KSC-2006-114

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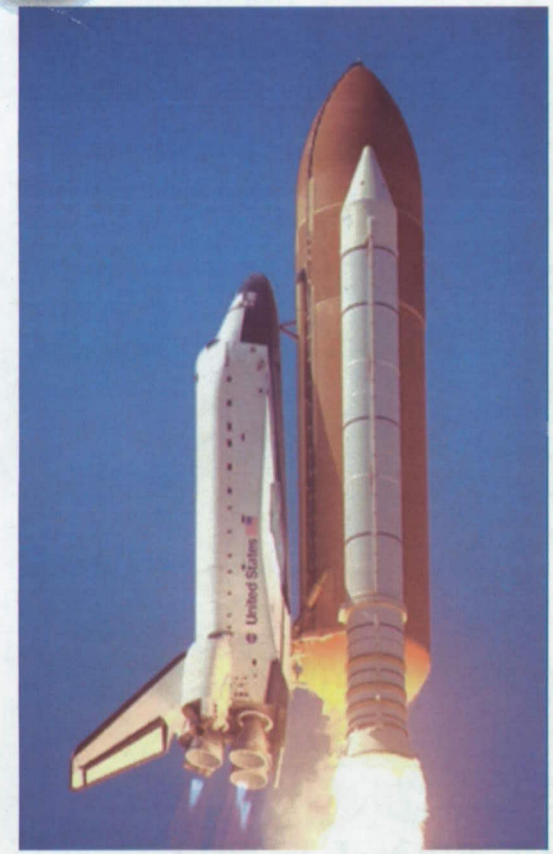


External Tank (ET) Thermal Protection System (TPS) Non-Destructive Evaluation (NDE) Super Problem Resolution Team (SPRT) Activities

Presented at the Quantitative NDE Conference Portland, Oregon August 2, 2006

Chris Davis

NASA Engineering Safety Center

Charter & Background

Charter

- Implement Findings and Recommendations (published on 9 August 2004) towards utilizing Non-Destructive Evaluation (NDE) to ensure no critical defects exist in the foam.
- Utilize NESC resources via this SPRT to assist the ET Program in implementing the Findings and Recommendations. Minimize ET Program resources.

Background

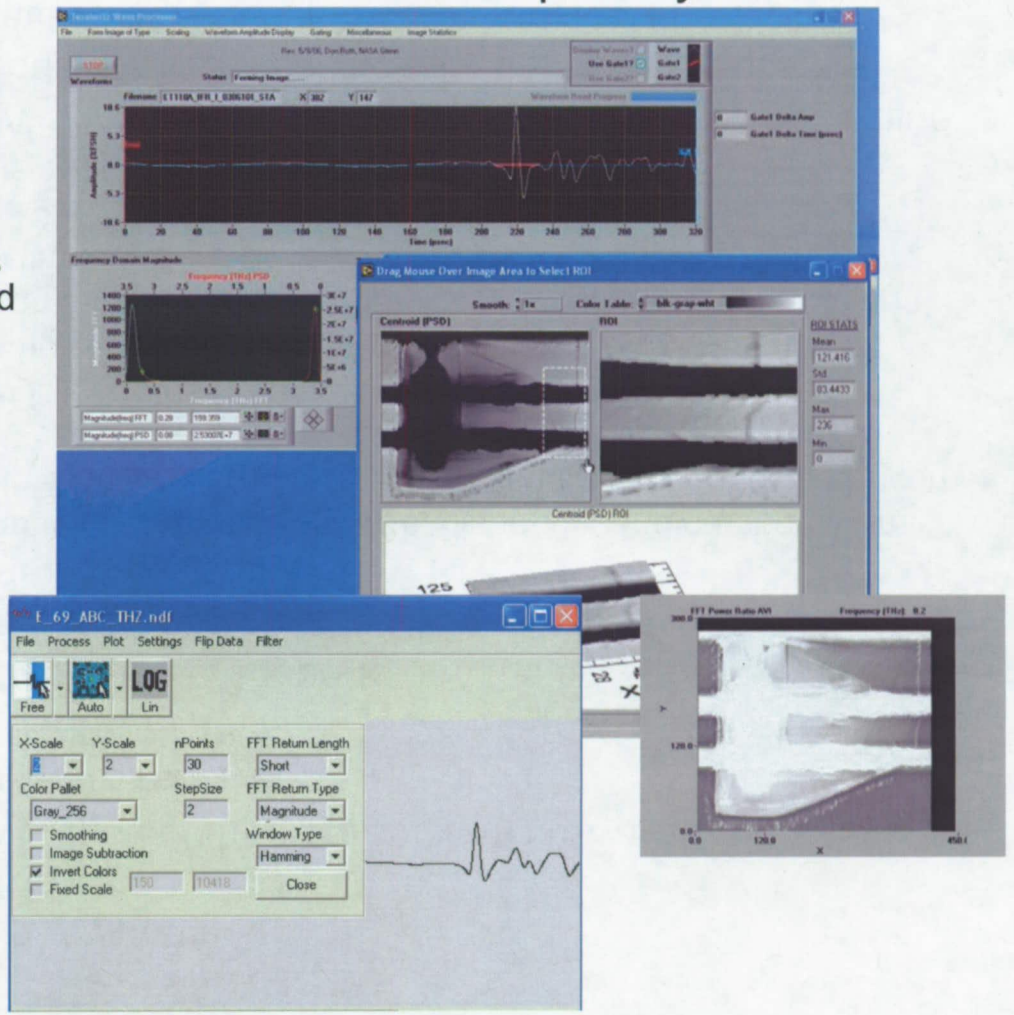
- NDE SPRT developed a proposal for follow-on ET TPS NDE activities by 20 Dec 2004
- NESC Review Board [ITA] submittal on NESC in Jan 2005 and 2006
- This presentation updates the progress to date

NaI versus YSO detectors

NESC SPRT Activities
Software Status

- New version of DataViewer Software with Improved Capability Delivered that will be used for Certification Effort
- New Terahertz Wave Processor Software from GRC Developed and Deployed at MAF
  - Enhanced and Complementary Features and Algorithms to Existing Software Used at MAF
- New version of DataViewer Software with Improved Capability Delivered
- Matlab routines desired at MAF have been provided but need some revisions
- Work still to be completed this FY: Feasibility study of Phase Velocity for Quantifying Crushed Foam
- Future Considerations to address incorporation of:
  - Image Quality Mathematical Measure
  - Additional Advanced Signal Processing Capability for improved images (eg. Wavelet Analysis)

Ice Frost Ramp Analysis



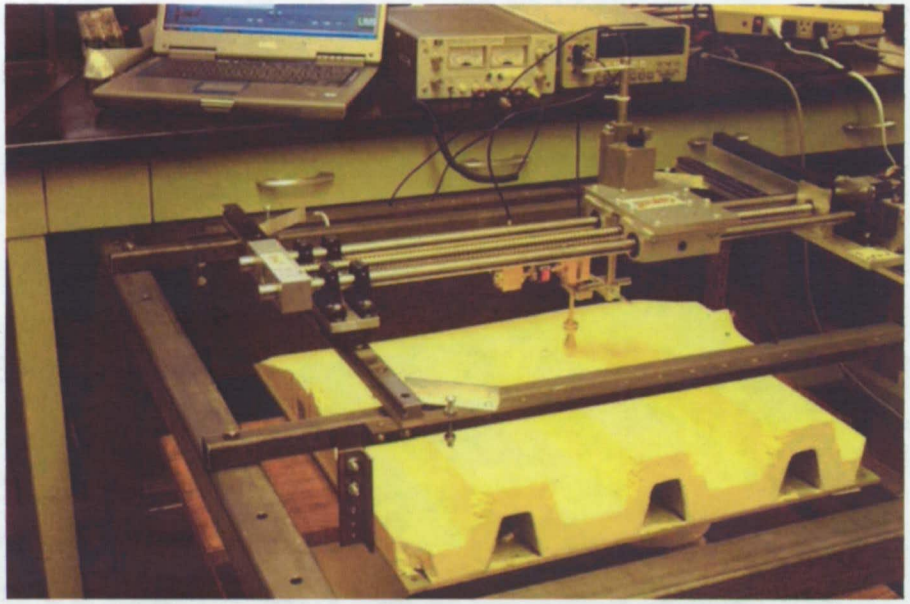
NESC SPRT Activities
New Methods

1.3 New NDE Technique Development

- Phase 3 reports from 4 researchers/methods (shearography, microwave, continuous wave (CW) THZ, and Laminography) were received.
- NRB approved Phase 4, stage 1 for $400K to advance $\leq$ 2 methods
- Subsequently, the SPRT team review of Phase 3 reports and the ET Program review at a TIM in Feb 2006, the focus changed to what could the SPRT provide to the ET Program in tangible products in the next 6-9 months
  - ET Program began using shearography for evaluating cracks, disbonds, and crushed foam. SPRT members directly influenced this. The ET Program did not consider disbonds a concern about a year ago.
  - MSFC NDE purchase all new methods systems (Phase 4, stage 2 is complete)
  - Further testing was required before the SPRT team could commit to the other 3 methods.
    - Continuous wave (CW) THZ and Microwave methods claimed significant improvement
    - Laminography researcher had limited capabilities to evaluate

- The team decided to fund ($400k) the following activities:
  - Head to head competition of CW THZ, Microwave, and existing THZ to determine if these 2 similar and new methods provided significant NDE capabilities. Additional methods will participate to get a comprehensive assessment of techniques
  - Modeling and further testing with Laminography
  - Automated acoustic stressing hardware and software shearography to be installed on MSFC system for validation.

mm-Wave PHASE 3 SUMMARY

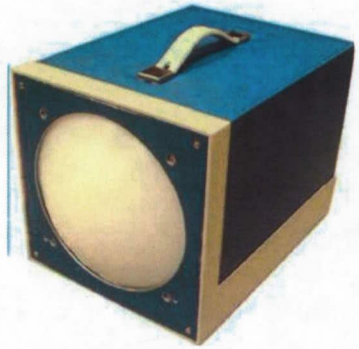


- The Phase III investigation involved examining the attributes of a 150 GHz reflectometer system.
  - The reflectometer incorporated a 6"-diameter lens antenna, resulting in a narrow beam at a focal distance of about 12".
  - For some applications, small horn antennas was also used. The size of the system can be significantly reduced to the size of a small flashlight.
  - The technique is very robust and the reflectometer is one-sided, non-contact, rugged and produces images with an extremely high degree of repeatability.
  - The reflectometer system, the overall size, weight and cost are relatively small and low.
  - The system uses continuous wave or CW (i.e., no pulsing), there is no need for time gating when producing an image.
  - Polarization diversity is an important feature of the technique. It was shown that using two orthogonal polarizations can yield additional and complementary information that can be used to more accurately evaluate the interior state of the SOFI near structural features with complex geometry (e.g., stringers, flange, bolts, etc.).

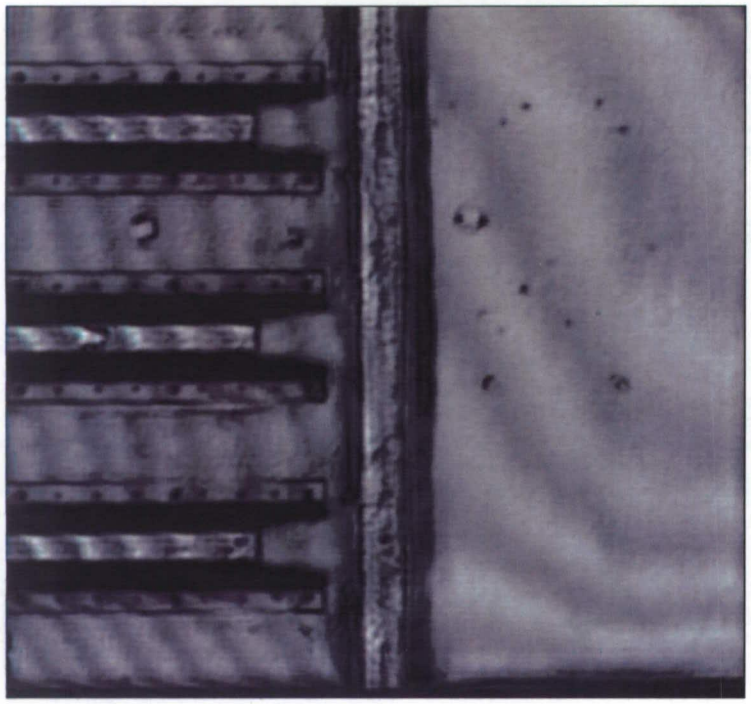
- Imaging the 24" by 24" blind panel with natural defects was the most important aspect of the Phase III investigation.
- Over 43 localized and extended defects including:
  - 8 delaminations
  - 2 delaminations/voids
  - 4 disbonds
  - 1 interface
  - 4 spray gun spatters
  - 26 voids
- Most of these defects were successfully correlated to their indications in the millimeter wave images. There were three defects that were not detected or "uncorrelated".

Continuous Wave THZ Phase 3 Summary

- Two new CW THz system that are fully housed in compact packages were constructed and tested on foam panels.
- Systems operate at two frequencies, 200 GHz and 380 GHz.



New CW THz system is fully housed in a compact package



Application of 200 GHz CW THz system to a test foam panel

- Compact, lightweight, easy to use system
- Higher frequencies = Shorter wavelengths
  - Advantages:
    - Compact design
    - Better resolution
    - Higher contrast
  - Disadvantages:
    - Higher attenuation at higher frequencies (380 GHz is better for thinner foam (<3" thick))
    - Must deal with standing waves in any CW image.
- Two frequencies can give better information

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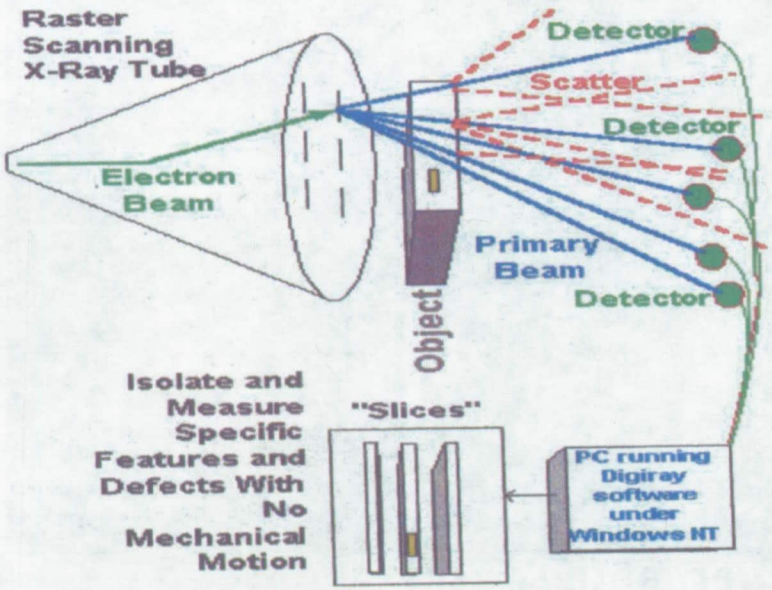
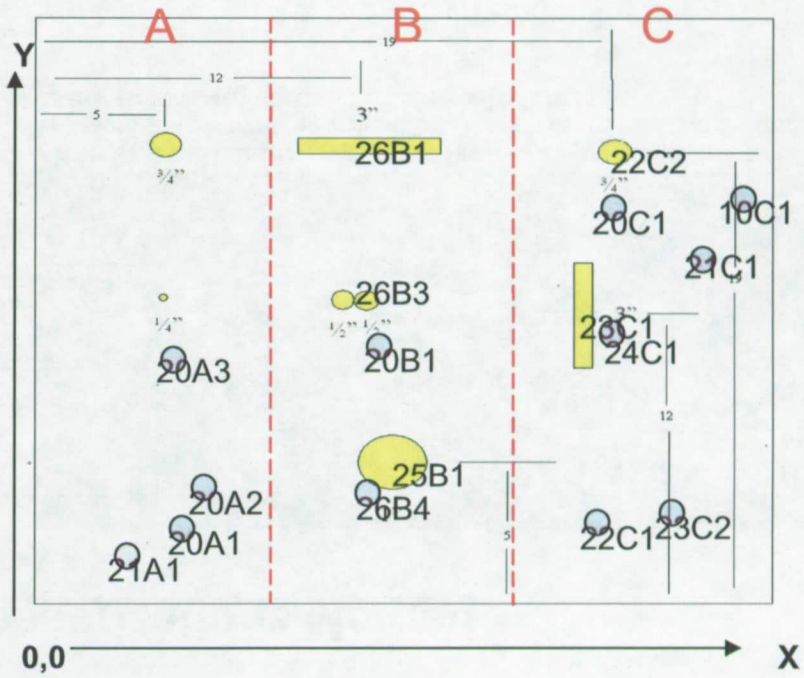
X-Ray Laminography Phase 3 Summary

- The Digiray final report demonstrated that it was able to detect all the flaws observed in the dissection of the panel.
- In addition several smaller voids and small regions of high density were identified in their report that were not seen in the dissection process.
- The x-ray geometry and flaw distribution as observed in the x-ray data and by dissection are shown below.





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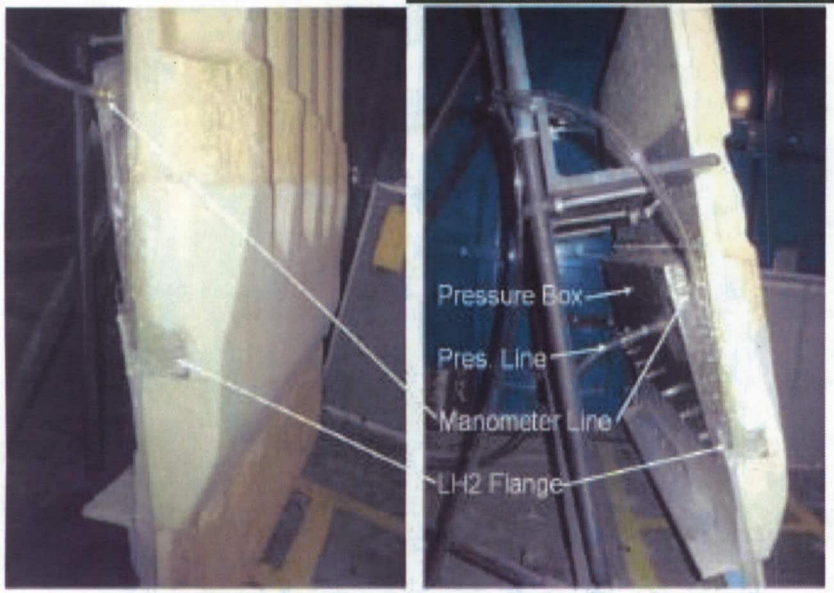
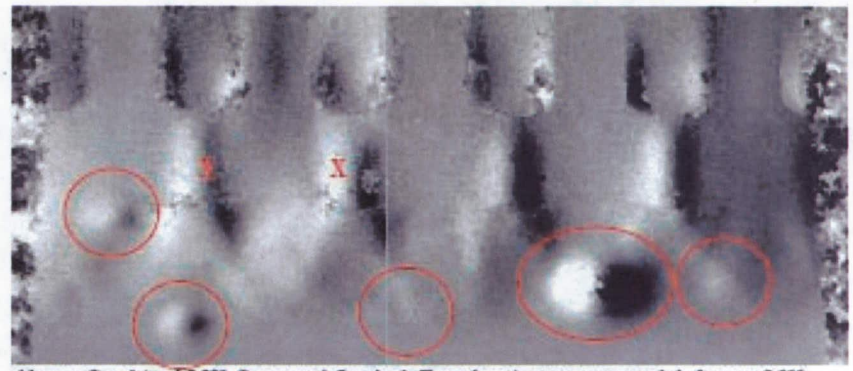
Phase 3 Shearography NDE Results

LH2 Flange Delta-Pressurizations Method



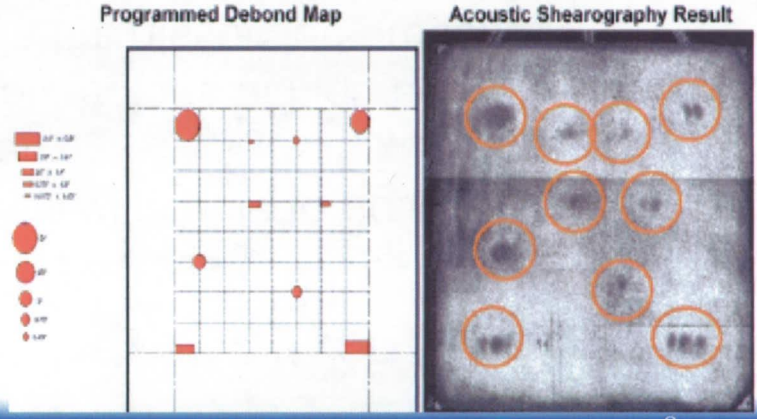
Panel #38 showing sealed edges and steel box on reverse side Allowing pressurization of the LH2 Flange.



Above: Combined LH2 Gross and fine leak Test showing programmed defects at LH2 Flange and nuts other voids at locations X are not quite detected with this 5 second hold time. These voids were detected after a 20 second hold time.

Acoustic Excitation Method: Acreage Foam Engineering Evaluation Certification

- Shearography has also been selected for providing the ET Program with unique capability in detecting kissing Debonds / Delaminations / Crushed Foam, in addition to enhancing the Voids detection capability currently pursued by the Program.
- During this Phase, LTI was able to define test parameters for Acreage inspection, and apply the method to actual vehicle Engineering Evaluation testing at the MAF.
- Shown here is one of the test panels results for preprogrammed substrate debonds. The smallest indication identified was 0.150" X 0.375", corresponding to a ½ sized cryo-injested flaw.



NESC SPRT Activities
New Methods & Certification

1.3 New NDE Technique Development

- Phase 4, stage 1 (continued)
  - Statement of Work complete
  - Test Plan for Run Off Test in-work. ECD 24 Aug 06.
  - Contract award ECD: 30 June 2006 or earlier
  - Complete Work ECD: Sep 2006 to coincide with ET Program certification activities

- Benefits to NESC
  - MSFC NDE purchase of all systems reduces the major expense of the follow-on phase 4 costs for NESC by $1M.
  - Phase 4 stage 1 should provide the ET Program with tangible products as well as greater capabilities instead of an incremental improvement.
  - Phase 4 activities should coincide with the ET Program certification activities.
  - ET Program liaisons, Walker and Ussery, have ensured the ET Program buy-in as well as contributing substantially to this team's progress.

- Overall, the progress with this team has resulted in a significant benefit to the ET Program and significantly reduced costs to the NESC

1.4 Certification

- ET Program, with SPRT support, is preparing for certification testing in Sep 06

Future Actions & Issues

Future Actions

- Conclude most of ET TPS SPRT tasks by EOY 06 to support ET Program certification work.
- Depending on Phase 4, stage 1 results and ET Program response, submit a follow-on proposal for Phase 4 stages 3-4 work, ECD: Nov 2006
    - Head to head testing may identify a technique that is promising but requires phase 3 and 4 work
- Re-convene SPRT to assess the ET Program certification in Mar 07 per the SPRT lead

Issues

- Procurements or work takes longer than expected is offset by adding 3 months (Oct – Dec 06).
- ET Program NDE engineer requests assistance with further evaluation of new vendors and methods
- Delays in ET Program performance certification tasks

Back Up Chart

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Current Status Of NDE For ET SOFI

Application	Method	Purpose	Activities
IFR's	BSX/THZ	Volumetric defects, cracks	Completed on ET-119 and ET-120; Working ET-118; Planned for ET-123
IFR's and Surrounding Acreage	Shearography	Shallow Delaminations and voids; crushed foam	Completed on ET-120; Planned for ET-118 and ET-123
LH Flange (Bipod region)	BSX/THZ	Volumetric Defects, cracks	Partially completed on ET-120; Working ET-118; Planned for ET-123
LH Flange and surrounding acreage (Bipod region)	Shearography	Shallow Delaminations and voids; crushed foam	Completed on ET-120; Planned for ET-118 and ET-123
Bipod	BSX/THZ	Volumetric Defects, cracks	Planned "time permitting" for ET-118 and ET-123
PAL Ramp Base Foam	Shearography	Shallow Delaminations and voids; crushed foam	Completed on ET-119 and ET-120; Planned for ET-118 and ET-123