ELV Payload Safety Workshop

WSTF and Pyrotechnics Update

Day 2
11:30 AM – 12:00 AM

Regor Saulsberry 575-635-7970
Harold Beeson 575-524-5722 (Core Capabilities)
Steve Mc Dougle 575-524-5196
• White Sands Test Facility (WSTF) Introduction and Payload Safety Applicable Capabilities
• Current Commercial Crew Frangible Joint Test Program
• Pyrovalve Specification Status/Update
• Pyrovalve Handbook Revision
White Sands Test Core Capabilities

Hazardous Testing and Analysis

- Rocket Propulsion Testing and Evaluation
- Oxygen Systems Testing and Analysis
- Propellants and Aerospace Fluids Testing and Analysis
- Hypervelocity Impact Testing
- Composite Pressure Systems Testing and Analysis
Oxygen Systems & Materials

• Evaluate and test materials, component and systems used for oxygen and oxygen enriched atmospheres
  – System design analysis, qualification and testing of flight and GSE hardware
  – Train designers, operators and managers of oxygen systems and M&P personnel (throughout agency and world)
• WSTF performs standard and special materials tests
  – NASA Std-6001 and 6016 testing to qualify materials for spacecraft habitable environments
  – Work with aerospace and industry standards organizations
• WSTF is the agency designated location for oxygen test and analysis
Habitable Crew Environments - NASA 6001 & 6016 Requirements

Standard Testing

- Flammability
- Toxicity Offgas
- Odor
- Vacuum Stability
- Reactive Fluids
• WSTF holds recognized expertise in the testing, evaluation (destructive and nondestructive) and analysis of composite pressure vessels (CPVs)

• Performs testing to evaluate:
  – Stress rupture (sustained pressure load)
  – Damage tolerance
  – Burst effects (hydraulic and pneumatic)
  – Service environment effects
  – Non-destructive evaluation methods

• WSTF teaches courses tailored to personnel responsible for the design, integration and operation of CPV: program managers, engineers, integrators and inspectors.
  • Throughout Agency, Commercial Space Flight and Industry

• WSTF develops and applies specialized CPV NDE
  • NESC Multi-purpose NDE Scanner (left) under development and will be validated prior to application
Hypervelocity Impact Testing

• The Remote Hypervelocity Test Laboratory is NASA’s designated facility for simulating micrometeoroid and orbital debris impacts on spacecraft hardware.

• Average of 575 shots per year (FY08-12)
  – Launch single 0.05mm to 25.4mm projectiles
  – Impact at velocities between 1.5 km/s - 8.5 km/s
    • Velocities to 10 km/s have been attained and capability is being developed

• Remotely evaluate hazardous test articles
  – Batteries, propellants, cryogenic, energized, pressurized articles
WSTF assesses the fire, explosion, compatibility, and safety hazards of hydrogen, oxygen, and hypergolic propellants.
  - The skills developed are being used for alternative propellants:
    - “Green” Propellants such as: Nitrous Oxide, NOFBx, Methane, Hydrogen Peroxide, Ionic Liquids (e.g. AF-M-315E), Alcohols, DMAZ
  - Evaluate and test materials, component and systems used for propellant and fluid systems
    - System design analysis, qualification and testing of flight and GSE hardware
    - Train designers, operators and managers of propellant systems and M&P personnel to WSTF developed manuals for safe use
  - WSTF performs standard and special materials tests
    - NASA and DoD Standard testing of fluids and to qualify materials
    - Work with aerospace and industry standards organizations
  - Highly specialized facilities for testing and analyzing pyrotechnic devices

Propellants & Aerospace Fluids
Propulsion Test

300 Area
Primarily dedicated to testing at ambient pressure conditions

400 Area
Primarily dedicated to simulated altitude testing
Technical Services Office –
Specialized Support for the Core Capabilities

Component Services Section
- Precision Cleaning (50A)
- Hydrostat to 30,000 psig
- NBIC Valve Repair in clean room
- $283K to date for Blue Origin (3 year)

Calibration Laboratory
- In house, pressure, temperature, load, and electrical calibration services and instrument repair
- Maintain component cleanliness
- External Customers – WSC, WSMR, and KSC

Fabrication
- ASME code equivalent fabrication shop
- CNC milling and turning
- Skilled in working with exotic materials including Monel®, Inconel®, titanium, carbon, and alloy steels
- Recent external customers – JSC, WSMR, and JPL (Low Density Supersonic Decelerator Simulator)

Industrial Imaging and Reporting
- 35mm ultra high speed infrared shadowgraph (2 million fps)
- High speed video (120,000 fps)
- Writing, editing, formatting support to meet NASA and specific publication standards

Flight and Critical Hardware
- Engineering support for ISS Respiratory Support Pack
- Integration and engineering support for MPCV Service Module propulsion system – OMS Engine

Design and Analysis
- Test system certification per NASA and industry requirements
- GSE design
- Currently supporting Wallops Sounding Rocket Program and Wallops Mid-Atlantic Regional Spaceport (MARS)
The NESC, at the request of the Commercial Crew Program (CCP), conducted an assessment of FJs that are planned for use in human-rated launch vehicles or other human-rated applications.

- Involved historical research, mechanical analysis and modeling
  - Initial assessment performed the summer of 2013 and is now complete and results were documented in an extensive formal test report which was briefed to CCP
- One of the recommendations of this assessment (being acted on) was to perform an FJ empirical test program to, in the words of the CCP Chief Engineer:
  “provide confidence for (their) use in human spaceflight.”
What is a Frangible Joint?

• A flight-proven design that functions to separate Launch vehicle stages, payload fairings, etc.
  – Debris free separation
  – Significantly lower shock than a Linear Shape Charge (LSC) separation

MLAS Coast Skirt Separates using a Frangible Joint

An example of a stage separation FJ installation. Three sections or assemblies are installed to cover 360° circumference
• Configuration
  • Test specimens are of the tang and clevis design and the flanges will be flat on both the tang and the clevis for design simplicity (similar to MLAS)
    – Leg and ligament thickness, charge load, curvature radius and operating temperatures will be varied based on a Design of Experiments (DOE) matrix
      • Determine relative effects and identify primary drives
• Objectives
  • Reduce engineering uncertainty in the mechanics of FJ operation, by determining the sensitivities in the FJ design
  • Understand what drivers (factor sensitivities) impact reliability so the designs can be better evaluated in regards to crew risk
  • As necessary, make recommendations for improving robustness of FJ designs

• Team membership is divided into 5 sub-teams with a lead identified for each of the sub-teams
  • Test Team
  • Data Team
  • Analysis Team
  • Documentation Team
  • Schedule Team
  • Sub-Contract Monitoring Team
• Status:
  • 3 major procurements for approximately 160 test joint from Ensign Bickford
  • Test plans released
  • Advanced test system built-up and extensive instrumentation all validated (consistent microsecond timing)
  • The first two test series successfully completed
• 8 channel Photon Doppler velocimeter for accurate velocity and deformation measurement in the microsecond temporal realm.
• High Speed Video and Full Field Strain measurement, digital Image correlation (DIC)
  – Two Kirana 5,000,000 f/sec at high resolution
  – Four Shimadzu running DIC at 1,000,000 f/sec
  – Several Photron and Phantom for lower speed DIC and general Video needs
• Other instrumentation
  – IR Video to evaluate thermal environment
  – Shorting and shock pins to evaluate Velocity of Detonation variations
  – High speed fiber Bragg gratin for strain etc.
  – Accelerometers
  – Flash X-ray if needed
Frangible Joint Test Facility - Layout
Pyrovalve Specification
NASA-SPEC-5022
• NESC-RP- 10-00614 Pyrovalve Reliability Assessment for Expendable Launch Vehicle Payloads found that no NASA specification provided the minimum criteria for parent-metal design NC pyrovalves to meet NASA and Range Safety requirements for ELV payload applications
  – Also needed as a baseline for NESC assessment analysis
• The assessment developed a new pyrovalve manufacturing and testing specification and proposed that it be published and made available for use by programs
The specification sets the manufacturing and test requirements for normally closed (NC) “parent metal” shear section valves and provides applications guidelines to ensure consistent reliability in preventing leakage or other failure induced release of hazardous gases or fluids from launch vehicle payloads which are subject to NASA Payload Safety and USAF Range Safety Requirements.
• Questions were raised as to whether to publish the requirements as a specification or a standard. The decision was made to keep it as a specification.
• The document underwent extensive editing in collaboration with the Standards group and was made ready for Agency-wide review.
• Note that the Pyrovalve Specification deals with the bottom (flow barrier) section of the pyrovalve
• The top portion of the pyrovalve where the pyrotechnic charges are housed is the “primer chamber assembly” and is not covered

Simplified Normally-Closed Pyrovalve Block Diagram
• Agency-wide Review was closed on 2/21/14
• 165 comments were received
  – Many of the comments have to do with whether the specification is really needed, or if the requirements should be put in a different format, if they should be incorporated into an already existing document or other similar concern. Some of those have been discussed with the interested parties
  – All of the comments have been resolved with the originators and the process is proceeding
  – Expected to be published by mid-2015
Pyrovalve Handbook Revision
NASA HDBK-5013
Regor Saulsberry
Steve McDougle
• Pyrovalve Application and Performance Handbook (NASA-HDBK-5013)
  – Provides engineering information and guidance related to the design, testing, and use of pyrovalves
  – Development of the handbook began in 2002
  – The handbook was approved in June 2009
• Pyrovalve Application and Performance Handbook
  – Consists primarily of information collected during the Mars Observer Propulsion and Pyrotechnic Corrective Action Test Program (MOCATP) (conducted 1995-1998)
    • Experimental investigation of pyrotechnic leakage and fuel interaction
    • Three spacecraft failures investigated
      – Mars Observer test program 1992
      – Landsat 6 in 1993
      – Telstar 402 in 1994
• The handbook covers
  – An overview of typical applications
  – An overview of spacecraft applications and environments
  – System design and performance requirements
  – Ram design and sealing concepts
  – Initiator selection
  – Service life and reliability determination
  – Hazards analysis
  – Pyrovalve system testing
• Extensive edits of the handbook were completed on April 30, 2013
  – By consensus, some comments from the original Agency-wide review were deferred to the first revision. Those have been reviewed and incorporated
  – Much unneeded information such as Space Shuttle background information and propellant properties was eliminated
  – The document is now about 216 pages and 30 Mb in size versus 520 pages and 88 Mb previously
– Despite the overall reduction in size, the results of three NESC Independent Assessments have been added to the handbook

- Investigation of four ground test anomalies occurred during ground testing in which the NSIs fired, but the booster charge did not
- Quantification of the improvement in performance with a new (“V-shaped” flow channel, stainless steel body) primer chamber assembly design versus the original (“Y-shaped” flow channel, aluminum body)
- The reliability and safety of pyrovalves in payloads carried on ELVs during ground processing operations
• The new Pyrovalve Specification which is in work will not be included in the Handbook
• WSTF and NASA Tech Standards is finishing the editing and preparing the document for Agency-wide Review (AWR)
  – Comments will be compiled and sent to WSTF for resolution
  – Final editing
  – Other approval steps
• Objective is to start AWR by the end of 2014