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>International Space Station</th>
<th>Rocket Engine Test Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle/Test Stand</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Added</strong> DIaK from on-board users.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Layer 2</th>
<th>International Space Station</th>
<th>Rocket Engine Test Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronaut/Test Conductor</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Added</strong> DIaK from broad group of experts.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Layer 3</th>
<th>International Space Station</th>
<th>Rocket Engine Test Stand</th>
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</thead>
<tbody>
<tr>
<td>Control Room</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Added</strong> DIaK resources from larger community</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Layer 4</th>
<th>International Space Station</th>
<th>Rocket Engine Test Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back Control Room</td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
</tbody>
</table>

**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

Leak
Decreasing Pressure

Pressure Leak
Decreasing

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CORE ELEMENTS: Architecture, taxonomy, and ontology (ATO) for DIaK management
CORE ELEMENTS: ATO for DIaK 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 System Process

Intelligent Subsystem Process

Intelligent Process

Intelligent Sensor Processes

Intelligent Component Processes

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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

- **Wait for Valve State Change**
  - **No**
  - **Do Closed Elements Form a Boundary?**
    - **Yes**
      - **Define Pressurizable Subsystem**
    - **No**

- **Pressurizable Subsystems**
  - **PS**
  - **For Each PS**
    - **Do Sensors Indicate a Change in Pressure?**
      - **Yes**
        - **Check All Pressure Sensors**
      - **No**

- **Mark All Elements of PS SUSPECT for Leak Anomaly**
  - **For Each Element**
    - **Change Health Parameters in Leak Process Model to SUSPECT**

- **Root-Cause-Analysis**
  - **Root Cause**

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Intelligent Sensors: Virtual and Physical

- Virtual Intelligent Sensors provide benefits of ISHM capabilities to existing data acquisition systems by adding Intelligent Sensor capability.

```
Sensor 1
Sensor 2
...  
Sensor N

DAS

VIRTUAL INTELLIGENT SENSOR
Smart
  • TEDS
  • NCAP
Intelligent
  • Other EDS
  • Health Algorithms

To Control Room & existing applications

SENSOR

INTELLIGENT SENSOR

ISHM
NCAP

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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

Transient 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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