Integrated Health Management for Systems-of-Systems

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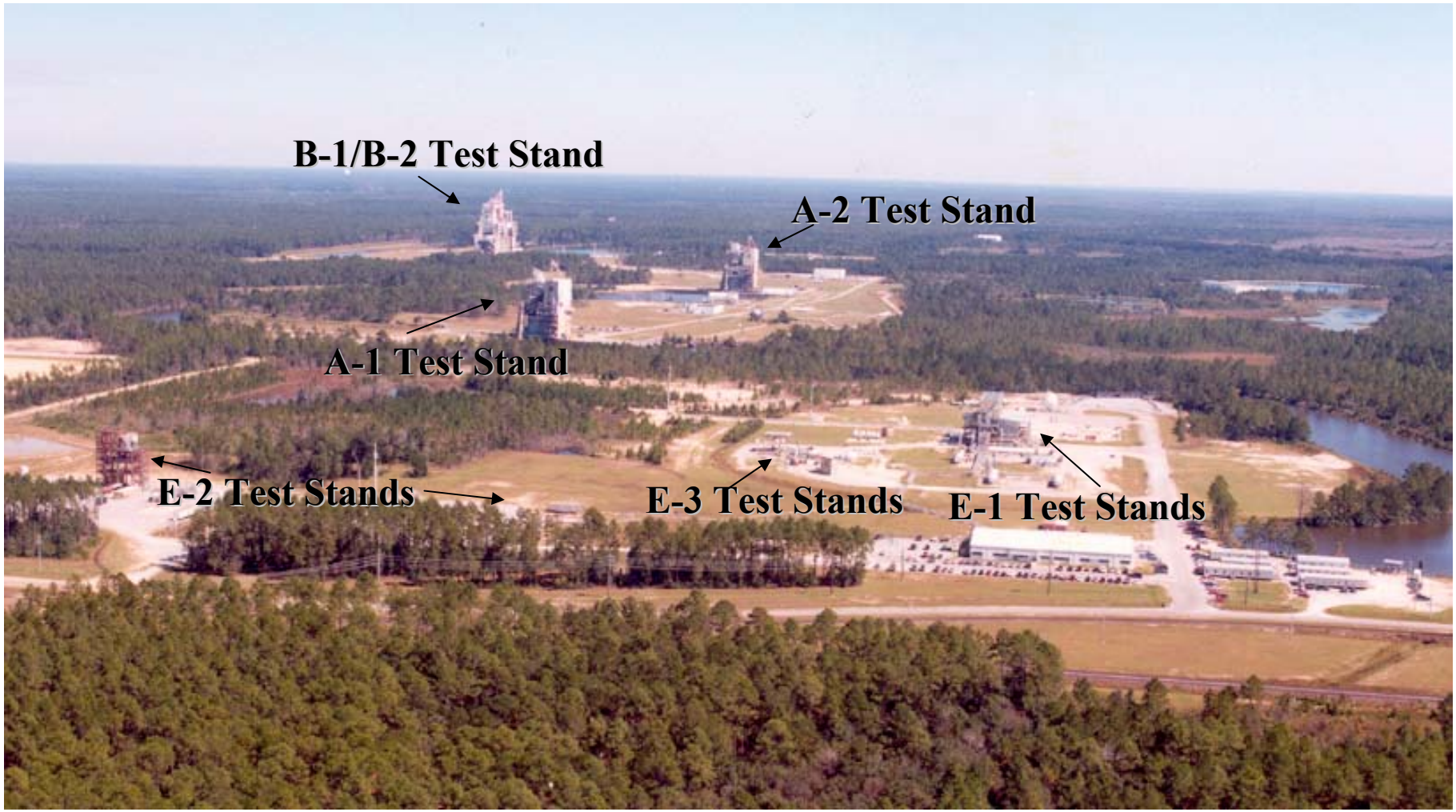
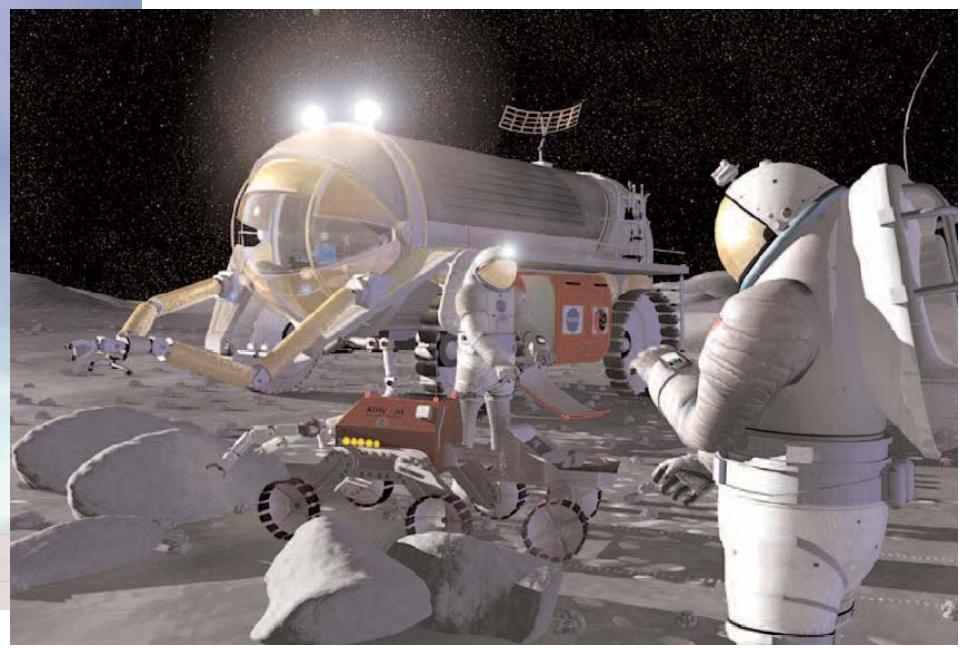
SSC Provides a Range of Test Facilities



ISHM Vision for Exploration

To increase the safety, affordability and sustainability of Exploration missions through Integrated Health Management of complex, mission-critical vehicles and systems.



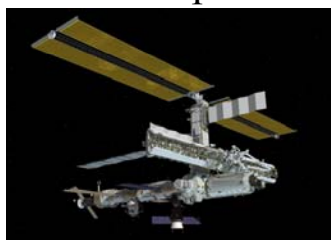
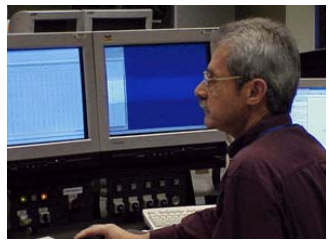
Objectives of ISHM Capabilities

Complete knowledge of the condition of every element in a system (sensors, components, and processes).

- Determination of the quality, accuracy, and reliability of the data (in the case of sensors).
- Detection of anomalous behavior of the system elements.
- Determination of the cause of anomalous behaviors (diagnostics).
- Prediction of future anomaly occurrences (prognosis).
- Guidance on following operating procedures to avoid human mistakes.
- Recommend a reasonable course of action to fix a problem.
- Store relevant information pertaining to system performance and health for use by management and investigation teams.
- Provide an integrated view of the system.

Technology measured by TRL and Functional Capability Level (FCL) in %

ISHM Layers In Existing Operations

	International Space Station	Rocket Engine Test Stand
Layer 1 Vehicle/ Test Stand		
Layer 2 Astronaut/ Test Conductor		
Layer 3 Control Room		
Layer 4 Back Control Room		

ISHM Challenges

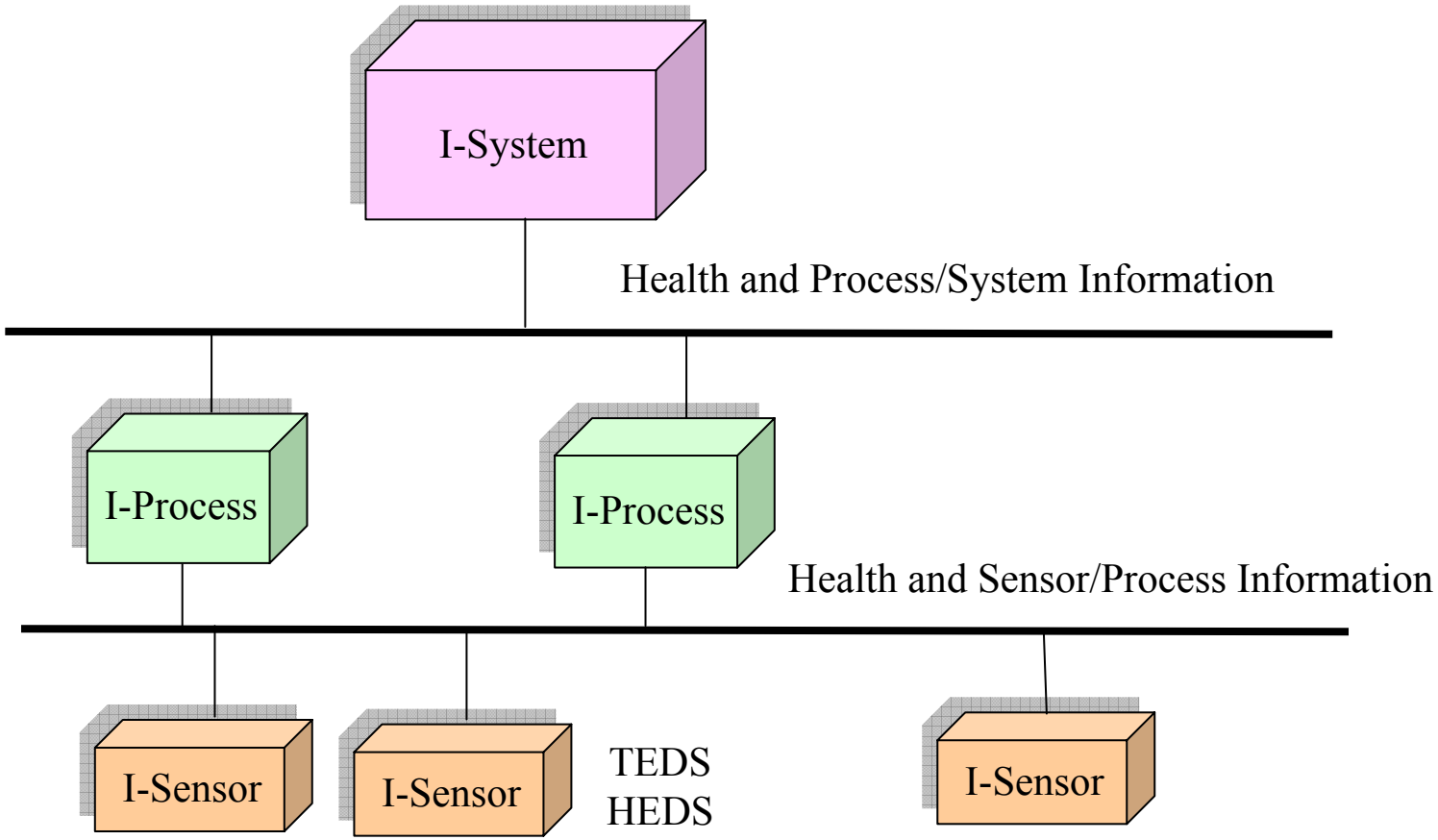
- ISHM Architectures and Frameworks: must support "intelligent" data, information, and knowledge management (storage, availability, interpretation, integration, maintenance, modification, flexibility, evolution).
- Sensor health assessment.
- Models for failures; methods for detection.
- Complete data base of sensor/process/system failures.
- Advanced/Intelligent Integrated Control Functionality (PSU).
- Credibility: Quantify benefits of ISHM technologies.
- Visualization for awareness and quick reaction by operator (Visual ISHM).

ISHM Credibility

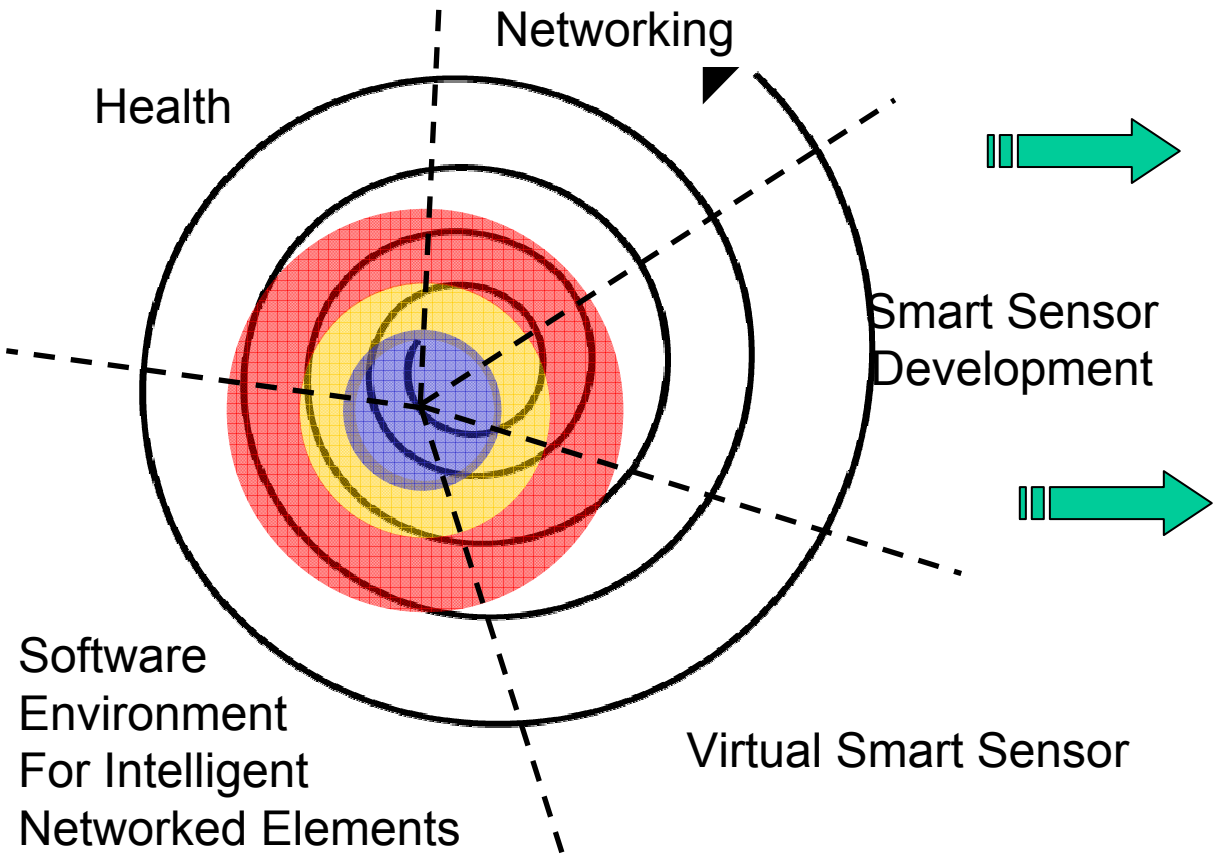
- Measure benefits of ISHM-enabled systems.
- Prove effective integration of distributed intelligent elements (real or virtual).
  - Deliver timely information.
  - Deliver context-proper information
- Prove expandability on relevant continuous operation systems.
- Prove self evolution of ISHM (again needs relevant continuous operation system).

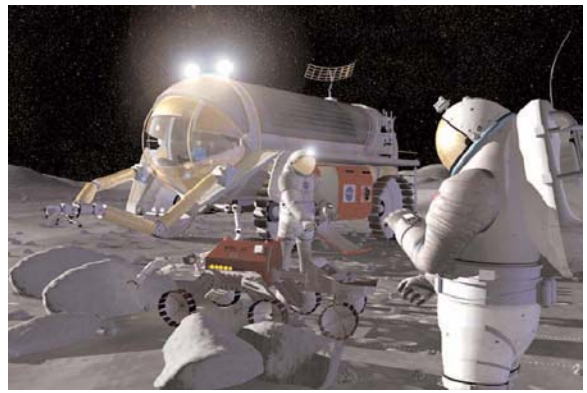
All can be done to reach a high percent of Functional Capability Level (X%), with existing ISHM technologies.

Real or Virtual Framework Architecture



ISHM Spiral Development Model





Phase 0 | **Phase 1** | **Phase 2**

ISHM Development Tools

- Hardware Testbeds
  - Test Stands
  - International Space Station
- Software Testbeds/Environments – appropriate tools that allow reasoning and decision making involving time and behaviors, in a setting that includes knowledge, information, and data, from a wide range of ISHM related technologies.

Summary ISHM Testbed Environments

SSC ISHM Testbed Environments

Test Stand as System of Systems

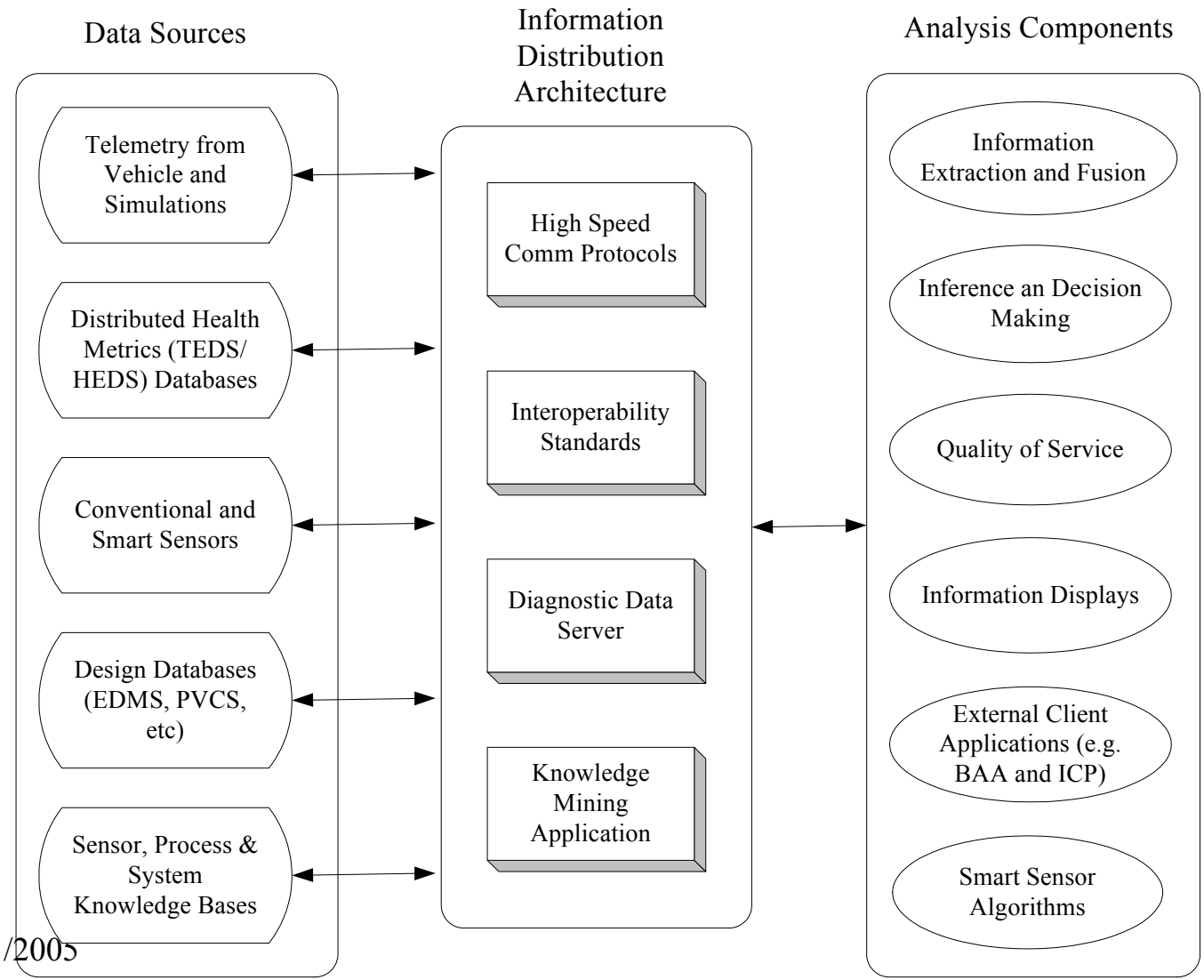
Test Stand with ISHM to properly test the Test Article

DACS Laboratory/Cryo Component TF
Verification of components, sensors, data acquisition and processing systems, controls, software.

ISHM Technologies
- Integration Architecture/Framework for networked intelligent elements
- Data/Information/Knowledge Management (storage, transmission, maintenance, evolution, suitability (context), availability (timely))

We Provide
- A base/flexible architecture.
- A catalog of methods/algorithms.
- A catalog of anomalies.
- Intelligent networked elements and/or hook-ups (HW/SW)

JSC/SSC ISHM Testbed Architecture



Test Stand with its ISHM: Effective Testing of test articles with ISHM capabilities

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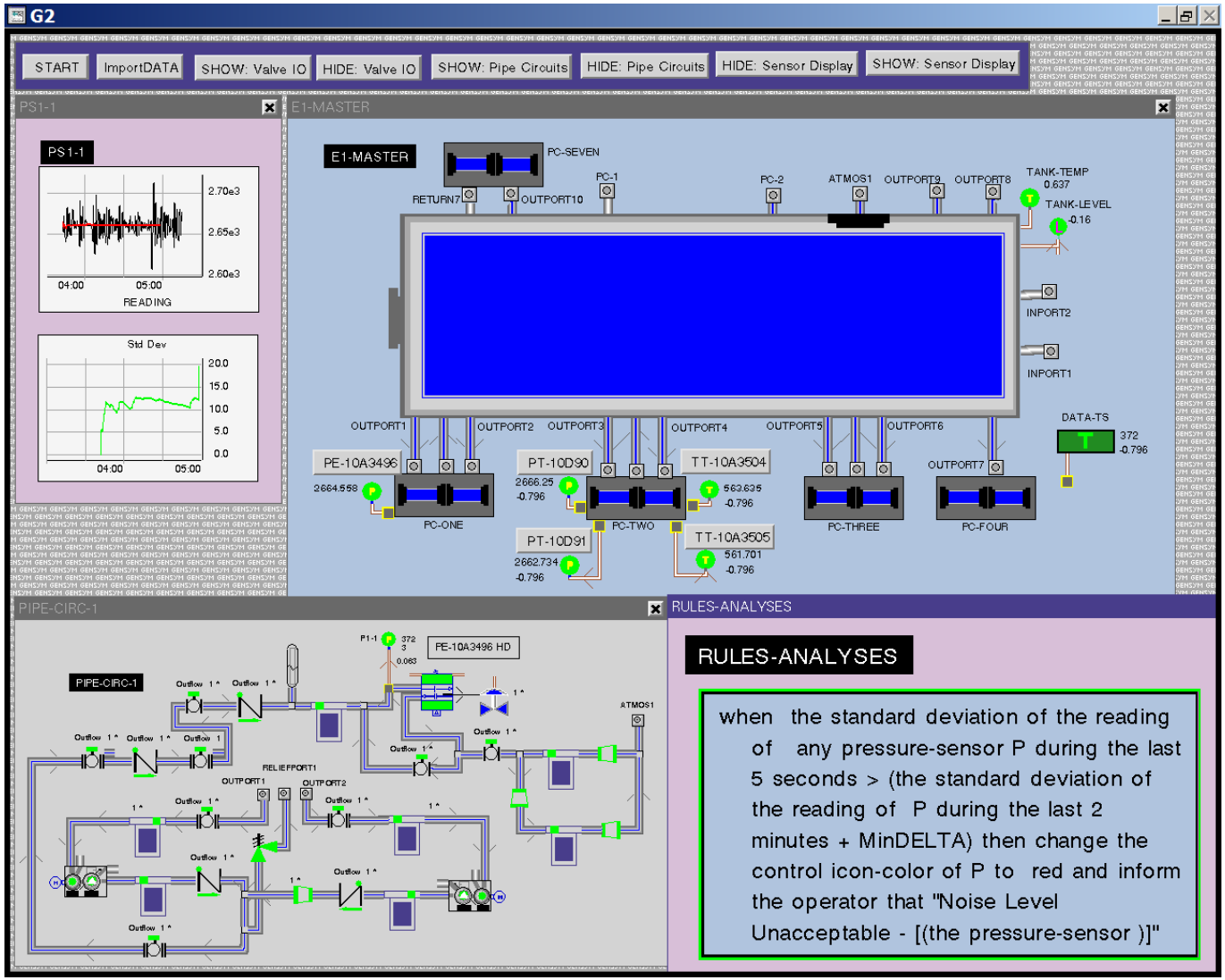

ISHM DACS LAB SIMULATION, TEST SYSTEMS INTEGRATION, & VERIFICATION

DACS Development Testbed

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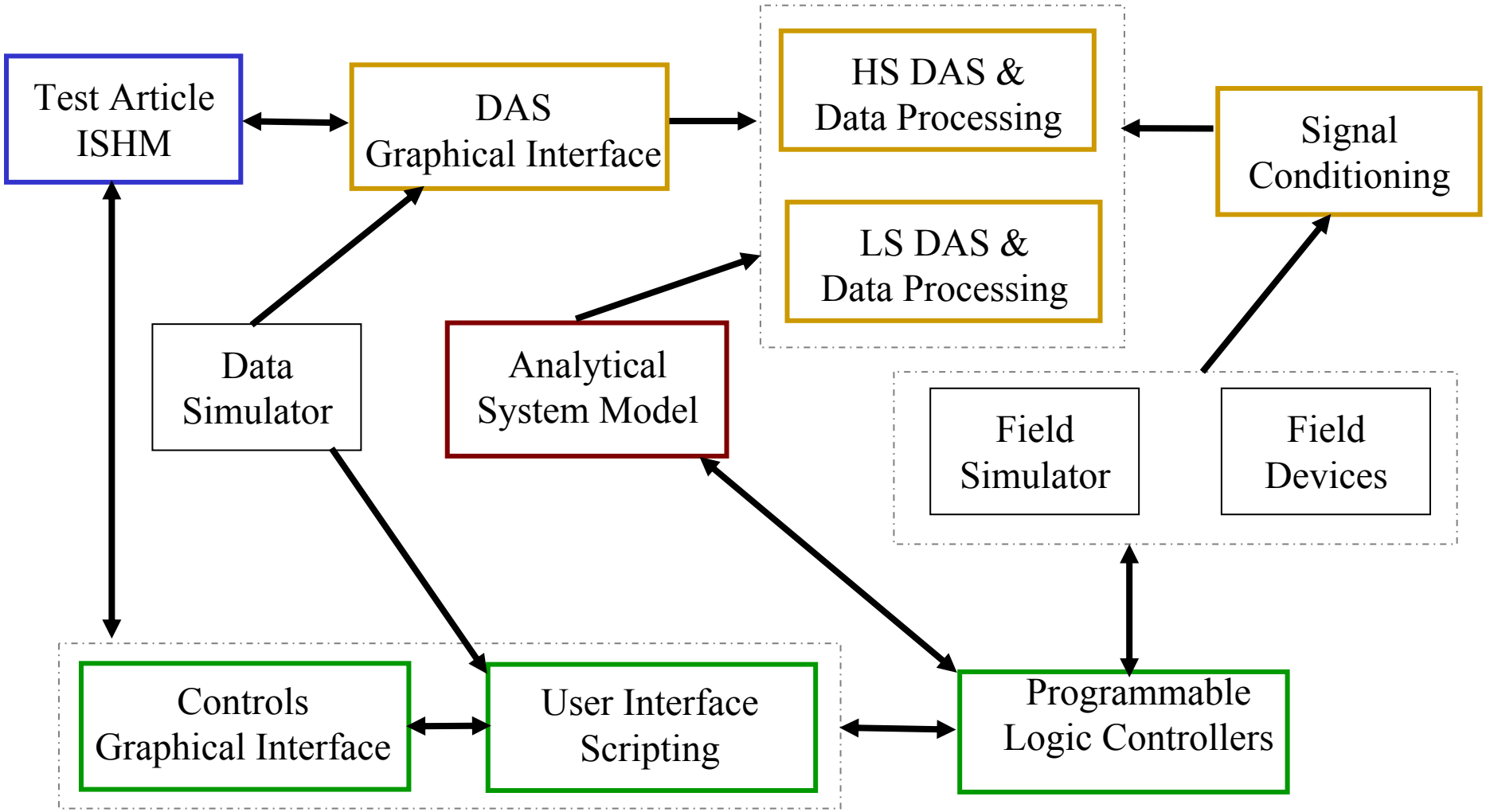
CONTROLS DEVELOPMENT

DAS DEVELOPMENT

Valve Testing: DACS Laboratory

Verification Process



DACS Development Laboratory

The Development Laboratory Provides an "Off-Stand" Data Acquisition & Control System (DACS) with capability to provide support to propulsion ground testing projects.

- DACS Development & Verification – Development and verification of control screens, controls PLC software, data acquisition software
- Controlled Trouble Shooting – Can isolate systems and inject known parameters to target specific areas of interest.
- Field Simulation Capability – Ability to simulate the field environment by utilizing a one to one match of hardware and software as in the E-Complex Test Facilities.
- Hardware Qualification – Qualification of signal conditioners, data acquisition, controls processors and I/O, and testing of field devices prior to installation.
- Risk Reduction – Provides an environment to verify that systems are fully operable prior to integration within the test stands, which aids in providing safety, significant cost savings, and risk reduction.

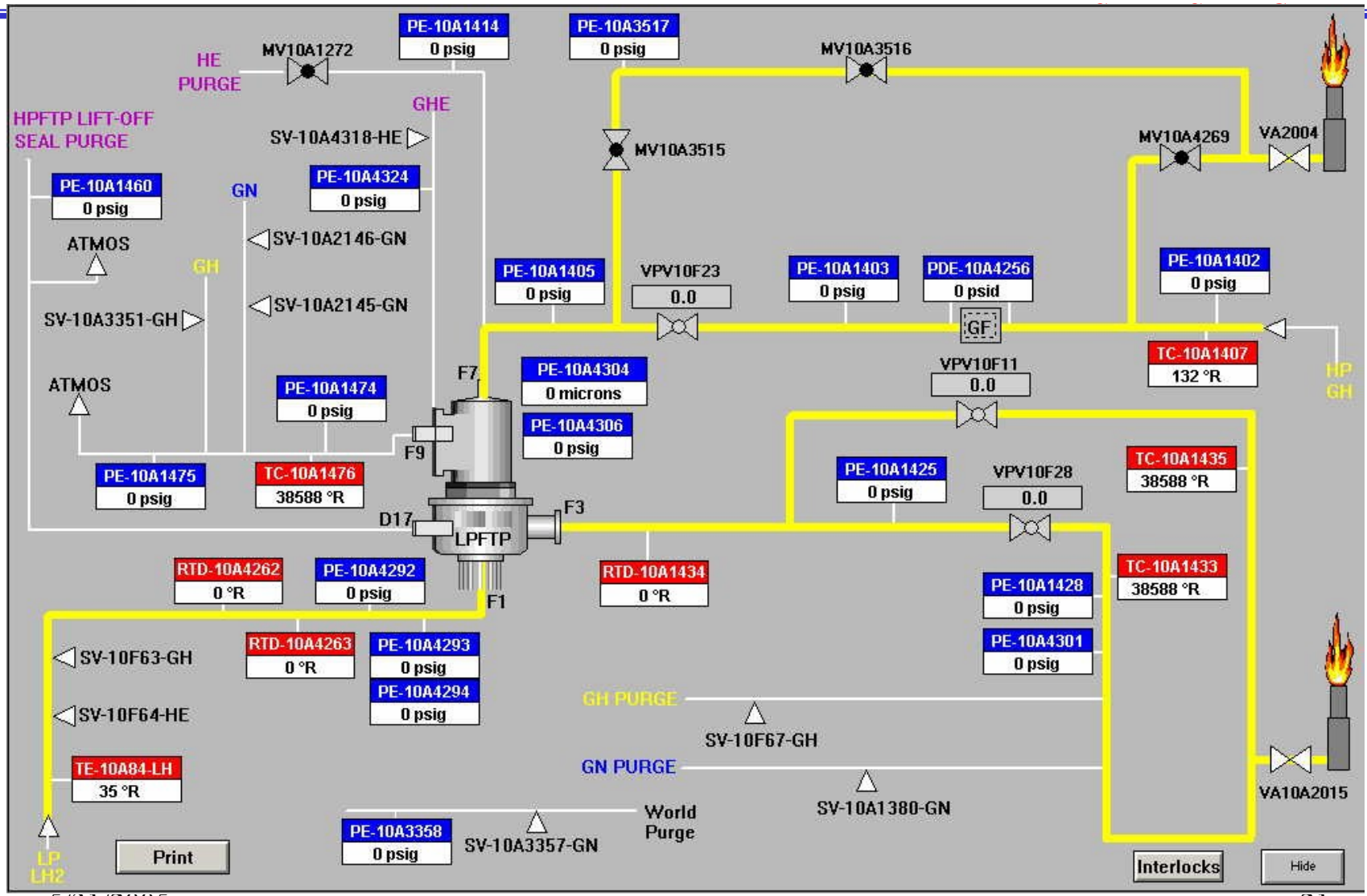
DACS Development Laboratory

- Various System/Sub-System Simulation Capability – Can simulate end-to-end test and validate input and output parameters.
- Low/ High Speed Data Acquisition – All system simulations can be recorded via HS or LS DAS for retention of data.
- Evaluation of System Upgrades
- Evaluation and Integration of New Technologies – Can evaluate new technologies and verify configurations prior to implementing integration into existing systems.
- Verified Spare Equipment – Ability to qualify spare equipment and maintain calibration cycles for utilization within the test cells.

DACS Development Laboratory

- Control Capabilities
  - Multitude of Various Types of Controls Capabilities
  - Five SLC-500 Processors for E1 Simulation – Can handle a multi-processor simulated environment
  - Flexible Integration of Field Devices
    - I/O Checkout Cabinet
    - Mobile I/O Checkout Cart
  - Controls Display & Ladder Logic Software
- Data Acquisition Capabilities
  - Pacific Instruments Signal Conditioners
  - Techkor RMS & Speed Conditioners
  - Tustin MUX/ADC (analog, discrete, & collector)
  - Racal High Speed DAS Channels (100 Ksps)
  - Voltage & Frequency Standards
  - Termination Cabinet & Patch Panel
  - DAS LabView & G2 Software

Controls Screen Development

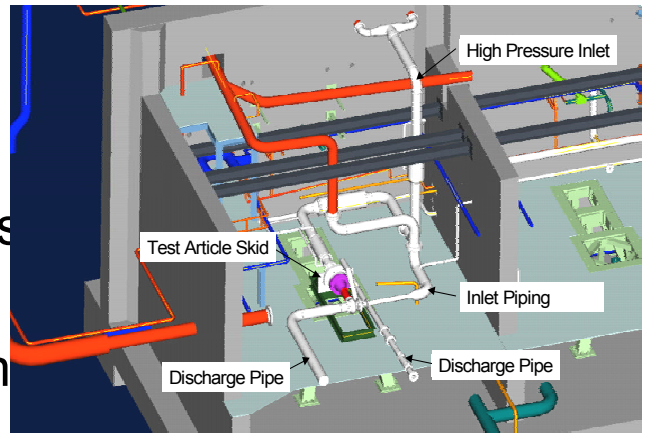


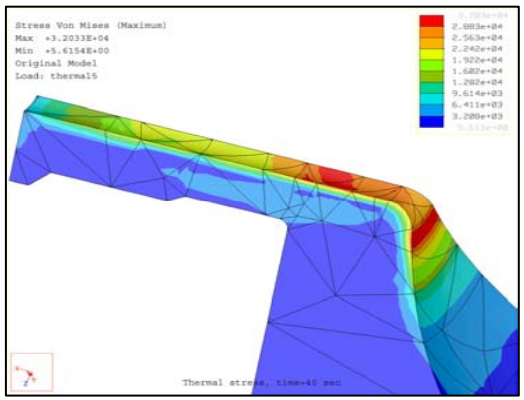
Stennis Modeling Capabilities

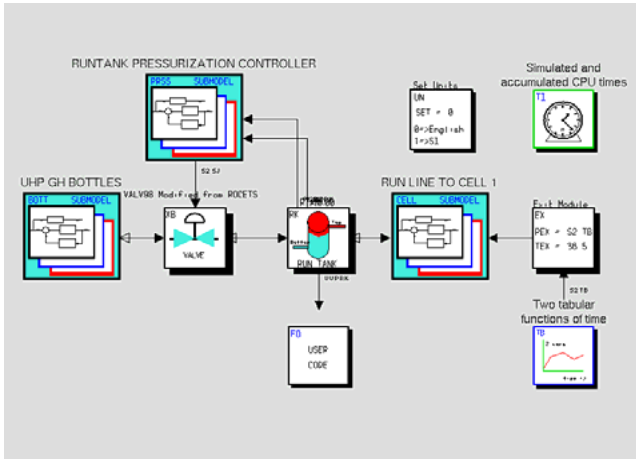
The Right Tools to Model, Predict & Enhance Test Capabilities

Industry Standard & Custom Methods

- Rocket Propulsion Test Analysis (RPTA)
- Pro/Engineer (CAD) & Pro/Mechanica (Analysis
- ROCETS Code (Rocket Engine Transients Sim
- Fanno Flow Code
- NIST properties for real Fluids
- ALGOR Pipeplus







COMPONENT, ENGINE, & FULL SCALE INTEGRATION TESTING

SSC Provides a Range of Facilities

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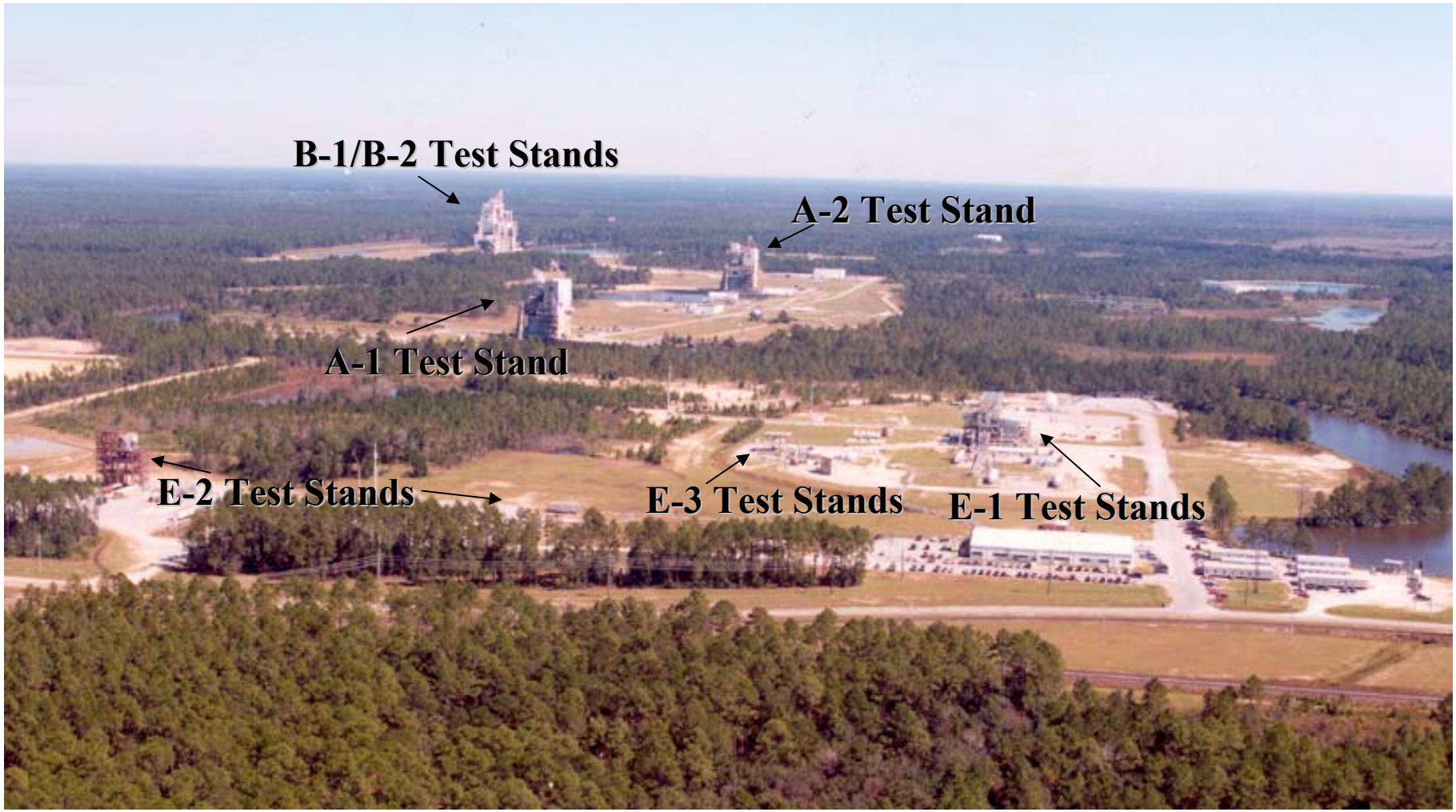

E-1 Test Stand Provides Large Thrust Component Test Capability

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THRUST CAPABILITIES:

- Cell 1 – 750,000 lbf horizontal thrust
- Cell 2 – 60,000 lbf at angles up to 10° above horizontal
- Cell 3 – 60,000 lbf at angles up to 10° above horizontal

HIGH PRESSURE GAS AND CRYOGENIC LIQUID VESSELS:

- LOX Storage: Total of 48,240 gal @ 165 - 9,000 psig
- LOX Catch Tank 28,000 gal
- LH_2 Storage: Total of 75,653 gal @ 33 - 8,500 psig
- LN_2 Storage Tank 28,000 gal @165 psig
- UHP GH_2: Total of 1,875 ft^3 @ 15,000 psig
- UHP GN_2 Storage: Total of 2,750 ft^3 @ 4,500 -15,000 psig
- HP He 1,515 ft^3 @ 4,500 psig

TEST CONTROL CENTER (TCC):

- 128 High Speed Data Channels
- 512 Low Speed Analog Channels
- Facility control consoles
- Environmentally controlled
- Closed-circuit television
- Graphics display instrumentation system

E-1 Test Stand

SSC ISHM Testbeds: Technology Development Chart

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Thrust (K Pounds)	Potential Testbeds	TRL	SW Off-line	SW On-Line	SW + HW On-Line
0-0.5	Portable Test Stand	Increasing TRL of Propulsion Test Article ↓ Increasing Scale/Size/Complexity			X
1-30	E3				X
30-100	E2			X	
100-750	E1		X	X	
1000	A-1/A-2		X (SSME)		
1000	B-1/B-2		X (RS68)		Holy Grail

Summary

- ISHM technologies are critical technologies for future space missions.
- The development effort leverages
  - Technology
  - Available test bed resources
  - Broad team expertise
- Brings technology developers, research scientists, and operations people together to design, test, and validate.