Date: Sat, 1 Feb 2003 11:27:25 -0700 (MST)
From: "J. Raymond Skarda" <rskarda@lanl.gov>
To: c.g.miller@larc.nasa.gov
Subject: best wishes

Charles,

I pulled up my web browser here while working and was saddened to see news of Columbia. After the short time I was priviledged to spend in the Branch, one thing I am certain of, is that the shaping of safer and improved launch vehicles rests heavily on the past, present and future contributions of the Aerothermodynamcis Branch and AAA Directorate. Please pass my regards on to the others in the group.

Sincerely,

Ray

RB-1

X-Sender: j.n.moss@pop.larc.nasa.gov
Date: Mon, 03 Feb 2003 08:23:44 -0500
To: c.e.glass@larc.nasa.gov
From: "James N. Moss" <j.n.moss@larc.nasa.gov>
Subject: Columbia
Cc: r.g.wilmoth@larc.nasa.gov, c.g.miller@larc.nasa.gov

>Date: Mon, 3 Feb 2003 07:25:01 -0500
>From: Graeme Bird <gabird@compuserve.com>
>Subject: Columbia
>Sender: Graeme Bird <gabird@compuserve.com>
>To: "James N. Moss" <j.n.moss@larc.nasa.gov>
>
>Jim,
>
>I was extremely sorry to hear of the loss of Colombia.
>
> As it happened, I heard the news just as I was testing the OpenGL surface
>representations of the Shuttle surface properties in the DS3V program.
>Watching the news conferences today, I was interested to note that there
>were signs of aerothermal and aerodynamic problems as much as seven minutes
>before breakup around 60 km. Most of my technical library that should
>contain some trajectory information is down at Culburra and I am not sure
>whether the corresponding altutude was sufficiently high that DSMC
>calculations could have some relevance.
>
>I am enclosing a small zipped executable DS3V.EXE that produces a screen
>dump DS3V.BMP from the program. This is for reentry at 105 km. The
>calculation was for a half-body and the surface plot includes the mirror
>image in the plane of symmetry. That is the reason for the large force in
>the z (yaw) direction. The surface image can be manipulated to any viewing
>angle and the flowfield cut can be in any plane normal to one of the axes.
>I am currently working on the "Detailed Plot" screens and the single
>processor program will be finished in about a week. Winteracter gives
>sufficient access to the operating system to permit a parallel version and
>I intend to move straight on to this in the hope that a firewire network
>under XP Pro will allow an efficient implementation. Just as the single
>processor version has automatic cell adaption, the parallel version will
>have automatic domain adaption.
>
>The 105 km calculation gives a reasonable result (heating about 10-20%
>high) in just a day or two. The surface triangles could be readily
>modified to simulate damage. Parallel calculations could go as low as 90
>km for the complete vehicle and local calculations for a damaged region
>could go as low as 80 km with a single processor and almost to pek-heating
>with a parallel machine.Best wishes,
>
>Graeme
>
>
>

RB-2


DS3V.EXE

Date: Mon, 3 Feb 2003 14:47:30 -0500
To: <s.j.alter@larc.nasa.gov>, <b.p.anderson@larc.nasa.gov>,
<s.a.berry@larc.nasa.gov>, <k.l.bibb@larc.nasa.gov>,
<g.r.bittner@larc.nasa.gov>, <m.v.bobskill@larc.nasa.gov>,
<g.j.brauckmann@larc.nasa.gov>, <g.m.buck@larc.nasa.gov>,
<m.difulvio@larc.nasa.gov>, <j.l.everhart@larc.nasa.gov>,
<m.v.foretich@larc.nasa.gov>, <c.e.glass@larc.nasa.gov>,
<p.a.gnoffo@larc.nasa.gov>, <del.l.green@larc.nasa.gov>,
<f.a.greene@larc.nasa.gov>, <h.h.hamilton@larc.nasa.gov>,
<h.s.hogge@larc.nasa.gov>, <s.d.holland@larc.nasa.gov>,
<b.r.hollis@larc.nasa.gov>, <t.j.horvath@larc.nasa.gov>,
<kenneth.m.jones@larc.nasa.gov>, <w.l.kleb@larc.nasa.gov>,
<v.r.lessard@larc.nasa.gov>, <d.s.liechty@larc.nasa.gov>,
<m.f.lindsey@larc.nasa.gov>, <n.r.merski@larc.nasa.gov>,
<c.g.miller@larc.nasa.gov>, <j.n.moss@larc.nasa.gov>,
<k.j.murphy@larc.nasa.gov>, <r.j.nowak@larc.nasa.gov>,
<w.p.phillips@larc.nasa.gov>, <r.k.prabhu@larc.nasa.gov>,
<v.v.raman@larc.nasa.gov>, <m.n.rhode@larc.nasa.gov>,
<w.i.scallion@larc.nasa.gov>, <h.h.senter@larc.nasa.gov>,
<k.sutton@larc.nasa.gov>, <r.a.thompson@larc.nasa.gov>,
<g.w.watts@larc.nasa.gov>, <k.j.weilmuenster@larc.nasa.gov>,
<r.a.wheless@larc.nasa.gov>, <r.g.wilmoth@larc.nasa.gov>,
<w.a.wood@larc.nasa.gov>, <w.c.woods@larc.nasa.gov>,
<s.a.wright@larc.nasa.gov>, <e.v.zoby@larc.nasa.gov>
From: "Mary F. Lindsey" <m.f.lindsey@larc.nasa.gov>
Subject: Fwd: STS-107 Memorial Service

> X-Sender: m.pitts@express.larc.nasa.gov
> Date: Mon, 3 Feb 2003 14:25:51 -0500
> To: title=secretary@larc.nasa.gov
> From: Margarette Pitts <m.pitts@larc.nasa.gov>
> Subject: STS-107 Memorial Service
> Date: Mon, 3 Feb 2003 14:25:59 -0500 (EST)
>
> Please forward the following information to the employees in your organization:
>
> Langley civil service and contractor employees are invited to participate in a memorial service for the STS-107 crew being held at the Johnson Space Center tomorrow. Speakers will include President Bush and Administrator O'Keefe.
>
> The memorial will be broadcast via NASA TV and be held in the Reid Conference Center.
>
> Employees are asked to be in place by 12:50 p.m. Associate Director Douglas Dwoyer will make opening remarks on behalf of Acting Director Freeman. The service is expected to conclude about 1:30.
> ***
> Margarette Pitts
> Office of External Affairs
> Building 1219, Room 304
> Mail Stop 115
> NASA Langley Research Center
> Hampton, VA 23681-2199

RB-3

757-864-6124 - Phone
757-864-6333 - Fax

* *

Mary F. Lindsey
Secretary
Aerothermodynamcs Branch

NASA Langley Research Center
Mail Stop 408A
Hampton, VA 23681-2199

757-864-5221 (Phone)
757-864-8670 (Fax)
E-mail: m.f.lindsey@larc.nasa.gov
* *

X-Sender: e.v.zoby@pop.larc.nasa.gov
Date: Tue, 4 Feb 2003 13:12:17 -0500
To: Charles Miller <c.g.miller@larc.nasa.gov>,
"FREEMAN, DELMA C, JR" <D.C.FREEMAN@larc.nasa.gov>
From: "e. vincent zoby" <e.v.zoby@larc.nasa.gov>
Subject: Fwd: Shuttle Aeroheating

can i have correspondence with peter or not?

> From: Erbland Peter J Civ AFRL/VAA <Peter.Erbland@wpafb.af.mil>
> To: Hayes James R Civ AFRL/VAAA <James.Hayes@wpafb.af.mil>
> Cc: "E. Vincent Zoby (E-mail)" <e.v.zoby@larc.nasa.gov>
> Subject: Shuttle Aeroheating
> Date: Tue, 4 Feb 2003 11:30:25 -0500
>
> Jim, Vince
>
> Do you recall if any work was ever done to look at "damaged tile" flowfield perturbations and our ability to predict the aerothermal consequences. I am aware of experimental work to study forward and aft-facing steps but was curious about other issues such as longitudinal cuts or channels/groves along the surface.
>
> Peter
>
> --
> ---
> Peter Erbland, Ph.D.
> Technical Advisor
> Aeronautical Sciences Division
>
> Air Vehicles Directorate
> AFRL/VAA
> 2130 Eighth Street, Rm. 290
> Wright-Patterson AFB OH 45433-7542
>
> Tel: (937) 255-6852 DSN: 785-6852
> Fax: (937) 656-4210 E-mail: peter.erbland@wpafb.af.mil
>
> Air Force Research Laboratory|AFRL
> --
> ---

E. Vincent Zoby Internet: e.v.zoby@larc.nasa.gov
NASA-Langley Research Center Telephone : (757) 864-4386
MS 408A FAX : (757) 864-8670
Hampton, VA 23681-2199

"Why be difficult when,
with just a little more effort,

RB-4

I can be completely impossible?"

- -

Bushnell portion Previously released on Columbia Site

X-Sender: j.w.paulson@express.larc.nasa.gov
Date: Wed, 05 Feb 2003 13:50:07 -0500
To: c.g.miller@larc.nasa.gov
From: "John W. Paulson" <j.w.paulson@larc.nasa.gov>
Subject: Fwd: Shuttle Heating/TPS

Charles,
Have you seen this from Dennis? Sure sounds close to what we were talking about the other day. Don't get"non-laminar" flow above Mach 18!! What do you make of the stuff coming off over California? That is really a pretty low dynamic pressure environment to be pulling things off I would think.....
Later,
JP

X-Sender: d.m.bushnell@express.larc.nasa.gov
Date: Wed, 5 Feb 2003 12:13:59 -0500
To: j.w.paulson@larc.nasa.gov
From: "Dennis m. Bushnell" <d.m.bushnell@larc.nasa.gov>
Subject: Fwd: Shuttle Heating/TPS

Date: Wed, 5 Feb 2003 09:03:38 -0500
To: d.l.dwoyer@larc.nasa.gov, d.c.freeman@larc.nasa.gov, c.m.darden@larc.nasa.gov, c.e.harris@larc.nasa.gov, r.m.martin@larc.nasa.gov, a.kumar@larc.nasa.gov, m.p.saunders@larc.nasa.gov, j.m.mckenzie@larc.nasa.gov, m.j.shuart@larc.nasa.gov, g.r.taylor@larc.nasa.gov
From: "Dennis m. Bushnell" <d.m.bushnell@larc.nasa.gov>
Subject: Shuttle Heating/TPS
Cc:
Bcc:
X-Attachments:

Was on Travel - Just returned,reason this was not sent earlier...[called Doug on this Saturday around noon].Maybe "you'all" already know this...

1.Undersigned was on the Walt Williams/NASA Chief Engineer Shuttle First Flight Certification team in 1980/81 Responsible for Boundary Layer Transition/TPS/Re-entry Heating.The report we [John Bertin and I] sent in indicated the Following:

- Peak Heating is at some 218 Kft.IF the flow is turbulent at Peak heating the heat shield would/could burn through the wheel well doors [even with undamaged tiles].

- Transition data from previous flights [Prime,Asset,etc.] indicated Transition Reynolds Numbers at Shuttle Hypersonic Conditions on admittedly rough surfaces well below a Million Reynolds Number but the data were all over the map.Taking the lower bound [with a rough surface] Turbulent flow at peak heating appeared possible....We therefore specified tile-to-tile and tile gap smoothness criteria which were pretty severe.

- As I recall the observed shuttle transition is usually around 180Kft.

RB-7

2.On the first flight there were thousands of dings/gouges in the tiles post flight which were almost all on the left wing and traced to ice impingement from launch vibrations dislodgment of the ice which builds up on the external tank dump line - WHICH IS LOCATED IN PROXIMITY TO THE LEFT WING ON THE STACK [Dump line is attached to the tank but runs down the side of the tank near where the windward side of the left wing is positioned when mated to the tank in the launch stack].Why this dump line was not repositioned to the other side of the tank away from the orbiter I do not understand....Over the years each flight has experienced a unique set of heat shield damage from this ice impingement and as a consequence shuttle transition varies mightily flight-to-flight.Several times this damage was quite severe.

3.All of this [1 above] is for undamaged [in the sense of thermal protection,not transition/roughness] tiles.More extensive tile damage,whether from external tank insulation or ice impingement,would obviously add insult to injury and compromise TPS integrity AS WELL AS ACT AS A BOUNDARY LAYER TRIP.IF the gouges were extensive enough then free shear layers form which have VERY LOW TRANSITION REYNOLDS NUMBERS [below a hundred thousand] AND large Impingement HEATING PEAKS.

We [the agency] should have done more analysis of this whole situation/taken it more seriously as well as repositioned that tank dump line to minimize ice impingement....The ice buildup/fracture patterns/subsequent impact patterns/effects due to launch vibration/loads is not deterministic.Just the ice,sans tank insulation,could conceivably have caused "Grievous Harm"...

Dennis Bushnell

John W. Paulson, Jr.
Head, Vehicle Analysis Branch
(757) 864-5071 Phone
(757) 864- 8671 FAX
j.w.paulson@larc.nasa.gov

Date: Wed, 5 Feb 2003 14:14:46 -0500 (EST)
From: Mark P Saunders <m.p.saunders@larc.nasa.gov>
To: Charles Miller <C.G.MILLER@larc.nasa.gov>

† From: Mark Saunders <m.p.saunders@larc.nasa.gov>
Reply-to: Mark Saunders <m.p.saunders@larc.nasa.gov>
MIME-Version: 1.0
Content-Type: text/plain; charset=iso-8859-1
Subject: MM: Evening Status Update

Meeting Invitation from Mark Saunders

The location of this meeting has been changed.

Title:	Evening Status Update
Location:	B1219, R232
Time Zone:	USA Eastern (USA)
Date:	Wednesday, February 5, 2003
Time:	4:00 PM to 5:00 PM
Guests:	B1219, R232, Ajay Kumar, Cindy Lee, Charles Miller, John W. Paulson, Alan H. Phillips, Mark Saunders, Mark J. Shuart

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RB-8

Date: Wed, 5 Feb 2003 14:35:27 -0500 (EST)
To: Charles Miller <C.G.MILLER@larc.nasa.gov>
From: Mark Saunders <m.p.saunders@larc.nasa.gov>
Reply-to: Mark Saunders <m.p.saunders@larc.nasa.gov>
Subject: MM: Evening Status Update

Meeting Invitation from Mark Saunders

Title:	Evening Status Update
Location:	B1219, R128
Time Zone:	USA Eastern (USA)
Date:	Every day from Wednesday, February 5, 2003
Time:	4:00 PM to 5:00 PM
Guests:	B1219, R128, Ajay Kumar, Cindy Lee, Charles Miller, John W. Paulson, Alan H. Phillips, Mark Saunders, Mark J. Shuart

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RB-9

X-Sender: r.j.nowak@pop.larc.nasa.gov
Date: Wed, 05 Feb 2003 15:28:18 -0500
To: Charles Miller <c.g.miller@larc.nasa.gov>, e.v.zoby@larc.nasa.gov
From: Robert Nowak <r.j.nowak@larc.nasa.gov>
Subject: Flow in cavities

Charles,

Attached is a two page summary on cavities -- what I know is available. Most relevant work is by Roane Hunt NASA TN D-8400, 1977. Have original paper,

Bob


Cavity-Gap-Flow-Summary-01.doc

Robert J. Nowak
Mail Stop 408A
Building 1251, Room 229B
NASA Langley Research Center
Hampton VA 23681-2199

Phone: 757-864-1391

RB-11

Cavity Flow Heating Summary

Work on 3-D shock-boundary layer interaction as with a wedge (i.e. proturbance) on a plate. Both experiments and CFD in US – Contact for info: Chris Glass at LaRC.

Numerous experimental studies in 1970's - 1980's in the LaRC 8-Ft HTT on simulated full size shuttle tile gaps and cavities on simulated shuttle TPS. Focus on work to understand flow in gaps between tiles and in cavities if a tile was lost – what it took to un-zip the tiles. Little (not sure how much) CFD done to compare with data. References at LaRC.

Specifically: L. Roane Hunt, retired LaRC and still in area, did experiments in LaRC 8-Ft HTT on flow over simulated tile cavities. If more than one tile was missing then there was potential for tiles un zipping,. Have original paper see abstract second page. This works seems most relevant to Shuttle problem.

Additionally, Don Avery, still at LaRC, did experimental studies (including M.S. thesis) on flow in simulated gaps between tiles in LaRC 8-Ft HTT and has several publications. I talked to him, 2-05-03, and he could be a contact for flow in gaps. See abstract second page of a NASA TP

Several tests were run in LaRC 8-Ft HTT on flow between gaps in elevons,

Experimental work in LaRC 8-Ft HTT was done by Al Wieting on flow in cavities.

Most, but not all (see second page) work in LaRC 8-Ft HTT regarding gaps and cavities was done on a flat plate.

Survey paper by Don Nestler at G.E. includes pre-1985 work cavities, steps, protuberances, etc.

Bob Nowak has a list of references on gap flow.

Bob Nowak has requested an LaRC Library search on flow in gaps and cavities,

Have in-hand a literature search by LaRC Library on flow behind backward facing steps.

Fundamental Mach-6 experiments on flow into gap under a backward facing step (i.e. X-33 metallic heat shield problem); starting to model with GASP. Contact Bob Nowak at LaRC.

Bob Nowak has these three in hand –hard original copies.

Hunt, L. Roane, **"Aerodynamic heating in large cavities in an array of RSI tiles,"**NASA-TN-D-8400, May 1977. Abstract: A large panel of reusable surface insulation (RSI) tiles including lost tile cavities was aerothermally tested in the Langley 8 foot high temperature structures tunnel to determine both the heat load within the cavities and the structural performance of the RSI surrounding the cavities. Tests were conducted with a turbulent boundary layer at a nominal free stream Mach number of 6.6, a total temperature of 1800 K, a Reynolds number per meter of 5 million, and a dynamic pressure of 62 kPa. The maximum aerodynamic heating to the floor of the cavity was two to three times the normal surface heating. The cavity heating rates agreed with data from other facilities and were successfully correlated with an empirical equation. A zippering failure occurred to a tile downstream of a double tile cavity when the separated flow attached to the floor of the cavity and forced the tile from its position.

CONCLUDING REMARKS A thermal protection system panel 91.4 cm by 137.2 cm consisting of reusuable surface insulation (RSI) tiles bonded to a primary structure was modified to include single and double lost-tile cavities. This panel was subjected to four aerothermal tests in the Langley 8-foot high-temperature structures tunnel to determine both the aerodynamic heat load within the cavities and the structural performance of the RSI surrounding the cavities. Tests were conducted with a turbulent boundary layer at a nominal free-stream Mach number of 6.6, a total temperature of 1800 K, a Reynolds-number per meter of 5×10^6, and a dynamic pressure of 62 kPa.

The maximum aerodynamic heating to the floor of the cavity was two or three times the normal surface heating. The cavity heating rates agreed with other data for cavities of various sizes and flow orientations and were successfully correlated with an empirical equation. Calculated structure temperature for a 3.81-cm-deep single-tile cavity exposed to simulated shuttle entry conditions indicated that the aluminum structural skin would melt if the tile were lost within the first 1000 s of entry. The strain isolator pad (SIP) does not offer extended thermal protection to the structure when a tile is lost. A zippering failure occurred to the tile downstream of the double lost-tile cavity when the separated flow attached to the floor of the cavity. The attached flow ablated the SIP beneath the tile and forced the tile from its position.

Hunt, L. Roane, **"Aerodynamic heating and loading within large open cavities in cone and cone-cylinder-flare models at Mach 6.7."** NASA-TN-D-7403, March 1974. Abstract: The aerodynamic heating and loading distributions within large cavities exposed by surface openings to hypersonic flow were determined in the 8-foot high-temperature structures tunnel. Cone and cone-cylinder-flare models with cavities having regular and irregular surface-opening shapes were aerothermally tested at various angles of attack up to 30 deg. Tests were conducted at a Mach number of 6.7, a total temperature of 1800 K, a dynamic pressure of 80 kPa, and a stream unit Reynolds number of 6,000,000 per meter. The results showed that the heating rates at internal reattachment were generally lower but of the same order as the corresponding external heating rates; however, other internal heating rates were an order of magnitude lower. The internal flow showed characteristics of being funneled into jets or being dispersed dependent upon the internal surface contour.

Avery, Don E. **"Experimental aerodynamic heating to simulated space shuttle tiles in laminar and turbulent boundary layers with variable flow angles at a nominal Mach number of 7." , NASA TP 2307**, August 1985. Astract: The heat transfer to simulated shuttle thermal protection system tiles was investigated experimentally by using a highly instrumented metallic thin wall tile arranged with other metal tiles in a staggered tile array. Cold wall heating rate data for laminar and turbulent flow were obtained in the Langley 8 foot high Temperature Tunnel at a nominal Mach number of 7, a nominal total temperature of 3300R, a free stream unit Reynolds number from 3.4 x 10 sup 5 to 2.2 10 sup 6 per foot, and a free stream dynamic pressure from 2.1 to 9.0 psia. Experimental data are presented to illustrate the effects of flow angularity and gap width on both local peak heating and overall heating loads. For the conditions of the present study, the results show that localized and total heating are sensitive to changes in flow angle only for the test conditions of turbulent boundary layer flow with high kinetic energy and that a flow angle from 30 deg to 50 deg will minimize the local heating.

X-Sender: r.j.nowak@pop.larc.nasa.gov
Date: Wed, 05 Feb 2003 19:14:53 -0500
To: Charles Miller <c.g.miller@larc.nasa.gov>
From: Robert Nowak <r.j.nowak@larc.nasa.gov>
Subject: Cavity & CFD
Cc: Tom Horvath <t.j.horvath@larc.nasa.gov>

Charles,
Since the work by Hunt* is Shuttle related, it would seem like a CFD start to run his conditions and see what level of gridding is needed to resolve/match his heat flux levels/trends in a cavity. [Test media is methane/air combustion for his test.] I have a search request to Library to find any references that used Hunt's work especially any CFD.

*Hunt, L. Roane, "Aerodynamic heating in large cavities in an array of RSI tiles,"NASA-TN-D-8400, May 1977.

Additionally we could consider running a similar test in 20-M6 on a flat plate [yes a flat plate!] where we could have a large enough cavity to get detailed phosphor/IR heating on the floor and rear forward-facing step/edge of the cavity. Need to consider appropriate scale factors

Just some thoughts.

Bob
Robert J. Nowak
Mail Stop 408A
Building 1251, Room 229B
NASA Langley Research Center
Hampton VA 23681-2199

Phone: 757-864-1391

RB-12

To: "ZOBY, ERNEST V" <E.V.ZOBY@LaRC.NASA.GOV>, "WURSTER, KATHRYN E" <K.E.WURSTER@LaRC.NASA.GOV>, "HORVATH, THOMAS J" <T.J.HORVATH@LaRC.NASA.GOV>, "HAMILTON, HUBBARD HARRIS" <H.H.HAMILTON@LaRC.NASA.GOV>, "SCALLION, WILLIAM I" <W.I.SCALLION@LaRC.NASA.GOV>, "BRAUCKMANN, GREGORY J" <G.J.BRAUCKMANN@LaRC.NASA.GOV>, "WOODS, WILLIAM C" <W.C.WOODS@LaRC.NASA.GOV>
From: Charles Miller <c.g.miller@express.larc.nasa.gov>
Subject: Fwd: Shuttle Heating/TPS
Cc:
Bcc:
X-Attachments:

Heard about this note from Dennis. For your information. Again, do not disseminate this information. Thanks

Charles

> X-Sender: j.w.paulson@express.larc.nasa.gov
> Date: Wed, 05 Feb 2003 13:50:07 -0500
> To: c.g.miller@larc.nasa.gov
> From: "John W. Paulson" <j.w.paulson@larc.nasa.gov>
> Subject: Fwd: Shuttle Heating/TPS
>
> Charles,
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> Later,
> JP
>
> > X-Sender: d.m.bushnell@express.larc.nasa.gov
> > Date: Wed, 5 Feb 2003 12:13:59 -0500
> > To: j.w.paulson@larc.nasa.gov
> > From: "Dennis m. Bushnell" <d.m.bushnell@larc.nasa.gov>
> > Subject: Fwd: Shuttle Heating/TPS
> >
> > > Date: Wed, 5 Feb 2003 09:03:38 -0500
> > > To: d.l.dwoyer@larc.nasa.gov, d.c.freeman@larc.nasa.gov, c.m.darden@larc.nasa.gov, c.e.harris@larc.nasa.gov, r.m.martin@larc.nasa.gov, a.kumar@larc.nasa.gov, m.p.saunders@larc.nasa.gov, j.m.mckenzie@larc.nasa.gov, m.j.shuart@larc.nasa.gov, g.r.taylor@larc.nasa.gov
> > > From: "Dennis m. Bushnell" <d.m.bushnell@larc.nasa.gov>
> > > Subject: Shuttle Heating/TPS
> > > Cc:
> > > Bcc:
> > > X-Attachments:
> > >
> > > Was on Travel - Just returned,reason this was not sent earlier...[called Doug on this Saturday around noon].Maybe "you'all" already know this...

RB-13

1.Undersigned was on the Walt Williams/NASA Chief Engineer Shuttle First Flight Certification team in 1980/81 Responsible for Boundary Layer Transition/TPS/Re-entry Heating.The report we [John Bertin and I] sent in indicated the Following:

- Peak Heating is at some 218 Kft.IF the flow is turbulent at Peak heating the heat shield would/could burn through the wheel well doors [even with undamaged tiles].

- Transition data from previous flights [Prime,Asset,etc.] indicated Transition Reynolds Numbers at Shuttle Hypersonic Conditions on admittedly rough surfaces well below a Million Reynolds Number but the data were all over the map.Taking the lower bound [with a rough surface] Turbulent flow at peak heating appeared possible....We therefore specified tile-to-tile and tile gap smoothness criteria which were pretty severe.

- As I recall the observed shuttle transition is usually around 180Kft.

2.On the first flight there were thousands of dings/gouges in the tiles post flight which were almost all on the left wing and traced to ice impingement from launch vibrations dislodgment of the ice which builds up on the external tank dump line - WHICH IS LOCATED IN PROXIMITY TO THE LEFT WING ON THE STACK [Dump line is attached to the tank but runs down the side of the tank near where the windward side of the left wing is positioned when mated to the tank in the launch stack].Why this dump line was not repositioned to the other side of the tank away from the orbiter I do not understand....Over the years each flight has experienced a unique set of heat shield damage from this ice impingement and as a consequence shuttle transition varies mightily flight-to-flight.Several times this damage was quite severe.

3.All of this [1 above] is for undamaged [in the sense of thermal protection,not transition/roughness] tiles.More extensive tile damage,whether from external tank insulation or ice impingement,would obviously add insult to injury and compromise TPS integrity AS WELL AS ACT AS A BOUNDARY LAYER TRIP.IF the gouges were extensive enough then free shear layers form which have VERY LOW TRANSITION REYNOLDS NUMBERS [below a hundred thousand] AND large Impingement HEATING PEAKS.

We [the agency] should have done more analysis of this whole situation/taken it more seriously as well as repositioned that tank dump line to minimize ice impingement....The ice buildup/fracture patterns/subsequent impact patterns/effects due to launch vibration/loads is not deterministic.Just the ice,sans tank insulation,could conceivably have caused "Grievous Harm"...

Dennis Bushnell

John W. Paulson, Jr.
Head, Vehicle Analysis Branch
(757) 864-5071 Phone
(757) 864- 8671 FAX
j.w.paulson@larc.nasa.gov

X-Sender: r.j.nowak@pop.larc.nasa.gov
Date: Wed, 05 Feb 2003 20:08:51 -0500
To: Charles Miller <c.g.miller@larc.nasa.gov>
From: Robert Nowak <r.j.nowak@larc.nasa.gov>
Subject: Update on cavity paper

Charles,
Reworded to make more readable.
Bob


Cavity-Gap-Flow-Summary.doc

Robert J. Nowak
Mail Stop 408A
Building 1251, Room 229B
NASA Langley Research Center
Hampton VA 23681-2199

Phone: 757-864-1391

RB-14

Cavity Flow Heating Summary

Numerous experimental studies in 1970's - 1980's in the LaRC 8-Ft HTT on simulated full size shuttle tile gaps and cavities on simulated shuttle TPS. Focus on work to understand flow in gaps between tiles and in cavities if a tile was lost – what it took to un-zip the tiles. Little if any (not sure how much) subsequent CFD done to compare with data.

Of Special Interest is experimental work that L. Roane Hunt did in LaRC 8-Ft HTT on flow over simulated tile cavities. **This works seems most relevant to Shuttle: Hunt found that if more than one tile was missing then there was potential for tiles un zipping,. See attached conclusions.**

Hunt also did experiments on a cavity in a cone and looked at internal flow, see attached abstract..

Additionally, Don Avery, still at LaRC, did experimental studies (including M.S. thesis) on flow in simulated gaps between tiles in LaRC 8-Ft HTT and has several publications. Nowak talked to him, 2-05-03, and he could be a contact for flow in gaps. See attached abstract.

Experimental work in LaRC 8-Ft HTT was done by Al Wieting on flow in cavities.

Several tests were run in LaRC 8-Ft HTT on flow between gaps in elevons.

Survey paper by Don Nestler at G.E. includes pre-1985 work cavities, steps, protuberances, etc.

Nowak has a list of references on gap flow.

Nowak has requested an LaRC Library search on flow in gaps and cavities

Nowak has in-hand a literature search by LaRC Library on flow behind backward facing steps.

Fundamental Mach-6 experiments on flow into gap under a backward facing step (i.e. X-33 metallic heat shield problem); starting to model with GASP. Bob Nowak at LaRC.

Much work has been done on 3-D shock-boundary layer interaction with a wedge on a plate. Both experiments and CFD in US – Contact for info: Chris Glass at LaRC. (could consider this work as a protuberance)

Abstracts of three reports

Hunt, L. Roane, **"Aerodynamic heating in large cavities in an array of RSI tiles,"**NASA-TN-D-8400, May 1977.

Concluding Remarks "A thermal protection system panel 91.4 cm by 137.2 cm consisting of reusuable surface insulation (RSI) tiles bonded to a primary structure was modified to include single and double lost-tile cavities. This panel was subjected to four aerothermal tests in the Langley 8-foot high-temperature structures tunnel to determine both the aerodynamic heat load within the cavities and the structural performance of the RSI surrounding the cavities. Tests were conducted with a turbulent boundary layer at a nominal free-stream Mach number of 6.6, a total temperature of 1800 K, a Reynolds-number per meter of 5×10^6, and a dynamic pressure of 62 kPa. ["Conditions at Mach 7, 25 – 40 Km"]

The maximum aerodynamic heating to the floor of the cavity was two or three times the normal surface heating. The cavity heating rates agreed with other data for cavities of various sizes and flow orientations and were successfully correlated with an empirical equation. **Calculated structure temperature for a 3.81-cm-deep single-tile cavity exposed to simulated shuttle entry conditions indicated that the aluminum structural skin would melt if the tile were lost within the first 1000 s of entry.** The strain isolator pad (SIP) does not offer extended thermal protection to the structure when a tile is lost. **A zippering failure occurred to the tile downstream of the double lost-tile cavity when the separated flow attached to the floor of the cavity.** The attached flow ablated the SIP beneath the tile and forced the tile from its position."

Hunt, L. Roane, "Aerodynamic heating and loading within large open cavities in cone and cone-cylinder-flare models at Mach 6.7." NASA-TN-D-7403, March 1974.

Abstract: The aerodynamic heating and loading distributions within large cavities exposed by surface openings to hypersonic flow were determined in the 8-foot high-temperature structures tunnel. Cone and cone-cylinder-flare models with cavities having regular and irregular surface-opening shapes were aerothermally tested at various angles of attack up to 30 deg. Tests were conducted at a Mach number of 6.7, a total temperature of 1800 K, a dynamic pressure of 80 kPa, and a stream unit Reynolds number of 6,000,000 per meter. The results showed that the heating rates at internal reattachment were generally lower but of the same order as the corresponding external heating rates; however, other internal heating rates were an order of magnitude lower. The internal flow showed characteristics of being funneled into jets or being dispersed dependent upon the internal surface contour.

Avery, Don E. "Experimental aerodynamic heating to simulated space shuttle tiles in laminar and turbulent boundary layers with variable flow angles at a nominal Mach number of 7." , NASA TP 2307, August 1985.

Abstract: The heat transfer to simulated shuttle thermal protection system tiles was investigated experimentally by using a highly instrumented metallic thin wall tile arranged with other metal tiles in a staggered tile array. Cold wall heating rate data for laminar and turbulent flow were obtained in the Langley 8 foot high Temperature Tunnel at a nominal Mach number of 7, a nominal total temperature of 3300R, a free stream unit Reynolds number from 3.4 x 10 sup 5 to 2.2 10 sup 6 per foot, and a free stream dynamic pressure from 2.1 to 9.0 psia. Experimental data are presented to illustrate the effects of flow angularity and gap width on both local peak heating and overall heating loads. For the conditions of the present study, the results show that localized and total heating are sensitive to changes in flow angle only for the test conditions of turbulent boundary layer flow with high kinetic energy and that a flow angle from 30 deg to 50 deg will minimize the local heating.

To: "J. Raymond Skarda" <rskarda@lanl.gov>
From: Charles Miller <c.g.miller@express.larc.nasa.gov>
Subject: Re: best wishes
Cc:
Bcc:
X-Attachments:

Ray,

Thanks for the kind words. Pete Gnoffo is down the hall retrieving files for the orbiter in the event we are asked to assist in the investigation. Sure hope all is well with you and your family.

Best wishes

Charles

> Charles,
>
> I pulled up my web browser here while working and was saddened to see news of Columbia. After the short time I was priviledged to spend in the Branch, one thing I am certain of, is that the shaping of safer and improved launch vehicles rests heavily on the past, present and future contributions of the Aerothermodynamcis Branch and AAA Directorate. Please pass my regards on to the others in the group.
>
> Sincerely,
>
> Ray

RB-16

To: "KUMAR, AJAY" <A.KUMAR@LaRC.NASA.GOV>
From: Charles Miller <c.g.miller@express.larc.nasa.gov>
Subject: Accident
Cc:
Bcc:
X-Attachments:

Ajay,

Just got off the phone with Chuck Campbell of the Aerosciences Branch at JSC. Lot of speculation, but the focus appears to be converging on the external environment over the left wing. Ricky Thompson believes we can provide laminar, and most importantly, turbulent heating distributions within a week or so at flight conditions. This assumes a smooth wing surface and also assumes we can get priority on NAS. While doing these predictions with existing surface and volume grids, we would build new grids in an effort to model a missing tile and could probably provide solutions within three weeks. Meanwhile, Pete Gnoffo came into work this morning and began retrieving files of shuttle predictions performed previously and is ready to exercise his unstructured code (HEFSS) on the orbiter. Tom Horvath believes we could rapidly modify one of our existing 0.0075 scale orbiter models and perform a parametric study of the effects of transition due to perturbations in the vicinity of the wing leading edge. The flow is quite complex in the wing leading edge shock-shock interaction region, and transitions at fairly high velocities immediately downstream of this region. Probably the worst possible area for damage to the CC leading edge or a tile in close proximity to the leading edge. A region of extremely high heating is the gap between the elevons at the wing trailing edge, and a transition wedge that passed over this gap might make matters a lot worst. Tom has already talked to Scott Berry up at Purdue to check on model availability and to see if Scott did any leading edge transition work, which he has not. Newspaper reporters have been in touch with Steve Schneider and Scott since the reporters were somehow aware of the work we did on using ground-based IR to obtain surface temperature distributions on the orbiter in flight and to compared this data to wind tunnel measurements.

Please don't hesitate to call at any time if word comes into LaRC asking for assistance. The AB wants to help in any way possible, as evident by all the communication among branch members today.

Guess I'll get back to evaluating OSP proposals. The deadline for the LaRC response is rapidly approaching and the evaluation is shouldered by John Paulson and myself.

Thanks

Charles

RB-17

To: "SCALLION, WILLIAM I" <W.I.SCALLION@LaRC.NASA.GOV>, "BRAUCKMANN, GREGORY J" <G.J.BRAUCKMANN@LaRC.NASA.GOV>, "HORVATH, THOMAS J" <T.J.HORVATH@LaRC.NASA.GOV>, "GNOFFO, PETER A" <P.A.GNOFFO@LaRC.NASA.GOV>, "KLEB, WILLIAM L" <W.L.KLEB@LaRC.NASA.GOV>, "THOMPSON, RICHARD A" <R.A.THOMPSON@LaRC.NASA.GOV>, <E.V.ZOBY@LaRC.NASA.GOV>
From: Charles Miller <c.g.miller@express.larc.nasa.gov>
Subject: Columbia Accident
Cc: "DIFULVIO, MICHAEL" <M.DIFULVIO@LaRC.NASA.GOV>
Bcc:
X-Attachments:

I would like for us to get-together in the AB conference room tomorrow (Monday) at 9:00 a.m. to discuss possible contributions our branch can make towards understanding the cause(s) of the Columbia accident, assuming the cause(s) is attributable to surface roughness effects, voids due to loss of tile(s), charring of the CC leading edge due to damaged coating, etc. on the left wing; and the corresponding amplified or augmented heating. Our services have not been officially requested at the time of this e-mail, although Ajay Kumar asked me to be prepared to assist in any way possible and I was called by Chuck Campbell of the Aerosciences Branch at JSC last night asking if we would be available to help if so needed.

Bill Scallion - we need your vast knowledge of shuttle aerodynamics and your guidance having worked Challenger
Greg Brauckmann - please review your asymmetric boundary layer transition work for the orbiter;
please check on availability of orbiter force and moment models
may want to examine effect of a trip(s) on the leading edge; possible surface voids also
use IR during force and moment tests to confirm trip/void effectiveness
Tom Horvath - please determine if we can rapidly provide heating distributions for various trip locations
qualitative and quantitative; 0.0075 scale ceramic models
simulate damage to CC leading edge, particularly in shock-shock region, and loss of a tile(s)
Pete Gnoffo - the lessons learned from previous LAURA solutions and the possibility of HEFSS solutions
Bill Kleb - the lessons learned from your orbiter abort study
Ricky Thompson - findings from recent LAURA predictions performed to establish our credibility to Boeing
Vince Zoby - for your wealth of aeroheating knowledge, past work on the orbiter, insight and tough questions

Since I'm trying to pull this together quickly, I may have left some key folks out of the invite. Please feel free to invite other folks to this meeting as appropriate.

Thanks

Charles

RB-18

To: "KUMAR, AJAY" <A.KUMAR@LaRC.NASA.GOV>
From: Charles Miller <c.g.miller@express.larc.nasa.gov>
Subject: Fwd: Columbia Accident
Cc:
Bcc:
X-Attachments:

Ajay,

For your information. If any requests come in from JSC at the working level, I'll let you know right away. Meanwhile, we will try to get our ducks in a roll so to be prepared.

Charles

> Date: Sun, 2 Feb 2003 20:32:53 -0500
> To: "SCALLION, WILLIAM I" <W.I.SCALLION@LaRC.NASA.GOV>, "BRAUCKMANN, GREGORY J" <G.J.BRAUCKMANN@LaRC.NASA.GOV>, "HORVATH, THOMAS J" <T.J.HORVATH@LaRC.NASA.GOV>, "GNOFFO, PETER A" <P.A.GNOFFO@LaRC.NASA.GOV>, "KLEB, WILLIAM L" <W.L.KLEB@LaRC.NASA.GOV>, "THOMPSON, RICHARD A" <R.A.THOMPSON@LaRC.NASA.GOV>, <E.V.ZOBY@LaRC.NASA.GOV>
> From: Charles Miller <c.g.miller@express.larc.nasa.gov>
> Subject: Columbia Accident
> Cc: "DIFULVIO, MICHAEL" <M.DIFULVIO@LaRC.NASA.GOV>
> Bcc:
> X-Attachments:
>
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>
> Bill Scallion - we need your vast knowledge of shuttle aerodynamics and your guidance having worked Challenger
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> please check on availability of orbiter force and moment models
> may want to examine effect of a trip(s) on the leading edge; possible surface voids also
> use IR during force and moment tests to confirm trip/void effectiveness
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> qualitative and quantitative; 0.0075 scale ceramic models
> simulate damage to CC leading edge, particularly in shock-shock region, and loss of a tile(s)
> Pete Gnoffo - the lessons learned from previous LAURA solutions and the possibility of HEFSS solutions
> Bill Kleb - the lessons learned from your orbiter abort study
> Ricky Thompson - findings from recent LAURA predictions performed to establish our credibility to Boeing
> Vince Zoby - for your wealth of aeroheating knowledge, past work on the orbiter, insight and tough questions

RB-19

Since I'm trying to pull this together quickly, I may have left some key folks out of the invite. Please feel free to invite other folks to this meeting as appropriate.

Thanks

Charles

To: "e. vincent zoby" <e.v.zoby@larc.nasa.gov>
From: Charles Miller <c.g.miller@express.larc.nasa.gov>
Subject: Re: Fwd: Shuttle Aeroheating
Cc:
Bcc:
X-Attachments:

Vince,

Yes, you can discuss technical issues with Peter, whereby the information is in the open literature or was generated before the accident. Specifics/details concerning the accident are not to be discussed at this time. So, talk away.

Also, we are to communicate thru Ajay Kumar, as he reports to Del Freeman/senior staff each morning. Ajay will be calling me each afternoon to get a progress/status report. He made it quite clear there is a chain of command that we are to honor.

Charles

> can i have correspondence with peter or not?
>
> > From: Erbland Peter J Civ AFRL/VAA <Peter.Erbland@wpafb.af.mil>
> > To: Hayes James R Civ AFRL/VAAA <James.Hayes@wpafb.af.mil>
> > Cc: "E. Vincent Zoby (E-mail)" <e.v.zoby@larc.nasa.gov>
> > Subject: Shuttle Aeroheating
> > Date: Tue, 4 Feb 2003 11:30:25 -0500
> >
> > Jim, Vince
> >
> > Do you recall if any work was ever done to look at "damaged tile" flowfield perturbations and our ability to predict the aerothermal consequences. I am aware of experimental work to study forward and aft-facing steps but was curious about other issues such as longitudinal cuts or channels/groves along the surface.
> >
> > Peter
> >
> > ----------
> > Peter Erbland, Ph.D.
> > Technical Advisor
> > Aeronautical Sciences Division
> >
> > Air Vehicles Directorate
> > AFRL/VAA
> > 2130 Eighth Street, Rm. 290
> > Wright-Patterson AFB OH 45433-7542
> >
> > Tel: (937) 255-6852 DSN: 785-6852
> > Fax: (937) 656-4210 E-mail: peter.erbland@wpafb.af.mil

RB-20

Air Force Research Laboratory|AFRL

E. Vincent Zoby Internet: e.v.zoby@larc.nasa.gov
NASA-Langley Research Center Telephone : (757) 864-4386
MS 408A FAX : (757) 864-8670
Hampton, VA 23681-2199

"Why be difficult when,
with just a little more effort,
I can be completely impossible?"

To: jose.m.caram@nasa.gov
From: Charles Miller <c.g.miller@express.larc.nasa.gov>
Subject: Information
Cc:
Bcc:
X-Attachments:

Joe,

Received you fax. Several branch members studying it now. Plan is for Tom Horvath to go into the Mach 6 tunnel tomorrow with ceramic orbiter model. Our original phosphor system finally died a number of months ago and the new system won't be available until later this month; thus, we are working with another organization at LaRC to set up an IR system. Tom will have a scaled 7 by 30 inch gash, 2 inches deep, placed outboard of the left wing landing gear door as a start.

Charles

RB-23