Implementation of Integrated System Fault Management Capability

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Fault Management to support rocket engine test mission with highly reliable and accurate measurements; while improving availability and life-cycle costs.
### CURRENT FM APPROACH

<table>
<thead>
<tr>
<th>Layer 1</th>
<th>Vehicle/Test Stand</th>
<th>Signal threshold violation detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer 2</td>
<td>Astronaut/Test Conductor</td>
<td>Added DIaK from on-board users.</td>
</tr>
<tr>
<td>Layer 3</td>
<td>Control Room</td>
<td>Added DIaK from broad group of experts.</td>
</tr>
<tr>
<td>Layer 4</td>
<td>Back Control Room</td>
<td>Added DIaK resources from larger community</td>
</tr>
</tbody>
</table>

**International Space Station**

**Rocket Engine Test Stand**

**RELEASED - Printed documents may be obsolete; validate prior to use.**
SSC ISFM Capabilities

ISFM Models (Embedded Data, Information, and Knowledge):
MTTP Implementation

Health Anomaly Database:
Health Electronic Data Sheets
Repository of anomalies

Anomaly Detection:
Leaks, etc.

Intelligent Sensors: IEEE Standard+Health

Embedding of Predictive Models

Root Cause Analysis

Integrated Awareness:
3-D Health Visualization of MTTP
CORE ELEMENTS: Architecture, taxonomy, and ontology (ATO) for DIaK management
CORE ELEMENTS: ATO for DlaK Management

Process models are generic and are encapsulated within subsystems

Valve Processes:
- Opening
- Closing
- Leaking

Tank Processes:
- Fill
- Pressurization
- Over-Pressurization
- Leaking
- Pressure collapse

Intelligent Component Processes

Intelligent Sensor Processes

Intelligent Subsystem Processes

Intelligent Process

Intelligent System Process

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CORE ELEMENTS: ATO for DIAK Management

Process models are generic and are encapsulated within subsystems

Leak through a valve shared by two pressurizable subsystems: (1) Valve is twice suspect, and (2) If pressure increases in one subsystem and decreases in the other, then Valve is leaking.
Checking for Pressure Leaks: Continuous and Comprehensive Vigilance

![Flowchart Diagram]

- Wait for Valve State Change
- Do Closed Elements Form a Boundary?
- Define Pressurizable Subsystem
- Pressurizable Subsystems
  - PS
  - PS
  - For Each PS
  - Check All Pressure Sensors
    - Do Sensors Indicate a Change in Pressure?
      - Yes: Root-Cause-Analysis
      - No: Mark All Elements of PS SUSPECT for Leak Anomaly
        - For Each Element
          - Change Health Parameters in Leak Process Model to SUSPECT
            - Root Cause
Virtual Intelligent Sensors provide benefits of ISHM capabilities to existing data acquisition systems by adding Intelligent Sensor capability.
Execution of Fault Management
(Courtesy of General Atomics Corporation)

Measured upstream and downstream pressures

Smart Sensors

Diagnosis Manager Analyzes Events

Inferred Obstruction of flow

Integrated 3-D Awareness

Alarm notification & Recommendation

ISHM Model

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Field Pilot Implementation
A1 and J-2X IFM MODEL

A-1 Test Stand at SSC

Predicted sensor values

Transrent Model
Real-Time

J-2X Engine

PWR Transient Model
Real-Time

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Field Pilot Implementation
GROUND OPERATIONS HEALTH MANAGEMENT (GOHM)

LC-20 ISHM Model (KSC)

Sensor anomalies detected during the demonstration

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NASA SSC ISHM TECHNOLOGIES AND PARTNERSHIPS FOR ROCKET ENGINE TESTING