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Bulletin

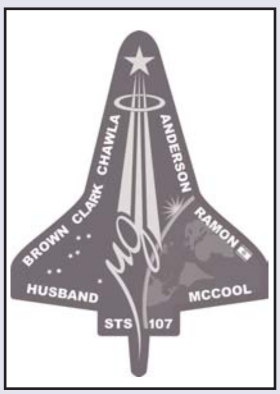
September 18, 2003

Volume 22, No. 5

http://www.lockheedmartin.com/michoud/

CAIB Issues Columbia Accident Report

Board gives "thumbs-up" to quality and workmanship at Michoud



Editor's Note: *The following are direct excerpts from the Report Synopsis of the Columbia Accident Investigation Board edited to fit the space available.*

REPORT SYNOPSIS

The Columbia Accident Investigation Board's independent investigation into the tragic February 1, 2003, loss of the Space Shuttle *Columbia* and its seven-member crew lasted nearly seven months and involved 13 Board members, approximately 120 Board investigators, and thousands of NASA and support personnel. Because the events that initiated the accident were not apparent for some time, the investigation's depth and breadth were unprecedented in NASA history. Further, the Board determined early in the investigation that it intended to put this accident into context. We considered it unlikely that the accident was a random event; rather, it was likely related in some degree to NASA's budgets, history, and program culture, as well as to the politics, compromises, and changing priorities of the democratic process. We are convinced that the management practices overseeing the Space Shuttle Program were as much a cause of the accident as the foam that struck the left wing.

PART ONE: THE ACCIDENT

Chapter 1 relates the history of the Space Shuttle Program before the *Challenger* accident. With the end looming for the Apollo moon exploration program, NASA unsuccessfully attempted to get approval for an equally ambitious and expensive space exploration program. Most of the proposed programs started with space stations in low-Earth orbit and included a reliable, economical, medium-lift vehicle to travel safely to and from low-Earth orbit. After many failed attempts, and finally agreeing to what would be untenable compromises, NASA gained approval from the Nixon Administration to develop, on a fixed budget, only the transport vehicle. To satisfy the Administration's requirement that the system be economically justifiable, the vehicle had to capture essentially all space launch business, and to do that, it had to meet wide-ranging requirements. These sometimes-competing requirements resulted in a compromise vehicle that was less than optimal for manned flights. NASA designed and developed a remarkably capable and resilient vehicle, but one that has never met any of its original requirements for reliability, cost, ease of turnaround, maintainability, or, regrettably, safety.

Chapter 2 documents the final flight of *Columbia*. Designated STS-107, this was the Space Shuttle Program's 113th flight and *Columbia's* 28th. The flight was close to trouble-free. Unfortunately, there were no indications to either the crew onboard *Columbia* or to engineers in Mission Control that the mission was in trouble as a result of a foam strike during ascent. Mission management failed to detect weak signals that the Orbiter was in trouble and take corrective action. *Columbia* was launched from Launch Complex 39-A on January 16, 2003, at 10:39 a.m. Eastern Standard Time (EST). At 81.7 seconds after launch, when the Shuttle was at about 65,600 feet and traveling at Mach 2.46 (1,650 mph), a large piece of handcrafted insulating foam came off an area where the Orbiter attaches to the External Tank. At 81.9 seconds, it struck the leading edge of

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External Tank Related Findings

- NASA does not fully understand the mechanisms that cause foam loss on almost all flights from larger areas of foam coverage and from areas that are sculpted by hand.
- There are no qualified non-destructive evaluation techniques for the as-installed foam to determine the characteristics of the foam before flight.
- Foam loss from an External Tank is unrelated to the tank's age and to its total pre-launch exposure to the elements. Therefore, the foam loss on STS-107 is unrelated to either the age or exposure of External Tank 93 before launch.
- The Board found no indications of negligence in the application of the External Tank Thermal Protection System.
- The Board found instances of left bipod ramp shedding on launch that NASA was not aware of, bringing the total known left bipod ramp shedding events to 7 out of 72 missions for which imagery of the launch or External Tank separation is available.
- Subsurface defects were found during the dissection of three bipod foam ramps, suggesting that similar defects were likely present in the left bipod ramp of External Tank 93 used on STS-107.
- Foam loss occurred on more than 80 percent of the 79 missions for which imagery was available to confirm or rule out foam loss.
- Thirty percent of all missions lacked sufficient imagery to determine if foam had been lost.
- Analysis of numerous separate variables indicated that none could be identified as the sole initiating factor of bipod foam loss. The Board therefore concludes that a combination of several factors resulted in bipod foam loss.

Report

Continued from Page 1

Columbia's left wing. This event was not detected by the crew on board or seen by ground support teams until the next day, during detailed reviews of all launch camera photography and videos. Chapter 2 reconstructs in detail the events leading to the loss of *Columbia* and her crew.

In Chapter 3, the Board analyzes all the information available to conclude that the direct, physical action that initiated the chain of events leading to the loss of *Columbia* and her crew was the foam strike during ascent. This chapter reviews five analytical paths - aerodynamic, thermodynamic, sensor data timeline, debris reconstruction, and imaging evidence - to show that all five independently arrive at the same conclusion. The subsequent impact testing conducted by the Board is also discussed. That conclusion is that *Columbia* re-entered Earth's atmosphere with a pre-existing breach in the leading edge of its left wing in the vicinity of Reinforced Carbon-Carbon (RCC) panel 8. This breach, caused by the foam strike on ascent, was of sufficient size to allow superheated air (probably exceeding 5,000 degrees Fahrenheit) to penetrate the cavity behind the RCC panel. The breach widened, destroying the insulation protecting the wing's leading edge support structure, and the superheated air eventually melted the thin aluminum wing spar. Once in the interior, the superheated air began to destroy the left wing. Analysis indicates that the Orbiter continued to fly its pre-planned flight profile, although, still unknown to anyone on the ground or aboard *Columbia*, her control systems were working furiously to maintain that flight profile. Finally, over Texas, the increasing aerodynamic forces the Orbiter experienced in the denser levels of the atmosphere overcame the catastrophically damaged left wing, causing the Orbiter to fall out of control at speeds in excess of 10,000 mph. The chapter details the recovery of about 38 percent of the Orbiter (some 84,000 pieces) and the reconstruction and analysis of this debris. It presents findings and recommendations to make future Space Shuttle operations safer.

Chapter 4 describes the investigation into other possible physical factors that may have contributed to the accident. The chapter opens with the methodology of the fault tree analysis, which is an engineering tool for identifying every conceivable fault, then determining whether that fault could have caused the system in question to fail. In all, more than 3,000 individual elements in the *Columbia* accident fault tree were examined. In addition, the Board analyzed the more plausible fault scenarios, including the impact of space weather, collisions with micrometeoroids or "space junk," willful damage, flight crew performance, and failure of some critical Shuttle hardware. The Board concludes in Chapter 4 that despite certain fault tree exceptions left "open" because they cannot be conclusively disproved, none of these factors caused or contributed to the accident. This chapter also contains findings and recommendations to make Space Shuttle operations safer.

PART TWO: WHY THE ACCIDENT OCCURRED

Part Two, "Why the Accident Occurred," examines NASA's organizational, historical, and cultural factors, as well as how these factors contributed to the accident.

Chapter 5 examines the post-*Challenger* history of NASA and its Human Space Flight Program. A summary of the relevant portions of the *Challenger* investigation recommendations is presented, followed by a review of NASA budgets to indicate how committed the nation is to supporting human space flight, and within the NASA budget we look at how the Space Shuttle Program has fared. Next, organizational and management history, such as shifting management systems and locations, are reviewed.

Chapter 6 documents management performance related to *Columbia* to establish events analyzed in later chapters. The chapter begins with a review of the history of foam strikes on the Orbiter to determine how Space Shuttle Program managers rationalized the danger from repeated strikes on the Orbiter's Thermal Protection System. Next is an explanation of the intense pressure the program was under to stay on schedule, driven largely by the self-imposed requirement to complete the International Space Station. Chapter 6 then relates in detail the effort by some NASA engineers to obtain additional imagery of *Columbia* to determine if the foam strike had damaged the Orbiter, and how management dealt with that effort.

In Chapter 7, the Board presents its view that NASA's organizational culture had as much to do with this accident as foam did. By examining safety history, organizational theory, best business practices, and current safety failures, the report notes that only significant structural changes to NASA's organizational culture will enable it to succeed. This chapter measures the Shuttle Program's practices against this organizational context and finds them wanting. The Board concludes that NASA's current organization does not provide effective checks and balances, does not have an independent safety program, and has not demonstrated the characteristics of a learning organization. Chapter 7 provides recommendations for adjustments in organizational culture.

Chapter 8, the final chapter in Part Two, draws from the previous chapters on history, budgets, culture, organization, and safety practices, and analyzes how all these factors contributed to this accident. The chapter opens with "echoes of *Challenger*" that compares the two accidents. This chapter captures the Board's views of the need to adjust management to enhance safety margins in Shuttle operations, and reaffirms the Board's position that without these changes, we have no confidence that other "corrective actions" will improve the safety of Shuttle operations.

PART THREE: A LOOK AHEAD

Part Three summarizes the Board's conclusions on what needs to be done to resume our journey into space, lists significant observations the Board made that are unrelated to the accident but should be recorded, and provides a summary of the Board's recommendations.

In Chapter 9, the Board first reviews its short-term recommendations. These return-to-flight recommendations are the minimum that must be done to essentially fix the problems that were identified by this accident. Next, the report discusses what needs to be done to operate the Shuttle in the mid-term, three to 15 years. Based on NASA's history of ignoring external recommendations, or making improvements that atrophy with time, the Board has no confidence that the Space Shuttle can be safely operated for more than a few years based solely on renewed post-accident vigilance. The third part of the chapter discusses the poor record this nation has, in the Board's view, of developing either a complement to or a replacement for the Space Shuttle. The report is critical of several bodies in the U.S. government that share responsibility for this situation, and expresses an opinion on how to proceed from here, but does not suggest what the next vehicle should look like.

Chapter 10 contains findings, observations, and recommendations that the Board developed over the course of this extensive investigation that are not directly related to the accident but should prove helpful to NASA.

Chapter 11 is a compilation of all the recommendations in the previous chapters. (*A complete list of these recommendations can be found on Pages 6 and 7 of this issue.)*

For full text of the CAIB final report, go to: http://gumbo/ and look under General RTF News. ■

NASA Begins New Phase to Safely Fly Again

Implementation Plan is blueprint for launch in 2004

NASA's recently released Implementation Plan is the roadmap to Return To Flight and responds to Columbia Accident Investigation Board findings in three areas: systemic cultural and organizational issues, requirements for returning safely to flight and technical excellence.

The plan states "NASA will pursue an in-depth assessment to identify and define areas where we can improve our culture and take aggressive corrective action." The 158-page plan includes numerous categories. Below are some of the main points NASA included in its evolving plan:

- Reassess safety and mission assurance leadership and structure
- Improve communication and decision making by focusing on safety first, then on other mission objectives
- Perform more testing on shuttle hardware rather than relying on computer-based analysis
- Benchmark other high-risk entities such as nuclear power and chemical plants, military flight test groups and oil drilling operations to learn best practices to apply to the Space program
- Eliminate critical ascent debris such as the ET's bipod assembly
- Develop with contractor a program to understand root causes of foam shedding
- Upgrade imagery and inspection capabilities to ensure any shuttle damage is identified quickly
- Launch near-term missions during the day for best camera shots
- Respond to future on-orbit problems with more options such as repair kits to patch Thermal Protection Systems tile and reinforced carbon-carbon damage
- Prepare contingency plan that would allow stranded shuttle crews to stay on International Space Station until they can get home safely ■

Stafford-Covey Technical Panel Reviews Return to Flight Activities at Michoud

Assuring implementation of the Columbia Accident Investigation Board's (CAIB) 29 recommendations and those 15 specific to Return to Flight is no diminutive task.

To achieve this goal, NASA Administrator **Sean O'Keefe** established the Stafford-Covey Return to Flight (RTF) Task Group. Its mission is to perform an independent assessment of NASA's actions to implement the recommendations of the CAIB, as they relate to the safety and operational readiness of STS-114.

Presided over by veteran astronauts, Apollo commander **Tom Stafford** and Space Shuttle commander **Dick Covey**, the team is comprised of experts and industry professionals with broad experience in program management, engineering, safety, hardware integration and systems evaluation.

Over the next two years, the Task Group will work closely with NASA's Return to Flight team, led by Associate Administrator of Space Flight **Bill Readdy**. They will call on Space Shuttle contractors, scrutinize hardware, conduct public meetings and issue a final written report to NASA.

To understand and oversee the execution of specific technical issues in support of CAIB recommendations, the Task Group established a Technical Panel. Ten members, led by **Joseph Cuzzupoli**, retired NASA engineer and vice president of Kistler Aerospace, visited Michoud last month to assess the progress of the External Tank recommended items.

After a three-hour technical review outlining progress in all ET RTF areas, Cuzzupoli noted, "Michoud is on the right track to accomplish what's necessary to return to flight safely."

External Tank undergoes Return to Flight scrutiny

Members of the Stafford-Covey Return to Flight Technical Panel meet with NASA and Lockheed Martin personnel to determine External Tank RTF status. The three-hour review statused all eight of the Columbia Accident Investigation Board's recommendations that pertain to the ET.

Before concluding their Michoud visit, members toured the ET production facility and the two recently completed Modification Centers, while concentrating their attention on the critical bipod redesign activities.

"The most important challenge Michoud employees face is to stay focused on Return to Flight issues," Cuzzupoli explained. "And get them accomplished as quickly and correctly as possible." ■

For more information on the Stafford-Covey RTF Task Group, go to: http://www.returntoflight.org

NASA Directs Modifications to the ET in Return to Flight Plan

ET Bipod Redesign - *The Critical First Step*

1 As the lead for the most visible External Tank Return to Flight activity, **Matt Wallo** works to keep his bipod redesign team focused on its goal - to design, develop and verify the ET bipod closeout area.

Last month, the Columbia Accident Investigation Board concluded that foam from the bipod area detached and impacted the shuttle's left wing during ascent and recommended an aggressive campaign to eliminate foam debris, particularly in the bipod area. The new design will eliminate the need for the foam ramp that was used to keep ice from forming on the bipod fitting prior to launch.

Resting on a copper plate, the prototype design uses four heaters in the copper base to prevent ice formation. According to Wallo, bipods installed on existing ETs will be removed, modified and re-installed with minimal disruption to hardware. Any required machining is within the existing capability of the machine shop and/or vendors and will not impede existing ET production.

"We completed some critical development testing of the new design at the Marshall Space Flight Center during June, and have demonstrated that the heaters work in keeping ice off the fitting," Wallo said. "We repeated this testing at Eglin Air Force Base in July, finding some issues that we recently incorporated into the design. A retest is slated for the third week of September."

Wallo said the team also completed a structural capability test in Building 404 in early July that demonstrated that the new modifications did not affect the structural capability of the fitting.

The redesigned bipod configuration

"These tests prove the thermal concept works, and more importantly, that the redesign doesn't impact the structural integrity of the fitting."

Verification tests for the bipod redesign are currently on schedule this month in several locations: a full-up structural test at Michoud, a thermal verification retest at Eglin AFB, Fla. and wind tunnel tests at the Arnold AFB Engineering Development Center, Tenn.

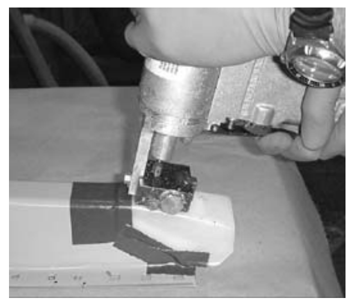
Final approval of the redesign concept will take place at a Critical Design Review next month. Certification for technicians who will install the new design is also in work, with the ultimate goal to begin production activity shortly thereafter. ■

Each weekday morning, the NASA-Lockheed Martin External Tank Return to Flight (RTF) Organization meets to discuss progress and hear updates on pivotal issues pertaining to a safe return to flight. Bipod redesign remains at the center of these discussions, but significant developments continue in other areas as well.

2 Intertank/Liquid Hydrogen Flange

The Intertank/Liquid Hydrogen (LH2) flange closeout team is charged with reducing or eliminating foam debris from the flange area. To meet its goal, the flange team is working to find the root cause of why a small amount of foam comes off that area. In order to do that, **Eugene Sweet's** team has involved nearly every test lab at the Marshall Space Flight Center and Michoud.

"We will never spray a flange in the same configuration again," Sweet asserts. "We know we can produce a better closeout, so we've been working with our Quality and Prod Ops people to develop different techniques and processes. We've down-selected several and are getting test articles built. The better the closeout, the better the chance of not producing a divot out of that flange location."



Foam injected into stringer ends.

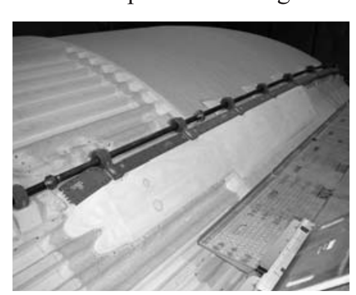
In order to better understand the foam loss mechanism, Sweet's group spent months dissecting flange foam with the employees who conducted the manual spray operation. Both the process and the material were literally under the magnifying glass.

"They've seen their product, and we've had the good fortune to take this same group of guys and work with them shoulder to shoulder to come up with the flange enhancements," Sweet says.

3 Protuberance Airloads (PAL) Ramps

The ET PAL ramps run under the Orbiter's right wing and protect the cable trays and pressurization lines on the Liquid Oxygen (LO2) and LH2 tanks from cross flow during ascent.

The primary path to RTF for the PAL ramps is validating the current Thermal Protection Systems (TPS) design. The TPS verification team is in the process of doing just that (*see Page 5*). Longer term, the PAL ramps team is assessing redesign solutions to reduce potential sources of TPS debris. These include eliminating or replacing the ramps with a smaller ramp or by using an alternative aeroelastic solution.



LO2 PAL (Protuberance Airloads) ramp

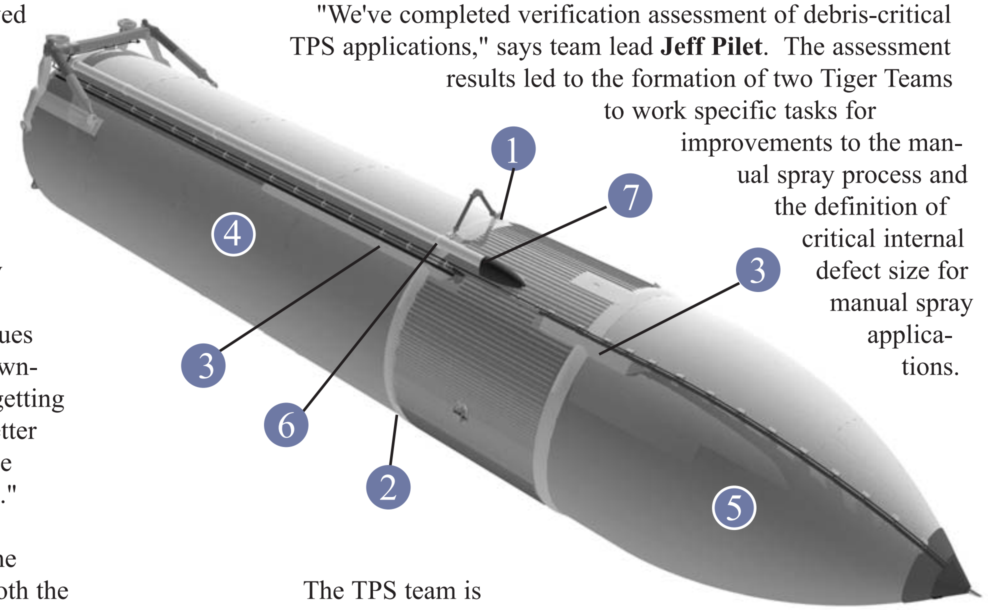
"The challenge is to define and coordinate a complex test program involving a number of wind tunnel tests at four different sites while also conducting structural testing at Marshall," says team lead **Richard Smith**.

The team plans a wind tunnel test on full-scale flight hardware in February 2004, which could lead to a final choice of redesign options next spring, Smith adds.

4 Thermal Protection Systems Verification

This team is reassessing Thermal Protection Systems (TPS) verification data and identifying opportunities for improvements and added confidence prior to RTF.

"We've completed verification assessment of debris-critical TPS applications," says team lead **Jeff Pilet**. The assessment results led to the formation of two Tiger Teams to work specific tasks for improvements to the manual spray process and the definition of critical internal defect size for manual spray applications.



The TPS team is currently developing verification rationale to present to the RTF organization for the ET-120 LO2 PAL ramp foam and for the tank's acreage foam.

Pilet says his team will finish its work prior to tank delivery.

5 Non-Destructive Evaluation (NDE)

Traditional NDE methods haven't worked in the past on complex hand-sprayed foam areas of the ET, says team lead **Warren Ussery**. So the team has rigorously investigated state-of-the-art techniques and recently selected two methods for qualification testing.

The first is terahertz imaging - a form of radiation between microwave and infrared light that penetrates foam and reflects off the tank's aluminum surface to find defects.

The second method is backscatter radiography where x-rays are shot into the foam, interact with the foam molecules and produce a backscatter image of defects.

The team will test 2-foot and 3-foot square panels sprayed with flange and PAL ramp closeouts. "The panels will have artificially-inserted defects to see if the two methods can discover the defects," Ussery says.

If testing is successful, the team will employ NDE for limited use on PAL ramps and flange closeouts next month.

6 Liquid Oxygen Feedline Bellows

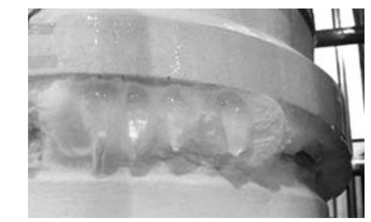
Another Michoud RTF team is looking at eliminating or containing ice that might form on the LO2 feedline bellows.

The team is currently analyzing and testing several options, including: 1) a boot insulating wrap similar to ones flown on Atlas launch vehicles that will contain but not prevent ice, 2) a heated gaseous nitrogen purge to prevent ice formation and 3) a "Drip Lip" extended rain shield foam configuration to channel condensate away from ice-forming areas.

"Initially, I thought this task would be relatively easy, but it has proven to be just the opposite," explains team lead **Mark Pokrywka**.

The team considered filling the ring between the bellows and rain shield with insulating foam, but a one-inch foam layer protruding from the shield may be necessary, producing another possible debris source.

"If you decide to have less than one inch protruding, then you'll get ice build up on the exterior of your fix under certain conditions," says Pokrywka. "Either way is unacceptable."



Ice formed on lower feedline bellows during ice characterization test.

The team is learning that each proposed solution has good and bad qualities.

"The trick is to find the one that is doable in the time allotted and solves the bellows ice debris issue without failing or becoming a new debris source," Pokrywka says.

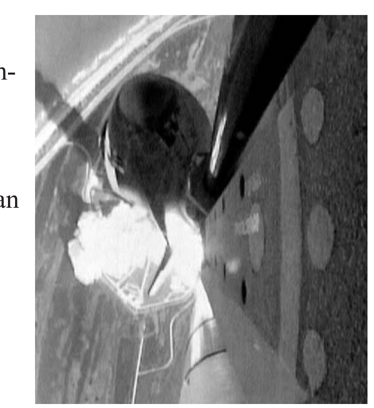
7 Enhanced In-Flight Imagery

The final RTF area focuses on developing options to install an ET camera and has already passed its Critical Design Review.

"We wanted to come up with a camera system that wouldn't add additional protuberances to the tank because we didn't want any more debris sources," says team lead **Angelo Greconia**, who is part of a larger NASA-Lockheed Martin team.

The camera will be tucked inside the LO2 feedline fairing with a field of view scanning the flange, bipod and bellows areas and parts of the Orbiter. Mission Control will have the ability to switch to the live camera shot during launch.

The camera is eight inches long, two inches wide and two inches high and weighs less than a pound. Packaging is taking place at Johnson Space Center where qualification testing is scheduled later this month.



ET camera view on STS-112

Michoud technicians will soon begin installation by drilling holes in ET-120, the first tank in line to fly, Greconia said. Final checkout will also take place at Michoud. ■

CAIB Recommendations - *RTF and Beyond*

[RTF] = *Indicates mandatory activity for Return to Flight*

PART ONE - THE ACCIDENT

Thermal Protection System

- **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. [RTF]**

- 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. [RTF]

- 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. [RTF]

- 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. [RTF]

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

- 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.

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

- 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.

- 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.

Imaging

- 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. [RTF]

- Provide a capability to obtain and downlink high-resolution images of the External Tank after it separates. [RTF]

- 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. [RTF]

- 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. [RTF]

Orbiter Sensor Data

- 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.

- 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.

Wiring

- 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.

Bolt Catchers

- Test and qualify the flight hardware bolt catchers. [RTF]

Closeouts

- Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures. [RTF]

Micrometeoroid and Orbital Debris

- 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.

Foreign Object Debris

- 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." [RTF]

PART TWO - WHY THE ACCIDENT OCCURRED

Scheduling

- 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. [RTF]

Continued on Page 7

Recommendations, Continued from Page 6

Training

- 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. [RTF]

Organization

- 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 subsystem, 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

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

- 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.

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

PART THREE – A LOOK AHEAD

Organization

- 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. In addition, NASA should submit annual reports to Congress, as part of the budget review process, on its implementation activities. [RTF]

Recertification

- 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.

Closeout Photos/Drawing System

- 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. [RTF]

- 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

What will I do today to help return to safe flight ?

Mod Centers Open to Retrofit ETs

The long anticipated drive to get back to flight has begun. Michoud Operations has opened two ET Modification Centers, one in Building 420, Cell 1 and the other in Final Assembly, Position 4.

NASA and Lockheed Martin selected two mod centers over one to best meet the demanding Return to Flight schedule.

ET-120 is the first tank scheduled for retrofitting in Bldg 420, followed by ET-121 in Final Assembly. Three tanks, ET-117, ET-118 and ET-119, reside at Kennedy Space Center and are in the queue to return to Michoud pending schedule.

James Moffett, Modification Centers manager, monitors day-to-day operations and is responsible for delivering retrofitted ETs on time to support RTF schedules.

Bring 'Em On!
External Tanks are rolling into the two mod centers (Bldgs. 420 & 103) for critical retrofitting. Tanks from both Michoud and Kennedy Space Center will pass through the centers before returning to flight.

"We've completed all the preventive maintenance and proof loads of existing tooling to bring the two centers up to speed," Moffett said. "The stands and platforms are modified. We've identified key personnel and support organizations to get us going."

Originally, the mod centers were to open September 4 but opened earlier to accommodate the unique work and to meet any contingency that might impact the schedule.

"The main concern is that some of the retrofit activities will be work done for the first time," said Moffett.

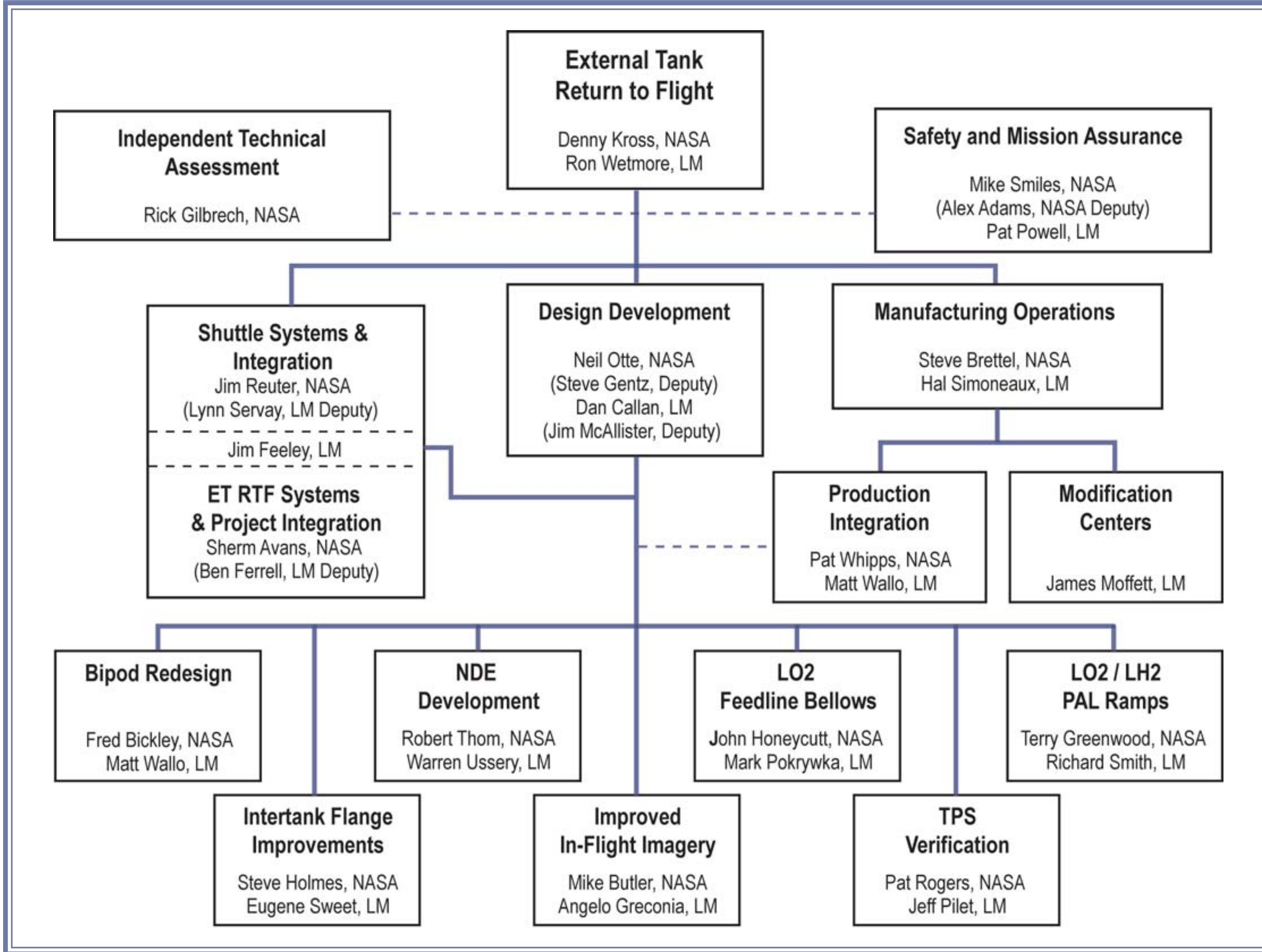
"However, we've recently added Cell 'A' in the VAB as part of the mod center operation to process the LH2/Intertank flange enhancement. Otherwise the work would have to be done in the horizontal position, possibly slowing us down."

Technicians have already removed foam residue from specific parts of ET-120's flange area and will prime the surface pending engineering approval. Next in line is ET-121 to remove gross and residue foam from the plus Z in the flange area.

ET-120 will be the first tank to exit the mod centers in a few months and will be the first to fly.

"I think everyone is ready to pick up the pace in the mod centers," Moffett said. "It just rings in the fact that we have now shifted from the investigative phase to the retrofit phase, which puts us that much closer to returning to flight." ■

The NASA / Lockheed Martin Return to Flight Organization Chart



Mission Success

Bulletin

Volume 22 • Number 5 • September 18, 2003

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Mission Success Bulletin is published by the Communications Department.

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