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SUMMARY OF THE OFFICE OF INSPECTOR GENERAL'S REVIEWS ON ASPECTS OF NASA'S RESPONSE TO THE COLUMBIA ACCIDENT INVESTIGATION BOARD REPORT

OFFICE OF INSPECTOR GENERAL

National Aeronautics and
Space Administration

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Contents

SUMMARY ____ 1

APPENDIX A ____ 9

STATUS OF CAIB RECOMMENDATIONS

APPENDIX B ____ 11

RTF RECOMMENDATIONS

APPENDIX C ____ 33

CTF RECOMMENDATIONS

APPENDIX D ____ 49

AUDIT COVERAGE

APPENDIX E ____ 51

REPORT DISTRIBUTION

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NASA OFFICE OF INSPECTOR GENERAL

SUMMARY OF THE OFFICE OF INSPECTOR GENERAL'S REVIEWS ON ASPECTS OF NASA'S RESPONSE TO THE COLUMBIA ACCIDENT INVESTIGATION BOARD REPORT

The NASA Office of Inspector General (OIG) has been reviewing NASA's preparation for the return to flight (RTF) of the space shuttle since the Columbia Accident Investigation Board (CAIB) issued its final report in August 2003. Dedicated employees of NASA and NASA contractors have been working tirelessly to implement the recommendations of the CAIB—a monumental effort—and we believe they have done an excellent job. We note, though, the inherent risks of the Space Shuttle Program (SSP) and the great challenges in managing those risks.

The OIG's involvement included reviewing NASA's plans for proposed solutions to technical issues—such as the redesign of solid rocket booster bolt catchers and proposed design changes to the space shuttle's external fuel tank, including revised procedures for spraying insulating foam—and actively participating in crew and vehicle safety contingency training. The OIG's Office of Audits (OA) took a multi-disciplined approach to the reviews by teaming aerospace specialists, safety specialists, auditors, and analysts. Although the multi-disciplined approach taken allowed us to better assess NASA's planned actions, we only have limited insight into many of the issues that NASA engineers and managers have been trying to resolve in the RTF effort. OA review teams have worked with personnel throughout NASA and have found a consistent commitment to excellence and to the return of space flight.

Our review of NASA's progress in addressing the recommendations of the CAIB covered the broad subject categories of technical, organizational, and financial issues. The approaches we used ranged from formal audits, reviews, and evaluations to real-time observations and monitoring of selected RTF activities. In many instances, we worked alongside key NASA project officials as they formulated and began implementing NASA's RTF plans. We reviewed RTF plans for feasibility, assessed the degree to which those plans addressed specific recommendations of the CAIB, and observed implementation of the plans. We performed fieldwork at NASA Headquarters, Johnson Space Center, Kennedy Space Center, Marshall Space Flight Center, and various contractor locations.

This report is a summary of OIG Office of Audits' activities on NASA's response to the CAIB Report. In general, we found that NASA was meeting its RTF objectives. During our reviews, performed from September 2003 through May 2005, we identified no significant issues or problems that would indicate an unacceptable risk for returning the

space shuttle to flight that the SSP is not already engaged in solving. It should be noted that some of our earlier reviews, such as IG-04-020, "Status of NASA OIG Review of External Tank Thermal Protection System Debris Shedding," June 8, 2004, and "Status of NASA Office of Inspector General Review of Space Shuttle Imaging, Audit Assignment A-04-007-00," April 16, 2004, were simply reviews of NASA's plans to address the CAIB recommendations, not of the actual implementation of the plans or actions taken beyond the planning stage.

Background

On February 1, 2003, NASA mission control at the Johnson Space Center lost communication with the space shuttle *Columbia* during its return to Earth. NASA declared a mishap after determining that *Columbia* had experienced a critical failure in the atmosphere over eastern Texas. In accordance with NASA's plan for contingency operations, the NASA Administrator established the CAIB to identify the cause of the accident and to make recommendations for resolving known problems in order to safely return the space shuttle to flight. Because of the importance of the CAIB investigation, the NASA Administrator appointed the NASA Inspector General to the Board as an observer.

The CAIB found that the technical cause of the loss of *Columbia* and its crew was a breach in the thermal protection system (TPS) on the leading edge of the left wing. The breach was caused by a piece of insulating foam from the external tank (ET) striking the reinforced carbon-carbon (RCC) on the lower half of the wing. The CAIB also found that NASA's organizational culture and structure contributed as much to the *Columbia's* accident as any technical failure.

The CAIB's August 2003 final report contained 29 recommendations related to the physical and organizational causes of the accident. Of the 29 recommendations, 15 related primarily to the physical causes of the accident, and the CAIB stated that these must be addressed before the space shuttle returns to flight (RTF recommendations). The remaining 14 recommendations, related mostly to the accident's organizational causes, were described by the CAIB as "continuing to fly" (CTF) recommendations and reflect its views on what's needed to safely operate the space shuttle and future spacecraft in the mid- to long-term.

In response to the CAIB Report, the NASA Administrator established an RTF Planning Team and tasked it to help the SSP plan and implement actions to address each of the CAIB's 29 recommendations. The NASA Administrator also established the RTF Task Group, made up of industry and aerospace professionals, to evaluate and report on the progress of NASA's response to the CAIB Report; to review the closure of the CAIB's 15 RTF recommendations; and to monitor safety and operational readiness.

NASA initially published its "Implementation Plan for Space Shuttle Return to Flight and Beyond" (Implementation Plan) on September 8, 2003, and regularly updates it. The Implementation Plan provides details on how NASA either has addressed or plans to address each of the CAIB recommendations. The last update was March 18, 2005, which is reflected in this report.

NASA has also developed budget estimates for implementing the CAIB recommendations required to return the space shuttle to flight. According to NASA, the cost for returning the shuttle to flight, estimated at $1.428 billion as of March 18, 2005, will remain uncertain until the completion of the first RTF missions to the International Space Station (ISS) in Fiscal Year 2005. In addition, NASA is still defining technical concepts in connection with implementing the CAIB recommendations, which will also affect the budget estimate. The Government Accountability Office's report, GAO-05-34, "Space Shuttle: Costs for Hubble Servicing Mission and Implementation of Safety Recommendations Not Yet Definitive," November 19, 2004, states that NASA's support for the estimate was insufficient—either because key documents were missing or the estimates lacked sufficient detail. Other GAO and NASA reports relevant to the RTF effort are listed in Appendix D. We have conducted audit activities to independently provide insight into NASA's response to the CAIB Report because of the importance of this issue.

Status of CAIB Recommendations

As of the last plenary session, February 18, 2005, the RTF Task Group had closed 7 of the 15 RTF recommendations and conditionally closed 1; 7 remained open. Of the 14 CTF recommendations, NASA had closed 4; 10 remained open. See Appendix A for tables showing the status of the 29 recommendations, Appendix B for details on the RTF recommendations, and Appendix C for details on the CTF recommendations.

Based on work performed by the OIG's Office of Audits (OA), we believe that NASA appropriately closed (or conditionally closed) all but one of the 12 CAIB recommendations it has closed. We do not concur with NASA's closure of Recommendation 4.2-2, "Inspect Orbiter Wiring," because we do not believe that NASA's actions met the intent of the recommendation.

Topic Areas

The OA focused its work on the topic areas of orbiter wiring, ET debris shedding, imaging, bolt catchers, shuttle mission management team (MMT) training, and organizational issues. The OA review of NASA's plans identified management challenges related to the safety and quality assurance of space flight hardware as well as technical challenges related to debris shedding. Other areas were also reviewed, although

to a lesser degree. OA reviews of other issues, including the vital repair aspect of the space shuttle orbiter's TPS, are ongoing. A brief discussion of NASA's actions to address the key topic areas and OIG review results follows. For details, see Appendix B (RTF recommendations) and Appendix C (CTF recommendations).

Orbiter Wiring

CTF Recommendation 4.2-2, "Inspect Orbiter Wiring," was closed through the SSP Requirements Control Board (the RTF Task Group did not review the recommendation because it was not an RTF recommendation). In general, NASA plans to proceed with the inspection and detection process in place since August 1999 and fund the development of Destructive Evaluation Age Life Testing. NASA has canceled plans to continue developing and testing state-of-the-art technology for evaluating orbiter wiring based on their conclusion that the new technology would not be cost effective or ready before the planned 2010 shuttle retirement and funding constraints.

In our March 16, 2005, discussion draft report, "Review of Orbiter Wiring," we disagreed with the closing of this recommendation. We concluded that without new evaluation technology, inaccessible Kapton[1] wiring will continue to be a safety risk for the space shuttle and future space vehicles. NASA should establish a formal procedure that will transmit lessons learned from the canceled technology development plans to facilitate development of new evaluation technology for wiring inspection of the next-generation space vehicle. NASA should also formally assess the risk of aging and damaged orbiter wiring and develop a risk mitigation plan based on that risk assessment. We do not concur with the closure of R4.2-2 because we do not believe that NASA's actions met the intent of the recommendation. Draft reports are not publicly available; our final report, which will be publicly available, will not be issued until June at the earliest. We will consider management comments in response to the draft report in preparing the final report, which may result in modifications to the draft report.

External Tank Debris Shedding

RTF Recommendation 3.2-1, "External Tank Debris Shedding," is currently open pending NASA's completion of planned work. NASA's analysis not only identified the failure mechanisms associated with debris shedding but also determined probabilities for the occurrence or recurrence of debris shedding, provided a detailed map of the points of impact, and assessed the degree of damage. NASA adopted a phased approach for implementing actions to address R3.2-1, one of which was the redesign of the ET to reduce to an acceptable level the amount of foam debris generated during launch, which NASA has done.

[1] Kapton is a specific composite film used for insulation.

At the time of our review, from October 2003 through April 2004, NASA was developing plans to address this issue. We reviewed NASA's plans to make the external tanks safer and, as stated in IG-04-020, "Status of NASA OIG Review of External Tank Thermal Protection System Debris Shedding," June 8, 2004, we concluded that NASA was taking the appropriate steps to address R3.2-1. In the last 2 months, the OIG has reviewed NASA's ongoing efforts to categorize and eliminate debris from the ET. NASA continues to perform characterization testing to describe and classify ice accumulation on certain areas of the ET and to predict through analysis the likelihood and consequences of that ice impacting the orbiter. We believe that the SSP is taking substantial action to reduce the risk of ice from the ET hitting the orbiter. We will continue to monitor ET debris reduction efforts up to launch.

Imaging

This set of RTF recommendations (R3.4-1, R3.4-2, R3.4-3, and R6.3-2) addresses imaging the ET and the orbiter to identify debris and damage during ascent and orbit. The recommendations cover ground-based imagery (R3.4-1), high-resolution images of the ET (R3.4-2), high-resolution images of the orbiter (R3.4-3), and on-orbit imaging of the orbiter by national assets (R6.3-2). Two of the recommendations are closed (R3.4-2 and R6.3-2), one was conditionally closed (R3.4-1), and one remains open (R3.4-3).

Major elements of NASA's plans to address these recommendations include developing a suite of improved ground and airborne cameras; equipping the flight crew with handheld, high-resolution digital still cameras; installing a variety of vehicle-mounted digital cameras; installing sensors on the end of a boom system that is installed on the orbiter; and using a variety of national assets to help evaluate the condition of the orbiter when it is on orbit.

In our memorandum "Status of NASA Office of Inspector General Review of Space Shuttle Imaging," April 16, 2004, we concluded that NASA was taking the appropriate steps to address R3.4-2 and R6.3-2. We concur with the RTF Task Group's closure of R3.4-2 and R6.3-2, and we concur with the conditional closure of R3.4-1. With regard to the open recommendation, R3.4-3, we concur with the RTF Task Group's March 18, 2005, position that the on-vehicle ascent imagery is not sufficient to close this recommendation. We also concur with the RTF Task Group's assessment that it needs to review the orbiter boom sensor system (OBSS) in order to determine whether NASA's actions meet the intent of R3.4-3 (currently the OBSS is addressed under R6.4-1).

Bolt Catchers

RTF Recommendation 4.2-1, "Bolt Catchers," is closed. NASA performed a technical redesign that consisted of the bolt catcher housing being fabricated from a single piece of aluminum that removes the weld from the original two-piece assembly. Additionally,

NASA selected a new energy-absorbing material and thermal protection material, as well as redesigned and resized attachment bolts and inserts on the ET. NASA demonstrated that the structural qualification of the assembly complies with the requirement to withstand 1.4 times the maximum load expected in operation.

As reported in our memorandum IG-04-024, "Government Mandatory Inspections for Solid Rocket Booster Bolt Catchers," September 28, 2004, NASA's redesign of the bolt catchers met the intent of the recommendation. Although we concur with this recommendation being closed, we noted deficiencies in NASA's quality assurance plans that need to be addressed by the Defense Contract Management Agency. We will continue to conduct audits to ensure those deficiencies are appropriately addressed.

Shuttle Mission Management Team Training

RTF Recommendation 6.3-1, "Expanded Training of Shuttle Mission Management Team," is open pending the first RTF mission. The SSP developed an MMT Training Plan that includes self-study readings, training courses, and full-up mission simulations. Because the recommendation is an RTF requirement, the RTF Task Group has extensively reviewed the recommendation.

As part of our review of NASA's plans for implementing actions to address the recommendation, we attended, reviewed, and commented on every core training course and attended and commented on 11 MMT simulations. As of May 5, 2005, NASA's lessons learned database included details on 79 comments we had provided the MMT concerning improvements that could be made, of which 70 had been acted upon.[2] We also submitted numerous comments on the proposed MMT Training Plan, which the SSP incorporated into the approved MMT Training Plan. In our review of the MMT training database, we noted areas of internal control weaknesses and inaccuracies. The weaknesses existed because no checks and balances were in place that would ensure the correct recording of MMT members' participation. Based on our input, the SSP made corrections to the processes and the training database.

Most MMT training events have been completed. While we verified the key elements of the MMT expanded training plan, the proof of success will be in the performance of the MMT during the first RTF mission. The OIG will continue to assess MMT performance through that mission, scheduled for July 2005 (STS-114).

[2] NASA employees and other authorized persons can access the Space Shuttle Program's Web site at http://sspweb.jsc.nasa.gov/webdata/mmt/ for details (see the lessons learned documents available under "Training Data").

Organizational Issues

RTF Recommendation 9.1-1, "Detailed Plan for Organizational Change," is open. The CAIB required that NASA prepare a detailed plan for defining, establishing, transitioning, and implementing CTF Recommendations 7.5-1, 7.5-2 and 7.5-3. NASA published "NASA's Plan for Implementing Safe and Reliable Operations" in November 2004 to address organizational issues included in R9.1-1. The November 2004 plan, commonly referred to as the 9.1-1 Plan, includes the following reorganization steps:

- Introduce a formalized technical authority concept administered by the Chief Engineer.
- Strengthen the Office of Safety and Mission Assurance (SMA) in three areas (authority, independence, and capability).
- Strengthen the integration functions of the Space Shuttle Integration Office.

NASA submitted closure rationale to the RTF Task Group, but the RTF Task Group has kept the recommendation open pending further implementation of the 9.1-1 Plan.

In our discussion draft report, "Risks Associated With NASA's Plan for Technical Authority and Safety and Mission Assurance," April 25, 2005, we concluded that NASA's actions were generally responsive to the recommendation. However, we offered an enhancement that, if implemented, will improve the independence of the SMA Office. Draft reports are not publicly available; our final report, which will be publicly available, will not be issued until late July. We will consider management comments in response to the draft report in preparing the final report, which may result in modifications to the draft report.

Other

We conducted an audit of the incentive and award fee structure under NASA's Space Flight Operations Contract (SFOC) with United Space Alliance (USA). The purpose of the audit was to determine whether the incentive and award fee structure of the SFOC was conducive to safe space shuttle operations.

We conducted this audit because Volume V, Appendix G.9 of the CAIB Report, "Report to CAIB: Contracts, Incentives and Safety/Technical Excellence," presents an analysis of the SFOC and its fee structure and notes that "NASA relies very extensively on contract financial incentives to motivate major shuttle program contractors." USA's work affects the safety of NASA astronauts and the space shuttle orbiters, as well as space hardware, personnel, and equipment.

We were unable to reach a conclusion on whether the fee structure of the SFOC was conducive to safe shuttle operations. However, we made two observations (without recommendations) relating to management of the SFOC award fee process that may be relevant to future management of that process. The observations concerned

- shifts in NASA's weighting of the "operational safety" and "quality" award fee evaluation factors and

- changes in the communication of award fee evaluation criteria to USA.

NASA made changes to the SFOC award fee process in response to our observations, which should improve the management of the contract.

Appendix A
Status of CAIB Recommendations

Table A-1: Return-to-Flight Recommendations				
Recommendation	**Open**	**Conditionally Closed**	**Closed by RTF Task Group**	**OIG Review**
Part One – The Accident				
R3.2-1 – External Tank Debris Shedding	X			concur
R3.3-2 – Orbiter Hardening	X			ongoing
R3.3-1 – RCC Non-Destructive Testing			X	concur
R6.4-1 – Thermal Protection System On-Orbit Inspection and Repair	X			ongoing
R3.4-1 – Ground-Based Imagery		X		ongoing
R3.4-2 – High-Resolution Images of ET			X	concur
R3.4-3 – High-Resolution Images of Orbiter	X			ongoing
R6.3-2 – National Imagery and Mapping Agency Memorandum of Agreement			X	concur
R4.2-1 – Bolt Catchers			X	concur
R4.2-3 – Closeout Inspections			X	concur
R4.2-5 – Define Foreign Object Debris			X	concur
Part Two – Why the Accident Occurred				
R6.2-1 – Review of Shuttle Flight Schedule	X			concur with comment
R6.3-1 – Expanded Training of Shuttle MMT	X			ongoing
Part Three – A Look Ahead				
R9.1-1 – Detailed Plan for Organizational Change	X			ongoing
R10.3-1 – Digitize Closeout Photos			X	concur
Total	**7**	**1**	**7**	

Table A-2: "Continuing to Fly" Recommendations			
Recommendation	**Open**	**Closed by NASA**	**OIG Review**
Part One – The Accident			
R3.3-3 – Sustain Leading Edge Damage	X		concur
R3.3-4 – Flown Reinforced Carbon-Carbon Database	X		concur
R3.3-5 – Launch Pad Leaching Zinc Primer		X	concur
R3.8-1 – Spare Reinforced Carbon-Carbon Panels	X		ongoing
R3.8-2 – Computer Models of TPS Damage	X		ongoing
R3.6-1 – Modular Auxiliary Data System Update		X	concur
R3.6-2 – Modular Auxiliary Data System Redesign	X		concur
R4.2-2 – Inspect Orbiter Wiring		X	nonconcur
R4.2-4 – Micrometeoroid and Orbital Debris Degree of Safety	X		ongoing
Part Two – Why the Accident Occurred			
R7.5-1 – Independent Technical Authority Organization	X		ongoing
R7.5-2 – Independent Safety and Mission Assurance	X		ongoing
R7.5-3 – Reorganize Space Shuttle Integration Office	X		ongoing
Part Three – A Look Ahead			
R9.2-1 – Space Shuttle Mid-Life Recertification	X		concur
R10.3-2 – Upgrade Engineering Drawings		X	concur
Total	**10**	**4**	

Appendix B
RTF Recommendations

CAIB Return-to-Flight Recommendations, Actions, and OIG Review

R3.2-1 – External Tank Debris Shedding 11
R3.3-2 – Orbiter Hardening 13
R3.3-1 – RCC Non-Destructive Testing 15
R6.4-1 – TPS On-Orbit Inspection and Repair 16
R3.4-1 – Ground-Based Imagery 19
R3.4-2 – High-Resolution Images of ET 20
R3.4-3 – High-Resolution Images of Orbiter 21
R6.3-2 – National Imagery and Mapping Agency Memorandum of Agreement 22
R4.2-1 – Bolt Catchers 23
R4.2-3 – Closeout Inspections 24
R4.2-5 – Define Foreign Object Debris 25
R6.2-1 – Review of Shuttle Flight Schedule 26
R6.3-1 – Expanded Training of Shuttle MMT 27
R9.1-1 – Detailed Plan for Organizational Change 29
R10.3-1 – Digitize Closeout Photos 30

Part One – The Accident

R3.2-1 – External Tank Debris Shedding

Recommendation: Initiate an aggressive program to eliminate all External Tank Thermal Protection System debris-shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank.

Status of Recommendation: Open

The recommendation is open pending NASA's completion of planned work.

The RTF Task Group's interpretation of the recommendation was that NASA needed to simply eliminate critical foam debris. The goal was not to eliminate all of the foam debris but to eradicate only the debris generated at specific locations where its size/mass,

velocity, trajectory, and impact would have the potential to cause serious or catastrophic damage to the orbiter and orbiter systems. To accomplish that goal, NASA

- mapped the sources of foam debris and performed impact tolerance tests that incorporated both destructive and non-destructive testing techniques under a wide range of engineering models during launch/ascent environments;
- ascertained the failure mechanisms that led to debris generation;
- identified the points of impact; and
- assessed actual/potential damage by the performance of transport and energy analyses.

NASA's analyses not only identified the failure mechanisms associated with debris shedding but also determined probabilities for the occurrence or recurrence of debris shedding, provided a detailed map of the points of impact, and assessed the degree of damage. NASA's final step is to either eliminate the debris at its source or implement engineering controls that minimize the impact if shedding occurs.

NASA adopted a phased approach in accordance with a typical hazard reduction precedence sequence. Phase 1 included developing and implementing those modifications to the ET that would eliminate known critical debris sources. Phase 2 consisted of developing, certifying, implementing, and improving design and production enhancements that would further reduce debris. Phase 3 included exploring the possibility of eliminating all of the debris. However, Phase 3 will not be implemented because NASA plans to retire the space shuttles by 2010.

NASA redesigned the ET to reduce to an acceptable level the amount of foam debris generated during launch. The RTF Task Group stated that the new design is much improved and believes it will be the safest ever. The performance of the final TPS Design Certification Review was completed on March 9, 2005.

OIG Review: Concur

We issued management memorandum IG-04-020, "Status of NASA OIG Review of External Tank Thermal Protection System Debris Shedding," June 8, 2004. Based on the results of our review, conducted from October 2003 through April 2004, we concluded that NASA was taking the appropriate steps to address the CAIB recommendation. NASA has closed all Nonconformance Documents and resolved production issues. However, one issue was not completely addressed: the formation of ice on the liquid oxygen feedline bellows. We will continue to monitor ET activities up to and during launch.

As of April 2005, NASA had not established an engineering requirement that would eliminate all ice, nor had NASA adopted a standard for acceptable levels of ice. The RTF Task Group stated that the ET redesign will eliminate 40 percent to 70 percent of ice formation. However, NASA would have to adopt a standard in order to determine whether the 40- to 70-percent reduction is acceptable.

We believe that ice accumulation remains a problem because of the potential for its release during launch and ascent. The ice debris could be of sufficient size or mass that, once released, could achieve a velocity and trajectory enabling the ice to impact and cause damage to critical flight systems. Consequences from such an event are too severe to ignore. Even though the redesign reduces ice formation by 40 to 70 percent, additional testing and analysis will be required to determine the acceptable levels of ice formation, accumulation, and release.

NASA completed characterization testing in April 2005 to describe and classify the type of ice accumulation. The ice liberation tests of how, why, and when ice releases will immediately follow characterization testing.

The level of ice accumulation on the bellows, as well as the nearby feedline bracket, is a concern. The testing and analysis used to establish a requirement for an acceptable level of ice residing on the ET is being conducted simultaneously with testing designed to establish an acceptable level of released ice, or ice debris. Although the testing is in-process, NASA believes that the acceptable mass of ice debris is in the range of 0.003 to 0.0708 pounds. NASA stated that it will not return the space shuttle to flight without sound rationale that supports a safe launch. Ice accumulation and ice debris will figure into that decision. NASA will conduct additional computer modeling and analyses, as necessary, with the goal of establishing a requirement either before or immediately following the Flight Readiness Review scheduled for June 2005.

Eliminating all ice through the design and implementation of hard engineering controls or use of a sacrificial material that could draw ice away from critical areas is also being considered. Without requisite empirical test data, introduction of an untested control could pose additional risks that may not be understood. NASA's ET Debris Team stated that the time and complexity of the additional testing and analyses required will delay the implementation of a hard engineering control. As a result, such controls will not be implemented until after the first two ETs are manufactured.

R3.3-2 – Orbiter Hardening

Recommendation: Initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced

Carbon-Carbon and acreage tiles. This program should determine the actual impact resistance of current materials and the effect of likely debris strikes.

Status of Recommendation: Open

This recommendation is open pending NASA's completion of work on orbiter side windows, main landing gear door voids, forward reaction control system stud failures, and RCC impact testing.

The RTF Task Group's interpretation of the CAIB recommendation was that NASA should initiate a program that would increase the orbiter's ability to sustain minor debris damage by selecting and implementing design changes prior to returning to flight and define additional changes (if required) for the duration of the SSP through 2010. NASA's approach was to focus primarily on modifications to the ET that would either eliminate or reduce foam debris rather than increase the orbiter's ability to sustain damage. NASA stated that orbiter hardening provides an additional level of risk mitigation above and beyond NASA's primary control.

NASA developed and implemented a detailed test, an engineering model, and an analysis program that determined the impact resistance of existing materials, such as shuttle tile and RCC, and the effects of likely debris strikes. An important element of the program was the formation of both a System Integration Team and Orbiter Damage Impact Assessment Team.

The System Integration Team was tasked with defining critical debris sources (such as trajectories, velocity, and mass) and suggesting design improvements. The Orbiter Damage Impact Assessment Team was formed to develop capability models for high-temperature reusable surface insulation (shuttle tile) and RCC. The work involved both large- and small-scale material testing and was in-process as of April 2005. The Orbiter Damage Impact Assessment Team was also tasked with, and has completed, the performance of damage assessments and the establishment of an acceptable level of risk.

The hardening improvement plan, which the SSP approved, identified possible problems with the side windows. In the model, the side windows of the orbiter regularly sustain impact damage during ascent, while on orbit, and during ground operations. As a result, the thickness of orbiter side windows was increased. New windows were installed on Orbiter Vehicle (OV)-103 and work is in-process on the remaining orbiter vehicles.

NASA found that the main landing gear door and leading edge system carrier panels (current design) were at a lower risk than originally thought. Main landing gear voids in the thermal barrier design were identified and filled on OV-103 and OV-104. Installation of the wing spar design modifications to provide additional protection from the sneak

flow of heated plasma during reentry were completed for OV-103 in February 2005 and are expected to be completed for OV-104 in May 2005.

Flight history data identified stud failures in two carrier panels. Forward reaction control system stud elimination was completed on OV-103 and OV-104 and work is in-process on OV-105.

RCC impact testing was completed in April 2005. Final tile and RCC model verification should also be completed sometime in April and the damage and tolerance test analyses completed in early April 2005.

OIG Review: Ongoing

We participated in each Debris Summit and will continue to monitor NASA's activities on this issue. We believe that NASA is taking the appropriate steps toward fully addressing the recommendation.

R3.3-1 – RCC Non-Destructive Testing

Recommendation: Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology.

Status of Recommendation: Closed

The RTF Task Group closed the recommendation.

NASA fully complied with the recommendation. RCC flight hardware was returned for a complete factory-level inspection to Lockheed Martin Missiles and Fire Control in Texas. Inspection included x-ray analysis and ultrasonic inspection for tubular voids as well as delaminations and eddy current inspection to ensure the surface coating of silicon carbide was intact and the correct thickness.

The SSP also added procedures to conduct flash thermography of all RCC components after each flight to ensure that none of those components were damaged during the flight.

OIG Review: Concur

We reviewed the process over the last few months and traveled to the factory to witness the inspection process. We believe that the actions in response to the recommendation are complete.

R6.4-1 – TPS On-Orbit Inspection and Repair

Recommendation: For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities available when near to or docked at the International Space Station.

For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.

Accomplish an on-orbit Thermal Protection System inspection, using appropriate assets and capabilities, early in all missions.

The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking.

Status of Recommendation: Open

The NASA Implementation Plan states that the fundamental strategy for RTF is to modify the ET to control critical debris liberation. NASA states in the Implementation Plan that it will resume shuttle missions only when it has confidence that the ET will not liberate critical debris.

NASA also states in the Plan that while TPS inspection and repair capability is an important part of the risk mitigation plan for damaged TPS, that capability does not offer an alternative to prelaunch flight rationale requiring the ET to perform at the level determined necessary to control critical debris liberation. However, NASA agreed that inspection capability, as well as development of the tools and a process that will support potential on-orbit TPS repair, is important. To further address the on-orbit inspection element, NASA chose to address the OBSS and R-bar pitch maneuver inspection elements from R3.4-3 in conjunction with this recommendation (R6.4-1).

NASA also pointed out that additional risks are associated with creating and deploying a fully autonomous inspection capability without ISS resources. As a result, under direction from the Space Flight Leadership Council, NASA is focusing its efforts on developing and implementing inspection and repair capability appropriate for the first two RTF missions using ISS resources as required.

NASA states in the Implementation Plan that it has greatly expanded the capabilities to detect debris liberation during ascent, to identify points of origin, and to identify impact sites on the orbiter TPS for evaluation. The detection capabilities include the use of high-

speed cameras, aircraft-mounted cameras, radar, an impact detection sensor system, and a suite of on-orbit shuttle and ISS sensors. The shuttle and ISS sensor suite includes the OBSS, the Shuttle Remote Manipulator System, the Space Station Remote Manipulator System, an experimental wing leading edge (WLE) impact sensor detection system, and digital photography during the R-bar pitch maneuver. The combined detection and inspection capabilities and accompanying repair techniques are designed to provide NASA with the means for detection, inspection and, if necessary, repair of the orbiter TPS.

NASA has defined the critical damage threshold for TPS inspections as shown in the following table.

Critical Damage Threshold		
Tile Around Doors	Acreage Tiles	RCC
1 inch	3 inches	0.020-inch by 2-inch cracks

NASA asserts that damage smaller than the defined thresholds should not result in increased risk to entry. NASA based that conclusion on extensive tests and analytical modeling. However, NASA states that even though it will have the capability to detect damage, the damage detection capabilities will not be certified prior to the first RTF mission.

NASA states that the central objective of the first two RTF missions will be to verify the performance of the integrated shuttle system, with inspection as a priority. However, NASA points out that there is limited operational time available to inspect during any mission, and conditions during inspection may not always be optimal. NASA goes on to state that inspections that take place early in the mission will detect damage from ascent debris, but may not find damage sustained while onorbit; for instance, damage from a micrometeoroid or orbital debris strike. Any focused inspections will be guided by the results of ascent imagery that should indicate any areas of potential concern and by the initial OBSS scans and crew camera photos.

Techniques for repairing tile and RCC by extra-vehicular activity are under development. NASA's position is that the combination of detection and inspection capabilities and repair techniques will increase the probability that any damage that does occur can be detected and the consequences mitigated in flight. NASA's long-term plans for TPS risk mitigation will refine and improve all elements of the near-term plans, ensuring an effective system of inspection and repair.

As discussed in the RTF Task Group Third Interim Report, January 28, 2005, the RTF Task Group agreed to keep the recommendation open pending review of OBSS and WLE

sensor data. While some repair techniques for RTF exists, those techniques are expected to be somewhat limited. The RTF Task Group continues to point out that detailed test objectives planned for the first RTF mission will be necessary to further understand the repair techniques being developed.

OIG Review: Ongoing

Although we have not conducted any formal reviews on the repair elements of this recommendation, we previously reviewed certain inspection elements and suspended "Space Shuttle Imaging" (Assignment No. A-04-007-00) on April 16, 2004, because we believe that NASA's plans satisfy the intent of the recommendation. We interviewed SSP and project officials as well as a CAIB member for clarification of intent. In addition, we reviewed the pitch maneuver and associated risk, reviewed downlink and dissemination capability, and laser-based boom sensors.

We have intermittently followed NASA's progress in meeting the on-orbit inspection elements of this recommendation. We interviewed project managers and key people involved in sensor selection and various design elements, reviewed related documentation, participated in virtual reality simulators and astronaut training labs, and observed OBSS testing and demonstrations of next-generation inspection sensors.

NASA is addressing the OBSS-related inspection element of this recommendation and has developed a variety of methods and techniques that can be implemented along RTF timelines with performance potential that meet CAIB requirements. Because of the dynamic nature of catastrophic damage criteria, the performance testing of sensors under consideration, and the evaluation of other sensor alternatives, we will continue to monitor NASA's progress on meeting the inspection element of this recommendation as follows:

- NASA had defined the critical damage threshold for the RCC as a 0.20-inch by 2.0-inch crack. Boom sensor performance has been shown to exceed the earlier 0.25-inch requirement for the RCC. NASA should continue to monitor the evolving damage criteria. NASA should also continue to examine improvements to the current sensor suite on board the OBSS and also consider alternatives, including two-dimensional, high-resolution digital cameras currently under review.

- Review the downlink capability for on-orbit imagery and examine the reliability and redundancy of the baselined digital television system as well as the performance capability of the analog backup.

We have not followed NASA's progress on meeting the repair elements of this recommendation. Based on a cursory review of the Implementation Plan, we believe that NASA has developed an effective plan for responding to the recommendation. With the

exception of a comprehensive repair capability, NASA's near-term TPS risk mitigation plans will be implemented before RTF. To further develop a comprehensive repair capability, NASA states in the Implementation Plan that it needs to use the first two RTF missions for repair process test and development. The RTF Task Group stated that NASA needs to take a hard look at the risks associated with the RCC and tile repair options, address a variety of specific concerns enumerated within the RTF Task Group's report, and weigh options against the associated advantages. We concur with the RTF Task Group and will continue to monitor NASA's progress in this area.

R3.4-1 – Ground-Based Imagery

Recommendation: Upgrade the imaging system to be capable of providing a minimum of three useful views of the Space Shuttle from liftoff to at least Solid Rocket Booster separation, along any expected ascent azimuth. The operational status of these assets should be included in the Launch Commit Criteria for future launches. Consider using ships or aircraft to provide additional views of the Shuttle during ascent.

Status of Recommendation: Conditionally Closed

As reported in the Implementation Plan, NASA is developing a suite of improved ground and airborne cameras that satisfies the intent of this recommendation. The improved suite of ground cameras will maximize the ability to capture three complementary views of the shuttle and provide the SSP with engineering data that give a better and continued understanding of the ascent environment and performance of the shuttle hardware elements within the environment. NASA states in the Plan that ground imagery may allow NASA to detect ascent debris and identify potential damage to the orbiter for on-orbit assessment.

NASA will acquire four types of imagery from the ground cameras:

- primary imagery—film images used as the primary analysis tools for launch and ascent operations;
- fall-back imagery—back-up imagery for use when the primary imagery is unavailable;
- quick-look imagery—imagery provided to the Image Analysis labs shortly after launch for initial assessments; and
- tracker imagery—images used to guide the camera tracking mounts and for analysis when needed.

Any anomalous situations identified in the post-ascent quick-look assessments will be used to optimize the on-orbit inspections described in R6.4-1. NASA has increased the

number of ground cameras and added additional short-, medium-, and long-range camera sites, including eight new quick-look locations.

In addition to ground cameras, NASA approved the development and implementation of an aircraft-based imaging system known as the WB-57 Ascent Video Experiment that will provide both ascent and entry imagery. The use of an airborne imaging system will provide opportunities to better observe the vehicle during days of heavier cloud cover and in areas obscured from ground cameras by the exhaust plume following launch.

OIG Review: Ongoing

We suspended "Space Shuttle Imaging" (Assignment No. A-04-007-00) on April 16, 2004, because we believe that NASA's plans satisfy the intent of the recommendation. We interviewed SSP and project officials as well as a CAIB member for clarification of intent; studied camera locations, related equipment, and analysis tools; reviewed relevant briefing material; reviewed downlink and dissemination capability; and reviewed the process for transitioning imaging services from the Air Force to NASA. With the exception of a cursory review of the Implementation Plan, we have not followed NASA's progress on this recommendation since April 2004. At that time, NASA was in the final stages of implementing a comprehensive plan. The Plan discusses a variety of redundant ground and air-based imaging systems that provide multiple views of the shuttle during launch and enhance NASA's ability to characterize the ascent environment with a particular focus on identifying ascent debris. We concur with the conditional closure of the recommendation, which is subject to documentation being completed, but we will continue to monitor NASA's progress.

R3.4-2 – High-Resolution Images of ET

Recommendation: Provide a capability to obtain and downlink high-resolution images of the External Tank after it separates.

Status of Recommendation: Closed

The RTF Task Group closed the recommendation.

The Implementation Plan states that NASA plans to equip the flight crew with handheld high-resolution digital still cameras with telephoto lenses. NASA will also replace the standard 35-millimeter orbiter umbilical well camera with a high-resolution digital camera. Umbilical and handheld camera images will be downlinked after safe orbit operations are established. The MMT will use the images for quick-look analysis to determine whether any ET anomalies that require additional on-orbit inspections exist (see R3.4-3 and R6.4-1). The new capabilities satisfy the imaging objectives of ET

design change verification, debris environment assessment, and general flight documentation.

OIG Review: Concur

We suspended "Space Shuttle Imaging" (Assignment No. A-04-007-00) on April 16, 2004, because we believe that NASA's plans satisfy the intent of the recommendation. We have followed NASA's progress on this recommendation. We interviewed SSP and project officials as well as a CAIB member for clarification of intent, studied the rationale for locating the camera in the umbilical well, reviewed relevant briefing material, reviewed downlink and dissemination capability, and reviewed the Implementation Plan. In responding to the recommendation, NASA worked successfully to find a balance in optimizing performance while adhering to the RTF timeline. We concur with the closure of the recommendation.

R3.4-3 – High-Resolution Images of Orbiter

Recommendation: Provide a capability to obtain and downlink high-resolution images of the underside of the Orbiter wing leading edge and forward section of both wings' Thermal Protection System.

Status of Recommendation: Open

As stated in the Implementation Plan, for the first few RTF missions, NASA will use on-orbit inspections to meet the requirement to assess the health and status of the TPS. The on-vehicle ascent imagery suite does not provide complete imagery of the underside of the orbiter or guarantee detection of all potential impacts to the orbiter. However, as NASA states in the Plan, on-vehicle ascent imagery will be a valuable source of engineering, performance, and environmental data and will be useful for understanding in-flight anomalies. NASA's long-term strategy will include improving on-vehicle ascent imagery. NASA is addressing the WLE and OBSS parts of the recommendation under R6.4-1.

In the Implementation Plan, NASA states that it will have cameras on the ET liquid oxygen feedline fairing and the solid rocket booster forward skirt. The ET liquid oxygen feedline fairing camera will take images of the ET bipod areas, the underside of the shuttle fuselage, and the right wing from liftoff through the first 15 minutes of flight. The new location of the ET camera will reduce the likelihood that the booster separation module plume will obscure its views. The images from the camera will be transmitted to ground stations in real time.

NASA also states in the Plan that an additional complement of aft-looking cameras located on the solid rocket booster forward skirt and forward-looking cameras located on the solid rocket booster ET attachment ring will be added to subsequent flights. The additional cameras will provide comprehensive views of the orbiter's underside during ascent.

NASA's Plan calls for it to continue researching options that improve camera resolution, functionality in reduced lighting conditions, and alternative camera mounting configurations. In the meantime, work is proceeding on the new solid rocket booster camera designs and implementation of the approved ET and solid rocket booster cameras and WLE sensors.

OIG Review: Ongoing

We suspended "Space Shuttle Imaging" (Assignment No. A-04-007-00) on April 16, 2004, because we believe that NASA's plans satisfy the intent of the recommendation. We interviewed SSP and project officials as well as a CAIB member for clarification of intent. We also studied the rationale for locating the camera in the umbilical well and the rationale for ET and booster camera locations, reviewed downlink and dissemination capability as well as the process for transitioning imaging services from the Air Force to NASA.

With the exception of a cursory review of the Implementation Plan, we have not followed NASA's progress on addressing the recommendation since April 2004. Based on our cursory review, we concur with RTF Task Group's position that the on-vehicle ascent imagery suite does not provide complete imagery of the orbiter's underside or guarantee detection of all impacts to the orbiter. We also concur with the RTF Task Group assessment that to determine whether NASA meets the intent of this recommendation, R3.4-3 and R6.4-1 must be reviewed jointly. Pending the review of OBSS and WLE sensor data (covered in R6.4-1), this recommendation will remain open.

R6.3-2 – National Imagery and Mapping Agency Memorandum of Agreement

Recommendation: Modify the Memorandum of Agreement with the National Imagery and Mapping Agency to make the imaging of each Shuttle flight while on orbit a standard requirement.

Status of Recommendation: Closed

The RTF Task Group closed the recommendation.

NASA states in the Implementation Plan that a Memorandum of Agreement with the National Imagery and Mapping Agency (now the National Geospatial Intelligence Agency) provides as a standard requirement on-orbit assessment of the condition of each orbiter vehicle. In addition, NASA has initiated discussions with other agencies to explore the use of national assets to help evaluate the condition of the orbiter vehicle. Additional agreements have been developed and are in final review. The operational teams have developed standard operating procedures to implement agreements with the appropriate Government agencies.

OIG Review: Concur

We suspended "Space Shuttle Imaging" (Assignment No. A-04-007-00) on April 16, 2004, because NASA was taking the necessary steps to establish protocols with other Federal agencies and departments to image the space shuttle onorbit. We are not including specific details because the information is sensitive.

With the exception of reviewing the Implementation Plan, we did not follow NASA's progress in response to the recommendation, but we believe that NASA is appropriately responding to the recommendation, paying particular attention to the constraints associated with certain imagery. NASA is also making progress in ensuring that personnel have appropriate clearances and are trained in security policy and procedures. NASA states in the Implementation Plan that it will complete the steps before the first RTF mission. We concur with the closure of the recommendation.

R4.2-1 – Bolt Catchers

Recommendation: Test and qualify the flight hardware bolt catchers.

Status of Recommendation: Closed

NASA closed the recommendation through the formal Critical Design Review process (May 2004) and Qualification Testing process (October 2004). The closure package was sent to the RTF Task Group, which closed the recommendation.

NASA performed a technical redesign that consisted of the bolt catcher housing being fabricated from a single piece of aluminum that removes the weld from the original two-piece assembly. Additionally, NASA has selected a new energy absorbing material and thermal protection material and redesigned and resized attachment bolts and inserts on the ET. NASA demonstrated that the structural qualification of the assembly complies with the requirement to withstand 1.4 times the maximum load expected in operation.

OIG Review: Concur

We conducted an audit and published memorandum IG-04-024, "Government Mandatory Inspections for Solid Rocket Booster Bolt Catchers," September 28, 2004. We concluded that the redesigned bolt catchers met the intent of the recommendation and concurred with the closure of the recommendation.

However, during the course of the audit, we discovered deficiencies in NASA's quality assurance plans. Three recommendations were made:

1. Defense Contract Management Agency Letters of Delegation for the redesigned bolt catchers must provide detailed inspection requirements in accordance with NASA Procedural Requirements (NPR) 8735.2, "Management of Government Safety and Mission Assurance Surveillance Functions for NASA Contracts."

2. The Marshall Safety and Mission Assurance Office must provide oversight for the bolt catchers in accordance with NPR 8735.2 for the quality surveillance delegated to Defense Contract Management Agency to include ensuring inspections are performed as required and that Defense Contract Management Agency Quality Assurance Representatives are trained and qualified.

3. Defense Contract Management Agency provides appropriate notification to the Marshall Safety and Mission Assurance Lead for any inspection problems and maintains all required documentation to include inspection records in accordance with its Letter of Delegation.

NASA management concurred with the recommendations. Although the recommendations remain open as of May 2005, we believe that the actions taken and planned by NASA management are responsive to the intent of the audit recommendations. However, we will continue to conduct audits of the Defense Contract Management Agency to ensure those deficiencies are appropriately addressed and to determine whether additional deficiencies or systemic problems exist.

R4.2-3 – Closeout Inspections

Recommendation: Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures.

Status of Recommendation: Closed

NASA closed the recommendation in June 2004 through the SSP Requirements Control Board. The Space Flight Leadership Council approved the closure package. The RTF Task Group concurred with the closure.

NASA not only revised the procedures for intertank closeout inspections but also expanded the concept to all flight hardware projects. A program audit of all final closeouts was performed to ensure compliance with the existing guidelines that a minimum of two persons witness final flight hardware closures for both quality assurance and security purposes. Program level requirements documents have been revised to strengthen and more thoroughly document the two-person closeout rule.

OIG Review: Concur

We conducted an audit and published management letter IG-04-020, "Status of NASA OIG Review of External Tank Thermal Protection System Debris Shedding," June 8, 2004. The report contained no recommendations, and we agreed that NASA was taking the appropriate steps to address the recommendation.

R4.2-5 – Define Foreign Object Debris

Recommendation: Kennedy Space Center Quality Assurance and United Space Alliance must return to the straightforward, industry-standard definition of "Foreign Object Debris," and eliminate any alternate or statistically deceptive definitions like "processing debris."

Status of Recommendation: Closed

The RTF Task Group closed the recommendation. NASA and USA completed the initial benchmarking exercises, identified best practices, modified operating plans and database procedures, and conducted the rollout orientation and initial employee training. Official, full-up implementation began on July 1, 2004. NASA's position is that the full intent of the recommendation was met.

OIG Review: Concur

We concur with the RTF Task Group's closure of the recommendation and believe that an audit of NASA's corrective actions in response to the recommendation is unnecessary.

We believe that the recommendation expressed concern over NASA's use of two separate categories: processing debris and foreign object damage. Because of that, an incorrect

assumption could be made that processing debris was not a serious concern. The CAIB recommended that NASA should adopt what it called a straightforward, industry-standard definition of foreign object debris (FOD).

NASA established a multidiscipline team comprising both NASA civil service employees and contractors to perform fact-finding and benchmarking and gain a better understanding of the industry standards and best practices for FOD prevention. NASA and USA adopted a more comprehensive definition and established FOD control requirements that were taken from the National Aerospace FOD Prevention, Inc., guidelines and industry standards. Those definitions included items such as FOD, foreign object damage, and clean-as-you-go.

NASA redefined FOD as a "substance, debris or article alien to a vehicle or system that could potentially cause damage." The new FOD program eliminated the various categories of FOD, including processing debris. NASA now treats all FOD as preventable with equal importance. In addition, NASA implemented control requirements designed to ensure that the responsibility and authority for the control of FOD was at an operations level where most of the FOD was generated. NASA elevated the importance of comprehensive independent monitoring by contractors and the Government. The increased level of monitoring, which includes inspections, audits, and FOD walks, should also identify areas where additional improvement to the FOD program can be achieved.

Part Two – Why the Accident Occurred

R6.2-1 – Review of Shuttle Flight Schedule

Recommendation: Adopt and maintain a Shuttle flight schedule that is consistent with available resources. Although schedule deadlines are an important management tool, those deadlines must be regularly evaluated to ensure that any additional risk incurred to meet the schedule is recognized, understood, and acceptable.

Status of Recommendation: Open

The RTF Task Group's position is that the recommendation should remain open.

The RTF Task Group assessed NASA's response to the scheduling recommendation and concurred with NASA's position that it has adopted a shuttle flight schedule consistent with the available resources. Congress approved the initial Fiscal Year 2005 budget at the requested level. NASA is reallocating funds to shuttle processing for the RTF effort.

However, as a result of recent budget cuts to the program and the workforce, NASA will need to evaluate any potential impact.

According to the Implementation Plan, schedule threats are regularly assessed and unacceptable risks mitigated. In support of the Program Operating Plan (POP) process, NASA shuttle processing and management of USA Ground Operations use the Equivalent Flow Model (EFM) to plan resources that in NASA's view are consistent with the shuttle flight schedule provided in the POP guidelines. The EFM is a software tool that calculates processing resource requirements by using past performance and a planned manifest. To assess and manage the manifest, NASA developed a process called the Manifest Assessment System. The system tailors the schedule to incorporate manifest constraints and influences, which allows adequate margins to accommodate a normalized amount of changes.

OIG Review: Concur With Comment

We conducted an audit, "Review of Shuttle Flight Scheduling" (Assignment No. A-04-011-00), but suspended it because we believe NASA was taking appropriate steps for maintaining a flight schedule that is consistent with available resources. However, we believe that NASA needs to be vigilant in ensuring that its flight schedule is rational and does not become more important than its conscience. NASA employees must not feel undue pressure that would cause them to focus more on adhering to the RTF timeline than prudently assessing flight risks. We also concur with the RTF Task Group to keep the recommendation open in order to evaluate recent budget impacts.

R6.3-1 – Expanded Training of Shuttle MMT

Recommendation: Implement an expanded training program in which the Mission Management Team faces potential crew and vehicle safety contingencies beyond launch and ascent. These contingencies should involve potential loss of Shuttle or crew, contain numerous uncertainties and unknowns, and require the Mission Management Team to assemble and interact with support organizations across NASA/Contractor lines and in various locations.

Status of Recommendation: Open

NASA has undertaken a dramatically expanded training plan, which includes self-study readings, training courses, and full-up mission simulations to practice what was learned. An 8-day, complete end-to-end dress rehearsal of the first RTF mission took place at both Kennedy Space Center and Johnson Space Center in February and March 2005. Based on the results of the end-to-end dress rehearsal, the SSP held an additional, 1-day

simulation. Because the recommendation is an RTF constraint, the RTF Task Group has extensively reviewed the recommendation.

OIG Review: Ongoing

We have an ongoing audit, "Shuttle Mission Management Team" (Assignment No. A-04-014-00), on the recommendation. We identified concerns with NASA's MMT Training Plan, internal control weaknesses, and inaccuracies in the MMT training database, as well as a lack of training objectives for the simulations.

MMT Training Plan. As part of our review, we attended, reviewed, and commented on every core training course and attended and commented on 11 MMT simulations. We used the opportunity to discuss our concerns as they arose directly with the MMT so that the MMT could address those concerns during the plan's development. As of May 5, 2005, NASA's database details the 79 comments we had provided the MMT concerning improvements that could be made, of which 70 have been acted upon. Although these were not formal recommendations, we are in the process of validating the actions taken to address them. The comments we provided on the proposed MMT Training Plan have been incorporated into the approved MMT Training Plan. The SSP Requirements Control Board approved the MMT Training Plan and the MMT Roles and Responsibilities.

MMT Training Database. We reviewed the SSP MMT training database in March 2004 and June 2004. We noted areas of internal control weaknesses and inaccuracies. For example, some MMT members were receiving credit for attending simulations or training courses when their name was not on the sign-in sheets. In some cases, the database had several training activities in one column, which resulted in a member receiving credit for having attended all the training activities listed in the column, even if only one activity had been attended. The weaknesses existed because no checks and balances were in place that would ensure the correct recording of MMT member participation in the expanded training program. As a result, the SSP made corrections to the processes and training database. On April 29, 2005, the SSP approved a unique work instruction that incorporates the checks and balances required to ensure internal controls are in place, which should ensure that training records accurately reflect the MMT members' training and certification. MMT members must obtain certification prior to participating in prelaunch or on-orbit activities. We provided our observations for improvement.

Simulation Training Objectives. We submitted comments to the MMT Chair on several areas: operational risk management, NASA culture, definition of MMT roles and responsibilities, the lack of training objectives for the simulations, and improvements in information management. We also provided comments to the RTF Task Group, which it included with its requirements for RTF approval. Although we reviewed the additional

RTF Task Group requirements, we are not commenting on them as they fall outside the scope of our audit.

Most MMT training events have been completed. While we verified the key elements of the MMT expanded training program, the proof of success will be in the performance of the MMT during the first RTF mission. The OIG will continue to assess MMT performance through that mission, scheduled for July 2005 (STS-114).

In order for us to verify that the MMT applies the knowledge gained from the training simulations, we plan to audit the RTF mission and comment as appropriate.

Part Three – A Look Ahead

R9.1-1 – Detailed Plan for Organizational Change

Recommendation: Prepare a detailed plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office as described in R7.5-1, R7.5-2, and R7.5-3. In addition, NASA should submit annual reports to Congress, as part of the budget review process, on its implementation activities.

Status of Recommendation: Open

NASA published "NASA's Plan for Implementing Safe and Reliable Operations," November 15, 2004 (commonly referred to as the 9.1-1 Plan). That plan describes the newly established technical authority, improvements to the SMA Office, and the reorganized Space Shuttle Systems Engineering and Integration Office. Although the CAIB only recommended that NASA comply with R9.1-1 before returning the space shuttle to flight, NASA is jointly addressing R9.1-1 and the reorganization steps called for in three CTF recommendations (R7.5-1, R7.5-2, and R7.5-3). For R7.5-1, NASA introduced a formalized technical authority concept and a system of governing warrants. For R7.5-2, NASA strengthened the authority, independence, and capability of SMA. For R7.5-3, NASA reorganized the Space Shuttle Integration Office. See Appendix C for details.

NASA submitted closure rationale to the RTF Task Group, but the RTF Task Group has kept the recommendation open pending further implementation of the 9.1-1 Plan.

OIG Review: Ongoing

Because NASA's rationale in meeting the intent of this recommendation is dependent upon the reorganization steps called for in the three CTF recommendations (R7.5-1, R7.5-2, and R7.5-3), we audited those CTF recommendations. On December 8, 2003, we issued "Comments on Proposed Options for NASA's Implementation of Columbia Accident Investigation Board Recommendations 7.5-1 and 7.5-2" to the Administrator.

On April 2, 2004, we issued an informal e-mail advising NASA management of our concerns with the implementation of R7.5-1 and R7.5-2. We have an ongoing audit, "Risks Associated With NASA's Plan for Technical Authority and Safety and Mission Assurance" (Assignment No. A-04-004-00), of the reorganization steps called for in the three CTF recommendations (R7.5-1, R7.5-2, and R7.5-3). A discussion draft audit report was issued April 25, 2005. Informal comments received on May 4, 2005, in response to the discussion draft are not reflected in this summary. We will consider those comments in preparing the draft report, which may result in modifications to the discussion draft report. Draft reports are not publicly available. Our final report, which will be publicly available, will not be issued until July at the earliest.

Although NASA has taken steps to address CAIB concerns related to the Space Shuttle Integration Office (R7.5-3), we believe that NASA's draft plan for the organization structure of the technical authority poses some risks (R7.5-1). Specifically, while the plan makes it clear that Technical Warrant Holders are ultimately accountable for technical requirements, the draft plan does not include processes and procedures to monitor the warrant system and to ensure that the integrity, competence, and independence of the individual Technical Warrant Holders are maintained. However, we did not make any recommendations on the draft plan because implementation is still in the early stages of development. We will continue to monitor NASA's implementation of the technical authority. Additionally, NASA has diverged from the explicit intent of the CAIB recommendation (R7.5-2) and does not implement direct line funding or reporting for all SMA personnel. SMA funding will continue to be potentially subject to programmatic budget pressures, particularly as vehicle retirement draws near. Additionally, NASA still needs a method of independently verifying that SMA functions are effectively providing all personnel a defined path for elevating their concerns.

R10.3-1 – Digitize Closeout Photos

Recommendation: Develop an interim program of closeout photographs for all critical sub-systems that differ from engineering drawings. Digitize the closeout photograph system so that images are immediately available for on-orbit troubleshooting.

Status of Recommendation: Closed

NASA considers the recommendation closed. The RTF Task Group accepted the closure rationale that NASA submitted.

NASA formed a Photo Closeout Team consisting of members from the engineering, quality assurance, and technical communities to identify and implement necessary upgrades to process and equipment involved in vehicle closeout photography. The team's focus was on

- increasing the quantity and quality of closeout photographs, and
- improving the retrieval process through a user-friendly Web-based graphical system.

OIG Review: Concur

We conducted our assessment in June 2004. We interviewed the project engineer, attended the RTF Task Group plenary session, and studied the closeout briefing presented at the plenary session. We concur with the closeout position because the SSP has greatly improved the quality and accessibility of the closeout photograph system as mandated by the CAIB.

Appendix C
CTF Recommendations

CAIB "Continuing to Fly" Recommendations, Actions, and OIG Review

R3.3-3 – Sustain Leading Edge Damage 33
R3.3-4 – Flown RCC Database 34
R3.3-5 – Launch Pad Leaching Zinc Primer 34
R3.8-1 – Spare RCC Panels 35
R3.8-2 – Computer Models of TPS Damage 36
R3.6-1 – Modular Auxiliary Data System Update 37
R3.6-2 – MADS Redesign 38
R4.2-2 – Inspect Orbiter Wiring 39
R4.2-4 – Micrometeoroid and Orbital Debris Degree of Safety 40
R7.5-1 – Independent Technical Authority Organization 41
R7.5-2 – Independent Safety and Mission Assurance 43
R7.5-3 – Reorganize Space Shuttle Integration Office 45
R9.2-1 – Space Shuttle Mid-Life Recertification 46
R10.3-2 – Upgrade Engineering Drawings 46

Part One – The Accident

R3.3-3 – Sustain Leading Edge Damage

Recommendation: To the extent possible, increase the Orbiter's ability to successfully re-enter Earth's atmosphere with minor leading edge structural subsystem damage.

Status of Recommendation: Open

Because this recommendation is not an RTF constraint, the RTF Task Group will not review or concur on its closure.

As a result of shuttle design and the material characteristics of RCC, NASA can do little to change the actual material characteristics in order to address the recommendation. The CAIB recognized that fact and added the caveat of "to the extent possible" to the recommendation. One way that NASA has identified that reentry with minor damage might be possible is to fly entry trajectories that reduce the amount of aerodynamic

heating the space shuttle normally encounters. Those cooler trajectories, however, are not certified for flight. NASA is studying whether the cooler trajectories can be safely flown and certified for Shuttle entry.

OIG Review: Concur

Although we have not conducted any formal reviews on the recommendation, we believe that limited options are available and support the direction NASA has taken to close the recommendation.

R3.3-4 – Flown RCC Database

Recommendation: In order to understand the true material characteristics of Reinforced Carbon-Carbon components, develop a comprehensive database of flown Reinforced Carbon-Carbon material characteristics by destructive testing and evaluation.

Status of Recommendation: Open

Because this recommendation is not an RTF constraint, the RTF Task Group will not review or concur on its closure.

NASA continues to analyze flown RCC to understand the effects of flight on the material characteristics of flown RCC. Plans exist for analyzing a panel and a nose cap from *Discovery* that were damaged during the refurbishment process. Although not the contractor's fault, the damage to the nose cap occurred while the part was baking in an oven during refurbishment. NASA is developing plans to cut pieces from the panel into sample sizes that can be analyzed by various labs.

OIG Review: Concur

Although we have not conducted any formal reviews on the recommendation, we believe that NASA is taking the appropriate steps to address the recommendation.

R3.3-5 – Launch Pad Leaching Zinc Primer

Recommendation: Improve the maintenance of launch pad structures to minimize the leaching of zinc primer onto Reinforced Carbon-Carbon components.

Status of Recommendation: Closed

NASA closed this recommendation in April 2004 through the SSP Requirements Control Board. Because this recommendation was not an RTF constraint, the RTF Task Group did not review or concur on its closure.

NASA will mitigate the zinc-leaching problem by better preventative maintenance and launch pad cleaning procedures to preserve the primer's top coating, and then continue inspections and perform tests to make sure zinc leaching does not occur.

Mitigation actions include the following:

- Better corrosion control of the pad by painting any spots where zinc primer is evident. Pad inspections will be done quarterly rather than yearly to identify areas for painting.
- A washdown of the pad before the vehicle is brought out, so less zinc migrates to the vehicle.
- After a launch, a more thorough washdown of the pad will be conducted to remove solid rocket booster exhaust reside, which attacks the launch pad paint.

OIG Review: Concur

We conducted an assessment in June 2004. We interviewed the project engineer and studied the closeout briefing presented to the SSP Requirements Control Board. We believe that the SSP has a viable plan that lessens the possibility of zinc leaching onto the orbiter structure. The SSP funded the actions in the mitigation plan. Even though the recommendation is not an RTF-specific recommendation, SSP stated that the actions are expected to be completed before RTF.

R3.8-1 – Spare RCC Panels

Recommendation: Obtain sufficient spare Reinforced Carbon-Carbon panel assemblies and associated support components to ensure that decisions on Reinforced Carbon-Carbon maintenance are made on the basis of component specifications, free of external pressures relating to schedules, costs, or other considerations.

Status of Recommendation: Open

Because this recommendation is not an RTF constraint, the RTF Task Group will not review or concur on its closure.

NASA continues to debate the number of panels needed from now until the end of the SSP. The cost of the panels has increased substantially, and the SSP is balancing the need for spare panels with other risk-reducing RTF actions.

OIG Review: Ongoing

We have not conducted any formal reviews on the recommendation because NASA has not selected a course of action.

R3.8-2 – Computer Models of TPS Damage

Recommendation: Develop, validate, and maintain physics-based computer models to evaluate Thermal Protection System damage from debris impacts. These tools should provide realistic and timely estimates of any impact damage from possible debris from any source that may ultimately impact the Orbiter. Establish impact damage thresholds that trigger responsive corrective action, such as on-orbit inspection and repair, when indicated.

Status of Recommendation: Open

Because this recommendation is not an RTF constraint, the RTF Task Group will not review or concur on its closure.

NASA is committed to closing this recommendation prior to RTF even though it is not an RTF-required action. NASA engineers are developing a physics-based model that uses DYNA Model computer code and finite element modeling designed to predict when impacts from debris may have damaged the shuttle's TPS. The model will be used to predict damage, estimate the significance of that damage, and help quantify the risk of that damage to the crew and vehicle on reentry.

NASA has calculated foam damage thresholds based on the prediction of a through crack. DYNA Model validation is underway and on schedule for modeling foam against RCC. NASA continues to calculate the ice damage threshold, also based on the prediction of through cracks, and will perform a correlation of the model results to the threshold for the start of delamination.

OIG Review: Ongoing

Although we have not conducted any formal reviews on the recommendation, we believe that groundbreaking work has occurred. We have followed NASA's progress in addressing the recommendation. We reviewed work on the DYNA Model development effort, witnessed the impact testing of RCC at both Glenn Research Center and Southwest

Research Institute in San Antonio, studied the effects of foam shedding from the ET, and attended the debris summit at Houston. We will continue to follow the progress of the ongoing work.

R3.6-1 – Modular Auxiliary Data System Update

Recommendation: The Modular Auxiliary Data System instrumentation and sensor suite on each Orbiter should be maintained and updated to include current sensor and data acquisition technologies.

Status of Recommendation: Closed

NASA closed the recommendation in May 2004 through the SSP Requirements Control Board. Because this recommendation was not an RTF constraint, the RTF Task Group did not review or concur on its closure.

As reported in NASA's Implementation Plan, NASA will maintain the Modular Auxiliary Data System (MADS), including flight hardware, ground support equipment, sensor components, and data acquisition components for the remainder of the SSP. Upgrades to the current system and additional sensor requirements are covered under R3.6-2.

OIG Review: Concur

We closed our review on the recommendation, "Review of Orbiter Modular Auxiliary Data System" (Assignment No. A-04-019-00), on April 28, 2005. We reviewed and found NASA's plans for maintaining the existing MADS to be adequate. Because of implementation constraints and system compatibility issues associated with the implementation of the "current sensor and data acquisition technologies" elements of the recommendation, NASA requested to transfer nonmaintenance elements of this recommendation to R3.6-2. The CAIB accepted the transfer.

NASA developed a viable plan that addresses the maintenance elements of the recommendation by acquiring and certifying new MADS wideband instrumentation tape that should extend through 2006 the operational life of the MADS recorder. With the cancellation of the Vehicle Health Monitoring System (VHMS) (which is addressed under R3.6-2), MADS is no longer scheduled as previously planned for replacement in 2006. NASA will continue procurement and certification efforts to ensure a usable supply of the new tape through 2010.

The sourcing of magnetic tape was a key element for ensuring that MADS would continue to operate through the end of life for the space shuttle. We concur with NASA's

closure of the recommendation because NASA met the intent of the maintenance elements of the recommendation.

R3.6-2 – MADS Redesign

Recommendation: The Modular Auxiliary Data System should be redesigned to include engineering performance and vehicle health information, and have the ability to be reconfigured during flight in order to allow certain data to be recorded, telemetered, or both as needs change.

Status of Recommendation: Open

Because this recommendation is not an RTF constraint, the RTF Task Group will not review or concur on its closure.

The Implementation Plan states that NASA was planning for the VHMS to collect, condition, sample, time-tag, and store sensor data. The collected data would be downlinked to the ground during flight operations or archived for download after landing. VHMS was planned to also allow the addition of other sensor data and instrumentation systems. However, in December 2004, the SSP canceled the VHMS project.

Independent of the VHMS cancellation, NASA was redesigning MADS to enable the downlink of vehicle data to ground stations during missions by routing digital data through the Pulse Code Modulation Unit to a solid-state recording unit. NASA was also considering the use of additional sensors to measure pressure, temperature, and strain.

OIG Review: Concur

We closed our review on the recommendation, "Review of Orbiter Modular Auxiliary Data System" (Assignment No. A-04-019-00), on April 28, 2005. We found that NASA's plans for developing the VHMS were adequate, reasonable, and complete. However, we identified a number of areas that had a potential to affect the ultimate implementation of the plans, including indefinite funding path, high demands for scarce personnel resources, an aggressive implementation schedule, a high level of invasiveness required to install common sensor suites across all orbiters, and the relatively low priority of MADS and VHMS.

We had intended to recommend that NASA reassess the overall value and feasibility of VHMS within the context of the President's Vision for Space Exploration, NASA's changing space exploration strategy, and potential implementation constraints. As part of such a reassessment, we thought that NASA should also consider the availability of other orbiter data sources that could satisfy key elements of R3.6-1 and R3.6-2.

NASA canceled the VHMS project because, in light of the President's Vision for Space Exploration, the SSP determined that the VHMS project was not a high priority investment. VHMS was not considered a direct safety upgrade. Although VHMS would have provided additional insight into the condition of the orbiter during an individual mission, VHMS did not directly affect the probability of catastrophic damage to the vehicle.

Our review was based on the premise that VHMS would fully address the CAIB recommendations related to MADS. This assignment was closed because our review objectives, finding, and intended recommendation became outdated with the cancellation of VHMS.

R4.2-2 – Inspect Orbiter Wiring

Recommendation: As part of the Shuttle Service Life Extension Program and potential 40-year service life, develop a state-of-the-art means to inspect all Orbiter wiring, including that which is inaccessible.

Status of Recommendation: Closed

NASA closed this recommendation in June 2004 through the SSP Requirements Control Board. Because this recommendation was not an RTF constraint, the RTF Task Group did not review or concur on its closure.

NASA plans to proceed with the inspection and detection process in place since August 1999 and to fund the development of Destructive Evaluation Age Life Testing.

Mitigation actions for orbiter wiring that were implemented since the CAIB Report include the following:

- The SSP is separating redundant wires that were in the same wire bundle to minimize the risk of losing a critical system to which the wire bundle was attached. Redundant wires are designed to perform the same function and serve as a backup to each other should one of the wires fail during flight.

- The SSP implemented a database known as the Avionics Damage Database that provides graphical images of historical wiring damage showing the severity and location of wiring damage. The images can be used to highlight higher risk areas for more thorough visual inspection.

- The SSP will study wiring removed during repair work to determine the extent of aging and give insight into the remaining life of shuttle wiring. Preliminary study results were to be available in April 2005.

OIG Review: Nonconcur

We conducted an audit, "Review of Orbiter Wiring" (Assignment No. A-04-010-00), and issued a discussion draft report on this recommendation on March 16, 2005. Informal comments received in response to the discussion draft are reflected in this summary. We expect to issue a draft report for formal comments in May 2005.

We conducted investigations and interviews throughout the last half of 2004. We interviewed the lead wiring investigator for the CAIB, the Nation's leading expert in Kapton (a specific composite film used for insulation) wiring; SSP managers; orbiter electrical engineers; and scientists researching new evaluation technology. We also studied program documents, which included plans for implementing the recommendation, the closeout briefing presented to the SSP Requirements Control Board, and notes from the briefing. Additionally, we reviewed technical studies on wire aging and inspection.

NASA has canceled plans to continue developing and testing state-of-the-art technology for evaluating orbiter wiring based on their conclusion that the new technology would not be cost effective or ready before the planned 2010 shuttle retirement and funding constraints. Without new evaluation technology, the inability to detect unseen wiring problems will continue to be a safety risk for the orbiter and any next-generation space vehicles. NASA should establish a formal procedure that will transmit lessons learned from the canceled technology development plans to facilitate development of new evaluation technology for wiring inspection of the next generation space vehicle. In order to meet the intent of the CAIB recommendation, NASA should not consider the end of service life in the development of a comprehensive evaluation. NASA should also formally assess the risk of aging and damaged orbiter wiring and develop a risk mitigation plan based on that risk assessment. We do not concur with the closure of this recommendation because we do not believe that NASA's actions met the intent of the recommendation.

R4.2-4 – Micrometeoroid and Orbital Debris Degree of Safety

Recommendation: Require the Space Shuttle to be operated with the same degree of safety for micrometeoroid and orbital debris as the degree of safety calculated for the International Space Station. Change the micrometeoroid and orbital debris safety criteria from guidelines to requirements.

Status of Recommendation: Open

Because this recommendation is not an RTF constraint, the RTF Task Group will not review or concur on its closure.

The Implementation Plan reports that in order to comply with the recommendation to operate the orbiter with the same degree of safety for micrometeoroid and orbital debris (MMOD) as calculated for the ISS, NASA is evaluating the following options for possible implementation in the long term:

- orbiter vehicle design upgrades to decrease vulnerability to MMOD,
- operational changes during the docked mission phase,
- the development of an inspection capability to detect and repair critical damage, and
- the addition of an onboard impact sensor system to detect critical damage that may occur to the TPS during ascent or while on orbit.

Once the orbiter's degree of safety is fully defined, NASA will change the MMOD safety criteria from guidelines to requirements.

OIG Review: Ongoing

We will follow NASA's progress in meeting the recommendation. We interviewed project managers and contract support staff and reviewed related documentation, including the Implementation Plan, and concur with NASA's approach. NASA has developed a viable plan that includes vehicle hardening, attitude adjustments while docked with the ISS, detection of MMOD impacts, identification and interrogation of impacts through on-orbit inspection, repair of critical impact damage through on-orbit repair techniques, and contingency shuttle crew support operations. Although many of the capabilities related to detection, inspection, and repair have not been proven during an actual flight test or are under development, the logic is sound.

Part Two – Why the Accident Occurred

R7.5-1 – Independent Technical Authority Organization

Recommendation: Establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards

throughout the life cycle of the Shuttle System. The independent technical authority does the following as a minimum:

- Develop and maintain technical standards for all Space Shuttle Program projects and elements
- Be the sole waiver-granting authority for all technical standards
- Conduct trend and risk analysis at the sub-system, system, and enterprise levels
- Own the failure mode, effects analysis and hazard reporting systems
- Conduct integrated hazard analysis
- Decide what is and is not an anomalous event
- Independently verify launch readiness
- Approve the provisions of the recertification program called for in [R9.2-1].

The Technical Engineering Authority should be funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost.

Status of Recommendation: Open

Although this recommendation is not an RTF constraint, the RTF Task Group will review and concur on its closure in conjunction with R9.1-1.

NASA introduced a formalized technical authority concept administered by the Chief Engineer. The Chief Engineer is charged with developing a technical conscience throughout the engineering community. Technical authority and technical conscience are to be built into the NASA culture to uphold sound technical decisions by personnel who are outside the SSP. The Chief Engineer empowered selected individuals through a system of governing warrants. Those individuals will be subject matter experts operating independently from major programs. The warrant system is intended to provide a disciplined, formal procedure that is standardized across NASA and recognized inside and outside of NASA as a way of executing independent technical authority.

NASA submitted closure rationale to the RTF Task Group, but the RTF Task Group has kept the recommendation open while awaiting further implementation of the 9.1-1 Plan.

OIG Review: Ongoing

We have an ongoing audit, "Risks Associated With NASA's Plan for Technical Authority and Safety and Mission Assurance" (Assignment No. A-04-004-00), on the recommendation. On December 8, 2003, we issued "Comments on Proposed Options for

NASA's Implementation of Columbia Accident Investigation Board Recommendations 7.5-1 and 7.5-2" to the Administrator. So that the input could be taken into account as early as possible, we provided NASA with our observations on its draft Independent Technical Authority plan on April 2, 2004.

A discussion draft audit report on Assignment No. A-04-004-00 was issued April 25, 2005. Informal comments received on May 4, 2005, in response to the discussion draft are not reflected in this summary. We will consider those comments in preparing the draft report, which may result in modifications to the discussion draft report. Draft reports are not publicly available. Our final report, which will be publicly available, will not be issued until July at the earliest.

We believe that the organizational structure outlined for the technical authority in the draft plan poses some risks. Specifically, while the plan makes it clear that Technical Warrant Holders are ultimately accountable for technical requirements, it does not include processes and procedures to monitor the warrant system and to ensure that the integrity, competence, and independence of the individual Technical Warrant Holders are maintained. Additionally, there continues to be a healthy debate over what standards and requirements the Technical Warrant Holders will own, what ownership means, and how engineering and SMA standards will be integrated to ensure that both technical and safety concerns are appropriately addressed. Because the implementation of the plan is still under development and we provided our observations to NASA's draft plan on April 2, 2004, we did not make any recommendations in our discussion draft report issued April 25, 2005. However, we will continue to monitor NASA's implementation of the technical authority.

R7.5-2 – Independent Safety and Mission Assurance

Recommendation: NASA Headquarters Office of Safety and Mission Assurance should have direct line authority over the entire Space Shuttle Program safety organization and should be independently resourced.

Status of Recommendation: Open

Although this recommendation is not an RTF constraint, the RTF Task Group will review and concur on its closure in conjunction with R9.1-1.

NASA strengthened the Office of SMA in three areas: authority, independence, and capability. NASA's plan calls for the following changes:

- SMA authority will be enhanced by allowing the Headquarters Chief SMA Officer influence over selection, relief, and performance evaluations of Center and Program SMA directors.

- SMA independence will be strengthened by creating funding for SMA labor by way of directed service pools. Those pools will be determined by the institutional committees and will be more independent from program influences. SMA labor will be applied to programs or projects in areas and levels deemed necessary by the SMA directors and their institutional chain of authority.

- SMA capability will be increased by hiring additional SMA personnel at Headquarters and the Centers.

Specific to the SSP, SMA will be strengthened by hiring additional staff for the SSP's SMA Office. That office will integrate the safety, reliability, and quality activities performed by all Centers for the various project and program elements. In addition, Center SMA directors will have a more thorough knowledge of the readiness of SMA elements to support the space shuttle mission by conducting a more wide-ranging review, which would culminate with the SSP SMA Office's concurrence on the Certificate of Flight Readiness.

NASA submitted closure rationale to the RTF Task Group, but the RTF Task Group has kept the recommendation open while awaiting further implementation of the 9.1-1 Plan.

OIG Review: Ongoing

We have an ongoing audit, "Risks Associated With NASA's Plan for Technical Authority and Safety and Mission Assurance" (Assignment No. A-04-004-00), on the recommendation. On December 8, 2003, we issued "Comments on Proposed Options for NASA's Implementation of Columbia Accident Investigation Board Recommendations 7.5-1 and 7.5-2" to the Administrator.

A discussion draft audit report was issued April 25, 2005. Informal comments received on May 4, 2005, in response to the discussion draft are not reflected in this summary. We will consider those comments in preparing the draft report, which may result in modifications to the discussion draft report. Draft reports are not publicly available. Our final report, which will be publicly available, will not be issued until July at the earliest.

We believe NASA's plan to strengthen the independent funding and reporting paths have significantly improved SMA functions across the Agency. However, NASA has

diverged from the explicit intent of the CAIB recommendation and does not implement direct line funding or reporting for all SMA personnel. The funding for SMA is more insulated from SSP control than the pre-*Columbia* period. However, SMA funding will continue to be subject to programmatic budget pressures especially as vehicle retirement draws near. Additionally, NASA still needs a method to independently verify that SMA functions are effectively providing all personnel a defined path for elevating their concerns. Failure to fully implement independent reporting and funding paths will prevent NASA from addressing the cultural concerns associated with speaking up and over the institutional or program chain of commands, and may ultimately prevent the Agency from making the best SMA decisions. We believe that NASA should establish at the appropriate Centers a small cadre of SMA personnel who have independent funding and direct-line reporting to the Chief SMA Office at Headquarters.

R7.5-3 – Reorganize Space Shuttle Integration Office

Recommendation: Reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Orbiter.

Status of Recommendation: Open

Although this recommendation is not an RTF constraint, the RTF Task Group will review and concur on its closure in conjunction with R9.1-1.

NASA strengthened the integration of all elements of the SSP by forming the Space Shuttle Systems Engineering and Integration Office (SEIO). The SEIO manager reports directly to the SSP Manager, and SEIO's charter clearly establishes the authority and accountability for integration of all space shuttle elements.

NASA submitted closure rationale to the RTF Task Group, but the RTF Task Group has kept the recommendation open while awaiting further implementation of the 9.1-1 Plan.

OIG Review: Ongoing

We have an ongoing audit, "Risks Associated With NASA's Plan for Technical Authority and Safety and Mission Assurance" (Assignment No. A-04-004-00), on the recommendation. A discussion draft audit report was issued April 25, 2005. Informal comments received on May 4, 2005, in response to the discussion draft are not reflected in this summary. We will consider those comments in preparing the draft report, which may result in modifications to the discussion draft report. Draft reports are not publicly available. Our final report, which will be publicly available, will not be issued until July at the earliest.

We believe that NASA has made numerous positive steps toward meeting the intent of the recommendation. We concur with NASA's response to Recommendation 7.5-3 because it integrates all the elements of the SSP into the SEIO.

Part Three – A Look Ahead

R9.2-1 – Space Shuttle Mid-Life Recertification

Recommendation: Prior to operating the Shuttle beyond 2010, develop and conduct a vehicle recertification at the material, component, subsystem, and system levels. Recertification requirements should be included in the Service Life Extension Program.

Status of Recommendation: Open

This recommendation is open pending the final assessment presentation for all Criticality 1 hardware to the SSP Requirements Control Board. All Criticality 1 hardware is being assessed prior to RTF, with other lower criticality hardware assessments continuing through 2006. Because this recommendation is not an RTF constraint, the RTF Task Group will not review or concur on its closure.

The President's Vision for Space Exploration advocates retiring the space shuttle by 2010. Therefore, the vehicle mid-life recertification efforts were de-scoped to reflect the shorter lifespan. Rather than conduct a time-consuming and expensive recertification effort with little overall gain, NASA chose to revalidate and review the operational loads, vibration, and acoustic and thermal environments of the space shuttle's original systems certification.

OIG Review: Concur

Although we have not conducted any formal reviews on the recommendation, we concur with NASA's de-scoping of the recertification effort because of the accelerated retirement of the space shuttle vehicles. NASA's efforts to revalidate the operational environment should improve the safety and reliability of the space shuttle and potentially reduce the risk of future problems.

R10.3-2 – Upgrade Engineering Drawings

Recommendation: Provide adequate resources for a long-term program to upgrade the Shuttle engineering drawing system including:

- Reviewing drawings for accuracy

- Converting all drawings to a computer-aided drafting system
- Incorporating engineering changes

Status of Recommendation: Closed

NASA closed this recommendation in June 2004 through the formal SSP Requirements Control Board. Because this recommendation was not an RTF constraint, the RTF Task Group did not review or concur on its closure.

NASA planned to convert all orbiter drawings to computer-aided design models and incorporate all outstanding engineering orders. However, that would have taken 3 years and $150 million to accomplish. Because of the accelerated retirement of the space shuttle vehicles, NASA decided not to undertake the computer-aided design upgrade, but did incorporate some outstanding engineering orders into the existing computer-aided design models.

OIG Review: Concur

Although we have not conducted any formal activity on the recommendation, we concur with NASA's downscaling of the engineering drawing effort because of the accelerated retirement of the space shuttle vehicles.

Appendix D
Audit Coverage

Government Accountability Office (GAO)

GAO-05-492R, "NASA: Compliance with Cost Limits," April 8, 2005
GAO-05-230, "Space Shuttle: Actions Needed to Better Position NASA to Sustain Its Workforce Through Retirement," March 9, 2005
GAO-05-242, "NASA's Space Vision: Business Case for Prometheus 1 Needed to Ensure Requirements Match Available Resources," February 28, 2005
GAO-05-34, "Space Shuttle: Costs for Hubble Servicing Mission and Implementation of Safety Recommendations Not Yet Definitive," November 19, 2004
GAO-04-201T, "NASA: Shuttle Fleet's Safe Return to Flight Is Key to Space Station Progress," October 29, 2003
GAO-03-1107, "Space Station: Impact of the Grounding of the Shuttle Fleet," September 12, 2003

NASA Reports

"Memorandum on NASA's Response to the Columbia Accident Investigation Board's Recommendations Concerning the Modular Auxiliary Data System (A-04-019-00)," April 28, 2005
IG-04-024, "Final Memorandum on Government Mandatory Inspections for Solid Rocket Booster Bolt Catchers," September 28, 2004
IG-04-020, "Status of NASA OIG Review of External Tank Thermal Protection System Debris Shedding," June 8, 2004
"Status of NASA Office of Inspector General Review of Space Shuttle Imaging, Audit Assignment A-04-007-00," April 16, 2004
IG-04-014, "Audit of Incentive/Award Fee Structure Under the Space Flight Operations Contract," March 23, 2004

NASA OIG Assignments (draft reports not available outside of NASA)

A-04-004-00, "Risks Associated With NASA's Plan for Technical Authority and Safety and Mission Assurance" (discussion draft issued April 25, 2005)
A-04-010-00, "Review of Orbiter Wiring" (discussion draft issued March 16, 2005)
A-04-011-00, "Review of Shuttle Flight Scheduling" (suspended)
A-04-014-00, "Review of NASA's Actions to Implement an Expanded Training Program for the Shuttle Mission Management Team" (ongoing)

Appendix E
Report Distribution

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House Committee on Science
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Acronyms

CAIB	Columbia Accident Investigation Board
CTF	Continuing to Fly
EFM	Equivalent Flow Model
ET	External Tank
FOD	Foreign Object Debris
GAO	Government Accountability Office
ISS	International Space Station
MADS	Modular Auxiliary Data System
MMOD	Micrometeoroid and Orbital Debris
MMT	Mission Management Team
NPR	NASA Procedural Requirements
OA	Office of Audits
OBSS	Orbiter Boom Sensor System
OIG	Office of Inspector General
OV	Orbiter Vehicle
POP	Program Operating Plan
RCC	Reinforced Carbon-Carbon
RTF	Return to Flight
SEIO	Space Shuttle Systems Engineering and Integration Office
SFOC	Space Flight Operations Contract
SMA	Safety and Mission Assurance
SSP	Space Shuttle Program
STS	Space Transport System
TPS	Thermal Protection System
USA	United Space Alliance
VHMS	Vehicle Health Monitoring System
WLE	Wing Leading Edge

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