Implementation of Integrated System Fault Management Capability

NASA Stennis Space Center
Engineering and Science Directorate
Science and Technology Division, EA41

Fernando Figueroa, John Schmalzel (NASA)
Jon Morris, Harvey Smith, Mark Turowski (Jacobs Technology)

April 2008
Fault Management to support rocket engine test mission with highly reliable and accurate measurements; while improving availability and life-cycle costs.

RELEASED - Printed documents may be obsolete; validate prior to use.
CURRENT FM APPROACH

International Space Station

Layer 1
Vehicle/Test Stand

Layer 2
Astronaut/Test Conductor

Layer 3
Control Room

Layer 4
Back Control Room

Rocket Engine Test Stand

Signal threshold violation detection

Added DIaK from on-board users.

Added DIaK from broad group of experts.

Added DIaK resources from larger community

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

MTTP

RELEASED - Printed documents may be obsolete; validate prior to use.
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 Component Processes

Intelligent System Process

Intelligent Subsystem Process

Intelligent Process

Intelligent Sensor Processes

RELEASED - Printed documents may be obsolete; validate prior to use.
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
- Do Closed Elements Form a Boundary?
  - Yes: Define Pressurizable Subsystem
  - No
- Pressurizable Subsystems
  - For Each PS
    - 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

Released - printed documents may be obsolete; validate prior to use.
Intelligent Sensors: Virtual and Physical

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

**Virtual Intelligent Sensor**
- TEDS
- NCAP
- Other EDS
- Health Algorithms

**Sensor 1** → **Sensor 2** → ... → **Sensor N** → **DAS** → **VIRTUAL INTELLIGENT SENSOR** → **To Control Room & existing applications**

**Smart**
- TEDS
- NCAP

**Intelligent**
- Other EDS
- Health Algorithms

**Network**

**REleased** - Printed documents may be obsolete; validate prior to use.
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

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

RELEASED - Printed documents may be obsolete; validate prior to use.
Field Pilot Implementation
GROUND OPERATIONS HEALTH MANAGEMENT (GOHM)

LC-20 ISHM Model (KSC)

Sensor anomalies detected during the demonstration

RELEASED - Printed documents may be obsolete; validate prior to use.
Open Systems Architectures

Prognostics & Anomaly Detection

Integrated Awareness

IEEE 1451 Smart & Intelligent Sensors

NASA SSC ISHM TECHNOLOGIES AND PARTNERSHIPS FOR ROCKET ENGINE TESTING

RELEASED - Printed documents may be obsolete; validate prior to use.