National Aeronautics and
Space Administration

Office of Inspector General
Washington, DC 20546-0001

APR 28 2006

TO: Associate Administrator for Space Operations

FROM: Assistant Inspector General for Auditing

SUBJECT: Final Memorandum on the Review of Space Shuttle Cold Plates (Report No. IG-06-012; Assignment No. S-06-004)

The Office of Inspector General (OIG) has completed a review of Space Shuttle cold plates. The review was conducted in response to concerns expressed to this office that (1) Orbiter Vehicle 104 (OV-104) was approved for flight with a potentially damaged cold plate in the avionics cooling system, (2) damage to cold plates overall was excessive, and (3) damage to cold plates was not accurately reported in the Problem Reporting and Corrective Action (PRACA) system. (See Enclosure 1 for details on the review's scope and methodology.)

Executive Summary

We substantiated the concern that OV-104 was approved for one flight with a potentially damaged cold plate in the avionics cooling system. However, we recognize that acceptance of the additional risk associated with that approval was made at an appropriately high level. At the time the Space Shuttle Program (SSP) made the decision to approve the cold plate for the OV-104 mission, the actual damage to the cold plate was unknown. The SSP Program Requirements Control Board (PRCB) considered input from multiple sources concerning the cold plate and determined that the overall risk of flying with the potentially damaged cold plate was low and acceptable in light of the need for the OV-104 to be available for a rescue mission. Although the PRCB was willing to accept the risk for one mission, it was not willing to accept the cumulative effects of this same risk over multiple missions. As a result, the cold plate was removed and replaced in January 2006.

We partially substantiated the concern that damage to cold plates was excessive. We only partially substantiated the concern because we could not establish a comparative baseline to identify an "excessive" level of cold plate damage. However, we did determine that the number of cold plate problems reported in the PRACA system had increased from an average of 16.5 per year from 1990 through 2000 to 39.6 per year from 2001 through 2005. In his comments to the draft of this memorandum, the Associate Administrator for Space Operations stated that because of increased maintenance efforts and handling, the opportunity for cold plate damage to occur was significantly higher during the 2001 through 2005 timeframe. He stated that a more accurate method to

damage would be to determine the ratio between the number of cold plate problems reported and the number of opportunities to cause damage. We acknowledge that the ratio would provide a better indication of "excessive" damage. However, we believe that the increase in the raw number of problems was, at minimum, indicative of handling problems and that the corrective actions taken in response to our recommendations will reduce those overall numbers.

The third concern that damage to cold plates was not accurately reported in the PRACA system is being reviewed in conjunction with a separate OIG review, "Audit of the Space Shuttle Program Problem Reporting and Corrective Action Process at Kennedy Space Center" (A-05-024-00).

We recommended that the Space Shuttle Program (SSP) improve the accuracy of measuring cold plate damage by implementing an assessment method that is based on actual cold plate damage data. We also recommended that the SSP ensure that technician proficiency is improved through training and certification, and, lastly, that the Kennedy Space Center Safety and Mission Assurance (SMA) Office establish a Government mandatory inspection point for cold plates until the problems with cold plate damage are resolved. Although outside the scope of our review, we noted that the SSP had not established a plan to determine the number of cold plate spares needed through the end of the program. Accordingly, we recommended that the SSP develop an end-of-program plan to balance the need for spares against the acquisition of hardware that may become obsolete when the shuttle program ends.

Management's comments on a draft of this memorandum are responsive (see Enclosure 2). We have closed one recommendation and will close the other four upon completion and verification of management's corrective action.

Background

Cold plates dissipate heat from electronic components to ensure that the components do not overheat and stop working. Within the Space Shuttle orbiters, cold plates are used in the avionics compartments to protect the avionics boxes. Cold water or Freon is pumped through hollow chambers inside the cold plate and, through conduction, the heat is transferred from the electronic components to the cold plate. The heat is then transferred out of the cold plate through cooling loops to heat exchangers and radiators on the orbiter. The constantly circulating water or Freon through the cold plates allows the avionics boxes to remain in constant operation without overheating. If a single cold plate fails, the loss to the Shuttle cooling system would likely result in excessive heat buildup that would result in mission termination, as required by the SSP flight rules.[1]

Each cold plate is a precision-engineered component that is expensive, time-consuming to produce, and easily damaged. Each orbiter contains a set of 80 cold plates located in three different avionics compartments. Each complete set of 80 cold plates costs NASA

[1] National Space Transportation System 12820, "Space Shuttle Operational Flight Rules, All Flights," May 10, 2005.

approximately $29 million—an average cost per cold plate of $362,500. According to Boeing production schedules, it takes 4 months to produce a single cold plate. Cold plates are produced using aluminum or stainless steel and vary in size and shape depending on where they will be installed. The top and bottom layers of the cold plate, called the upper and lower face sheets, are very thin (22 thousandths and 17 thousandths of an inch, respectively). Because the face sheets are not much thicker than aluminum cans, the cold plates are very susceptible to damage.

Cold plates are engineered and manufactured by the Boeing Company. The space flight operations contractor, United Space Alliance (USA), is responsible for inspecting and replacing cold plates in the Shuttle orbiters. Overall cold plate planning, integration, and problem resolution is performed by the Active Thermal Control Systems (ATCS) problem resolution team, which includes team members from NASA, USA, and Boeing.

Potentially Damaged Cold Plate on OV-104

We substantiated the concern that OV-104 was approved for one flight with a potentially damaged cold plate in the avionics cooling system. However, we recognize that acceptance of the additional risk associated with that one flight approval was made at an appropriately high level. The PRCB considered input from multiple sources concerning the cold plate and was willing to accept the risk and approve the cold plate for one mission; it was not willing to accept the cumulative effects of this same risk over multiple missions. As a result, the cold plate was removed and replaced in January 2006.

Potential Damage. Potential damage to the cold plate[2] was identified through analysis and testing done by the ATCS problem resolution team. According to the team, the cold plate likely sustained damage during its original installation in the early 1980s. During that installation, a rubber O-ring, normally used as a gasket between the cooling system piping and the cold plate, was wedged between the cold plate and the shelf to which the cold plate was mounted. Kennedy Space Center technicians and engineers discovered the O-ring during maintenance operations on December 21, 2004. Engineers at the manufacturing facility conducted tests attempting to duplicate the damage to the cold plate. The test results indicated that the impression made by the O-ring could have damaged the bottom face sheet of the cold plate which, in a worst case scenario, could result in cold plate failure and risk successful accomplishment of the mission.

Engineers could not assess the actual damage without removing the cold plate, which could not be done without powering down OV-104. According to USA personnel, powering down and replacing the cold plate would take at least 10–14 days. According to USA documents and a USA briefing to the PRCB on April 15, 2005, the cold plate could not be removed and inspected and still meet OV-104's vehicle processing timeline. At that time, OV-104 was scheduled to be the standby rescue vehicle for the Space Transportation System (STS) 114 mission, originally scheduled for May 2005, and to fly the following Shuttle mission, STS-121, tentatively scheduled for later in 2005.

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[2] The specific cold plate was located in Avionics Bay 3A, part number V070-613213-001, serial number AW8170.

Because of the appearance of schedule pressure, we had initially addressed the decision to fly with the potentially damaged cold plate in a May 5, 2005, memorandum that accompanied the NASA OIG draft report, "Summary of the Office of Inspector General's Reviews on Aspects of NASA's Response to the Columbia Accident Investigation Board Report." In that memorandum, the Inspector General expressed concern that schedule pressure could be driving the decision not to replace the cold plate and requested that the Administrator revisit that decision. In response to the memorandum, the Associate Administrator for Space Operations stated that "there was no pressure to raise schedule above the safety and technical risk considerations in arriving at the final risk decision."

Flight Approval. The Space Shuttle Orbiter Project Office (OPO) based its recommendation to fly with the potentially damaged cold plate on analysis performed by the ATCS problem resolution team and an engineer independent of the ATCS. The OPO asked the ATCS problem resolution team to determine if there were viable alternatives to removing the cold plate that would not increase flight risk to an unacceptable level. If an alternative proved acceptable, it would allow processing to continue on OV-104 so that the STS-114 schedule could be maintained. The ATCS performed additional analysis of the potential cold plate damage and concluded that the cold plate would likely be acceptable for an additional flight, but not without increased risk. The ATCS was able to develop a single-flight alternative but continued to recommend to the OPO that the cold plate be removed and inspected prior to the next flight.

The OPO also asked a NASA strain analyst, independent of the ATCS problem resolution team, to review the analysis of the cold plate damage testing data and recommend whether the cold plate should be removed and inspected. That analyst concluded that the increased risk of flying with the potentially damaged cold plate was very low. Subsequently the OPO, based on that input and the ATCS input, recommended a "single-flight justification" to the PRCB, concluding that the risk of flying with the potentially damaged cold plate was acceptable. The PRCB, as the senior management decision authority for the SSP, considered all of the input concerning the cold plate and determined that the overall risk of flying with the potentially damaged cold plate was low and acceptable in light of the need for OV-104 to be available for a rescue mission. During the same meeting, the PRCB ruled out flying this cold plate for more than one mission. While the PRCB was willing to accept this low risk for one mission, it was not willing to accept the cumulative effects of this same risk over multiple missions.

Excessive Damage to Cold Plates

We partially substantiated the concern that damage to cold plates was excessive. We only partially substantiated the concern because we could not establish a comparative baseline to identify an "excessive" level of cold plate damage. However, we did determine that the number of cold plate problems reported in the PRACA system had increased from an average of 16.5 per year from 1990 through 2000 to 39.6 per year from 2001 through 2005. We did not attempt to substantiate that the increase or the original number of problems was excessive; however, we consider an increase of this magnitude to be material. We identified several factors that we believe could have contributed to the increased level of reported cold plate damage, including damage measurement and damage assessment methods, technician training, and Government quality inspections.

Damage Measurement Method. Testing and analysis performed by USA showed significant variability in the existing method of measuring cold plate damage. That method entails making mold impressions of the damage and reading those impressions to determine the dimensions of the damaged area. The mold impression process begins with a technician using mold material to create an inverse image of the actual damage on the cold plate (which is normally a dent, ding, or scratch). The mold material is pressed onto the cold plate over and around the damaged area and the technician applies light manual pressure to force the mold material into the scratch, dent, or ding. The mold impression is stereoscopically examined using an optical comparator[3] to determine the corresponding length, width, and depth of the actual cold plate damage. Because the optical comparator cannot directly read the height of the damaged area, which corresponds to the depth of the damage, the technician must manually identify the highest point of the damaged area and cut that area in half using a razor blade. The mold is then turned on its side and the now flat cross-section of the damaged area is measured. Because this method relies on the technician to identify the highest point of damage, any difference in judgment as to the high point will result in different depth measurements, which can be material when measuring by thousandths of an inch.

To better understand the variability of the mold impression process, USA performed a detailed study in which two technicians prepared and measured mold impressions of the same damage. The measurements made of the length and width of the damage did not vary between the two technicians; however, the measurements made of the depth of the damage varied by approximately 65 percent. Based on that large variance, USA concluded that the existing method for measuring the depth of damage using mold impressions does not provide an acceptable level of confidence and reliability necessary to assess actual cold plate damage. Because the depth measurement is key in deciding whether to use or scrap a cold plate, USA concluded, and we agree, that a more accurate and precise method to measure cold plate damage should be identified and used.

Damage Assessment Method. The method for predicting the degree of damage to a cold plate is not based on actual cold plate damage assessments but is instead based on the material properties of the aluminum and stainless steel used in manufacturing the cold plates. The method requires that engineers compute the amount of strain placed on the aluminum or stainless steel when the cold plate was damaged. The computation is based on the mold impression measurements of the cold plate damage and results in a strain value. That strain value is then compared to the maximum strain that the aluminum or stainless steel can withstand prior to breaking, which is 18 and 40 percent, respectively. Exceeding these levels of strain (18 or 40 percent) could result in a fracture to the material, which could affect the performance of the cold plate. Therefore, if the strain value of the cold plate damage equals or exceeds 18 or 40 percent, the cold plate will

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[3] An optical comparator is a tool similar in appearance to a microscope but is used to view much larger items under increased magnification.

likely be scrapped; if it is less than 18 or 40 percent, the cold plate will likely be repaired and placed back in service.

USA and the ATCS problem resolution team stated that using this method as the basis for the decision to scrap or use a cold plate may not be reasonable because it does not take into consideration all factors, such as the location of the damage, that might influence the degree of damage to the cold plate. In September 2004, the ATCS problem resolution team proposed a test that would determine the correlation between exceeding the maximum strain levels (18 and 40 percent) and actual cold plate damage. The test is critical in determining whether the material properties method of scrapping cold plates is reasonable. We reviewed the test plan and believe that the test would improve the SSP's ability to determine when a cold plate should be scrapped, repaired, or used in an "as-is" condition.

Technician Training. While USA provided awareness training to ensure technicians understood that cold plates can be easily damaged, it had not established task-specific training for cold plate installation and removal. In addition, not all technicians we interviewed were familiar with the processes or had used the tools required to assist in a cold plate and hardware component installation or removal. In addition to initial training, we believe that technicians also need refresher training as it is sometimes more than a year between the removal of a cold plate and its reinstallation. We believe the SSP should ensure that USA implements a training and certification program for cold plate technicians.

Government Quality Inspections. Kennedy SMA personnel do not monitor cold plate removal or installation because the Space Flight Operations Quality Planning Requirements Document (QPRD) does not require Government inspections for cold plate work. The QPRD identifies the mandatory inspection points for both NASA and USA. Those inspection points are generally identified and implemented based on SSP requirements or operational experience. The QPRD details minimum inspection requirements but states that additional inspections may be performed when necessary. For example, mandatory inspections can be added if repetitive problems have occurred or if there is a documented history of problems.

Our review of PRACA data found 379 PRACA reports that described at least one instance of cold plate damage from 1990 through December 7, 2005. Many of these reports noted multiple instances of damage in a single PRACA report. Analysis of this data showed a substantial increase in reports of cold plate damage beginning in 2001. From 1990 through 2000, there were 181 PRACA reports that included at least one instance of cold plate damage. From 2001 through 2005, there were 198 PRACA reports which noted at least one instance of cold plate damage. The annual average number of PRACA reports of cold plate damage went from 16.5 for 1990–2000 to 39.6 for 2001-2005. For example, between 2001 and 2003, 11 cold plates, valued at $2.79 million, were deemed so badly damaged as to be no longer usable and had to be scrapped. We believe the problems associated with cold plates are systemic and, in accordance with the QPRD, quality inspections should have been established within the cold plate maintenance processes. Requiring SMA personnel to observe the removal and installation process would allow them to determine and document whether cold plate damage was pre-existing or occurred during Shuttle processing at Kennedy Space Center. By establishing when, where, and how the cold plate damage occurred, SMA could improve its ability to prevent damage by addressing the root causes for the cold plate problems.

Acquisition Strategy for Cold Plate Spares

Although outside the scope of our review, we noted that the SSP had not established an end-of-program plan to balance flight hardware acquisition with diminishing flight hardware requirements. As the end of the SSP approaches, it will be necessary to balance the critical requirement for flight spares against acquiring hardware that could become obsolete. A written plan that contains critical data and assumptions, such as the number of Shuttle flights through 2010 and manufacturing times required for individual cold plates, would assist in identifying the number of cold plates needed through the end of the Shuttle Program. Such a plan would also help ensure the best use of SSP funds in acquiring this critical flight hardware.

Management Comments on the Finding and OIG Response

Management Comments. The Associate Administrator for Space Operations took exception to our conclusion that the concern regarding excessive cold plate damage was partially substantiated by the raw number comparisons of problem reports between the timeframes of 1990 through 2000 and 2001 through 2005. He stated that cold plates are damaged primarily during the installation and removal of the electronic components that sit on top of the cold plates. From 2001 through 2005, three orbiters were subjected to the maintenance and modification process, which increased the opportunity for cold plate damage because the electronic components are removed and reinstalled as part of that process. The Associate Administrator stated that a more accurate method to determine whether cold plate damage was excessive would be to use the ratio between the number of cold plate problems reported and the number of opportunities to cause damage (those opportunities being greater during maintenance and modification).

OIG Response. We acknowledge that using a ratio would provide a better indication of excessive damage. However, we stated that we could not make an absolute determination that damage was excessive because we could not establish a comparative baseline to measure against. We still believe that the increase in the raw number of problems was, at minimum, indicative of handling problems and that the corrective actions taken in response to our recommendations will reduce those overall numbers.

Recommendations, Management's Response, and Evaluation of Management's Response

Recommendation 1. We recommended that the Manager, Space Shuttle Program, develop an accurate method for measuring mold impressions that results in an acceptable level of variability when assessing cold plate damage.

Management's Response. The Associate Administrator for Space Operations concurred, stating that his office would use samples from cold plate testing currently in progress to develop processes for accurately reading mold impressions.

Evaluation of Management's Response. Management's planned action is responsive. The recommendation is resolved and will be closed upon completion and verification of management's corrective action.

Recommendation 2. We recommended that the Manager, Space Shuttle Program, conduct the cold plate test proposed by the ATCS problem resolution team and implement its findings.

Management's Response. The Associate Administrator concurred, stating that the test is in progress and that the test results would be used to evaluate future cold plate damage.

Evaluation of Management's Response. Management's planned action is responsive. The recommendation is resolved and will be closed upon completion and verification of management's corrective action.

Recommendation 3. We recommended that the Manager, Space Shuttle Program, verify that USA implements formal training and certification requirements to maintain technician proficiency in handling cold plate hardware.

Management's Response. The Associate Administrator concurred, stating that USA developed two cold plate training courses and two new certification programs for cold plate technicians. The training courses are required for personnel working in and around cold plates and provide instruction on how to protect cold plates during removal, installation, and repair. The two certification programs were created to ensure that personnel have been adequately trained and have had experience in performing cold plate operations. The first certification covers all methods for the installation and removal of cold plates. The second certification covers handling, repair, and replacement of cold plates.

Evaluation of Management's Response. Management's planned action is responsive. We requested a copy of the training courses and certification programs from the Shuttle Processing Office at Kennedy Space Center. As of the date of this memorandum, we had not received those documents and, therefore, could not close the recommendation. The recommendation is resolved but will remain open until we verify management's corrective action.

Recommendation 4. We recommended that the Manager, Space Shuttle Program, develop a cold plate acquisition strategy to ensure that sufficient cold plate spares are available to support the remaining life of the Space Shuttle fleet, balancing the critical requirement for flight spares against the unnecessary acquisition of hardware that could become obsolete.

Management's Response. The Associate Administrator concurred and included the acquisition plan details in his comments.

Evaluation of Management's Response. We reviewed the acquisition plan and believe it provides for an adequate number of cold plate spares through the end of the program. Management's actions are responsive, and the recommendation is closed.

Recommendation 5. We recommended that the Director, Kennedy Safety and Mission Assurance, establish a Government mandatory inspection point to witness and inspect cold plate work until such time as the cold plate process and the number of cold plate problems reported are stabilized.

Management's Response. The Associate Administrator concurred, stating that a temporary Government mandatory inspection point would be instituted to inspect the cold plate surfaces after removal and before the installation of electronic components. Data collected from the inspections will be analyzed and, if that analysis indicates that the process is under control, the temporary Government mandatory inspection point may be removed; if not, a permanent or extended inspection point may be considered.

Evaluation of Management's Response. Management's planned action is responsive. The recommendation is resolved and will be closed upon completion and verification of management's corrective action.

We appreciate the courtesies extended the audit staff during the review. If you have any questions, or need additional information, please contact Ms. Carol N. Gorman, Space Operations and Exploration Director, at 202-358-2562 or me at 202-358-2572.

Evelyn R. Klemstine

Evelyn R. Klemstine

2 Enclosures

cc:
Director, Johnson Space Center
  Manager, Space Shuttle Program (JSC/MA)
  Manager, Space Shuttle Safety and Mission Assurance Office (JSC/MX)
Director, Kennedy Space Center
  Director, Safety and Mission Assurance (KSC/SA)
Director, Management Systems Division

Scope and Methodology

We conducted this review from March 2005 through April 2006 in response to concerns received in March 2005 concerning SSP cold plates. The objective of our review was to determine whether the concerns could be substantiated.

We interviewed NASA SSP and SMA officials located at NASA Headquarters, Johnson Space Center, and Kennedy Space Center regarding the justification for OV-104's approval for flight in April 2005 and ongoing problems with cold plates on the orbiters. We also interviewed USA and Boeing personnel regarding the processes for inspecting, reporting, and correcting cold plate damage. We visited the cold plate manufacturing plant in Palmdale, California and the shuttle processing facilities at Kennedy Space Center.

We collected, reviewed, and analyzed documents dated from 1990 through 2006 related to cold plate manufacturing, processing, problem reporting, and testing. Specifically, we reviewed NASA and contractor policy and procedures related to reporting and resolving damage to cold plates, cold plate problem reports, NASA and contractor analyses related to damage assessment and testing methodologies, proposed cold plate test plans, and cold plate technician training requirements.

This review was conducted in accordance with the President's Council on Integrity and Efficiency, Quality Standards for Inspections.

Management's Comments

National Aeronautics and
Space Administration
Headquarters
Washington, DC 20546-0001

April 18, 2006

Reply to Attn of: Space Operations Mission Directorate

TO: Assistant Inspector General for Auditing

FROM: Associate Administrator for Space Operations

SUBJECT: Draft Memorandum on the Review of Space Shuttle Cold Plates (Assignment Number S-06-004)

We have reviewed the subject draft memorandum and thank you for the opportunity to provide comments. This response has been coordinated with the Kennedy Space Center (KSC) Office of Safety and Mission Assurance and Johnson Space Center, Space Shuttle Program Office. The consolidated Space Operations Mission Directorate (SOMD) comments and responses to the five recommendations are enclosed.

We concur with the Office Inspector General (OIG) that the decision to approve for one flight the potentially damaged OV-104 cold plate in Avionics Bay 3A was technically sound and approved at an appropriately high level. The Space Shuttle Orbiter Project Office (OPO) based its rationale to fly with this potentially damaged cold plate on the review of mold impression data and stress analysis results performed by the Active Thermal Control System (ATCS) problem resolution team (PRT). The Space Shuttle Program (SSP) Program Requirements Control Board (PRCB) weighed the recommendation from OPO and approved the rationale to fly for one mission. The Avionics Bay 3 cold plate was subsequently removed and replaced in January 2006.

We would also note that we have taken additional mitigation actions to minimize cold plate damage. We are providing these additional mitigation actions for your consideration to include in your memorandum. Protective covers have been fabricated to protect the cold plates while the line replaceable units (LRUs) are not installed. There will be three ship-sets available. Also, Engineering is conducting a pretask briefing prior to each LRU installation or removal. These briefings are to ensure that Shop, Quality, and Engineering personnel have reviewed the procedure and understand the instructions. Engineering will be present for all LRU installations.

We take exception to the premise that excessive cold plate damage is partially substantiated by the raw number comparison of Problem Reports (PRs) between the timeframes of 1990 through 2000 and 2001 through 2005. Cold plates are damaged primarily during the removal or installation of LRUs that are attached to cold plates. The damage typically consists of scratches and small dents to the face sheet. During the 2001 through 2005 timeframe three orbiters were subjected to Orbiter Maintenance Down Period (OMDP)/Orbiter Major Modification (OMM) processing requirements. Also, Orbiter Columbia, OV-102, LRUs were reinstalled at Kennedy Space Center (KSC) after its successful OMDP at Palmdale in 2001. During OMDP/OMM activities, LRUs are removed from the cold plates so structural inspections can be performed throughout the vehicle. Then the LRUs are reinstalled. Thus, during the 2001 through 2005 timeframe, the opportunity for damage to cold plates was significantly higher compared to the 1990 through 2000 timeframe when the fleet was flying regularly. We feel a more accurate method to determine if there is excessive cold plate damage should be the ratio between the numbers of PRs divided by the number of LRUs removed and reinstalled (number of opportunities to cause damage) and then compared between the two timeframes, not just a raw PR count.

We acknowledge the hard work and professionalism of the NASA OIG in this recent audit. We are always looking for opportunities to improve ourselves and our systems, and we appreciate the expertise and insights provided by the OIG on this matter. If you have any questions regarding these comments, please contact the Headquarters point of contact for this audit Mr. Jonathan Krezel on 202-358-1141.

William H. Gerstenmaier

Enclosure

cc:
Director, Johnson Space Center
  Manager, Space Shuttle Program (JSC/MA)
  Manager, Space Shuttle Safety and Mission Assurance Office (JSC/MX)
Director, Kennedy Space Center
  Director, Safety and Mission Assurance (KSC/SA)
Director, Management Systems Division
Space Operations Mission Directorate
  Space Shuttle/Mr. Hill
  /Mr. Krezel

Responses to
Office of Inspector General
Draft Memorandum No. S-06-004
Review of Space Shuttle Cold Plates

<u>Recommendations for Corrective Action</u>:

Recommendation 1. The Manager, Space Shuttle Program, should develop an accurate method for measuring mold impressions that results in an acceptable level of variability when assessing cold plate damage.

Response. Concur. Once the cold plate damage testing is completed (described in Recommendation 2 Response), test samples/standards from Boeing Huntington Beach will be used in developing the calibration methods and processes for mold impressions and the subsequent readings.

Action Required. The estimated completion date for the cold plate testing is April 24, 2006. United Space Alliance (USA) Ground Operations (GO) received the test samples/standards in early March 2006. USA GO quality and the PRT are developing calibration methods and processes to perform mold impressions and subsequent readings. Proof of completion of corrective action will be review of documentation of the calibration methods and processes.

Estimated Completion of Corrective Action – March 15, 2007
Estimated Closure Date – April 30, 2007

Recommendation 2. The Manager, Space Shuttle Program, should conduct the cold plate test proposed by the ATCS problem resolution team and implement its findings.

Response. Concur. The cold plate damage test plan was developed by the ATCS PRT with support from the Stress and Materials and Properties community. The test objective is to develop test verified criteria for use in the evaluation of damaged cold plates. The test consists of placing multiple damage sites of known depth and geometry on a flight-like spare cold plate. The test article will be subjected to pressure conditions that simulate the ground and flight operational environments. Leak checks will be performed at predetermined intervals up to the 40-mission test completion in order to determine the tolerance to induced damage.

Evaluation of cold plate damage with the updated criteria will begin immediately after test completion. The existing spare damaged cold plate inventory will be inspected and evaluated using the newly developed criteria. Those plates with acceptable damage will be returned to spares and added to the flight-ready inventory. Any future damage to the vehicle installed cold plates will also be evaluated using the new criteria developed from the test.

Actions Required. The test was put in work earlier this year and is currently in the mission simulation phase. As of March 15, 2006, 20 equivalent missions have been completed without failure. According to the present schedule, the mass spectrometer leak test for the fortieth and final mission will be performed on April 12, 2006. Proof and burst testing will follow, with an estimated completion date of April 24, 2006.

Estimated Completion of Corrective Action – May 15, 2006
Estimated Closure Date – June 30, 2006

Recommendation 3. The Manager, Space Shuttle Program, should verify that USA implements formal training and certification requirements to maintain technician proficiency in handling cold plate hardware.

Response. Concur. USA Tech Training and USA GO Engineering have created two new training courses to ensure that personnel have been adequately trained and have the experience to perform cold plate operations. The first is Cold Plate Familiarization (CS250USA). This class is a computer-based training format. This class is required for personnel working in and around cold plates. The primary focus is to provide education on the susceptibility of cold plates to damage, ensure that surface protection is in place, and prevent surface contact. The second one is Cold Plate Handling and Cold Plate Mounted LRU Removal and Replacement (MS319USA). This class provides instruction on the use of Ground Support Equipment and other methods for installing and removing cold plate mounted LRU or black boxes. This class also includes protection of the cold plates during handling, repair, and installation.

There are two new technician certifications created to ensure that personnel have been adequately trained and have had experience in performing cold plate operations. The first is Cold Plate Mounted LRU Removal/Replacement (Certification #1011). This certification covers all methods for the installation and removal of cold plate mounted LRUs. The second one is Cold Plate Handling (Certification #1012). This certification covers handling, repair, and removal and replacement of cold plates.

A limited set of personnel (29) was selected for acquisition of these certifications. These personnel were selected because of their experience in cold plate operations. The number of personnel targeted for the certification was also limited to ensure that proficiency would be maintained.

Actions Required. USA GO will be prepared to implement the required certifications for cold plate operations starting on April 3, 2006.

Request that this recommendation be closed on issuance of the final report.

Recommendation 4. The Manager, Space Shuttle Program, should develop a cold plate acquisition strategy to ensure that sufficient cold plate spares are available to support the remaining life of the Space Shuttle fleet, balancing the critical requirement for flight spares against the unnecessary acquisition of hardware that could become obsolete.

Response. Concur. The ATCS PRT and the Logistics support team have developed the following plan to address cold plate production and spares requirements that will support the current 2010 End-of-Program. The plan takes into account contingencies such as OV-104 going offline in 2008 and Palmdale cold plate production capability. The plan also allows for adjustment of future requirements based on the results of the ongoing cold plate damage testing (reference testing being performed in Recommendation 2 Response).

The goal is to support a ship-set of spares. A ship-set consists of 80 total cold plates in 45 different configurations. This goal will be met through productions, repairs, and core builds for future requirements. This contingency core build will greatly reduce the production time for long-lead, low-cost items, resulting in possible cost avoidance. The need for additional cold plate spares of at-risk configurations will be assessed upon completion of the cold plate damage testing.

Actions Required. The following table reflects the details in achieving the goal of supporting a ship-set of spares through the use of production, repairs, and core builds for future requirements:

2006 status:	0 balances for 15 cold plate configurations 9 production cold plates 19 cold plate repairs Cores have been built to support ship-set if needed
2007 status:	Eliminate zero balance cold plate configurations.
2008 status:	Existing repairs at Palmdale with emphasis on single spare available configurations. Productions as required to replace assets removed from a vehicle.
2009 status:	Productions and repairs as required to replace assets removed from a vehicle until a vehicle stands down.

Request that this recommendation be closed on issuance of the final report.

Recommendation 5. The Director, Kennedy Safety and Mission Assurance, should establish a Government Mandatory Inspection Point (GMIP) to witness and inspect cold plate work until such time as the cold plate process and the number of cold plate problems reported are stabilized.

KSC Response. Concur. A temporary GMIP will be instituted to inspect the cold plate surfaces after LRU removal and prior to LRU installations. The inspection will compare the visible area of the cold plate to the preexisting damage map prior to the installation of the cold plates and the LRUs which are installed on top of the cold plates. This visual inspection will enable NASA increased visibility into integrity of Shuttle processing and the ability to identify and report cold plate damage. Additionally, NASA will know with increased fidelity when the damage occurred. The data from the temporary GMIP will be analyzed, and if the process is in control, the temporary GMIP will be subject for removal. Otherwise the temporary GMIP may be considered for a permanent GMIP or the extension to gather additional data. The temporary GMIP for the cold plate inspection will be documented in the Quality Planning Requirements Document (QPRD). KSC Safety and Mission Assurance will submit the request for a Temporary GMIP in accordance with the requirements of KDP-P-3601, Supplemental Government Inspection Points (Inspections Beyond QPRD Requirements). The temporary GMIP process will document the rationale, specific inspection characteristics, and the duration.

Actions Required. The temporary GMIP will be submitted by March 31, 2006. Planning and approval will be completed by June 26, 2006.

Corrective action will be considered complete upon publishing of the new GMIP in the QPRD.

Estimated Completion of Corrective Action – July 24, 2006
Estimated Closure Date – August 30, 2006