KSC ENGINEERING

Legacy of the Space Shuttle Program

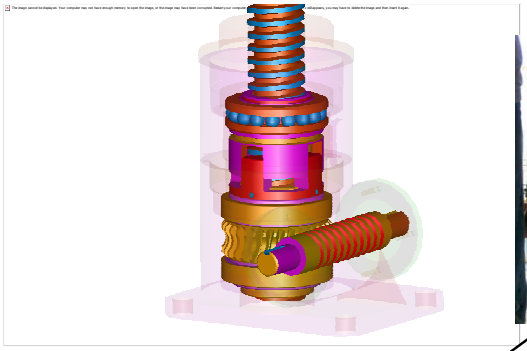
Ground Operations

NASA-Contractor Chief Engineers Council

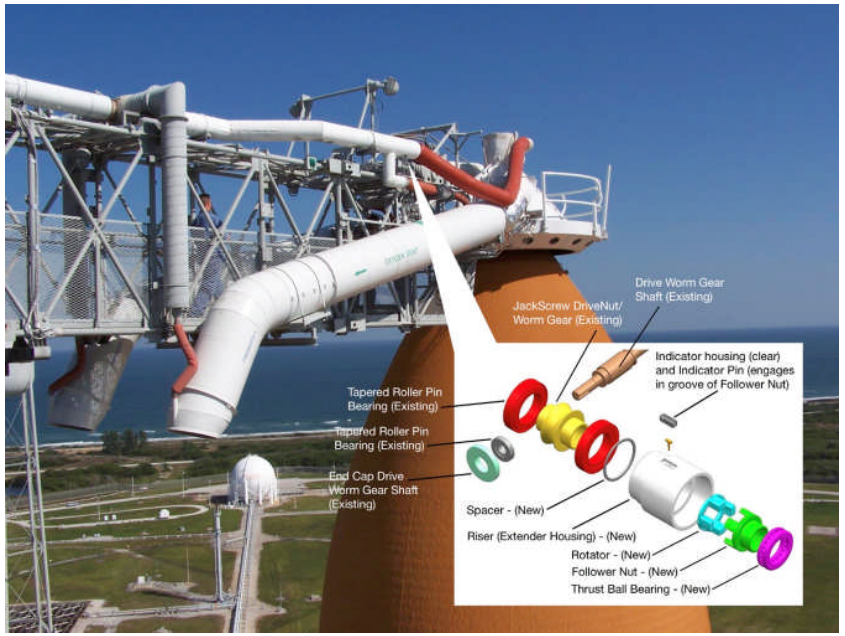
8/24/2010-8/26/2010

Fail-Safe Jackscrew

- Prevents catastrophic failures in jackscrews
- Fail-safe concept incorporates a redundant follower nut that bears axial jack load upon failure of the primary nut
- Wear indicator provides status of primary nut wear by measuring axial gap between the primary and follower nut, eliminating need for disassembly for inspection (can be remotely monitored)
- Fail safe capability designed to retrofit existing COTS jackscrews
- Used in GOX Vent arm and Tail Service Mast (TSM)

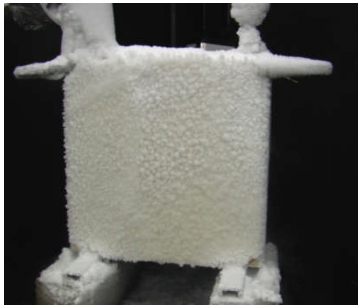


Secondary Nut (New)

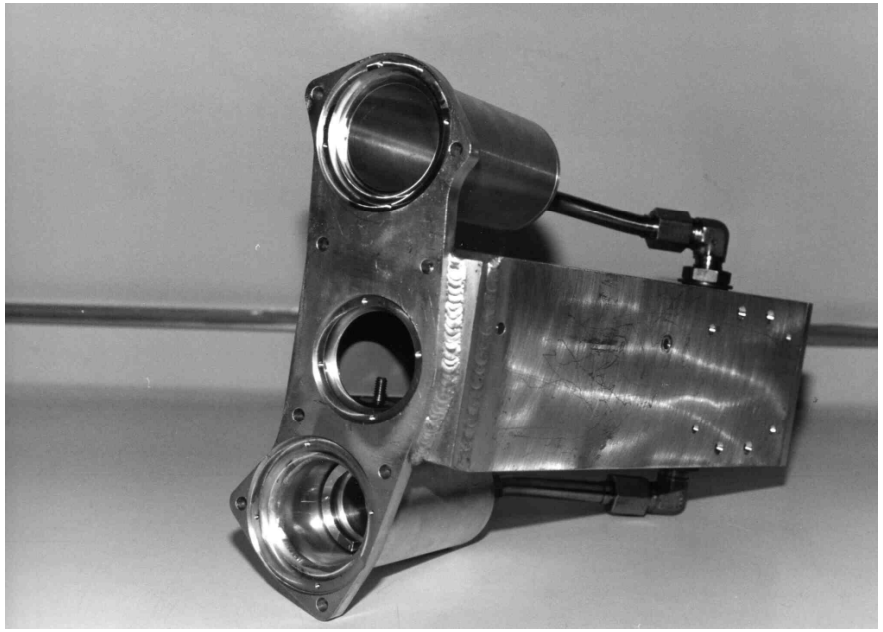


Infrared Ice Detection and Measurement

- NASA needed to address catastrophic issue with ice forming on the External Tank so a cooperative agreement was developed between KSC and TARDEC/MDA
- Ice Camera was developed for tank Spray on Foam Insulation to detect and determine ice thickness
- System includes a visual and IR camera housed in nitrogen purged enclosures
- Uses an infrared strobe, focal plane sensor array, and filter wheel to collect successive images driven by NASA requirements
- Has successfully supported several missions including STS-116 when ice/frost was detected and verified visually



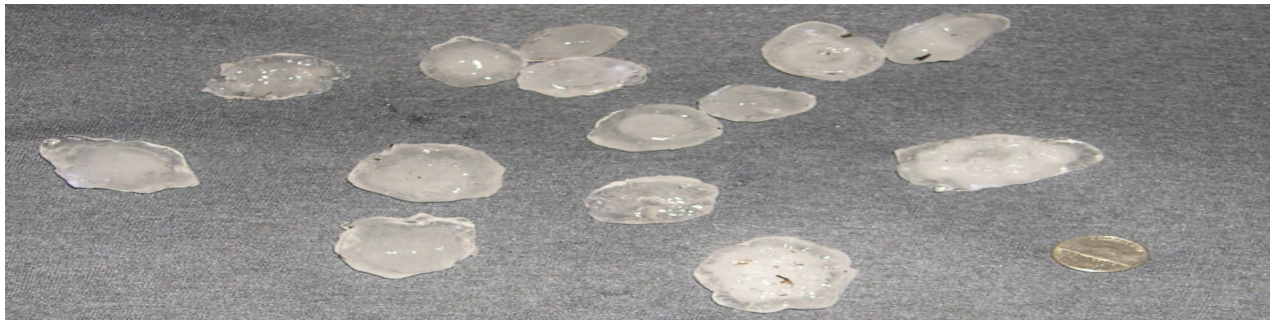
GOX Vent Hood Ice Detection



Concern that the vents on the ET were icing up during fueling prompted the development of a camera that could look into the GOX vent hood and provide video of the vents.

Hail Detection Monitor

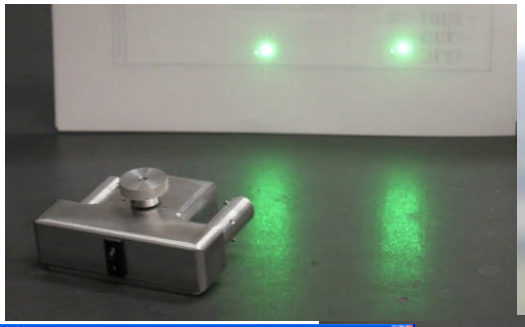
- Hail Monitor utilizes acoustical sensor to determine if hail is present and quantifies size – remotely near vehicle
- Has verified close proximity hail did not reach vehicle several times

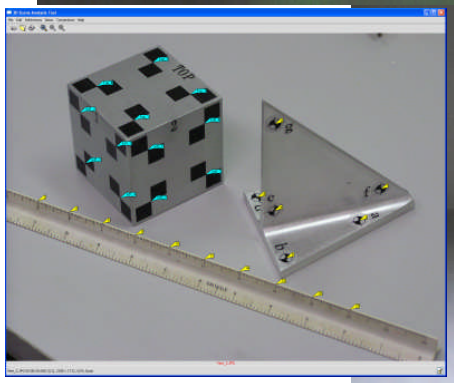


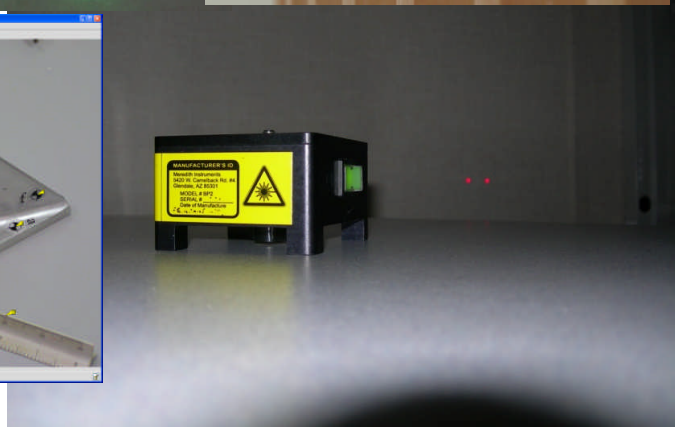
Hail from Feb-07

Laser scaling device

- External Tank SOFI damage due to numerous sources (Hail, Birds..etc.)
- Necessary to assess damage from ~100 ft without personnel access
- Laser scaling device provides visual reference for image analysis to determine damage size
- Software package provides means to quantify unknown areas using laser dots
- NASA innovation resulted in commercially available unit for other applications (i.e. Crime Scene Investigation)
- Laser scaling device led to visual cube scaling device, can be placed in picture for reference to enable 3-D scaling

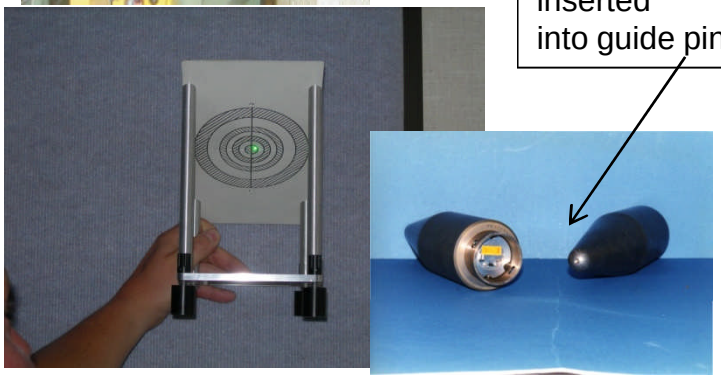






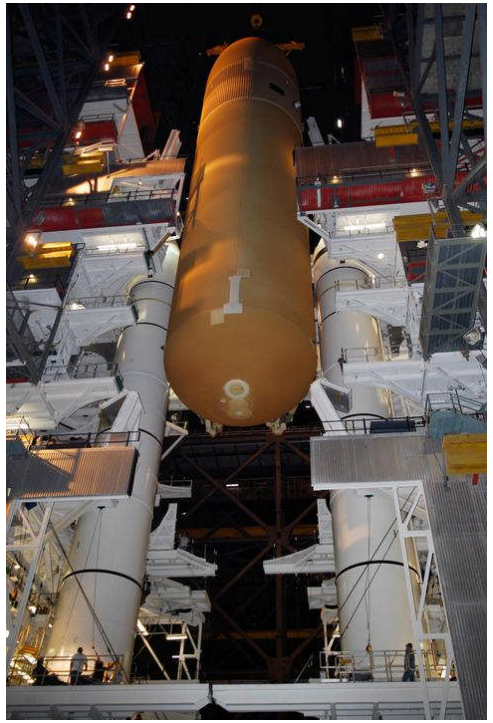
Launch Vehicle Processing - Mating ET to SRB's

- Laser Indicator and Bulls eye target used for guiding forward end of External Tank onto the Solid Rocket Boosters.
- No Visual Verification access not possible



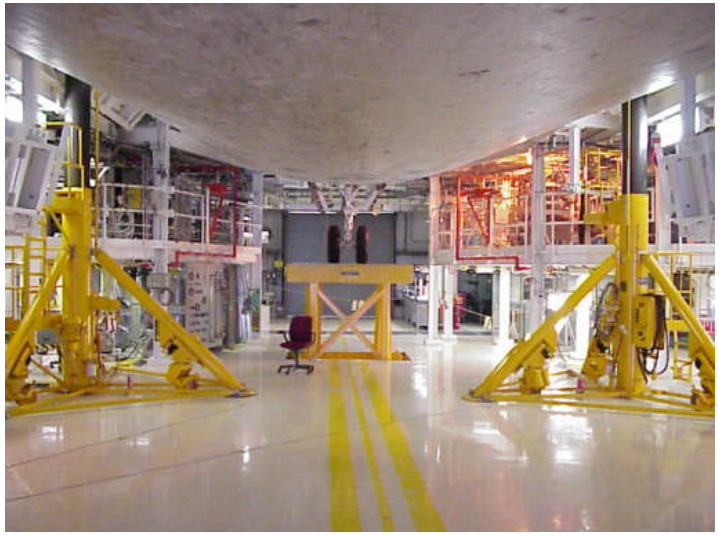
Laser point permanently inserted into guide pin

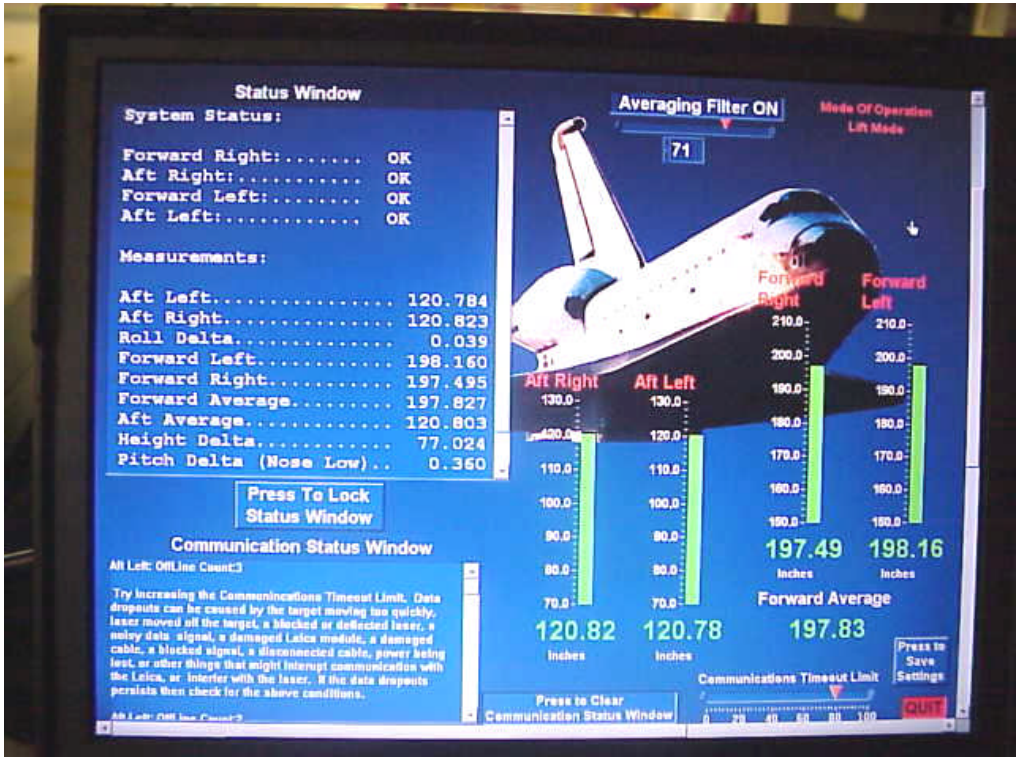
- ET Centering Alignment System used for mating aft end of External Tank to the Solid Rocket Boosters.

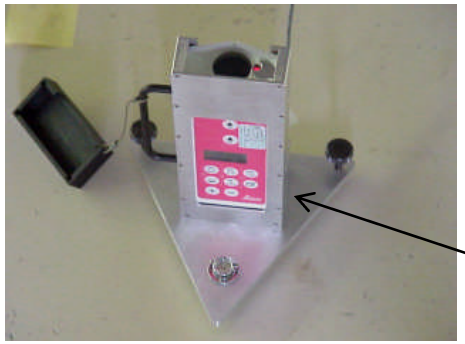


Ultrasonic Range finders and laser crosshairs with permanent magnets attached to the SRBs. Cables bring the distance measurements back to a module that displays the degree of misalignment.

- Orbiter Jack and Leveling System utilizes COTS laser distance measurement device to level the orbiter on its jacks, subsequent modification led to upgraded wireless system.







Leica Laser Distance Measurement Device

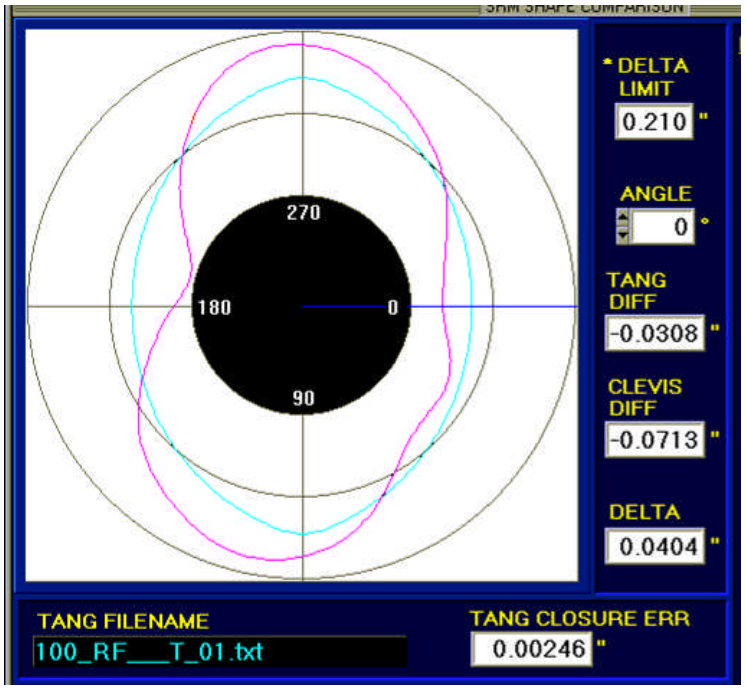
Launch Vehicle Processing

- Circularity Measurement Tool - Mating of SRB Segments would not be possible without determination of out-of-round state of segments
- SRB Stacking Enhancement Tools – Lifting assemble provides adjustability to shape segment for mate. Monitors rate of descent and parallelism.

Circularity Measuring Tool

Performing Measurements

FWD Shaping Beam



Display of FWD to AFT Segment Out-of-Round

Launch Vehicle Processing

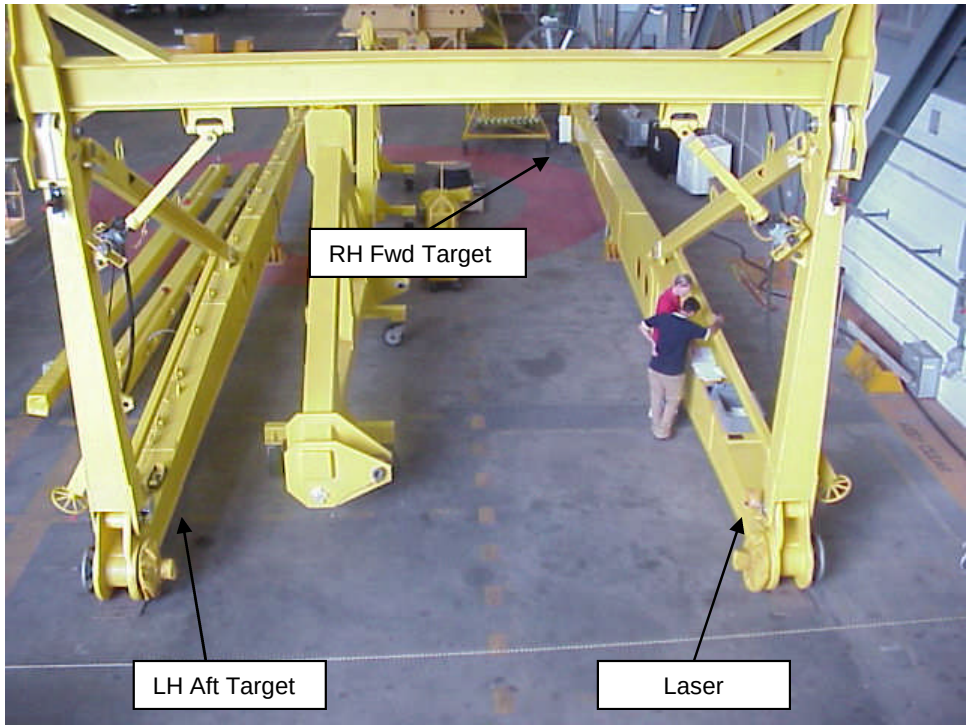
- Wireless Hydra Set – partnered with Del Mar Avionics (funded > 90%)
- Remote control and display
- Meets NASA Safety and Reliability redundancy requirements for lifting critical space hardware
- DEL MAR developed into COTS product
- Enables small incremental movements of critical hardware for mate/demate

DEL MAR AVIONICS®

Laser Alignment Tool

The GOX vent hood, shown lifted over the ET in the figure, must be accurately located to capture oxygen boil-off.

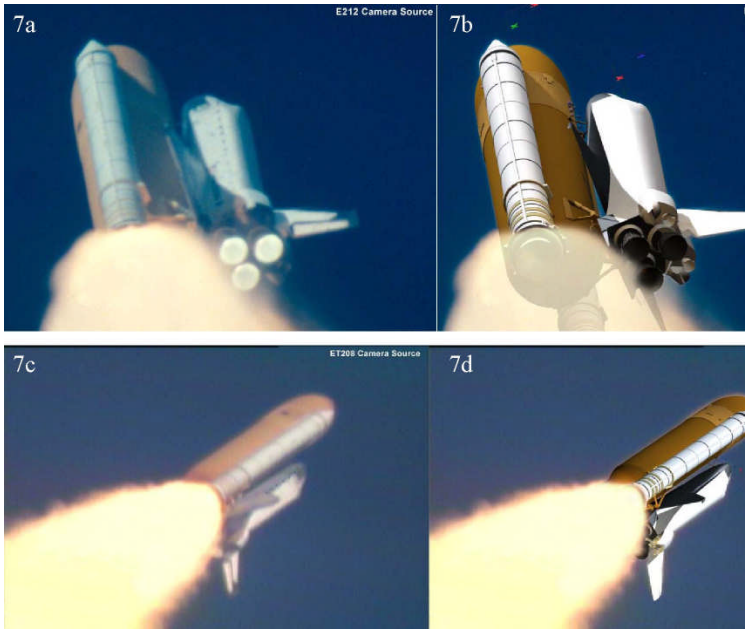
An ultrasonic rangefinder and laser were built into a fixture that could be located on the ET spike, providing the critical distance and location information.



The Orbiter Sling was damaged during a move operation. A laser system was developed to monitor strain in the sling (Doug Willard), proving a real time feedback to the users to prevent damage to this critical piece of GSE.

Image Analysis

- Developed during the Columbia Accident Investigation
- Ascent camera images (Cape Canaveral / Cocoa Beach) using common references utilized custom photogrammetry software to determine the trajectory, velocity and contact location of the SOFI impacting the RCC



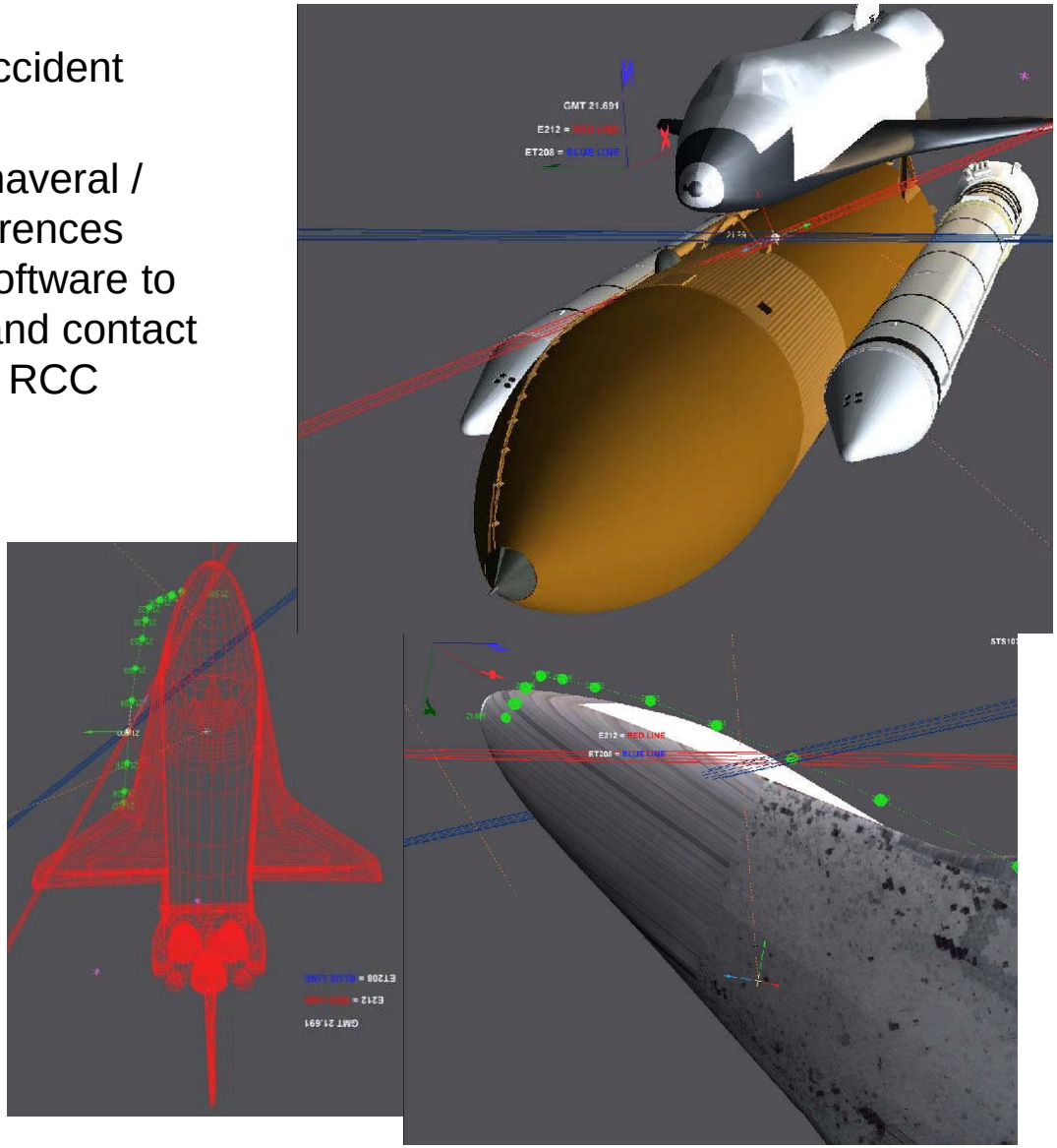
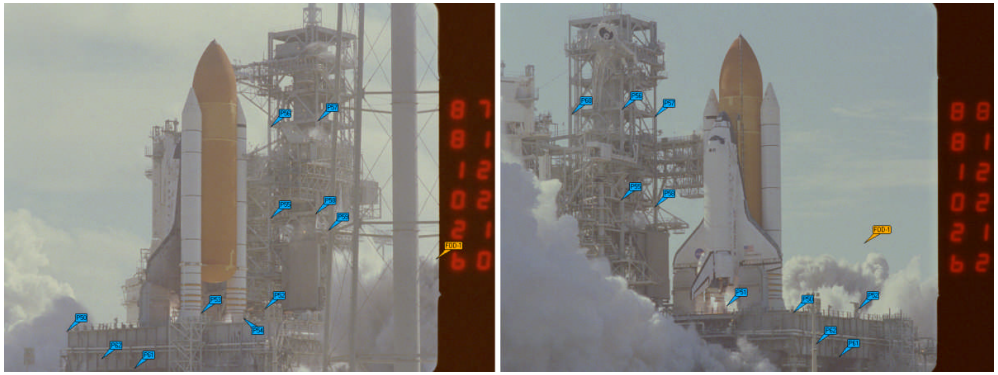


Image Analysis

- Flame Trench Incident – During the launch of STS-124, several thousand bricks from the Flame Trench east wall released due to the SRB plume. One piece of debris caught on camera, caused concern because of its high trajectory “high flyer”. Photogrammetry determined trajectory of FOD, this correlated to SRB nozzle throat plug material, not brick.



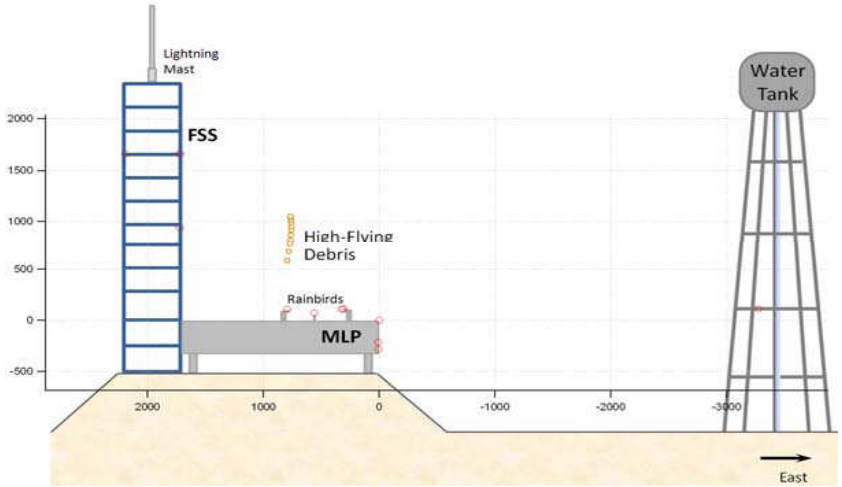
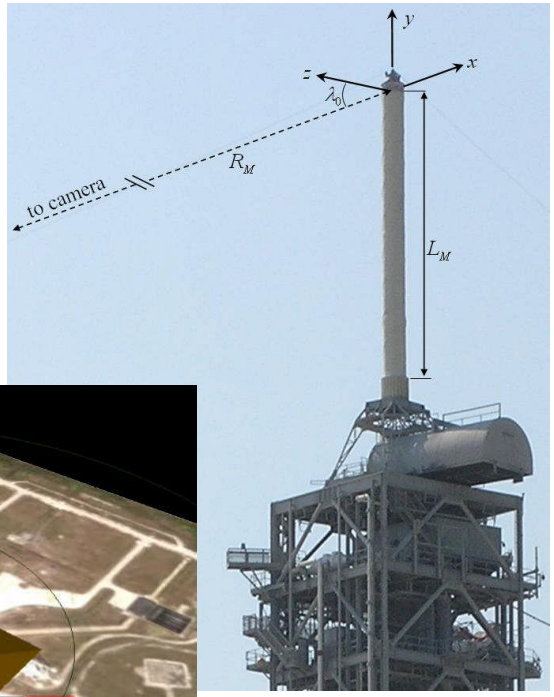
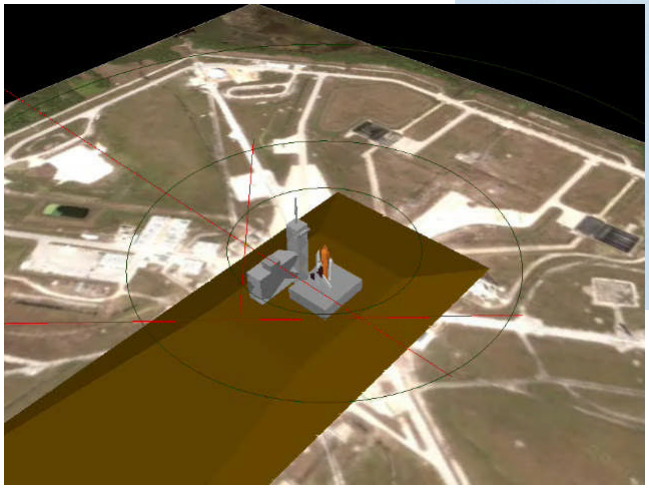
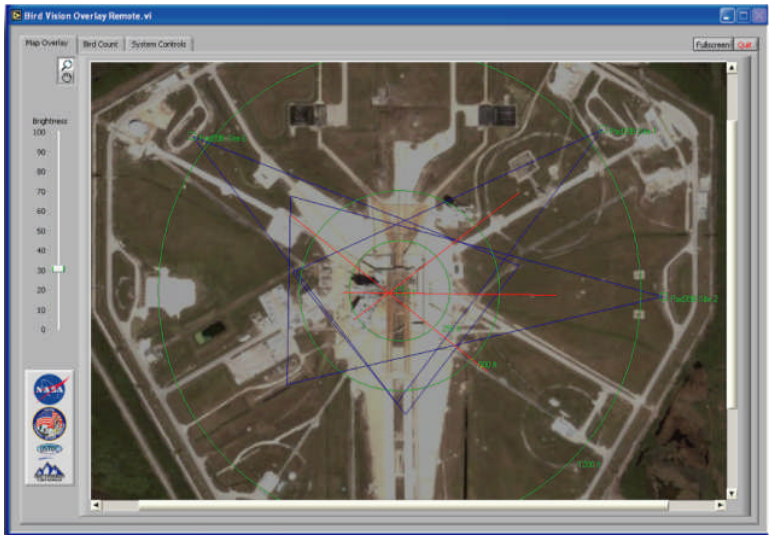


Image Analysis

- Shuttle Launch Bird Vision System - Provides real-time bird location image to the NTD's computer in the LCC Firing Room during launch.
- Lightning mast common reference
- 500 ft cone of influence over vehicle

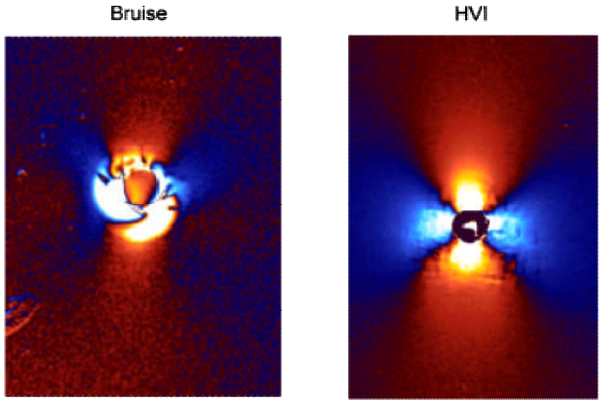


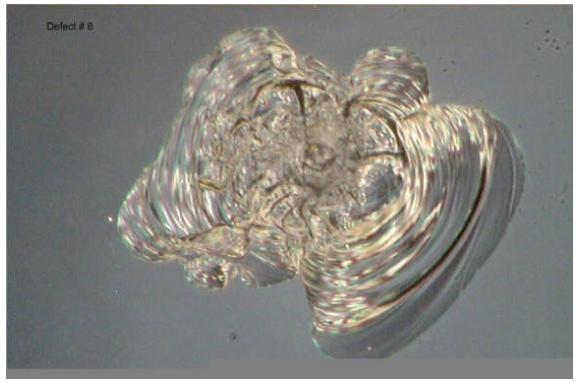




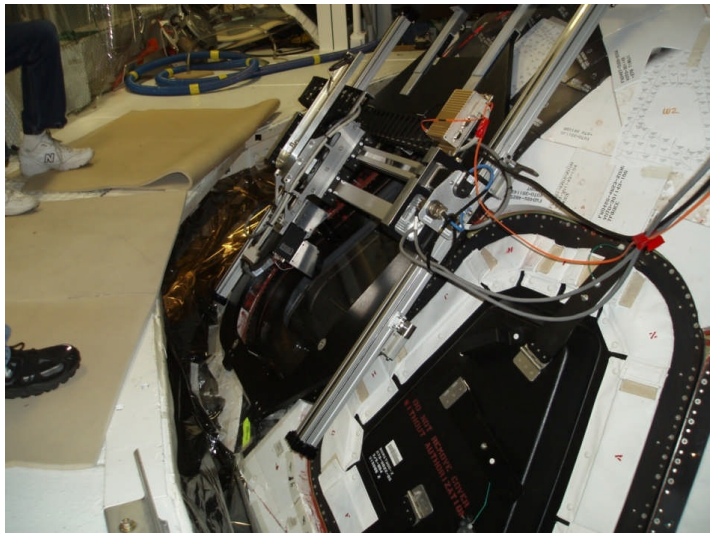
Glass Inspection

- Integrated Window Inspection Tool (IWIT) - Locates (positional accuracy = .001) images and maps defects on orbiter windows utilizing stress camera from Stress Photonics Inc.



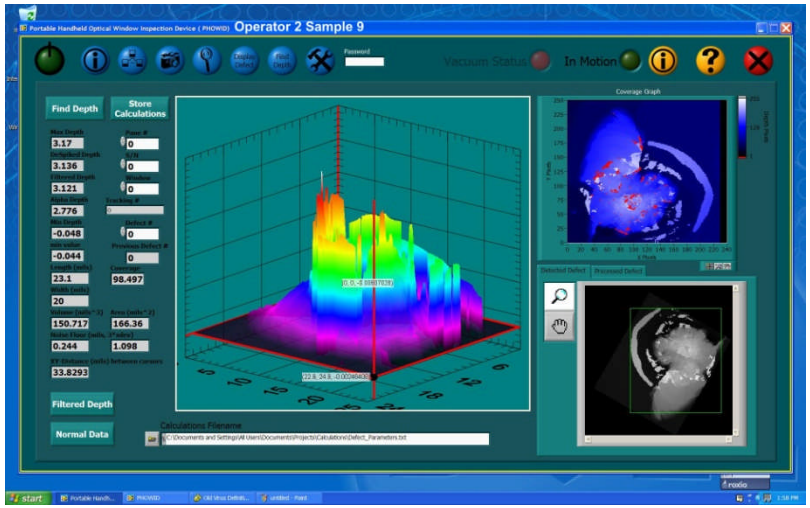


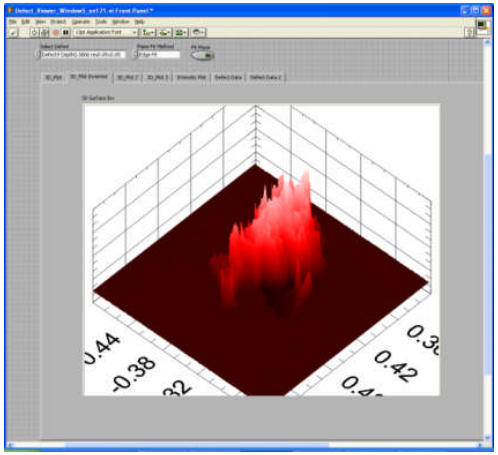
Hyper Velocity Impact (HVI)

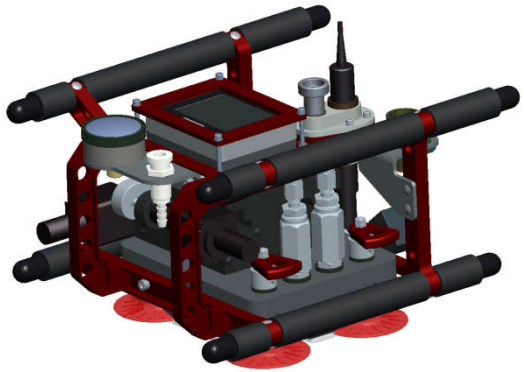


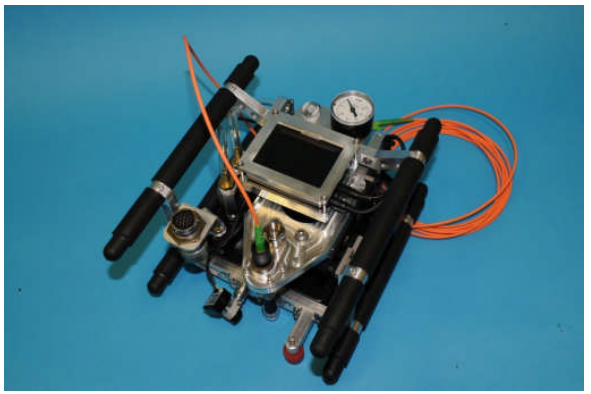
Glass Inspection

- Positioned-by-Hand Optical Window Inspection Device (PHOWID) – Positioned on glass by hand and attaches with redundant vacuum suction cups. Scans glass defects utilizing confocal chromatic pen to measure depth (critical size = 0.0006”)









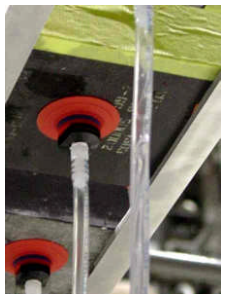
RCS Nozzle Inspection Tools

The reaction control system nozzles require inspection of the firing chamber for pitting, clogged fuel/oxidizer lines, and dirty acoustic holes.

A Teflon tool was fabricated to provide a safe and efficient means of inspection.

Water Detection and removal from Insulation (TPS and Cryogenics insulation)

- Orbiter TPS Water detection and removal – During the life of the program Orbiters landing in DFRC have been subjected to rain and tiles absorb water. Tile water detection gun and hygrometer help determine location and extent of water. Removal system attached with suction cups and uses facility vacuum drying system to remove water. Can be used on other materials/applications.

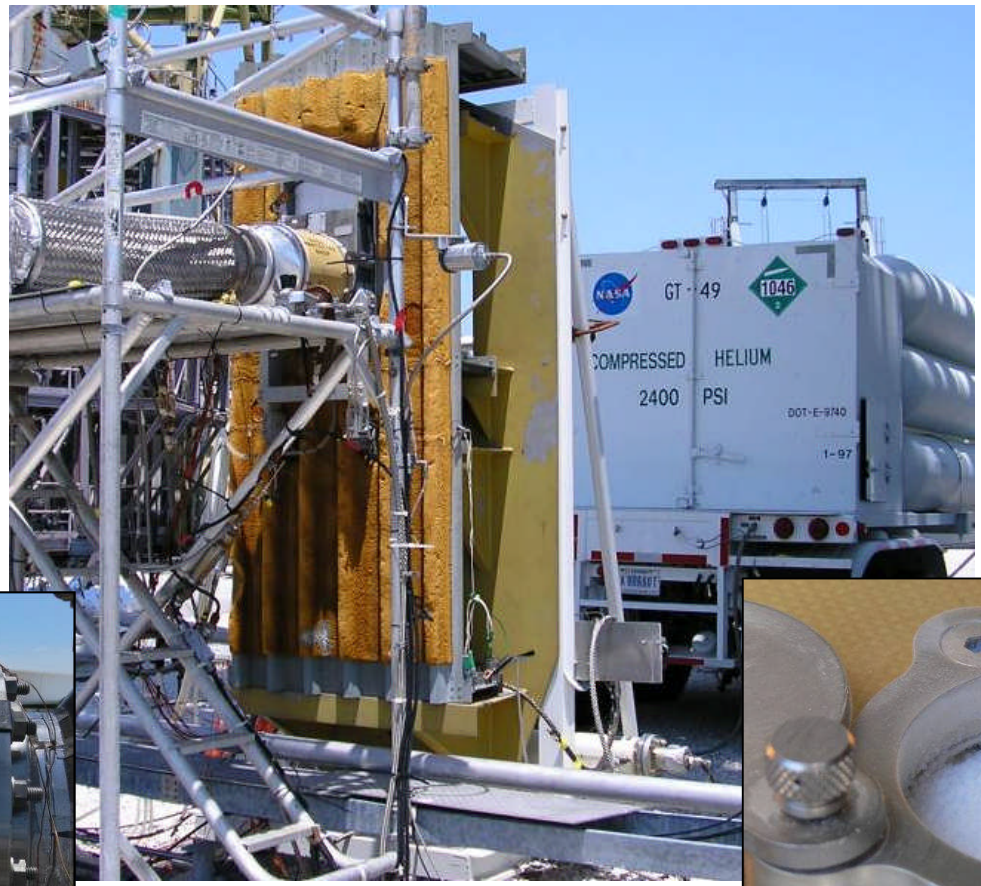


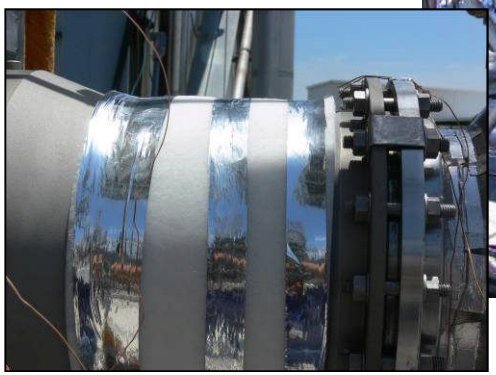
Water Detection Gun

Hygrometer

Aerogel Insulation

- During the STS-114 the ET GH2 Vent Shroud formed ice and Liquid Nitrogen. Purge shroud design was modified to incorporate multiple wraps of aerogel blanket directly on the QD cold surface within the main helium purge cavity. Testing showed the outer surface of the Shroud was maintained above freezing with no ice formation.





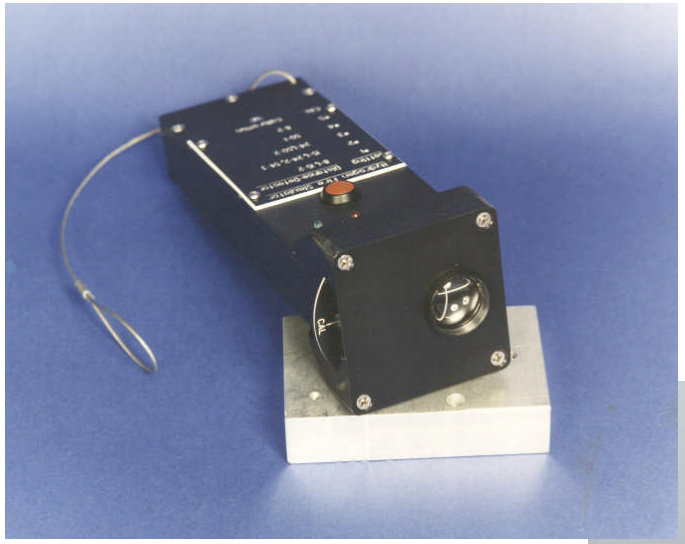
Leak Detection

- Ultrasonic leak detector was developed to find system leaks on any medium
- Can be used with ultrasonic sound transponder to perform unpressurized leak detection
- The technology has also been commercialized and is now sold by UE Systems

Fire Detection

Ultra Violet Hydrogen Fire Detector –

- Originally designed for use at the Pads for hydrogen fire detection
- Reliability of sensor detection capability was improved for shuttle program
- UV H2 Fire Simulator unit also created for in place field calibration
- Cross Country lines, tower, egress routes



Hazardous Gas Detection

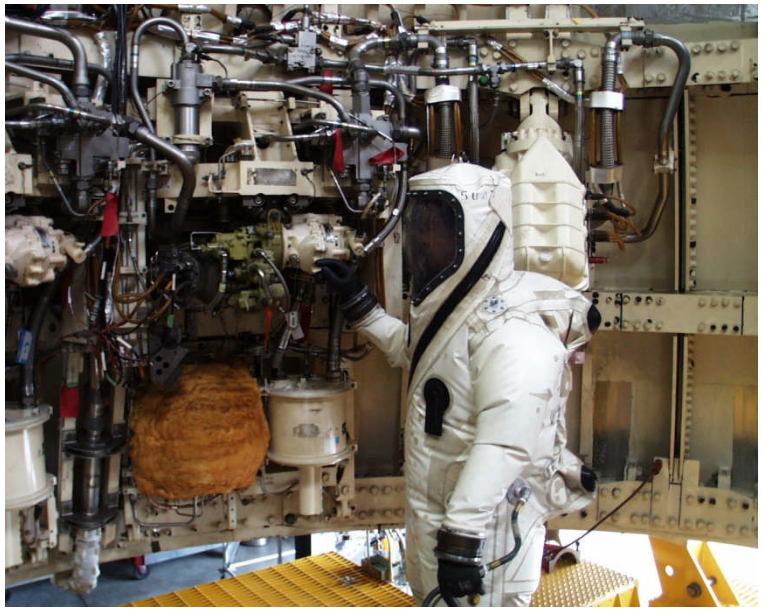
- Modern, state of the art system with common sampling system and identical twin quadrupole mass spectrometers
- Integral part of the launch operations ground support equipment
- Successful in detecting numerous leaks during launch countdown activities
- 5 different gases (H2, He, O2, Ar, N)
- Resolution sampling to 3-4 ppm in a very dynamic background
- Worked very closely with NIST for development of primary gas standards

Chemochromic Hydrogen Leak Detectors

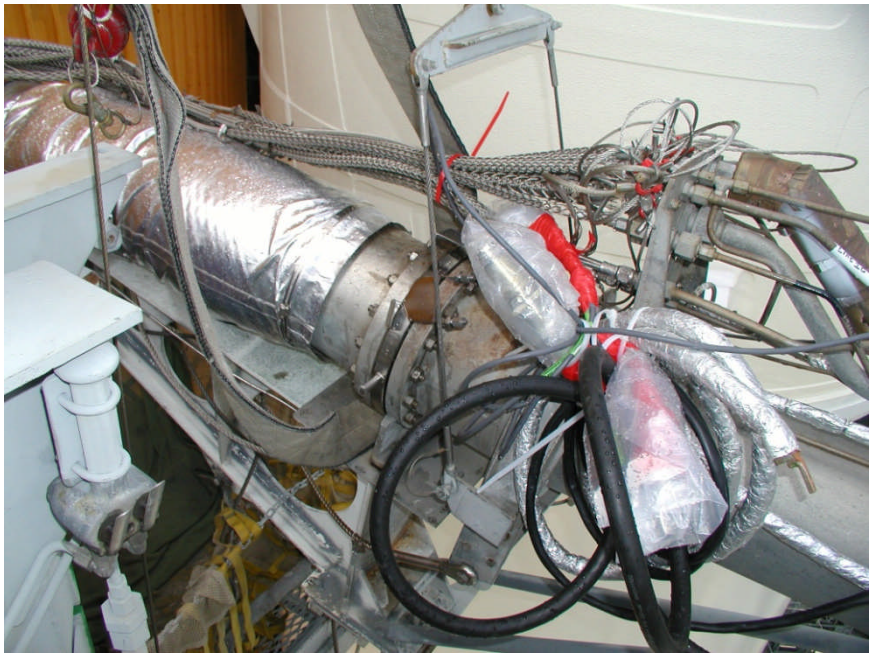
- Detector for sensing hydrogen gas leakage
- Change in color of detector material indicates where leaks are occurring
- Can detect leaks visually or electronically
- Can be molded or spun into rigid or pliable shapes
- Usable in variable temperature environments
- Requires no power to operate
- Nonhazardous – environmentally friendly
- Can be reversible or irreversible
- Inexpensive to manufacture

Self Contained Atmospheric Protective Ensemble (SCAPE)

- Protects workers from the hazards of handling toxic rocket propellants
- Innovative modifications to improve safety, comfort, and operational capability
  - Better sizing
  - Bubble type visor
  - Improved air distribution
  - Relocation of exhaust valves to improve internal gas concentrations
- Provides an internal air source and body cooling for up to two hours
- Two versions:
  - Category 1 – autonomous version which relies on a liquid air supplied environmental control unit
  - Category 4 – uses an external line supply



Valve Sensor



Sensor developed to detect leakage through a vent valve.

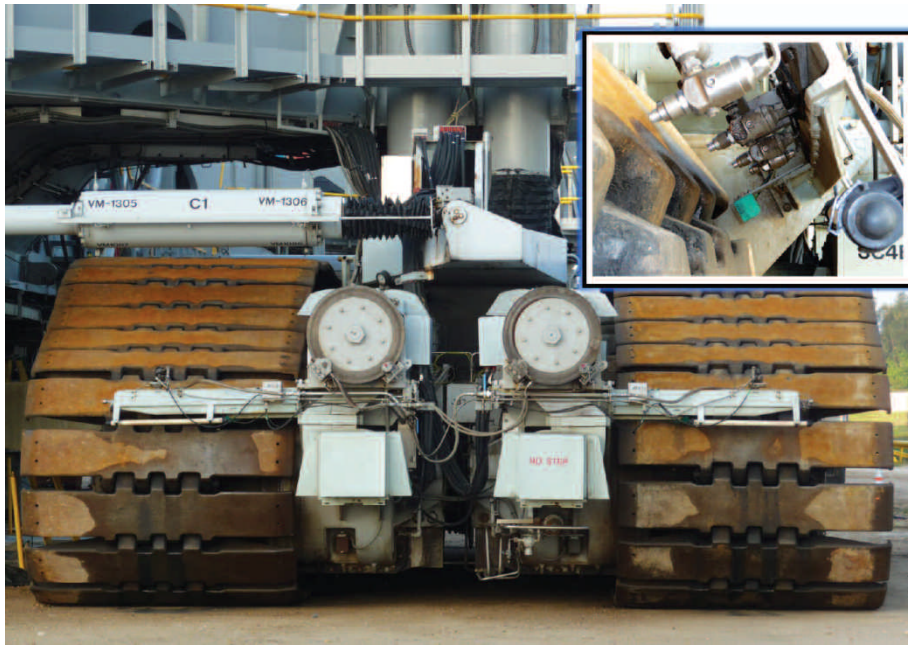
During an ET tanking test it was noticed that too much Helium was being used to maintain LH2 pressure. One possibility was leakage through the vent valve. The sensor shown above was designed, constructed, tested, and installed in the field in about one week by ASRC, the Prototype Shop and Stan Starr of our lab.

The sensor showed that the valve was not leaking which started a year long effort to track down the problem. Stan Starr of our group supported this effort, eventually solving it by having the pressurization orifices calibrated.

This activity demonstrated how our lab was starting to move into an analysis support role where we interfaced with other groups, but didn't necessarily build hardware.

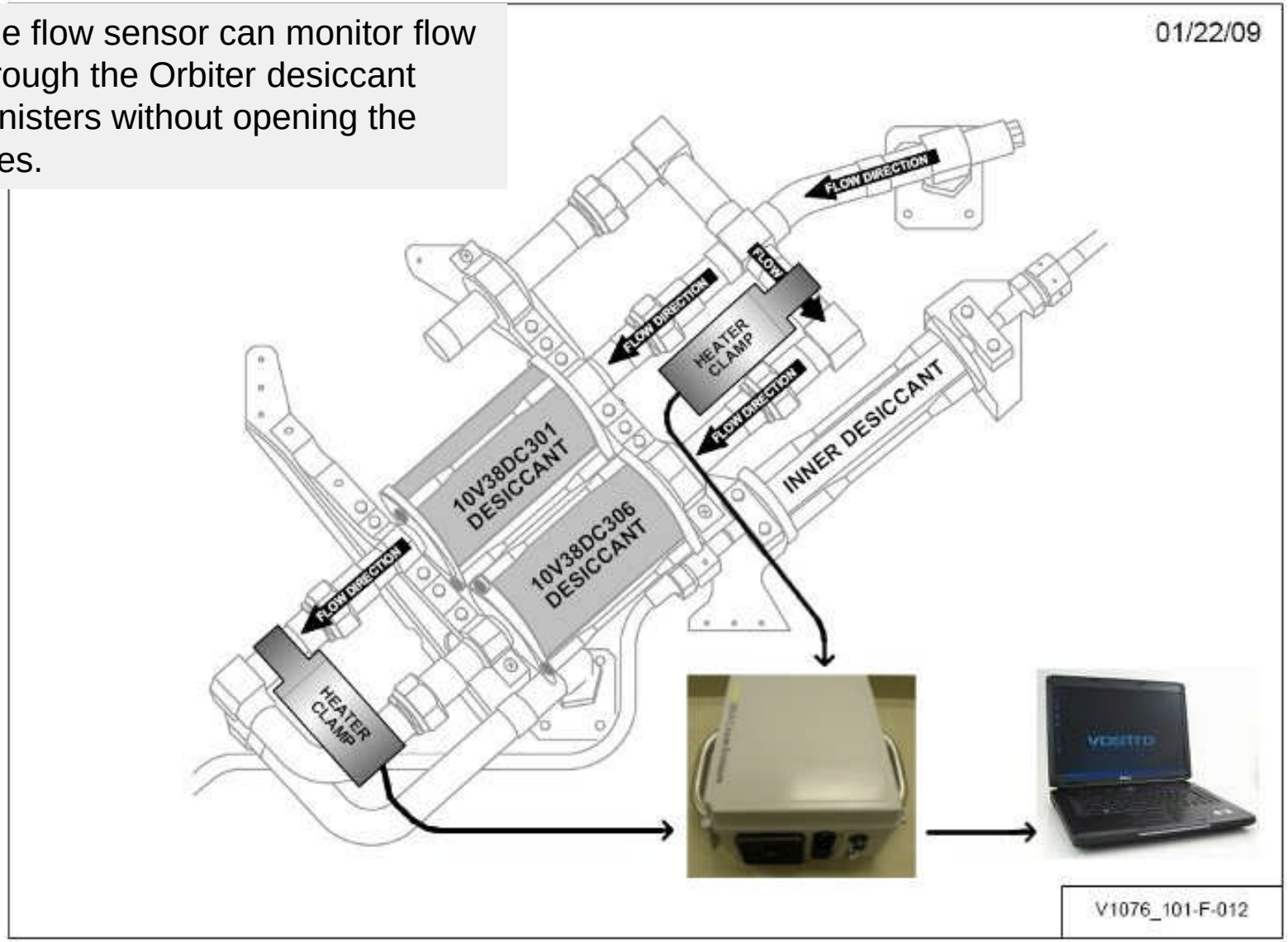
“Green” Lubricant

- Developed after an environmental problem was discovered with the material used to lubricate the crawler pins that link the “shoes”
- KSC co-developed a biodegradable, non-toxic lubricant with Sun Coast Chemicals
- “Crawler Track Lube” meets all requirements of EPA and NASA
- New lubricant had a longer service life and could be applied at longer intervals



Orbiter Desiccant Canister Flow Sensor

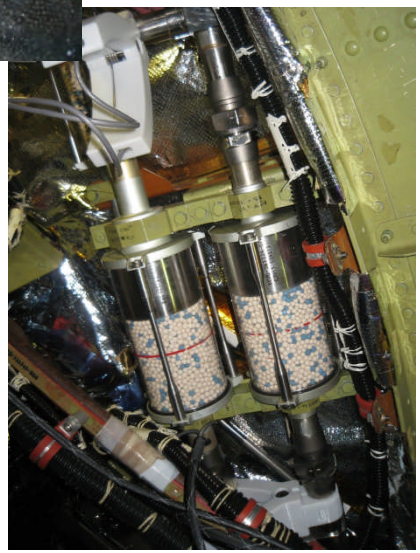
The flow sensor can monitor flow through the Orbiter desiccant canisters without opening the lines.



Orbiter Desiccant Canister Flow Sensor

LH Side/Overhead Manifold

LH FWD
Outer Cavity
Manifold



Self Diagnosing Wire Systems

Time Domain Reflectometry (TDR)

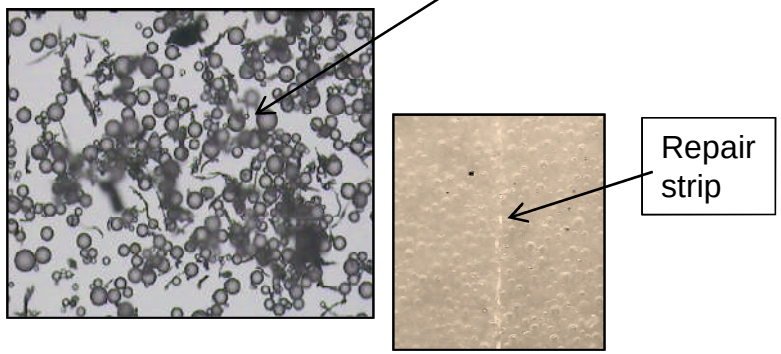
•Fault detection currently utilizes time domain reflectometry

• System will locate damage on powered or unpowered cables (current state-of-the-art requires wire to be unpowered)

MLP Test set-up for launch

Self Healing Wire insulation:

- Microcapsules release self-healing material when damaged
- Microcapsule applications include protective coatings (corrosion inhibiters and indicators)



Wire construction with fiber detection layer and outer insulation layer

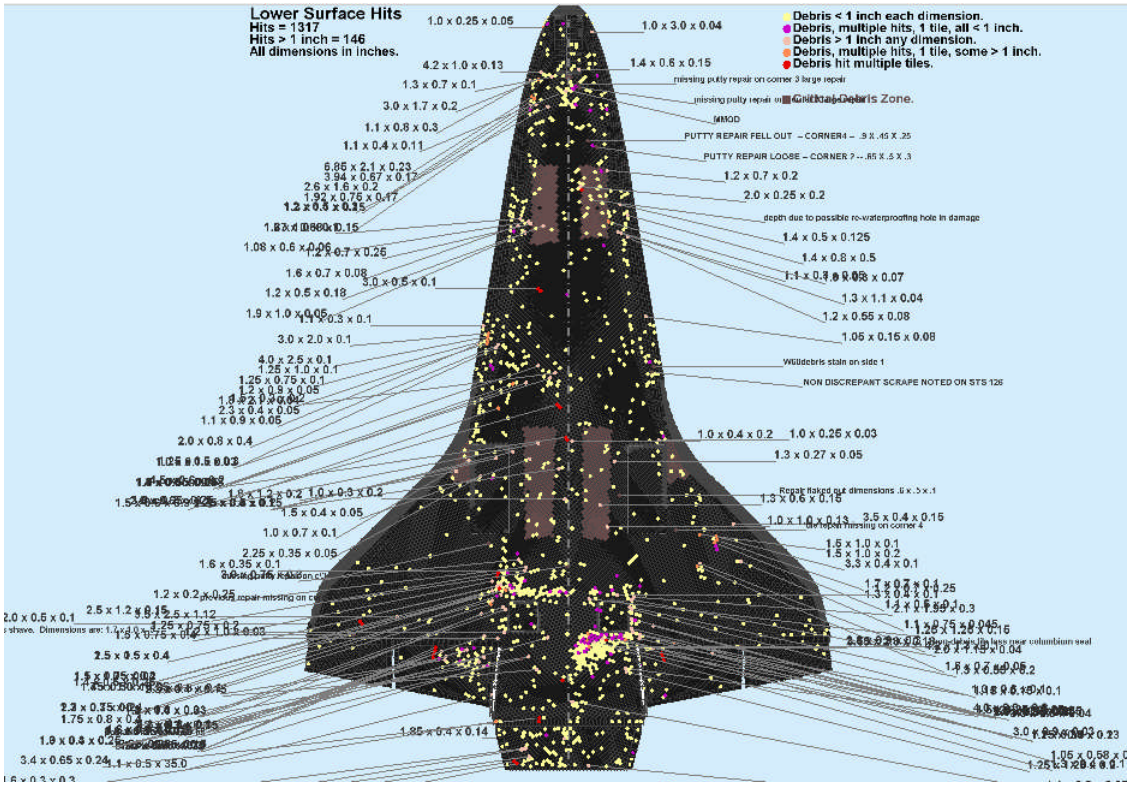
Wire construction with metallic layer and transparent outer insulation layer

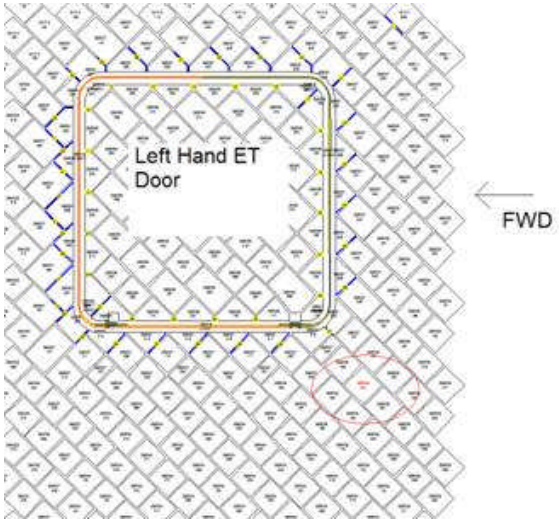
Computer Based Solutions for Processing

- Collaborative Integrated Processing Solution (CIPS)
  - End to end solution for management of requirements, configuration, supply chain, asset lifecycle, process engineering, and integrated data
- Solumina
  - Electronic authoring/display of work instructions
  - Real time status update to all users
  - Multi-person electronic buyoff of work instructions, electronic data collection, and imbedded links to reference material
  - Electronic change tracking and configuration management of work instructions and electronic approvals
  - Automated controls for constraints management, data validations, configuration, and reporting of consumption of parts and materials
- Systems Maintenance Automated Repair Tasks (SMART)
  - Uses evaluation criteria for discrepant conditions to automatically populate a document with predefined steps for safe, effective, and efficient repair
  - Stores tacit (corporate) knowledge merging hardware specification requirements with repair methods, sequences, and required equipment
  - Saves processing time and expense, increases productivity, and improves quality

Tile Mapping

- The Debris team developed an eMaps tool to track tile damages found after landing.
- This system replaced a hand drawn map with exact tile numbers, dimensions, and photographs of all damages.





There is a tile aft and inboard of the LH2 ET door that has been hit 54 times since Return to Flight.

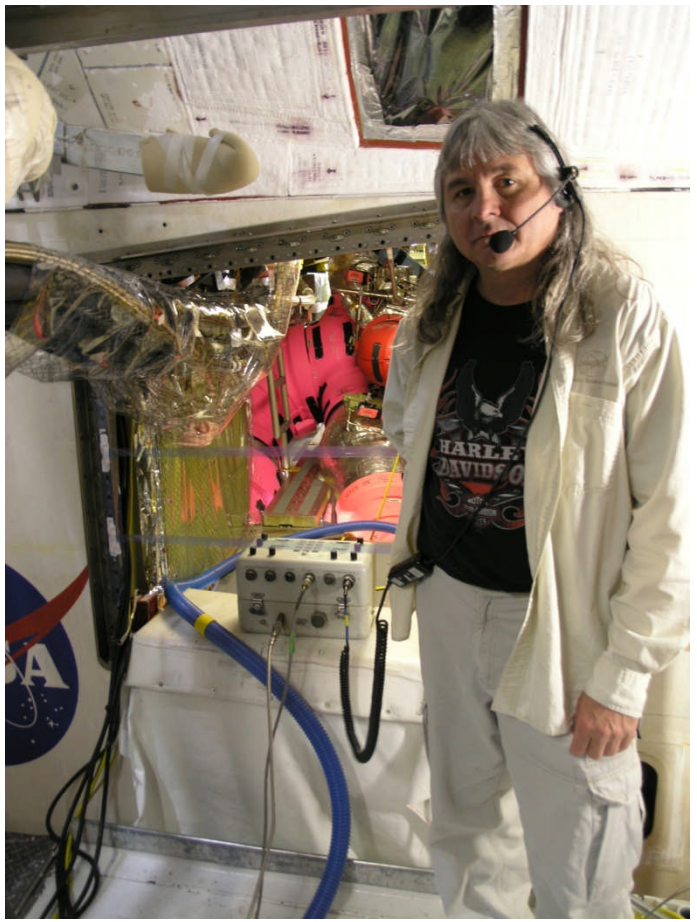
Integrated Network Control System

- Highly reliable and highly automated network system that sends data and commands between Shuttle Launch Control Center (LCC) and hardware end items
- Bridges modern industry automation technologies with customized aerospace industry communication protocols and associated legacy end item equipment
- Provides data reliability, integrity, and emergency safing systems to ensure safe and successful launch operations
- Connectivity with 40,000 end items located within 28 separate ground systems, all dispersed to 10 facilities over 16 square miles

By distributing data over the network, as opposed to wiring through terminal boards, the dual-channel redundant media network module on the left easily replaces the roomfull of terminal distibutors (center). On the right is an open terminal distributor showing cable and wiring.

Operational Intercommunication System

- One of a kind communication system conceived, designed, built, and operated at KSC
- Based on digital technology to replace existing analog system
- Installed in every major processing facility, office buildings, and various labs
- Provided unlimited conferencing on 512 communication channels and support for thousands of end users
- Utilized commercially available, off the shelf components and custom designed circuit boards



Space Shuttle Book – “Wings in Orbit” -

KSC ENGINEERING

Our people are a large part of the “Legacy” -