significantly. Other mediums, such as liquid helium and liquid neon, are being considered. Note that the thermal modeling so far has considered only the ball. Model development is in work on the inserts and adjoining hardware.

NDE of all flight spares is being conducted in an effort to find more balls with subsurface indications. These would then be put in test. Finding no indications in any of the flight spares might support the theory that OV-103's ball was an outlier, i.e., that it had subsurface cracks when installed in the line.

More to come.

Hugo

-----Original Message-----

From: HATAMLEH, OMAR (JSC-NC) (SAIC)

To: ERMINGER, MARK D. (JSC-NC) (NASA); JOHNSON, M. S. (SCOTT) (JSC-NC) (NASA); BROWNE, DAVID M. (JSC-NC) (NASA)

Cc: CULBERTSON, FRANK L., JR (JSC-NA) (SAIC); CAZES, DAVID (JSC-NA) (SAIC); EVATT, GARVIN T. (GT) (JSC-NC) (SAIC); BALU, BRIAN K. (JSC-NC) (SAIC); DYER, KEITH W. (JSC-NC) (SAIC); AUGUSTYN, JOSEPH (JSC-REMOTE); MARTINEZ, HUGO E. (JSC-NC) (GHG); TIPTON, MICHAEL R. (JSC-NX) (SAIC); PRINCE, GORMAN W. (BILLY) (JSC-NC) (GHG); ISHMAEL, MOHAMED I. (GEORGE) (JSC-NC) (SAIC); CLEMENTS, DANIEL L. (JSC-NC) (GHG); ALMASRI, WALEED (JSC-REMOTE); AL-HAYEK, FAREED A. (JSC-NC) (SAIC)

Sent: 12/27/2002 6:10 PM

Subject: RE: BSTRA ball test status

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These Oregon balls were produced much later and have process

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Updates to the JSC activities will be provided in a separate email note. The next meeting is scheduled for Monday at a time to be disclosed later.

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>From: MARTINEZ, HUGO E. (JSC-NC) (GHG)
>Sent: Monday, December 23, 2002 1:44 PM
>To: BROWNE, DAVID M. (JSC-NC) (NASA); CULBERTSON, FRANK L., JR
>(JSC-NA) (SAIC); CAZES, DAVID (JSC-NA) (SAIC); EVATT, GARVIN T. (GT)
>(JSC-NC) (SAIC); DYER, KEITH W. (JSC-NC) (SAIC); JOHNSON, M. S. (SCOTT)
>(JSC-NC) (NASA); ERMINGER, MARK D. (JSC-NC) (NASA); ALMASRI, WALEED;
>BALU, BRIAN; CLEMENTS, DANIEL; HATAMLEH, OMAR; ISHMAEL, MOHAMED;
>jaugust0; PRINCE, GORMAN; TIPTON, MICHAEL
>Subject: BSTRA ball test status
>
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>Friday, December 20th on three separate 2.24" BSTRA balls in order to
>help build flight rationale. These three tests, which are being run in
>parallel, attempt to prove the theory that cracks will develop and then
>arrest prior to going completely through a ball. Partly into the tests
>this morning, no cracks have conclusively been observed, although one
>faint indication is being inspected further. In addition, another
>ball, a flight spares of a smaller size, was eddy current inspected and
>found to have subsurface indications not detetable with dye pen and
>visual checks. Testing will continue today and will resume on the
>evening of the 26th.
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>Test #1: 2.24" ball, notch in ball, instrumented. Purpose is to help
>validate computer model by assessing residual stresses and thermal

>response. Have completed first 5 thermal cycles from ambient to LN2
>(-320F), and there appears a faint line or shadow in the notch near one
>end being inspected further to confirm or deny a crack. Continued with
>6th thermal cycles (this second set of 5 cycles is from 200 F to LN2)
>until a crack is confirmed. If no cracks develop at the conclusion of
>these 10 cycles, a more severe method of creating a crack will be
>developed. If a crack develops, the same temperature cycle will be
>repeated until the ball fails or the crack arrests. The more severe
>method, which is under development as a contingency, could use boiling
>water and an alcohol/dry ice bath to produce a much higher temperature
>gradient.
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>test is to show crack growth and subsequent arrest while under
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>scheduled to:
>1. Simulate nominal loads seen during propellant loading (11,000 lbs
>applied and removed while in LN2 bath) for 5 cycles, then inspect.
>2. Simulate nominal loads seen during flight (41,000 lbs applied and
>removed while in LN2 bath) for 30 cycles, then inspect.
>3. Apply margin loads above nominal flight loads (49,000 applied and
>removed while in LN2 bath) for 5 cycles, then inspect.
>4. Apply margin loads above nominal flight loads (61,000 applied and
>removed while in LN2 bath) for 5 cycles, then inspect.
>5. Apply margin loads above nominal flight loads (71,000 applied and
>removed while in LN2 bath) for 5 cycles, then inspect.
>
>Currently, test #2a is 3 cycles into the 41,000 lbs testing, with no
>cracks visible after the 11,000 testing was completed. As in test #1,
>testing will continue until a crack develops / arrests. Inspections
>are visual after every cycle, and eddy current after every 5th cycle.

>*Instrumentation removed.
>
>Test #2b: Same as #2a, but without notch in ball: Purpose of test is
>to show crack initiation, growth and subsequent crack arrest while
>under flight-like thermal and mechanical loads, but on a pristine ball
>which more closely resembles flight balls. The test sequence is the
>same as in Test #2a:
>
>The 35 nominal cycles are complete (5 cycles at 11,000 lbs plus 30
>cycles at 41,000 lbs), and margin testing has commenced for a total of
>43 cycles so far. There are no indications of a crack via visual or
>eddy current at this time.
>
>MSFC activity:
>In addition to the Huntington Beach testing, MSFC is working on
>metallography of balls of various sizes in order to rationalize
>extrapolating these results to the different size balls used in the
>Orbiter (2.24", 1.75", and 1.25"). In addition, MSFC is working on a
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>
>Hugo E. Martinez, PE
>Shuttle SR&QA Propulsion & Power Lead Engineer
>JSC NC62
>Phone: 281 244-1974

>Fax: 281 244-1849
>
>Providing for a safer tomorrow, today.
>

Mark Kowaleski, 07:57 AM 1/3/2003 -0500, Fwd: FW: BSTRA ball test status

X-Sender: mkowales@mail.hq.nasa.gov
X-Mailer: QUALCOMM Windows Eudora Version 4.3.2
Date: Fri, 03 Jan 2003 07:57:52 -0500
To: rpatrican@hq.nasa.gov, gwhite1@mail.hq.nasa.gov, mcard@hq.nasa.gov, prutledg@mail.hq.nasa.gov
From: Mark Kowaleski <mkowales@hq.nasa.gov>
Subject: Fwd: FW: BSTRA ball test status
Cc: wbihner@mail.hq.nasa.gov

From: "ERMINGER, MARK D. (JSC-NC) (NASA)" <mark.d.erminger@nasa.gov>
To: "MARSHALL, YOLANDA Y. (JSC-NA) (NASA)" <yolanda.y.marshall@nasa.gov>, "'H - O'Connor Bryan'" <boconnor@mail.hq.nasa.gov>
Cc: "JOHNSON, GARY W. (JSC-NA) (NASA)" <gary.w.johnson@nasa.gov>, "JOHNSON, M. S. (SCOTT) (JSC-NC) (NASA)" <m.s.johnson@nasa.gov>, "'H - Kowaleski Mark'" <mkowales@mail.hq.nasa.gov>, "H - Bihner Bill (wbihner@mail.hq.nasa.gov)" <wbihner@mail.hq.nasa.gov>, "MARTINEZ, HUGO E. (JSC-NC) (GHG)" <hugo.e.martinez1@jsc.nasa.gov>
Subject: FW: BSTRA ball test status
Date: Fri, 3 Jan 2003 05:57:14 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)

-----Original Message-----
From: MARTINEZ, HUGO E. (JSC-NC) (GHG)
Sent: Thursday, January 02, 2003 6:16 PM
To: HATAMLEH, OMAR (JSC-NC) (SAIC); ERMINGER, MARK D. (JSC-NC) (NASA); JOHNSON, M. S. (SCOTT) (JSC-NC) (NASA); BROWNE, DAVID M. (JSC-NC) (NASA)
Cc: CULBERTSON, FRANK L., JR (JSC-NA) (SAIC); CAZES, DAVID (JSC-NA) (SAIC); EVATT, GARVIN T. (GT) (JSC-NC) (SAIC); BALU, BRIAN K. (JSC-NC) (SAIC); DYER, KEITH W. (JSC-NC) (SAIC); AUGUSTYN, JOSEPH (JSC-REMOTE); TIPTON, MICHAEL R. (JSC-NX) (SAIC); PRINCE, GORMAN W. (BILLY) (JSC-NC) (GHG); ISHMAEL, MOHAMED I. (GEORGE) (JSC-NC) (SAIC); CLEMENTS, DANIEL L. (JSC-NC) (GHG); ALMASRI, WALEED (JSC-REMOTE); AL-HAYEK, FAREED A. (JSC-NC) (SAIC)
Subject: RE: BSTRA ball test status

Cracks have finally been observed in 2 of 3 balls at Huntington Beach using method developed at MSFC, but no conclusions can yet be drawn. FOD continues to be a serious discussion topic. At the meeting today with Ralph Roe, the Huntington Beach and MSFC test status was given, the status of the JSC remote tool development was presented, and thoughts on flight rationale were discussed.

Plans are for testing to conclude Jan 8th, although a PRCB will be held on the 6th to discuss preliminary FRR charts for STS-107. The team will not report to Ralph Roe until Monday the 6th at 9:00 am unless testing over the weekend fails (crack does not arrest or FOD is generated). In the meantime, the SSME Project will have an answer on FOD tolerance (not expected to be good). If a naturally cracked (vs. notched) ball generates FOD or does not arrest, we will have a problem necessitating the inspection of OV-102's balls. If any other ball generates FOD or does not arrest, the Test #2b ball with two in-line notches can be used to prove arrest and no FOD generation.

Huntington Beach test status:

Test #1 Update: Completed incremental thermal shock at 350 F without cracking. Abandoned this test (this is the test where they started at 200 F and quenched at -100 F, then incremented the initial temperature by 25 degrees each time and quenched again) and will crack with a wedge now.

Test #2a Update: During 275 F to -100 F incremental thermal shock, got multiple cracking about 320 degrees around. Will now subject it to flight-like thermal/mechanical per 4x testing. 4x testing repeats the nominal flight portion of test#2a three additional times in order to encompass 30 missions (OV-102 has seen 28 missions).

Test #2b Update: Had stopped testing and put in two series "thumbnail" notches and put into 212 F to 32 F rapid thermal cycles. Saw a crack between notches, detected via eddy current, not yet visible. Will then go into 4x testing.

MSFC Status:

Both cracked 2.24" balls at MSFC are undergoing testing per HB's test #2 plan and no crack growth has been seen. Both of these balls were initially cracked using a severe thermal gradient. Similarly, 1.75" and 1.25" balls are undergoing testing per test #2. One 1.75" ball had cracked without a notch and without a severe thermal environment (see below) and has opened up a new crack via testing. The maximum length of a crack is 0.4 inches but shallow and stable, it appears.

JSC Remote Tool Development Update:

Developers claim they have "tremendous control" of ball. Some technical issues, such as needing more articulation, cleaning the device for use on the fleet, and establishing the vehicle BSTRA joint configuration are being worked. They are building an articulating joint at the end effector to address the first issue. The device will be ready this coming Sunday.

Other:

SRQA got an action to perform a PRA on the potential for FOD generation. We will be working on the feasibility of this tomorrow (Jan 3rd). While we haven't coordinated with the PRA analysts yet, we feel that getting realistic numbers would not be possible with the available data.

Hugo

-----Original Message-----

From: MARTINEZ, HUGO E. (JSC-NC) (GHG)

Sent: Wednesday, January 01, 2003 2:23 PM

To: HATAMLEH, OMAR (JSC-NC) (SAIC); ERMINGER, MARK D. (JSC-NC) (NASA); JOHNSON, M. S. (SCOTT) (JSC-NC) (NASA); BROWNE, DAVID M. (JSC-NC) (NASA)

Cc: CULBERTSON, FRANK L., JR (JSC-NA) (SAIC); CAZES, DAVID (JSC-NA) (SAIC); EVATT, GARVIN T. (GT) (JSC-NC) (SAIC); BALU, BRIAN K. (JSC-NC) (SAIC); DYER, KEITH W. (JSC-NC) (SAIC); AUGUSTYN, JOSEPH (JSC-REMOTE); TIPTON, MICHAEL R. (JSC-NX) (SAIC); PRINCE, GORMAN W. (BILLY) (JSC-NC) (GHG); ISHMAEL, MOHAMED I. (GEORGE) (JSC-NC) (SAIC); CLEMENTS, DANIEL L. (JSC-NC) (GHG); ALMASRI, WALEED (JSC-REMOTE); AL-HAYEK, FAREED A. (JSC-NC) (SAIC)

Subject: RE: BSTRA ball test status

Testing at Huntington Beach and MSFC continues, as does the development of thermal and stress models in an attempt to build flight rationale for STS-107. The generation of FOD has not at all been alleviated after branched cracking was detected on an MSFC ball subjected to extreme temperature gradients.

Huntington Beach testing continues on the 3 balls in an effort to first create cracks and then to show arrest (no surface growth) under a repeated load profile. All testing described in the original email below is complete, but no cracks have been created. Huntington Beach is

adding steps to their test procedure to incorporate crack initiation techniques developed at MSFC: the use of a dry ice/alcohol bath (-100°F) which allows for quicker quenching.

Test #1 Update: Since dunking the notched 2.24" cabinet ball in LN2 created no cracks (nor did boiling water to ice water thermal shocks), the ball is now being heated to an incrementally higher temperature and quenched at -100°F dry ice/alcohol. This series of thermal shocks is in effort to "sneak up" on the critical conditions required to crack a ball. The first set of 5 thermal shock cycles began at 200°F, and subsequent sets beginning at 225°F and 250°F yielded no cracks. As of December 30th, the set beginning at 275°F was in work. Plans are to continue incrementing the initial temperature by 25°F, running 5 cycles. Inspections are run visually and with eddy current after the first and 5th cycles in each set.

Test #2a Update: Taking the notched 2.24" flight spares ball through a series of flight-like thermal mechanical cycles described below yielded no cracking. The same series of thermal shocks is being used on this ball as in test #1 above, that is, purely thermal cycles, in an effort to crack it. On 200°F cycles, saw an eddy current indication and again during 225°F cycles deep in the notch. It appears to be growing about an 1/8th of an inch on one edge of the notch but is not yet visible on the surface. Once it is seen on the surface, testing will proceed to Phase II, testing for crack arrest under flight-like thermal mechanical/loading. Eddy current and visual inspections are being conducted after every cycle at this time. Testing is now in the set of 5 cycles at 250°F, but so far no surface cracks have appeared.

Test #2b Update: Taking the second 2.24" flight spares ball (without a notch) through a series of flight-like thermal mechanical cycles described below yielded no cracking. In an effort to expedite the creation of a crack, two in-line notches are being EDM'd into the ball, approximately 0.050" between them. The ball with then be subjected to a total of 1000 rapid thermal cycles from boiling water to ice water in an effort to crack it before resuming flight-like thermal/mechanical cycling.

MSFC Status: Besides developing a technique for quicker quenching, MSFC personnel have cracked both notched and pristine 2.24" balls using severe thermal cycles. In addition, they have cracked a flight spares ball (one of 1.75" diameter, without a notch, that had pre-existing subsurface flaws) with nominal thermal cycles (from ambient to LN2 temperature). Because of the similarity between LN2 temperature and LO2's temperature (flight temperature), cracking of the 1.75" ball lends credibility to the theory that the OV-103 ball might have had subsurface cracks which surfaced when subjected to cryogenic cycles. Note however that the test does not simulate the thermal mass and mechanical loading seen on the flight vehicle during loading and flight. Secondly, the fact that a flight spares ball had subsurface defects which propagated to a surface crack tends to indict the acceptance criteria.

The concern of particle liberation upstream of an SSME has been fueled by the type of cracking detected on the severely cracked 2.24" balls. Coordination with the SSME Project on the engine's tolerance to FOD is being conducted in an attempt to clear this concern.

Thermal modeling indicates that LN2 is not a good test fluid for balls in LH2 service (1.25"). If liquid hydrogen is used to simulate these conditions, safety considerations will slow testing significantly. Other mediums, such as liquid helium and liquid neon, are being considered. Note that the thermal modeling so far has considered only the ball. Model development is in work on the inserts and adjoining hardware.

NDE of all flight spares is being conducted in an effort to find more balls with subsurface indications. These would then be put in test. Finding no indications in any of the flight spares might support the theory that OV-103's ball was an outlier, i.e., that it had subsurface cracks when installed in the line.

More to come.

Hugo

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To: ERMINGER, MARK D. (JSC-NC) (NASA); JOHNSON, M. S. (SCOTT) (JSC-NC) (NASA);

Mark Kowaleski, 07:57 AM 1/3/2003 -0500, Fwd: FW: BSTRA ball test status

BROWNE, DAVID M. (JSC-NC) (NASA)

Cc: CULBERTSON, FRANK L., JR (JSC-NA) (SAIC); CAZES, DAVID (JSC-NA) (SAIC); EVATT, GARVIN T. (GT) (JSC-NC) (SAIC); BALU, BRIAN K. (JSC-NC) (SAIC); DYER, KEITH W. (JSC-NC) (SAIC); AUGUSTYN, JOSEPH (JSC-REMOTE); MARTINEZ, HUGO E. (JSC-NC) (GHG); TIPTON, MICHAEL R. (JSC-NX) (SAIC); PRINCE, GORMAN W. (BILLY) (JSC-NC) (GHG); ISHMAEL, MOHAMED I. (GEORGE) (JSC-NC) (SAIC); CLEMENTS, DANIEL L. (JSC-NC) (GHG); ALMASRI, WALEED (JSC-REMOTE); AL-HAYEK, FAREED A. (JSC-NC) (SAIC)

Sent: 12/27/2002 6:10 PM

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>Hugo E. Martinez, PE

>Shuttle SR&QA Propulsion & Power Lead Engineer

>JSC NC62

>Phone: 281 244-1974

>

>Fax: 281 244-1849

>

>Providing for a safer tomorrow, today.

>

Bill Loewy, 03:29 PM 1/24/2003 -0500, Fwd: STS-107 FRR Tagup Action Item Closed (#1)

X-Authentication-Warning: spinoza.public.hq.nasa.gov: majordom set sender to owner-hqpar using -f
X-Sender: bloewy@mail.hq.nasa.gov
X-Mailer: QUALCOMM Windows Eudora Version 4.3.2
Date: Fri, 24 Jan 2003 15:29:52 -0500
To: hqpar@lists.hq.nasa.gov
From: Bill Loewy <bloewy@hq.nasa.gov>
Subject: Fwd: STS-107 FRR Tagup Action Item Closed (#1)
Sender: owner-hqpar@lists.hq.nasa.gov

>
>Subject: STS-107 FRR Tagup Action Item Closed (#1)
>Date: Fri, 24 Jan 2003 12:57:32 -0600
>X-Mailer: Internet Mail Service (5.5.2653.19)
>
>> The following action assigned at the STS-107 FRR Tag-up
>> held on Tuesday, January 07, 2003 has been closed:
>>
>> Action # 010703-1
>> Actionee: JSC-Hugo Martinez
>> Action: How many BSTRA balls failed the ATP nitrogen
>> immersion test?
>Response:
>None of the balls failed the screening at Arrowhead but about 45% failed the
>sub-vendor's check.
>
->>

****
Bill Loewy
NASA Headquarters
Code QS
Office of Safety and Mission Assurance
Washington DC 20546
Bill.Loewy@hq.nasa.gov
****

"Mission success starts with safety"

Wayne R. Frazier, 08:51 AM 2/3/2003 -0500, Fwd: NYT Article

X-Sender: wfrazier@mail.hq.nasa.gov
X-Mailer: QUALCOMM Windows Eudora Version 4.3.2
Date: Mon, 03 Feb 2003 08:51:31 -0500
To: jlloyd@hq.nasa.gov, prutledg@hq.nasa.gov, jlemke <jlemke@hq.nasa.gov>
From: "Wayne R. Frazier" <wfrazier@hq.nasa.gov>
Subject: Fwd: NYT Article

Gil White and I were discussing this after seeing it on CNN. We'll get an action out of this for sure so we might as well start. If indeed Mr. Goldin (remember him) was a factor in this decision to "let them go" because he said it was the same story every year ("the sky is falling"), we'll probably see him on CNN soon also. We may want to extract some excerpts from the reports from the last 10 years and the NASA response to show we did not ignore them.

W

X-Sender: bloewy@mail.hq.nasa.gov
X-Mailer: QUALCOMM Windows Eudora Version 4.3.2
Date: Mon, 03 Feb 2003 08:26:06 -0500
To: Bryan.Oconnor@hq.nasa.gov, jlloyd@hq.nasa.gov, pete.rutledge@hq.nasa.gov
From: Bill Loewy <bloewy@hq.nasa.gov>
Subject: NYT Article
Cc: wfrazier@hq.nasa.gov, jlemke@mail.hq.nasa.gov

This is the article in the New York Times has Michael Greenfield calling the ASAP and Code M up to his office.

On the web at http://www.nytimes.com/2003/02/03/national/03NASA.html

February 3, 2003

NASA Dismissed Advisers Who Warned About Safety

By WILLIAM J. BROAD and CARL HULSE

hen an expert NASA panel warned last year that safety troubles loomed for the fleet of shuttles if the agency's budget was not increased, NASA removed five of the panel's nine members and two of its consultants. Some of them now say the agency was trying to suppress their criticisms.

A sixth member, a retired three-star admiral, Bernard M. Kauderer, was so upset at the firings that he quit the group, NASA's Aerospace Safety Advisory Panel, a group of industry and academic experts charged with monitoring safety at the space agency.

NASA said it changed the charter of the group so that new members, younger and more skilled, could be added. "It had nothing to do with shooting the messenger," said Sonja Alexander, a spokeswoman at NASA headquarters in Washington.

Members of Congress who heard testimony from the panel last spring said yesterday that they would re-examine whether budget constraints had undermined safety, but several said they doubted it. The Bush administration said that it would propose a $470 million increase in NASA spending today, and that the increase was planned before the Columbia's destruction.

Dr. Seymour C. Himmel, who was fired from the advisory panel, said yesterday that "we were telling it like it was and were disagreeing with some of the agency's actions."

The eight departed panel members and consultants had long experience with the shuttles' systems and their troubles. In interviews yesterday, some said NASA had developed an institutional myopia about the panel's warnings, advice and observations, however pointed.

The panel's most recent report, which came out last March and included analyses by the six departed members, warned that work on long-term shuttle safety "had deteriorated." Tight budgets, it said, were forcing an emphasis on short-term planning and adding to a backlog of planned improvements. The report called for sweeping change.

"I have never been as worried for space shuttle safety as I am right now," Dr. Richard D. Blomberg, the panel's chairman, told Congress in April. "All of my instincts suggest that the current approach is planting the seeds for future danger."

His worry, he continued, "is not for the present flight or the next or perhaps the one after that." He added, "One of the roots of my concern is that nobody will know for sure when the safety margin has been eroded too far." He could not be reached for comment yesterday.

Leading members of Congressional committees with oversight of the space program promised yesterday that they would investigate whether the budget policies of the administration and Congress were a factor in the loss of the shuttle.

"A large part of our inquiry will be examining what policies contributed to the loss of the Columbia and what policies should follow the tragedy," said Representative Sherwood Boehlert, a New York Republican who heads the House Science Committee. But he said he believed the agency had been adequately funded. "Have we done the right things?" he said. "I think the answer is yes."

The breakup of the Columbia as it began re-entry Saturday morning has put renewed focus on a series of government and independent reports that questioned the fitness of the aging shuttle fleet, the impact of scarce federal money, competing priorities and programs at NASA and a changing work force.

As recently as last week, the General Accounting Office said that the space agency was continuing to be challenged by shortages of trained staff members. Over the years other panels have issued similar reports. For example, a NASA committee reported in 2000 that more money and staff members were needed to support operations critical to shuttle safety.

Some lawmakers also contend that the shuttle program has been shortchanged in recent years while the International Space Station now under construction experienced cost overruns. They said budget problems prevented NASA from initiating safety upgrades in the shuttle.

The new NASA administrator, Sean O'Keefe, has been struggling since his appointment to control space station costs.

Senator Kay Bailey Hutchison, Republican of Texas, said she was "very concerned that we were diluting our mission with these budget cuts" though NASA assured her that safety remained the agency's top priority.

Lawmakers said they also wanted to explore whether NASA's efforts to reorganize its management approach played any role in the disaster.

"You always have to strike a balance between management efficiency and safety, and in the days ahead the Senate subcommittee I sit on needs to look at how that balance is being set." said Senator Ron Wyden, Democrat of Oregon, a member of the Subcommittee on Science, Technology and Space.

The Aerospace Safety Advisory Panel was set up after the 1967 Apollo fire that killed three astronauts on the ground. It was authorized to study the safety culture of NASA's programs and report to the agency each year on its findings. The panel has wide access to all of NASA's facilities as well was its armies of managers and technicians.

Dr. John G. Stewart, one of the fired consultants, who specialized in studies of NASA's work force, said he was most upset because the firings came in midcycle as the panel was working hard toward its next report. Dr. Stewart had argued for years that NASA's work force cuts were getting dangerous. Yesterday, he said the warnings were finally beginning to be heard when he was forced off the panel.

He said much of the investigative spadework he had recently done at the Kennedy Space Center in Florida and the Johnson Space Center in Houston went unused.

"These work force issues are very important," he said.

But Ms. Alexander of NASA said the newly added panel members were skilled and

knowledgeable. One of them, Robert B. Sieck, was formerly director of shuttle processing at the Kennedy Space Center and served as launch director for 52 space shuttle launches.

The newly departed members and consultants, Ms. Alexander added, had an average tenure on the panel of 12 years. The panel's charter, she said, was changed in April 2001 to require a rotation of the membership.

"They were forced out in order to refresh the panel with members carrying skill sets applicable to new technologies and ideas" on how to make the shuttle and other NASA projects safer, she said.

Dr. Norris J. Krone, a fired panel member who heads the University Research Foundation at the University of Maryland, which does civil aeronautics research, said he resented the manner in which he and his colleagues were fired.

"It's unusual to terminate people from a high-level group like that in midterm," he said. "We all thought it was ill-advised."

The White House said late yesterday that Mr. O'Keefe, NASA's administrator, would meet the president Monday and then "fully inform" chairmen and ranking members of the committees and subcommittees with jurisdiction over NASA and its budget.

Staff members of the House Science Committee, which delivered the main Congressional report on the 1986 Challenger explosion, were researching records of the Challenger inquiry yesterday. They were also trying to assemble data on the NASA budget to show precisely the history of funding on the shuttle program and shuttle safety.

"We are going to let everything see the light of day," said Congressman Boehlert, who said an initial review could find no evidence that Congress ever denied a NASA request for resources pinned to safety.

Lawmakers and other space experts on Capitol Hill, however, said it was no secret that NASA has had major difficulties.

"NASA has got a lot of problems, there is no question about it," said one senior official. "They have been under a lot of scrutiny because of some high profile screwups and the enormous cost overruns in the space station."

No hearings have yet been set on Columbia, but lawmakers want to move ahead quickly. The House science panel already had a major session scheduled for Feb.27 on NASA and officials now expect that hearing to be expanded and refocused.

Lawmakers and staff members who will help run the hearings say they intend any House and Senate sessions to complement the NASA and outside inquiries.

"Everyone is going to be working off the same facts but looking at them from different angles," said David Goldston, chief of staff for the Science Committee. "I think that is healthy but it all has to be coordinated."

****
Bill Loewy
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Washington DC 20546
Bill.Loewy@hq.nasa.gov
****

Wayne R. Frazier, 08:51 AM 2/3/2003 -0500, Fwd: NYT Article

"Mission success starts with safety"

~~~~~~
Wayne R. Frazier
NASA Headquarters - Code QS
Office of Safety and Mission Assurance
Washington,DC 20546-0001
Ph: 202 358-0588 Fax: 202 358-3104
~~~~~~

"Mission success starts with safety"

ERMINGER, MARK D. (JSC-NC) (NASA), 11:29 AM 2/1/2003 -0600, FW: STS-107 Launch+4 Day Co

From: "ERMINGER, MARK D. (JSC-NC) (NASA)" <mark.d.erminger@nasa.gov>
To: "H - Lloyd Jim (E-mail)" <james.d.lloyd@hq.nasa.gov>,
"H - Patrican Rich (E-mail)" <rpatrica@hq.nasa.gov>,
"h - Rutledge Pete (E-mail)" <prutledg@hq.nasa.gov>
Subject: FW: STS-107 Launch+4 Day Consolidated Film/Video Report
Date: Sat, 1 Feb 2003 11:29:25 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)

-----Original Message-----
From: Page-1, Robert [mailto:Robert.W.Page@nasa.gov]
Sent: Wednesday, January 29, 2003 12:56 PM
To: Abner, Charlie; ALFARO, KAREN (JSC-SP5) (LM); Atkinson, Bill C.; Ayotte-1, William; BAHR, PATRICIA A. (PAT) (JSC-SJ) (NASA); BALU, BRIAN K. (JSC-NC) (SAIC); Bauder, Stephen P; Blue, John B; Brewer, John M; BROWN, KENNETH L. (JSC-MV6) (NASA); Bursian, Henry; Burt, Rick; Butler, Mike; BYRNE, GREGORY J., PHD (JSC-SX) (NASA); Cash, Steve; Chapman, John; Chitko, Pete J.; BOYKIN, CHRISTINE M. (JSC-MS2) (NASA); Clever, William W.; Davis, Benny; DERRY, STEPHEN M. (STEVE) (JSC-EG3) (NASA); DISLER, JONATHAN M. (JON) (JSC-SX) (LM); DYE, PAUL F. (JSC-DA8) (NASA); Engler, Tom; ERMINGER, MARK D. (JSC-NC) (NASA); Fagan, Michael; Ferris, Frances; Fisher, Gary; Fricke, Robert W.; Fuller, Mike; GALBREATH, GREGORY F. (GREG) (JSC-ES2) (NASA); Gardze, Eric P.; GLANVILLE, ROY W. (JSC-NC) (NASA); Glenn-1, Malcolm; Goldman, Gene; GOMEZ, REYNALDO J. (RAY) (JSC-EG3) (NASA); Gordon, Steve L; Greenwood, Terry F.; BYRNE, GREGORY J., PHD (JSC-SX) (NASA); Guidi-1, John; HALSELL, JAMES D (JSC-REMOTE); HAM, LINDA J. (JSC-MA2) (NASA); Harris, Yolanda; Hawkins, Tyrell; HAYNES, DENA S. (JSC-EV) (NASA); Herst, Terri; Holderman, Mark L.; Holmes, Steven G.; Hopson, George; Huff, Joy N.; IVINS, MARSHA S. (JSC-CB) (NASA); Jim Ross; Jones-1, Frank; Kaminsky, James; Kelley-1, David; Kienitz, Fred; Kynard, Mike; Lafleur, Tom C; Laufenberg, Katherine M; Leggett, Kenneth D; Leinbach-1, Mike; LIN, JILL D. (JSC-MV5) (NASA); Lorelei Lohrli-Kirk; Maddux, Lewis; Mango, Ed; Martin, David M.; MARTINEZ, HUGO E. (JSC-NC) (GHG); MAYER, FRED F. (JSC-NC) (SAIC); MCCORMACK, DONALD L. (DON) (JSC-MV6) (NASA); Moore, Dennis; Moyer, David; Muddle, William H.; Muhar, Mark; Murphy, Alan; Nagle, Scott M; Nash, Richard; Newton, John; Oliu-1, Armando; Ortiz-Longo, Carlos V.; Otte, Neil; Otto, Scott; Owens, Karen K.; Page-1, Robert; PATTERSON, JOE K. (KEN) (JSC-DM) (USA); Preston, Ken; PREVETT, DONALD E. (DON) (JSC-EP) (NASA); Purtle, Lawrence; Ramon, Rudolph; Revay, Kenneth P; Rieckhoff, Tom; Rivera, Jorge; Rudolphi, Michael; Segert-1 Randall; Smelser, Jerry; Snoddy, Jim; SNYDER, MICHAEL W. (JSC-SX) (LM); Sofge, Al (NASA HQ); Speece-1, Bob; Stevenson-1, Charlie; Sutton, Marcy; Swan, Bobbie G.; Teehan, Paul; Tepool, Ronald; Tinsley, John; WALLACE, RODNEY O. (ROD) (JSC-MS2) (NASA); WALTERS, JAMES B. (BRITT) (JSC-SM) (NASA); White, Doug; Williams, Tom; Wilson, David; Wilson, Thomas F.; Woolhouse, Dwight; Worlund, Len
Subject: STS-107 Launch+4 Day Consolidated Film/Video Report

Attached is a copy of the STS-113 Launch+4 Day Consolidated Film/Video Report.

<<107CFVR_L+4.pdf>>

During my computer replacement, I lost the distribution list and have been working ro restore it. Please review over the list of names that this is being sent to and verify that the proper individuals are getting it. Also, the following were getting it before and I cannot find e-mail addresses for them. If you have one, please provide it to me; Bakes, Russell; Conte, Barbara A; Counts, Parker; Feeley, James; Jones, Ferdinand; Kan, Kenneth; Kopfinger, Philip; Lamkin, Bill; Nichols, Stanley;Robertson, James;

Sanofsky, Kerry; Schomburg, Calvin.

Bob Page
KSC/MK-SIO
(321)867-8516

107CFVR_L+4.pdf

STS-107
Launch+4 Day
Consolidated Film/Video Report
KSC, JSC, MSFC and Program Integration
Film/Video Analysis Teams

22 January 2003

This report consolidates the multi-center post flight photo reviews into a single list of observations for engineering review. This integrates the photo review process into the IFA / PRACA process to ensure that the identified observations are assessed and dispositioned prior to the next flight per established problem reporting criteria.

CFVR–107-01

Camera: E204, E208, E212
Time: UTC 016:15:40:21.699

During ascent at approximately 81 seconds MET, debris was seen to originate from an area near the ET/Orbiter forward attach bipod. Due to lighting conditions in the area, it is not known whether the debris originated as a single item which broke up or if it originated as several separate items. Four objects are seen or surmised from the data.

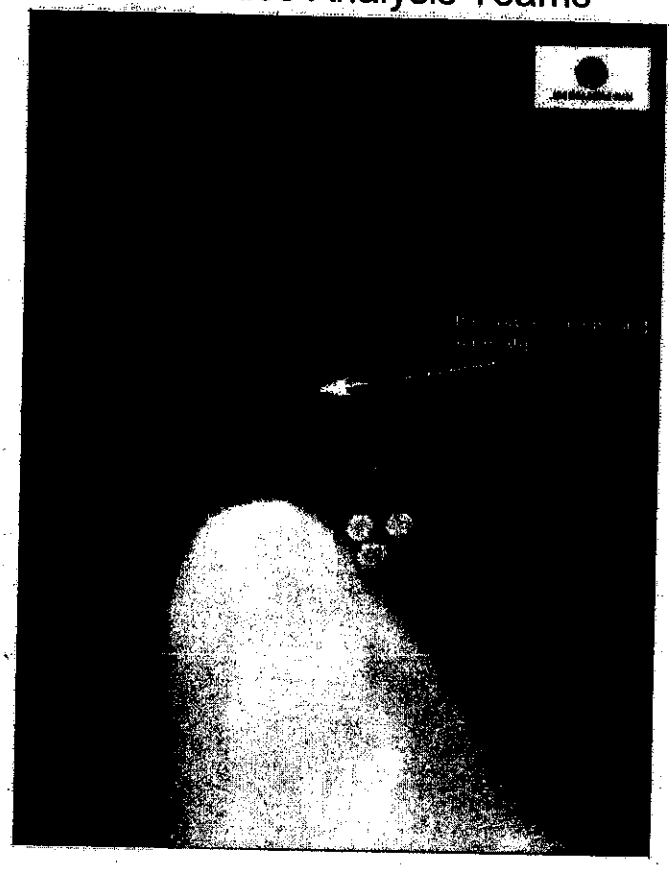
Object #1, the largest of the items, was a light-colored piece of debris which appeared (016:15:40:21.699 UTC) to move outboard in a -Y direction, then fell aft along the left Orbiter fuselage and struck the underside (-Z) of the leading edge of the left wing (016:15:40:21.882 UTC). The strike appears to have occurred on or relatively close to the wing glove near the Orbiter fuselage. After striking the left wing, the debris broke into a spray of white-colored particles that fell aft along the underside (-Z side) of the Orbiter left wing. The spray of particles was last seen near the LSRB exhaust plume.

Object #2, darker and smaller in appearance than the first, is visible in the frame immediately following the appearance of Object #1. Its travel path seems to be slightly more outboard and more in the –Z direction than the first. This object actually strikes the wing before Object #1. (A spray of particles is seen traversing aft prior to the strike from Object #1).

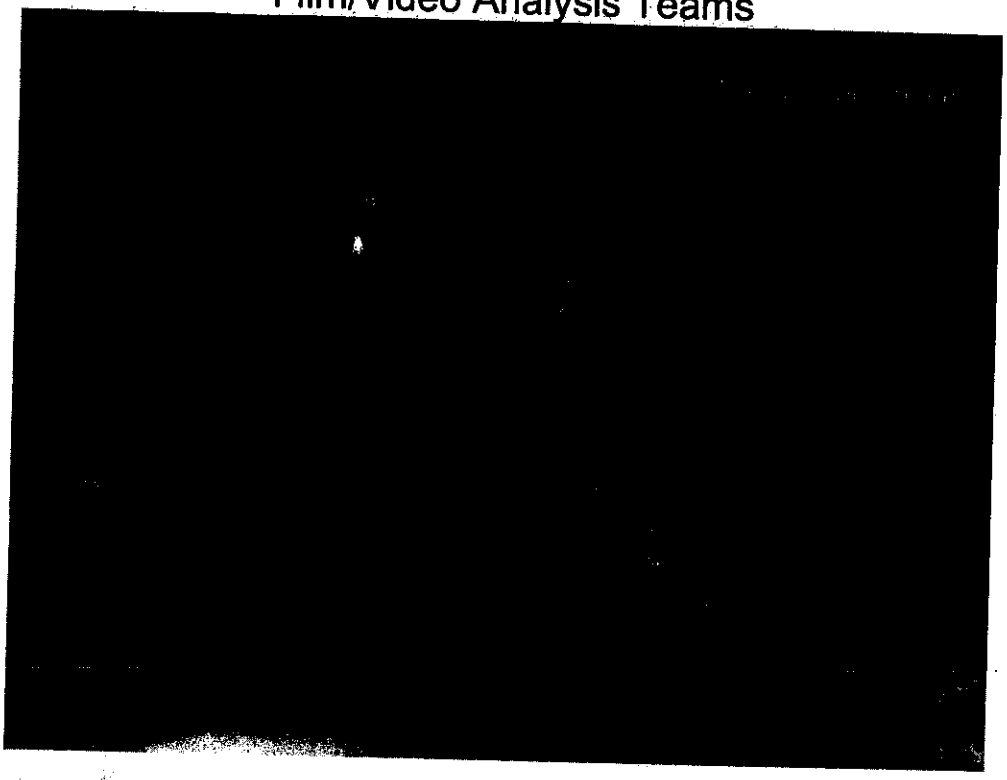
Object #3 is not seen directly in any views. However, evidence of its existence comes from a second spray of particles at the same time as and parallel to the spray from Object #2.

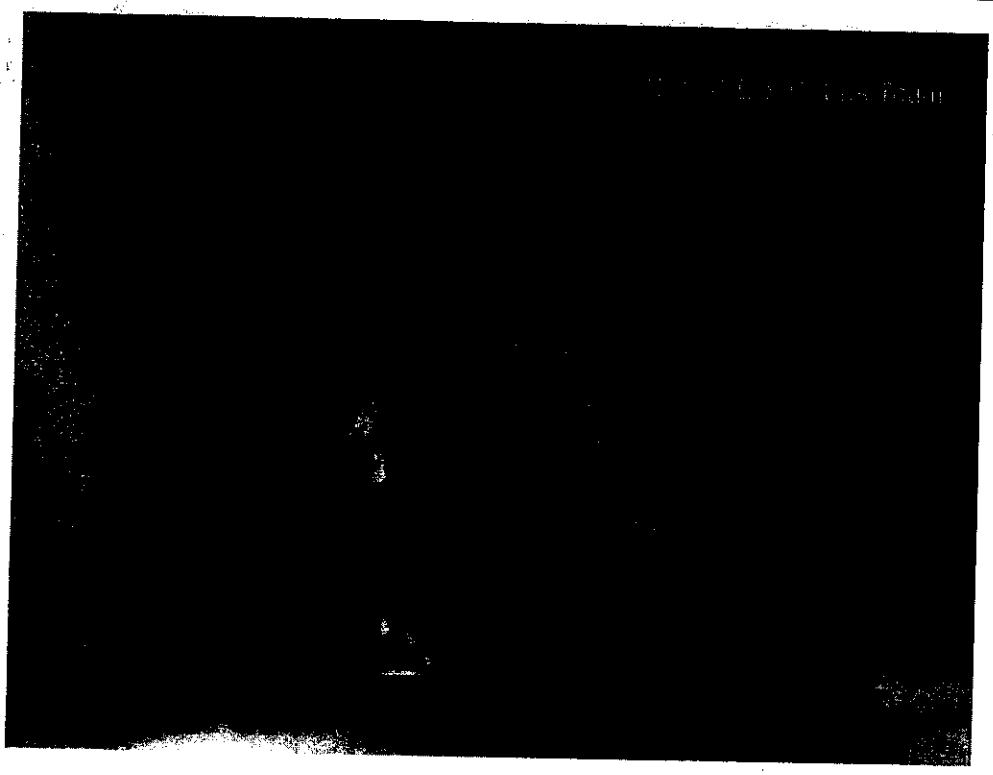
Object #4 does not appear to strike the Orbiter, but is seen as it crosses over the ET vertical strut. This object may be part of the debris cloud from Object #2/3.

STS-107
Launch+4 Day
Consolidated Film/Video Report
KSC, JSC, MSFC and Program Integration
Film/Video Analysis Teams



STS-107
Launch+4 Day
Consolidated Film/Video Report
KSC, JSC, MSFC and Program Integration
Film/Video Analysis Teams





STS-107
Launch+4 Day
Consolidated Film/Video Report
KSC, JSC, MSFC and Program Integration
Film/Video Analysis Teams

Comparison views of the strike area immediately before and after the event were examined for indications of damage to the wing. The resolution on the films and videos is insufficient to see individual tiles. Of the multiple views that should have been available to view this event, many were unuseable. Based on the resolution of the views available, no conclusions can be reached on the extent of any damage that may have occurred from this event.

Secondary effects from the spray of materials following the strikes was also considered. The MER was contacted to determine the Elevon positions at the time of the strike. Since the Left Inboard Elevon was slightly down, there is also the possibility of strikes there.

Time		Elevon Position (deg)	
G.m.t.	MET (sec)	LIB	LOB
016:15:40:20	80	2.56	-4.87
016:15:40:21	81	1.63	-4.87
016:15:40:22	82	0.71	-4.87
016:15:40:23	83	0.24	-3.71
016:15:40:24	84	0.24	-2.09

Note: For the elevons, a negative deflection is Up, positive is Down

A preliminary assessment of debris impact conditions predicted an impact to the Orbiter lower surface at location Xo1049, Yo185 (results provided on January 17, 2003) Impact velocity was estimated to be approximately 750 ft/sec with an impact angle estimated to be less than 20 degrees.
Further analysis will be performed.

STS-107
Launch+4 Day
Consolidated Film/Video Report
KSC, JSC, MSFC and Program Integration
Film/Video Analysis Teams

CFVR–107-02

Camera: E-220, E-222, E-223, E-224
Time: UTC 15:39:33.196

Approximately 33 seconds after T-0 (15:39:33.196 UTC) several particles are observed falling away from the –Z portion of the LH SRB ETA ring. Particles are probably pieces of the instafoam closeout on the ETA ring. (E-220, E-222, E-223, E-224)

From Post-Flight SRB Inspection:

The LH ETA ring instafoam closeout exhibited missing foam on the aft side. The areas of missing foam were sooted, indicating they came off in flight and not as the result of water impact. The largest area was approximately 3 inches in diameter by 2-1/2 inches deep. This appears to correlate with the debris seen coming from this area on the tracking films (E-220, E-222, E-223, E-224).

Missing Instafoam, with sooting, from the aft side of the LH ETA ring.

STS-107
Launch+4 Day
Consolidated Film/Video Report
KSC, JSC, MSFC and Program Integration
Film/Video Analysis Teams

Bob Page
KSC/MK-SIO
(321)867-8516

Mark Kowaleski, 08:48 AM 2/14/2003 -0500, missing Mutli-Tile Loss Thermal Analysis?

X-Sender: mkowales@mail.hq.nasa.gov
X-Mailer: QUALCOMM Windows Eudora Version 4.3.2
Date: Fri, 14 Feb 2003 08:48:43 -0500
To: boconnor@mail.hq.nasa.gov, prutledg@mail.hq.nasa.gov,
jlloyd@mail.hq.nasa.gov
From: Mark Kowaleski <mkowales@hq.nasa.gov>
Subject: missing Mutli-Tile Loss Thermal Analysis?
Cc: pphillip@mail.hq.nasa.gov, mark.d.erminger1@jsc.nasa.gov

Bryan,

I'm not sure if you have seen these yet? Here is the Project's analysis of foam transport mechanisms and TPS damage assessment.

I am still trying to get my hands on the "Mult-Tile Loss Thermal Analysis," but keep getting stone-walled by JSC and HCAT. Have you, by chance, seen the thermal analysis already? It is referenced at the end of the package as being necessary to validate the conclusion of no safety-of-flight issue on the last page of Orbiter charts. A few of the charts show some serious damage potential crossing the MLG Door/Orbiter interface at multiple locations around the perimiter of the MLG Door.

Specifically, the thermal analysis missing (chart on page 10 of Orbiter TPS damage assessment) concerns larger wing damage areas and MLG Door damage.

I tried getting the analysis from Orbiter Project, Integration Office, Linda Ham directly, and HCAT, but no one seems to want to answer the mail. SMA/Erminger asked the Shuttle Project (on my behalf) a few days after the mishap for the analysis but was told that he needed to go through HCAT.

FYI, these charts showed up for the first time at HQ on Feb 1st via FAX in the HCAT. I noticed them laying on a table.

I'm probably being paranoid and it is likely that the CAIB has already seen the data??? But I am concerned about my inability to get my hands on the rest of the thermal analysis and I'm even more concerned that SMA/Erminger was told that you needed to talk to Dittemore directly to get that specific information.

Mark

Date: Mon, 10 Feb 2003 11:38:46 -0500
To: hcat@hq.nasa.gov
From: Mark Kowaleski <mkowales@hq.nasa.gov>
Subject: Re: Fwd: stress/thermal analysis request
Cc: boconnor,jlloyd,prutledge,merminger

Bill (HCAT),

OK, no problem. This is my request to the HCAT for this information.

We need a copy of the STS-107 TPS Muli-Tile Loss Thermal Analysis data package described below.

Please provide it when it becomes available.

Thanks,

Mark

Date: Mon, 10 Feb 2003 08:18:32 -0500
To: lham

Mark Kowaleski, 08:48 AM 2/14/2003 -0500, missing Mutli-Tile Loss Thermal Analysis?

From: Mark Kowaleski <mkowales@hq.nasa.gov>
Subject: Fwd: stress/thermal analysis request
Cc: stuart.l.mcclung@nasa.gov,boconnor,jlloyd,prutledge,merminger,ymarshall

Hello Linda,

I work for Bryan O'Connor as the HQ Shuttle Safety Manger in Code Q. Stuart McClung said that I needed to request the STS-107 TPS Muli-Tile Loss Thermal Analysis data package from you (see note below). I have been trying to get this document for over a week and no one seems to either want to part with it or locate it.

We have the Foam Transport Assessment and the TPS Damage Assessment from Boeing. The requested analysis is referenced in the conclusion of the Boeing Orbiter TPS Assessment, dated 1-23-03.

Would you please get me a copy of the thermal analysis? We need it for the NASA Administrator's talking points for his testimony on Wednesday.

Mark

At 10:23 AM 2/10/2003 -0500, you wrote:
Mark,

You need to work requests for information from JSC through the HCAT, unless it is a CAIB request. CAIB requests need to be worked thru the Task Force.

Bill Hill

To: boconnor
From: Mark Kowaleski <mkowales@hq.nasa.gov>
Subject: Fwd: STS-107 Ascent Debris Assessments

Bryan,

We have pursued multiple channels to obtain the ET debris and Orbiter TPS damage assessment.

As you can see, we have reached some brick walls.

Mark Erminger requested the data on my behalf but was turned down by Lambert Austin (see message below).

I called Lambert's office but he never called back.

I contacted Code M to ask for the data and I was told that the data is "restricted access."

I finally got a copy by strong-arming someone in Code M but was told "not to divulge my source."

The thermal

Mark

From: "ERMINGER, MARK D. (JSC-NC) (NASA)" <mark.d.erminger@nasa.gov>
To: "H - Kowaleski Mark (E-mail)" <mkowales@mail.hq.nasa.gov>
Subject: STS-107 Ascent Debris Assessments
Date: Wed, 5 Feb 2003 08:28:52 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)

Mark Kowaleski, 08:48 AM 2/14/2003 -0500, missing Mutli-Tile Loss Thermal Analysis?

I spoke to Lambert Austin and he said that Bryan should request this information from Ron Dittemore. Systems Integration did an analysis and so did Orbiter.

Debris.ppt

STS-107 MMT Debris Traj Assessment.ppt

Orbiter Assessment of STS-107 ET Bipod Insulation Ramp Impact

P. Parker
D. Chao
I. Norman
M. Dunham

January 23, 2003

Order of Analysis

- **Orbiter assessment of ascent debris damage includes**
  - **Evaluation of potential for debris to damage tile and RCC**
    - **Program "Crater" is official evaluation tool**
      - Available test data for SOFI on tile was reviewed
      - No SOFI on RCC test data available
    - **Even for worst case, SIP and densified tile layer will remain when SOFI is impactor**
  - **Thermal analysis of areas with damaged tiles**
    - **Thermal analysis will predict potential tile erosion and temperatures on structure**
  - **Structural assessment based on thermal environment defined above**
    - **Basis is previous Micrometeriod and Orbital Debris (M/OD) study performed in 1996**

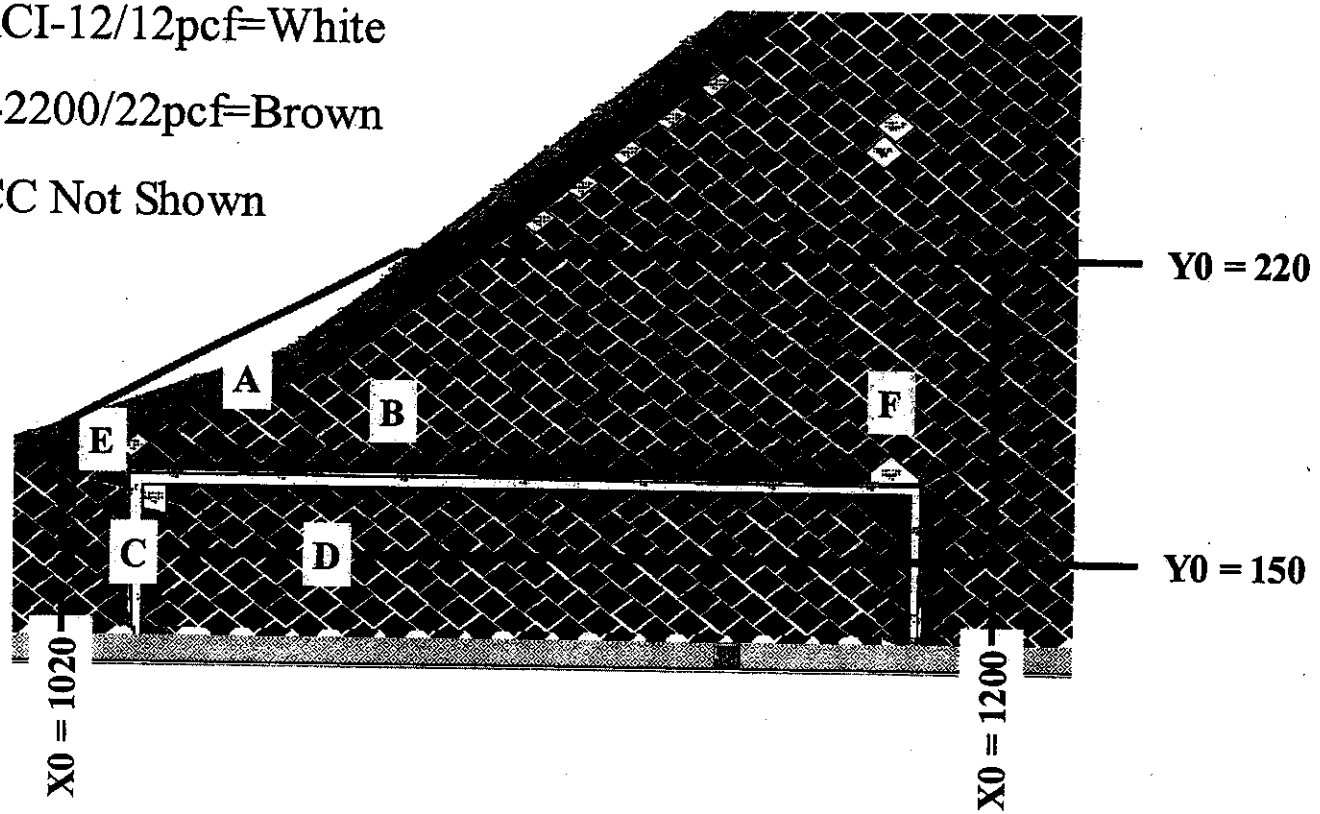
System Integration Inputs Were Matched Against Orbiter Tile/RCC to Determine Critical Locations

LI-900/9pcf=Black

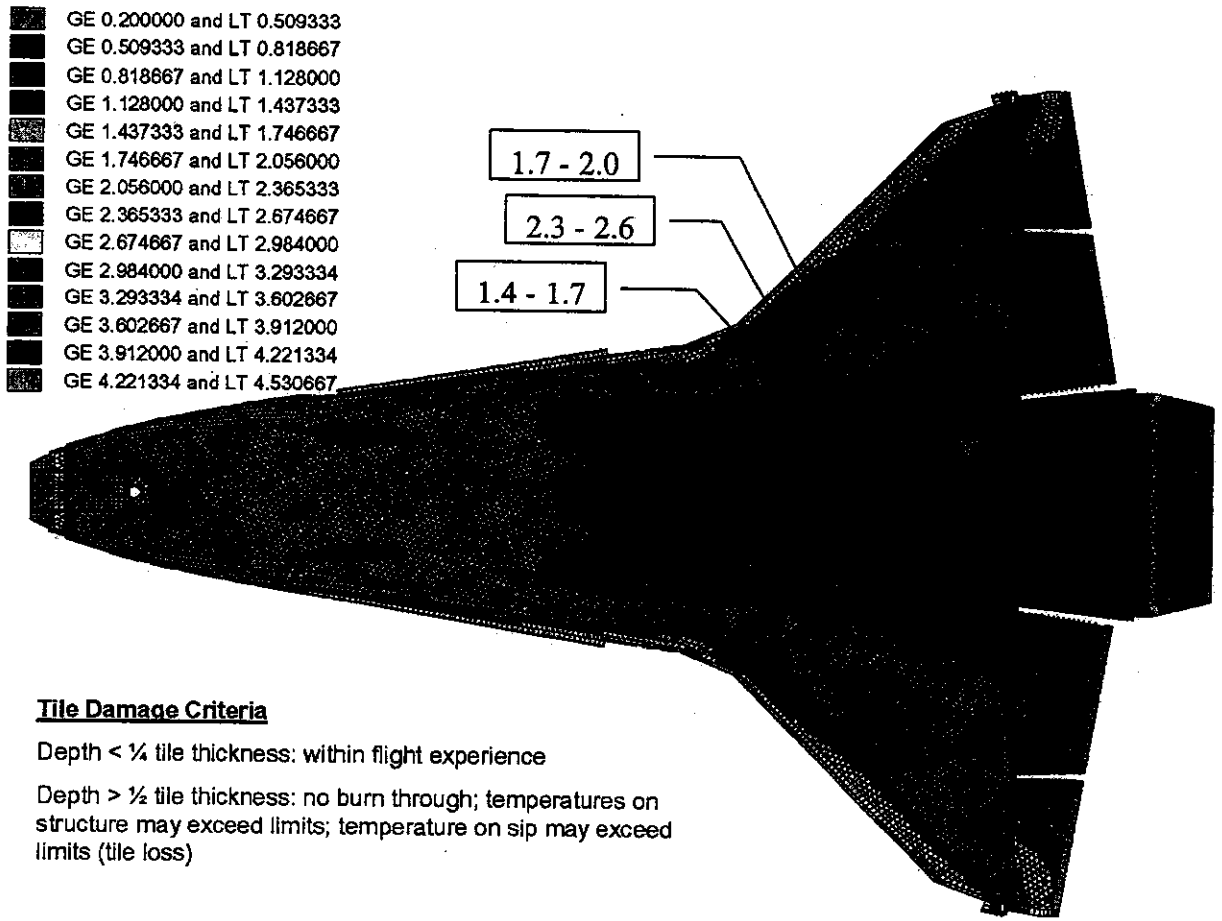
FRCI-12/12pcf=White

LI-2200/22pcf=Brown

RCC Not Shown



Tile Thickness



Tile Damage Criteria

Depth < ¼ tile thickness: within flight experience

Depth > ½ tile thickness: no burn through; temperatures on structure may exceed limits; temperature on sip may exceed limits (tile loss)

Damage Results From "Crater" Equations Show Significant Tile Damage

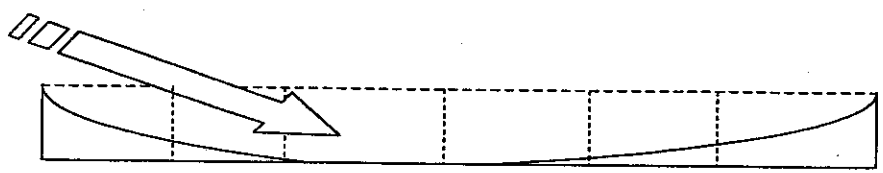
- "Crater" indicates that multiple tiles would be taken down to densified layer
  - However, program was designed to be conservative due to large number of unknowns
  - Crater reports damage for test conditions that show no damage

Tile Information		Location			Impactor		Calculated Damage		
Type	Thickness	Letter	X	Y	Angle	Velocity	Depth	Length	Width
9 lb	2.6 - 2.8	A	1060	190	13	720	4.7	25.8	7.2
22 lb	2.6 - 2.8	A	1060	190	13	720	3.2	25.8	7.2
9 lb	2.3 - 2.4	B	1090	180	6	700	2.8	31.9	7.2
9 lb	2.0 - 2.4	C	1036	150	8	680	3.3	29.8	7.2
22 lb	2.0 - 2.4	C	1036	150	8	680	2.3	28.6	7.2
9 lb	1.9 - 2.0	D	1075	150	8	710	3.4	32.2	7.2
12 lb	2.8 -3.1	E	1029	177	10	680	2.9	19.0	2.4
22 lb	2.8 -3.1	E	1029	177	10	680	2.6	19.0	2.4
9 lb	1.7	F	1184	182	6	730	2.8	32.8	2.4

Damage data and tile thickness are given in inches.

Debris Size = 20" x 16" x 6"

(Density = 2.4 lb/ft^3)



Review of Test Data Indicates Conservatism for Tile Penetration

- **The existing SOFI on tile test data used to create Crater was reviewed along with STS-87 Southwest Research data**
  - **Crater overpredicted penetration of tile coating significantly**
    - **Initial penetration to described by normal velocity**
      - Varies with volume/mass of projectile (e.g., 200ft/sec for 3cu. In)
    - **Significant energy is required for the softer SOFI particle to penetrate the relatively hard tile coating**
      - Test results do show that it is possible at sufficient mass and velocity
    - **Conversely, once tile is penetrated SOFI can cause significant damage**
      - Minor variations in total energy (above penetration level) can cause significant tile damage
  - **Flight condition is significantly outside of test database**
    - **Volume of ramp is 1920cu in vs 3 cu in for test**

(Potentially) Similar STS-50 Impact Demonstrates that Damage is Possible

- Damage to aft lower tile (0.5"d x 9"L x 4" W) on wing was found after STS-50 landing; wheel well camera also observed missing ET bipod ramp insulation similar in size
- Small variation in energy input could substantially increase damage
- Incidence angle for STS-107 is predicted higher than STS-50

Volume = 1920in3

L (in)	d (in)	V (ft/sec)	Angle	Vadj (in/sec)	Flt Damage	damage (depth)	Normal Energy	
20	6	**700**	**3.2**	69	**0.50**	0.53	100%	STS-50 (estimated conditions)
20	6	770	3.2	116		0.75	121%	STS-50 plus 10% velocity
20	6	700	5.2	361		1.60	264%	STS-50 plus 2 deg incidence angle
20	6	600	3.2	2		0.05	73%	STS-50 "threshold"
20	6	720	10	1100		3.37	1024%	STS-107
20	6	788	10	1243		3.66	1228%	STS-107 + 10% energy
20	6	914	10	1505		4.16	1650%	STS-107 + 50% energy
20	6	720	10	700		2.49	551%	STS-107 with V* = 800

V*	C	density (SOFI)	density (tile)	Strength (tile)	
400	0.0195	0.0014	0.0052	53	219912

Volume	V* (in/sec)	Ratio	power	V* (ft/sec)	
0.11	650C	1.0	3.5	542	test
0.33	450C	0.8		375	test
1.00	320C	0.8		267	test
3.00	250C	1.0		208	test
1920	40C	1.0		33	flight

Volume vs V* (velocity to penetrate tile coating)

RCC Predicted Damage at Incidence Angles Greater than 15 Degrees Based on Ice Database

Impactor		Damage
Angle	Velocity (fps)	Depth (in.)
5	720	0.11
10	720	0.18
15	720	0.23
20	720	0.28
25	720	0.33

Debris Size = 20" x 10" x 6"

Density = 2.4 lb/ft^3

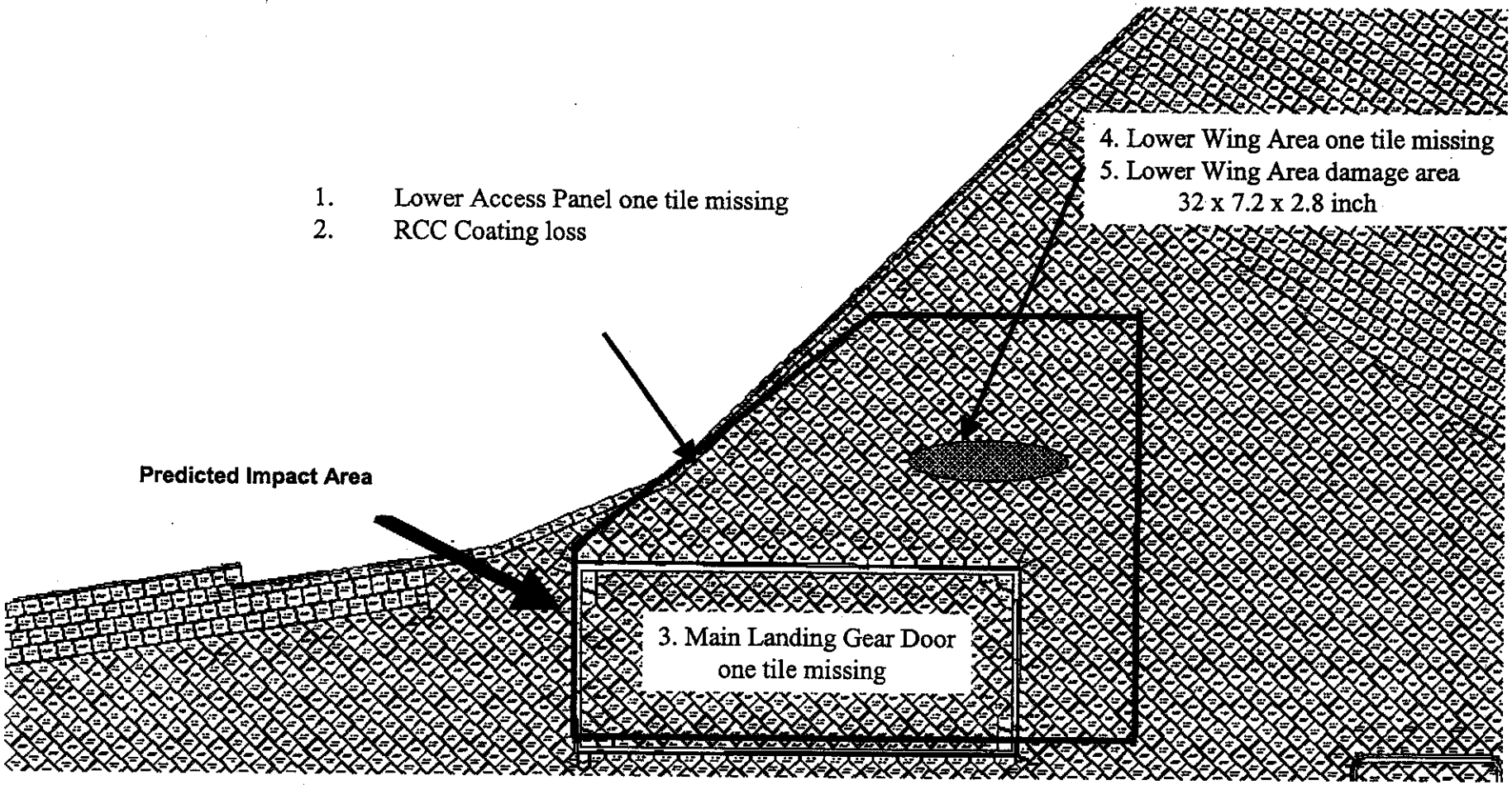
45° angle of wing was taken into account

Nominal panel thickness is 0.233 in.

RCC is clearly capable of withstanding impacts of at least 15 degrees; relative softness of SOFI (compared to ice) would indicate greater capability

- Maximum reported angle of 21 degrees is not an problem
  - Looking at using Window ice and RTV data as an analog

Thermal Analysis Assessment of Debris Impacted Lower Surface in STS-107 Mission Locations



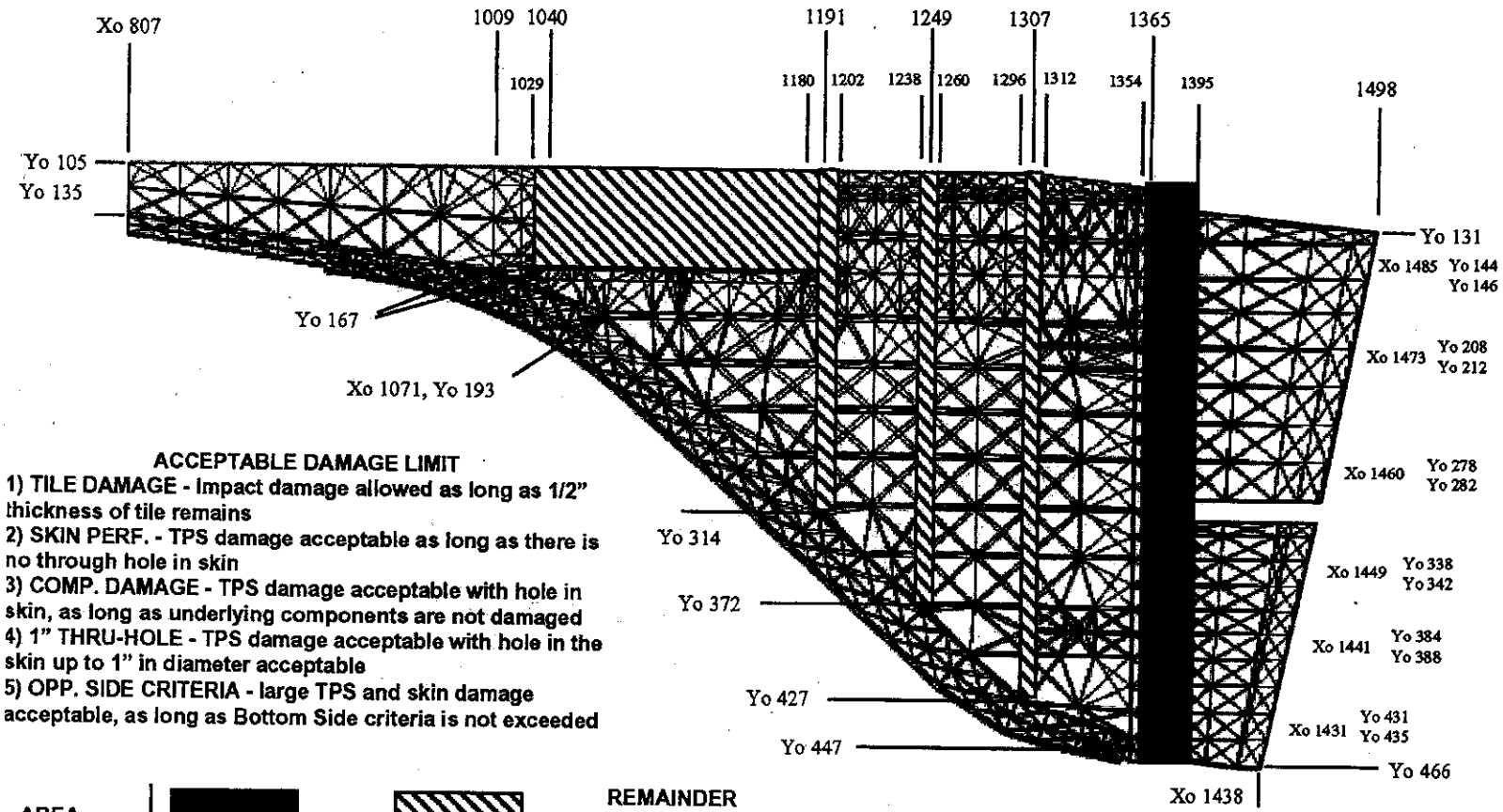
Impacted Lower Surface Location Thermal Predictions

Case	Location	Assumptions	Results
1	Access Panel (one tile missing)	Loss to last layer of TMM Densified layer ~ .2 inches	Temperature of Al Tube Carrier 790 °F No issue
2	RCC Panel 9 Lower Flange OML (Coating Missing)	Coating loss and Carbon substrate exposed	Substrate thickness: 0.193 inches Loss .09 inches No issue
3	Main Landing Gear Door (one tile missing)	Loss to last 2 layers of TMM Densified layer ~ .4 inches	Temperature of Structure 540 °F No issue
4	Lower Wing Area (one tile missing)	Loss to last 2 layers of TMM Densified layer ~ .4 inches	Temperature below 350 °F design req. No issue
5	Lower Wing Area (32 x 7.2 x 2.8 inch) Damage	Loss to last layers of TMM Densified layer ~ .2 inches	
6	Main Landing Gear Door (several tiles Lost)	Loss to last layers of TMM Densified layer ~ .2 inches	

Structural Assessment Provides for Intact Contingency Landing with Damaged Tiles

- Criteria for M/OD study were to assess on-orbit risk that cannot be controlled
- Study allowed for significant degradation beyond design criteria
  - Structural temperatures well beyond 350F design (due to loss of tile)
    - Repair of structure required
  - Small holes in structure, allowing internal plasma flow, were permissible if not in critical area
    - Not expected for STS-107
  - Factor of Safety not maintained for design conditions
  - Critical subsystems were included in evaluation
    - Wing has few subsytems except in landing gear box and elevon cove
    - Wing spars are considered critical structures
- Conditions identified to ensure intact contingency landing

Wing Lower Surface M/OD Failure Criteria



ACCEPTABLE DAMAGE LIMIT

1) TILE DAMAGE - Impact damage allowed as long as 1/2" thickness of tile remains
2) SKIN PERF. - TPS damage acceptable as long as there is no through hole in skin
3) COMP. DAMAGE - TPS damage acceptable with hole in skin, as long as underlying components are not damaged
4) 1" THRU-HOLE - TPS damage acceptable with hole in the skin up to 1" in diameter acceptable
5) OPP. SIDE CRITERIA - large TPS and skin damage acceptable, as long as Bottom Side criteria is not exceeded

AREA			REMAINDER OF WING
Top Side	3) COMP. DAMAGE	3) COMP. DAMAGE	5) OPP. SIDE CRITERIA
Bottom Side	1) TILE DAMAGE	2) SKIN PERF.	4) 1" THRU-HOLE

Summary and Conclusion

- Impact analysis ("Crater") indicates potential for large TPS damage
  - Review of test data shows wide variation in impact response
  - RCC damage limited to coating based on soft SOFI
- Thermal analysis of wing with missing tile is in work
  - Single tile missing shows local structural damage is possible, but no burn through
  - Multiple tile missing analysis is on-going
- M/OD criteria used to assess structural impacts of tile loss
  - Allows significant temperature exceedance, even some burn through
    - Impact to vehicle turnaround possible, but maintains safe return capability

<u>Conclusion</u>

- Contingent on multiple tile loss thermal analysis showing no violation of M/OD criteria, safe return indicated even with significant tile damage

Debris Transport Assessment of Debris Impacting Orbiter Lower Surface in STS-107 Mission

STS-107 MMT

January 24, 2003

Subcontract 1970483303

W.B.S. 1.2.2.1 / 20037

PDRD SC004

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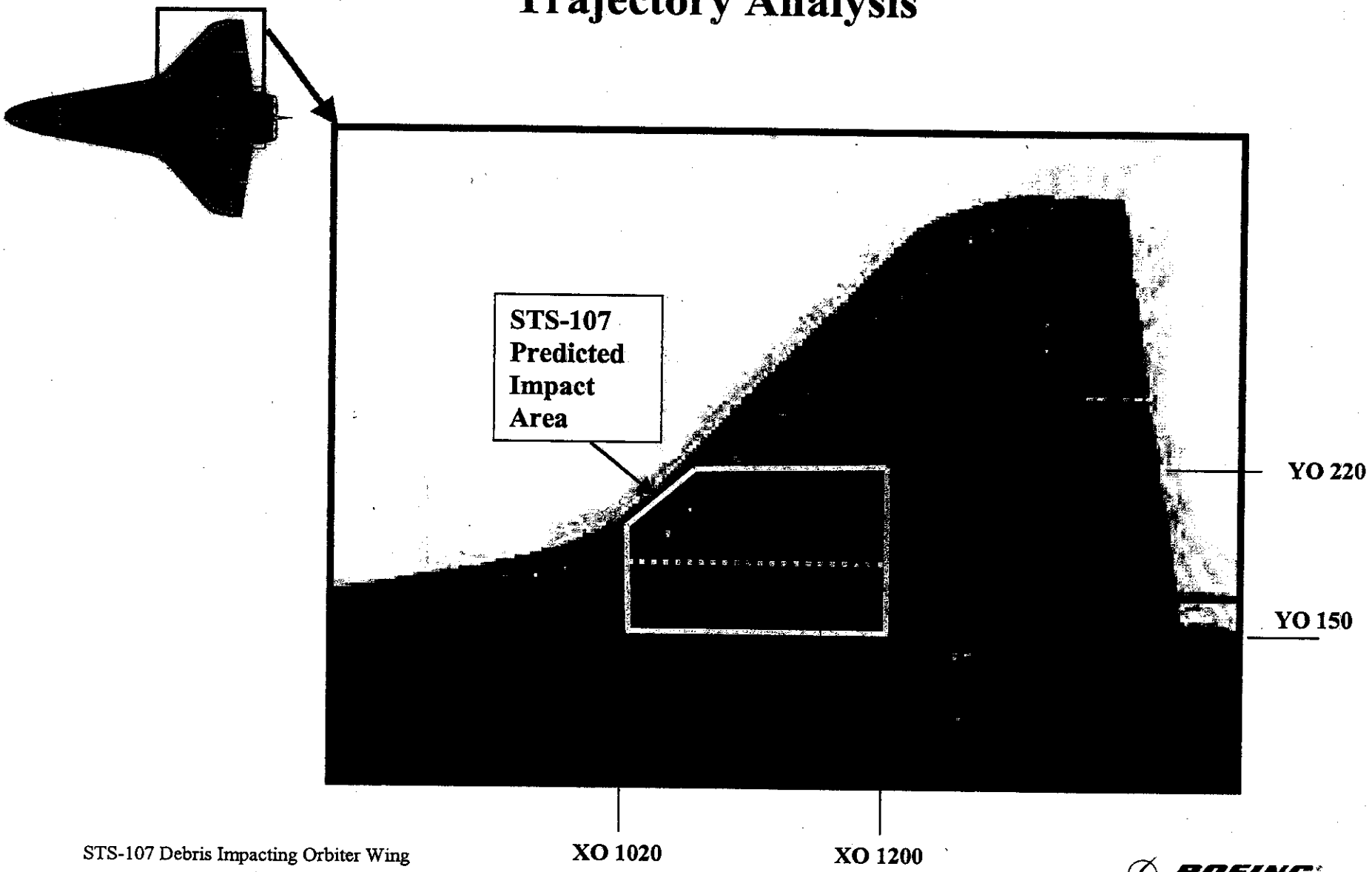
BOEING

Debris Impact Conditions to Be Evaluated for Area on Orbiter Lower Surface

- **Issue** – At about 82 seconds into the flight, multiple pieces of debris were seen emanating from the ET bipod area and later seen impacting the Orbiter lower surface
- **Film Analysis Results indicate impact at about 1/3 of the wing from vehicle centerline**
  - 3 pieces of debris were observed
  - Debris can be 20" long
  - Debris appeared to break-up upon Orbiter impact
    - A shower of debris is seen soon after impact
- **Debris Trajectory Analysis estimated the impact conditions for what was observed**
  - Assumed debris particle emanates from bipod ramp area (XO 389, YO 50)
  - Three debris sizes analyzed:
    - 20" x 16" x 6" (representing bipod ramp)
    - 20" x 10" x 6" (representing bipod ramp)
    - 20" x 10" x 2" (representing flange foam)
  - Debris material considered to be foam (density = 2.4 lb/ft3)
  - Trajectories based on ballistic coefficient for Mach = 2.5 alpha 3.0
  - The distribution of impact conditions on predicted impact area estimated from combination of trajectory results and existing debris database
- **Film review continuing to better define impact area**

Predicted Impact Area Derived from Film Observations and Trajectory Analysis



STS-107 Debris Impacting Orbiter Wing

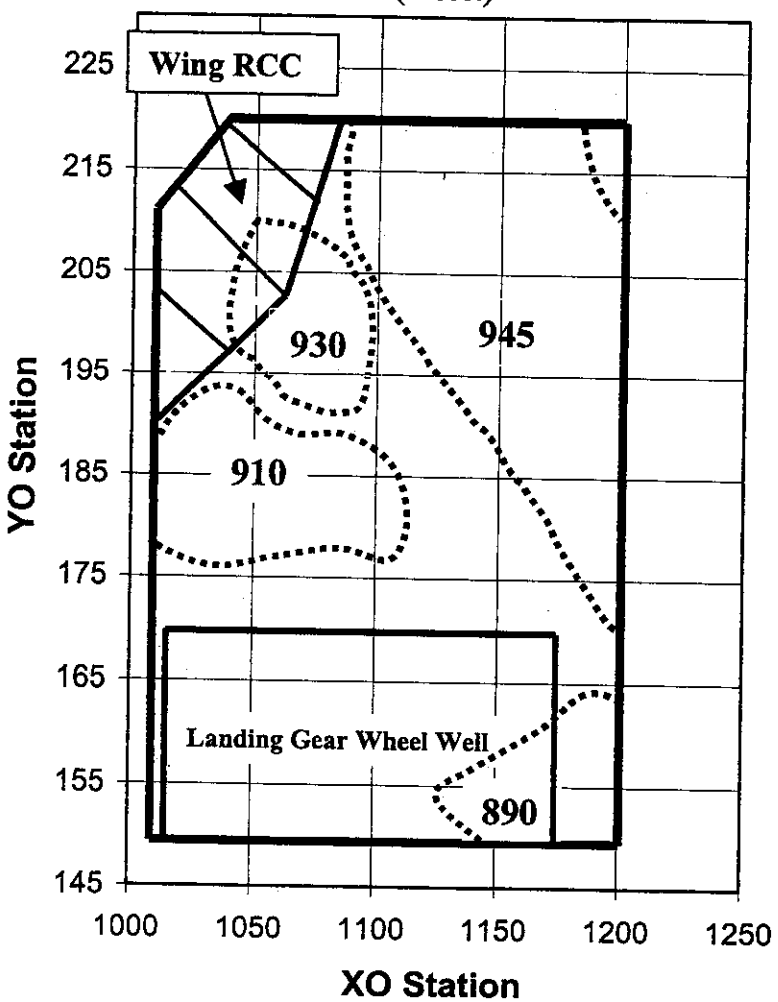
BOEING

Velocity and Impact Angle Distribution Inside Impact Area

(Debris Size = 20" x 10" x 2", Density = 2.4 lb/ft3)

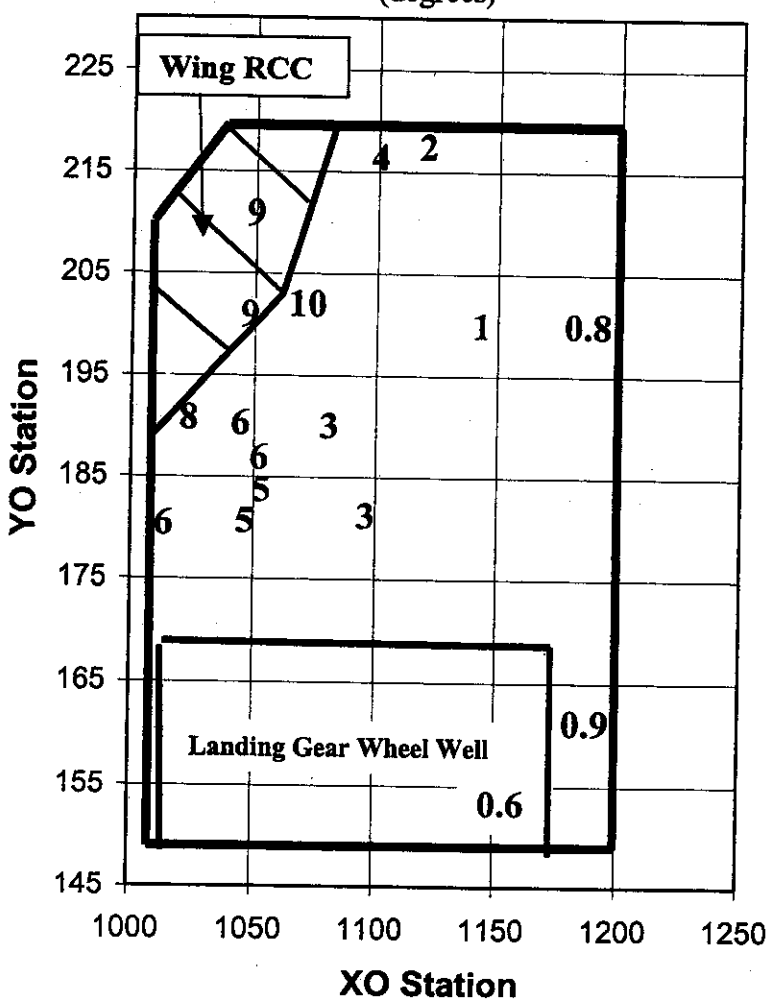
Impact Velocity

(ft/sec.)



Impact Angle

(degrees)



STS-107 Debris Impacting Orbiter Wing

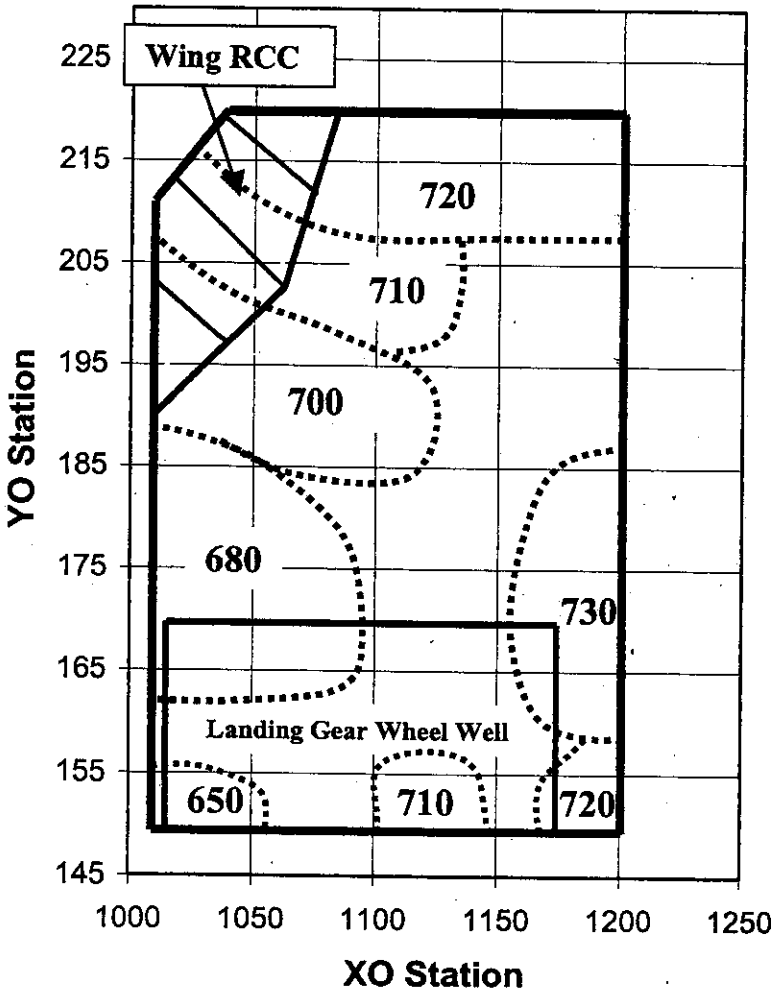
BOEING

Velocity and Impact Angle Distribution Inside Impact Area

(Debris Size = 20" x 10" x 6", Density = 2.4 lb/ft3)

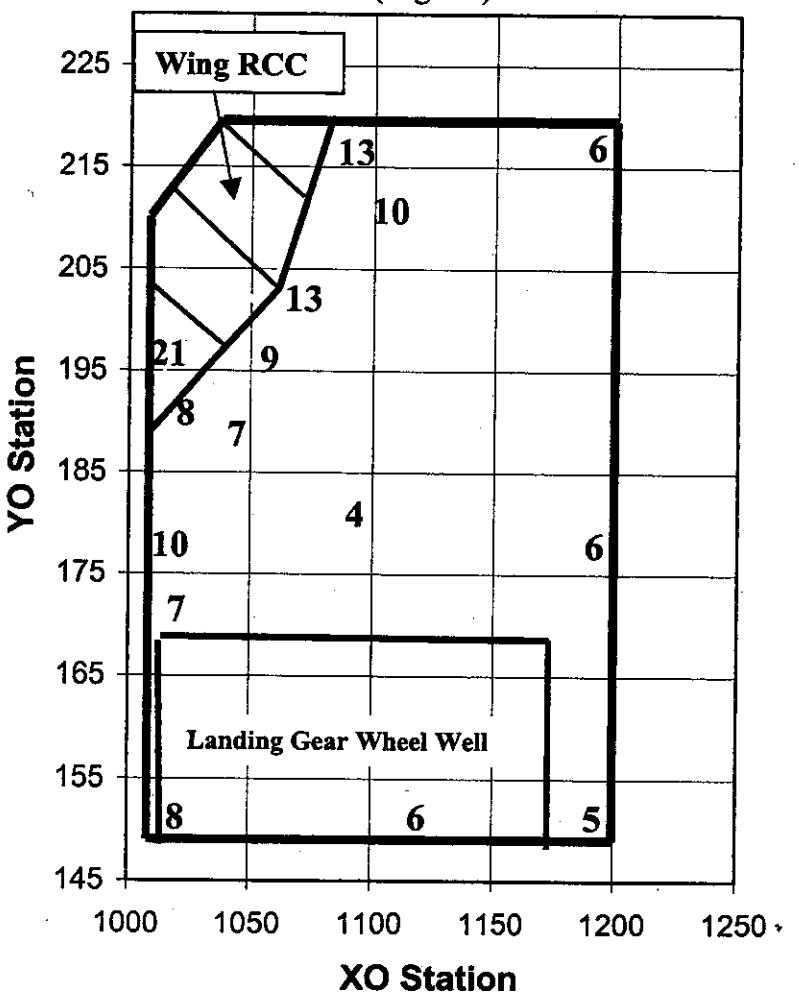
Impact Velocity

(ft/sec.)



Impact Angle

(degrees)

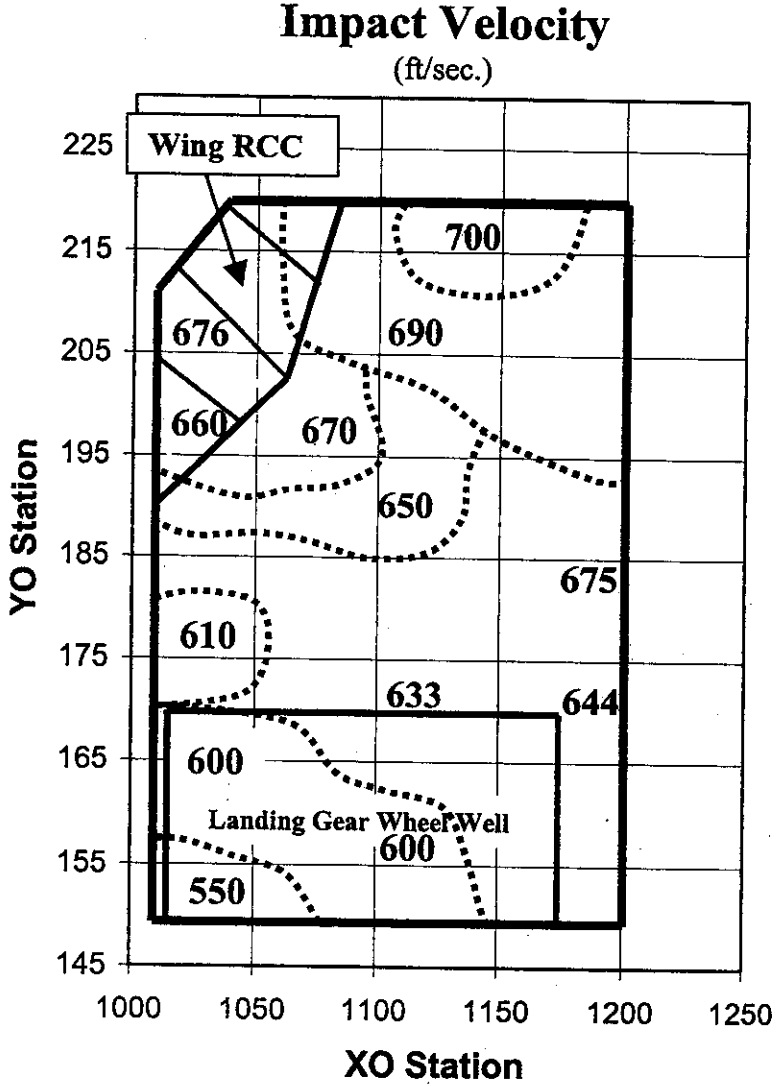


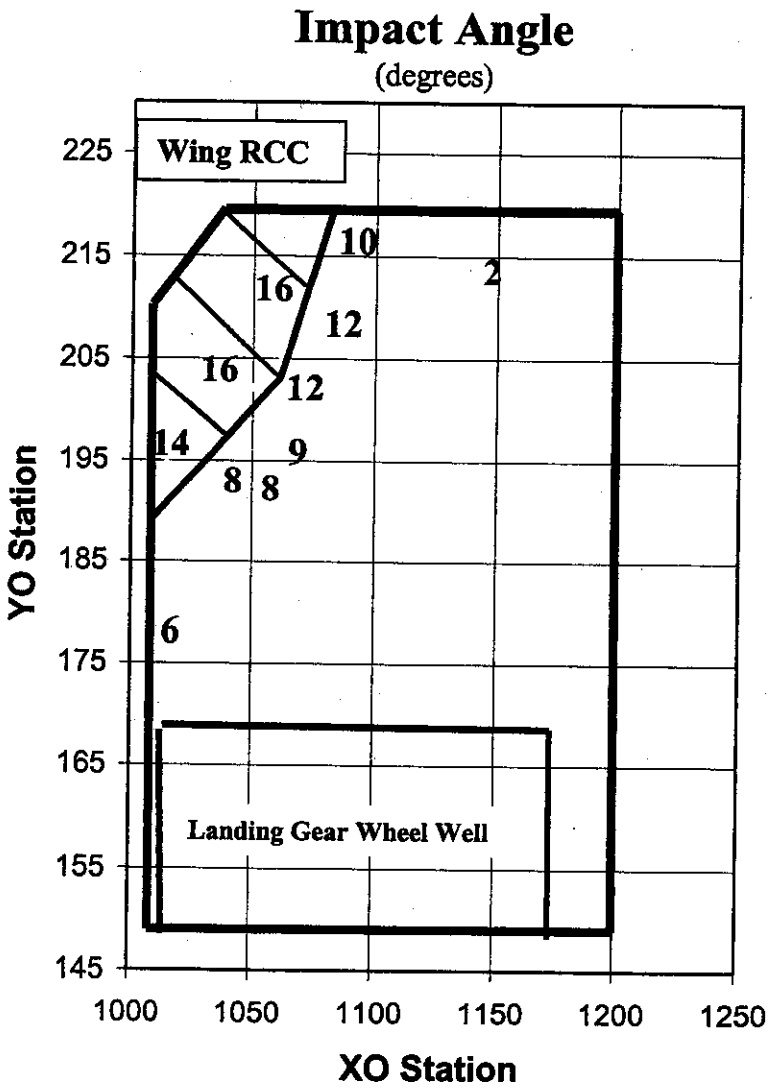
STS-107 Debris Impacting Orbiter Wing

BOEING

Velocity and Impact Angle Distribution Inside Impact Area

(Debris Size = 20" x 16" x 6", Density = 2.4 lb/ft3)





STS-107 Debris Impacting Orbiter Wing

BOEING

Back-Up

Debris Emanating From Bipod Area Impacts Orbiter Lower Wing

Issue - At about 82 seconds into the flight, multiple pieces of debris were seen emanating from the ET bipod area and later seen impacting the Orbiter lower surface