NASA

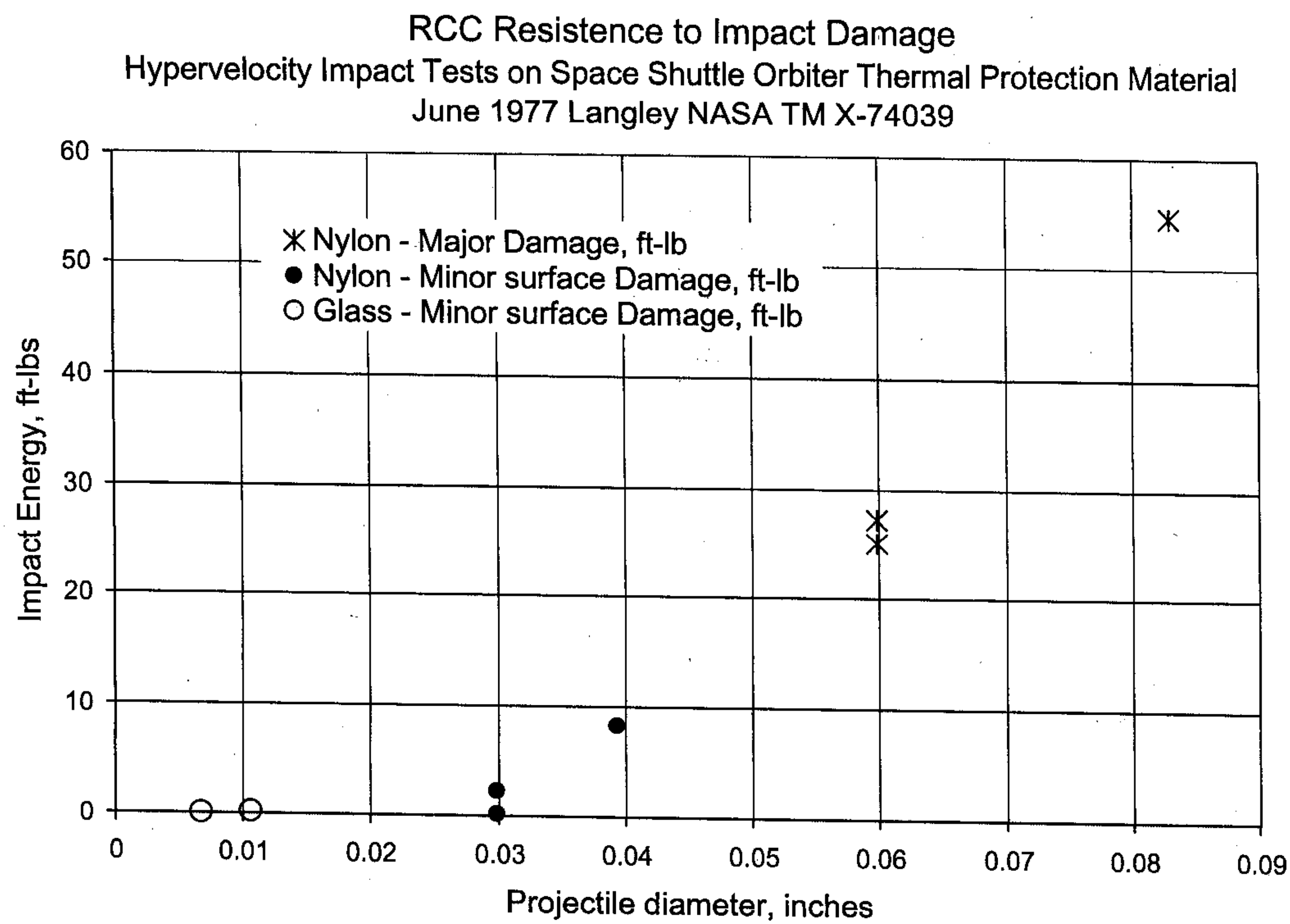
SECTION 9

Hypervelocity Impact Tests on Space Shuttle Orbiter Using Nylon and Glass Projectiles Thermal Protection Material

June 1977

NASA/Langley

NASA TM X-74039


RCC Resistence to Impact Damage
Hypervelocity Impact Tests on Space Shuttle Orbiter Thermal Protection Material
June 1977 Langley NASA TM X-74039
Impact Energy, ft-lbs
60
50
40
30
20
10
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
Projectile diameter, inches
Nylon - Major Damage, ft-lb
Nylon - Minor surface Damage, ft-lb
Glass - Minor surface Damage, ft-lb

Test Results for Ice Impact On Orbiter RCC Surfaces

November 1984

Ice, cylinder shape

Michele Lewis

From: Bell, Dan R. [DRBell@xch-bsco-06.ksc.nasa.gov]
Sent: Tuesday, January 21, 2003 12:55 PM
To: KOWAL, T. J. (JOHN) (JSC-ES3) (NASA)
Subject: Impact Data

FW: ET Briefing STS-112 Foam.   STS-87/89 Info

<<FW: ET Briefing - STS-112 Foam Loss>> <<STS-87/89 Info>>

Michele Lewis

From: Sheehan, Gerald [GSheeha@xch-bsco-06.ksc.nasa.gov]
Sent: Tuesday, January 21, 2003 9:53 AM
To: EXT-Abner, Charlie A #KSCEMS; EXT-Herman, Robert S; Bell, Dan R.; Holmes, Stephen E.; Madden, Craig J.; McCarley, Michael C.; Mulholland, John P; Muhar, M M; Engle, James M.; Luecking, Robert B.
Cc: Fuller, Mike J.; Cabe, William L. (Butch); Crawford, Johnny R.; Leonard, Wil E.; Seraphine, Alan C.
Subject: FW: ET Briefing - STS-112 Foam Loss

Importance: High

ET Briefing.pdf

All-
....just to jog my memory, I asked Kim to pull the STS-113 FRR
briefing
from ET on the last time they lost part of the bipod SLA closeout (on
STS-112/ET-115). FYI
GDS

> -----Original Message-----
> From: Cochran, Kimberlee D.
> Sent: Tuesday, January 21, 2003 9:40 AM
> To: Sheehan, Gerald
> Subject: ET Briefing
> Importance: High
>
> <<ET Briefing.pdf>>
>
> Kim Cochran
> Technical Publications
> 321.861.4627
> 721Z-K084
>
>

Michele Lewis

From: Chaffey, Michele L [michele.l.chaffey@boeing.com]
Sent: Tuesday, January 21, 2003 9:25 AM
To: Bell, Dan R.
Subject: STS-87/89 Info

87DAMAGE.PDF sts89frr.ppt

Here is the briefing and IL I sent out with the STS-87/89 info. The IL has a little more technical detail about the analyses performed.
<<87DAMAGE.PDF>>
<<sts89frr.ppt>>

Michele Chaffey
Orbiter Aero/Thermal Analysis
NASA Systems
(714)372-0261

OV-102 (STS-87) TPS Damage

Presenter
R. Gatto
Date
January 6, 1998

Observation:

- An Unusual Number of Damaged Tiles Was Observed on OV-102

Concern:

- Potential Temperature or Margins Violations on OV-102
- Potential of Similar TPS Damage on Next Flight OV-105 (STS-89)

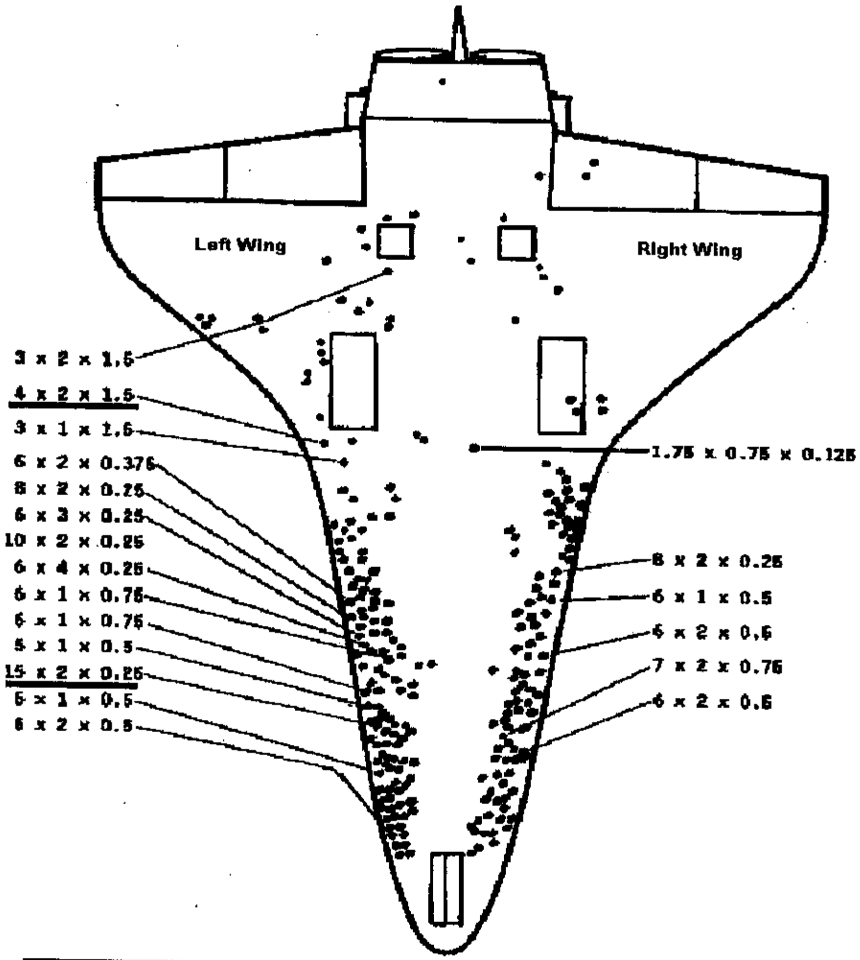
Discussion:

- OV-102 TPS Sustained a Total Of 308 Hits During STS-87
  - Lower Surface had 244 Hits with 109 Hits > 1" in Length
- Major Damage Area on the Lower Surface Is Between the Nose Landing Gear and Main Landing Gear Doors
  - Largest Damage Located on the Glove Measuring 15"x 2"x.25"
  - Deepest Damage Located Forward of Left Main Gear Door Measuring 4"x 2"x1.5"

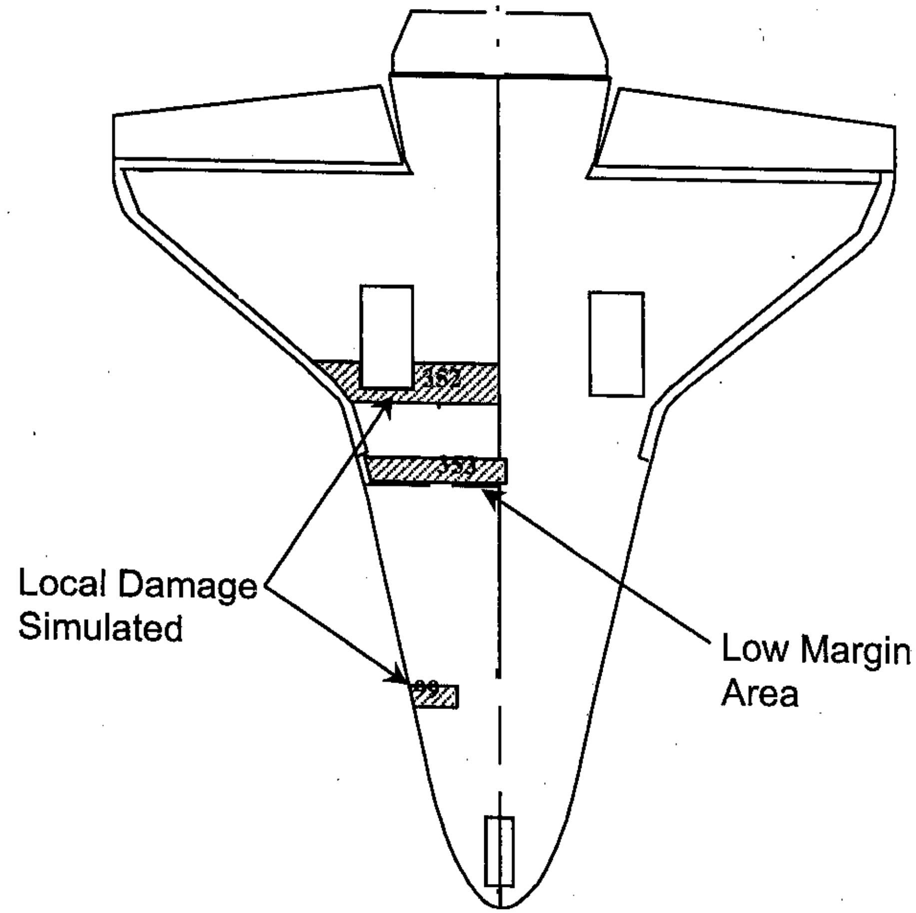
OV-102 (STS-87) TPS Damage

Presenter: R. Gatto
Date: January 6, 1998

Lower Surface Tile Damage



Thermal Math Model (TMM) Locations



OV-102 (STS-87) TPS Damage

Presenter
R. Gatto

Date
January 6, 1998

Actions Taken To Evaluate STS-87:

- Evaluated the Impact of TPS Damage on OV-102 STS-87
  - Reviewed Flight Data - OI, MADS, Physical Conditions
  - Identified and Removed Tiles and Inspected Structure Under Tiles
  - Performed Thermal/Structural Analysis at TPS Damage Sites
    - Simulated Local TPS Damage at Two Worst Sites and Estimated TPS and Structural Temperatures

Results of STS-87 Evaluation:

- Actual STS-87 Damage Was Determined to be Limited to TPS
  - Flight Data and Tile Removal/Inspection Found No Structural Damage
  - Analysis Simulation Indicates Damage Limited to TPS
    - Analysis Correlates with Observed TPS Surface at Damage Sites Being Near and Just Above Melting Temperatures
    - Structure Temperatures Would Not Exceed Acceptable Limits
- 101 Tiles Are Being Replaced on OV-102

OV-102 (STS-87) TPS Damage

Presenter
R. Gatto

Date
January 6, 1998

Actions Taken To Evaluate STS-89:

- Evaluated Impact of Two Potential Damage Scenarios on STS-89
  - Evaluated Local TPS Damage As Seen on STS-87 But With Impact at More Critical Locations Within the Observed Flow Path
    - Impact at Thin Tile Location Has Tile Loss Down to Densified Layer
  - Evaluated Potential Reduction on Safety Margins if STS-89 Tile Damage Is More Severe Than STS-87 Experience
    - Identified Critical Margin Concern Is Bottom Panel Temperature Gradients - Extensive Efforts Over the Years to Install Heat Sink Material to Make Gradients As Mild As Possible
    - Simulated 25% Tile Damage Over One Frame Bay of Bottom Panels

Results of STS-89 Evaluation:

- Local Damage Similar to STS-87 Experience at Thin Tile Locations Would Have Safe Vehicle Return But With Possible Local Structural Repairs
  - Tile Loss Down to Densified Layer Gives Local Peaks to 500F with Possible Structural Repair - Adjacent Structure Picks Up Load for Safe Vehicle Return

OV-102 (STS-87) TPS Damage

Presenter
R. Gatto

Date
January 6, 1998

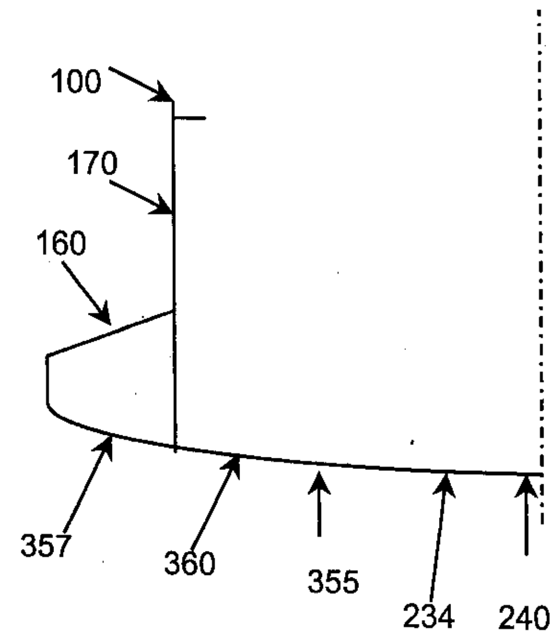
Results of STS-89 Evaluation, Cont.:

- Simulation with Damage More Severe than STS-87 Significantly Degraded Safety Margins
  - 25% Decrease in Tile Thickness in Out Board Panels Gives Large Increase in In-Plane Gradients and Thermal Stresses
  - Cannot Achieve Required 1.40 Factor of Safety - Approximate Contingency Capability Is:

    TAEM - F.S. = 1.0 at 1.8 g's

    Land - F.S. = 1.2 at 5.5 feet/sec

    = 1.4 at 3.0 feet/sec



CONCLUDE - With Hypothesized Damage (Second Scenario), Factor of Safety Will Be Less Than 1.0

OV-102 (STS-87) TPS Damage

Presenter
R. Gatto

Date
January 6, 1998

Conclusions:

- STS-87
  - No Local Temperatures Exceeding Structural Temperature Limits
  - Safety Margin of 1.40 Not Violated
- STS-87 Severity of Impacts on STS-89 Would Have Safe Vehicle Return But With Possible Local Structural Damage
  - Possible Structural Temperature Peaks to 500F in Thin Sandwich Parts Could Require Local Structural Repair
- Potential STS-89 Damage More Severe than STS-87 Could Significantly Degrade Safety Margins
  - Wider Area of Impact Damage on Bottom Panels Results In Unacceptable Margins

Backup

OV-102 (STS-87) TPS Damage

Presenter
R. Gatto
Date
January 6, 1998

Results of STS-87 Evaluation:

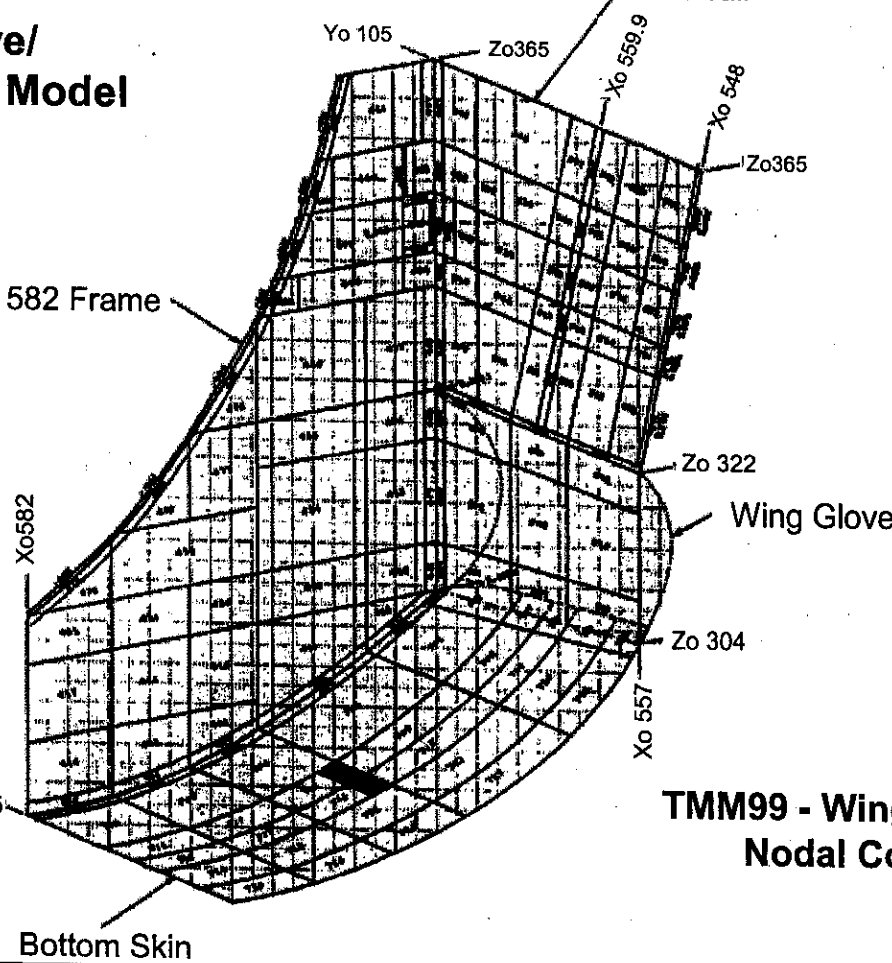
- OI Structural Temperature Data Indicated Nominal Temperatures
- Tempilabels Inside the Wing Area Indicated Nominal Temperature
- No Evidence of Structural Damage Under Removed Tiles Was Observed

Location	Tile Damage	Surface Temp	Structure Temp	Comments
TMM 99	Limited Fusing	3100°	276°	No Impact
TMM 352	Limited Fusing	2800°	309°	No Impact

OV-102 (STS-87) TPS Damage

Presenter: R. Gatto
Date: January 6, 1998

Detailed Wing Glove/ Chine Certification Model Used in Evaluation

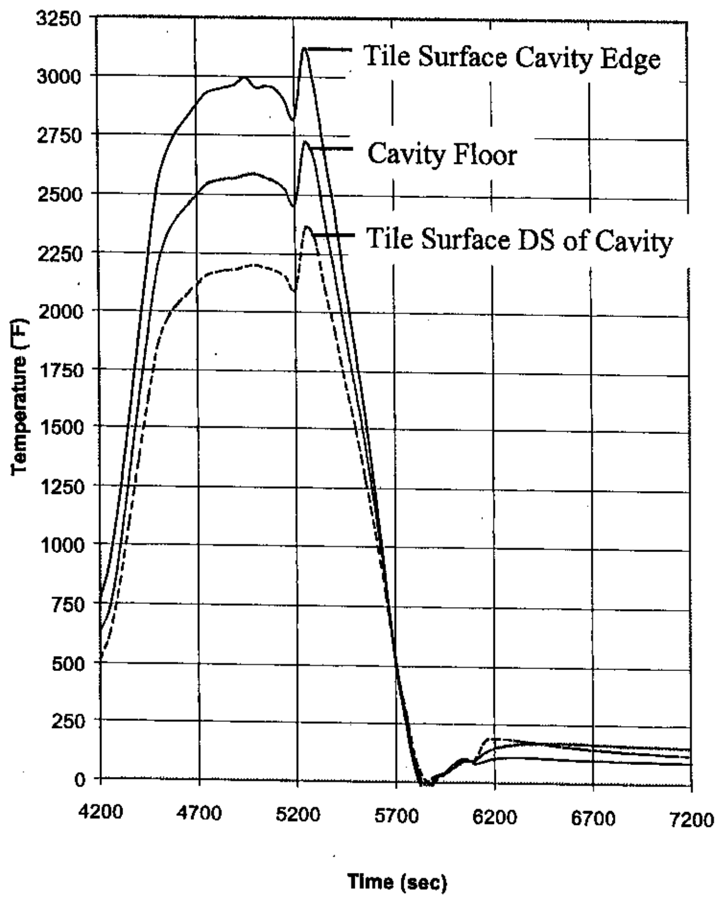


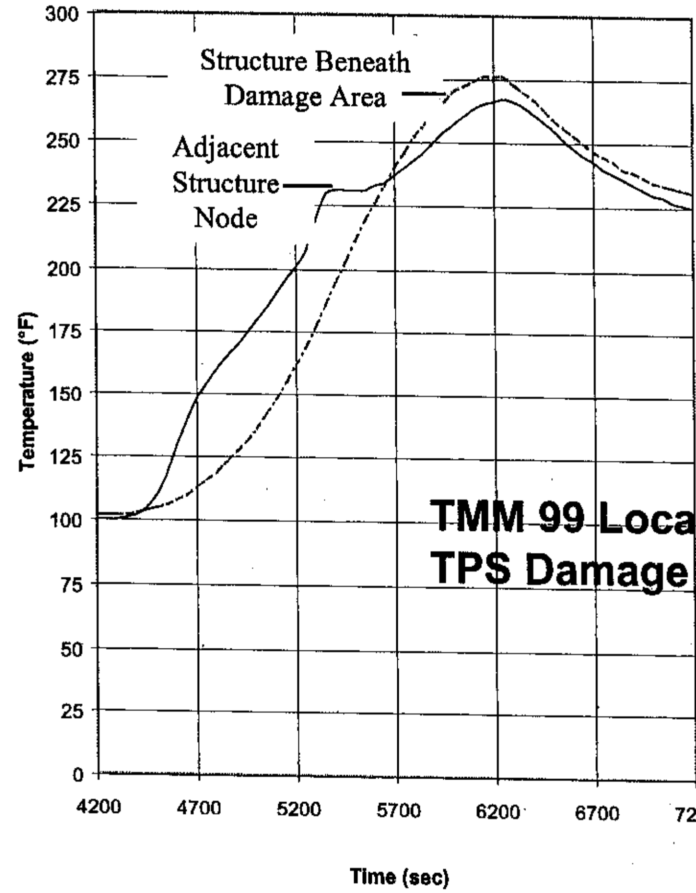
TMM99 - Wing Glove at X_o582 Nodal Configuration

OV-102 (STS-87) TPS Damage

Presenter: R. Gatto
Date: January 6, 1998

Temperatures Indicate TPS Surface Damage; Structure Okay



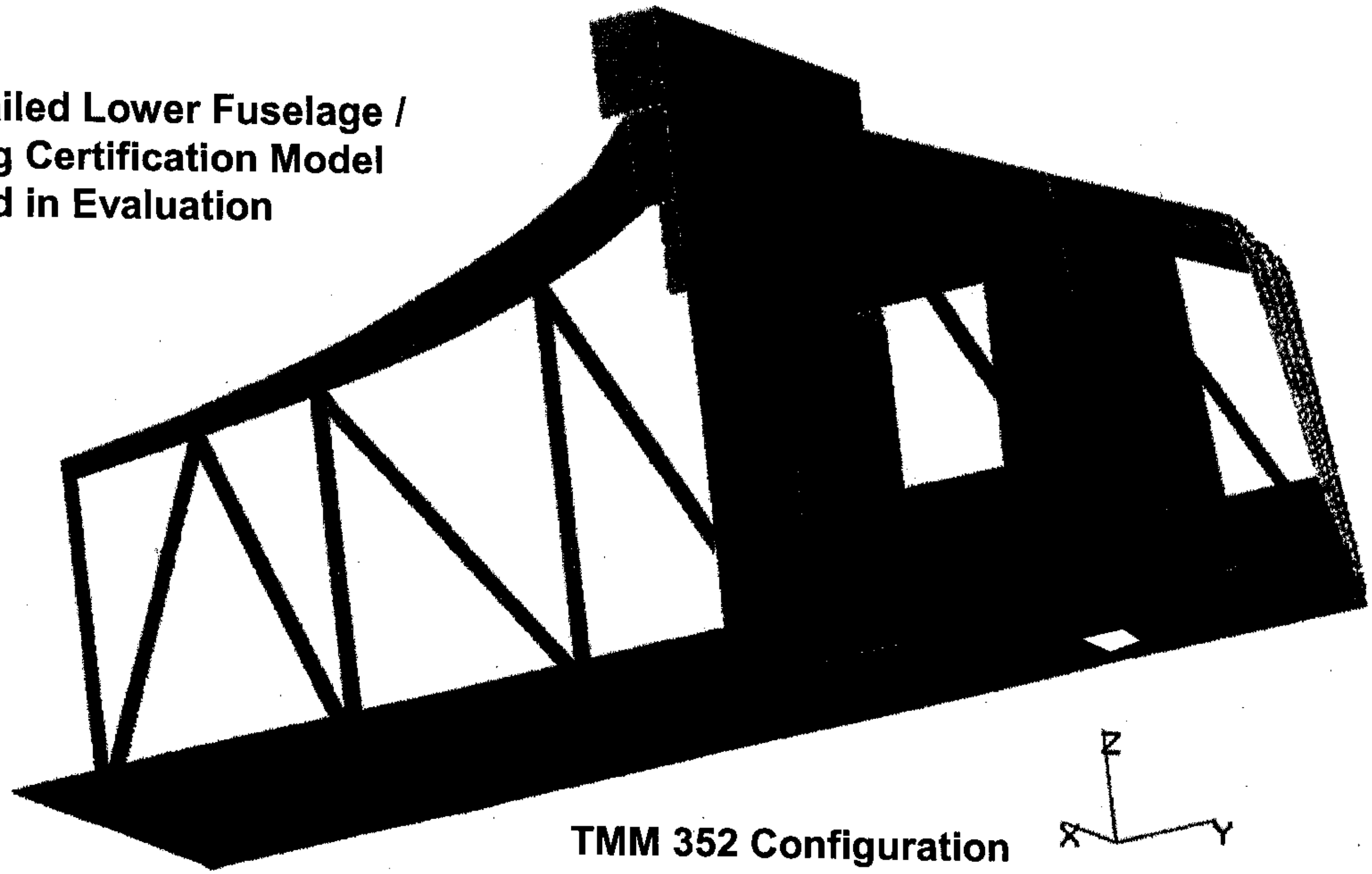


TMM 99 Local TPS Damage - EOM

OV-102 (STS-87) TPS Damage

Presenter	R. Gatto
Date	January 6, 1998

Detailed Lower Fuselage / Wing Certification Model Used in Evaluation

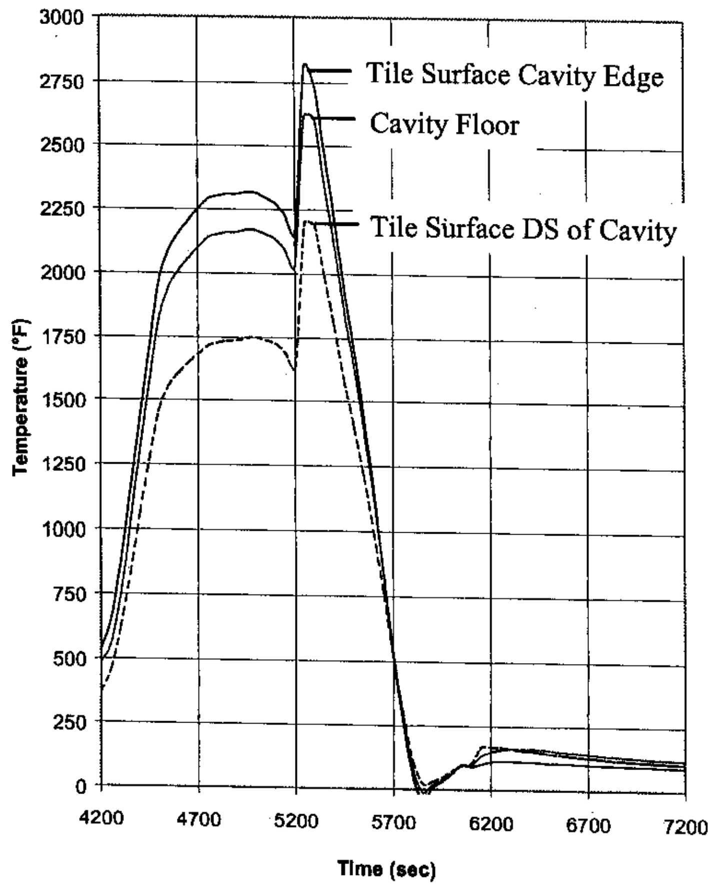


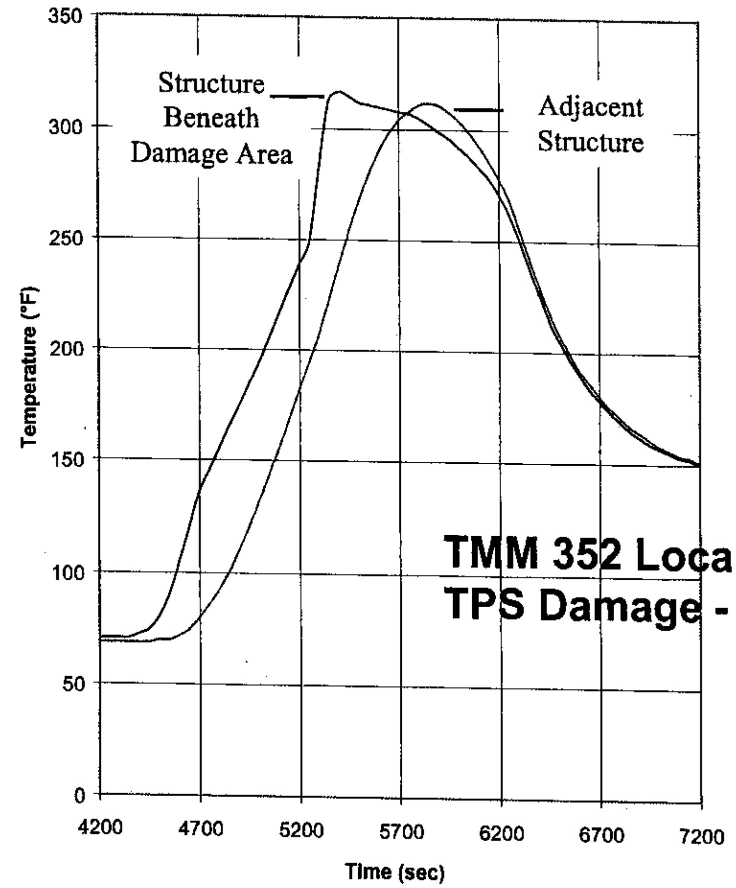
TMM 352 Configuration

OV-102 (STS-87) TPS Damage

Presenter	Date
R. Gatto	January 6, 1998

Local TPS Surface Damage Expected; Structure Acceptable





TMM 352 Local TPS Damage - EOM

OV-102 (STS-87) TPS Damage

Presenter
R. Gatto

Date
January 6, 1998

Results of STS-89 Evaluation:

- Local TPS and Structural Temperature Similar to STS-87 Experience if Damage is Similar
  - Debris Strike Producing Tile Loss to Densified Layer Could Cause Structural Thermal Damage

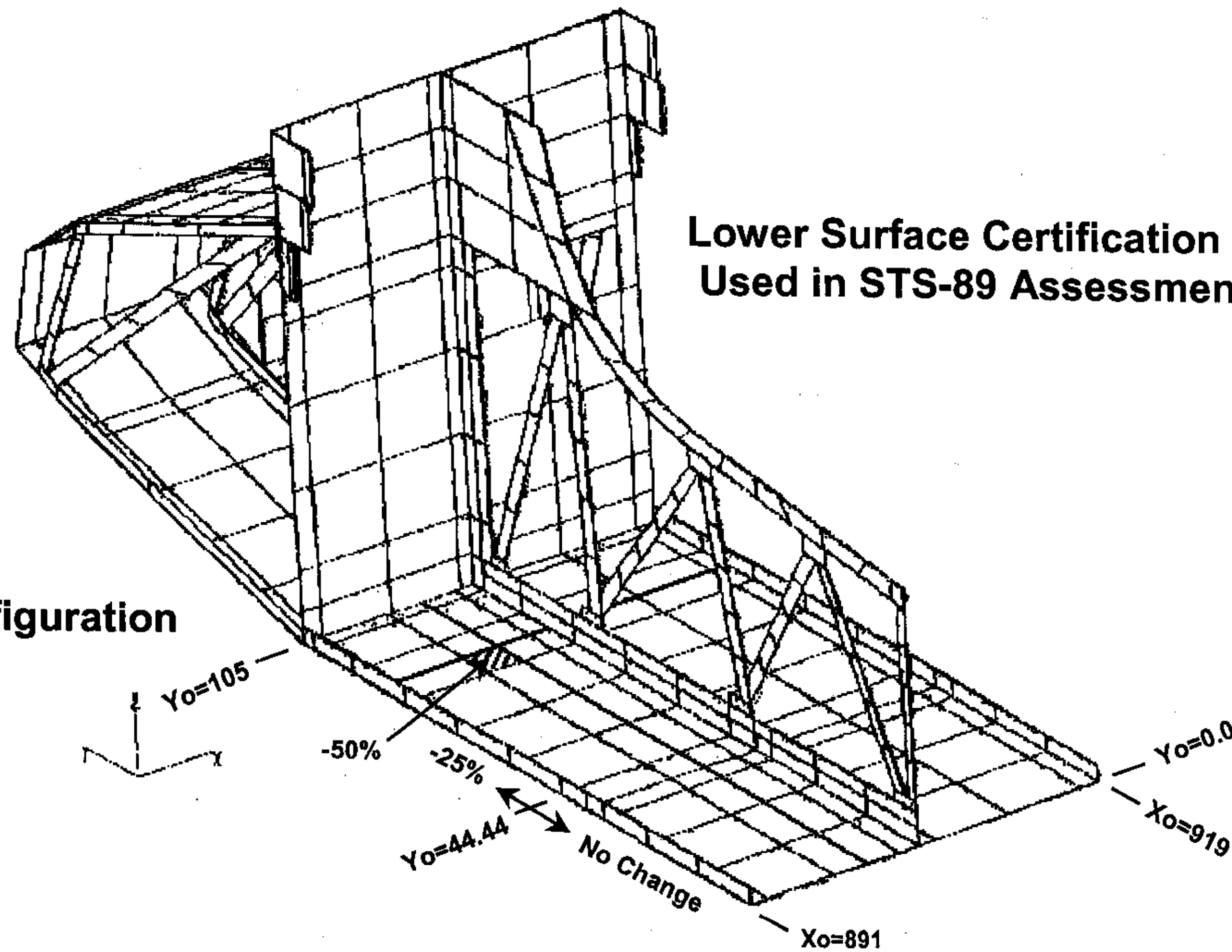
	Location	Tile Damage	Surface Temp °F	Structure Temp °F	Comments
EOM	TMM 99	Limited Melting	3100	272	No Issue
	TMM 352 • 50% Loss • Loss to Densified	Tile Surface Melting	2850 3150	330 506	No Issue Debond H/C
	TMM 353	Minimal	2420	366	Margin Issue
TAL	TMM 99	Tile Melting Burrowing	3300	195	No Issue
	TMM352 Densified	Minimal	2850	425	Local Structure Damage

OV-102 (STS-87) TPS Damage

Presenter
R. Gatto
Date
January 6, 1998

Lower Surface Certification Model
Used in STS-89 Assessment

TMM 353 Configuration

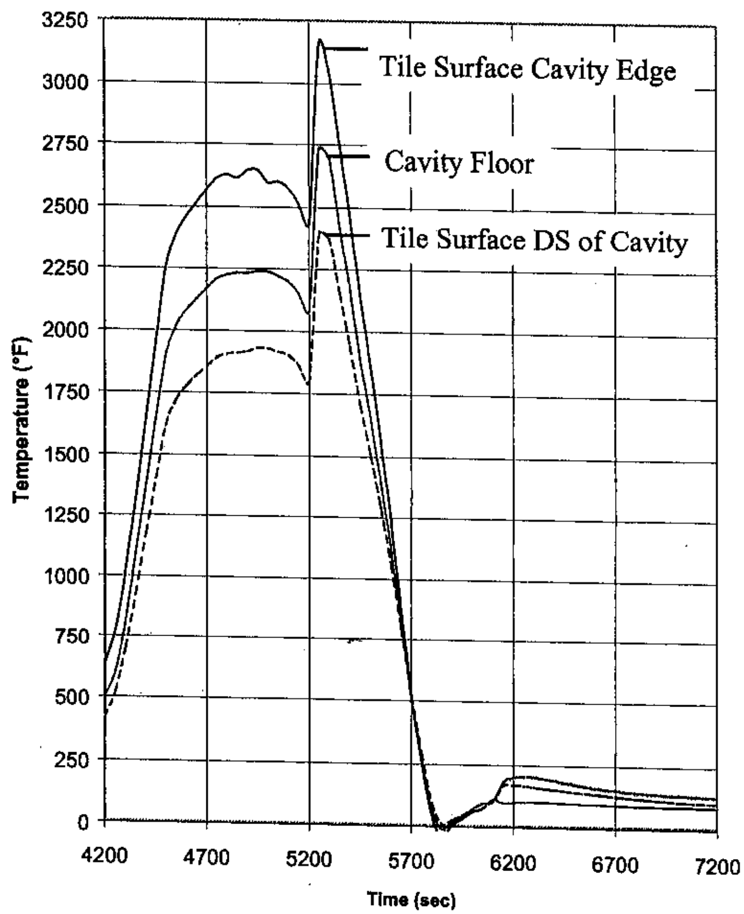


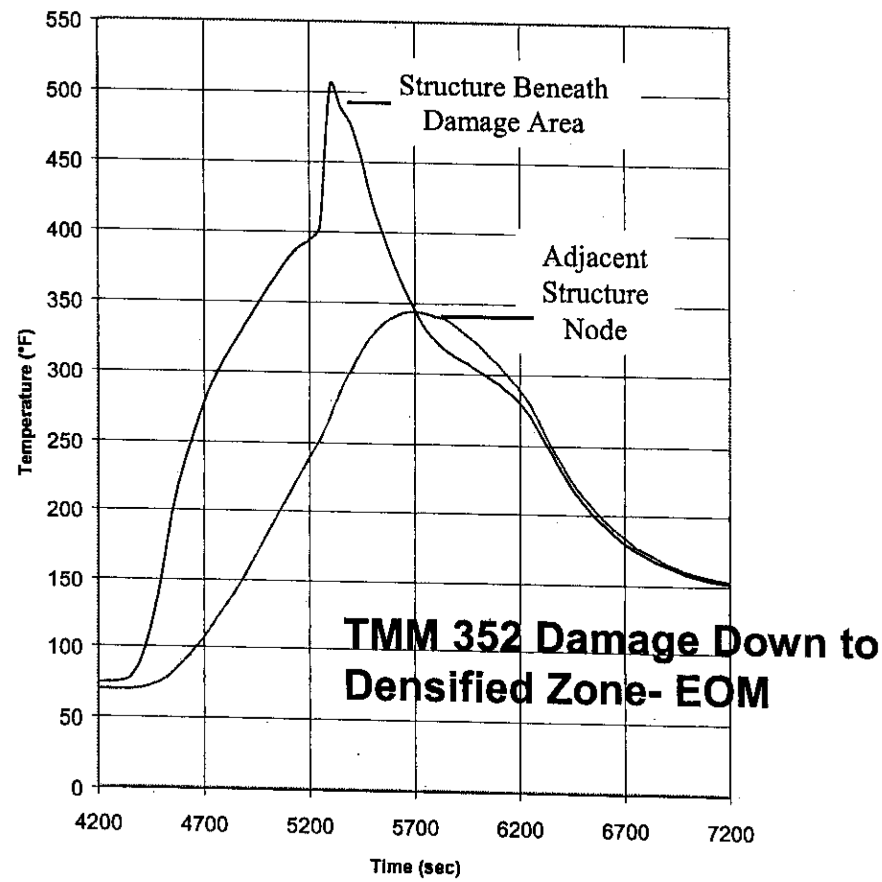
OV-102 (STS-87) TPS Damage

Presenter
R. Gatto

Date
January 6, 1998

Tile Damage to Densified Zone Produces Structural Damage





Michele Lewis

om: Page-1, Robert [Robert.W.Page@nasa.gov]
ent: Wednesday, January 29, 2003 1:56 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

107CFVR_L+4.
pdf

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;
ofsky, Kerry; Schomburg, Calvin.

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

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.