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

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Mississippi Engineering Society Winter Meeting
Jackson, MS
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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

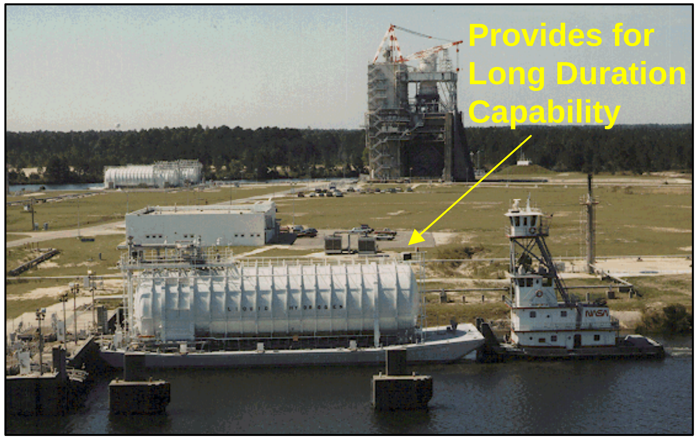
Subscale

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

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

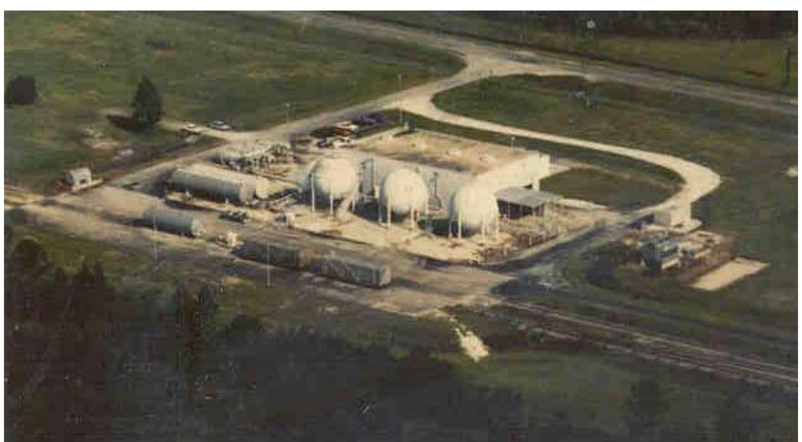
Components …Engines … Stages

SSC Support Facilities



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

<u>High Pressure Industrial Water (HPIW)</u>
330,000 gpm Delivery System



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

<u>Additional Support</u>

- Laboratories
  - ✓ Gas and Material Analysis
  - ✓ Measurement Standards and Calibration
  - ✓ Environmental
- Shops
- Utilities

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

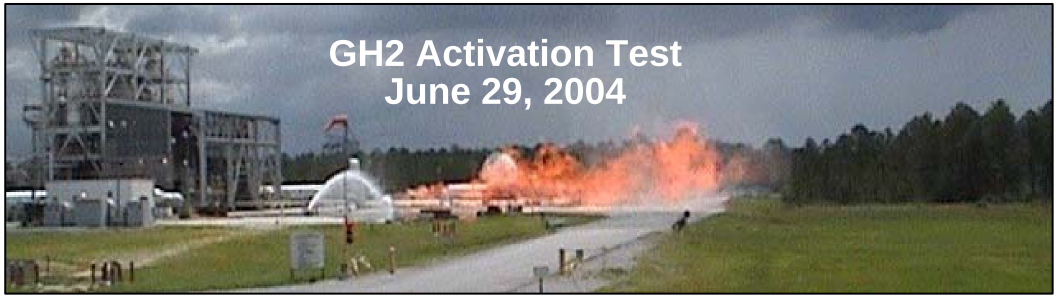
Integrated Facility Simulation and Analysis

- 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

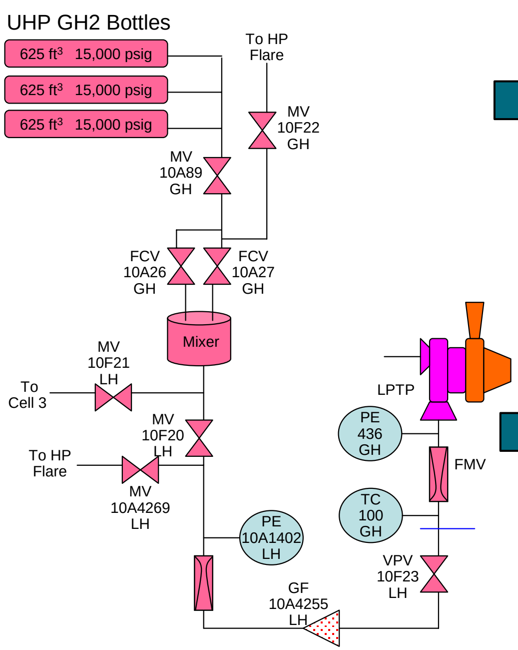
Integrated Performance Modeling Capabilities Substantially Improves Understanding & Knowledge of Test Systems Performance that has Translated to Efficient Test Facility Design, Activation & Test Operations

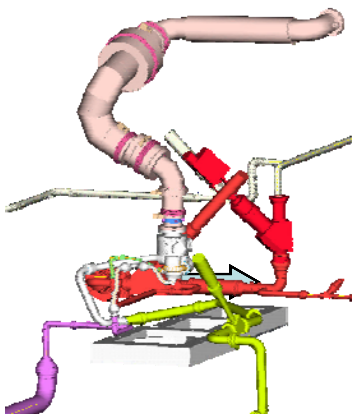


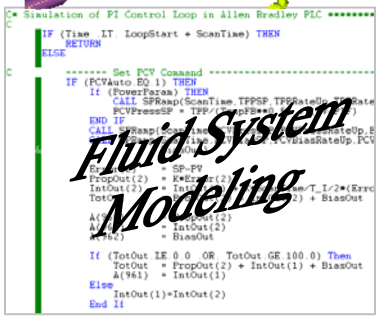
System Design

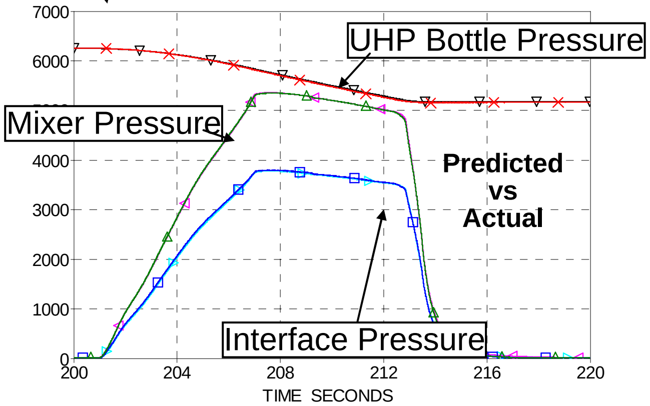
Modeling

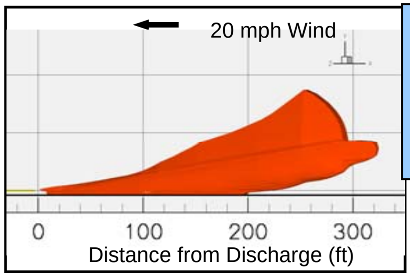
Test and Data Analysis









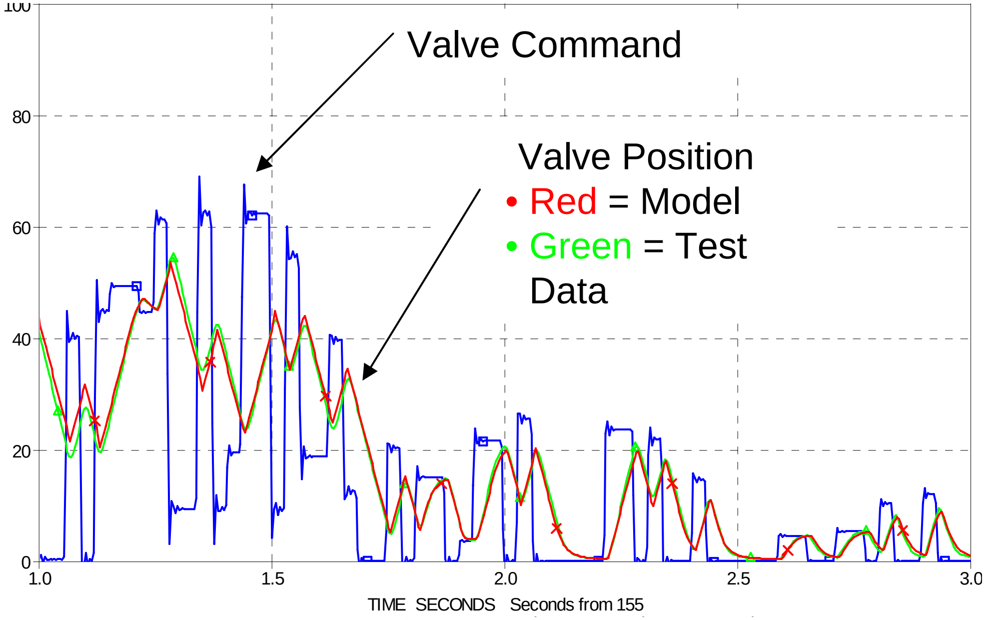


Advanced Capabilities in CFD Modeling & Analysis

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



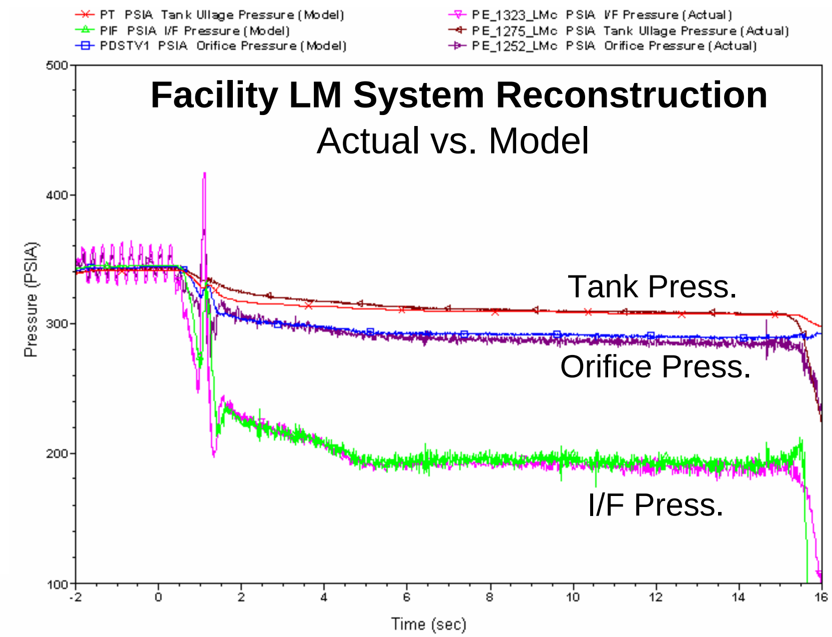
A Significant Advantage of the RPTA Model is the Coupling of Control Logic (Electro-Mechanical Process) with Thermodynamic Processes

Recent LOX/Methane Testing at E-3

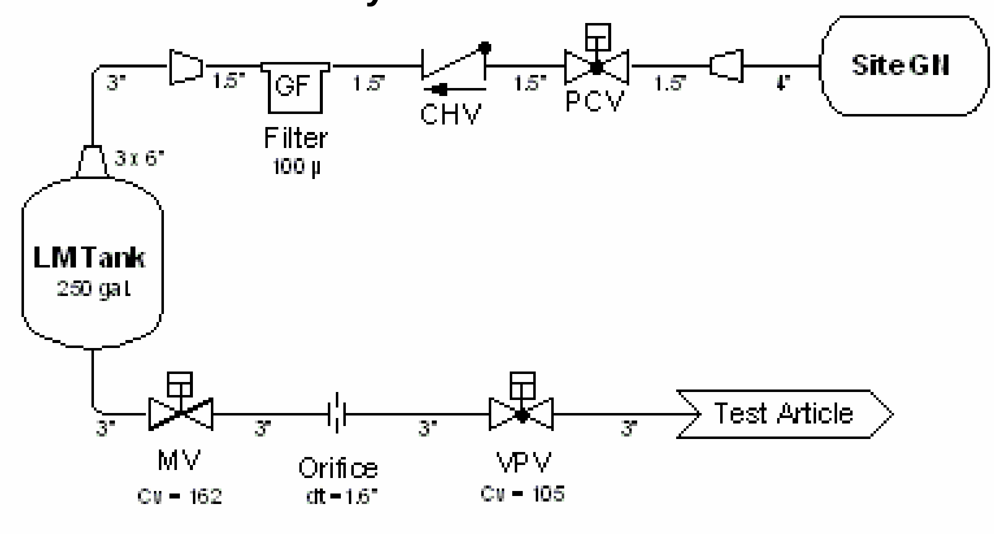
15 klbf Advent Engine Test Program – Nov 06

Facility Activated and Test Performed

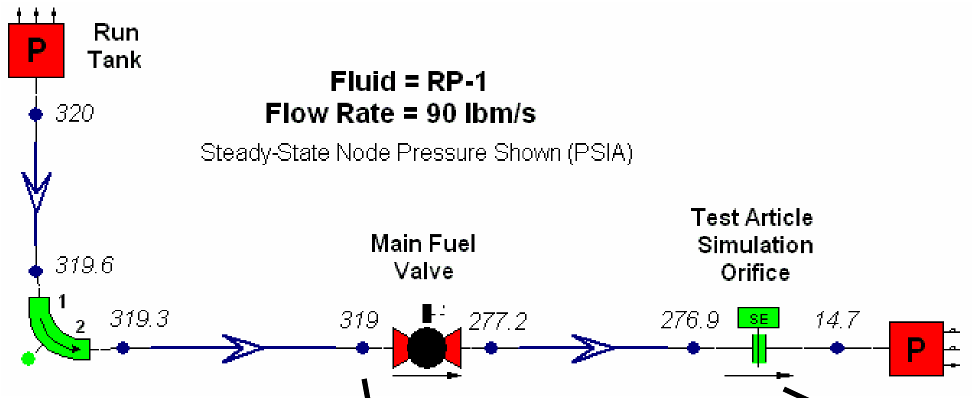
- **Liquid Methane (LM) & Liquid Oxygen (LOX) Propellants Used**
- **Facility Model Results and Facility Test Activation Results Agree Well**
- **Test Capability: ~25 seconds**



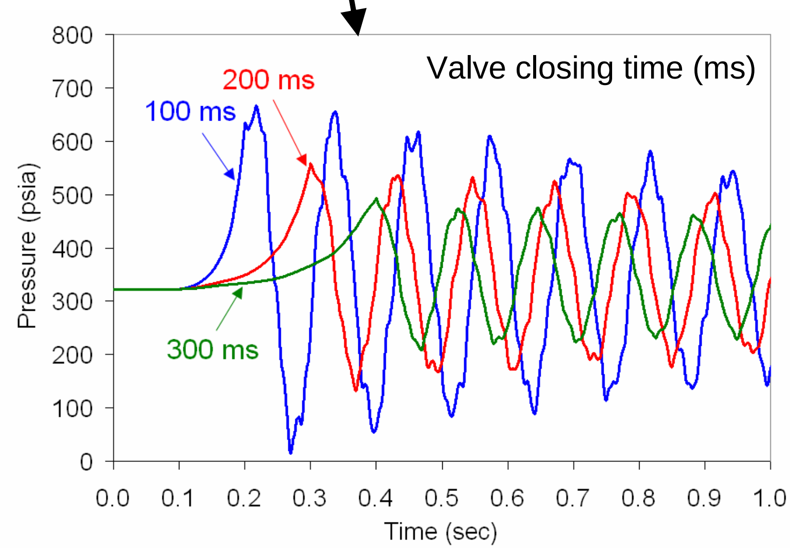
LM System Schematic



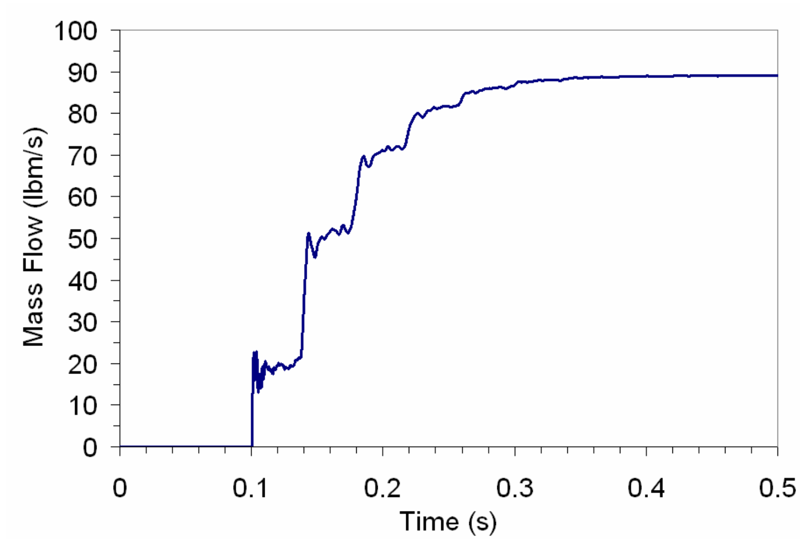
Comprehensive & Rapid Piping System Design & Analysis Capability



- 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



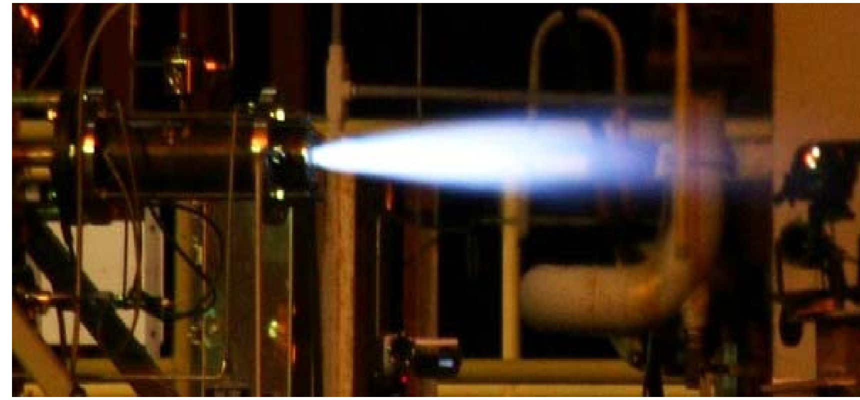
Water Hammer Effect Due to Rapid Closure of Main Fuel Valve



Propellant Flow to Test Article Due to Rapid Opening of Main Fuel Valve

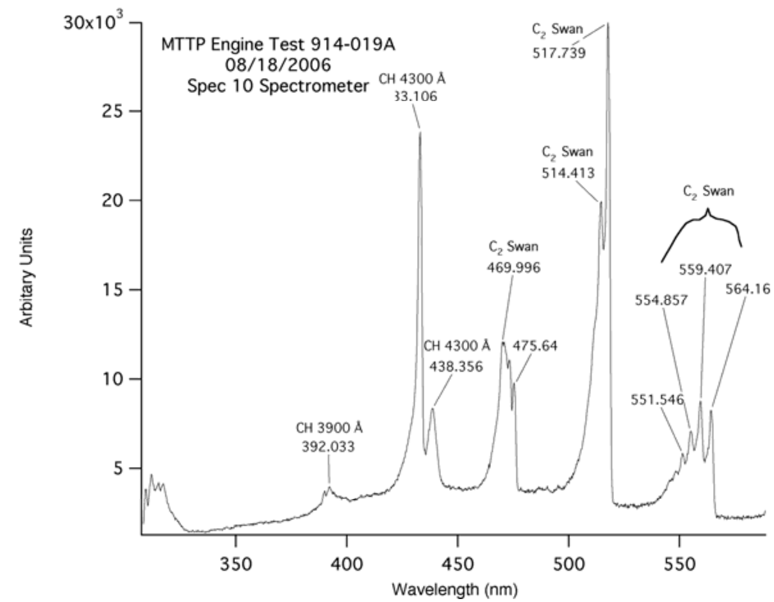
Recent Project: Methane Technology Testbed Project (MTTP)

- 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



Night firing of MTTP thruster

MTTP Test Skid



Exhaust spectrum for GOX/GM combustion

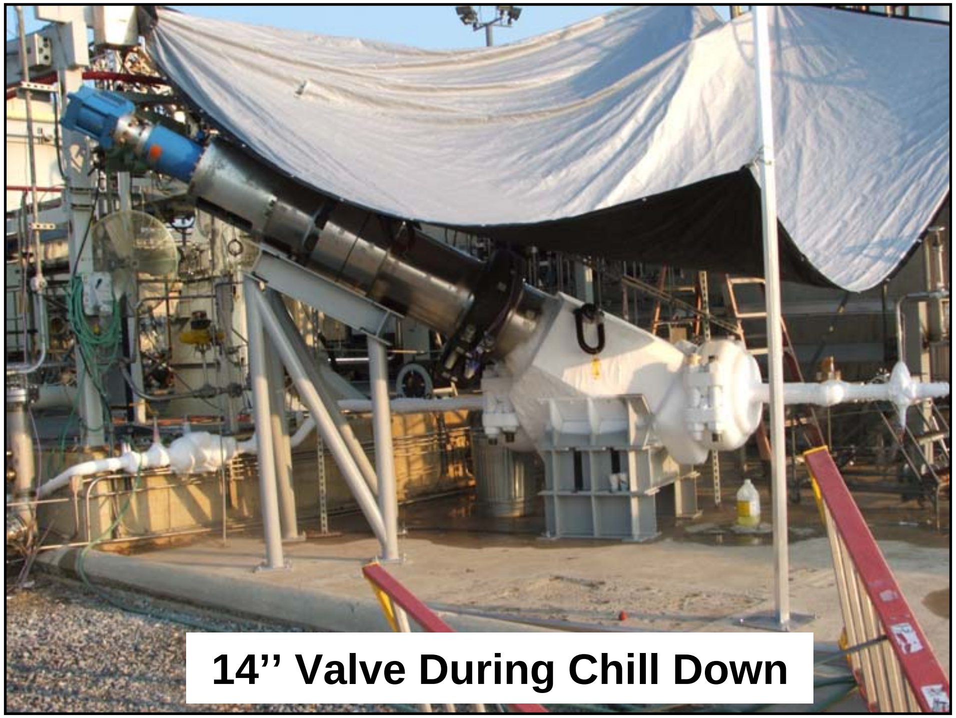
Recent Project: 14'' Valve Test
Description of Test Objectives

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

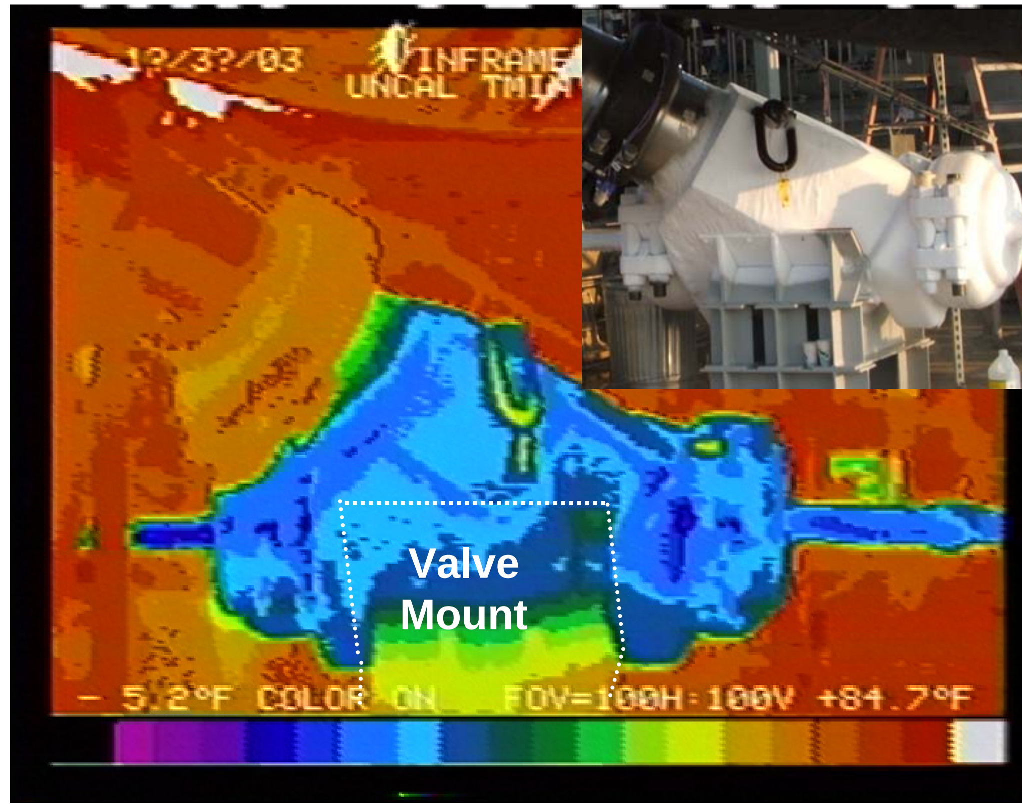
- Conducted Valve Chill Down Test at the E-2 Test Stand
- Used Liquid Nitrogen (LN) to Chill Down the Valve
- Instrumented Valve with Multiple Thermocouples on the Valve Body and Stem
- During Chill Down Operations, the Valve was Cycled Multiple Times to Test Proper Valve Operation at Low Temperatures



14'' Valve During Chill Down

14'' Valve Test Results

Picture of Frost Line After 23 Hours of Chilling



Thermal Image of Valve After Test

Test Results

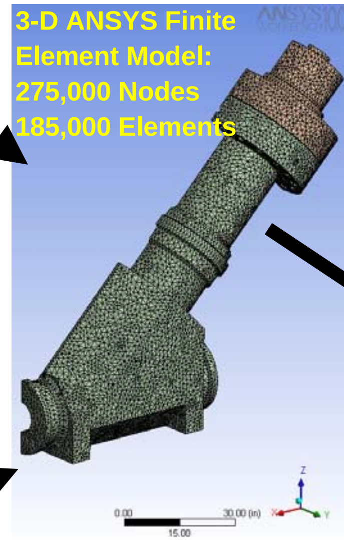
- Test Lasted About 24 Hours
- About 6500 gal of LN Was Used for the Valve to Reach a Steady State Condition
- Boil Off Results Were Used to Calculate the Steady State Heat Load of the Valve

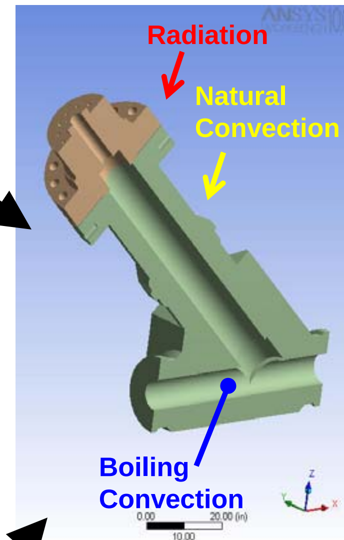
Analytical Accomplishments

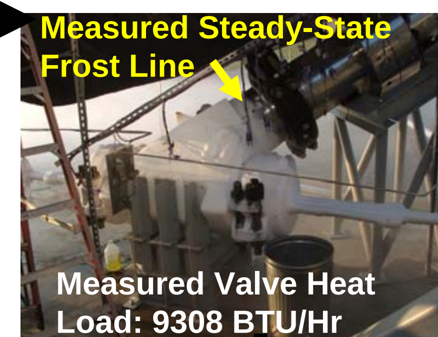
- Identified Issue with Asymmetric Bonnet Wear at Cryogenic Temperatures
- Verified Analytical Predictions for the Heat Load of the Valve
  - Determined the Valve Heat Load
  - Determined the Valve Chill Down Time Constant
  - Test Results Will Be Used to Guide Bonnet Re-Design

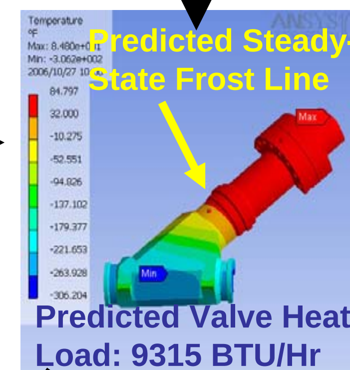
14” Valve
ANSYS Workbench Thermal Simulation

Geometry Description → Analysis Model → Loads & Boundary Conditions → ***Validated Results***

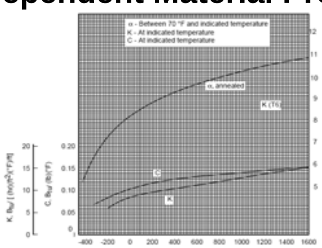


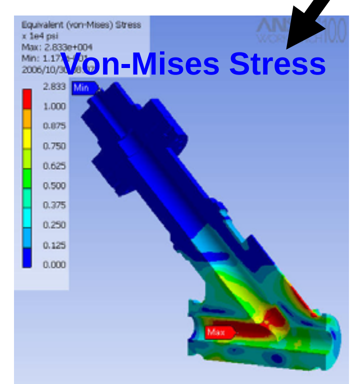


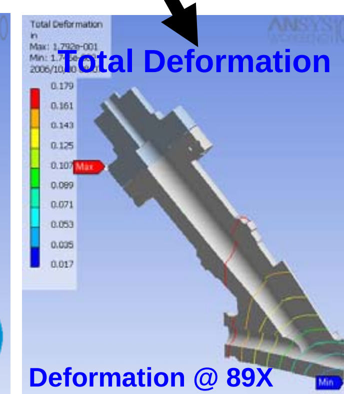




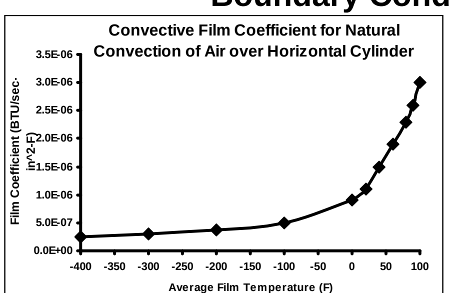
NIST / MIL-HDBK Temperature Dependent Material Properties

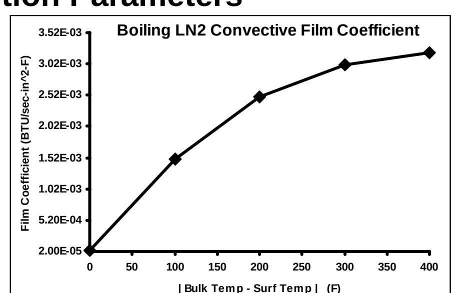






Empirically Based Temperature Dependent Boundary Condition Parameters





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

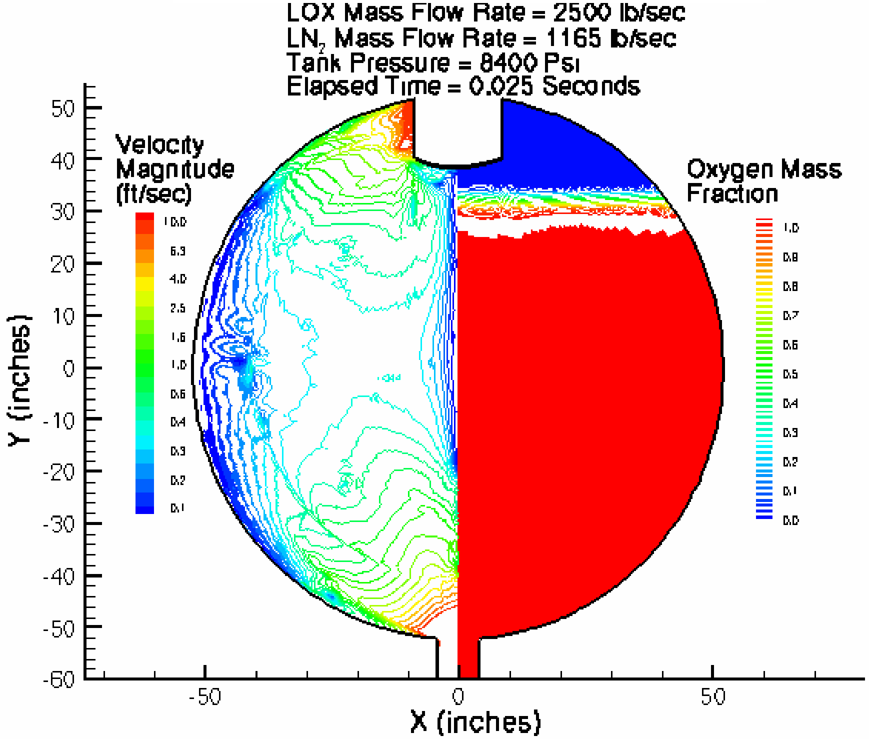
Analysis Boundary Conditions

- 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% N_2 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)

HP LOX Tank Propellant Discharge Simulation



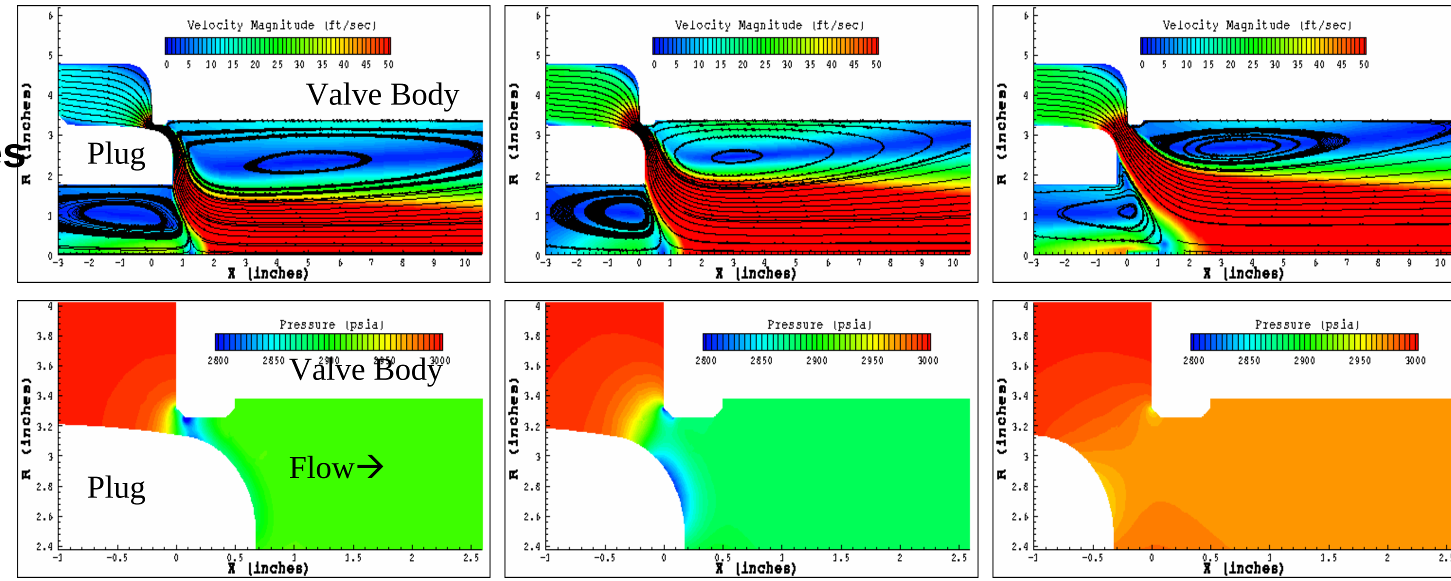
Computational Fluid Dynamics (CFD) Modeling

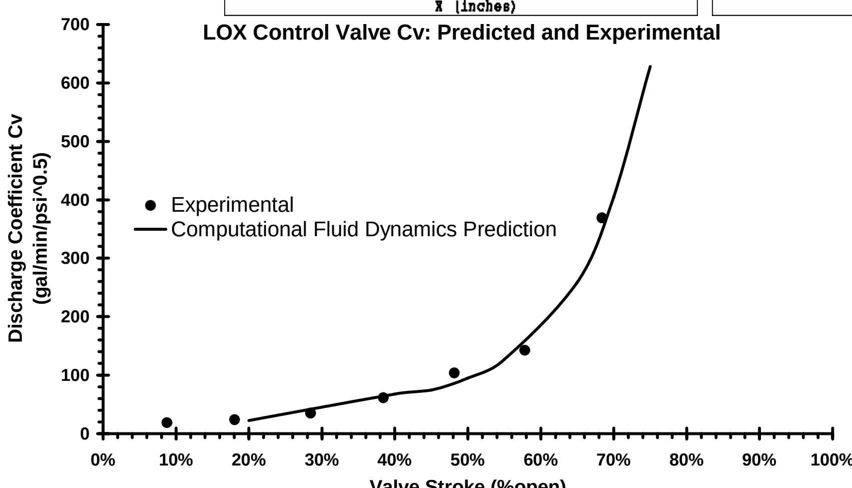
- Understanding a Valve's Flow Capacity (C_v) as a Function of Valve Stroke is Critical When Calculating the Propellant Flow Rates to a Test Article

2.75" Stroke | **3.25" Stroke** | **3.75" Stroke**

Velocity & Streamlines

Pressure





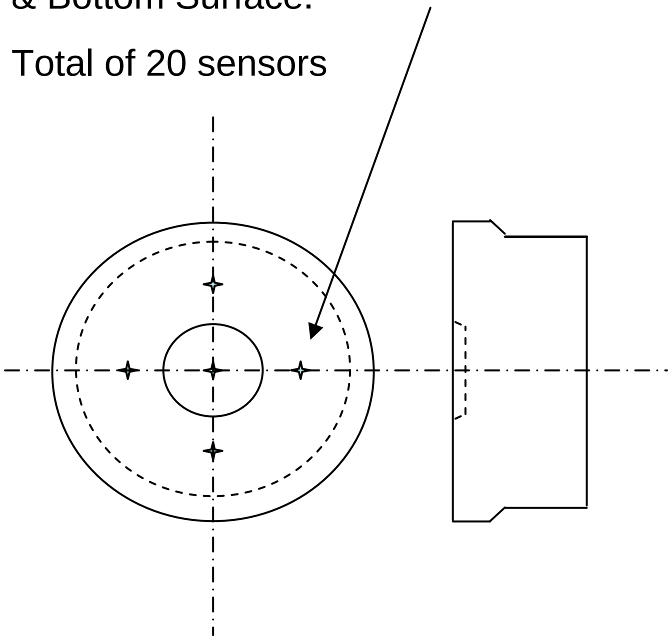
- CFD Used to Predict the Flow Field & C_v Curve for a Modified LOX Control Valve
- Yields a Good Understanding of How the Flow Field Changes as the Valve Opens & Affects C_v curve
- Analysis Reveals Areas Where Cavitation May Occur as Well as Areas of High Velocity That Are Important When the Working 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

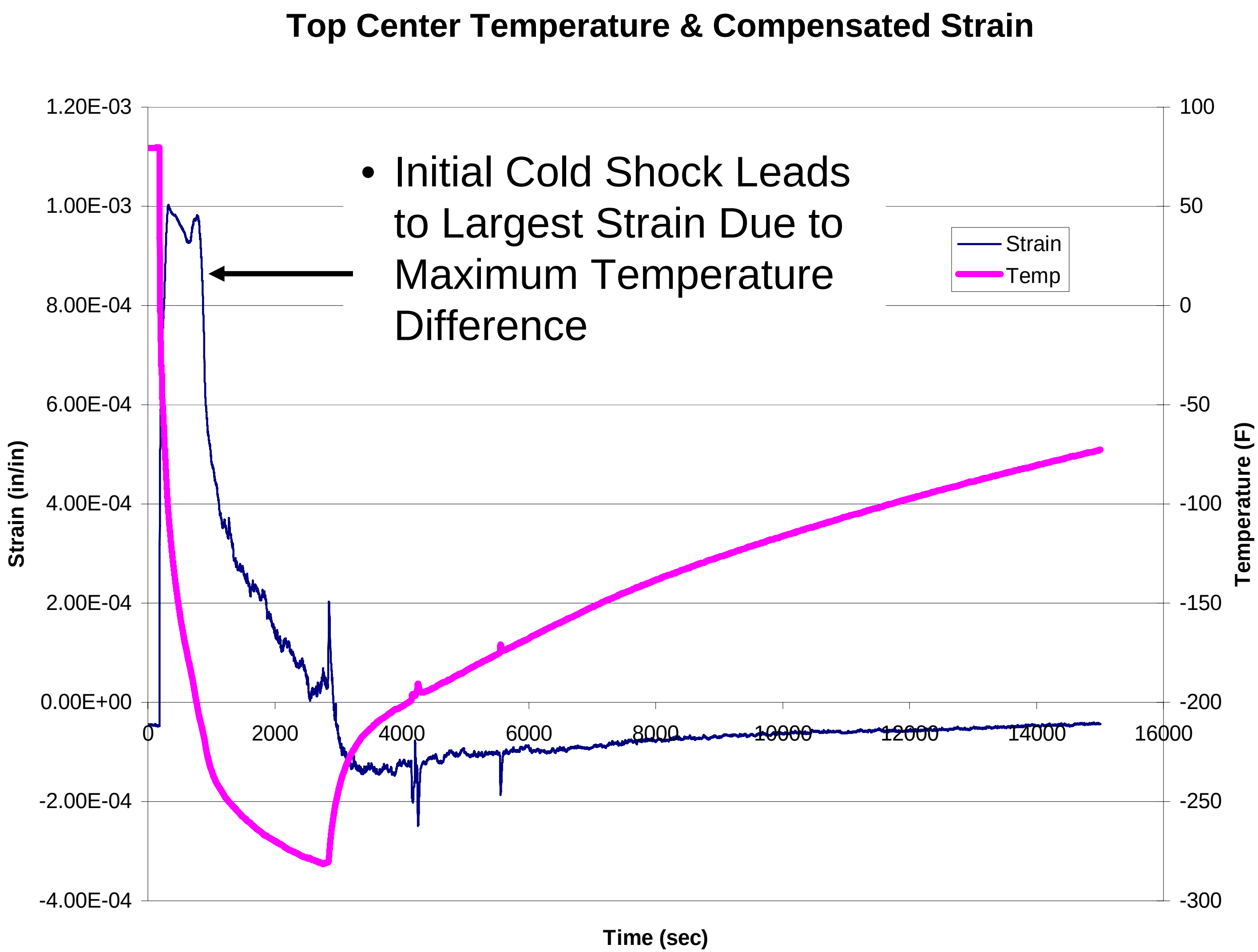


Dye Penetration Testing

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

Thermal Fatigue Considerations



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

<u>For Additional Information/Discussion Please Contact :</u>

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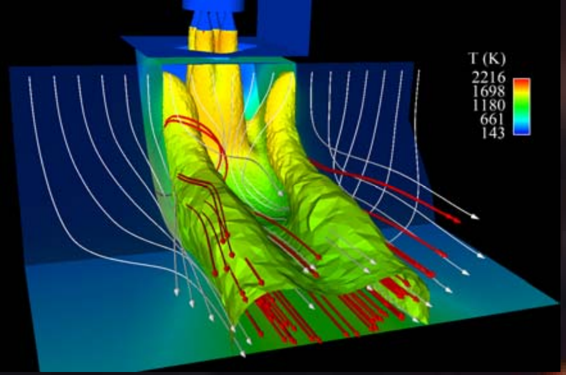
Harry Ryan 228-688-2757, Email: Harry.M.Ryan@nasa.gov



Stennis Space Center Engineering and Test Directorate

David Coote and Harry Ryan
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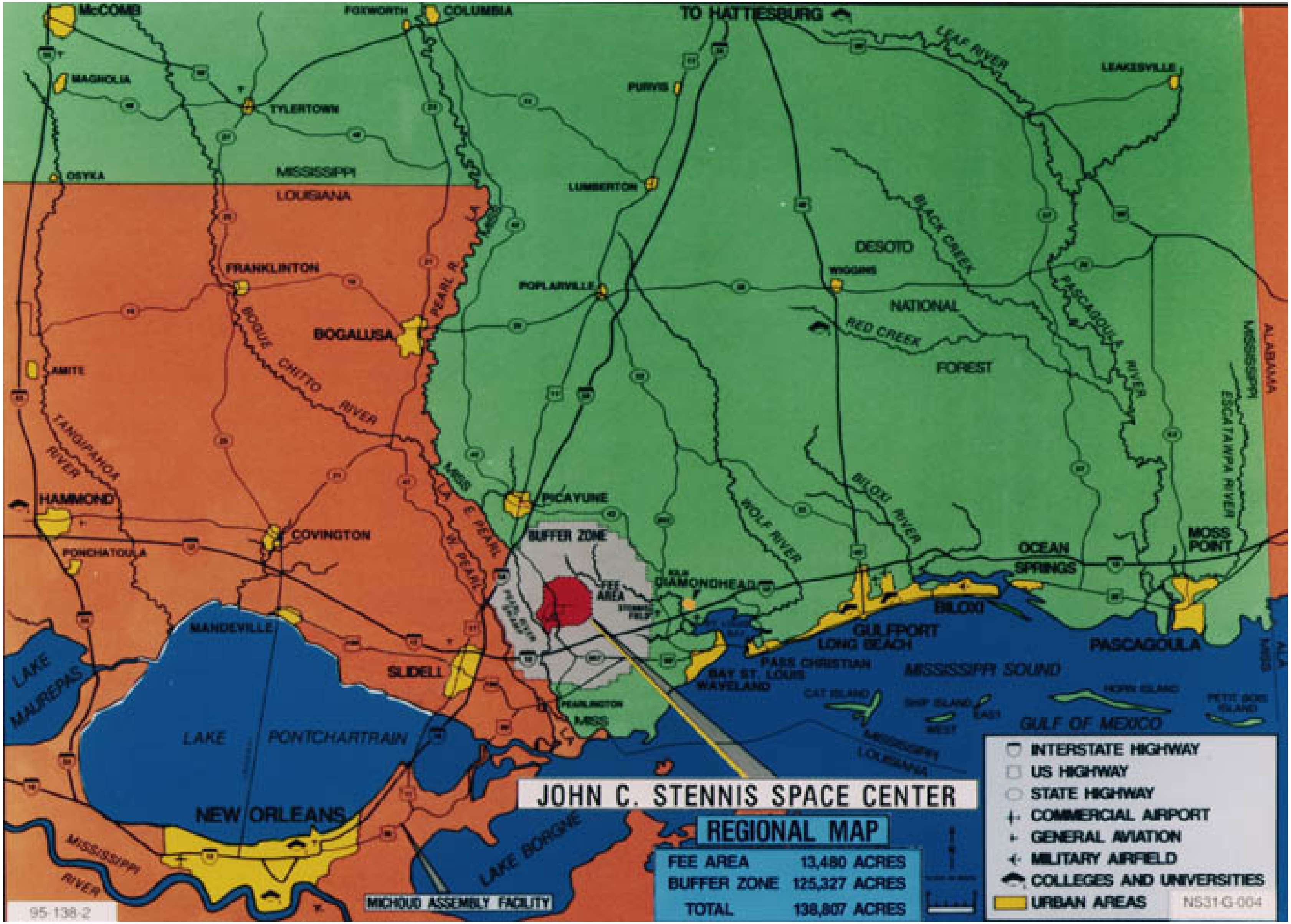
NASA, Stennis Space Center, MS, 39529, USA

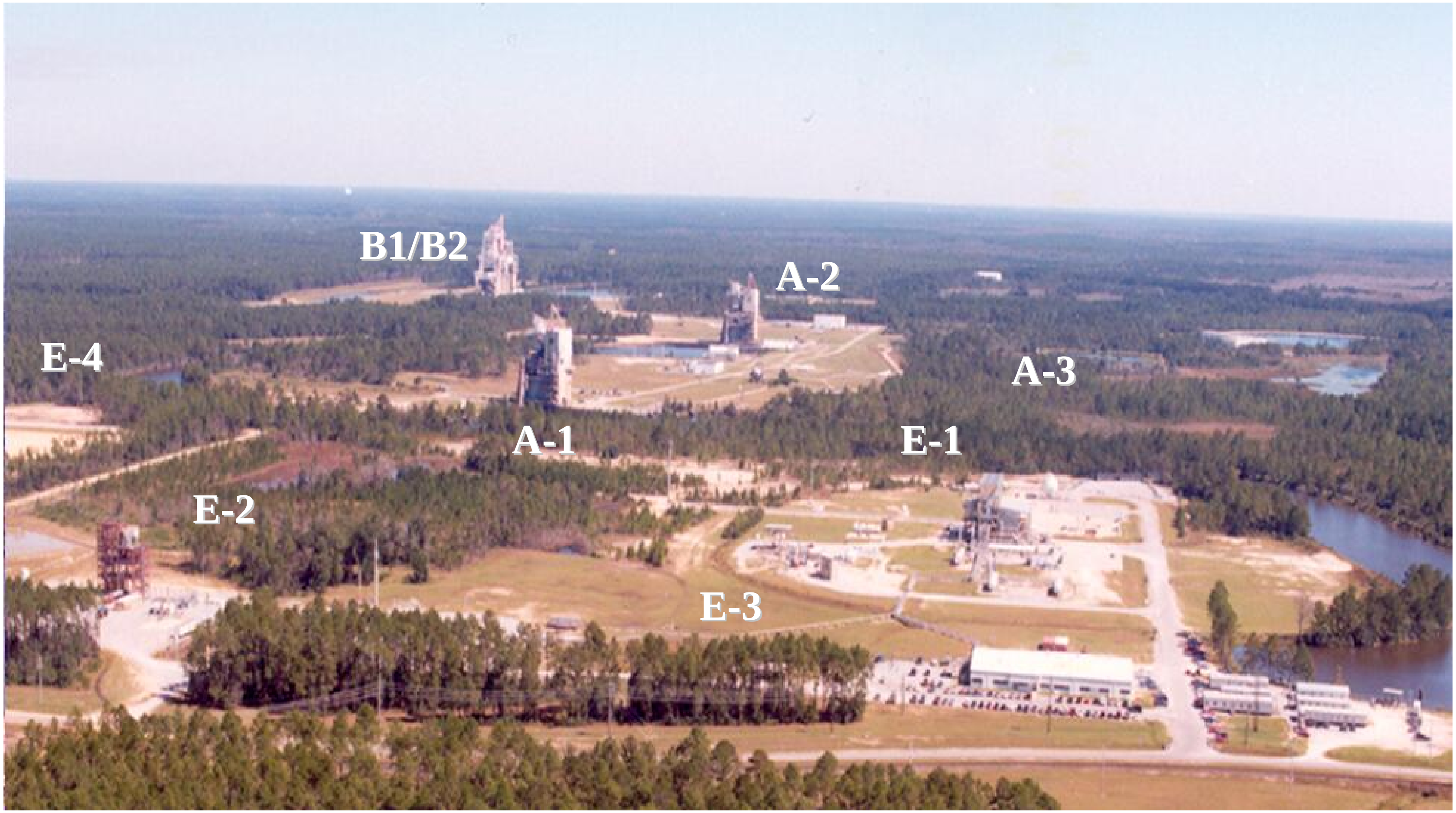
Arnold Association of Professional Societies (AAPS) Luncheon
Tullahoma, TN

January 21, 2009

SSC Regional Map



Facilities & Operations



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

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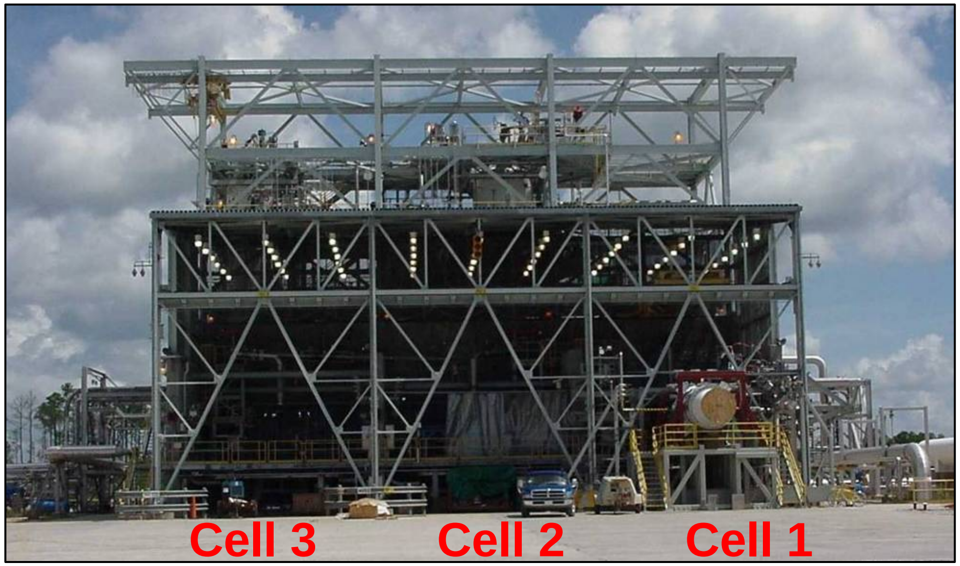
NASA-SSC Test Facilities – E Complex

Component and Engine Testing (E-1)

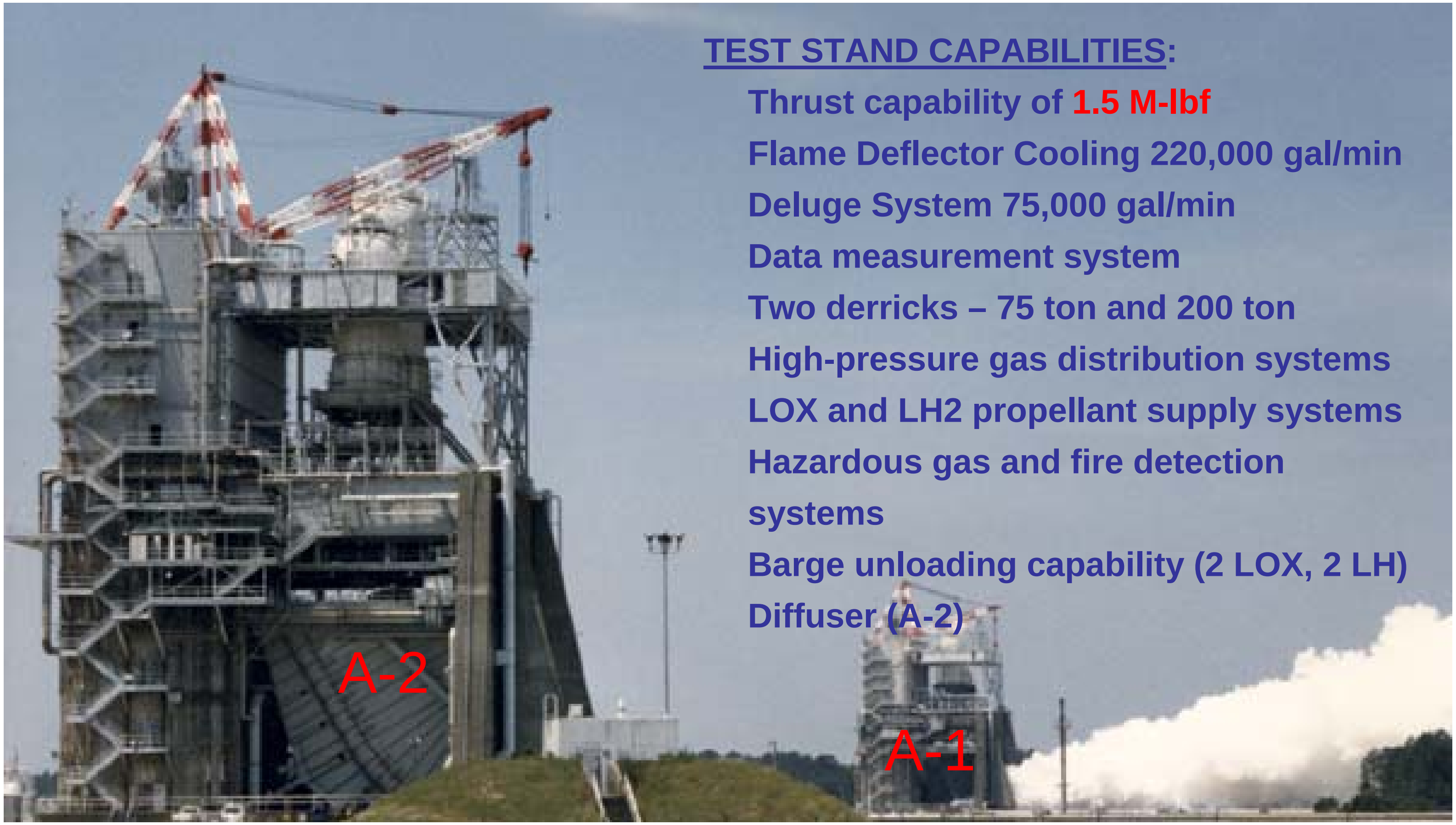


- High Pressure (Long Run) Capabilities
  - LOX/LH/RP ~ 8,500 psi
  - GN/GH ~ 15,000 psi
  - GHe ~ 10,000 psi
- State-of-the-Art DAC Systems
- E-1 Cell 1
  - Primarily Designed for Pressure-Fed LOX/LH/RP & Hybrid Test Articles
  - Thrust Loads up to 750K lb_f (horiz.)
- E-1 Cell 2
  - Designed for LH 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 Test Facilities – A Complex

❑ Full-scale Engine Development & Certification

- Saturn V 2nd Stage J-2 engine (1.15 M-lbf cluster of 5 LH_2/LOX J-2 engines)
- SSME (375 K-lb LH_2/LOX**)** development, flight acceptance, & 65kft altitude (A-2)
- X-33 Aerospike

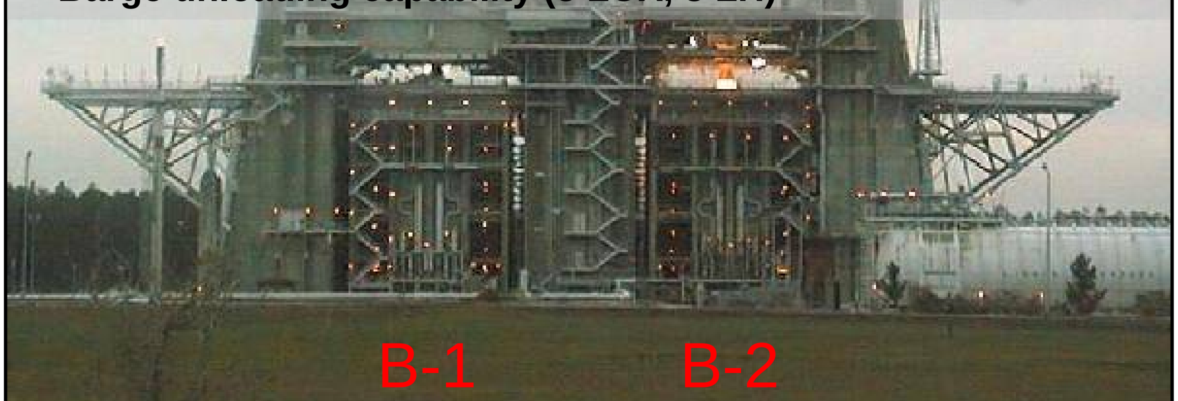


NASA-SSC Test Facilities – B Complex

- **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 LH_2/LOX SSME)
  - Delta IV Common Booster Core (650 K-lbf LH_2/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)



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  - 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

SSC Design & Analysis Division

- RPTA Model
- CFD Crunch/FDNS
- MathCad/Excel Models

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**

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**

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

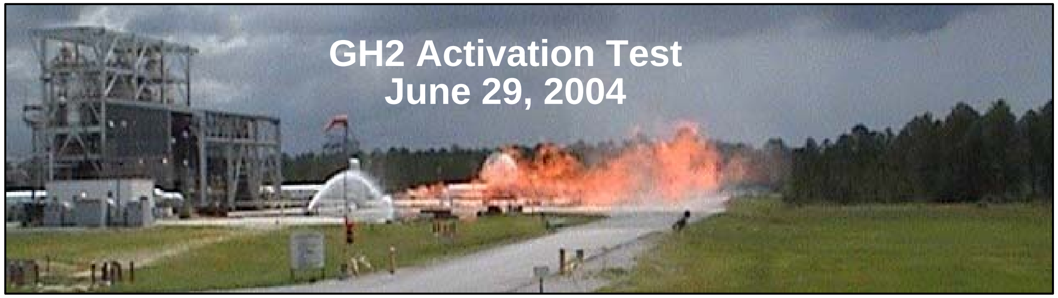
Expanding Beyond SSC E-Complex

- **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

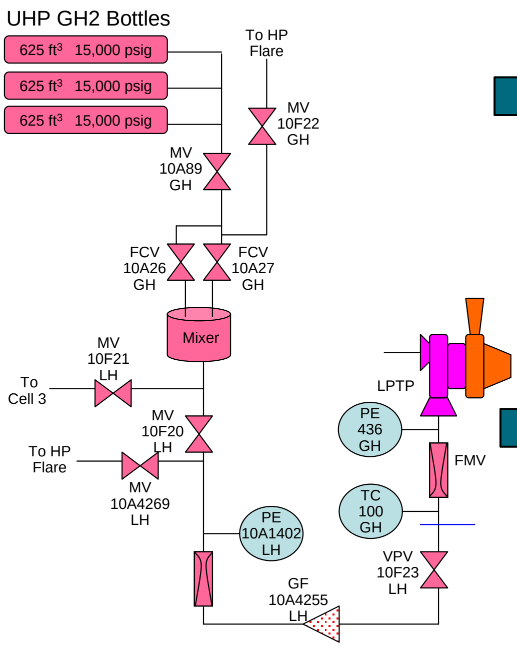
Integrated Performance Modeling Capabilities Substantially Improves Understanding & Knowledge of Test Systems Performance that has Translated to Efficient Test Facility Design, Activation & Test Operations

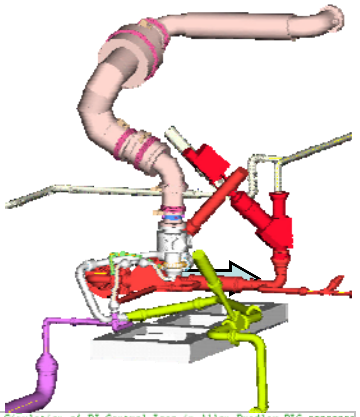


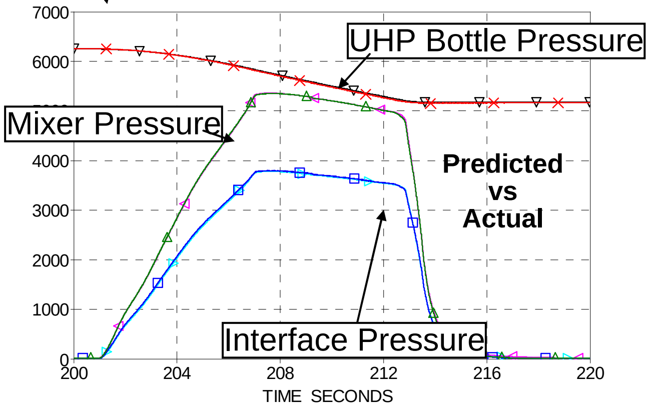
Modeling

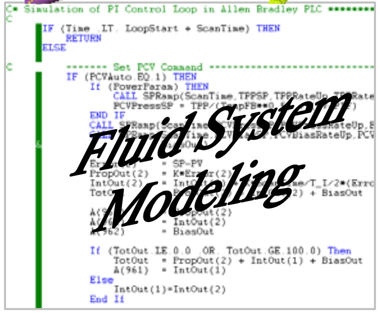
Test and Data Analysis

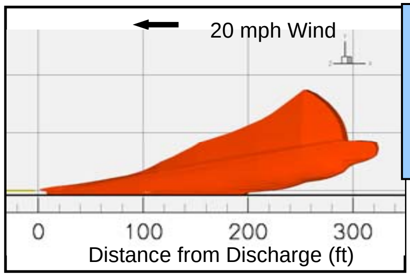
System Design









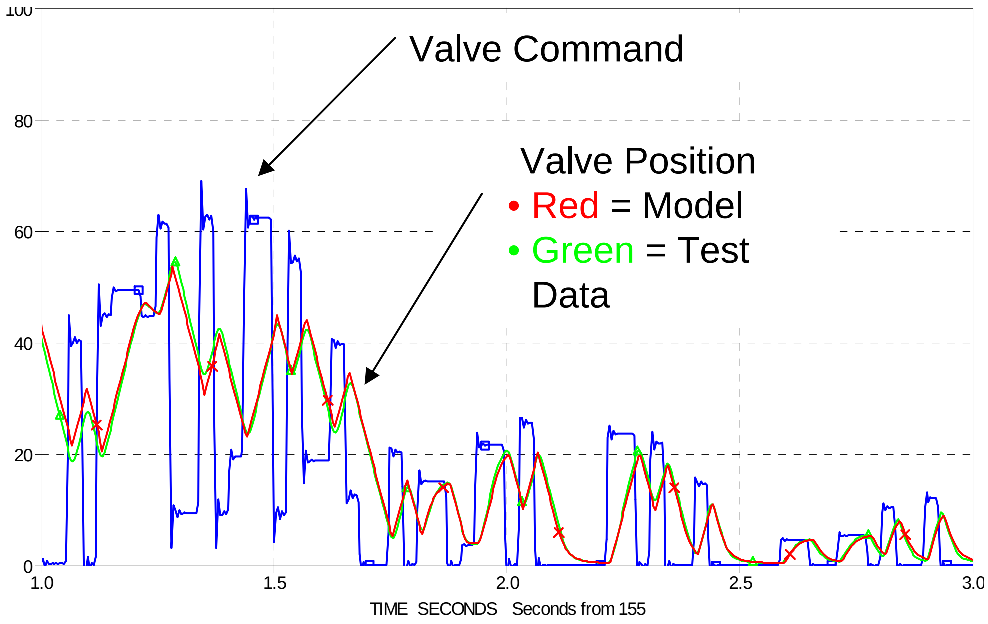


Advanced Capabilities in CFD Modeling & Analysis

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

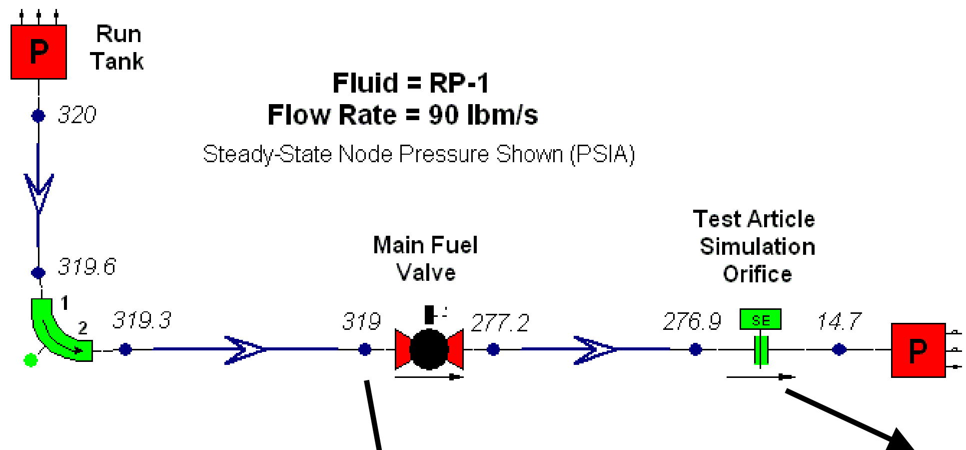


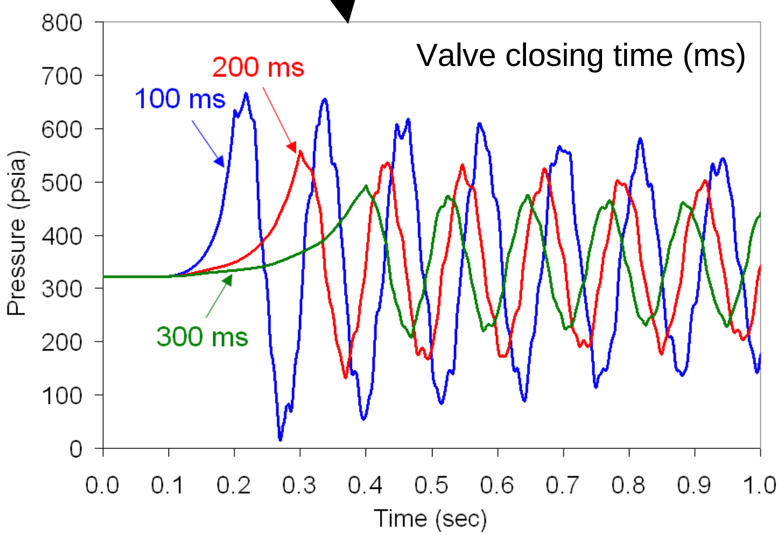
A Significant Advantage of the RPTA Model is the Coupling of Control Logic (Electro-Mechanical Process) with Thermodynamic Processes

9/19/2003

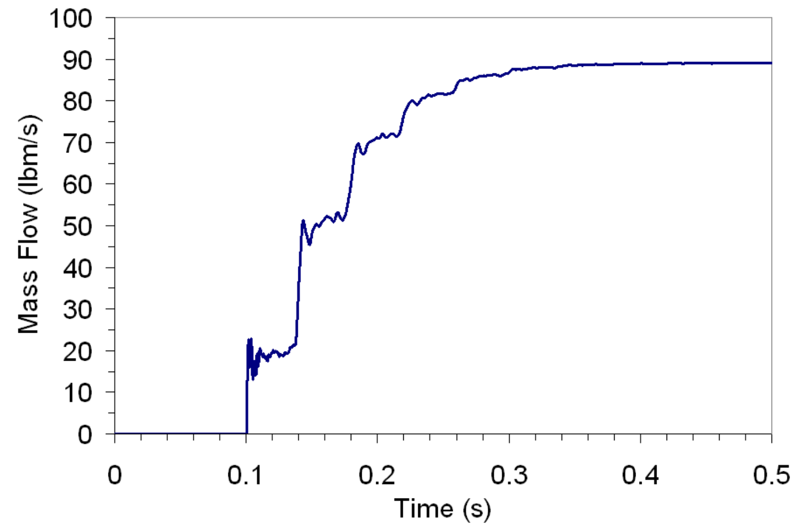
Comprehensive & Rapid Piping System Design & Analysis Capability

- 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



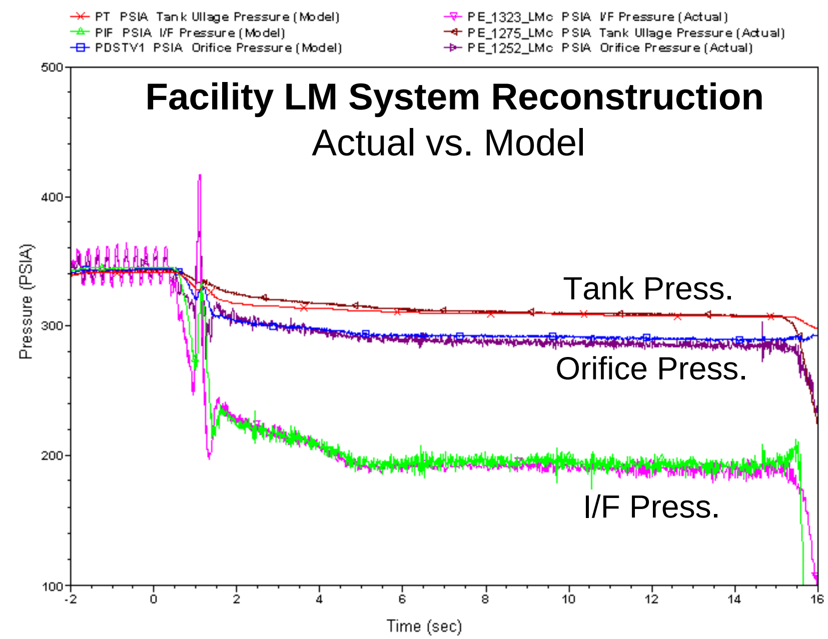
Propellant Flow to Test Article Due to Rapid Opening of Main Fuel Valve

Recent LOX/Methane Testing at E-3

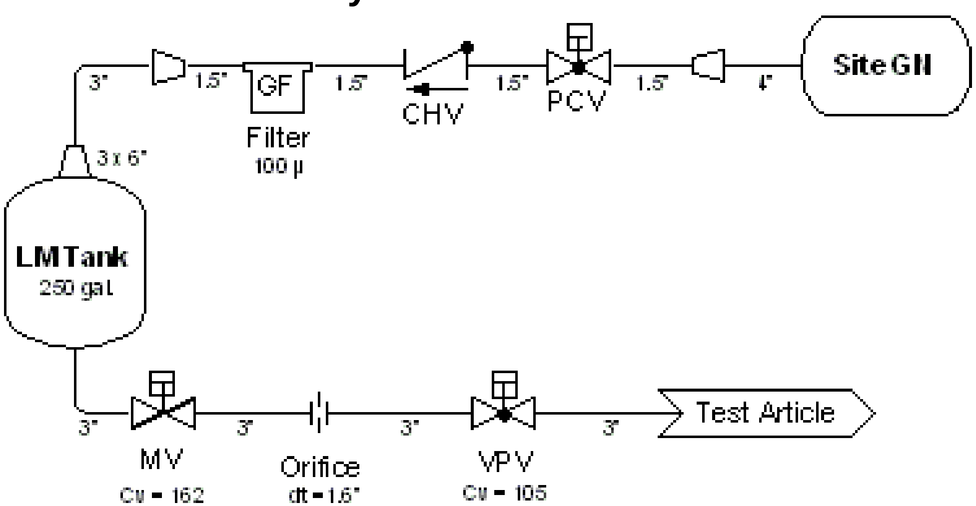
15 klbf Advent Engine Test Program – Nov 06

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



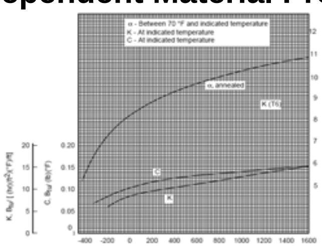
LM System Schematic

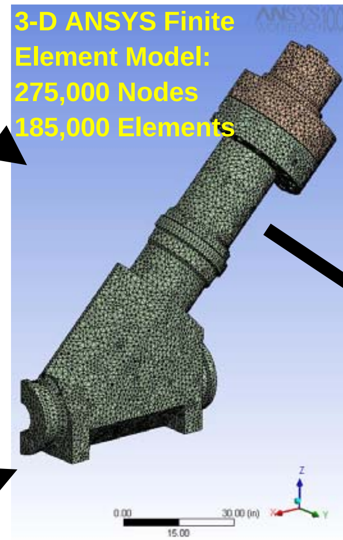


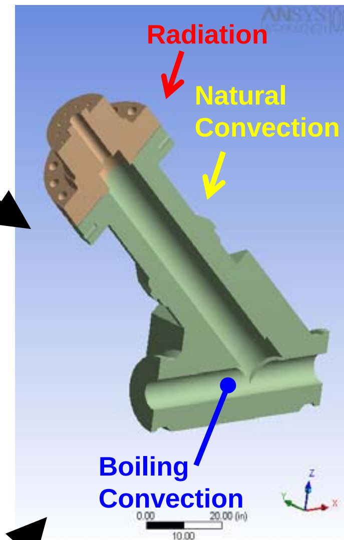
14" Valve
ANSYS Workbench Thermal Simulation

Geometry Description → Analysis Model → Loads & Boundary Conditions → ***Validated Results***

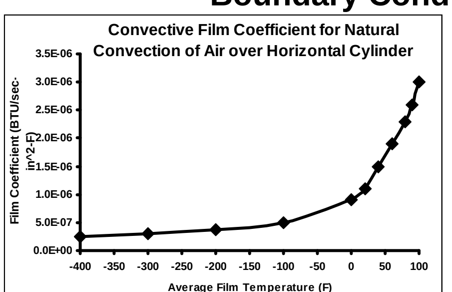
NIST / MIL-HDBK Temperature Dependent Material Properties

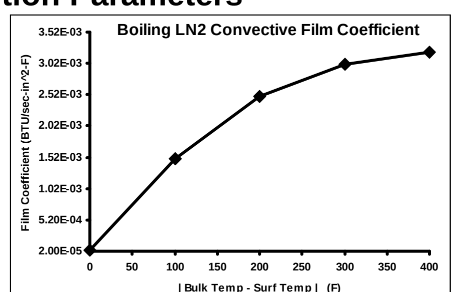


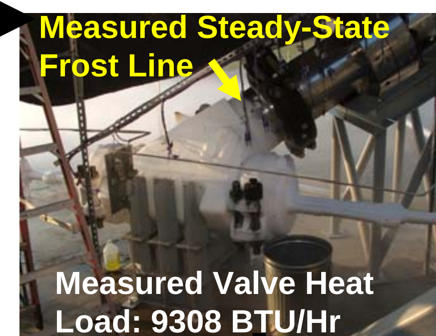


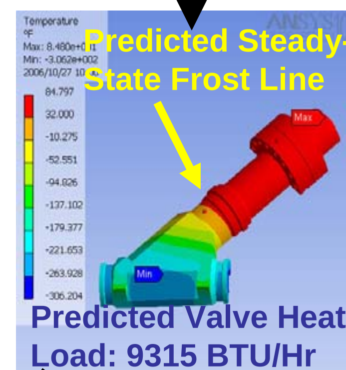


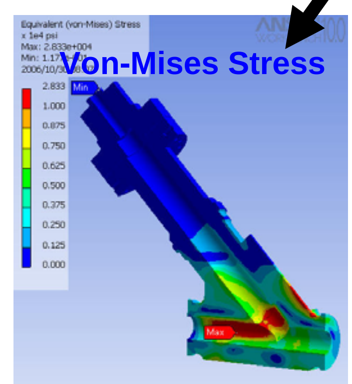
Empirically Based Temperature Dependent Boundary Condition Parameters

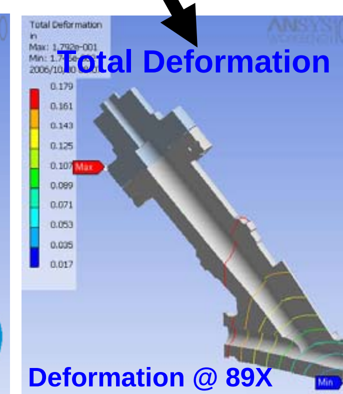












Computational Fluid Dynamics (CFD) Modeling

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

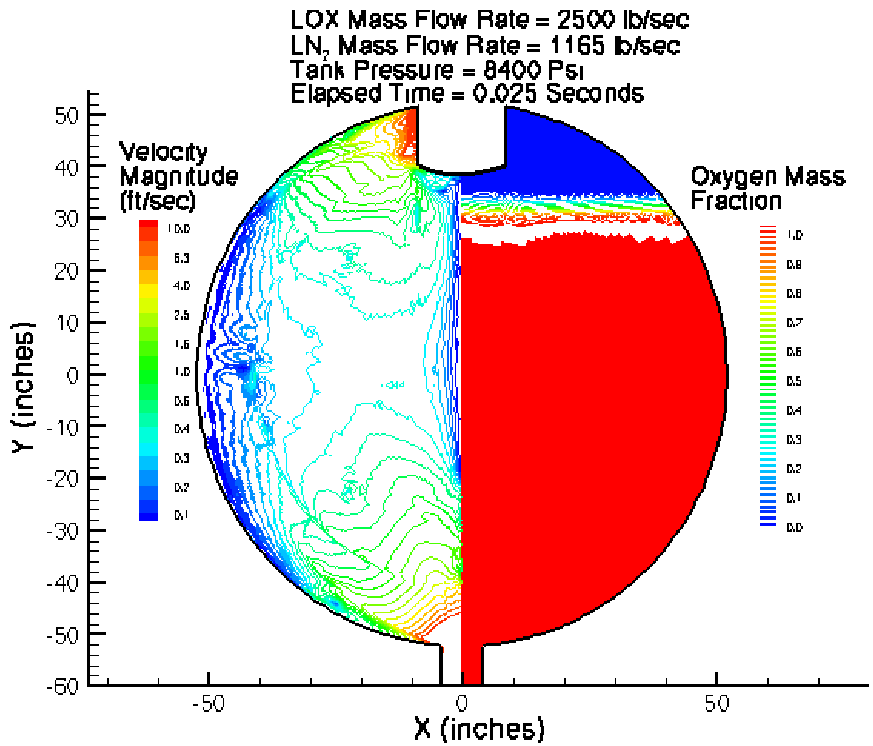
Analysis Boundary Conditions

- 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

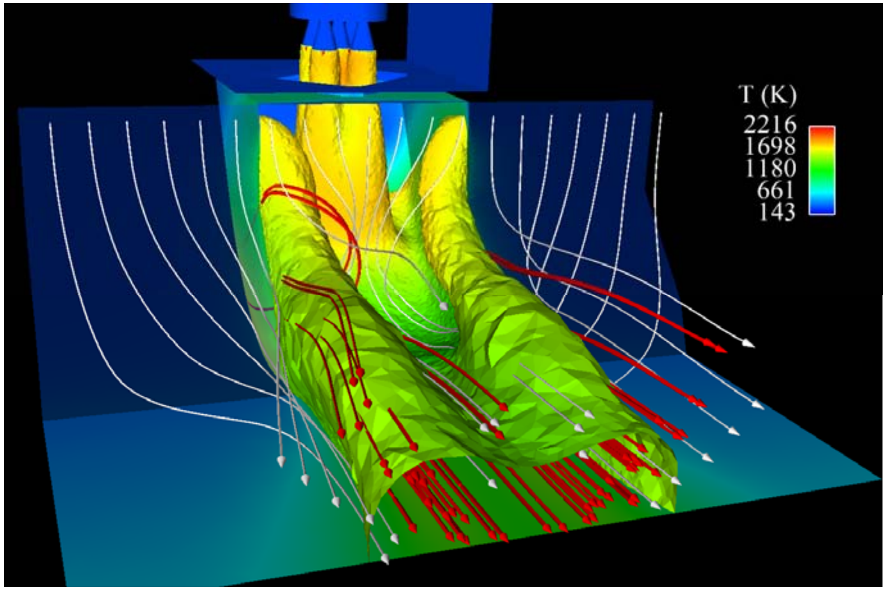
- GN Convective Mixing with LOX Propellant is Substantial
  - Only 50% Loaded LOX is Useable (<~2% N_2 Concentration)
- LOX Propellant Supply at Assessed Flow Rate & Pressure Limited to Approximately 4 seconds (vs an Estimated 10 seconds Determined Using Nominal Facility Pressurizing Gas & Propellant Supply Limits)

HP LOX Tank Propellant Discharge Simulation



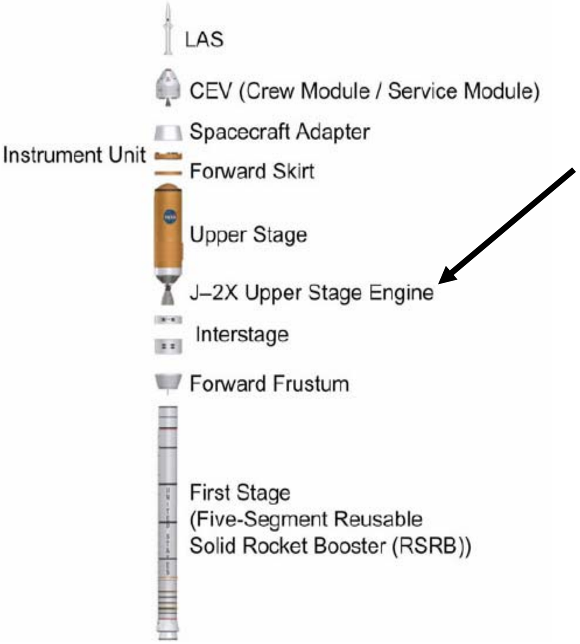
Advanced CFD Capability

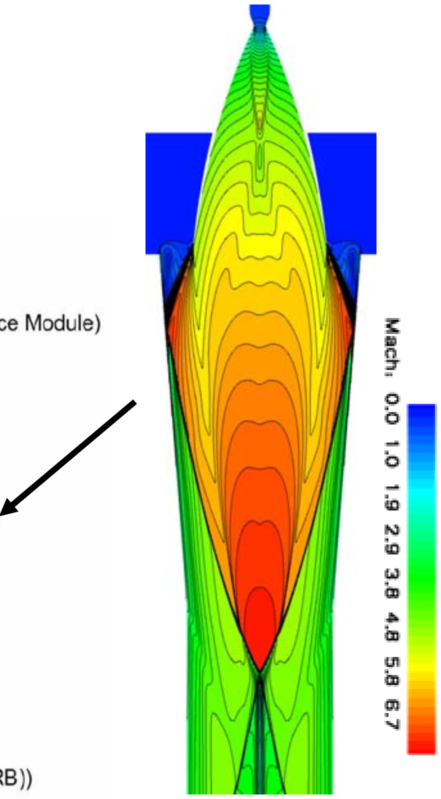
- **Employ CFD Techniques to Support Propulsion Testing in the Following Areas**:
  - Cryogenic Propellant Delivery Systems (e.g., Run Tanks, Piping)
  - Cryogenic Control Devices (e.g., Valves)
  - Plume Modeling
- **Dedicated Computational Cluster (48 Dual Processors) at NASA SSC**



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

ARES I

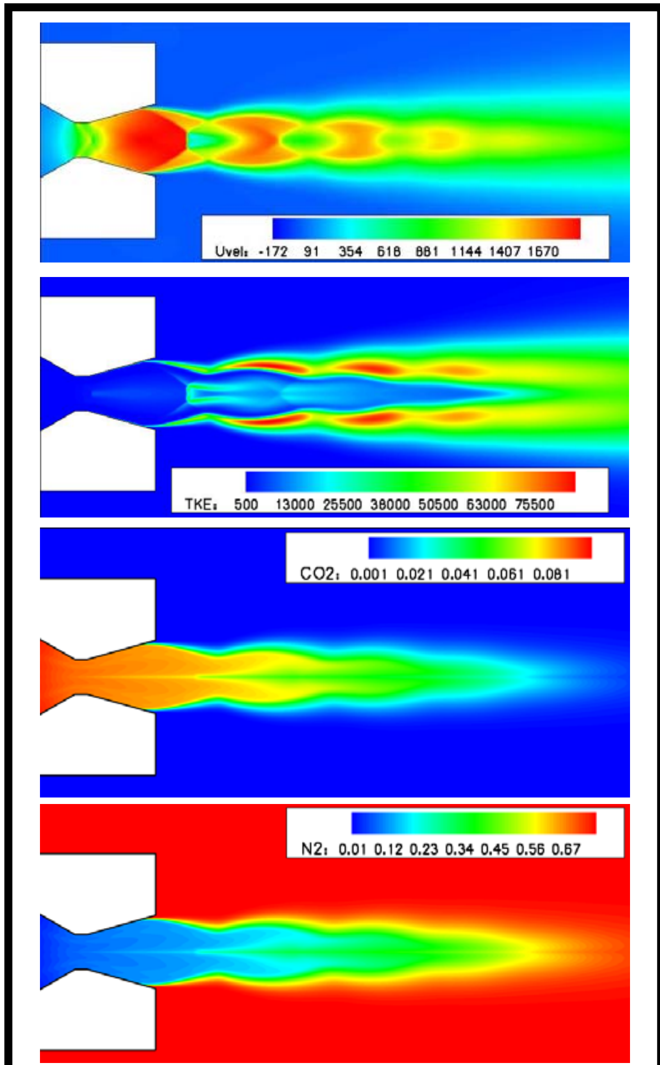


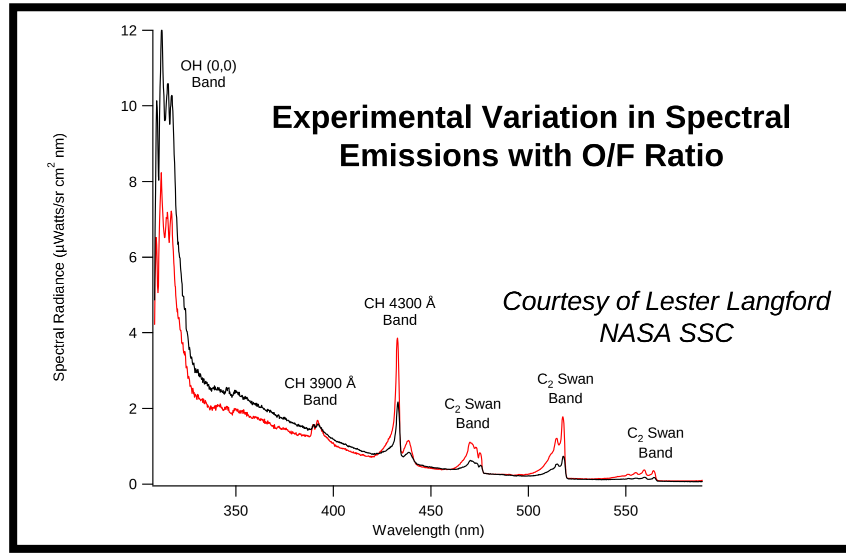


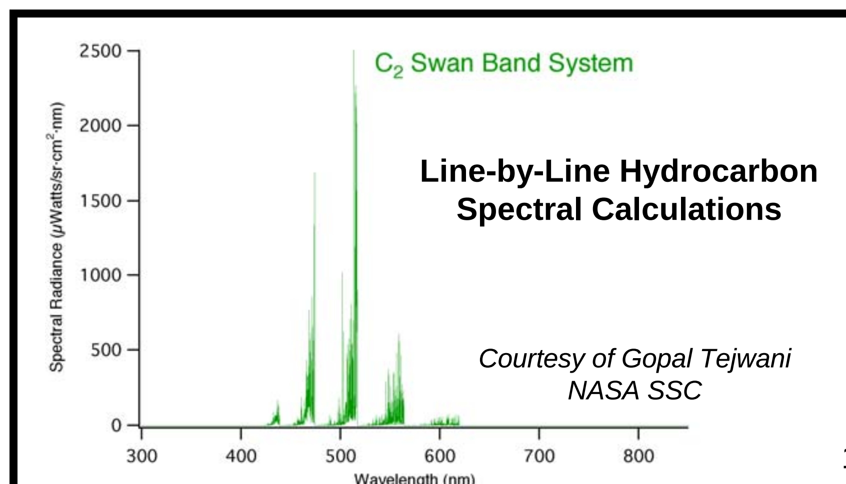
Computational Results of J-2X Altitude Diffuser Simulation (300 K-lbf)

MTTP Plume Simulations – CFD Model Validation

- 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)

For Additional Information/Discussion Please Contact :

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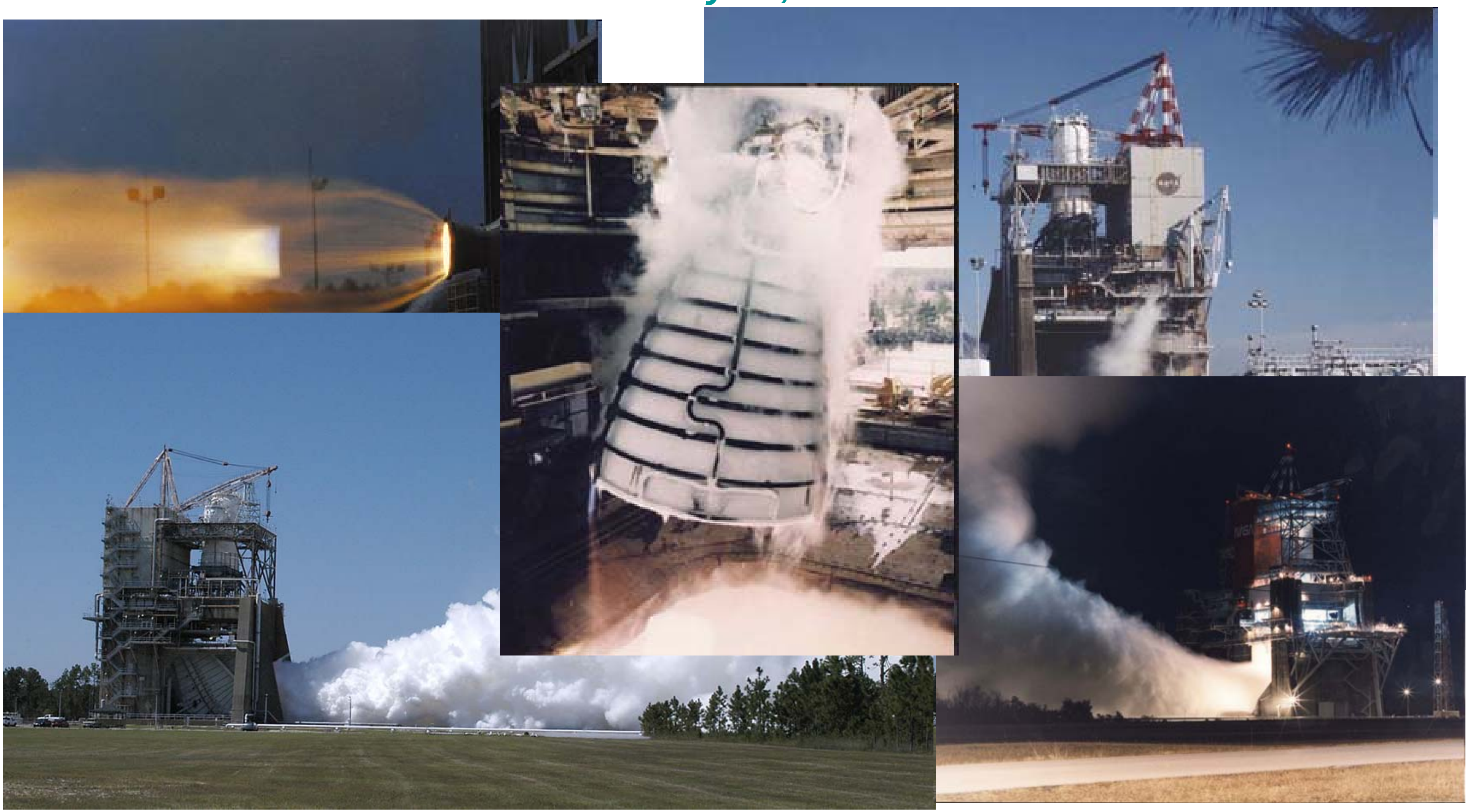
Harry Ryan 228-688-2757, Email: Harry.M.Ryan@nasa.gov

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., Test Project (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

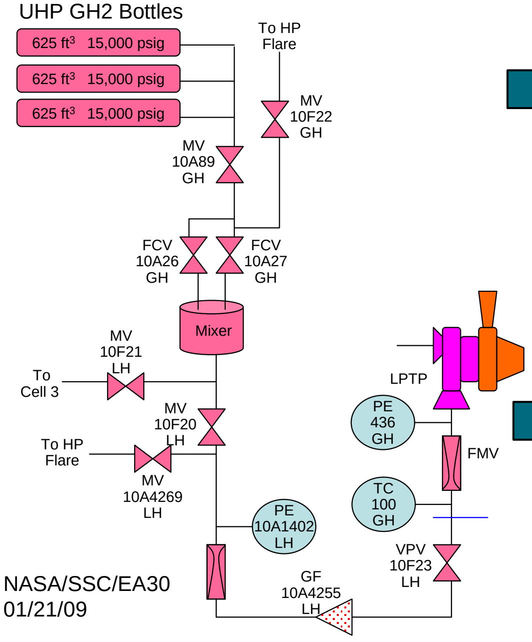
- Propellant System Modeling Allows For A Timely & Cost-Effective Assessment of the Propellant System Performance
- Integrated Performance Modeling Capabilities Has Translated to Efficient Test Facility Design, Activation & Test Operations

Integrated Facility Simulation and Analysis

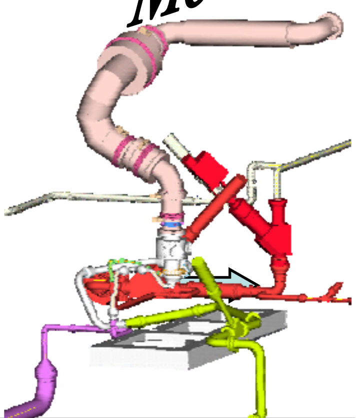
- Analytic Tools Available for Test Facility/Project Modeling & Analysis
- Comprehensive Propellant System Thermodynamic Modeling & Test Simulation

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

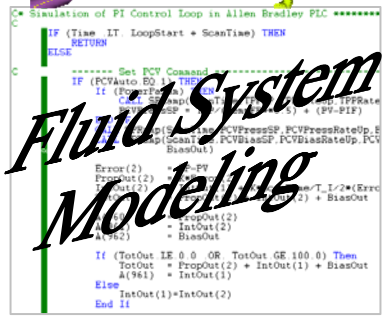
System Design



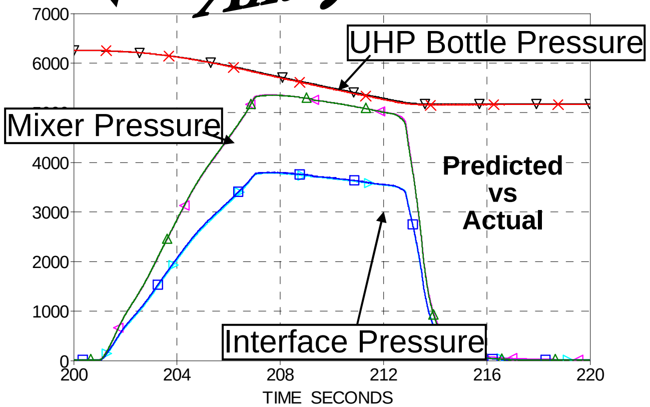
Modeling

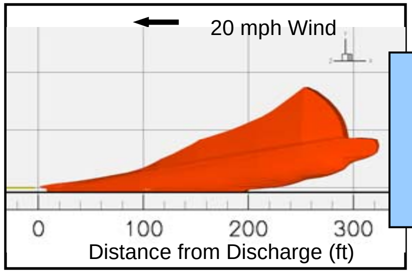


Fluid System Modeling



Test and Data Analysis





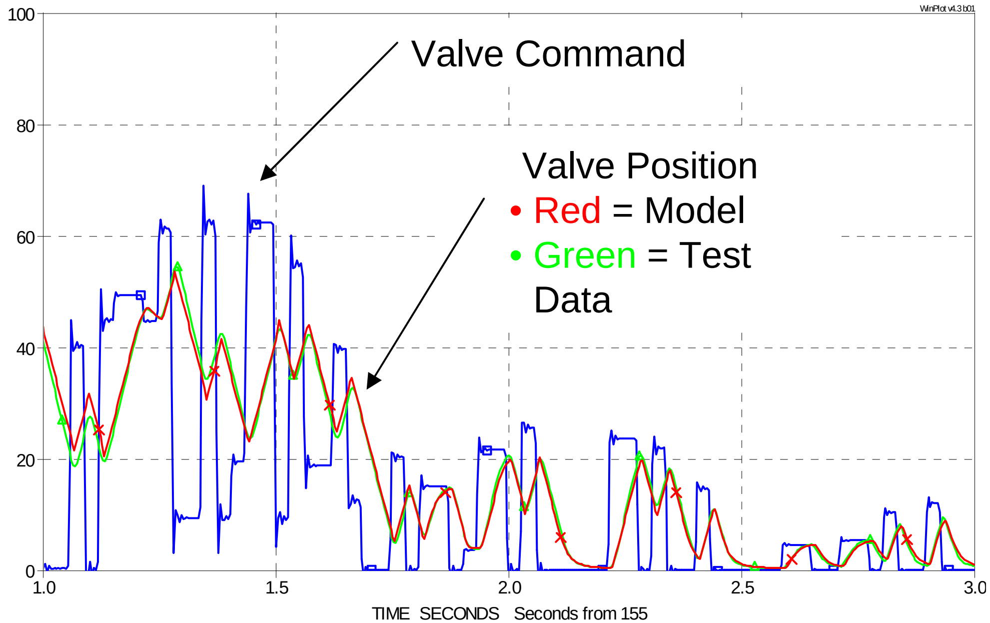
Advanced Capabilities in CFD Modeling & Analysis

NASA/SSC/EA30
01/21/09

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

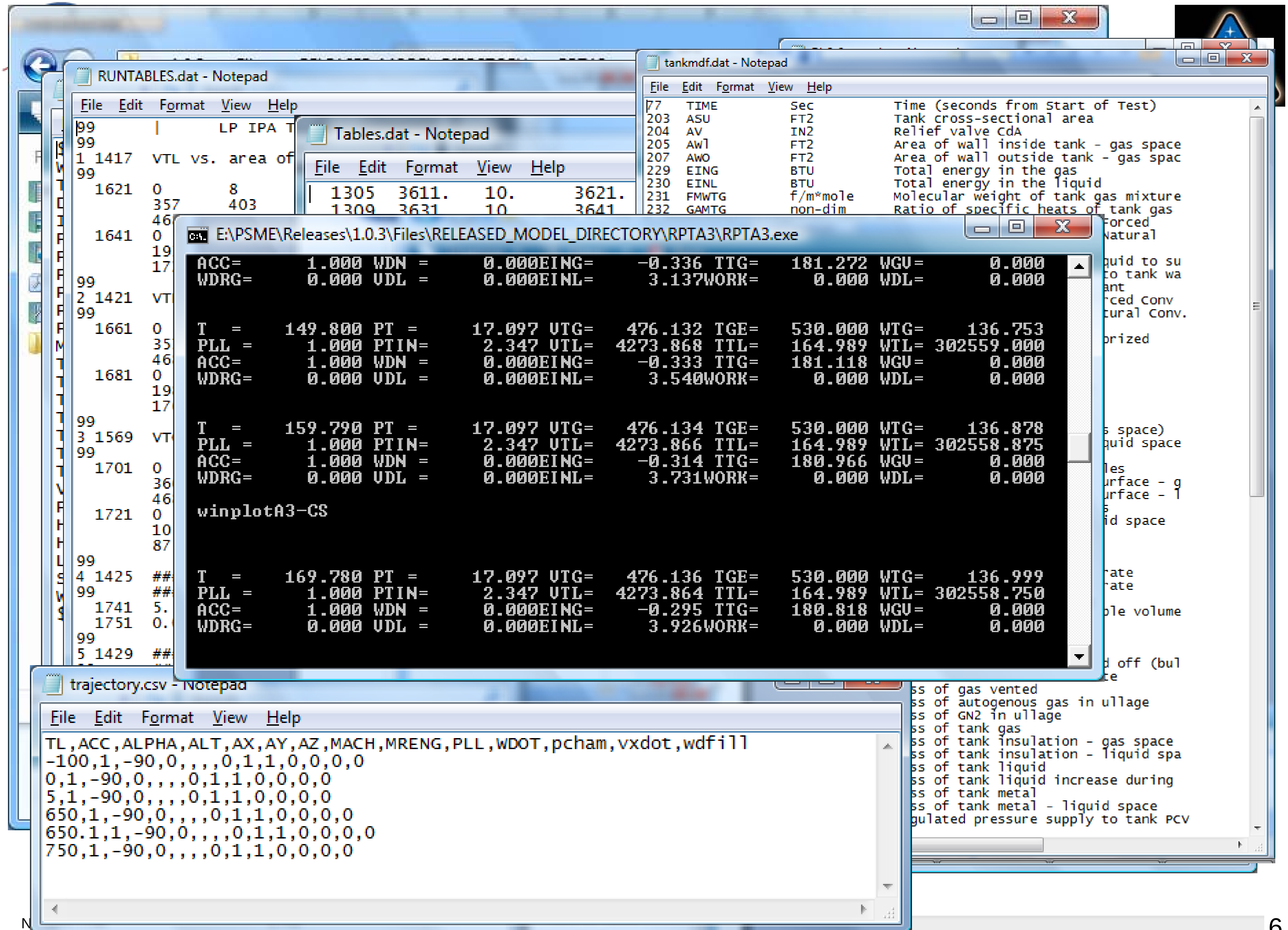


A Significant Feature of the RPTA Model is the Coupling of Control Logic (Electro-Mechanical Process) with Thermodynamic Processes

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



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357 403
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1681 0
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3 1569
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1701 0
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99
4 1425
99
1741 5.
1751 0.
99
5 1429
Tables.dat - Notepad
File Edit Format View Help
1305 3611. 10. 3621.
tankmdf.dat - Notepad
File Edit Format View Help
77 TIME Sec Time (seconds from Start of Test)
203 ASU FT2 Tank cross-sectional area
204 AV IN2 Relief valve CdA
205 AWI FT2 Area of wall inside tank - gas space
207 AWO FT2 Area of wall outside tank - gas spac
229 EING BTU Total energy in the gas
230 EINL BTU Total energy in the liquid
231 FMWTG f/m*mole Molecular weight of tank gas mixture
232 GAMTG non-dim Ratio of specific heats of tank gas
ss of gas vented
ss of autogenous gas in ullage
ss of GN2 in ullage
ss of tank gas
ss of tank insulation - gas space
ss of tank insulation - liquid spa
ss of tank liquid
ss of tank liquid increase during
ss of tank metal
ss of tank metal - liquid space
gulated pressure supply to tank PCV
E:\PSME\Releases\1.0.3\Files\RELEASED_MODEL_DIRECTORY\RPTA3\RPTA3.exe
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WDRG= 0.000 VDL = 0.000EINL= 3.137WORK= 0.000 WDL= 0.000
T = 149.800 PT = 17.097 VTG= 476.132 TGE= 530.000 WTG= 136.753
PLL = 1.000 PTIN= 2.347 VTL= 4273.868 TTL= 164.989 WTL= 302559.000
ACC= 1.000 WDN = 0.000EING= -0.333 TTG= 181.118 WGV= 0.000
WDRG= 0.000 VDL = 0.000EINL= 3.540WORK= 0.000 WDL= 0.000
T = 159.790 PT = 17.097 VTG= 476.134 TGE= 530.000 WTG= 136.878
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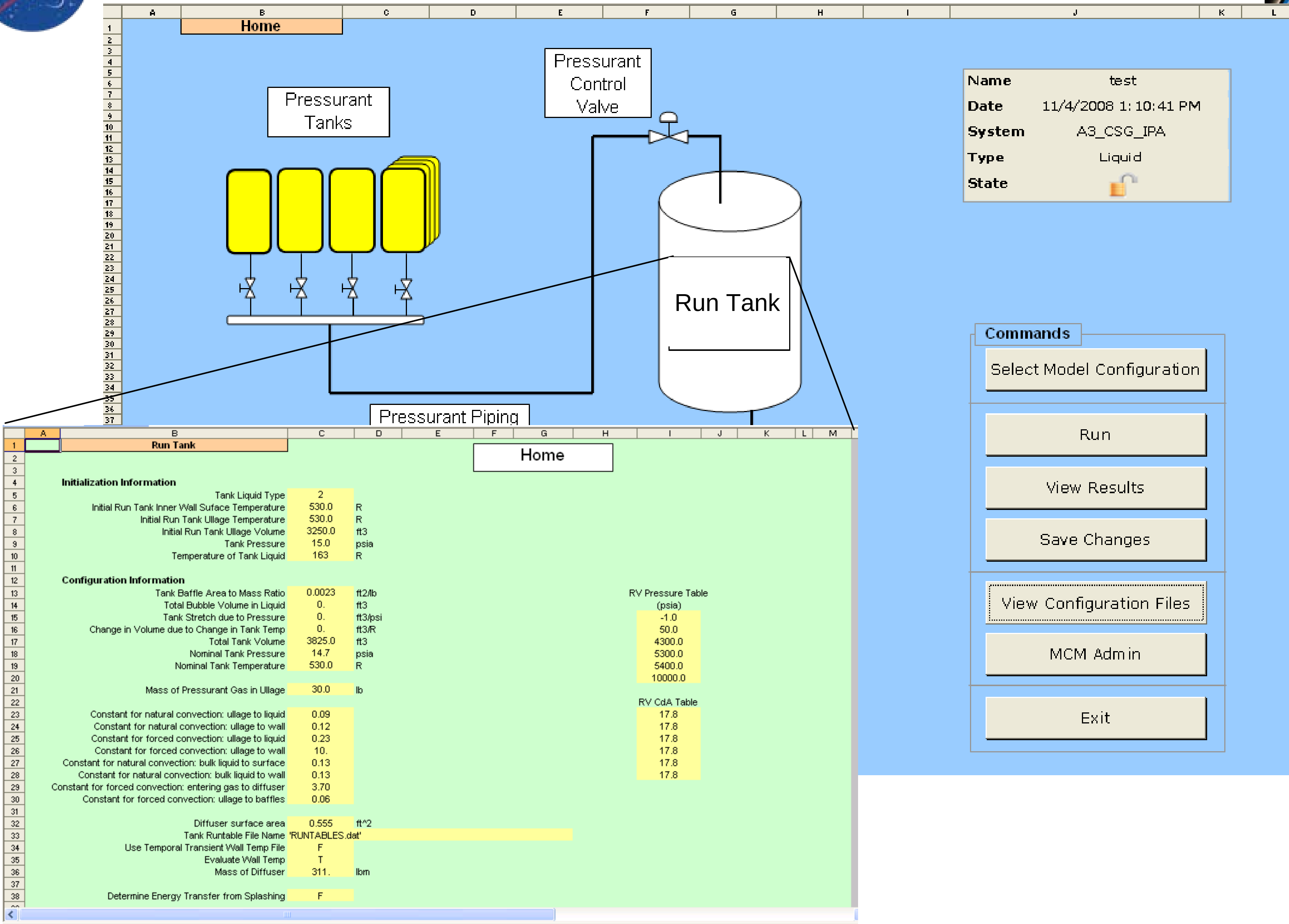
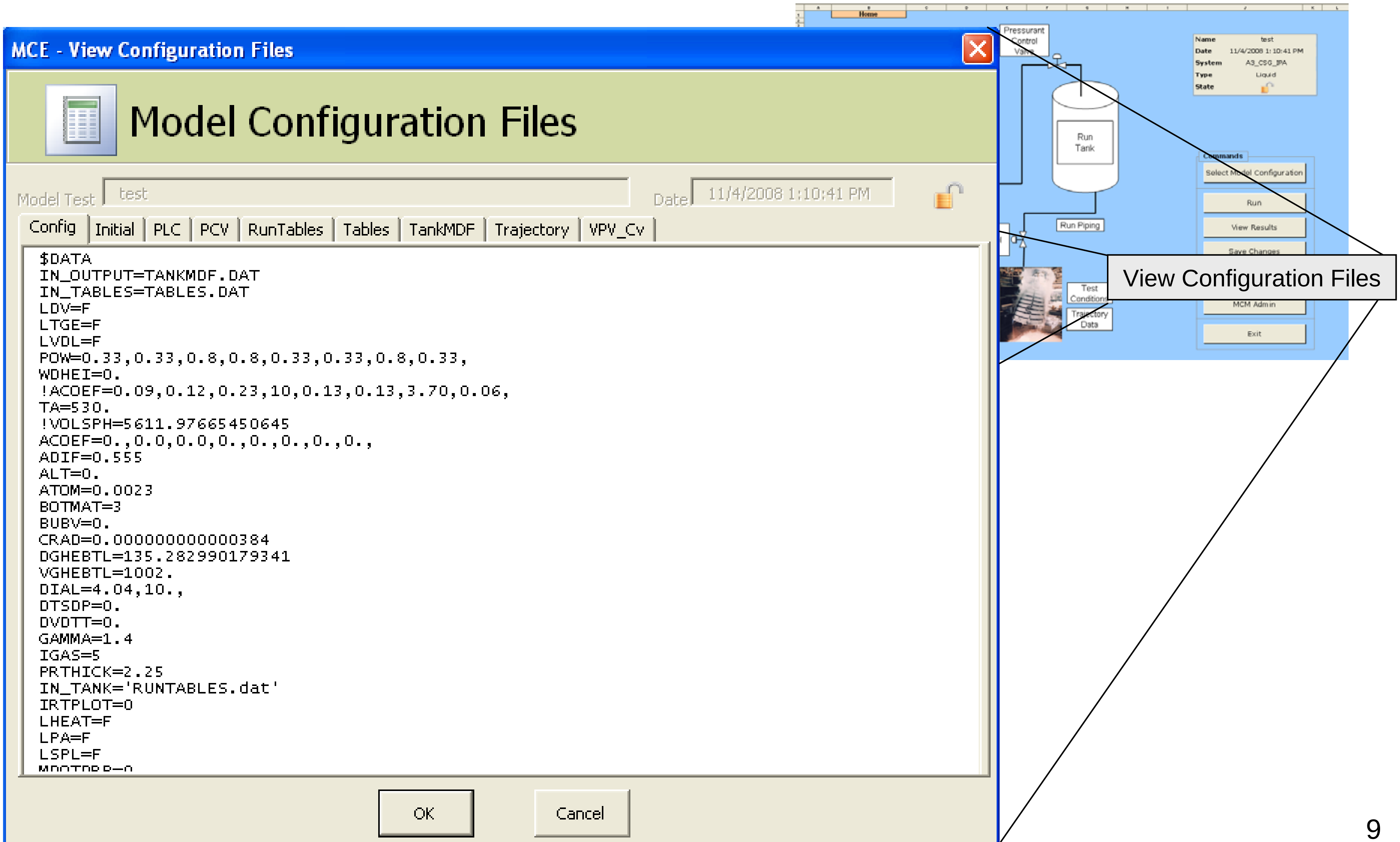
Propellant Systems Modeling Environment

PSME

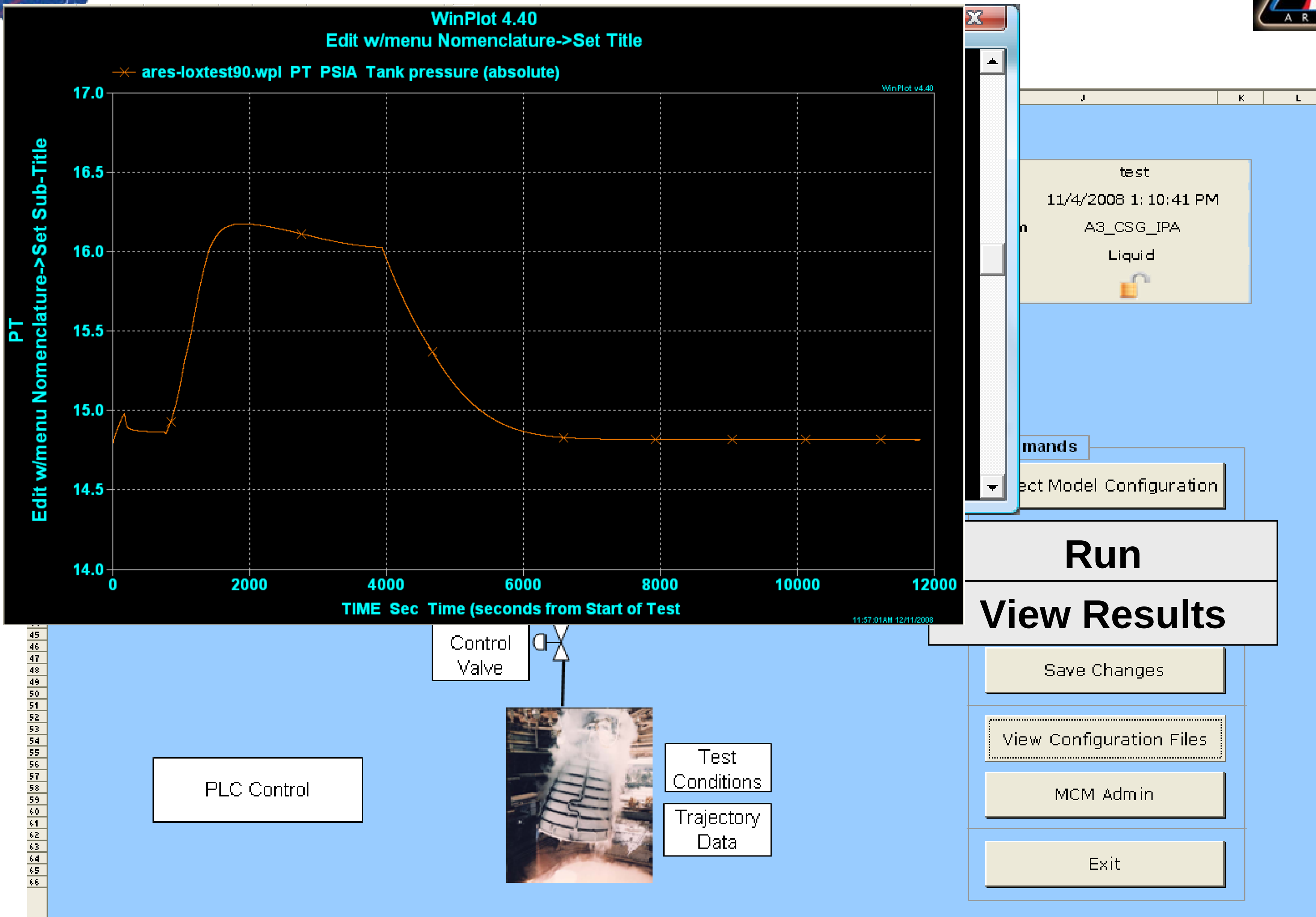
GUI interface Significantly Simplifies Model Set-up



Provides Access to All Configuration Data

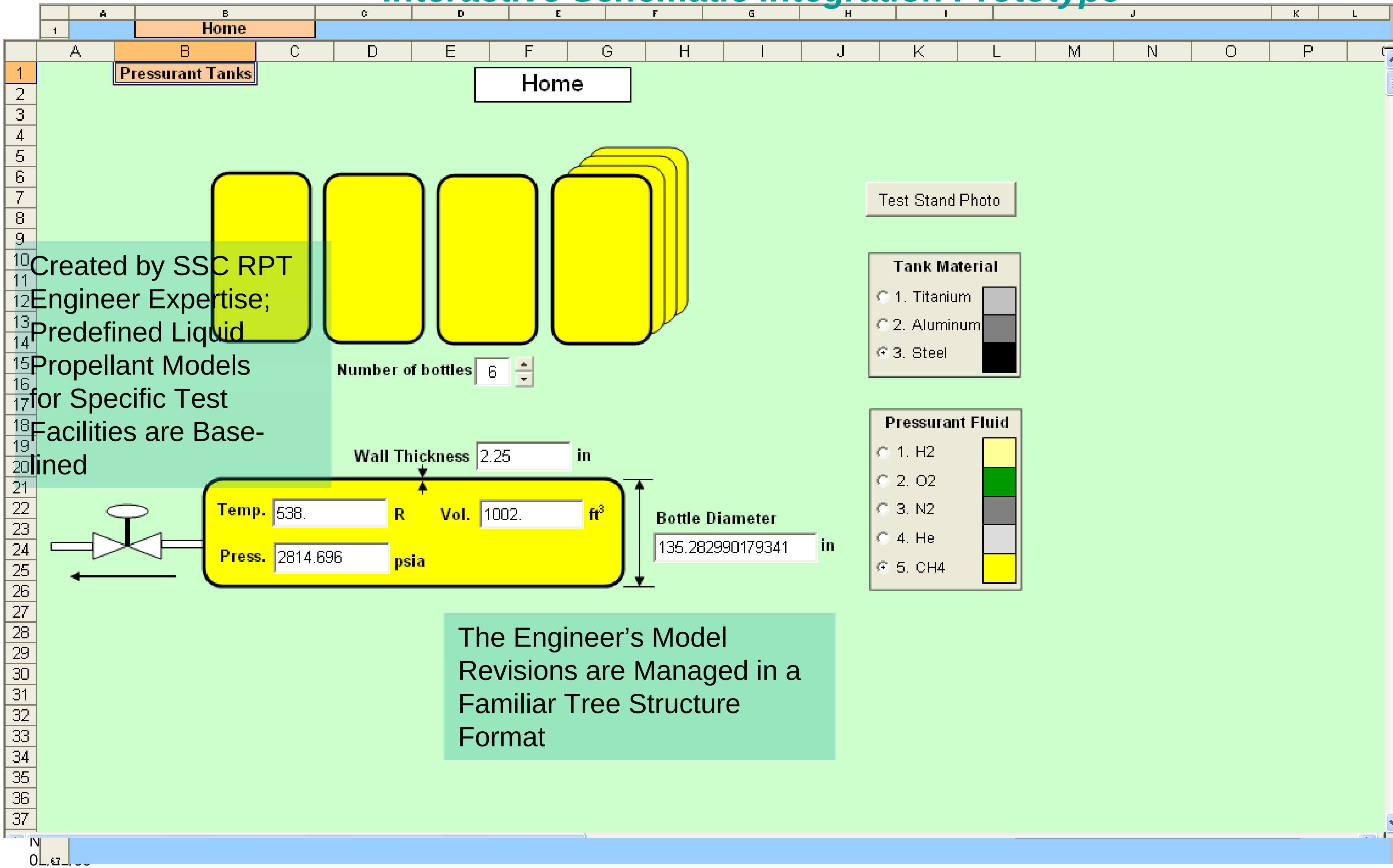


Model Execution & WinPlot Results



Propellant Systems Modeling Environment Model Library & Configuration Editor

Interactive Schematic Integration Prototype

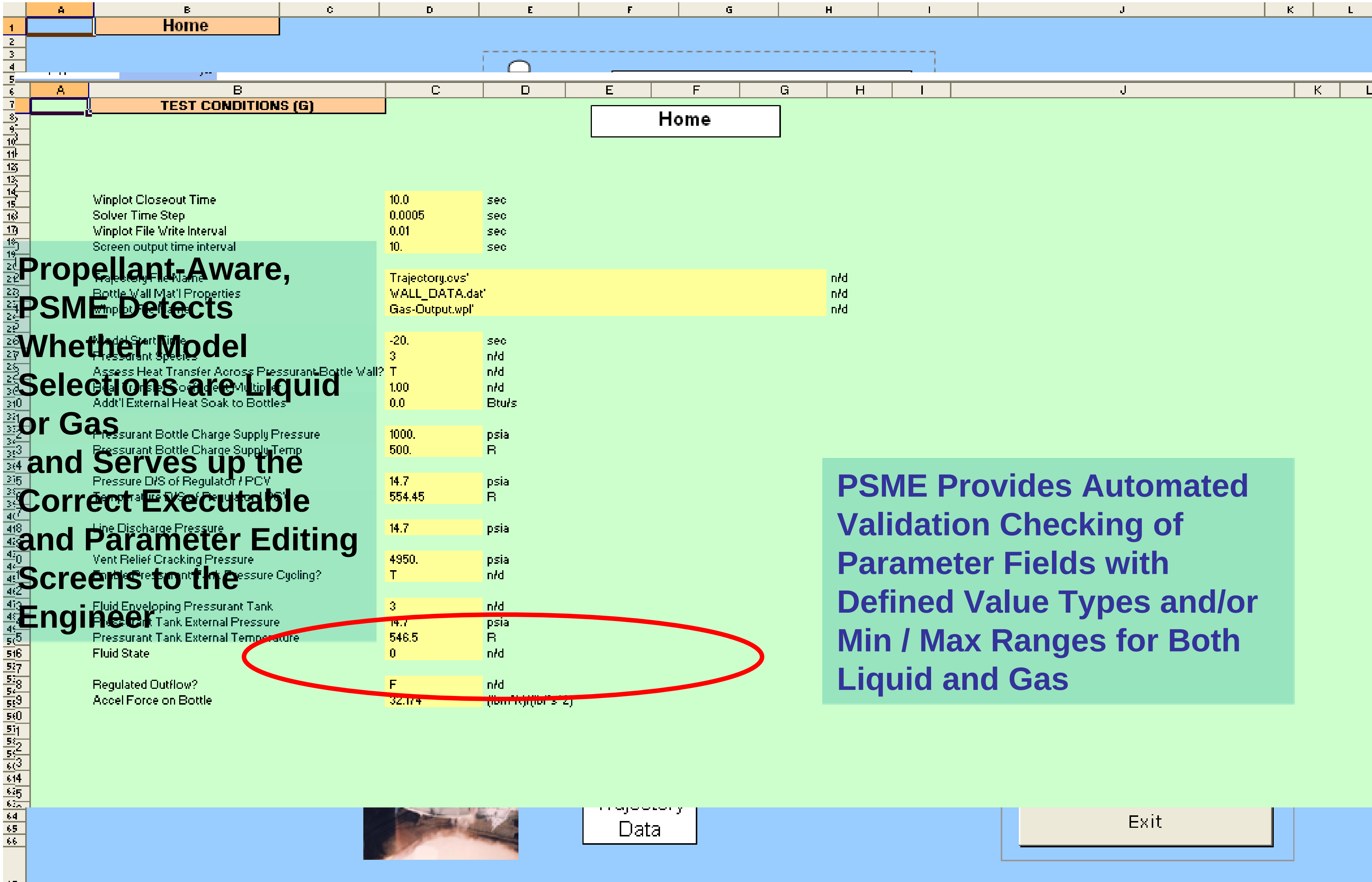


Created by SSC RPT Engineer Expertise; Predefined Liquid Propellant Models for Specific Test Facilities are Base-lined

The Engineer's Model Revisions are Managed in a Familiar Tree Structure Format

Propellant Systems Modeling Environment

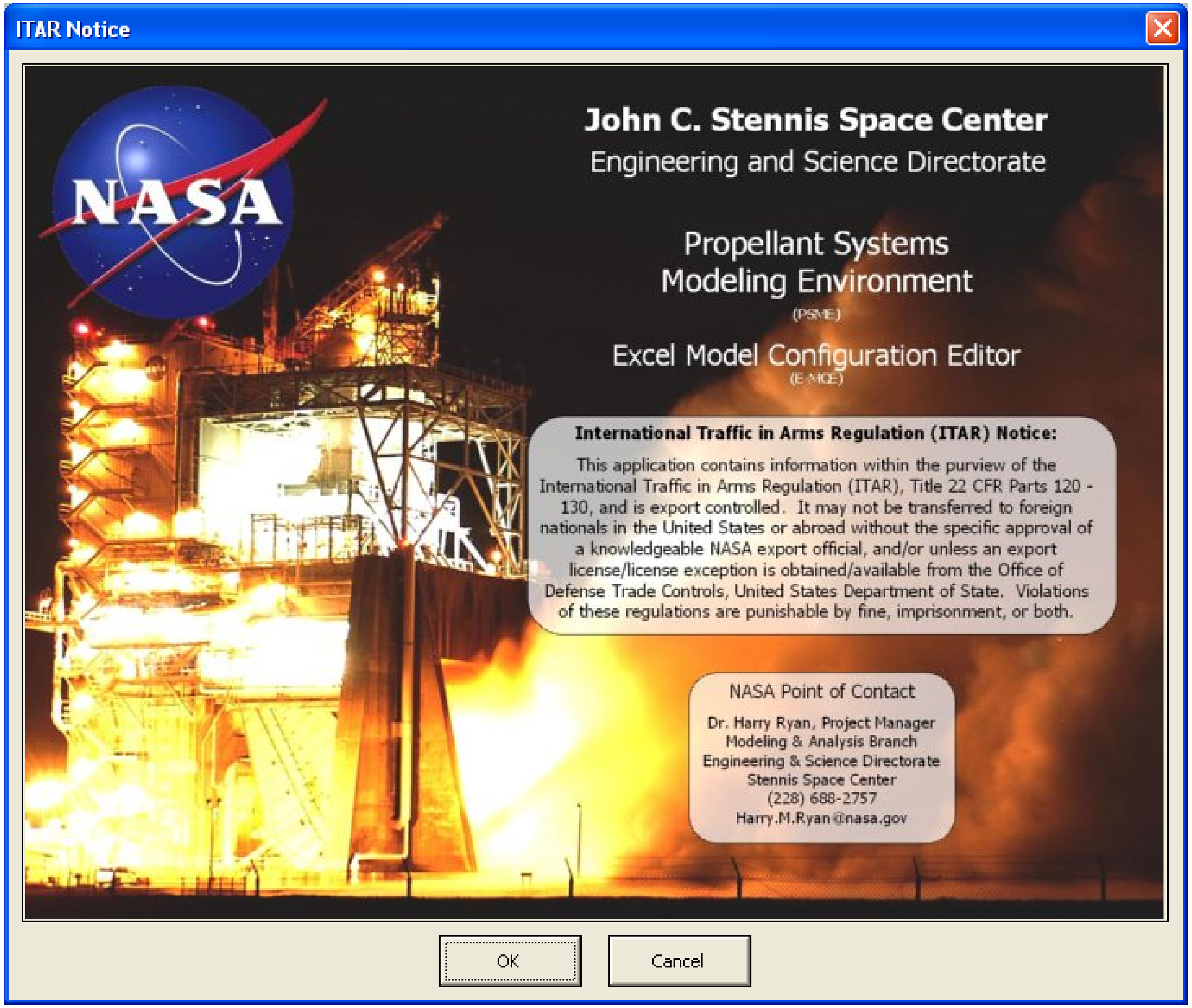
Gas Model Support Scheduled in Early 2009



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

SSC Engineering & Test Directorate (ETD)



<u>For Additional Information/Discussion Please Contact :</u>

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