Return to Flight
Task Group

Executive Summary

June 28, 2005

EXECUTIVE SUMMARY

It has been 29 months since *Columbia* was lost over East Texas in February 2003. Seven months after the accident, the Columbia Accident Investigation Board (CAIB) released the first volume of its final report, citing a variety of technical, managerial, and cultural issues within NASA and the Space Shuttle Program. To their credit, NASA offered few excuses, embraced the report, and set about correcting the deficiencies noted by the accident board. Of the 29 recommendations issued by the CAIB, 15 were deemed critical enough that the accident board believed they should be implemented prior to returning the Space Shuttle fleet to flight. Some of these recommendations were relatively easy, most were straightforward, a few bordered on the impossible, and others have been largely overcome by events, especially with the decision by the President to retire the Space Shuttle by 2010.

The Return to Flight Task Group (RTF TG) was chartered by the NASA Administrator in July 2003 to provide an independent assessment of the implementation of the 15 CAIB return-to-flight recommendations. An important observation must be stated up-front: neither the CAIB nor the RTF TG believes that all risk can be eliminated from Space Shuttle operations; nor do we believe that the Space Shuttle is inherently unsafe. What the CAIB and RTF TG do believe, however, is that NASA and the American public need to understand the risks associated with space travel, and make every reasonable effort to minimize such risk.

Since the release of the CAIB report, NASA and the Space Shuttle Program have expended enormous effort and resources toward correcting the causes of the accident and preparing to fly again. Relative to the 15 specific recommendations that the CAIB indicated should be implemented prior to returning to flight, NASA has met or exceeded most of them – the Task Group believes that NASA has fully met the intent of the CAIB for 12 of these recommendations. The remaining three recommendations were so challenging that NASA could not completely comply with the intent of the CAIB, but conducted extensive study, analyses, hardware modifications, design certifications and made substantive progress. However, the inability to fully comply with all of the CAIB recommendations should not imply that the Space Shuttle is unsafe.

Workers in the Launch Control Center at the Kennedy space Center watch *Discovery* during her slow trip to LC-39B at the Kennedy Space Center.

Although the scorecard is impressive, it alone does not tell the complete story. The Task Group applauds NASA for their efforts, but urges continued vigilance to prevent another accident. Spaceflight is a demanding pursuit, and the President, Congress, NASA, and the American public must provide the proper resources and environment to ensure it is conducted in the safest and most efficient manner possible.

However, it is important to reiterate: the NASA Administrator and his staff – not the CAIB or the RTF TG – will ultimately determine if the remaining risk is sufficiently low to allow the Space Shuttle to return to flight. The Task Group can not, and will not, make a determination of the safety or reliability of the next flight; that is NASA's responsibility.

On the hardware side, Solid Rocket Booster Bolt Catcher was redesigned in order to qualify it to existing requirements. The External Tank has been modified to eliminate the bipod ramp foam that was the physical cause of the *Columbia* accident. The processes for manual application of foam insulation have been changed to include greater process control and quality inspection. Much has been learned about the foam and ice and what causes them to shed from the tank during ascent. Heaters have been added to areas of the External Tank to impede the formation of ice, and various other flaws in the design and manufacture of the tank were discovered and corrected along the way. Nevertheless, despite diligent work, it has proven impossible to completely eliminate debris shedding from the External Tank. The hard fact of the matter is that the External Tank will always shed debris, perhaps even pieces large enough to do significant damage to the Orbiter.

Before a crowd of photographers, *Discovery* is hoisted into a vertical position in the transfer aisle of the Vehicle Assembly Building at the Kennedy Space Center. After this the Orbiter was lifted into a High Bay to be mated with a waiting set of Solid Rocket Boosters and an External Tank.

Prior to *Columbia*, surprisingly little was known about the actual impact resistance of the Orbiter thermal protection system, especially the reinforced carbon-carbon (RCC) that makes up the wing leading edges and nosecap. A great deal of effort – both theoretical analysis and physical testing – has been expended over the past two years to quantify the durability and strength of the thermal protection system, particularly its ability to withstand debris impacts. However, because of the limited amount of time remaining before the Presidential mandate to retire the Space Shuttle fleet, NASA has chosen to implement only a limited number of improvements to harden the Orbiter to withstand debris strikes.

It was therefore prudent to develop a capability to repair any damage to the Orbiter before entry; a similar effort was cancelled in 1980 when it became apparent that it was unlikely to produce any meaningful results prior to the first flight of *Columbia* in 1981. Unfortunately, repairing damage to the thermal protection system again proved to be technically challenging almost to the point of impossibility. The thermal protection system was not designed to be repaired on-orbit, and virtually every approach developed thus far has limitations. While work will continue, it is likely that on-orbit repairs will provide only a limited capability for the remaining flights of the Space Shuttle Program.

The last resort, if debris does again cripple an Orbiter, is to provide a safe haven capability aboard the International Space Station where a Space Shuttle crew can await a rescue vehicle. NASA has made good progress in identifying the challenges associated with this concept, and the Task Group feels that a workable solution is in hand, although using it will certainly mean the end of the Space Shuttle Program, and very possibly the International Space Station Program also. Additionally, this capability is only planned for STS-114 and STS-121.

Along with the changes to the External Tank and Orbiter, NASA has implemented a host of improvements to the infrastructure and tools available to the Space Shuttle Program. Improved ground-based cameras will track the Space Shuttle during ascent, as will airborne cameras mounted on WB-57 aircraft. New cameras and instrumentation have been installed on the External Tank, Solid Rocket Boosters, and Orbiter. Agreements to use National assets are in place to support the Orbiter in space, as will instruments on the International Space Station and the newly-installed Orbiter Boom Sensor System. Dozens of new analytical models attempt to explain debris shedding, debris transport methods, and potential damage.

The CAIB went beyond the technical issues that were the direct cause of the *Columbia* accident, and cited “management” and “culture” as equally culpable. To that end, the accident board made a number of recommendations for changes to how the agency, especially the Space Shuttle Program, functions.

The Task Group feels that NASA has met the intent of the CAIB management recommendations. The establishment of an Independent Technical Authority within the Chief Engineer’s office moves technical requirements out of the direct control of the Space Shuttle Program management chain. This provides a check-and-balance when it comes time to approve waivers or deviations to a technical requirement since the Technical Authority is not constrained by budget or schedule pressures that may be present within the program. Although initiated prior to the release of the CAIB report, the establishment of the NASA Engineering and Safety Center (NESC) has created an independent body that provides technical assessments across the program. A restructured Safety and Mission Assurance (SMA) office increases the independence of SMA personnel. Reorganizing the systems engineering and systems integration activities within the Space Shuttle Program clears up several ambiguities that led to confused communications between elements.

The Mission Management Team (MMT), much maligned by the CAIB, has been reconstituted and has undergone extensive training, with multiple simulations of alternative scenarios, including the use of the International Space Station as a safe haven for the crew of a damaged Orbiter, and the launch of a rescue mission. Refurbished facilities for the MMT provide a

more conducive environment for their deliberations during each flight. It appears to the Task Group that the changes to the MMT have revitalized this group, but we urge caution that NASA must not allow this capability to atrophy as it had prior to the *Columbia* accident.

Publicly, NASA has said that the first two return-to-flight missions are "test flights" to assess the performance of the modified External Tank and to evaluate repair materials and techniques on orbit. However, in reality, the flights are planned as much for servicing the International Space Station as for testing. NASA intends to carefully monitor the performance and condition of the Space Shuttle during these two flights. For example, the launch rules require specific daylight conditions at the Kennedy Space Center and during External Tank separation to facilitate detailed imagery of the Orbiter and External Tank.

Risk acceptance and management are fundamental to leadership in hazardous technical activities and are the ultimate responsibility of any leader. Very few human endeavors, particularly related to high energy activities involving advanced technologies, are completely free of risk. Space flight in general, and human space flight in particular, is such that it is impossible to drive the risk to zero. While the return-to-flight efforts have eliminated or minimized many known risks, Space Shuttle missions will always be "accepted risk" operations. This requires that the people involved understand, document, and ultimately accept the risk associated with that activity. NASA must be vigilant to prevent the development of a false sense of security by accepting faulty assumptions, or otherwise inappropriate analyses, to justify return to flight and continued Space Shuttle operations.

As the CAIB opined, "NASA is a federal agency like no other. Its mission is unique, and its stunning technological accomplishments, a source of pride and inspiration without equal, represents the best in American skill and courage. At times NASA's efforts have riveted a nation, and it is never far from public view and close scrutiny from many quarters." With this in mind, the Task Group believes that NASA must always strive for the highest level of accomplishment, to exceed the expectations of the Nation, and to do what is right, despite easier options that may present themselves.

Assessment Summaries

Listed in numerical order, this is a summary of the Task Group assessments. More detail may be found in other sections of this report.

CAIB Recommendation 3.2-1: External Tank Debris Shedding. The physical cause of the loss of *Columbia* and its crew was a breach in the reinforced carbon-carbon on the leading edge of the left wing. This was the result of a piece of insulating foam which separated from the left bipod ramp section of the External Tank. During entry this breach allowed superheated air to penetrate through the leading edge insulation and progressively melt the aluminum structure of the left wing, resulting in a weakening of the structure until increasing aerodynamic forces caused loss of control, failure of the wing, and the break-up of the Orbiter. As such the CAIB wrote this recommendation to initiate an aggressive program to eliminate all debris shedding from the External Tank.

Unfortunately, it has been impractical to eliminate all debris shedding from the External Tank. Therefore, NASA went to extensive lengths to better understand the debris environment and the amount of debris the Orbiter could tolerate without critical damage. Most efforts were ultimately focused on achieving a balance between the debris shed by the ET and the ability of the Orbiter to tolerate the debris.

The Agency and its contractors modified the External Tank to eliminate the bipod ramp foam that was the physical cause of the *Columbia* accident. The processes for manual application of foam insulation have been changed to include greater process control and quality inspection.

An extensive effort has resulted in new knowledge about foam and ice and what causes them to shed from the tank during ascent. Heaters have been added to areas of the External Tank to impede the formation of ice, and various other flaws in the design and manufacture of the tank were discovered and corrected along the way.

The RTF TG concluded that NASA did not meet the intent of the CAIB Recommendation 3.2-1. Despite a great deal of excellent work on the part of the Agency and its contractors, the External Tank still sheds debris that could potentially cripple an Orbiter. The extensive work to develop debris models and transport analysis was, until recently, hampered by a lack of rigor in both development and testing. The debris-allowable requirements provided to the ET Project did not match what was later determined to be the impact tolerance of the Orbiter. That being said, the Task Group believes that the ET Project worked diligently to successfully meet the requirements they were provided; unfortunately, those requirements were later determined to be inadequate.

CAIB Recommendation 3.3-1: Reinforced Carbon-Carbon Non-Destructive Inspection. The accident board was surprised at how little was known about the impact resistance and effects of aging on the reinforced carbon-carbon used as part of the Orbiter thermal protection system. They recommended that NASA rebaseline all of the RCC components on each remaining Orbiter and also take advantage of advanced nondestructive inspection technology that was not available when the Space Shuttle Program began.

The RTF TG concluded that NASA met the intent of CAIB Recommendation 3.3-1 after the Agency removed all nosecap, chin panel, and wing leading edge RCC from each of the Orbiters and returned them to the manufacturer for evaluation. Testing methods used by the manufacturer included the same evaluations done during the original acceptance testing, as well as new technologies.

CAIB Recommendation 3.3-2: Orbiter Hardening. The *Columbia* accident clearly demonstrated that the Orbiter thermal protection system, including the reinforced carbon-carbon panels and acreage tiles, was vulnerable to impact damage from the existing debris environment.

The RTF TG concluded that despite tremendous effort by NASA and its contractors, the Agency did not fully meet the intent of CAIB Recommendation 3.3-2 due to the lack of a long-term approach to RCC hardening and the amount of remaining non-standard work coming out of the various design verification reviews. An early long-term plan for Orbiter hardening was abandoned after the Presidential decision to retire the Space Shuttle fleet no later than 2010. Through an extensive test and analysis effort, the Agency has learned a great deal about the impact resistance of the Orbiter and defined damage criteria. NASA has provided some increased hardening through hardware changes. The Orbiter is still vulnerable to the debris environment created by the External Tank. The Space Shuttle Program has acknowledged the possibility of critical debris damage and has developed an accepted risk rationale.

CAIB Recommendation 3.4-1: Ground-Based Imagery. The *Columbia* post-accident investigation was hampered by the lack of high-resolution imagery of the vehicle during ascent. The CAIB was concerned about the need to have an adequate number of appropriately-located cameras that operated properly to provide photographic coverage of the Space Shuttle from launch through separation of the Solid Rocket Boosters.

The RTF TG concluded that NASA met the intent of CAIB Recommendation 3.4-1 by increasing the number and capability of ground camera assets. Also, the Agency has arranged for airborne assets to mitigate the effects of cloud cover and improve higher altitude resolution, at least for the first two launches. From a hardware asset perspective, these changes should ensure an adequate capability to provide three useful views.

CAIB Recommendation 3.4-2: High-Resolution Images of External Tank. Although the Space Shuttle Program routinely attempted to photograph the External Tank after separation using hand-held cameras on the flight deck and film cameras in the Orbiter umbilical wells, none of these images were downlinked to the ground and the STS-107 images were therefore unavailable to the accident board. The CAIB recommended that high-resolution imagery of the ET should be obtained on each flight and downlinked to the ground as soon as practical after achieving orbit.

The RTF TG concluded that NASA met the intent of CAIB Recommendation 3.4-2 by using handheld camera images taken from the Orbiter flight deck and the addition of a digital umbilical well camera. The images from these cameras will be downlinked for evaluation during the first days on orbit.

CAIB Recommendation 3.4-3: High-Resolution Images of Orbiter. This was a concern to the CAIB because their investigation was hampered by the lack of high-resolution images. The accident board recommended that NASA provide a capability to obtain and downlink high-resolution images of the underside of the Orbiter wing leading edge and the forward portion of the thermal protection system tiles under both wings.

The RTF TG concluded that NASA met the intent of CAIB Recommendation 3.4-3 through the addition of the Orbiter Boom Sensor System (OBSS) with two sensor packages and the R-bar Pitch Maneuver (RPM) imagery from ISS. A full scan of the wing leading edge and nosecap will be accomplished by OBSS on Flight Day 2 with the capability for focused inspections on later flight days. Additional imagery is provided through several cameras on the External Tank and Solid Rocket Boosters. The Task Group cautions, however, this on-vehicle imagery suite does not provide complete imagery of the underside of the Orbiter or guarantee detection of all potential impacts to the Orbiter.

CAIB Recommendation 4.2-1: Solid Rocket Booster Bolt Catcher. While investigating the cause of the *Columbia* accident, the CAIB noted that the Solid Rocket Booster bolt catchers had not been properly flight qualified. Each SRB is connected to the External Tank by four separation bolts: three at the bottom plus a larger one at the top that weighs approximately 65 pounds. Static and dynamic testing, conducted as a result of the CAIB's inquiries, demonstrated that the bolt catchers flown on STS-107 had a factor of safety of 0.956, rather than 1.4 required by specification.

The RTF TG concluded that NASA has gone well beyond the intent of the CAIB in answering CAIB Recommendation 4.2-1. Instead of simply qualifying the existing bolt catchers, NASA undertook an extensive redesign of the bolt catchers, and then qualified the new design.

CAIB Recommendation 4.2-3: Two Person Closeout Inspections. While reviewing various security aspects of the Space Shuttle Program to eliminate terrorist activity or sabotage as possible causes of the *Columbia* accident, the CAIB noted a lapse in procedures at various NASA installations. There were several processes that did not require two people to be present when an area on the flight vehicle was closed-out (sealed prior to flight). Although unlikely, this could allow an individual to sabotage the vehicle without being observed. This was also against the general policy of "two sets of eyes are better than one" that provides additional technical and safety checks during closeouts. It is important to note, however, that the CAIB found no evidence that willful damage was a cause of the accident (Finding 4.2-12).

The RTF TG concluded that NASA had met the intent of CAIB Recommendation 4.2-3 through revised procedures at all locations that now require at least two people to be present during a closeout.

CAIB Recommendation 4.2-5: Kennedy Space Center Foreign Object Debris Definition. During January 2001 NASA generated new and non-standard definitions for Foreign Object Debris (FOD). The term "processing debris" was applied to debris found during the routine processing of the flight hardware. The term FOD applied only to debris found in flight hardware after final closeout inspections. These definitions were unique to the Space Shuttle Program at KSC. Because debris of any kind has critical safety implications, the CAIB wanted the standard, industry-wide definition reestablished for FOD.

The RTF TG concluded that NASA met the intent of CAIB Recommendation 4.2-5 when KSC and the United Space Alliance changed the definition of "Foreign Object Debris" to be consistent with the recognized and accepted industry standard. Further, the Agency has removed the misleading category of processing debris that caused concern. They have improved the training of the workforce, and implemented several improvements above and beyond the expectations defined in the CAIB recommendation.

CAIB Recommendation 6.2-1: Consistency with Resources. The CAIB explicitly recognized the legitimate use of schedules to drive a process. They were concerned, however, that the line between "beneficial" schedule pressures and those that become detrimental can not be defined or measured. In the case of *Columbia*, the CAIB discovered pressure on the Space Shuttle Program was created by the schedule for construction of the International Space Station. Indeed, the planned February 2004 completion of Node 2 of the ISS was being touted as a measure of NASA's ability to maintain a schedule.

The RTF TG concluded that NASA met the intent of CAIB Recommendation 6.2-1 since new tools and processes put in place by the Agency should preclude this type of undue schedule pressure in the future. The Task Group cautions, however, that resource sufficiency is also tied to the scheduled retirement date for the Space Shuttle. Any evaluation of keeping the Space Shuttle in service past 2010 should include a reassessment of actions and upgrades not undertaken by NASA, and any long term items already deleted from work and acquisition cycles, including the Service Life Extension Program.

CAIB Recommendation 6.3-1: Mission Management Team Improvements. The performance of the Mission Management Team (MMT) during the flight of *Columbia* has been widely criticized. Many of the additional capabilities embedded in other recommendations from the CAIB, such as imagery from various sources and vehicle damage tolerance maps, are intended to support MMT activities for the return to flight. The CAIB recommended that the MMT receive additional training to deal with potential crew and vehicle safety contingencies beyond the launch and ascent phases of flight.

The RTF TG concluded that NASA has met the intention of CAIB Recommendation 6.3-1 by developing a new training plan for the MMT. With the passage of time, the Task Group has been able to witness the implementation of most aspects of the plan. There have also been numerous simulations conducted to date including more than ten involving live, face-to-face exercises of various parts of the next mission. The various delays in launching STS-114 have allowed the MMT to further refine its procedures and have resulted in continual improvement. The Mission Management Team has made notable progress and maturity in addressing of the CAIB's concerns and the Agency has demonstrated a commitment to continual MMT improvement.

CAIB Recommendation 6.3-2: National Imagery and Mapping Agency Memorandum of Agreement. There was considerable public discussion of the decision during the flight of *Columbia* to forego requesting the assistance of other federal agencies in assessing the condition of the Orbiter. The CAIB wanted the Space Shuttle Program to have the procedures in place to get all possible data to investigate a potential problem. This included having the proper personnel maintain the appropriate security clearances to access data from National assets.

The RTF TG has concluded that NASA has met the intent of CAIB Recommendation 6.3-2. A revised Memorandum of Agreement is in place between NASA and the National Geospatial-Intelligence Agency (NGA – the successor to NIMA), and appropriate security clearances have been obtained by various NASA personnel. The coordination required to use this capability has also been exercised in various MMT simulations.

CAIB Recommendation 6.4-1: Thermal Protection System Inspection and Repair. This was a four-part CAIB recommendation. The RTF TG only assessed the parts of this recommendation applicable to inspection and repair for the return-to-flight effort.

After long and often spirited discussion, the RTF TG concluded that NASA has not met the intent of CAIB Recommendation 6.4-1 relative to TPS repair; the inspection part included in the assessment of Recommendation 3.4-3 did meet the intent of CAIB. The basic debate among the Task Group was more one of process than of fact; everybody agrees that the repair options on STS-114 "are what they are." The Task Group consensus – by a slim margin – was that each of the repair options that comprise the repair capability must be sufficiently tested and vetted so that NASA could implement it in an emergency situation with confidence that it would perform as expected. To date, the tile and RCC repair techniques developed by the Agency are not considered sufficiently mature to be a practicable repair capability for STS-114.

CAIB Recommendation 9.1-1: Detailed Plan for Organizational Change. The CAIB expected NASA to return to flight relatively quickly, and did not want to restrict this activity by requiring major organizational changes. Instead, the CAIB wrote a separate recommendation that NASA produce a detailed plan to implement the organizational changes embodied in three other recommendations – R7.5-1, Independent Technical Authority; R7.5-2, Safety and Mission Assurance; and R7.5-3, Systems Engineering and Integration. However, getting ready for the first return-to-flight mission has taken longer than initially expected, allowing NASA to proceed with many of the organizational changes recommended by the CAIB; the Task Group elected to assess the actual changes, in addition to the required plan.

The RTF TG believes that embodied in Recommendation 9.1-1, however, are a myriad of organizational and management issues raised by the CAIB, including "culture." The CAIB used the term "culture" throughout its report, although there are neither specific recommendations to change culture nor any suggestions on how it might be accomplished. Therefore, organizational culture, although important, was not considered a return-to-flight issue.

The RTF TG has concluded that NASA has met the intent of CAIB Recommendation 9.1-1 because the Agency has a mature plan to restructure the organization as envisioned by the accident board. The assessment of the actual changes, however, is mixed. The planned implementation of the Technical Authority comports with CAIB intent, but the initial resistance to this formulation still exists – it will take time to see if the process is robust enough to overcome the internal opposition. The planned response to R7.5-2 is intentionally not consistent with CAIB intent – NASA simply disagrees that the best organization for the field centers' Safety and Mission Assurance Offices to report directly to Headquarters. The Task Group is sympathetic to the NASA position. Implementation of R7.5-3 is uneven, with improved integration and system analysis but worrisome gaps in system engineering capability.

CAIB Recommendation 10.3-1: Digitize Closeout Photos. During the *Columbia* investigation, the accident board encountered numerous engineering drawings that were inaccurate. Further, they discovered that a large number of engineering change orders had not been incorporated into the drawings. Tied in with this, in many instances CAIB investigators were not able to access needed closeout photography for several weeks.

The RTF TG has concluded that NASA has met the intent of CAIB Recommendation 10.3-1. Standardized 6.1 megapixel cameras have been acquired for use in closeout and configuration photography. NASA identified enhancements to the Shuttle Image Management System (SIMS) database and necessary upgrades are complete. Updated training material has been developed for users of the SIMS database and users have received training at KSC, JSC, and MSFC. Through several integrated launch countdown simulations, the Space Shuttle Program staff has confirmed that the modifications to the SIMS database satisfy their needs.

The CAIB recommendation assumed that the Space Shuttle Program would continue for the long term, and indicated that the digital photography should be an interim solution pending the digitizing and updating of all Space Shuttle engineering drawings (R10.3-2). However, based on the Presidential decision to retire the Space Shuttle no later than 2010, the Task Group concurs with NASA's decision that it does not make economic sense to expend the resources to make major changes to the drawings. The digital closeout photography provides an adequate solution until the end of the program. The Task Group cautions, however, that if the decision is made to extend the Space Shuttle program past 2010 – or to use elements of it for a new heavy-lift vehicle – the engineering drawing issue should be corrected.

Raising the Bar Action SSP-3: Contingency Shuttle Crew Support. The CAIB report mentioned the feasibility of providing contingency life support on board the International Space Station for stranded Space Shuttle crewmembers until repair or rescue could be accomplished. The accident board, however, did not issue a specific recommendation to either evaluate or implement such a capability. As part of their return to flight efforts, NASA developed a capability called Contingency Shuttle Crew Support aboard the ISS for STS-114 and STS-121. Since this capability was an option of last-resort in several scenarios evaluated by the RTF TG, the Task Group elected to evaluate the capability as part of this report.

The RTF TG concluded that NASA has developed analyses and plans so that CSCS will offer a viable emergency capability for crew rescue. NASA set a Raising the Bar action for themselves and exceeded it by a significant margin. The Task Group commends NASA for its excellent work on SSP-3.

Integrated Vehicle Assessment. To assess NASA's ability to perform an integrated vehicle external damage assessment, the RTF TG established the Integrated Vehicle Assessment Panel (IVASP). With the addition of new cameras and sensors, NASA needed a method to capture and integrate the information gained from these sensors, use that information to perform a damage assessment, and present that information in a way that supported critical decision-making regarding potential damage and options to mitigate that damage.

Beginning from scratch, NASA has evolved a process that holds the promise of integrating a variety of new and disparate types of data into information that can support these complex decisions during flight. They have documented these processes, vetted them, trained to them, and revised them accordingly. As we have said, NASA needs an ability to manage risk during flight; NASA's processes to integrate these sensor data into information that can support damage assessments represent a significant step in that direction.

The Task Group commends NASA for its progress in this area and recommends that this work continue after STS-114. We further recommend that this process could even serve as a model for other cross-NASA integration projects.

Concluding Thought

To focus solely on the CAIB return-to-flight recommendations as a measure of the safety of STS-114 is inappropriate. The Task Group, while concluding that three recommendations were not fulfilled in their entirety, was not chartered to reach any conclusion regarding the

safety of the next flight. Indeed, addressing the CAIB recommendations has been only a part of the Agency's vast amount of work leading to return to flight. It is improper to calculate, on the basis of the Task Group's assessments, the likelihood of success for the next and subsequent flights. It is the responsibility of NASA, and only NASA, to define and accept the remaining risk for STS-114.

The Columbia Accident Investigation Board provided a valuable service to the *Columbia* families, NASA, and the nation by determining the cause of the accident and prescribing steps to reduce the risk for subsequent flights. As with most accident boards, the CAIB set a high standard, perhaps one that was not achievable within the technology, funding and schedule available to the Space Shuttle Program. Not everything the CAIB recommended could be accomplished, but this does not reflect poorly on the dedication or capabilities of the NASA workforce. The work accomplished since February 2003 has led to an improved vehicle and an enhanced understanding of its capabilities and limitations. In addition, NASA has begun to address organizational changes that will clarify lines of communications and responsibilities to provide an enhanced safety culture. Perhaps the most important lesson from the accident is a renewed respect for the risks inherent in space travel and the need to continually monitor and assess those risks.

Discovery at Launch Complex 39B at the Kennedy Space Center awaiting launch as STS-114.