Swanson, Greg

From: Swanson, Greg
Sent: Tuesday, February 06, 2001 3:19 PM
To: Swanson, Greg; Meyers, Charles; Hawkins, Jim
Subject: FW: RSRM RRC Issues

FYI

Dr. Gregory R. Swanson
ED22/Strength Analysis Group
e-mail: greg.swanson@msfc.nasa.gov
(256) 544-7191 voice, -7234 fax

From: Swanson, Greg
Sent: Tuesday, February 06, 2001 3:08 PM
To: Craig Bryson; Doug Wells; Kenneth Swaim; Lisa Hediger; Marcus Gregg; Pravin Aggarwal; Preston McGill; Sam Russell; Steve Androlake; Terry Hamm
Cc: Holt, Dan; Spanyer, Karen; McConnaughey, Paul; Cash, Steve
Subject: RSRM RRC Issues

Thiokol presented to the MSFC Fracture Control Board this morning about reuse of nonconforming hardware. Dan Holt from the RSRM project office asked that we give them a "heads up" on the concerns the Fracture Control Board has with the Relative Radius of Curvature (RRC) methodology Thiokol is using to determine residual stresses in RSRM case segment stub rings. What follows is my summary, in a preliminary form, of the issues the FCB has with the RRC methodology.

One part of the flight rational for reuse of distorted segments is the RRC determined residual stress. The residual stress must be limited to avoid stress corrosion crack growth of a small flaw (0.025 x 0.025 corner crack). This size flaw is one that could escape NDE after also surviving proof pressure testing.

The main issue the FCB has is that the RRC residual stress calculation is based on numerous assumptions that have not been verified with test data. An elastic/plastic analysis to determine residual stresses is highly dependent on load history (path), Finite Element Model (FEM) mesh density, and FEM solution algorithm. From the presented materials and an overview of the Thiokol report it is apparent that no testing was done to verify the RRC methodology. The RRC methodology is a new and novel approach that should be test verified before use for flight programs.

The FCB felt that removing knowledge of the residual stress in the stub ring does weaken the flight rational in regards to protection from stress corrosion cracking. The stub ring still has for supporting rational for flight the proof testing, NDE inspections, and environmental barriers (paint, foam, grease, etc.).

The FCB would also like to know if the stub ring is the highest stressed part due to cavity collapse loads or if the local deformation also highly loads the membrane.

A final issue is the multi cycle reuse of hardware and tracking of the plastic stress and strain over a segments life. This is an "aging fleet" issue and is not a direct responsibility of the FCB, but the FCB is concerned with the potential low cycle fatigue (LCF) and crack initiation that can be caused by multiple plastic cycles.

Greg Swanson
Dr. Gregory R. Swanson
ED22/Strength Analysis Group
e-mail: greg.swanson@msfc.nasa.gov
(256) 544-7191 voice, -7234 fax

From: Ortega, Rene
Sent: Monday, March 05, 2001 4:40 PM
To: Benefield, Philip
Cc: Aggarwal, Pravin
Subject: RE: Potential Engine Failure Items / Areas

Phillip,

Pravin and I talked about this and this is what we came up with:

Nozzle/Mcc: Aft Manifold, cold wall leaks, G15 flange, MCC welds 12 & 15, MCC Low life mount (lug) areas.

Powerhead/Pre-burners/Main Inj.: Lox post, Preburner liners, hot dog area, inter propellant plate, heat exchanger.

HPFTP/AT: Blades, vanes, turbine inlet housing, turbine exit diffuser, turbine housing, lift off seal.

HPOTP/AT: Turbine area in general.

Other: 7021 Duct (vibrations) and POGO Duct.

Rene.

From: Benefield, Philip
Sent: Thursday, March 01, 2001 4:38 PM
To: VanHooser, Katherine; Ray, Dawn; Swanson, Greg; Ortega, Rene; Aggarwal, Pravin
Cc: Kynard, Mike
Subject: Potential Engine Failure Items / Areas

As part of our studies for the Advanced Health Management System we've used the SSME FMEA and associated QRAS numbers to rank which areas of the engine are most likely to fail and consequently which areas we should direct our health monitoring attention to (so to speak). However, everyone has their own opinion as to the validity of the FMEA and QRAS scores -- most of which isn't good.

So, this leads me to you all -- the engineering experts of the SSME. People that have signed more MRs and analyzed more SSME parts than anyone at MSFC. I'd like to get your opinion on what you consider the most failure prone items / areas on the SSME -- in other words, with all the information you all have from working the program for the last x number of years, what items worry you?

Now, to be more specific, I'd like to break it up into the following components / areas:

* Nozzle / MCC
* Powerhead / Pre-burners / Main Inj.
* HPFTP/AT
* HPOTP/AT
* Other

For each of these categories, please give me your "top 5" worry items. Only answer those areas with which you have expertise. (Katherine: turbo, Dawn: CD, ...). In general, I'm looking for items on a piece-part level, i.e. HPOTP/AT TAD or Nozzle aft manifold, although I don't want to constrain you... maybe you're worried about a HPFTP/AT turbine-end failure...

Here's another way to think about it: Assume someone calls you and says there's been an engine failure at SSC at it was related to one of the five areas I listed above. What's the first five things that would go through your head in terms of what specific part (maybe assembly) failed?

Please give me a call / e-mail if you have any questions on this. As I've said, I'm looking for what you think based on your accrued knowledge; I'm not looking for a detailed study. I would think this exercies shouldn't take more than maybe an hour at most.

Thanks,
Philip

Philip A. Benefield
NASA / MSFC SSME Project
(256) 544-6146

++++++++++++++++++++++

> From: Trolinger, Joan
> Sent: Thursday, April 19, 2001 07:47 PM
> To: Stinson, Henry P
> Subject: You missed some excitement on Thursday...
>
> Henry -
>
> You missed some excitement on Thursday at 40 minutes before launch and even fewer minutes before "Go for Launch'" polling when I got a fanatic call for the MR Board secretarial assistant who stated an MR Board was to be held in 5 minutes! Well I grabbed a pen, a pad of paper and on my way to the elevator saw Mr. Cannon to tell him the first statement of this message. ANYWAY, I attended the MRB on ALL SSME combustion devices nozzles since the dawn of SSME! It seems that the Rocketdyne nozzle planning failed to include a drawing required dye pentrant inspection. This inspection was to be done on the nozzle steerhorn-tee block which undergoes EDM prior to having the steerhorn legs/tubes welded to it. After the weld another dye pentrant inspection is preformed, but this inspection is only on the O.D. Therefore the I.D. of the tee at the area where the weld is later performed did not receive an inspection for removed re-cast layer and such after the EDM. Because the Program has many nozzles that have been started very many times and for very many seconds with no problems with the tees and all the nozzles were all build to the same planning -- fleet leader rules and the fact that the missed inspection applied to the certification series nozzles, it was decided that the STS-100 Flight SSME nozzles could be "Used As Is." The MR was signed shortly before the "Go for Launch" polling and therefore, SSME was a "GO." After the MRB, I had just enough time to get from 4202 where the MRB was held to our area in 4203 where I got the television on and running in the conference room 5004. The countdown clock was on "T minus 1.15 Seconds" when the television revealed its picture. Well, the Shuttle launched while me and many others were watching. The weather was very clear and the camera tracked the Shuttle until just shy of 7 minutes into the Flight. We all waited until MECO and returned to work. Like I said, you missed some excitement on Thursday!
>
> - joan [| 8) X <-- smiling me in hat & bow tie

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END OF ATTACHED eMAIL -- END OF ENTIRE eMAIL

Swanson, Greg

From: Blaine Tew [Blaine.Tew@THIOKOL.COM]
Sent: Friday, April 20, 2001 1:29 PM
To: greg.swanson@msfc.nasa.gov
Cc: dan.holt@msfc.nasa.gov; Brian McQuivey; Ken Parsons; Ting Lai; Vicki Call
Subject: Relative Radius of Curvature

Response to MSFC RRC Questions...

Greg:

I have attached a prelimary copy of Thiokol's response to the memo from the Marshall fracture board regarding relative radius of curvature. This document is included in the handout we will distribute during our meeting next week. I would appreciate it if you would forward the document to members of the FCB who have an interest in the RRC issue so they can read it before the meeting. Thanks.

BTew

--- Preliminary ---

April 3, 2001
34A0-CY01-M0001

TO: Dan Holt

CC: B. McQuivey, V. Call, S. Graves, J. Lohrer, K. Parsons,

FROM: B. Tew, T. Lai
Thiokol Fracture Control Board

SUBJECT: Thiokol Fracture Control Board Response to Questions Raised by MSFC Fracture Control Board/Others Regarding Relative Radius of Curvature

1. Question/Issue: Relative Radius of Curvature residual stress calculation is based on numerous assumptions that have not been verified with test data. RRC methodology .... should be test verified before use for flight programs.

Thiokol should show test data that was used to anchor any of the models concerned. If test data was not used to anchor models or was not required, Thiokol should justify their position.

Response: The radius of curvature approach was developed to identify out-of-roundness in case segments (caused by a severe splashdown) beyond that measured by total indicator runout. Figure 1 shows an oval shape with a dashed circle inscribed that has a radius of curvature equal to that of the oval at their tangent point. Figure 2 is generally rounder than the oval in Figure 1; however, localized interior radii are substantially smaller. Localized residual stresses in a case shaped like that shown in Figure 2 may be significantly higher than the stresses seen in a generally oval-shaped case segment even though the TIR is smaller.

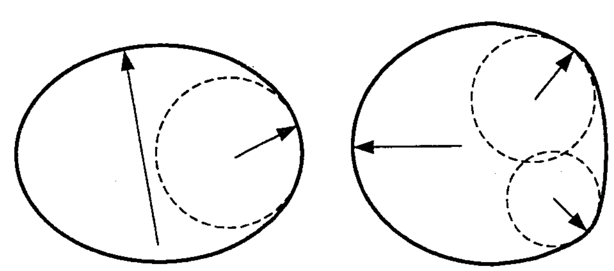

Figure 1 Figure 2

The selection of a limit for a localized radius of curvature was based on limiting residual stresses in the stiffener stub to 78 ksi. At this limit, the stress level is not high enough to cause a 0.025 by 0.025 corner crack in the stiffener stub outer ligament to propagate due to stress corrosion cracking. The 78 ksi stress limit was shown analytically to relate to a relative radius of curvature value of –900 in. (TWR-66632 p. 3).

The relative radius of curvature limit of –900 was incorporated in Thiokol engineering requirements in 1995.

Splashdown damage to stiffener stubs has been a concern for Thiokol for over 10 years. A Cracked Stiffener Stub Program Plan (TWR-19326 p.7) was developed in 1989 to enhance understanding of stiffener stubs damaged by splashdown. This plan included

- Comparison of three methods of measuring stub out-of-roundness,
- Development of a crack database,
- Measurement of residual stresses in parts damaged by splashdown using X-ray diffraction and strain gages,
- Nonlinear finite element analyses,
- Elastic-plastic fracture mechanics analyses,
- Analog testing of stiffener specimens,
- Evaluation of eddy current inspection system, and the
- Development of accept/reject/repair criteria.

Results of the X-ray diffraction and strain gage testing of residual stresses in the damaged stiffener segments are documented in TWR-19326. Residual stresses in three lightweight stiffener segments were evaluated. Lightweight S/N 023 (mislabeled S/N 032 in TWR) had not experienced a hard splashdown. Lightweight S/N 006 had experienced a hard splashdown and was so out-of-round (TIR of 0.72 in.) it could not be reassembled for proof test. Lightweight S/N 012 was not as badly damaged as S/N 006 (TIR of 0.25 in.) and was proof tested after water impact damage. Numerical TIR measurement data for these segments is no longer available, however, a graphical record of the TIR measurements is available in TWR-19326.

Residual stress measurements in TWR-19326 are similar to the elastic-plastic finite element analysis residual stress predictions given in TWR-66632. The following observations can be made:

Pre Proof Test (Comparing TWR-66632 Figure 16 with TWR-19326 Figure 27 near load centerline location)

- High tensile residual stresses are observed near the holes
- Residual tensile stresses near holes are higher than residual tensile stresses at outer edge of stiffener stub
- Residual stresses at inside surface of case wall are either fairly low tensile, or compressive

- Residual tensile stresses measured on outer edge of stub between holes are lower than those measured on outer edge of stub adjacent to holes

Post Proof Test (Comparing TWR-66632 Figure 24 with TWR-19326 Figure 28 near load centerline location)

- Residual stresses measured on stub outer edge are relatively small and tensile
- A substantial stress gradient exists across outer ligament of stiffener - tensile on stub outer edge, changing to moderate compressive stress near hole
- Compressive residual stress in inner ligament (between hole and case wall)

The X-ray diffraction data presented in TWR-19326 shows residual stress trends that are similar to elastic-plastic finite element analyses result provided in TWR-66632; however, no specific correlation between RRC and measured stress is provided. Several significant factors undoubtedly influenced the correlation between measured and predicted stress levels including:

- Residual stresses in stubs from heat treat quenching
- Residual stresses in stubs caused by glass bead or grit blast operations in refurbishment process
- Residual stresses caused by previous proof testing and splashdown events
- Variability in X-Ray diffraction measurement process, surface preparation, etc.
- Elastic-plastic finite element models did not include outer ligament cracks seen in measured parts
- Measured pre-proof and post-proof parts did not have same out-of-roundness (radius of curvature) values
- Stiffener segments had membrane material adjacent to stubs removed from one side (although ring continuity was maintained)

Any future residual stress measurements of out-of round stiffener segments will be influenced by many/all of these factors.

2. Question/Issue: Can Thiokol quantify how much not using radius of curvature weakens flight rationale? We flew for years using total indicator runout (TIR), and radius of curvature (ROC) is more conservative than TIR.

Response: Radius of curvature is a better screening approach than TIR simply because it identifies badly distorted localized regions in the case segment that are more likely to have residual stresses high enough to facilitate SCC under certain conditions.

In order for SCC to become a flight concern, pre-flight stress corrosion cracking must not only crack the outer ligament of the stub, but must also form a crack in the inner ligament. Since the stresses between the stiffener holes and the case wall are very low after proof testing, it is unlikely that this scenario is even a possibility. TWR 66632 Rev A (released November, 1997) shows stresses in the region adjacent to the splashdown load centerline, near the stiffener holes in the inner ligament are near zero or compressive. TWR-19326 (released July, 1991) shows measured residual stresses in this same region are compressive after proof test and prior to the installation of the T-ring. Following T-ring installation measured residual stresses near the centerline are 20 ksi or lower. Measured residual stresses in the knuckle region following T-ring installation are highly compressive.

Stress corrosion cracking requires high tensile stress, a wet environment, and an existing flaw or crack in the material. In addition to minimizing the residual tensile stresses in the stiffener stubs by radius of curvature screening and machine repair, Thiokol uses a very rigorous nondestructive inspection program with magnetic particle, eddy current, and visual inspection techniques to assure the structural integrity of the hardware. Additionally, case hardware is carefully protected from moisture by primer, paint, grease, rubber, and K5NA epoxy ablative material. Surface protection is verified when it is initially applied in the Insulation Work Center and is reverified several times prior to launch.

Another consideration is that undetectable flaws or cracks oriented perpendicular to primary proof test loads develop a residual compressive stress at the crack tip following the release of the proof test pressure. This means that potential crack propagation sites are effectively eliminated.

Limiting the residual stress in the outer ligament of a stiffener stub to a value below the stress corrosion cracking threshold removes any concern about stress corrosion cracking in the stiffener stubs causing flight safety issues. Even if residual stress is not precisely controlled, the probability of any flight safety issues due to SCC is extremely remote. The larger problem with SCC and residual stresses lies in hardware inspection, protection, and attrition.

3. Question/Issue: FCB would like to know if the stub ring is the highest stressed part due to cavity collapse loads or if the local deformation also highly loads the membrane. Does cavity collapse leave any residual loads in the membrane? If so, identify why it is not a concern.

Response: The highest residual stresses associated with splashdown are in the stiffeners. Finite element analyses show relatively low residual stress levels in the membrane adjacent to the stiffener stubs. Near the stubs, the membrane is also thickened approximately 0.100 in. to provide additional load carrying capability.

TWR-19326 Figure 33 shows residual stresses in a membrane section between the stiffener stubs before and after T-rings were installed. The highest tensile residual stress is 6 ksi near the load centerline on the inside of the case prior to the installation of the T-ring. The highest compressive residual stress is 20 ksi located on the outer surface of the membrane near the knuckle measured before the T-ring is installed. Following T-ring installation, the highest compressive residual stress (18 ksi) is on the outer surface near the load centerline. High tensile residual stresses in the case membrane near the stub may cause local yielding; however, the associated strain in flight is very low and not a cause for concern. Even if residual stress values seen in finite element models and X-ray diffraction testing are not representative of those seen in all stiffener segments, the successful proof test demonstrates the ability of each segment to safely undergo four additional flight pressurizations.

4. Question/Issue: A final issue is the multi-cycle reuse of hardware and tracking of the plastic stress and strain over a segments life. The FCB is concerned with the potential low cycle fatigue and crack initiation that can be caused by multiple plastic cycles.

Is low cycle fatigue a concern? Are loads needed to drive low cycle fatigue higher than those needed to drive stress corrosion cracking? Do we actually have multiple plastic cycles to be concerned about?

Response: Low cycle fatigue is a concern that we deal with. A plastic load cycle occurs when hardware is subject to a hard splashdown and again when it is subsequently proof tested. Stresses generated during splashdown and proof testing regularly exceed the yield strength of the material in localized regions. Fortunately, these high stress cycles occur in non-flight-critical times – at splashdown and during proof test in Clearfield.

From a crack initiation and growth standpoint, non-destructive inspection and proof testing provide a very effective screen for hardware that has been damaged in flight, splashdown, or subsequent transportation. Hardware that passes the inspection and proof test is capable of withstanding four additional pressurizations to MEOP without having cracks grow to a critical length.

Ortega, Rene

From: Ortega, Rene
Sent: Tuesday, April 24, 2001 5:14 PM
To: Caraccioli, Paul
Cc: Crane, Charlie; Ray, Dawn; Aggarwal, Pravin; Worlund, Len; Frady, Greg
Subject: RE: G6 stretch values

Paul,

RKDN has advertised a variability on the preload of the joint. In fact they have been adamant about their variability numbers. The single sample of stretch values we have (pre and post hot fire) indicates that this variability as quoted is questionable. And, they have yet to explain the difference in the measurements. This is a crit 1 joint and margin of separation and stud yielding are very dependant on the preload of the studs. This makes this joint a safety item, and understanding its behavior is a contributor to the safety of the joint. We have made no conclusion and yet not questioned the safety of the joint, but believe that there is a need to collect data to insure that we understand the variability of the assembly/measurement process to assure the joint meets our safety requirements (margins of safety and life).

Recording of the stretch values over time will eventually provide an indication of the variability of the measurement. RKDN has indicated their resistance of redetermining empirically this variability and even dig up the old paperwork that shows the original laboratory data.

Collecting the data and recording it is not a big deal and I have yet to understand the reluctance to it. The increased coining is a manifestation of higher loads, so we know we are doing something different for sure, but have yet to understand to depth of it. And that concerns me.

Rene.

From: Caraccioli, Paul
Sent: Tuesday, April 24, 2001 3:31 PM
To: Ortega, Rene
Cc: Crane, Charlie; Ray, Dawn; Aggarwal, Pravin; Worlund, Len; Frady, Greg
Subject: RE: G6 stretch values

Rene,
I have concern regarding the G6 preload being characterized in your note as a safety Item. Especially since a block II engine installation is underway and block II E2050 was cleared for installation today. Our rationale for closing the UCR is that the coining and raised metal (manifestation of the increased preload) do not affect sealing function and I do not know of any new information that would conflict with that disposition. I have had discussions with Rocketdyne regarding the recording of stretch values and have agreement that the values will be recorded for the installation of fuel pump 8015. The coining and raised metal UCR is on the combustion devices telecon agenda this Thursday and I think we need to know the specifics of the safety item at or before this meeting. In addition, Rocketdyne has requested that the justification for continued stretch value recording (specifically how will the data be used) be provided to support a decision of what to record and for what duration.
Thanks,
Paul Caraccioli
Combustion Devices
SSME Project Office

-----Original Message-----
From: Ortega, Rene
Sent: Tuesday, April 24, 2001 12:23 PM
To: Frady, Greg; Caraccioli, Paul
Cc: Crane, Charlie; Ray, Dawn; Aggarwal, Pravin
Subject: RE: G6 stretch values

Paul,

I thought we had an agreement that stretch values at assembly & disassembly for development pumps and at assembly for flight units would be recorded. The purpose is to track the stretch values measurements at this joint and to be able to assess the variability of the measurement. I thought we had discussed this over and over in the last few meetings and had an agreement. I consider the preload on this joint to be a safety item and it is imperative that we understand what the joint is doing and the consequence of the variability during the assembly process. If we don't look we won't be able to tell and will have to live with the consequences if there are any. When we talked about closing the UCR RKDN told us that the measurement would be taken through ARs. Now you tell us there is no need. But, we have one instance that shows the before and after measurements are not consistent and indicate a lack of understanding of the variability of the process.

Let's not be complacent. The greater our understanding of this joint the more safety added to the program.

Rene.

From: Caraccioli, Paul
Sent: Tuesday, April 24, 2001 10:21 AM
To: Ortega, Rene; Frady, Greg
Cc: Crane, Charlie; Ray, Dawn
Subject: G6 stretch values

There is currently no requirement for recording G6 stretch values for development pump installations. The close out of actions pertaining to the G6 coining and raised metal UCR will be reviewed this Thursday at the 1:00 combustion devices telecon. When we requested actions needed to support this closure a couple of weeks ago, there was no action or justification offered relative to stretch value recording. Please advise if there is a need to record these values and for what purpose they are required. Paper to record these values should be generated today to ensure the 8015 pump installation stretch values are recorded.

Swanson, Greg

From: Sims, Joe
Sent: Wednesday, May 02, 2001 9:23 AM
To: Swanson, Greg; Finnegan, Charles; Meyers, Charles
Cc: Popp, Chris; Wood, David
Subject: COPV Venting and Reusability

Good morning,

I have a concern/question I'd like to run by the three of you to calibrate my thinking a little bit, and to get you guys thinking about an issue that may be coming to a head sometime in the next few months. This issue will almost certainly be heard by and dealt with by the Fracture Control Board; I hope your early involvement will make this easier on all involved. Recall I sent you an e-mail (at least to Mr. Finnegan and Mr. Meyers) a few days back asking about leak before burst failure modes in COPVs.

A little background: in this upgrade for the SRB, we'll be replacing a low-pressure, all-metallic pressure vessel hydrazine system with a set of high-pressure, COPVs filled with helium. The high pressure helium will be used to drive the APUs which provide power for the thrust vector control subsystem. The entire TVC subsystem (eventually including the upgrade hardware) is contained within the aft skirt. Overall, it's a nice, neat upgrade, but I do have a concern with current plans on how the COPVs will be used.

Right now, the plans are to make the COPVs single mission components that will be scrapped following each mission. Now, all of the helium in the tanks will not be used in a single nominal mission, and in cases where we lose one APU (i.e., let's say an isolation valve failed closed right at liftoff), half of the tanks (3 each for the rock and tilt directions, for a total of 6 per booster) would come back at liftoff pressure -- none of the tanks, right now, will be vented during SRB descent. The upshot is that, unless things change, the tanks will splashdown, at 60 MPH, <u>every mission</u>, with ~3000 psig or so residual pressure. If we lost one APU (the other is cross-strapped and would drive both actuators in the booster), half the tanks would come back at ~5000 psig (or even higher, if we raise the working pressure of the system). A point of info: the current single tank size is ~26" in diameter, ~3' in length, so we're talking a pretty healthy frontal area exposed to water impact loads.

Given my admittedly non-expert understanding of damage tolerance of COPVs (or lack thereof), I consider this to be a serious hazard to the recovery crews who will be in very close proximity to these damaged, pressurized tanks -- if, somehow, the tanks survive the initial impact -- given their propensity for stress rupture. I have included a set of charts that show just how close these recovery crews get to the tanks (these charts only show the divers, but there are obviously other ground crews that operate in similar proximity once the boosters are towed back to Hangar AF). To increase the pucker factor even more, there are some slight rumblings suggesting we make these COPVs <u>reusable</u> -- in my opinion, an even worse idea than not venting them in the first place.

Given the strict requirements of the COPV requirements in KSC's Safety Practices Handbook KHB 1710.2, this may ultimately be a non-issue (i.e., we may be forced to vent them during descent to meet the KHB req'ts), but am I overly concerned here? Maybe I'm off in left field, here. What are your thoughts and experiences? Would you recommend that these tanks be vented during descent? If we don't vent them, would you recommend making them reusable? Any advice you can give will be greatly appreciated!

Joe

STS 102

Joe Sims, Propulsion Engineer
TD-52, Vehicle Subsystems Development Group
Main Propulsion Systems Team
Room 6130, Bldg. 4203
MSFC, AL 35812

(256)544-4650

Aggarwal, Pravin

From: Goldman, Gene
Sent: Thursday, June 14, 2001 3:23 PM
To: Aggarwal, Pravin
Subject: RE: Age sensitive material

Thanks, Pravin. I'll get with them to have this addressed.

From: Aggarwal, Pravin
Sent: Wednesday, June 13, 2001 2:39 PM
To: Goldman, Gene
Subject: Age sensitive material

Gene, I could gather this from my files. Lot of it is memory (if one can count).
Hope this will help.

-September/October 1998, PCP 0237: SSME Quality Control Plan was reviewed and approved by CCB. At that time I had asked several questions related to this plan. One of them was related to section 2.8 paragraph 4, I had suggested that All material like elastomers (not just elastomers) be added for degradation etc.

Rocketdyne response (Neil Bussiere) was "Age sensitive material are defined by contract (hence the reference to elastomers) any subsequent dating of these materials is also done by contract requirements. Any attempt to expand the definition of date-coded materials beyond the contract definition would require a formal contract change and allocation of associated funds"

I think, Rocketdyne was asked to address the concern outside the board.

My view as expressed at that time was to do the right thing and have proper system/plan. Some of this is due to, as I believe, not having proper requirement in CEI. Although, I think NSTS does have requirements. I had subsequently asked similar questions at the Controller coolant design change (ECP) and one other time at least. At one time, I had requested that the general storage issue and tracking of sensitive material be revisited as related to age (joint team by Rocketdyne/MSFC).

I can fax you the correspondence, if desired. Let me know if you need some thing else.

Thanks

Pravin Aggarwal
ED22
256-544-5345

P.S. I have some ideas to address wear and tear also.

From: "McGill, Preston" <preston.mcgill@msfc.nasa.gov>
To: "Otte, Neil" <neil.otte@msfc.nasa.gov>
Cc: "Gentz, Steven J" <Steven.J.Gentz@msfc.nasa.gov>,
"Rogers, Patrick" <Patrick.Rogers@msfc.nasa.gov>
Subject: et 104 flight readiness review
Date: Wed, 27 Jun 2001 15:56:19 -0500

Neil,

After a bit more thought I would like to point out a couple of items regarding the ET117 cracked membrane and ET 104 flight readiness review. With respect to fracture control, the membrane cracking is an escape since nothing in the fracture control procedure resulted in the detection of the defect. Acceptance of parent metal on the basis of post age and form NDE' was based on the likelihood of developing defects in the panels prior to or during these operations. Clearly we have an incident where defects were generated in the material following these operations and the fracture control plan may need to be modified to reflect this condition. Additionally, the single imminent failure test we performed on the rib membrane area did not survive the four mission life requirement. This specimen failed cryogenically at 95% of the imminent failure load. The point being that the proof test in this area does not guarantee mission life based on the simulated service mission profile used in lot acceptance of the material. Again, from a technical fracture control perspective this puts us in a risk assessment mode. Perhaps the entire point of the FRR presentation was to address this additional risk, but I'm not sure that was reflected in the presentation.

With respect to the ET fracture control plan I think that the MSFC FCB should review the plan in light of the ET117 incident and discuss the need for modifications to the plan. For example, if a visual pocket wipe down is what we are relying on for critical flaw detection in the parent metal then that needs to be stated and the risks understood. If additional inspections or approaches are to be considered or incorporated into tank processing then those should be reviewed as well.

With respect to ET104 I think that we are at some additional risk since we have demonstrated that we have an escape in the fracture control plan. That additional risk is mitigated to some extent based on the findings of the fault tree activities, residual strength of the ET117 defect (leak notwithstanding), and the inspection of additional panels, but I'm not sure that the additional risk came across clearly in the presentation.

Please contact me if you have any questions or concerns.

Preston
256 544 2604

Swanson, Greg

From: Boyd, Max
Sent: Friday, June 29, 2001 9:57 AM
To: Finnegan, Charles; Bell, James F; Swanson, Greg; Dean, Harry
Subject: FW: Node 2 NDE

Info from Kornel.

Max

-----Original Message-----
From: NAGY, KORNEL, PHD (JSC-ES) (NASA)
[mailto:kornel.nagy1@jsc.nasa.gov]
Sent: Thursday, June 28, 2001 1:42 PM
To: 'Boyd, Max'; 'Imtiaz Kauser (E-mail)'
Subject: Node 2 NDE

Max, I looked at the requirements in SSP 30558.
The following items were found:
1. In Appendix B Glossary, the following definition is given for proof test:

"A load or pressure in excess of limit load or maximum design pressure applied in order to verify the structural integrity of a part or to screen initial flaws in the part."

The purpose of the proof test is to screen for flaws. To screen for flaws requires an inspection method that can detect the presence of those flaws. A visual inspection by the human eye is not sufficient. An NDE method is required to screen for flaws.

2. Par. 4.4.1. Pressure vessels, subparagraph c. states:
"Pressure vessels whose failure at Maximum Design Pressure (MDP) would not be leak before burst, or would release a hazardous fluid, or whose loss of pressure would be potentially catastrophic, shall be safe-life vessels. All other pressure vessels shall be either safe-life or leak before burst at MDP."

Node 2 is a habitation module, loss of pressure in that module can result in the loss of crew, which is catastrophic failure. Loss of pressure can occur without the full unzipping of the module.

3. Par. 4.4.1. Pressure vessels, subparagraph g. states:
"NDE of safe-life pressure vessels shall include inspection of welds before and after proof testing."

Node 2 is a safe-life pressure vessel.

This is the result of my initial look at the requirements. Please call me to discuss.
Thanks
Kornel

Swanson, Greg

From: Boyd, Max
Sent: Tuesday, July 10, 2001 8:16 AM
To: Swanson, Greg; Finnegan, Charles; Bell, James F; Kornel Nagy (E-mail)
Subject: FW: NDE After Proof Test

WELD INSP.doc

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To: Boyd, Max
Subject: FW: NDE After Proof Test

Harry Dean
S&MA Lead
Node 2/Node 3

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[mailto:vincent.l.berend1@jsc.nasa.gov]
Sent: Monday, July 09, 2001 10:18 AM
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Max,

After reading Glenn Ecord's attachment, he makes the following points. First, "for safe life designs, a post proof inspection of welds is always necessary...to assure service life...". Second, if a pressurized compartment can be shown leak before burst, then post proof NDE may not be necessary. James reviewed the Alenia fracture control report this morning and the Node 2 primary structure is classified "safe life". There is no evidence of a leak before burst calculation or methodology employed for the pressure shell. Therefore, according to this logic, post proof NDE should be performed.

The safe life analyses of the Node 2 shell were performed with standard flaw sizes for the method of NDE used. Proof test cycles were included in the load spectrum. However, Glenn makes the point that "proof testing can open up or grow existing flaws, or in some cases, generate cracking." Flaws can also grow to unacceptable size during proof testing.

The JSC Safety Panel may buy off on no post proof test NDE if the Node 2 is shown to be leak before burst. This has not been done yet. A specific fracture mechanics calculation that shows that stability of a through flaw that is 10 times the wall thickness is required along with a safety assessment of the ramifications of an air leak through an orifice that size.

Post proof NDE or demonstration of leak before burst appear to be the two options right now. The best technical decision is to do the NDE. Note that the opinions expressed here are my own. Conclusions drawn from the Glenn Ecord discussion are my own interpretation.

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Subject: FW: NDE After Proof Test

Gentlemen,

Below is an example of questions that I am receiving from more and more persons including the fracture control board at MSFC. The issue has been prompted by a disagreement about post proof inspection on Node 2. Apparently the disagreement stems from a perceived precedent set by the Safety Panel for MPLM. I believe the issue exists because a clear understanding of requirements and purposes does not exist. The attached icon is an attempt to put things in perspective and presents the view that I have discussed with MSFC. I have not responded to individuals. I recommend clarification of the various aspects of the issue to the parties involved.

If anyone is in disagreement with what is presented in the icon please let me know immediately, because it reflects what I have told MSFC.

Thanks,

Glenn

-----Original Message-----
From: BEREND, VINCENT L. (JSC-OE) (NASA)
Sent: Tuesday, July 03, 2001 2:28 PM
To: ECORD, GLENN M. (JSC-EM) (NASA)
Cc: 'Dean, Harry'; PIDO, KELLE I. (JSC-OE) (NASA)
Subject: RE: NDE After Proof Test

Glenn, this is your area. Will you comment on how we treat "habitable vessel" differently from pressure vessels?

-----Original Message-----
From: Dean, Harry [mailto:Harry.Dean@msfc.nasa.gov]
Sent: Monday, July 02, 2001 5:05 PM
To: PIDO, KELLE I. (JSC-OE) (NASA); BEREND, VINCENT L. (JSC-OE) (NASA)
Subject: NDE After Proof Test

Has the SRP defined a category of "habitable vessel" (as opposed to pressure vessel) or some such thing so that there is not a requirement to NDE the welds after the proof test? Alenia seems to be under the assumption that the SRP set this precedent on MPLM and that Node 2 is not required (and they claim, not planning on) doing NDE after the proof test. Our hazard reports still indicate that it will be done. Can either one of you shed any light on this issue?

Harry Dean
S&MA Lead
Node 2/Node 3

INSPECTION OF HABITABLE MODULE OR PRESSURE VESSEL WELDS AFTER PROOF TESTING

Technical necessity and value for post-proof inspection of welds involves a number of considerations and requires a clear understanding of fracture control requirements, structural verification requirements, the relationship between habitable modules and pressure vessels (because of existing confusion), and safety philosophy.

For fracture control, "pressure vessels" and "habitable modules" are defined and addressed individually in SSP 30558C, "Fracture Control Requirements for Space Station". This is because habitable modules do not fit the pressure vessel definition and must be covered by a separate classification. This classification was developed for SSP 30558C to clearly differentiate pressure vessels and habitable modules. It might be noted that if pressure vessel requirements were directly and strictly applied to a habitable module the cost of a flight module would be greatly increased. As an example, a separate structural qualification test module, that would be eventually destroyed, would be required. This is not technically necessary when other defined tests and controls, specifically developed to assure structural integrity and safety of a habitable module, are applied .

However, it is not classification as a pressure vessel or a habitable module that makes a difference in whether welds must be inspected after proof testing. It is a matter of safety philosophy for pressurized hardware and avoidance of costs that do not tangibly increase safety. The philosophy and methodology are based on fracture control and address safety only (safety is the purpose of NASA fracture control requirements). Fracture control is not *required* for assurance of reliability or performance.

A pressure vessel or a module with a "leak-before-burst" design (using fracture control methodology) can eventually develop slow leakage if a large enough flaw is present and enough loading cycles are applied during service. If the fluid that would be leaked is not hazardous in itself and slow loss of the fluid is not hazardous for the application then such a failure would be benign in the context of safety. If the design is not leak-before-burst (fragmentary or abrupt rupture is possible) or leakage of fluid is a hazard then failure would be hazardous and "safe-life" assurance through fracture control methodology is required for full assurance of safety. These basic tenets underlie whether inspection of welds after proof testing is required for safety.

If "safe-life" is required, the initial (starting) flaw size in the flight hardware must be bounded to the extent necessary to assure rupture or leakage will not occur. Proof testing can "open up" or can grow existing flaws, or, in some cases, generate cracking. Inspection after proof testing is mandatory for "safe-life" hardware because existing flaws, not previously in evidence with pre-proof inspection may have developed, or grown to unacceptable size, or detection may have been enhanced by the proof strain. If the hardware is leak-before-burst and leakage is non-hazardous then the presence of flaws after proof testing is important for reliability (actual life), but is not significant information for safety.

It should always be remembered that fracture control is a safety requirement for avoidance of catastrophic hazards/events. It is unfortunate that decisions made for safety, based on fracture control, are defaulted into other areas.

A decision or position that a post-proof inspection of a weld is not necessary for safety is not a decision or position that a post proof inspection of the same weld is not necessary to full assurance of service life. For "*safe-life*" designs a post-proof inspection of welds is *always* necessary, from a fracture control aspect, to assure service life, hence assure safety. Ideally, all primary structure welds that are proof tested should be inspected after proof testing. This is especially true if weld failure would cause loss of the use of a major space asset, even though no safety hazard or destruction of the asset is associated with the failure. Most fracture control programs will have this requirement.

The philosophy regarding failure mode, based on fracture control methodology and required inspections for safety, has provided the payload community with significant latitude to reduce costs and use more "off-the-shelf" pressure vessel designs without any sacrifice of safety and essentially little, if any, affect on reliability. The same philosophy is applicable to the safety of habitable modules. However, there is more to structural integrity and structural verification than just fracture control requirements for safety. This fact seems to be frequently lost in hardware assessments and discussions of hardware acceptability.

It is incumbent on project managers and designers to assure system and component integrity and reliability. Fracture control methodology can be applied to achieve this, but is not a NASA requirement for this purpose. It is the responsibility of the Project to provide assurance that requirements that are necessary to achieve reliability, including fracture control methodolgy if such methodology is significant to life or performance, are applied to the given hardware. Structural verification should reflect this. The responsible safety authority has no direct responsibility in these areas. Decisions based on safety considerations, such as acceptance of the absence of post-proof inspection of the MPLM welds, may not always accommodate life or performance issues or concerns, and may involve special considerations not existing for other applications. Such decisions should not be regarded as modification or mitigation of any existing requirements.

Glenn Ecord

Ortega, Rene

From: Ortega, Rene
Sent: Friday, July 20, 2001 1:50 PM
To: 'William.Veljovich@West.Boeing.com'
Cc: Frady, Greg; Aggarwal, Pravin; Wilson, David
Subject: FW: ECP 1383 Structural Assessment

Bill,

Here is my response to the unsolicited comment:
The original request for the analysis package was made in February, 01. Which is prior to the 60 test database, although it shouldn't make a difference.
Also, I refer you to ECP 1383 page 4. Structural Analysis is listed as the first item used as justification/mitigation against the possibility of catastrophic failure. Certification hot fire testing is item #5 (By the way RKDNs requirement for this is 2 tests). Flight decisions are based on a multitude of things and yes testing is a major part of it. I hope that RKDN is not having the complacency of relying on test alone and broad brushing all other factors when making flight decisions. When consideration to other factors is duly given (such as analysis, inspection, traceability) then the free flow of information/communication and the best effort & attention to detail by all disciplines is what ensures the safety margin. And, finally test alone does not tell you what the safety margins are as required by CEI, thus requiring the need for analysis and its review by the appropriate peers.

Rene.

From: Frady, Greg
Sent: Friday, July 20, 2001 1:05 PM
To: Ortega, Rene; Aggarwal, Pravin
Subject: FW: ECP 1383 Structural Assessment

Be sure to read the bottom of the message as well.

-----Original Message-----
From: Veljovich, William [mailto:William.Veljovich@West.Boeing.com]
Sent: Friday, July 20, 2001 11:39 AM
To: Larson, John E
Cc: 'Frady, Greg'; Lim, Kristianto; Stump, Charles H
Subject: ECP 1383 Structural Assessment

John,

Greg Frady has requested a copy of the Structural Assessment package for the structural components (line, off-set mount/bracket, pressure transducer) associated with ECP 1383 (Preburner Fuel Supply Duct pressure measurement hardware). Please let Greg know how soon we may be able to send him a copy of the data package he is requesting (I believe that Kris is currently in the process of cleaning up and formalizing that package). I believe that Pravin has also expressed an interest in that package and that Greg plans to pass it on to Pravin.

Thanks

Bill

PS. Unsolicited comment: After approximately 60 successful tests of this hardware on the F12.1 port, I am totally baffled about what the stress analysis (no matter how perfect, clear or pristine it may be) would tell us that is more convincing or more compelling than the evidence represented by the 60 successful tests themselves. I wish somebody would enlighten me.

Swanson, Greg

From: Sam Ortega [sam.ortega@msfc.nasa.gov]
Sent: Tuesday, October 23, 2001 9:16 AM
To: David Richardson
Cc: eric.poole@msfc.nasa.gov; Greg.Swanson@msfc.nasa.gov
Subject: Re: Fracture TIM

Dave-

The question that remained after the TIM was "Are the phenolics fracture sensitive or not?"

The logic flow cart on page 8 of the Nozzle Fracture Control Plan skips all not structural parts from the beginning irregardless of the fact that the loss of the part could be catastrophic as questioned in the diamond of the flow chart. The phenolics should be addressed at least through that diamond.

If the phenolics are fracture sensitive then disposition rationale needs to be developed and placed in the fracture control plan. I would think that the contained/restrained logic could be used to satisfy this.

If they are not fracture sensitive then the rationale as to why should be included.

All of this is an effort to close the concern for good by documenting it in the Nozzle Fracture Control Plan.

I'll be at SORI for a phenolics material TIM today and tomorrow. If you have any questions you can call Eric at 256 544-2723 or me on my cell phone 256 348-1794.

If I don't hear from you I'll give a call Thursday to see how things are.

Thanks,
Sam

>As you recall there were questions in the Fracture TIM about the
>fracture critical nature of the Phenolics and Adhesives in the RSRM
>nozzle. Do you know what the final conclusions were from the FCB?
>We would like to close out the issue ASAP, and need to know what
>questions we should address.
>
>David Richardson
>(435) 863-6995
>david.richardson@thiokol.com

--

RSRM/Nozzle Subsystem Engineer
voice 256-544-9294
fax 256-544-5177
pager 800-946-4646 Pin 144-6522

Aggarwal, Pravin

From: Aggarwal, Pravin
Sent: Wednesday, October 24, 2001 9:52 AM
To: Jones, Preston
Subject: RE: Shuttle Privatization

Preston, I appreciate you taking me serious. I am excited and will like to identify my major concern as related to reuasable propulsion elements and privatization in general.

My concern is in out years when we will have a need to replanish, eat into exiting margins, need for maintaining a robust ground test program to maintain emperical margin instead of green runs only.
I have a feeling out years criteria may be just fleet leader/2 instead of a robust basis today which gives us true reliability. Wear and tear, Loss of suppliers, process revalidation are all expansive routes and need for these will be in out years. It is my hope Team is/will keep this on their RADAR screen while deciding a Business model.

Pravin

-----Original Message-----
From: Jones, Preston
To: Singer, Chris; Singer, Jody; Sackheim, Bob; McCool, Alex
Cc: Aggarwal, Pravin
Sent: 10/24/01 9:35 AM
Subject: FW: Shuttle Privatization

Bob, Chris, Jody/Alex, I asked Pravin to take a minute and review the privatization document. Please see his comments below. If this were a technical problem we would do study after study -- Why not on this one? I think it is brilliant idea that could bring in some very innovative approaches that we have not considered. We can write the RFP such that we are not obligated to any particular recommended course.

PRESTON JONES
TD60
WK: 256-544-5716
HM: 256-776-0537

> -----Original Message-----
>From: Aggarwal, Pravin
>Sent: Wednesday, October 24, 2001 8:12 AM
>To: Jones, Preston
>Subject: RE: Shuttle Privatization
>
>Preston, my buddy, you have done such a superb job in identifying the
>weakness or activities required that I am having hard time to add
>something new. So after some thought I am going to recommend another
>parallel/alternate route to collect the "Business Model" ideas while
>internal NASA teams duke it out among themselves.
>
>In my mind we have a situation; "Administration wants us to privatize
>the Shuttle program. However, we want to maintain a say in its use,
>availability, cost, and safety. EXPORT CONTROL also probably."
>
>So I nominate this idea:
>
>Advertise in Commerce Daily (?) an RFP asking industry to provide ideas
>for transferring and let them tell us the various possible "Business
>Models" , terms and conditions on which they will take over this
>venture and yet meet our stated primary objectives.

>Business model should include the penalty, replacements and upgrades
>needs (National asset).
>
>I would think using this approach will result in multiple ideas and we
>would not constraint the industry hand prior to shuffling of cards. In
>addition it will provide more options.
>
>In my mind we should not place our vision of transferring and managing
>of a project to private industry unless we want a Quasi-Govt. body.
>
>I appreciate you soliciting my comment related to this. Thanks
>
>Pravin Aggarwal
>ED22
>256-544-5345
>
> -----Original Message-----
> From: Jones, Preston
> Sent: Friday, October 19, 2001 3:27 PM
> To: Aggarwal, Pravin
> Subject: FW: Shuttle Privatization
>
>
> << File: Shuttle Privatization Comments.doc >>
> [Jones, Preston] My comments to SACKHIEM
>
>
> What I have from Denny.
> -----Original Message-----
> From: Kross, Denny
> Sent: Wednesday, October 10, 2001 6:57 AM
> To: Singer, Chris; Pollard, Kathy; Roberts, Lisa
> Subject: FW: Shuttle Privatization
>
>
>
> Chris, Kathy & Lisa,
>
> As noted in Art's note below, he is looking for
>some serious comments regarding the "Shuttle Privatization" document. I
>will review personally but I need your help. Since I am somewhat
>limited to being a sorta technical "weenie", I need some of your
>"common sense" thoughts on this document. The document and letter are
>attached. Please let me know what youse three folks think by COB
>Monday, 10/15/01.
>
> I appreciate your help.
>
> Thanx
>
> Denny
>
>
> << File: Concept of SSP Privatization 092801.pdf >> << File:
>MA-01-071 - Privatization of the Space Shuttle Program.doc >>
>
> -----Original Message-----
> From: Stephenson, Art
> Sent: Tuesday, October 09, 2001 8:31 PM
> To: Alex McCool; Amanda Goodson; Ann Whitaker; Axel Roth;
>Beth Partain; Bill Kilpatrick; Bob Sackheim; Charles Scales; David
>Bates; Dennis Kross; DENNIS SMITH; Gail Ralls; James Bilbro; Jan Davis;
>Jenny Campbell; Jim Kennedy; Roslin Hicks; Sheila Cloud; Stephen Beale;
>Tereasa Washington; William Hicks
> Cc: Stephenson, Art

> Subject: Shuttle Privatization
>
> Each of you should have received a copy of the 50 page "Shuttle
>Privatization" document. If not contact Alex McCool and ask for a copy.
>
> As I mentioned in staff meeting this morning, I would like each
>direct report staff member to read this document and provide me with:
>
> 1. Any concerns or questions you have regarding the approach(es)
>outlined in the document.
> 2. Any comments you wish to direct toward the architects of this
>document
> 3. Any suggestions you have for a better approach to some aspect
>of the proposed approach(es).
>
> I will call a meeting next week and would ask each of you to
>come to the meeting prepared to talk about your responses to the 3
>items above.
>
> You are requested to provide your comments to Roslin Hicks by
>next Tuesday COB. She will put the comments/questions into the document
>in a way we can see them along with the section of the report that you
>are addressing. She will also include your name with the comment so we
>know who is asking or commenting. This document with included
>comments/questions/suggestions will be the basis of our discussions in
>the meeting I will call late in the week, next week.
>
> Feel free to ask your staff to support you in this, but I expect
>each direct report to thoroughly read the document and represent your
>orgs views yourself in the meeting.
>
> Thanks for doing this. It is very important that we give this
>our best thinking.
>
> Ron Dittemore will be coming to the Center a week from today and
>I would like to engage him in an active and productive dialog at that
>time. Many of you will be invited to the meeting with Ron.
>
> Art

Swanson, Greg

From: Throckmorton, David
Sent: Friday, November 16, 2001 2:40 PM
To: Munafo, Paul
Cc: Kilpatrick, Bill; Swanson, Gregory
Subject: RE: Fracture Analysis "Help"

Mun --

Can you explain for me: what is the "wheel problem" ? As this is described as a fracture analysis issue, should there be involvement/participation by the Fracture Control Board?

Dave

From: Munafo, Paul
Sent: Friday, November 16, 2001 1:25 PM
To: 'HORIUCHI, GAIL K. (JSC-EM) (NASA)'; 'ralph.r.roe@jsc.nasa.gov'
Cc: Stephenson, Art; Kilpatrick, Bill; Throckmorton, David; McGill, Preston; Wells, Doug
Subject: RE: Fracture Analysis "Help"

Gail,
Preston McGill, Doug Wells and I have reviewed the package sent by Glen Ecord, and the bottom line is that we agree with the approach that you are taking. It's clearly necessary to run a test, since the bounding assumptions required for an analytical approach are necessarily so conservative that you quickly get driven to a negative result. You are using an Electro-Discharge-Machined (EDM) notch to simulate the corrosion pit, which is normal for this kind of a test because you can't replicate the corrosion pit accurately in the lab. Whether the (sharp) notch is a more severe condition than the corrosion pit, or vice versa, is arguable - I feel that it is, and Preston thinks it might not be - but that question will resolve itself as you monitor the condition of the notch between simulated landing cycles. The best result for the Program would be if you quickly develop a crack out of the notch - a condition that is certainly worse than the pit - and it subsequently survives a lot of landing cycles. The biggest threat seems to be that the test proves to be too conservative - it cracks quickly, then fails early in the test series - but we'll have to deal with that later if it happens. The most likely result will be somewhere inside of those two, such as a lot of cycles with not much happening.

In the longer term, we would like to work with you to develop an analog test that closely duplicates the strain field in the wheel - along the lines of what we did on the Space Station Node gussets - so that we'll have an experimental basis for reinforcing the results of this test, and for evaluating future problems of this kind. We'll get with Glen soon to begin this task.

Again, we agree with your approach, and we look forward to hearing about the results. If you need to contact me at any time over the weekend, please call me on my cell phone: 256-651-9927.

Paul M.

-----Original Message-----
From: HORIUCHI, GAIL K. (JSC-EM) (NASA)
[mailto:gail.k.horiuchi1@jsc.nasa.gov]
Sent: Friday, November 16, 2001 10:31 AM
To: 'Munafo, Paul'
Subject: FW: Fracture Analysis "Help"

> -----Original Message-----
> From: SHACK, PAUL E. (JSC-EA42) (NASA)
> Sent: Friday, November 16, 2001 9:10 AM
> To: HORIUCHI, GAIL K. (JSC-EM) (NASA); ECORD, GLENN M. (JSC-ES4) (NASA);
> JACOBS, JEREMY B. (JSC-ES4) (NASA); ORTIZ-LONGO, CARLOS R., PHD (JSC-ES)

> (NASA); BECKMAN, KEITH A. (JSC-ES) (NASA)
> Cc: SERIALE-GRUSH, JOYCE M. (JSC-EA) (NASA); MILLER, GLENN J. (JSC-ES)
> (NASA); KRAMER, JULIE A. (JSC-ES) (NASA)
> Subject: Fracture Analysis "Help"
>
> At yesterday's FRR, some questions came up from Code Q - Mike Greenfield -
> regarding pass/fail criteria and the applicability of fracture analysis to
> the wheel problem. There is a formal action to present the rationale and
> criteria at the L-2 review on November 27.
>
> The MSFC center director has also volunteered some help and gave Dittemore
> the name of Paul Monafo as their expert. Ralph would like our analysis
> people to contact MSFC and aprise them of the path we are on and our
> rationale for test and analysis. Getting their understanding and buy-in
> would help head off a possible confrontation on the 27th.
>
> In short - somebody please tagup with Monafo.

Main Landing Gear Wheel Tie Bolt Hole Corrosion	**Presenter:** Mike Porter
	Organization/Date: Orbiter/10/18/01

Observation:

- Main landing gear (MLG) wheels at Goodrich for refurbishment show signs of corrosion in tie-bolt hole locations (this was discovered by visual inspection)

Concern:

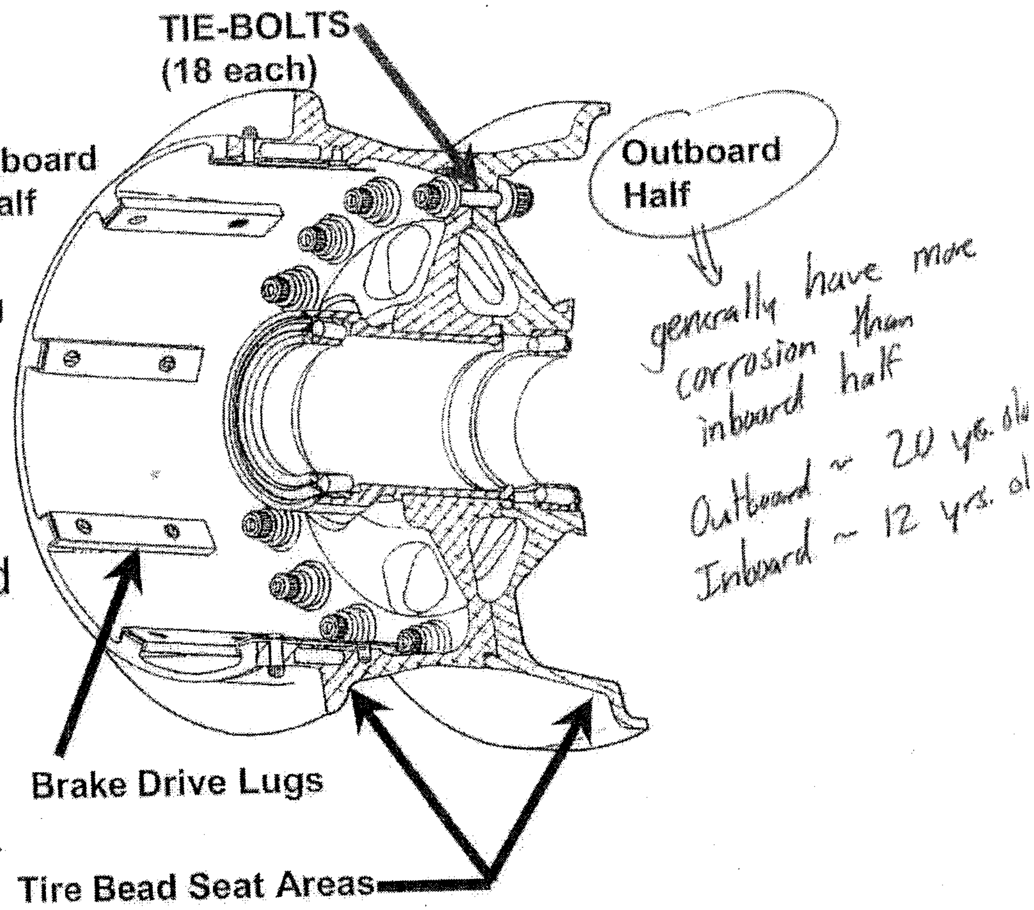
- *Condition of the wheels on OV-105 is unknown*
  - If corrosion exists, it could lead to stress concentration points, causing formation of a fatigue crack with eventual failure during landing/roll out

Nasa spec. 1249
NDE POD

Main Landing Gear Wheel Tie Bolt Hole Corrosion	Presenter: Mike Porter
	Organization/Date: Orbiter/10/17/01

Main Landing Gear Wheel

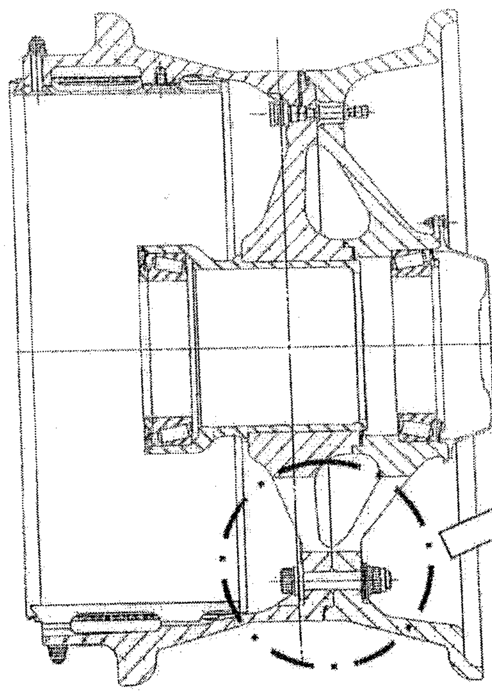
- The Orbiter's MLG wheel is a typical aircraft split wheel design
  - Aluminum wheel halves
    - Chemical film coating and primer/top coat provide corrosion protection
    - Holes And Wheel Halves Mating Surfaces have chem film and primer only
  - High strength Multi-Phase tie-bolts assemble the inner and outer wheel halves together
- Wheels are disassembled and assembled every flow due to one flight use of MLG tire
  - Tie-bolts are used for 4 torquings and then replaced
  - Tie-bolt washers inspected at every wheel assembly



Main Landing Gear Wheel Tie Bolt Hole Corrosion

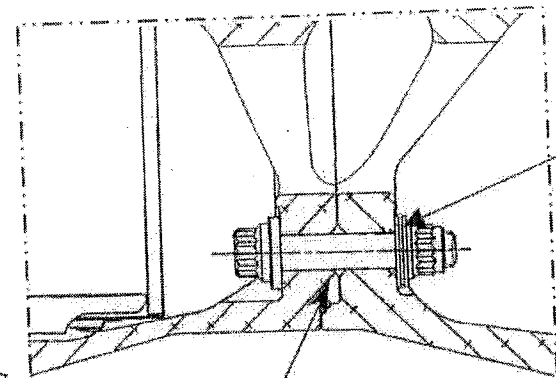
Presenter: Mike Porter

Organization/Date: Orbiter/10/17/01



MLG Wheel

Typical Tie Bolt attachment



Main Landing Gear Wheel Tie Bolt Hole Corrosion	Presenter: Mike Porter
	Organization/Date: Orbiter/10/18/01

Discussion:

- During the scheduled 10 flight refurbishment of six MLG wheels at Goodrich, visual inspection revealed signs of corrosion pits in tie-bolt hole areas
  - Corrosion on the edge radius of holes, washer bearing surfaces, and inside some holes
  - Corrosion seen on 1 – 4 of the 18 holes on all 12 wheel halves → only 2-3 outer halves have corrosion on the tie bolt radius
  - Corrosion pits are estimated to be 0.020 inches deep
    - Plan to rework surfaces to remove corrosion which will determine actual depth (they took 0.010" off & some corrosion still exists)
  - No cracks or flaws were discovered during NDI inspection
    - Dye-penetrant standard NDI
    - Eddy current special NDI (detects very small flaw sizes)
      - Eddy Current pencil probe detects 0.05 " Long x 0.025 " deep Flaws

→ dye-pen suggests "no crack"; eddy current special NDI has not yet been done on the bolt hole radius.

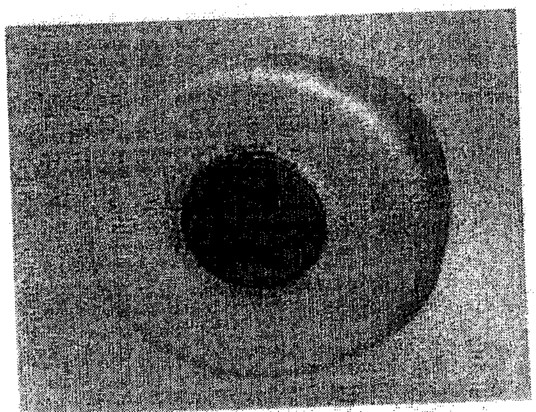
No flaw standard is available for use of special probe on wheel hole radius.
→ can't calibrate the probe now.

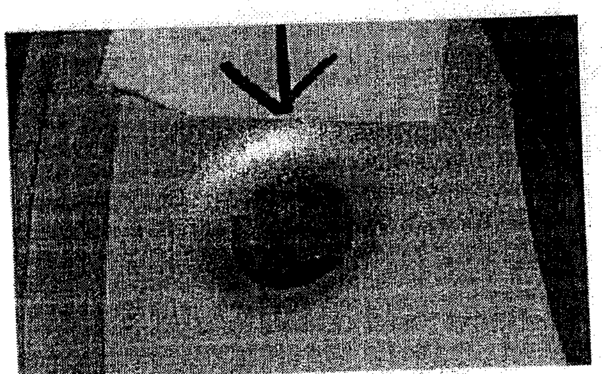
Main Landing Gear Wheel Tie Bolt Hole Corrosion

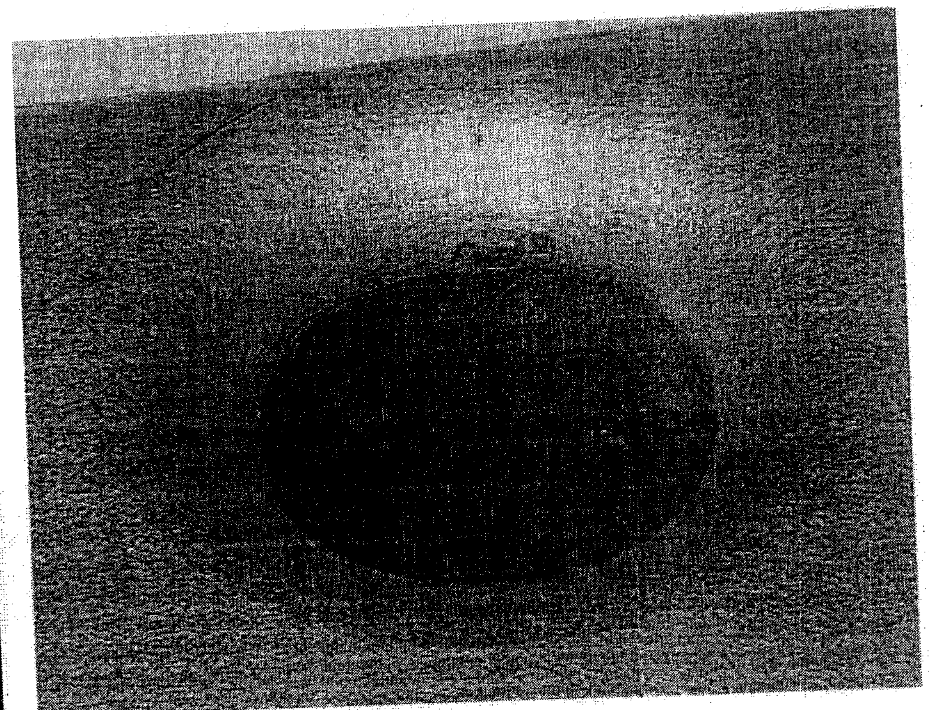
Presenter:
Mike Porter

Organization/Date:
Orbiter/10/17/01

Tie Bolt Hole Corrosion


View Showing Outboard Face of Wheel Half


View Showing Inboard Face (Mating Surface) of Wheel Half



Main Landing Gear Wheel Tie Bolt Hole Corrosion

Presenter:
Mike Porter
Organization/Date:
Orbiter/10/17/01

Discussion:

- Fracture control analysis req't imposed on the MLG wheel during the carbon brake wheel CDR in 1988
  - No fracture analysis used on NLG wheel and MLG baseline beryllium wheel design
  - No fracture analysis used on other Goodrich design wheels - unique to orbiter carbon brake wheel (Goodrich to verify)
- Fracture analysis performed by Goodrich
  - Analysis assumed the existence of an initial flaw of 0.030 deep by 0.060 wide crack
  - Most critical area is tie bolt hole radius on outboard wheel half
  - Analysis indicates crack goes unstable during 6th mission resulting with crack between tie bolt holes –not necessarily loss of wheel but changes stresses
  - Inboard wheel half tie bolt holes are good for 62 missions

Airbus A320

Magnaflux
Eddy current
probe made for
11-14-89
bolt hole radius

2 of 6 wheels have corrosion on bolt hole radius of outboard half

Main Landing Gear Wheel Tie Bolt Hole Corrosion

Presenter: Mike Porter

Organization/Date: Orbiter/10/17/01

Discussion:

- 10 mission refurbishment requirement was carryover from beryllium brake wheel design
  - Same outboard wheel half used for both configurations
    - Outboard wheel half has fracture critical area
  - Inboard wheel half required redesign to accommodate the carbon brake
- Extensive fatigue life testing for carbon brake wheel similar to beryllium brake wheel testing
  - Completed 990 mile slow roll test
    - Same requirement as beryllium brake wheel
  - Completed 7 dynamic high speed landing profiles
    - Added another abort landing profile for carbon brake wheel qualification program
- Added special NDI to tie bolt hole because of fracture control requirement
- Based on successful fatigue testing and conservatisms in facture analysis – program stayed With 10 Flight for Refurbishment

Main Landing Gear Wheel Tie Bolt Hole Corrosion

Presenter: Mike Porter
Organization/Date: Orbiter/10/17/01

Actions Completed:

- OV-105 wheels and the 6 wheels at Goodrich were processed similarly at KSC
- KSC inspected one loose MLG wheel (2 wheel halves) currently available in the tire shop for signs of corrosion
  - **3 tie bolt holes on inboard wheel half has possible indications of corrosion pits,**
    - **White powder present, possibly Al oxide, but not enough to verify / sample**
  - **KSC will perform special NDI (eddy current) on tie bolt holes with suspected corrosion pits**
  - **Outboard wheel half ok**
  - **KSC inspected 6 loose nose wheel halves**
    - 1 wheel half has indications of possible corrosion pit

108rjwheel.ppt 10/16/01 7:25 am

Main Landing Gear Wheel Tie Bolt Hole Corrosion

Presenter: Mike Porter

Organization/Date: Orbiter/10/17/01

Actions In Work/Actions Planned:

- Goodrich to rework all 12 wheel halves
  - Rework will determine the actual corrosion pit depth
    - Material will be machined until corrosion is no longer visible
    - If rework exceeds maximum allowable hole tolerance, than restricted flight usage MR may be required

- Seven additional wheels at the 10 flight limit are being expedited to Goodrich for inspection
- Goodrich to review procedures (KSC job cards) used during wheel processing at KSC
- Goodrich to visit KSC wheel tire shop November 7/8 for site and equipment review of wheel process

Main Landing Gear Wheel Tie Bolt Hole Corrosion

Presenter:
Mike Porter

Organization/Date:
Orbiter/10/18/01

Actions In Work/Actions Planned:

- **Corrosion can be the initiation of a fatigue crack**
  - Expect to find worst corrosion depth is < .030 inch fracture analysis flaw size
    - Visual approx 0.020 deep, Rework will determine actual depth
  - Then worst corrosion will still have full fracture life
    - Minimum of 6 Landings
  - Need to remove corrosion and blend area smooth
    - Corrosion will continue to grow
    - Need to know true depth of corrosion pits
- **Goodrich may make a second trip to KSC (post STS-108) to Review real time processing at the wheel and tire shop if needed to complete root cause investigation**
- **PRT to review/recommend future corrosion preventative options**

Main Landing Gear Wheel Tie Bolt Hole Corrosion

Presenter: Mike Porter

Organization/Date: Orbiter/10/17/01

Risk Assessment:

- No prior history of wheel corrosion reported
- No detrimental effects resulting from this condition are apparent on 6 wheels at Goodrich
  - No cracks found
- OV-105 wheels processed same as wheels at Goodrich
- No anomalies reported on OV-105 wheels

Main Landing Gear Wheel Tie Bolt Hole Corrosion

Presenter: Mike Porter

Organization/Date: Orbiter/10/17/01

Acceptable for STS 108 Rollout:

- If corrosion exists on OV-105 wheels, it is not expected to be worse than found on the 6 wheels at Goodrich
  - Wheels on OV-105 have been processed using the same procedures as the wheels at Goodrich
  - Wheels at Goodrich had reached their 10 flight limit
  - Wheels on OV-105 have a maximum of 8 flights usage
- No cracks detected by ~~"Special NDI"~~ Standard Dye Pen on 6 Wheels at Goodrich
- If cracks are small enough not to be detectible by Special NDI, fracture analysis predicts we are safe to fly STS-108
  - Minimum 6 flight life

Main Landing Gear Wheel Tie Bolt Hole Corrosion

Presenter:
Mike Porter

Organization/Date:
Orbiter/10/17/01

Back-up

Main Landing Gear Wheel Tie Bolt Hole Corrosion

Presenter: Mike Porter

Organization/Date: Orbiter/10/18/01

Wheel Assets:

- **30 Flight Wheels Total Plus 3 New Potential Spares**
  - 6 Wheels at Goodrich For Refurbishment (10 flights)
  - 7 Wheel With 10 Flights at KSC HDA
    - Sent to Goodrich 10/16/01 for Inspection
  - 4 Wheels on OV-105 (7-8 flights)
  - 4 Wheels on OV-103 (8-9 flights)
  - 4 Wheels on OV-102 (8-9 flights)
  - 4 Wheels in Wheel/tire Shop For OV-104 (6–9 flights)
  - 1 Loose Wheel in Wheel/tire Shop (10 Flights to be sent to Goodrich)
- **8 Spare Wheel Halves Available in Logistics Stores**
  - 3 Inner Halves and 5 Outer Halves (3 Potential Flight Assemblies)
  - Never Been Flown

Flight Rationale for STS-108 (OV-105) Based on Wheel Testing

- Stress and Fracture Analysis Limitations
  - Current crack analysis software, NASGRO 3.0, has inadequate capability for stresses above yield and for the specific 3D crack geometry
  - Historical Stress Data Was Possibly Over-Conservative
    - Strain-Gage Data Doesn't Represent Sub-Surface Stress Fields
- Rationale for Dynamometer Testing Using Flawed Wheel at WPAFB
  - EDM Flaw Bound Worst-Case Corrosion Pits in Worst-Case Locations & Orientations
  - Langley Demonstrated Similar Fatigue Life Behavior For EDM Flaws and Corrosion Pits
  - Dyno Tests Allow Accurate Representation of Actual Landing Load Spectrums
  - WPAFB Test Conditions Conservatively Bound Scenarios for the Next Three Flights
    - Worst Corrosion Pit Found to Date: 0.0385"-deep; EDM Flaw Size: 0.049"-deep
    - WPAFB Abort-like Load Case More Conservative Then Worst-Case Expected Landing
    - WPAFB Load Cases Include More Cycles Than Actual Landings
- Test Results
  - No Crack Growth Was Observed After 3 Required Nominal and 1 Abort-like Load Scenarios
    - Crack Growth Monitored Using Both eddy Current and Dye Penetrant NDE Techniques
    - Eddy Current Resolution Believed to Be +/- 0.005"
    - Tests Underway at JSC/ES to Verify Eddy Current Detectability Limits
- Conclusion: Testing showed adequate margin for flight
  - MSFC (Drs. Munafo, McGill, Swanson & Wells) evaluated the flight rationale as presented and accept the rationale for flight

Swanson, Greg

From: HORIUCHI, GAIL K. (JSC-EM) (NASA) [gail.k.horiuchi1@jsc.nasa.gov]
Sent: Wednesday, November 21, 2001 11:56 AM
To: Wells, Doug; McGill, Preston; Munafo, Paul; Bhat, Biliyar; Jones, Chip
Cc: Swanson, Greg; Gregg, Wayne; HORIUCHI, GAIL K. (JSC-EM) (NASA); FORMAN, ROYCE G. (JSC-EM) (NASA); ECORD, GLENN M. (JSC-ES4) (NASA); BECKMAN, KEITH A. (JSC-ES) (NASA); JACOBS, JEREMY B. (JSC-ES4) (NASA)
Subject: RE: Orbiter landing gear issue

Thanks Doug and Preston for all the time and help.

Royce got some verbal description from LaRC on their tests. And we should be getting the results sometime today - we will forward it on as soon as we receive it. They cycled at 75% of the yield strength on both a corrosion pit and an EDM slot. They found that the EDM slot may have started cracking first, but the total life was the same. Presumable the EDM recast layer cracks fast - our test here may collaborate that. We cycled an EDM slot here to determine the crack growth detect-ability with Eddy Current, and noticed the largest Eddy current response after the first 5,000 cycles. We are in the process of sectioning it and looking at it in the SEM today (the same procedure we will use on the wheel from Goodrich). We'll let you know what we find.

Thanks again, everyone have a great Thanksgiving,

Gail

-----Original Message-----
From: Wells, Doug [mailto:Douglas.N.Wells@msfc.nasa.gov]
Sent: Tuesday, November 20, 2001 6:09 PM
To: McGill, Preston; Munafo, Paul; Bhat, Biliyar; Jones, Chip
Cc: Swanson, Greg; Gregg, Wayne; 'HORIUCHI, GAIL K. (JSC-EM) (NASA)'
Subject: Orbiter landing gear issue

This is a summary of conversations held with the JSC folks on the orbiter wheel corrosion issue.

Gail Horiuchi from JSC called today to discuss a line item on their L-2 FRR charts that indicated MSFC's support for the rationale for flight for the orbiter wheels which have corrosion pits. Greg Swanson, Wayne Gregg and I held a brief telecon with the folks at JSC: Gail, Royce, et al. The initial statement presented to us implied we had reviewed the fracture analysis, the test approach, and based on the test approach, we approved the rationale for flight. We altered this slightly to de-emphasize the fracture assessment (I don't believe one exists which shows life) and altered our supporting statement to include all the supporting parts of the rationale, because I believe the full story is required to support the rationale. I my mind, the rationale centers around the fact that a good sample of the wheels in the fleet (7 of 30?) showed that the pitting exists without associated cracking and therefore the pits can be treated only as pits - not cracks. This allows the test data from the landing gear test rig at WPAFB with edm notches in critical areas of the wheel to support the rationale. The test is not attempting to show life on a crack-like defect, but on a defect of similar severity to the corrosion pits. The EDM notches survived 3 landings and 1 abort load case without any signs of cracking (still investigating). This does not help me to assess the life of a crack-like defect, but does tell me that the wheel should adequately tolerate the discontinuity of the corrosion pit. LaRC also has some data available to show that from a standard fatigue perspective, the EDM and corrosion pit are roughly equivalent. (We were not able to tell if this fatigue scenario was LCF or HCF).

Rationale for flight for the NDE flaw is still a question (wheels are fracture critical), but setting up a rationale that allows the corrosion pit to be separated into a non-crack-like category based on the investigation of the pits on a number of wheels allows the WPAFB base test to support flying with potential corrosion at reasonable risk. The flight rationale against crack-like defects would be the same as it has been for the last 20 years. I currently understand that the fracture life assessment was agreed to based on tests similar to those run recently at WPAFB.

This is likely too short to be coherent. I will be in VA from Wed. to Mon. Call at 804-836-5610 if needed.

Greg, Wayne and Gail: reply with clarifications if need be.

thanks,
doug