Overview of Engineering Design and Analysis at the NASA John C. Stennis Space Center

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Mississippi Engineering Society Winter Meeting
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SSC Regional Map
Complete Suite of Test Capability and Expertise

E-1 Stand
High Press., Full Scale Engine Components

E-2
High Press.
Mid-Scale & Subscale

E-3
High Press.
Small-Scale Subscale

A-1 … Full Scale Engine Devt. & Cert … A-2

B-1/B-2 … Full Scale Engine/Stage Devt. & Cert

Components … Engines … Stages
SSC Support Facilities

Cryogenic Propellant Storage Facility
Six (6) 100,000 Gallon LOX Barges
Three (3) 240,000 Gallon LH Barges

High Pressure Industrial Water (HPIW)
330,000 gpm Delivery System

High Pressure Gas Facility (HPGF)
(GN, GHe, GH, Air: ~ 3000 to 4000 psi)

Additional Support
• Laboratories
  ✓ Gas and Material Analysis
  ✓ Measurement Standards and Calibration
  ✓ Environmental
• Shops
• Utilities

Provides for Long Duration Capability
Propulsion Testing at the NASA John C. Stennis Space Center (SSC)

Video
NASA SSC Design & Analysis Division

Design and Analysis Division
- Configuration Management
- Records Retention DB Management

Mechanical and Component Systems
- Cryogenic Propellant Systems
- Storable Propellant Systems & HPIW
- Hydraulics/pneumatics Systems
- Press Gas/Purge Systems (TBA)
- Components
- Materials
- Ancillary Systems
  - TMS, Measurement Uncertainty
  - Standards & Specifications

Electrical Systems & Software
- Data Acquisition
- Instrumentation & Signal Conditioning
- Controls & Simulation
- DACS Lab Management
- Data Systems Management
- Ancillary Systems/Electrical Power

Systems Analysis & Modeling
- Modeling and Analysis development and integration into RPT
- Fluid Mechanics/Thermal Analysis of Propellant Systems
  - Liquid
  - Gas
- CFD
- Structures/Loads Analysis
- Thermal/Heat Transfer Analysis

Organization Goal:
- Develop and maintain propulsion test systems and facilities engineering competencies
  - Unique and focused technical knowledge across respective engineering disciplines applied to rocket propulsion testing. e.g.,
    - Materials selection and associated database management
    - Piping, electrical and data acquisition systems design for cryogenic, high flow, high pressure propellant supply regimes
    - Associated analytic modeling and systems analysis disciplines and techniques
    - Corresponding fluids structural, thermal and electrical engineering disciplines
Integrated Facility Simulation and Analysis

• To Support Propulsion Testing, SSC Has Developed & Implemented Analytic Modeling & Simulation Tools
  – Rocket Propulsion Test Analysis (RPTA) Model (FORTRAN) Used to Simulate Propulsion Test Facility Systems (e.g., LOX Run System)
    ✓ Heritage of Model Dates to Pressurization and Propellant Systems Design Tasks for Space Shuttle and X-33
    ✓ Model Adapted, Validated and Currently Used at SSC to Simulate Facility Pressurization and Propellant Systems
  – Computational Fluid Dynamics (CFD) Used for Select Propulsion Test Situations
  – Have Experienced Analysis Team that Routinely Solves Pressurization and Propellant System Problems
• Integrated Facility Simulation and Analysis Has Led to Substantial Project Cost and Schedule Savings
Integrated Facility Simulation and Analysis

- Analytic Tools Available for Propulsion Test Facility Modeling & Analysis
- Comprehensive Propellant System Thermodynamic Modeling & Test Simulation

Integrated Performance Modeling Capabilities Substantially Improves Understanding & Knowledge of Test Systems Performance that has Translated to Efficient Test Facility Design, Activation & Test Operations

GH2 Activation Test
June 29, 2004

Test and Data Analysis

Fluid System Modeling

Advanced Capabilities in CFD Modeling & Analysis
Rocket Propulsion Test Analysis (RPTA) Model

- Temporal Transient Thermodynamic Modeling of Integrated Propellant Systems
- Thermodynamic Control Volume Solver Model Accurately Models High-Pressure Cryogenic Fluids and High-Pressure Gaseous Systems. Model Features Include:
  - High-Fidelity Pressure Control Valve (PCV) & Closed Loop Control System Model
- RPTA Model Validated Through Test Data Comparisons
  - IPD Fuel Turbopump, RS-84 Sub-Scale Pre-Burner, RS-83 Pre-Burner Cold Flows, SSME Flowliner Activation & IPD Engine System

Pressure Control Valve (PCV) Model Developed & Validated

A Significant Advantage of the RPTA Model is the Coupling of Control Logic (Electro-Mechanical Process) with Thermodynamic Processes
Facility Activated and Test Performed

- Liquid Methane (LM) & Liquid Oxygen (LOX) Propellants Used
- Facility Model Results and Facility Test Activation Results Agree Well
- Test Capability: ~25 seconds

LM System Schematic
Comprehensive & Rapid Piping System Design & Analysis Capability

- Commercial Tools Employed to Augment Analysis
- Example: *FlowMaster* Piping System Analyzer
  - Allows for Steady-State or Transient Analysis, Compressible or Non-Compressible Flow
  - Includes Heat Transfer, Flow Balancing, Priming & Sizing Analysis

**Water Hammer Effect Due to Rapid Closure of Main Fuel Valve**

**Propellant Flow to Test Article Due to Rapid Opening of Main Fuel Valve**
Recent Project: Methane Technology Testbed Project (MTTP)

- MTTP provides portable, small-scale propulsion test capabilities
  - Can support gaseous methane, gaseous oxygen, liquid methane and kerosene-type propellants
  - Capable of supporting engines up to 1000-lbf thrust
- Tested 50-lbf thruster (right)
  - Plume diagnostics
  - Gained methane experience

![MTTP Test Skid](image)

![Night firing of MTTP thruster](image)

![Exhaust spectrum for GOX/GM combustion](image)
Recent Project: 14” Valve Test
Description of Test Objectives

**Test Objectives**

- Collect Data Needed to Support a Decision to Install a 14” Valve (26,000 lb) on the E-1 Test Stand as the High Pressure (8,500 psi service) LOX Tank Isolation Valve
- Determine the Behavior of the Valve in Simulated Operating Conditions
- Determine the 14” Valve Bonnet and Body Steady State Temperatures

**Test Details**

- Conducted Valve Chill Down Test at the E-2 Test Stand
- Used Liquid Nitrogen (LN) to Chill Down the Valve
- Instrumented Valve with Multiple Thermocouples on the Valve Body and Stem
- During Chill Down Operations, the Valve was Cycled Multiple Times to Test Proper Valve Operation at Low Temperatures
14” Valve Test Results

Test Results
• Test Lasted About 24 Hours
• About 6500 gal of LN Was Used for the Valve to Reach a Steady State Condition
• Boil Off Results Were Used to Calculate the Steady State Heat Load of the Valve

Analytical Accomplishments
• Identified Issue with Asymmetric Bonnet Wear at Cryogenic Temperatures
• Verified Analytical Predictions for the Heat Load of the Valve
  – Determined the Valve Heat Load
  – Determined the Valve Chill Down Time Constant
  – Test Results Will Be Used to Guide Bonnet Re-Design
14” Valve
ANSYS Workbench Thermal Simulation

Geometry Description

Analysis Model

Loads & Boundary Conditions

Validated Results

Pro-E Solid Model

3-D ANSYS Finite Element Model: 275,000 Nodes 185,000 Elements

Measured Valve Heat Load: 9308 BTU/Hr

Predicted Valve Heat Load: 9315 BTU/Hr

Measured Steady-State Frost Line

Predicted Steady-State Frost Line

NIST / MIL-HDBK Temperature Dependent Material Properties

Empirically Based Temperature Dependent Boundary Condition Parameters

Convective Film Coefficient for Natural Convection of Air over Horizontal Cylinder

Boiling LN2 Convective Film Coefficient

Von-Mises Stress

Total Deformation

Radiation

Natural Convection

Boiling Convection

Deformation @ 89X
Employed CFD Code to Model E-1 High Pressure LOX Flow Capability

- CFD Investigations Indicate Pressurizing Gas Diffuser Flow Significantly Limits Flow Duration for High Flow Rate Cases

Analysis Boundary Conditions

- HP LOX Tank at E-1 Test Stand
- Flow Case Assessed
  - 2500 lb/sec LOX Discharge Rate
  - 8400 psi Tank Pressure Maintained During Propellant Discharge

Results & Observations

- GN Convective Mixing with LOX Propellant is Substantial
  - Only 50% Loaded LOX is Useable (~2% N₂ Concentration)
- LOX Propellant Supply at Assessed Flow Rate & Pressure Limited to Approximately 4 seconds (vs an Estimated 10 seconds Determined Using Nominal Facility Pressurizing Gas & Propellant Supply Limits)
• Understanding a Valve’s Flow Capacity ($C_v$) as a Function of Valve Stroke is Critical When Calculating the Propellant Flow Rates to a Test Article.

Computational Fluid Dynamics (CFD) Modeling

• CFD Used to Predict the Flow Field & $C_v$ Curve for a Modified LOX Control Valve

• Yields a Good Understanding of How the Flow Field Changes as the Valve Opens & Affects $C_v$ curve

• Analysis Reveals Areas Where Cavitation May Occur as Well as Areas of High Velocity That Are Important When the Working Fluid is LOX
Thermal Fatigue Considerations

- The Goal of This Investigation Was to Simulate the Thermal Environment During Tank Chill Down and Apply What Was Learned in the Specimen Testing to Improve the Reliability of Analytical Model Calculations

- Performed Laboratory-Scale Testing

**Test Specimen**

- 5 Thermocouple & Strain Gage Pairs - 4 on 8” dia Spaced at 90°, 1 at Center. Typical on Both Top & Bottom Surface.
- Total of 20 sensors

**Test Procedure**

- Subject Top of Test Specimen to LN
- Record Strain & Temperature Data
- NDE Dye Penetration Test Performed for Crack Detection
- Testing for Crack Initiation Made After Each Thermal Cycle for the First 15 Cycles
- Subject Test Specimen to Greater Than 100 Cycles

![Dye Penetration Testing](image)
Thermal Fatigue Considerations

Top Center Temperature & Compensated Strain

- Initial Cold Shock Leads to Largest Strain Due to Maximum Temperature Difference

Lab-Scale Specimen Exposed to LN
Summary

• SSC has Developed a Suite of Effective Analytic Modeling and Analysis Tools Providing High Fidelity Assessment of Test Stand Performance
  – Rocket Propulsion Test Analysis (RPTA) Model, a 1-D Propellant System Analyzer
  – CFD Applied to Select Propulsion Test Situations
  – Finite Element Analysis (ANSYS/CFX)
• Analytic Tools Exercised Regularly on a Variety of Propulsion Test Projects by Experienced Analysts
  – Active Test Facilities (1.0 to 1.5 Mlbf Thrust, 8500 psi LOX/LH/RP-1 Supply)
  – Active Test Projects (e.g., J-2X PPA, J-2X at PBS, TGV)
• We are Planning to Augment our Staff
  – Fluid Mechanics/Systems Modeling & Analysis
  – Thermal Analysis

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Arnold Association of Professional Societies (AAPS) Luncheon
Tullahoma, TN

January 21, 2009
SSC’s ETD (Engineering and Science Directorate) manages, develops, and operates SSC Rocket Propulsion Test (RPT) capabilities and facilities.
Complete Suite of Test Capability and Expertise

E-1 Stand
High Press., Full Scale Engine Components

E-2
High Press. Mid-Scale & Subscale

E-3
High Press. Small-Scale Subscale

A-1 … Full Scale Engine Devt. & Cert … A-2

B-1/B-2 … Full Scale Engine/Stage Devt. & Cert

Components … Engines … Stages
NASA-SSC CFD Modeling Activities

NASA-SSC Test Facilities – E Complex

Component and Engine Testing (E-1)

• High Pressure (Long Run) Capabilities
  – LOX/LH/RP ~ 8,500 psi
  – GN/GH ~ 15,000 psi
  – GHe ~ 10,000 psi

• State-of-the-Art DAC Systems

• E-1 Cell 1
  - Primarily Designed for Pressure-Fed LOX/LH/RP & Hybrid Test Articles
  - Thrust Loads up to 750K lb_f (horiz.)

• E-1 Cell 2
  - Designed for LH Turbopump & Preburner Assembly Testing
  - Thrust Loads up to 60K lb_f

• E-1 Cell 3
  - Designed for LOX Turbopump, Preburner Assembly & Engine Testing
  - Thrust Loads up to 750K lb_f
NASA-SSC CFD Modeling Activities

NASA-SSC Test Facilities – A Complex

- Full-scale Engine Development & Certification
  - Saturn V 2nd Stage J-2 engine (1.15 M-lbf cluster of 5 LH₂/LOX J-2 engines)
  - SSME (375 K-lb LH₂/LOX) development, flight acceptance, & 65kft altitude (A-2)
  - X-33 Aerospike

TEST STAND CAPABILITIES:
- Thrust capability of 1.5 M-lbf
- Flame Deflector Cooling 220,000 gal/min
- Deluge System 75,000 gal/min
- Data measurement system
- Two derricks – 75 ton and 200 ton
- High-pressure gas distribution systems
- LOX and LH2 propellant supply systems
- Hazardous gas and fire detection systems
- Barge unloading capability (2 LOX, 2 LH)
- Diffuser (A-2)
Vehicle Stage & Full-scale Engine Testing

- SATURN V (7.7 M-lbf cluster of 5 RP-1/LOX F-1 engines)
- SSME MPTA (1.1 M-lbf cluster of 3 LH₂/LOX SSME)
- Delta IV Common Booster Core (650 K-lbf LH₂/LOX RS-68 engine)

TEST STAND CAPABILITIES:
- Thrust capability of 13 M-lbf
- Flame Deflector Cooling 330,000 gal/min
- Deluge System 123,000 gal/min
- Data measurement system
- Two derricks – 175 ton and 200 ton
- High-pressure gas distribution systems
- LOX and LH₂ propellant supply systems
- Hazardous gas and fire detection systems
- Barge unloading capability (3 LOX, 3 LH)
NASA SSC Design & Analysis Division

### Mechanical and Component Systems
- Cryogenic Propellant Systems
- Storable Propellant Systems & HPIW
- Hydraulics/pneumatics Systems
- Press Gas/Purge Systems (TBA)
- Components
- Materials
- Ancillary Systems
  - TMS, Measurement Uncertainty
  - Standards & Specifications

### Electrical Systems & Software
- Data Acquisition
- Instrumentation & Signal Conditioning
- Controls & Simulation
- DACS Lab Management
- Data Systems Management
- Ancillary Systems/Electrical Power

### Systems Analysis & Modeling
- Modeling and Analysis development and integration into RPT
- Fluid Mechanics/Thermal Analysis of Propellant Systems
  - Liquid
  - Gas
- CFD
- Structures/Loads Analysis
- Thermal/Heat Transfer Analysis

### Organization Goal:
- **Develop and maintain propulsion test systems and facilities engineering competencies**
  - Unique and focused technical knowledge across respective engineering disciplines applied to rocket propulsion testing. e.g.,
    - Materials selection and associated database management
    - Piping, electrical and data acquisition systems design for cryogenic, high flow, high pressure propellant supply regimes
    - Associated analytic modeling and systems analysis disciplines and techniques
    - Corresponding fluids structural, thermal and electrical engineering disciplines
  - Configuration Management
  - Records Retention DB Management
Integrated Facility Simulation and Analysis

• To Support Propulsion Testing, SSC Has Developed & Implemented Analytic Modeling & Simulation Tools
  – Rocket Propulsion Test Analysis (RPTA) Model (FORTRAN) Used to Simulate Propulsion Test Facility Systems (e.g., LOX Run System)
    ✓ Heritage of Model Dates to Pressurization and Propellant Systems Design Tasks for Space Shuttle and X-33
    ✓ Model Adapted, Validated and Currently Used at SSC to Simulate Facility Pressurization and Propellant Systems
  – Computational Fluid Dynamics (CFD) Used for Select Propulsion Test Situations
  – Have Experienced Analysis Team that Routinely Solves Pressurization and Propellant System Problems

• Integrated Facility Simulation and Analysis Has Led to Substantial Project Cost and Schedule Savings
D&A Capability Development

Strengthening Engineering Competencies
- Structural Analysis
- Control Systems design/development
- Thermal Analysis/Heat Transfer
- Fluid Mechanics specific to RPT

Analysis Tool Suite Growth
- Structural Analysis
  - ANSYS/CFX
- Purge systems design and analysis
  - Flowmaster
- Structural Heat Transfer/Thermal Analysis
  - SINDA
- Piping system modal analysis
  - Autopipe

Data Analysis Process Improvements
- Design & Data Management System
  - Record Retention System
  - Drawing Tree Development
  - Pro/E model MSK capability
    - A CM enhancement opportunity
- Wider access to analytic models
  - PSME Project
    - GUI
    - Server Access
- Internal Technical Reviews

SSC Design & Analysis Division
- RPTA Model
- CFD Crunch/FDNS
- MathCad/Excel Models

Comprehensive Test Site Engineering Support
- A,B & E Stand Modeling & Analysis
  - J-2X, A3, Subscale Sim, Steam Gen Projects
- Operations Support
  - Test stand activation & test
- Facility Operations Support, e.g.,
  - LO2 Barge Impeller Structural Margin Def.
  - A1/A2 LH2 Vent Duct Rupture Invest, and Resolution
  - HPGN system redesign
  - HP Air System Contamination
  - LH2 Sphere Bypass Design
  - UT inspection of B Stand HP Water Deluge Sys

Expanding Beyond SSC E-Complex
- Ares US Propellant Tank Operations Performance Analysis Support to MSFC
- PBS B2 Test Stand Design
- RS-68 Test vs Flight Performance
- LSAM (JSC) & CEV SBT (GRC/NESC)
Integrated Facility Simulation and Analysis

- Analytic Tools Available for Propulsion Test Facility Modeling & Analysis
- Comprehensive Propellant System Thermodynamic Modeling & Test Simulation

Integrated Performance Modeling Capabilities Substantially Improves Understanding & Knowledge of Test Systems Performance that has Translated to Efficient Test Facility Design, Activation & Test Operations

System Design

Modeling

Test and Data Analysis

Integrated Facility Simulation and Analysis

先进流体系统模型化与分析
Rocket Propulsion Test Analysis (RPTA) Model

- Temporal Transient Thermodynamic Modeling of Integrated Propellant Systems
- Thermodynamic Control Volume Solver Model Accurately Models High-Pressure Cryogenic Fluids and High-Pressure Gaseous Systems. Model Features Include:
  - High-Fidelity Pressure Control Valve (PCV) & Closed Loop Control System Model
- RPTA Model Validated Through Test Data Comparisons
  - IPD Fuel Turbopump, RS-84 Sub-Scale Pre-Burner, RS-83 Pre-Burner Cold Flows, SSME Flowliner Activation & IPD Engine System

Pressure Control Valve (PCV) Model Developed & Validated

A Significant Advantage of the RPTA Model is the Coupling of Control Logic (Electro-Mechanical Process) with Thermodynamic Processes
Comprehensive & Rapid Piping System Design & Analysis Capability

- Commercial Tools Employed to Augment Analysis
- Example: *FlowMaster* Piping System Analyzer
  - Allows for Steady-State or Transient Analysis, Compressible or Non-Compressible Flow
  - Includes Heat Transfer, Flow Balancing, Priming & Sizing Analysis

Water Hammer Effect Due to Rapid Closure of Main Fuel Valve

Propellant Flow to Test Article Due to Rapid Opening of Main Fuel Valve
Facility Activated and Test Performed

- Liquid Methane (LM) & Liquid Oxygen (LOX) Propellants Used
- Facility Model Results and Facility Test Activation Results Agree Well
- Test Capability: ~25 seconds

LM System Schematic
14” Valve
ANSYS Workbench Thermal Simulation

Geometry Description
- Pro-E Solid Model
- NIST / MIL-HDBK Temperature Dependent Material Properties

Analysis Model
- 3-D ANSYS Finite Element Model: 275,000 Nodes, 185,000 Elements
- Empirically Based Temperature Dependent Boundary Condition Parameters

Loads & Boundary Conditions
- Radiation
- Natural Convection
- Boiling Convection

Validated Results
- Measured Steady-State Frost Line
- Predicted Steady-State Frost Line
- Measured Valve Heat Load: 9308 BTU/Hr
- Predicted Valve Heat Load: 9315 BTU/Hr
- Von-Mises Stress
- Total Deformation
- Deformation @ 89X

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Measured Valve Heat Load: 9308 BTU/Hr
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Computational Fluid Dynamics (CFD) Modeling

Employed CFD Code to Model E-1 High Pressure LOX Flow Capability

- CFD Investigations Indicate Pressurizing Gas Diffuser Flow Significantly Limits Flow Duration for High Flow Rate Cases

Analysis Boundary Conditions

- HP LOX Tank at E-1 Test Stand
- Flow Case Assessed
  - 2500 lb/sec LOX Discharge Rate
  - 8400 psi Tank Pressure Maintained During Propellant Discharge

Results & Observations

- GN Convective Mixing with LOX Propellant is Substantial
  - Only 50% Loaded LOX is Useable (<~2% N₂ Concentration)
- LOX Propellant Supply at Assessed Flow Rate & Pressure Limited to Approximately 4 seconds (vs an Estimated 10 seconds Determined Using Nominal Facility Pressurizing Gas & Propellant Supply Limits)
Advanced CFD Capability

• Employ CFD Techniques to Support Propulsion Testing in the Following Areas:
  – Cryogenic Propellant Delivery Systems (e.g., Run Tanks, Piping)
  – Cryogenic Control Devices (e.g., Valves)
  – Plume Modeling

• Dedicated Computational Cluster (48 Dual Processors) at NASA SSC

Computational Results of Conceptual Ares 5 Stage Test at SSC B-2 Test Stand

ARES I

Computational Results of J-2X Altitude Diffuser Simulation (300 K-lbf)
• CFD data was used to support parallel efforts in the experimental plume diagnostics and line-by-line spectral radiation analysis.
Summary

• SSC has Developed a Suite of Effective Analytic Modeling and Analysis Tools Providing High Fidelity Assessment of Test Stand Performance
  – Rocket Propulsion Test Analysis (RPTA) Model, a 1-D Propellant System Analyzer
  – CFD Applied to Select Propulsion Test Situations
  – Finite Element Analysis (ANSYS/CFX)
• Analytic Tools Exercised Regularly on a Variety of Propulsion Test Projects by Experienced Analysts
  – Active Test Facilities (1.0 to 1.5 Mlbf Thrust, 8500 psi LOX/LH/RP-1 Supply)
  – Active Test Projects (e.g., J-2X PPA & Engine, A-3, Chemical Steam Generator)

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Liquid Propellant System Modeling

NASA Stennis Space Center (SSC)
Engineering & Test Directorate (ETD)
Design & Analysis Division
January 21, 2009
Liquid Propellant System Modeling

**Summary**

**Background**

- The Rocket Propulsion Test Analysis (RPTA) Model is an effective analytic modeling and analysis tool providing high fidelity assessment of propellant system performance.
  - RPTA adapted from a model originally developed for Shuttle & X-33 propellant system performance analyses.
  - RPTA model application:
    - Used extensively for:
      - SSC propellant system analysis (e.g., J-2X PPA, A-3, Chemical Steam Generator (CSG)) facility development, activation.
      - Test and facility maintenance and upgrades investigations, studies and trades.
      - Recently used for systems sizing and operations performance analysis of the LOX and LCH4 tanks for the Lunar Surface Ascent Module Team Study (May 2007).
      - Currently being employed to evaluate propellant load operations and performance of the Ares I LOX & LH tank for MSFC Team (January 2009).
  - A graphical user interface (GUI) developed for the RPTA model to allow ease of use of the model.

**Benefits**

- Propellant system modeling allows for a timely & cost-effective assessment of the propellant system performance.
- Integrated performance modeling capabilities has translated to efficient test facility design, activation & test operations.
Integrated Facility Simulation and Analysis

- Analytic Tools Available for Test Facility/Project Modeling & Analysis
- Comprehensive Propellant System Thermodynamic Modeling & Test Simulation

Integrated Performance Modeling Capabilities Substantially Improves Understanding & Knowledge of Test Systems Performance that has Translated to Efficient Test Facility Design, Activation & Test Operations

System Design

Test and Data Analysis

Fluid System Modeling

GH2 Activation Test
June 29, 2004

UHP Bottle Pressure
Mixer Pressure
Interface Pressure

Advanced Capabilities in CFD Modeling & Analysis

20 mph Wind

Distance from Discharge (ft)

0 100 200 300

TIME SECONDS

0 1000 2000 3000 4000 5000 6000 7000

UHP Bottle Pressure
Mixer Pressure
Interface Pressure

204 208 212 216 220

Distance from Discharge (ft)

0 100 200 300 400 500 600 700

TIME SECONDS

0 1000 2000 3000 4000 5000 6000 7000

UHP Bottle Pressure
Mixer Pressure
Interface Pressure

204 208 212 216 220

Distance from Discharge (ft)

0 100 200 300 400 500 600 700

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UHP Bottle Pressure
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Distance from Discharge (ft)
Rocket Propulsion Test Analysis (RPTA) Model

- Temporal Transient Thermodynamic Modeling of Integrated Propellant Systems
  - Thermodynamic Control Volume Solver Model Accurately Models Cryogenic and Storable Propellant and High-Pressure Gaseous Systems.
    - Includes High-Fidelity Pressure Control Valve (PCV) & Closed Loop Control System Algorithms
- Model Validated Through Numerous Test Data Reconstructions
  - J-2X PPA-1A, IPD Fuel Turbopump, RS-84 Sub-Scale Pre-Burner, RS-83 Pre-Burner Cold Flows, SSME Flowliner Activation & IPD Engine System

Pressure Control Valve (PCV) Model Developed & Validated

A Significant Feature of the RPTA Model is the Coupling of Control Logic (Electro-Mechanical Process) with Thermodynamic Processes
RPTA Model GUI Development

Background

• The RPTA Model provides focused and detailed analysis of a propellant system, from a single propellant tank to an integrated propellant system that includes
  - Propellant Tank
  - Facility Propellant Storage Tank
  - Pressurant Supply and System Control
  - Propellant Feed System
  - Test Article Simulation

• Requires a substantial amount of data defining boundary and initial conditions that requires esoteric knowledge of the model’s data file structure and the model’s code not required of the typical user
  - Following is a quick view of the model parameter data sets involved
Propellant Systems Modeling Environment

PSME
GUI interface Significantly Simplifies Model Set-up

- Pressurant Tanks
- Pressurant Cooling Valves
- Run Tank

Initialization Information:
- Tank Liquid Type: 2
- Initial Run Tank Inner Wall Surface Temperature: 63.9 °F
- Initial Run Tank Uplage Temperature: 63.9 °F
- Initial Run Tank Volume: 216.0 ft³
- Tank Pressure: 156 psi
- Temperature of Tank Liquid: 183 °F

Configuration Information:
- Tank Bottom Area to Tank Liquid Ratio: 0.0023 ft²
- RV Pressure Tube: 6.03 ft³
- RV Tank Liquid Volume: 6.03 ft³
- Change in Volume due to Change in Tank Temp: 0.01 ft³
- Total Tank Volume: 4.00 ft³
- Nominal Tank Pressure: 147 psi
- Nominal Tank Temperature: 163 °F
- Mass of Pressurant Gas in Usage: 31.6 lb

- Run
- View Results
- Save Changes
- View Configuration Files
- MCM Admin
- Exit
Provides Access to All Configuration Data

Model Configuration Files

$DATA
IN_OUTPUT=TANKMDF.DAT
IN_TABLES=TABLES.DAT
LDV=F
LTGE=F
LVOL=F
PFD=0.33,0.33,0.8,0.8,0.33,0.33,0.8,0.33,
WDHEI=0.
!ACOEF=0.09,0.12,0.23,0.1,0.13,0.13,3.70,0.06,
T-bars=0.
!VOLSPH=5611.9765450645
ACOEF=0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
ADIF=0.555
ALT=0.
ATOM=0.0023
BOMAT=3
BUV=0.
CRAD=0.0000000000000384
DGHEBTL=135.282990179341
EGHEBTL=1002.
DIAL=4.04,10.6
DTSDF=0.
DVTT=0.
GMMA=1.4
IGAS=5
PRTHICK=2.25
IN_TABLES='RUNTABLES.dat'
IRTPTLOT=0
LHEAT=F
LPF=F
LSPL=F
MNTTRC=F

OK  Cancel
Model Execution & WinPlot Results
Propellant Systems Modeling Environment
Model Library & Configuration Editor

Interactive Schematic Integration Prototype

Created by SSC RPT
Engineer Expertise;
Predefined Liquid
Propellant Models
for Specific Test
Facilities are Baseline

The Engineer’s Model
Revisions are Managed in a
Familiar Tree Structure Format
Propellant Systems Modeling Environment

Gas Model Support Scheduled in Early 2009

Propellant-Aware, PSME Detects Whether Model Selections are Liquid or Gas and Serves up the Correct Executable and Parameter Editing Screens to the Engineer.

PSME Provides Automated Validation Checking of Parameter Fields with Defined Value Types and/or Min / Max Ranges for Both Liquid and Gas.
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