DA01/Director, Marshall Space Flight Center

MSFC/QS01/Manager, Safety and Mission Assurance

MSFC/RS40/Audit Liaison Representative

SSC/AA00/Director, John C. Stennis Space Center

Recommendation Status

Recommendation No.	Resolved	Unresolved	Open/ECD*	Closed
1	Yes		November 30, 2004	
2	Yes		November 30, 2004	
3	Yes		November 30, 2004	

*Estimated completion date.

Objectives, Scope, and Methodology

Objectives

The primary objective was to assist NASA in returning to flight by reviewing actions taken to address the CAIB recommendation to “test and flight qualify the flight hardware bolt catchers.” Specific objectives included (1) determining the adequacy of plans to redesign the bolt catchers to meet Agency requirements to include a safety factor of 1.4, (2) assessing whether NASA has designed a comprehensive certification and testing program for the bolt catchers, and (3) evaluating the Agency’s quality assurance plans and determining if they are adequate to ensure product compliance. This memorandum addresses concerns with the Agency’s quality assurance plans to ensure product compliance.

Scope and Methodology

We conducted interviews and discussions with key NASA and contractor personnel involved in implementing the CAIB’s bolt catcher recommendation. We participated in the Critical Design Review (CDR), Delta CDR, and Pre-Board Review teaming with NASA and contractor personnel on the Structures, Safety and Mission Assurance, and Systems teams. We reviewed Thermal Protection System test results, and observed multiple separation bolt firings. We also participated in a sub-tier contractor tabletop review and toured the sub-tier contractor’s manufacturing facility. While these events were ongoing, we obtained and reviewed contractor and Defense Contract Management Agency (DCMA) inspection records for bolt catchers manufactured and flown through the Columbia mission (STS-107). This step was critical in determining the causes for breakdowns in the quality process cited by the CAIB. Specifically, the CAIB stated “Inadequate oversight and confusion over the requirement on the parts of NASA, United Space Alliance (USA), and the DCMA all contributed to this problem.”

Management Controls Reviewed

An assessment of management controls was not part of the review objectives; however, we observed that all management levels are involved in NASA’s effort to address the CAIB’s recommendation related to the bolt catchers.

Review Work

We performed work for this review at the Marshall Space Flight Center, Kennedy Space Center, and contractor facilities in the Huntsville, Alabama area from October 2003 to May 2004 in accordance with generally accepted government auditing standards.

Management Response

National Aeronautics and
Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812



July 2, 2004

DE01

Reply to Attn of:

TO: NASA Headquarters
Attn: W/David M. Cushing

THRU: NASA Headquarters
M/William F. Readdy *WR*

FROM: DE01/Axel Roth

SUBJECT: OIG Draft Memorandum on Government Mandatory Inspections for Solid Rocket Booster (SRB) Bolt Catchers, Assignment Number A-04-003-00

We have reviewed the subject draft memorandum and our comments and responses to the memo's three recommendations are enclosed. Thank you for the outstanding collaborative effort exhibited by your staff during this review. We will continue to encourage independent participation from your organization on this matter until all open issues relating to the SRB Bolt Catchers have been resolved.

If you have any questions or need additional information regarding our comments, please contact RS40/Danny Walker at (256) 544-0100.

A handwritten signature in black ink, appearing to read "Axel Roth".

Axel Roth
Associate Director

Enclosure

cc:
HQ/M/Ms. Cywanowicz
HQ/W/Mr. Carson
HQ/Q/Brian Hughitt
MP01/Mr. Rudolphi
MP41/Mr. Martin
PS01/Mr. Beale
QD01/Dr. Davis
QD22/Ms. Moore-Hartley
MSFC/M-DI/Mr. Brickhouse

Mission Success Starts with Safety

Enclosure 3
(Page 1 of 4)

**MSFC Response to the OIG Draft Memorandum on Government Mandatory
Inspections for Solid Rocket Booster (SRB) Bolt Catchers,
Assignment Number A-04-003-00**

General Comments

The SRB Project Office efforts to redesign the bolt catcher and rectify certification, quality assurance and safety margin concerns cited within the Columbia Accident Investigation Board (CAIB) Report (recommendation 4.2-1) have been a collaborative effort with the Office of Inspector General (OIG). The OIG has participated in all redesign reviews to date (Project Requirements Review, Preliminary Design Review, and Critical Design Review), and has also spent time with the SRB Chief Engineer and lead designers associated with this project. They have also visited both of the bolt catcher manufacturers, the prime contractor's facilities and all of the major test sites. Their investigative efforts and expertise have led to insightful lessons learned and much improved and more robust process at the bolt catcher manufacturers (Summa and General Products). Consequently, they are cognizant of all progress leading to qualification of the new bolt catchers and we expect the OIG to continue to participate through bolt catcher delivery, providing independent oversight to assure that the new bolt catchers meet the requirements for a safe return to flight.

NASA and United Space Alliance (USA) have initiated extensive reviews and have incorporated significant oversight to assure production robustness of the newly designed bolt catchers. Corrective actions for problems cited during the previous production of bolt catchers have been implemented and NASA/USA is ready for flight hardware production at General Products (Summa readiness is pending successful completion of open actions).

The OIG review objectives were to: 1) Determine the adequacy of plans to redesign the bolt catchers to meet Agency requirements to include a safety factor of 1.4; 2) Assess whether NASA has designed a comprehensive certification and testing program for the bolt catchers; 3) Evaluate the Agency's quality assurance plans and determine if they are adequate to ensure product compliance. The technical community and the OIG are in agreement that a rigorous design review process for the bolt catchers has been completed and qualification testing and analyses is ongoing thus satisfying objectives 1 and 2. Objective 3 is associated with the quality assurance aspects of manufacturing the new bolt catchers and this is the area that the OIG found deficiencies. It should be noted that the deficiencies were found primarily at Summa.

Response to the Recommendations

OIG Recommendation 1

The Manager, SRB Project Office, in coordination with the Marshall Safety & Mission Assurance (S&MA) Office, should direct that initial quality assessments for critical processes for the redesigned bolt catchers ensure that DCMA Letters of Delegation for the redesigned bolt catchers provide detailed inspection requirements in accordance with NPR 8735.2.

MSFC Response

Concur. Letters of Delegation from the SFOC Contracting Officer to DCMA are further broken down into DCMA sub-delegations. The revised sub-delegation form within DCMA has been written (Enclosure 1) by MSFC and communicated with the DCMA, to ensure the requirements of NPR 8735.2 are met. Detailed inspection requirements have been clearly defined in the sub-delegations and United Space Alliance (USA) purchase orders. Sub-delegations and purchase order requirements have also been formally communicated to and reviewed by the DCMA. Actual Government Mandatory Inspection Points (GMIP) incorporation into production work orders has been verified during pre-production reviews at General Products. This item remains open relative to Summa production. Formal closure will be ascertained during the pre-production review that is required prior to granting Summa manufacturing authority. Additionally, within the new sub-delegations, it is stated that DCMA is only authorized to re-delegate this function upon notification and approval by the DCMA Prime KSC Quality Assurance Representative (QAR) Point-of-Contact (POC). The authority to change or modify the terms and conditions of the sub-delegation rests with the NASA SRB S&MA POC's.

Corrective Action Official:	MP41/David Martin
Corrective Action Closure Official:	DE01/MSFC Associate Director
Projected Closure Date:	November 30, 2004

OIG Recommendation 2

The Manager, SRB Project Office, in coordination with the Marshall S&MA Office, should direct that initial quality assessments for critical processes for the redesigned bolt catchers ensure that the Marshall S&MA Office provides oversight for the bolt catchers in accordance with NPR 8735.2 for the quality surveillance delegated to DCMA to include ensuring inspections are performed as required and that DCMA QARs are trained and qualified.

MSFC Response

Concur. USA Product QAR has been assigned on a full time basis to provide oversight through qualification and first production hardware builds. DCMA will provide NASA oversight for all production builds. DCMA will be providing monthly reports to MSFC S&MA delineating actual required inspections performed. Actual inspection records are

generated and retained indefinitely per USA purchase order requirements. DCMA will retain all inspection records and are required to sign the DD 1149 document stating all required procurement quality assurance actions have been accomplished. DCMA shall ensure its personnel are adequately trained and certified in technical requirements required by this procurement.

Corrective Action Official: MP41/David Martin
Corrective Action Closure Official: DE01/MSFC Associate Director
Projected Closure Date: November 30, 2004

OIG Recommendation 3

The Manager, SRB Project Office, in coordination with the Marshall S&MA Office, should direct that initial quality assessments for critical processes for the redesigned bolt catchers ensure that DCMA provide appropriate notification to the Marshall S&MA Lead for any inspection problems and maintain all required documentation to include inspection records in accordance with its Letter of Delegation.

MSFC Response

Concur. As required per the sub-delegation, DCMA shall provide notification of inspection problems with bi-weekly and monthly vendor reports to NASA S&MA. Additionally, real-time reports, as needed, will be provided to the MSFC S&MA Residence Office and prime contractor QAR. As stated above, inspection records shall be generated and retained indefinitely as required by the USA purchase order. SRB S&MA and Project personnel have worked diligently to address OIG findings as well as USA audit findings (USA Quality System/Hardware Process Audit, March 17, 2003). Enclosure 2 is a USA briefing dated April 5, 2004, provided to the OIG and SRB project officials regarding status of the March 17, 2003, audit. Enclosure 3 provides evidence of closure and the detailed actions taken for all the USA findings.

Corrective Action Official: MP41/David Martin
Corrective Action Closure Official: DE01/MSFC Associate Director
Projected Closure Date: November 30, 2004