Timeline, Email Traffic, and Comments Regarding ALDF Personnel Involvement with STS 107 Columbia Flight

Revision B...included Jan 27 email to Carlisle Campbell previously missed but already released by NASA as well as email received from Campbell on 1/31/03 with the results of the Ames sim runs previously missed but already released along with notes on telecon about same.

Bob Daugherty March 3, 2003

January 27, 2003 Monday

Received a telephone call from Carlisle Campbell at JSC...works for the engineering directorate in Mechanical Systems...involved with doors, hatches, landing gear, etc for the Orbiter. Have worked with Carlisle for almost 20 years on landing and tire-related issues. He asked if I had heard about the issue with foam debris impacting the orbiter during ascent and I replied I had not. He filled me in on the issue, and mentioned that "people" were talking about not knowing exactly where the impact location was on the bottom of the orbiter but that some people mentioned that the gear door might be a vulnerable place to get damaged because of the nature of the thermal seal there. He mentioned that there had been lots of analysis, that the analysis said they didn't think there was a safety of flight issue, but that the gear door was in the "predicted target zone" of the impact. He emailed me two powerpoint documents that discussed the analysis and showed the predicted impact area. He mentioned the fact that "people" were throwing around possible worst-case scenarios regarding landing with two flat tires. This was the main reason for talking to us since we have previously provided JSC and the simulation folks, years ago, with models for just such a landing (not for the reason of them failing due to thermal damage...but just for covering all the bases and not caring why they might be flat). It just so happened that this very week, the astronaut training session at the Ames VMS was occurring where we already were looking at the effects of landing with one tire flat (again, the reason for such was not important), and whether or not the second tire on the strut would fail due to overload. We have done a lot of work on a load-persistence model we developed here at Langley and that was being evaluated. The astronauts were also looking for ground handling techniques that could help prevent the second tire from failing if they had a single tire flat at touchdown. So Carlisle and I knew the simulation community was in a position to very easily and quickly simulate a landing with two flat tires. We discussed the fact that "orbiter management" had not approved such simulations...I can't say whether its because they hadn't yet been approached or they just didn't think it was appropriate since the analysis of the thermal damage did not suggest a safety of flight concern. We then got Howard Law , JSC, Guidance and Control simulation engineer on the phone who was at Ames helping to run the load-persistence testing and asked him about whether they could easily do the simulation we thought would be good to do (the two flat tires) since it is just good engineering practice to simulate anything you can to gather contingency information. We discussed what their simulations had shown during the load persistence runs where the second tire had failed and now you were sliding on two flat tires. We determined that at low speed they were not using our models for drag correctly so I went and got together some old model information for sliding on a dragging strut and faxed him a flow chart for that model out at Ames. We also discussed the fact that some people at JSC were of the opinion that acquiring more information and visualizing the damage area was a good

thing to pursue and talked about the options regarding ground based telescopes, EVA's, etc. This discussion was simply two engineers talking...nothing special since neither of us have any expertise in this area. He mentioned that at that point there were no plans to visualize the damage since the orbiter had no arm, an EVA is very difficult due to the location underneath and lack of hand-holds, and that some thought that ground based telescopes might not have the resolution needed for a good view. We agreed that we thought it made good engineering sense to visualize the damage but were of the opinion that since folks higher up than us were pressing that issue we would not stick our nose in their business...we were just two engineers talking amongst ourselves.

January 27, 2003 Monday

Received several emails from Campbell showing the powerpoint presentations on the tile damage, and a video of the impact of the debris taken from behind the left wing (impact itself hidden from view):
Email subject lines:

Date: Mon, 27 Jan 2003 14:04:04 : STS-107 Post-Launch Film Review - Day 1
Date: Mon, 27 Jan 2003 14:06:03 FW: STS-107 Debris Briefing for MMT
Date: Mon, 27 Jan 2003 14:14:10 FW: STS-107 Debris Analysis Team Meeting
Date: Mon, 27 Jan 2003 14:16:52 FW: STS-107 Wing Debris Impact on Ascent: Final analysis case completed

I then watched the video and replied with the following email:
Date: Mon, 27 Jan 2003 4:35 Video you sent

Carlisle then replied with the following email:
Date: Mon, 27 Jan 2003 15:59:53 FW: Video you sent

I then replied to Carlisle with the following email:
Date: Mon, 27 Jan 2003 5:02 p.m. Re: FW: Video you sent

Faxed the dragging strut model to Howard Law on the same day Jan 27, 2003 late in the afternoon.

January 28, 2003 Tuesday

I sent the following email to Campbell:
Date: Tue, 28 Jan 2003 1:38 pm Tile Damage

I sent the following email to Mark Shuart to inform him of what was going on after he called me to inquire regarding things he had heard:
Date: Tue, 28 Jan 2003 2:15 pm Foam and Tile

And Carlisle replied with the following email:
Date: Tue, 28 Jan 2003 13:29:58 RE: Tile Damage

January 29, 2003 Wednesday

Had a three way telephone call with Carlisle Campbell and Howard Law and other folks at Ames VMS to discuss progress on the load-persistence simulations. After that we asked if Howard Law had been officially "asked" or "cleared" to do any simulations to support getting some "background" information in the simulator regarding what might happen if one were to land with two flat tires. Nobody had ever expressed any knowledge that the main gear door was actually involved in the damage area but we just felt that we should do everything we could to get as much info as possible to cover as many bases as possible.

I sent the following email to Mark Shuart to inform him of what was going on:
Date: Wed, 29 Jan 2003 3:51 pm Tile Damage Update

January 30, 2003 Thursday

In late afternoon I had a telephone conversation with Campbell who mentioned that they had been in a Landing Gear PRT (Problem Resolution Team?) meeting...this is a normal meeting not related to the issue at hand, I don't believe. They have them probably weekly whether they're flying or not I think. Apparently there were some comments by the Mission Operations folks about the thermal issue and them having to do some talking about making sure they had as many contingency plans figured out as possible since everybody wants to be ready for anything. Since Carlisle and I had been talking, we discussed as many bad things regarding the main gear as we could think of and it became apparent to me after doing some calculations that if the tires failed in the wheel well the door would be blown off and there could be big problems. Other things we discussed were the pyros that help deployment as a backup...etc. I asked Carlisle if he thought it was appropriate to voice these scenarios to MOD guys and he agreed it was a good thing so that we felt like we had done our best job or helping the system not let some worst-case scenarios slip thru the cracks.

I sent the following email to David Lechner at JSC (he's associated with the Mission Operations Directorate (MOD) and we've worked together often)

Date: Thurs, 30 Jan 2003 6:22 pm Main Gear Breach Concerns

January 31, 2003 Friday

I received a telephone call from David Lechner thanking me for voicing the scenarios in the email and he said they were having all kinds of discussions about being ready for various contingencies so that they would be ready to advise the Mission Management Team if necessary for them to make any decisions they may have to during entry. I can't speak for David, but I had no actual concern that anything disastrous would occur. We

discussed a belly landing at length and why that apparently is considered to be a loss-of vehicle event.

I received the following email from David Lechner in response to my email the night before:
Date: Fri, 31 Jan 2003 12:17:34 RE: Main Gear Breach Concerns

Later that afternoon, Carlisle Campbell called me and told me about the results of some simulator runs that had been made at Ames with two failed tires prior to landing. The results said that it appeared to be a controllable situation and he emailed the following email:

Subject: Ames Sim runs with two blown tires before landing
Date: Fri, 31 Jan 2003 14:59:01 –0600

We had a short telecon with Bob Doremus and David Paternostro...don't recall if there was anyone else in on the telecon. We discussed the results and were pleased that MOD had this information in their back pocket in case they needed it. I remember making the statement that after the landing, I bet we would find either that there was much more damage than predicted or a lot less damage than predicted. None of us expected a less-than-successful landing.

From: "CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)"
<carlisle.c.campbell@nasa.gov>
To: "'Bob Daugherty"' <r.h.daugherty@larc.nasa.gov>
Subject: FW: STS-107 Post-Launch Film Review - Day 1
Date: Mon, 27 Jan 2003 14:04:04 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)

-----Original Message-----
From: SMITH, JAMES P. (JSC-ES2) (NASA)
Sent: Wednesday, January 22, 2003 7:15 AM
To: DL ES2 Branch; DL ES2 Contractors
Subject: FW: STS-107 Post-Launch Film Review - Day 1

Watch the video first and see if you can spot anything.

-----Original Message-----
From: Pedraza, Michael A [mailto:michael.a.pedraza@usago.ksc.nasa.gov]
Sent: Tuesday, January 21, 2003 8:35 PM
Subject: STS-107 Post-Launch Film Review - Day 1

Michael Pedraza
Storekeeper/Expediter
MSC-44 RPSF
USK-337
Phone 861-6452
Fax 861-0374

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«´¨`·.¸ *Supply & Support*.¸.·´¨`»
(¸.·º (¸..·¨* *¨·..¸¸..·¨* *¨·..¸) º·.¸)

Attached is the Day 1 report and an MPG of Anomaly #1.

107film1.pdf

E212.mpg

From: "CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)"
<carlisle.c.campbell@nasa.gov>
To: "'Bob Daugherty'" <r.h.daugherty@larc.nasa.gov>
Subject: FW: STS-107 Debris Briefing for MMT
Date: Mon, 27 Jan 2003 14:06:03 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)

-----Original Message-----
From: ROCHA, ALAN R. (RODNEY) (JSC-ES2) (NASA)
Sent: Friday, January 24, 2003 10:32 AM
To: CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA); RICHART, JENE A. (JSC-MS2) (NASA)
Cc: MADDEN, CHRISTOPHER B. (CHRIS) (JSC-ES3) (NASA)
Subject: FW: STS-107 Debris Briefing for MMT

Here is the Orbiter thermal/stress assessment. I do not have the system integration (Carlos Ortiz/Boeing) debris trajectory analysis charts yet. Both were presented to MER team and MMT this morning. There is good potential for tile replacement and maybe local overheating of structure, but no burn-through. Though the assessment states, so far, that no safety of flight issues exist, there is open work on one more case, the MLG Door tiles. The MER team understood this open work, but in my opinion the MMT with Linda Ham did not get the full message of open work remaining.

Rodney Rocha
Structural Engineering Division (ES-SED)

ES Div. Chief Engineer (Space Shuttle DCE)
Chair, Space Shuttle Loads & Dynamics Panel

Mail Code ES2 Phone 281-483-8889
-----Original Message-----
From: White, Doug [mailto:Doug.White@USAHQ.UnitedSpaceAlliance.com]
Sent: Thursday, January 23, 2003 10:23 PM
To: Wilder, James; Reeves, William D; CURRY, DONALD M. (JSC-ES3) (NASA); SCHOMBURG, CALVIN (JSC-EA) (NASA); LEVY, VINCENT M. (JSC-EG) (NASA); ROCHA, ALAN R. (RODNEY) (JSC-ES2) (NASA)
Subject: FW: STS-107 Debris Briefing for MMT

Potential tile damage charts for the MMT tomorrow morning. Mike Dunham will pitch these.

Doug White
Director, Operations Requirements
281 282-2879 office
281 282-4438 fax
877 497-0336 pager
8774970336@archwireless.net
600 Gemini
Houston, TX 77058

"Never let the fear of striking out get in your way." -Babe Ruth

-----Original Message-----
From: Dunham, Michael J [mailto:Michael.J.Dunham@boeing.com]
Sent: Thursday, January 23, 2003 8:36 PM
To: EXT-Madera, Pamela L; EXT-White, Doug; Alvin Beckner-Jr (E-mail); Bo Bejmuk (E-mail); David Camp (E-mail); Douglas Cline (E-mail); Ed Alexander (E-mail); Frances Ferris (E-mail); Garland Parlier (E-mail); John Mulholland (E-mail); Mark Pickens (E-mail); Michael Burghardt (E-mail); Mike Fuller (E-mail); Norm Beougher (E-mail); Scott Christensen V (E-mail); Steve Harrison (E-mail)
Subject: STS-107 Debris Briefing for MMT

<<Debris.ppt>>

Michael J. Dunham
Boeing/Orbiter SSM - Stress, Loads and Dynamics
(281)-853-1697
(281)-853-1525 (Fax)
(281)-621-1924 (Pager)

Debris.ppt

From: "CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)"
<carlisle.c.campbell@nasa.gov>
To: "'Bob Daugherty'" <r.h.daugherty@larc.nasa.gov>
Subject: FW: STS-107 Debris Analysis Team Meeting
Date: Mon, 27 Jan 2003 14:14:10 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)

-----Original Message-----
From: ROCHA, ALAN R. (RODNEY) (JSC-ES2) (NASA)
Sent: Thursday, January 23, 2003 7:59 AM
To: SHACK, PAUL E. (JSC-EA42) (NASA); SERIALE-GRUSH, JOYCE M. (JSC-EA) (NASA); KRAMER, JULIE A. (JSC-EA4) (NASA); CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA); MILLER, GLENN J. (JSC-EA) (NASA)
Subject: FW: STS-107 Debris Analysis Team Meeting

FYI.

Rodney Rocha
Structural Engineering Division (ES-SED)

ES Div. Chief Engineer (Space Shuttle DCE)
Chair, Space Shuttle Loads & Dynamics Panel

Mail Code ES2 Phone 281-483-8889
-----Original Message-----
From: Madera, Pamela L [mailto:pam.l.madera@usahq.unitedspacealliance.com]
Sent: Wednesday, January 22, 2003 11:22 AM
To: CURRY, DONALD M. (JSC-ES3) (NASA); ROCHA, ALAN R. (RODNEY) (JSC-ES2) (NASA); LEVY, VINCENT M. (JSC-EG) (NASA); KOWAL, T. J. (JOHN) (JSC-ES3) (NASA); DERRY, STEPHEN M. (STEVE) (JSC-EG3) (NASA); Nagle, Scott M; Carlos Ortiz (E-mail); GOMEZ, REYNALDO J. (RAY) (JSC-EG3) (NASA); DISLER, JONATHAN M. (JON) (JSC-SX) (LM); Jacobs, William A
Cc: 'Scott Christensen V (E-mail)'; 'Norman Ignacio (Nacho) (E-mail)'; CHAO, DENNIS; Stoner-1, Michael D; 'Carlos Ortiz (E-mail)'; 'Michael J Dunham (E-mail)'; Sebesta, Stephen P; CORONADO, DIANA; "Craig Madden' (E-mail)'; Bell, Dan R.; Gordon, Michael P.; 'Paul A Parker (E-mail)'; ISHMAEL, MOHAMED I. (GEORGE) (JSC-NC) (SAIC); ALEXANDER, ED
Subject: STS-107 Debris Analysis Team Meeting

Rodney Rocha has conference room 221 in JSC Building 13 available for today's 1:00 PM telecon. Located on second floor. The dial in number is the same as below. I propose the following agenda:

Review of transport analysis (Carlos Ortiz - charts attached)
Discussion of appropriate Particle Size (Ortiz, Disler, all)
Review of Flight Design Plans for Assessing Options (Bill Jacobs)
Status of Impact Damage Assessment (P. Parker)
Status of Thermal Analysis (Norm Ignacio/Dennis Chao)
Approach for stress assessment (Dunham)
Discussion on Need/Rationale for Mandatory Viewing of damage site (All)

<<STS-107 Preliminary Debris Assessment - rev2.ppt>>

Pam Madera
Vehicle and Systems Analysis Subsystem Area Manager
Phone: 281-282-4453
Pager: 877-254-8252
(I can receive a short alpha numeric page by addressing e-mail to:
877-254-8252@archwireless.net)

-----Original Message-----
From: Madera, Pamela L

Sent: Monday, January 20, 2003 5:47 PM
To: CURRY, DONALD M; ROCHA, ALAN RODNEY; LEVY, VINCENT M; KOWAL, T JOHN; DERRY, STEPHEN M
Cc: 'Scott Christensen V (E-mail)'; 'Norman Ignacio (Nacho) (E-mail)'; CHAO, DENNIS; Stoner-1, Michael D; 'Carlos Ortiz (E-mail)'; 'Michael J Dunham (E-mail)'; Sebesta, Stephen P; CORONADO, DIANA; "Craig Madden' (E-mail)'; Bell, Dan R.; Gordon, Michael P.; Paul A Parker (E-mail)

Subject: STS-107 Debris Analysis Team Plans

The Boeing/USA team would like to meet with you Tuesday at 2:00 on meet-me-line number 877-668-7953 P/C 276237 to discuss analysis plans for assessing the STS-107 Debris Impact.

Pam Madera
Vehicle and Systems Analysis Subsystem Area Manager
Phone: 281-282-4453
Pager: 877-254-8252
(I can receive a short alpha numeric page by addressing e-mail to:
877-254-8252@archwireless.net)

STS-107 Preliminary Debris Assessment - rev2.ppt

From: "CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)"
<carlisle.c.campbell@nasa.gov>
To: "'Bob Daugherty'" <r.h.daugherty@larc.nasa.gov>
Subject: FW: STS-107 Wing Debris Impact on Ascent: Final analysis case com
pleted
Date: Mon, 27 Jan 2003 14:16:52 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)

> -----Original Message-----
> From: KOWAL, T. J. (JOHN) (JSC-ES3) (NASA)
> Sent: Monday, January 27, 2003 10:35 AM
> To: ROCHA, ALAN R. (RODNEY) (JSC-ES2) (NASA)
> Cc: ROGERS, JOSEPH E. (JOE) (JSC-ES2) (NASA); GALBREATH, GREGORY F.
> (GREG) (JSC-ES2) (NASA); JACOBS, JEREMY B. (JSC-ES4) (NASA); CURRY, DONALD
> M. (JSC-ES3) (NASA); RICKMAN, STEVEN L. (JSC-ES3) (NASA); SCHOMBURG,
> CALVIN (JSC-EA) (NASA); CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA);
> MADDEN, CHRISTOPHER B. (CHRIS) (JSC-ES3) (NASA)
> Subject: RE: STS-107 Wing Debris Impact on Ascent: Final analysis
> case completed
>
> I talked to Ignacio about the analysis he ran. In the case he ran, the
> large gouge is in the acreage of the door. If the gouge were to occur in
> a location where it passes over the thermal barrier on the perimeter of
> the door, the statement that there is "no breeching of the thermal and gas
> seals" would not be valid. I think this point should be clarified;
> otherwise, the note sent out this morning gives a false sense of security.
>
> John Kowal
> ES3/Thermal Branch
> NASA-Johnson Space Center
> (281) 483-8871
>
>
> -----Original Message-----
> From: ROCHA, ALAN R. (RODNEY) (JSC-ES2) (NASA)
> Sent: Sunday, January 26, 2003 7:45 PM
> To: SHACK, PAUL E. (JSC-EA42) (NASA); MCCORMACK, DONALD L. (DON)
> (JSC-MV6) (NASA); OUELLETTE, FRED A. (JSC-MV6) (NASA)
> Cc: ROGERS, JOSEPH E. (JOE) (JSC-ES2) (NASA); GALBREATH, GREGORY F.
> (GREG) (JSC-ES2) (NASA); JACOBS, JEREMY B. (JSC-ES4) (NASA);
> SERIALE-GRUSH, JOYCE M. (JSC-EA) (NASA); KRAMER, JULIE A. (JSC-EA4)
> (NASA); CURRY, DONALD M. (JSC-ES3) (NASA); KOWAL, T. J. (JOHN) (JSC-ES3)
> (NASA); RICKMAN, STEVEN L. (JSC-ES3) (NASA); SCHOMBURG, CALVIN (JSC-EA)
> (NASA); CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)
> Subject: STS-107 Wing Debris Impact on Ascent: Final analysis case
> completed
>
> As you recall from Friday's briefing to the MER, there remained open work
> to assess analytically predicted impact damage to the wing underside in
> the region of the main landing gear door. This area was considered a low
> probability hit area by the image analysis teams, but they admitted a
> debris strike here could not be ruled out.
>
> As with the other analyses performed and reported on Friday, this

> assessment by the Boeing multi-technical discipline engineering teams also
> employed the system integration's dispersed trajectories followed by
> serial results from the Crater damage prediction tool, thermal analysis,
> and stress analysis. It was reviewed and accepted by the ES-DCE (R. Rocha)
> by Sunday morning, Jan. 26. The case is defined by a large area gouge
> about 7 inch wide and about 30 inch long with sloped sides like a crater,
> and reaching down to the densified layer of the TPS.
>
> SUMMARY: Though this case predicted some higher temperatures at the outer
> layer of the honeycomb aluminum face sheet and subsequent debonding of the
> sheet, there is no predicted burn-through of the door, no breeching of the
> thermal and gas seals, nor is there door structural deformation or thermal
> warpage to open the seal to hot plasma intrusion. Though degradation of
> the TPS and door structure is likely (if the impact occurred here), there
> is no safety of flight (entry, descent, landing) issue.
>
> Note to Don M. and Fred O.: On Friday I believe the MER was thoroughly
> briefed and it was clear that open work remained (viz., the case
> summarized above), the message of open work was not clearly given, in my
> opinion, to Linda Ham at the MMT. I believe we left her the impression
> that engineering assessments and cases were all finished and we could
> state with finality no safety of flight issues or questions remaining.
> This very serious case could not be ruled out and it was a very good thing
> we carried it through to a finish.
>
>
> Rodney Rocha (ES2) x38889
> * Division Shuttle Chief Engineer (DCE), ES-Structural Engineering
> Division
> * Chair, Space Shuttle Loads & Dynamics Panel
>
>

Aircraft Landing Dynamics Facility
Langley Research Center
Hampton, VA 23681-2199

FACSIMILE TRANSMISSION

TO: Howard Law
FAX NUMBER: 650 604 7484
TELEPHONE NUMBER:
LOCATION:

FROM:
TELEPHONE NUMBER: (757)
FAX NUMBER: (757) 864-8090

COMMENTS: DRAGGING STRUT
MODEL - FLOW CHART -
COULDN'T FIND PLOT

Number of pages including lead: 6

Signature: Bob D Date: 1/27/03

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia
23665

NASA

Reply to Attn of 497

TO: NASA Johnson Space Center
Attn: VA/Richard Colonna, Manager, STS
Orbiter and GFE Projects Office

FROM: 497/Aerospace Technologist, Impact Dynamics Branch, SDD

SUBJECT: Results of Roll-on-Rim Capability Tests

A series of tests have been completed at the Langley Research Center's Aircraft Landing Dynamics Facility (ALDF) to determine the roll-on-rim capability of the Orbiter main wheel. Both a standard flight wheel inner half and a modified inner wheel half were tested. In addition, data were gathered to identify the behavior of a deflated tire during and after touchdown. This information is helpful in simulating a landing if a tire has deflated in orbit, a highly unlikely condition.

Because of the vertical load capability of the ALDF, only inner wheel halves were tested to identify their failure modes. This allowed full-scale loads to be applied to the wheel bead flanges. In our opinion, this testing mode does not compromise the validity of the results.

A standard flight wheel had previously been rolled on the B.F. Goodrich dynamometer wheel at rated load and at a speed of approximately 10 mph. It developed a crack and lost a small portion of bead flange after about 4,000 ft. and the test was stopped. The dynamometer surface was smooth steel. A similar test was conducted at the ALDF with a standard inner wheel half loaded to half the rated load. The surface was a simulated KSC runway. After about 650 ft., a portion of the bead flange failed and during the next revolution, the wheel half completely collapsed.

The first high-speed test involved landing a standard inner wheel half and observing its behavior. The wheel half was landed at a sink rate of 2.6 ft./sec. and forward speed of 150 kts. A rubber strap was attached to the wheel to facilitate spin-up and minimize wheel spin-up damage. Vertical load was about 25,000 lb. during this test. During spin-up and within the first 25 ft. of roll, the bead flange zippered off in 4 in. pieces. Ten feet later, the bead seat flange area and tube well disintegrated. Down load buffers, which limited travel of the drop test carriage, prevented the load from being applied to the wheel center section following wheel flange failure.

The next test was run to examine what benefit could be gained by using an inner wheel half with a much stronger bead flange (at a weight penalty of about 4 lbs. per inner wheel half). Touchdown conditions on this wheel half were 157 kts. groundspeed and 2.8 fps sink rate. This wheel survived spin-up and was loaded to about 65,000 lb. After about 130 ft., the wheel half disintegrated. Rolling resistance during this test was 5 percent of wheel vertical load.

The next test was designed to investigate the roll-on-center section capability of the wheel after the bead flanges and tube well have failed, but the center section did not spin-up and the wheel was skidded down the runway. The test speed was 159 kts. and the vertical load was about 70,000 lb. During the 450 ft. long slide, about 3 in. of wheel was worn away, and the friction coefficient was about .2.

The last test involved landing and rolling out on a tire deflated before the test to simulate a tire that has deflated in the wheel well either on the launch pad or in orbit. The conditions of this test included a ground speed of 157 kts. and a sink rate of 2.8 fps. Vertical load was maintained at 70,000 lb. The flat tire rolled approximately 1,050 ft. and produced a friction coefficient between .15 and .20. The tire disintegrated after a roll of 1,050 ft. Thereafter, the wheel rolled for 500 ft. on the intact beads that remained attached to the wheel. Rolling resistance while on the beads was .1.

These results indicate that no significant roll-on-rim capability is present in either the standard or modified inner wheel half. It appears that wheel failure at speeds of 160 kts. will undoubtedly result in some damage to the orbiter due to flying debris. Unfortunately, no method of predicting this damage is known. Most of the highest energy debris should be found in the 30-90 degree arc behind the wheel, with 90 degrees being vertical. Tire failure will result in the loss of large pieces of the 200 lb. tire, and prediction of these trajectories is also impossible.

A set of guidelines for predicting wheel failure along with an event flow chart is enclosed. Note that some of the events are only engineering judgments based on extremely limited test data.

It is assumed that some portion of this data along with the 1/3 scale skid results will be used to determine where to land the orbiter should a flat tire be detected in orbit. Although some damage to the orbiter is likely during a concrete runway landing with a flat tire, the unknown behavior of the tire and wheel on the lakebed surface during failure coupled with the lack of friction coefficient data on the lakebed surface at high bearing pressures is cause for concern. If flat tire lakebed landings are being considered, it is recommended that, at a minimum, tests be conducted at a lakebed site using a bare wheel loaded to 120,000 lb. using the towable load cart available at Edwards Air Force Base. If the wheel fails at low speed, then failure at high speed is almost certain. If the wheel simply digs in, then no information is gained as to high speed behavior. This test is inexpensive and capable of producing data that could help in the decision of where to land if an orbiter tire has lost pressure.

If you have any questions, feel free to contact Sandy Stubbs or me at FTS 928-2796.

Robert H. Daugherty

Enclosures
Set of Guidelines
Flowchart

cc (w/o Encl.):
101/Files
118/SD
244/SDD
497/IDB
497/RHDaugherty

NASA JSC
CB/JCasper
ES4/BHolder
ES6/CCampbell
EH221/HLaw
GA/BDO'Connor

B. F. Goodrich Co.
Aerospace and Defense Div.
Attn: J. Warren
P.O. Box 340
Troy, OH 45373

Rockwell International
AC19/MPorter
12214 Lakewood Blvd.
Downey, CA 90241

GUIDELINES FOR SIMULATING TIRE FAILURES

DEFINITIONS:

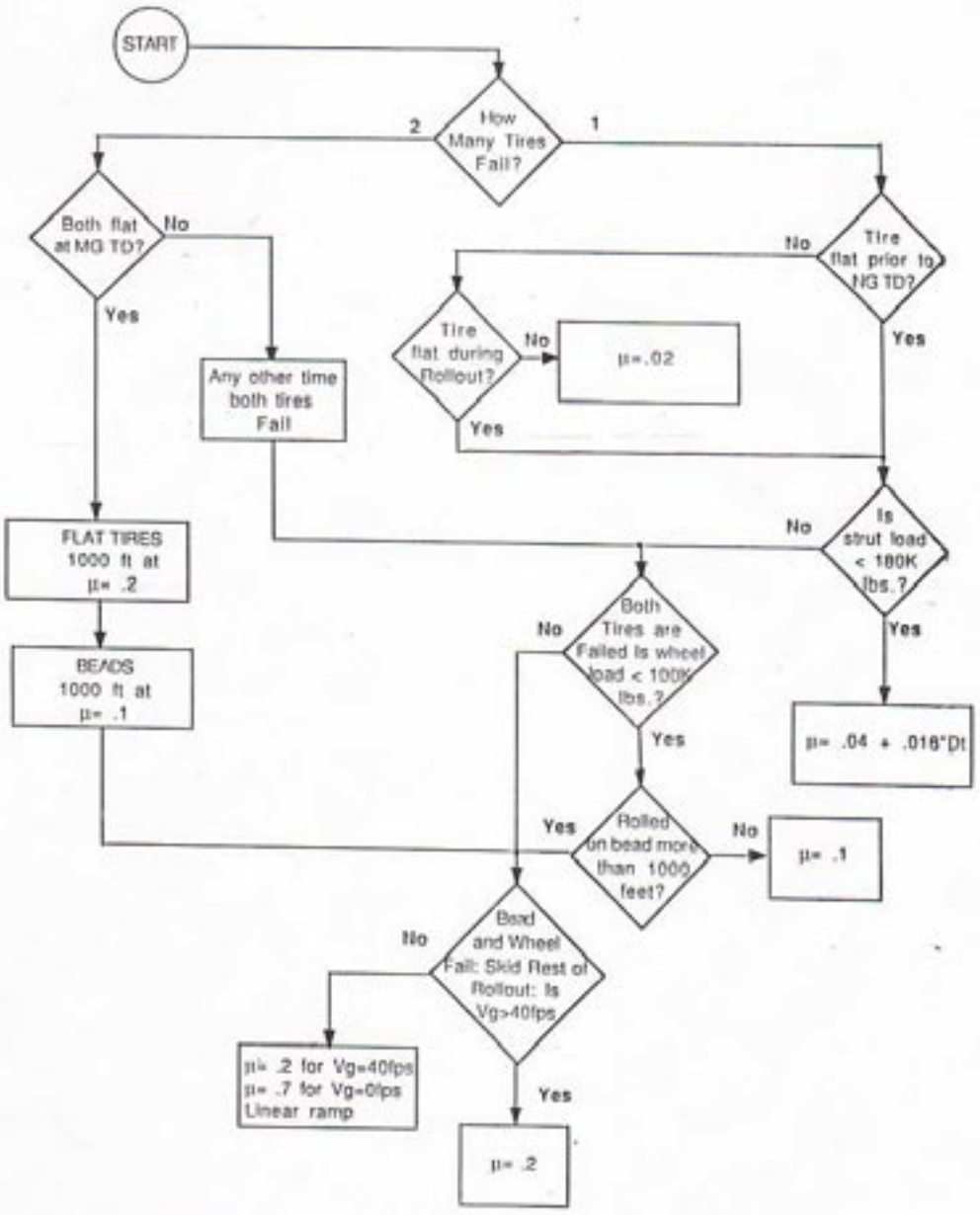
"GOOD" TIRE:	One that is inflated
"FLAT" TIRE:	One that has lost air but did not blow up due to overload
"FAILED" TIRE:	One that has : Blown up due to overload or Disintegrated due to flat tire roll.

1. Rolling on a "GOOD" TIRE: $\mu = .02$
2. Rolling on a "FLAT" TIRE: $\mu = .2$
3. Rolling on the bead: $\mu = .1$
4. Rolling on the rim flange or center section: $\mu = .05$
5. Skidding on center section, brake parts, axle, etc.: $\mu = .2$
6. Below about 40 fps, number 5 above ramps from $\mu = .2$ to $\mu = .7$ as speed approaches 0.

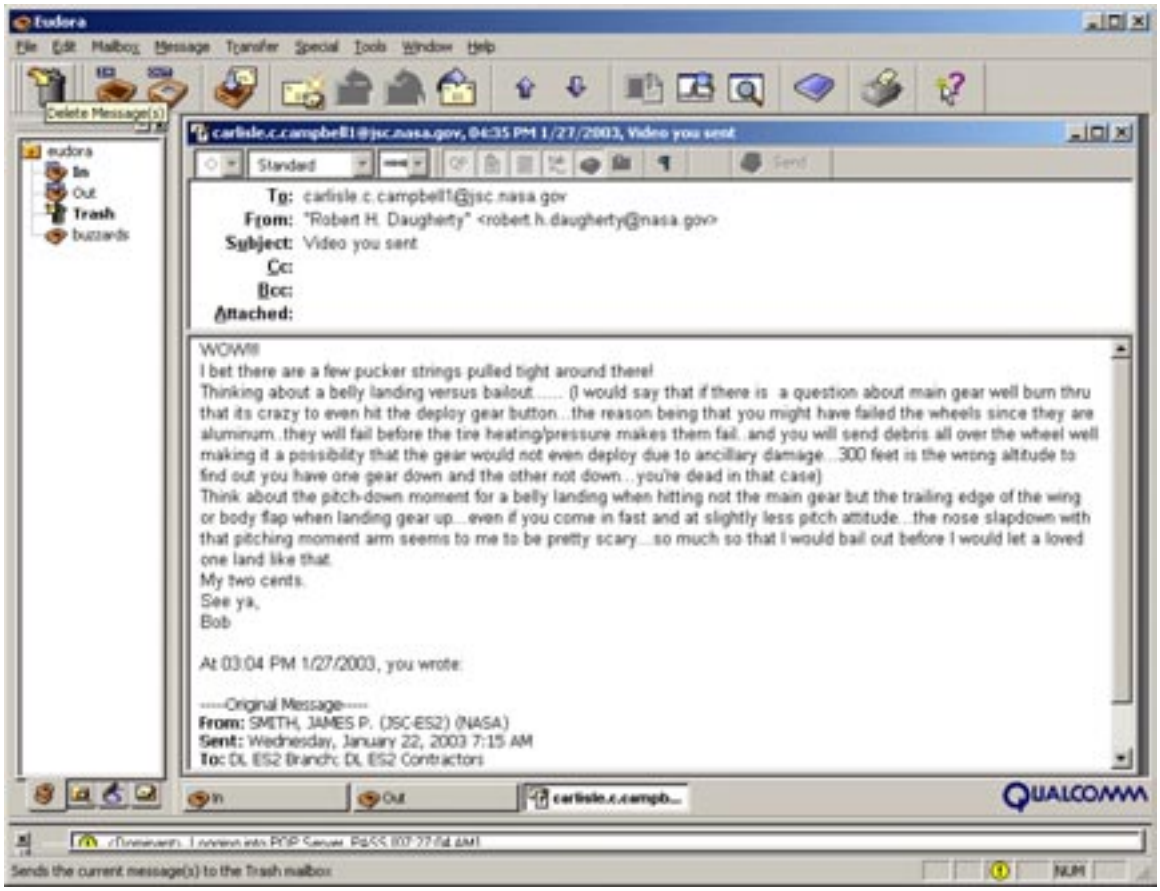
COMMENTS

NOTE: * indicates lower confidence than other comments

1. Flat tires can survive 1000' if loaded 70K or less.
2. Good tires loaded above 180K fail immediately.
3. *Failed tires roll on beads for 1000' if wheel loads are < 100K.
4. *If rolling on beads and wheel loads exceed 100K, then bead fails and rim flange breaks in 50'.
5. Center section may survive any length (flowchart assumes 0 length).
6. *For 1 good tire and 1 flat tire and strut load <180K then strut drag $\mu = .04 + .016 \times$ deflection of good tire.



Note: Dt = Deflection of good tire : should range from 0 to 10 in.



From: "CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)"
<carlisle.c.campbell@nasa.gov>
To: "'Bob Daugherty'" <r.h.daugherty@larc.nasa.gov>
Subject: FW: Video you sent
Date: Mon, 27 Jan 2003 15:59:53 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)

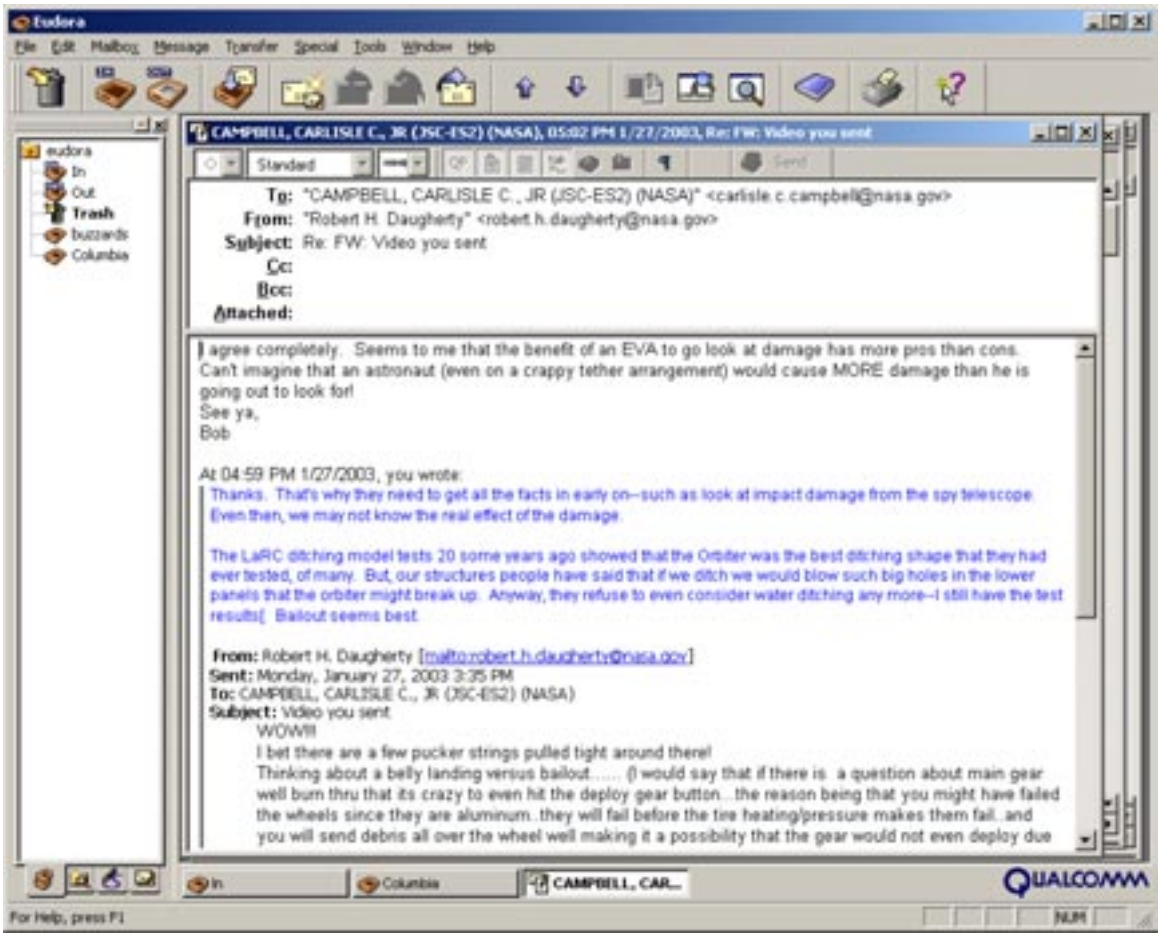
Thanks. That's why they need to get all the facts in early on--such as look at impact damage from the spy telescope. Even then, we may not know the real effect of the damage.

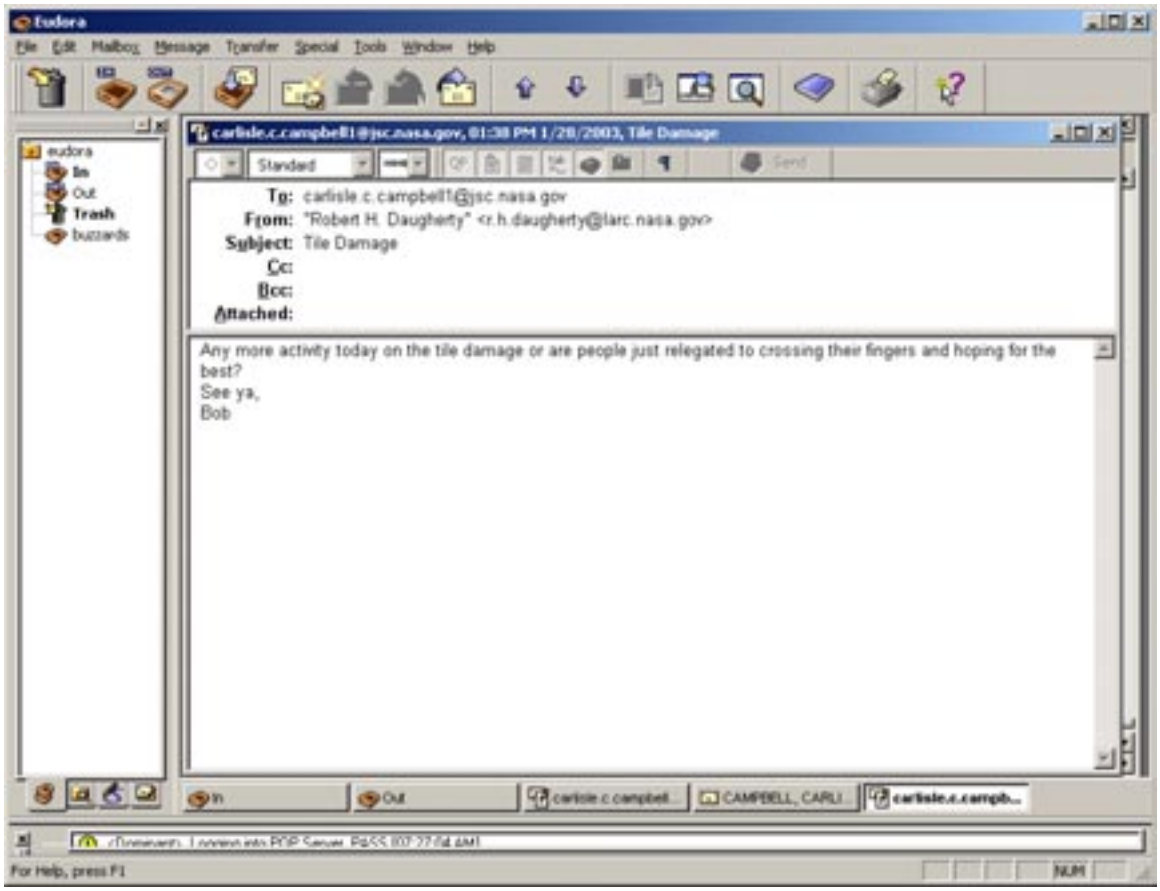
The LaRC ditching model tests 20 some years ago showed that the Orbiter was the best ditching shape that they had ever tested, of many. But, our structures people have said that if we ditch we would blow such big holes in the lower panels that the orbiter might break up. Anyway, they refuse to even consider water ditching any more--I still have the test results[Bailout seems best.

From: Robert H. Daugherty [mailto:robert.h.daugherty@nasa.gov]
Sent: Monday, January 27, 2003 3:35 PM
To: CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)
Subject: Video you sent

WOW!!!
I bet there are a few pucker strings pulled tight around there!
Thinking about a belly landing versus bailout..... (I would say that if there is a question about main gear well burn thru that its crazy to even hit the deploy gear button...the reason being that you might have failed the wheels since they are aluminum..they will fail before the tire heating/pressure makes them fail..and you will send debris all over the wheel well making it a possibility that the gear would not even deploy due to ancillary damage...300

feet is the wrong altitude to find out you have one gear down and the other not down...you're dead in that case)
Think about the pitch-down moment for a belly landing when hitting not the main gear but the trailing edge of the wing or body flap when landing gear up...even if you come in fast and at slightly less pitch attitude...the nose slapdown with that pitching moment arm seems to me to be pretty scary...so much so that I would bail out before I would let a loved one land like that.
My two cents.
See ya,
Bob

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carlisle.c.campbell1@jsc.nasa.gov, 01:38 PM 1/28/2003, Tile Damage
Standard
To: carlisle.c.campbell1@jsc.nasa.gov
From: "Robert H. Daugherty" <r.h.daugherty@larc.nasa.gov>
Subject: Tile Damage
Cc:
Bcc:
Attached:
Any more activity today on the tile damage or are people just relegated to crossing their fingers and hoping for the best?
See ya,
Bob
In
Out
CAMPBELL, CARLI
For Help, press F1
NUM

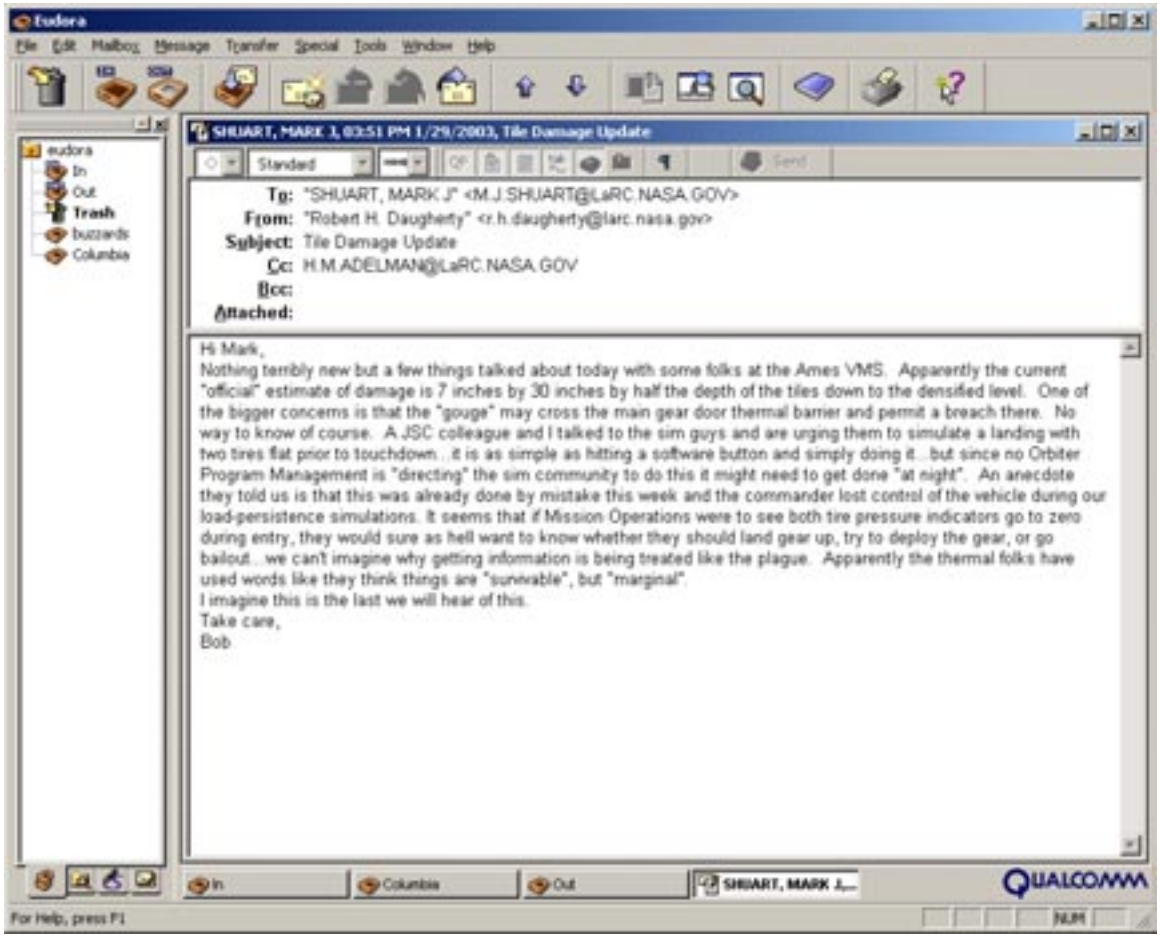
From: "CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)"
<carlisle.c.campbell@nasa.gov>
To: "'Robert H. Daugherty"' <r.h.daugherty@larc.nasa.gov>
Subject: RE: Tile Damage
Date: Tue, 28 Jan 2003 13:29:58 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)

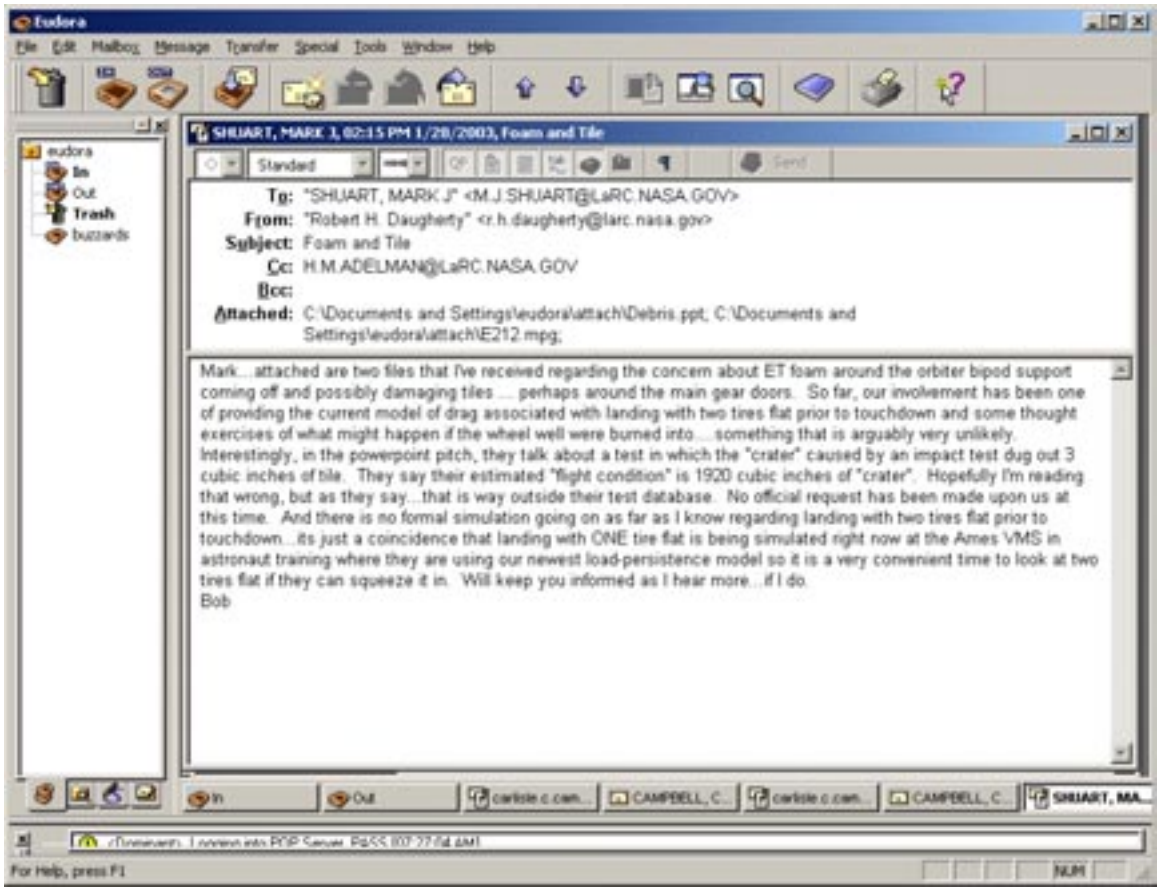
I have not heard anything new. I'll let you know if I do.

CCC

-----Original Message-----
From: Robert H. Daugherty [mailto:r.h.daugherty@larc.nasa.gov]
Sent: Tuesday, January 28, 2003 12:39 PM
To: CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)
Subject: Tile Damage

Any more activity today on the tile damage or are people just relegated to crossing their fingers and hoping for the best?
See ya,
Bob

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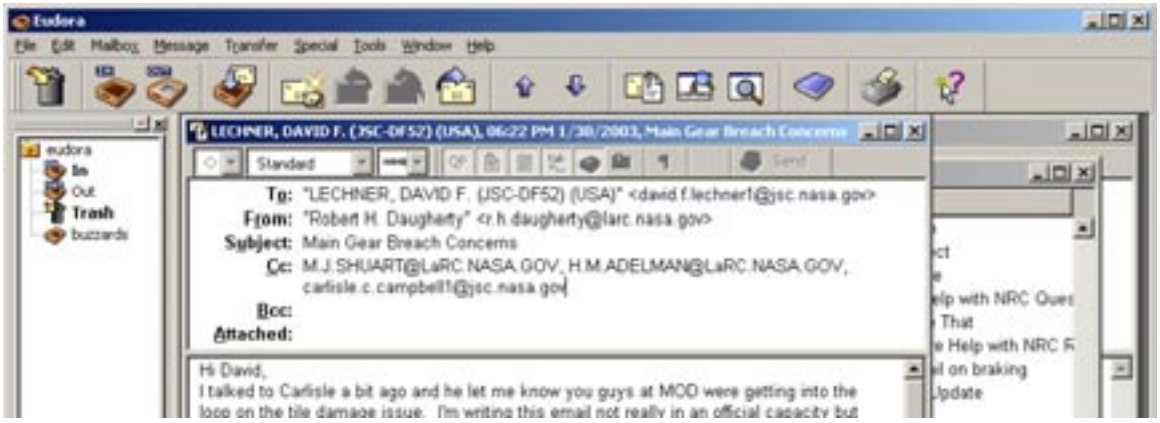
SHUART, MARK J, 02:15 PM 1/28/2003, Foam and Tile
Standard
To: "SHUART, MARK J" <M.J.SHUART@LaRC.NASA.GOV>
From: "Robert H. Daugherty" <r.h.daugherty@larc.nasa.gov>
Subject: Foam and Tile
Cc: H.M.ADELMAN@LaRC.NASA.GOV
Bcc:
Attached: C:\Documents and Settings\eudora\attach\Debris.ppt; C:\Documents and Settings\eudora\attach\E212.mpg;
Mark...attached are two files that I've received regarding the concern about ET foam around the orbiter bipod support coming off and possibly damaging tiles ... perhaps around the main gear doors. So far, our involvement has been one of providing the current model of drag associated with landing with two tires flat prior to touchdown and some thought exercises of what might happen if the wheel well were burned into....something that is arguably very unlikely. Interestingly, in the powerpoint pitch, they talk about a test in which the "crater" caused by an impact test dug out 3 cubic inches of tile. They say their estimated "flight condition" is 1920 cubic inches of "crater". Hopefully I'm reading that wrong, but as they say...that is way outside their test database. No official request has been made upon us at this time. And there is no formal simulation going on as far as I know regarding landing with two tires flat prior to touchdown...its just a coincidence that landing with ONE tire flat is being simulated right now at the Ames VMS in astronaut training where they are using our newest load-persistence model so it is a very convenient time to look at two tires flat if they can squeeze it in. Will keep you informed as I hear more...if I do.
Bob
In
Out
carlisle c.cam...
CAMPBELL, C...
carlisle c.cam...
CAMPBELL, C...
SHUART, MA...
For Help, press F1
NUM



Hi David,
I talked to Carlisle a bit ago and he let me know you guys at MOD were getting into the loop on the tile damage issue. I'm writing this email not really in an official capacity but since we've worked together so many times I feel like I can say pretty much anything to you. And before I begin I would offer that I am admittedly erring way on the side of absolute worst-case scenarios and I don't really believe things are as bad as I'm getting ready to make them out. But I certainly believe that to not be ready for a gut-wrenching decision after seeing instrumentation in the wheel well not be there after entry is irresponsible. One of my personal theories is that you should seriously consider the possibility of the gear not deploying at all if there is a substantial breach of the wheel well. The reason might be that as the temps increase, the wheel (aluminum) will lose material properties as it heats up and the tire pressure will increase. At some point the wheel could fail and send debris everywhere. While it is true there are thermal fuses in the wheel, if the rate of heating is high enough, since the tire is such a good insulator, the wheel may degrade in strength enough to let go far below the 1100 psi or so that the tire normally bursts at. It seems to me that with that much carnage in the wheel well, something could get screwed up enough to prevent deployment and then you are in a world of hurt. The following are scenarios that might be possible...and since there are so many of them, these are offered just to make sure that some things don't slip thru the cracks...I suspect many or all of these have been gone over by you guys already:

1. People talk about landing with two flat tires...I did too until this came up. If both tires blew up in the wheel well (not talking thermal fuse and venting but explosive decomp due to tire and/or wheel failure) the overpressure in the wheel well will be in the 40 + psi range. The resulting loads on the gear door (a quarter million lbs) would almost certainly blow the door off the hinges or at least send it out into the slip stream...catastrophic. Even if you could survive the heating, would the gear now deploy? And/or also, could you even reach the runway with this kind of drag?
2. The explosive bungies...what might be the possibility of these firing due to excessive heating? If they fired, would they send the gear door and/or the gear into the slipstream?
3. What might excessive heating do to all kinds of other hardware in the wheel well...the hydraulic fluid, uplocks, etc? Are there vulnerable hardware items that might prevent deployment?
4. If the gear didn't deploy (and you would have to consider this before making the commitment to gear deploy on final) what would happen control-wise if the other gear is down and one is up? (I think Howard Law and his community will tell you you're finished)
5. Do you belly land? Without any other planning you will have already committed to KSC. And what will happen during derotation in a gear up landing (trying to stay away from an asymmetric gear situation for example) since you will be hitting the aft end body flap and wings and pitching down extremely fast a la the old X-15 landings? My guess is you would have an extremely large vertical decel situation up in the nose for the crew. While directional control would be afforded in some part by the drag chute...do you want to count on that to keep you out of the moat?
6. If a belly landing is unacceptable, ditching/bailout might be next on the list. Not a good day.
7. Assuming you can get to the runway with the gear deployed but with two flat tires, can the commander control the vehicle both in pitch and lateral directions? One concern is excessive

drag (0.2 g's) during TD throughout the entire saddle region making the derotation uncontrollable due to saturated elevons...resulting in nose gear failure? The addition of crosswinds would make lateral control a tough thing too. Simulating this, because it is so ridiculously easy to do (sims going on this very minute at AMES with load-persistence) seems like a real no-brainer.

Admittedly this is over the top in many ways but this is a pretty bad time to get surprised and have to make decisions in the last 20 minutes. You can count on us to provide any support you think you need.
Best Regards,
Bob

From: "LECHNER, DAVID F. (JSC-DF52) (USA)" <david.f.lechner1@jsc.nasa.gov>
To: "'Robert H. Daugherty"' <r.h.daugherty@larc.nasa.gov>
Cc: M.J.SHUART@larc.nasa.gov, H.M.ADELMAN@larc.nasa.gov,
"CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)"
<carlisle.c.campbell@nasa.gov>
Subject: RE: Main Gear Breach Concerns
Date: Fri, 31 Jan 2003 12:17:34 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)

Bob,

I really appreciate the candid remarks. As always your points have generated extremely valuable discussion in our group. Thank you. We have been discussing and continue to discuss the all possible scenarios, signatures and decisions. Your input is beneficial. Like everyone, we hope that the debris impact analysis is correct and all this discussion is mute.

David F-M Lechner
Space Shuttle Mechanical Systems
Mechanical, Maintenance, Arm & Crew Systems (MMACS)
United Space Alliance, Johnson Space Center
(281) 483-1685

-----Original Message-----
From: Robert H. Daugherty [mailto:r.h.daugherty@larc.nasa.gov]
Sent: Thursday, January 30, 2003 5:23 PM
To: LECHNER, DAVID F. (JSC-DF52) (USA)
Cc: M.J.SHUART@larc.nasa.gov; H.M.ADELMAN@larc.nasa.gov; CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)
Subject: Main Gear Breach Concerns

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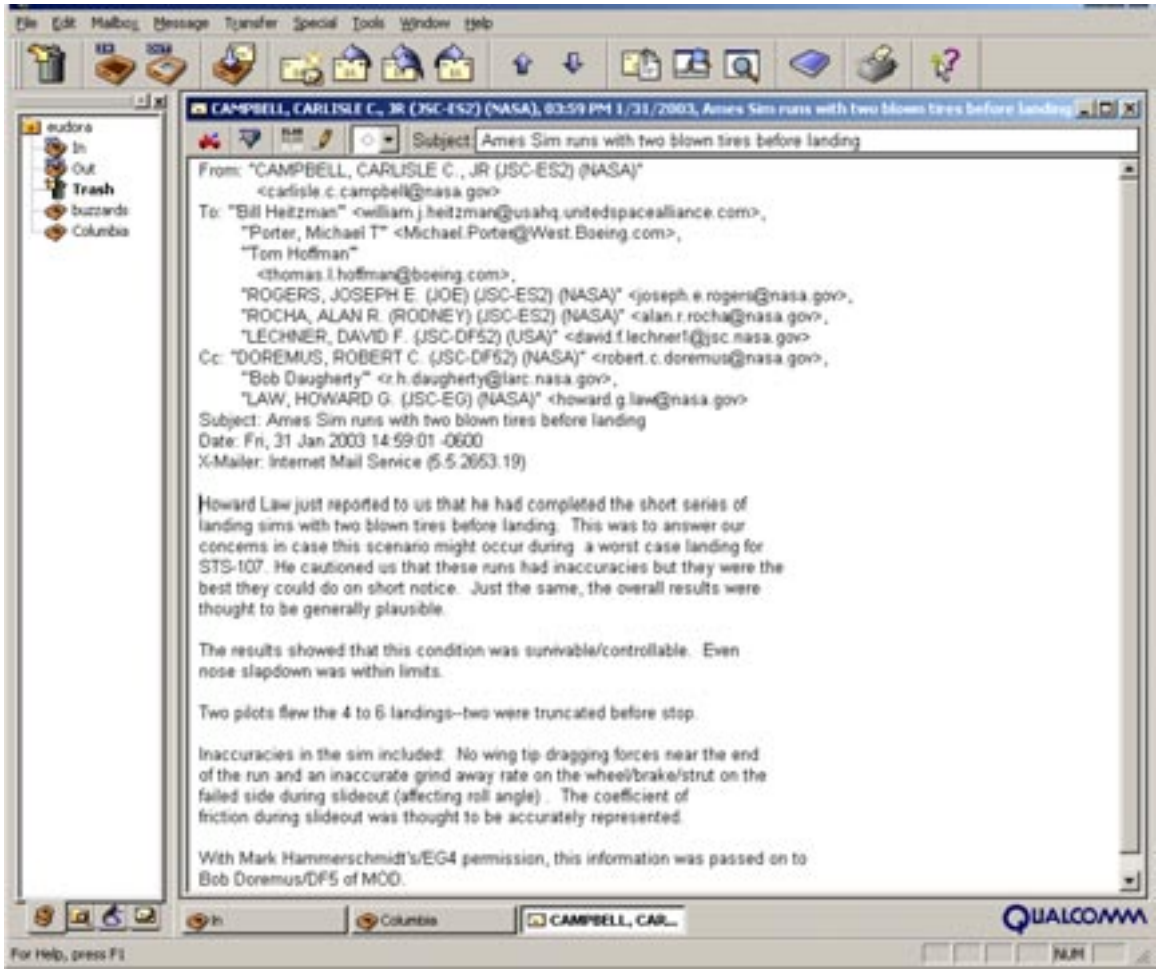
Bob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Columbia
CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA), 03:59 PM 1/31/2003, Ames Sim runs with two blown tires before landing
Subject: Ames Sim runs with two blown tires before landing
From: "CAMPBELL, CARLISLE C., JR (JSC-ES2) (NASA)"
<carlisle.c.campbell@nasa.gov>
To: "Bill Heitzman" <william.j.heitzman@usahq.unitedspacealliance.com>,
"Porter, Michael T" <Michael.Porter@West.Boeing.com>,
"Tom Hoffman"
<thomas.l.hoffman@boeing.com>,
"ROGERS, JOSEPH E. (JOE) (JSC-ES2) (NASA)" <joseph.e.rogers@nasa.gov>,
"ROCHA, ALAN R. (RODNEY) (JSC-ES2) (NASA)" <alan.r.rocha@nasa.gov>,
"LECHNER, DAVID F. (JSC-DF52) (USA)" <david.f.lechner1@jsc.nasa.gov>
Cc: "DOREMUS, ROBERT C. (JSC-DF52) (NASA)" <robert.c.doremus@nasa.gov>,
"Bob Daugherty" <r.h.daugherty@larc.nasa.gov>,
"LAW, HOWARD G. (JSC-EG) (NASA)" <howard.g.law@nasa.gov>
Subject: Ames Sim runs with two blown tires before landing
Date: Fri, 31 Jan 2003 14:59:01 -0600
X-Mailer: Internet Mail Service (5.5.2653.19)
Howard Law just reported to us that he had completed the short series of landing sims with two blown tires before landing. This was to answer our concerns in case this scenario might occur during a worst case landing for STS-107. He cautioned us that these runs had inaccuracies but they were the best they could do on short notice. Just the same, the overall results were thought to be generally plausible.
The results showed that this condition was survivable/controllable. Even nose slapdown was within limits.
Two pilots flew the 4 to 6 landings--two were truncated before stop.
Inaccuracies in the sim included: No wing tip dragging forces near the end of the run and an inaccurate grind away rate on the wheel/brake/strut on the failed side during slideout (affecting roll angle). The coefficient of friction during slideout was thought to be accurately represented.
With Mark Hammerschmidt's/EG4 permission, this information was passed on to Bob Doremus/DF5 of MOD.
In
Columbia
CAMPBELL, CAR...
QUALCOMM
For Help, press F1
NUM