NASA Program Flavor

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Roadmap for Prognostics CoE

Modeling – Algorithms – Uncertainty Mgt. – Decisioning – Health Reasoning – V&V

Controller Reconfiguration
- Decision making based on prognostic information

Integration
- Combine and process information from different, interacting subsystems

Uncertainty Management
- Quantification and containment of uncertainty

Distributed Prognostics
- Divide and conquer of algorithm processing

Prognostics for Actuators
- Detailed modeling of mechanics of physics-of-failure (ball jam, backlash, etc.)

Prognostics for Electronics
- Modeling of semiconductor components
- Experimental validation

Prognostics for Batteries
- Testbed for algorithm development
- Data Collection

V&V
- Validate proper operation of prognostic algorithms

-1 year now +1 years +2 years +3 years +4 years +5 years
Some Current NASA Activities in SHM

ROCKET ENGINE TEST STAND

ROBOTIC SPACE FLIGHT

AERONAUTICS

HUMAN SPACE FLIGHT

COMPOSITES

Ground Diagnostics for CLV and Ground Test / Integration Infrastructure

CLV Crew Abort Logic Development

LCROSS

Ground-Based Root Cause Determination; Data Analysis

IVHM

On-board and off-board Diagnostics, Prognostics, Logistics

Space Station Fault Analysis

Space Shuttle Main Engine Abnormal Condition Detection

Solid Rocket Motor Failure Detection and Prediction

Data Analysis / Mining for Mission Ops
Integrated Systems Health Management
Implementation Concept

Technology Development

ESMD, ARMD, SMD

NASA Missions

High Flight Maturity

Tech. Leverage

• Industry-Supplied Technologies
• Commercialization Opportunities

Highly Integrated Technologies Tested in Relevant Environments
Stacking preps of segments
• Stacking & integration of segments
• Integrated Test
• Ordnance Operations and closeouts

• Stacking preps of segments
  • Stacking & integration of segments on pedestal
  • Transfer of Ares I to ML
  • Integrated Test
  • Ordnance Operations and closeouts

• Refurbishment and packaging of parachutes

• Refurb of the Aft Skirt
  • Integration of the Forward Assembly
  • Hot fire of the Aft Skirt HPU

• Receiving, processing, and surge of loaded motor segments
  • Integration of the Aft Skirt with the aft motor segment

• Pad connections and validations
  • Final ordnance ops
  • Cryo load (refueling) and launch count

• Recovery of spent booster, parachutes, and forward skirt extension
  • Inspection & Disassembly of booster

Fault Detection, Isolation and Recovery
FDIR Task Objectives

- Select and mature ISHM tools to provide anomaly detection, fault isolation and fault recovery recommendation for CxP ground operations
  - Help meet launch availability rate through faster fault isolation and recovery recommendation
- Develop architecture for integrated fault detection, isolation and recovery (vehicle and ground)
- Identify path for integration of ground and vehicle fault models
- Identify path for certification of the FDIR architecture
- Assess FDIR capability
  - Scalability, Performance, Cost, Benefit
- Initiate proof-of-concept for ground subsystem prognostics applications
- Provide implementation/deployment options for integration with the Launch Control System
Integrated FDIR Concept

Deployment in phases

• Initial deployment
  – Capabilities
    • Anomaly Detection
    • Fault Detection and Fault Isolation
  – An FDIR application for the Liquid Hydrogen ground subsystem will be developed and validated within the Launch Control System
  – Requirement
    • Confirm tools will provide a “health/self-test” capability.
    • Minimize the risk to the other deployment activities

• Longer term deployment goals
  – Mature automated recovery recommendation capability
  – Mature prognostic capabilities for LRUs
    • Condition Based Maintenance vs. Reactive, Time-based Maintenance
  – Deploy FDIR capabilities to ground subsystems
  – Integrate vehicle and ground FDIR capabilities
FDIR Application Lifecycle

- Develop FDIR App Reqs.
- Develop/Update FDIR Modules
- Develop/Update Architecture
- Training on FDIR App for operators
- Tool Licenses (initial + annual)
- Tool Support
- Tools Training for developers
- Hardware Infrastructure
- V&V FDIR App
- Certify Tools
- Update Subsystem Reqs
- Tool Updates

Key:
- Per Subsystem
- One time / Infrequent

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What Are the Hurdles?

• Application-specific
  – Short time horizon
• Corporate culture
  – New technology has to buy its way on
• Competing with other functions
  – No interference (“do no harm”)
  – Weight
• S&T
  – Learning and adaptive systems
  – Software complexity
  – Decision Making
  – Uncertainty Management
Summary and Conclusions

• Health management is seen more and more as an enabler for aerospace applications
• Ongoing activities at NASA cover range of HM areas
• Needs
  – Research methodology
  – Overcome challenges in S&T
    • Learning and adaptive systems
      – Space is the “final frontier” for ISHM
    • Software complexity
      – V&V, certification
    • Uncertainty Management
      – Credible methods to manage uncertainty
    • Decision Making
      – Tie-in to logistics; reconfiguration
• Implementation will be slow and painful, often one small step at a time
  – Finding the right applications is crucial
  – Ground ➔ Aircraft ➔ Robotic craft ➔ Human space flight
  – Increasing level of comfort and confidence over time
  – Proving benefit over cost
  – Taming software complexity
• Overcome bottlenecks in academia, government, industry
  – Vision: coordination of programs, technology development, education
Call for Papers & Participation

International Conference of PHM Society 2009

September 28 – October 1, 2009
www.phmconference.org

This conference provides an international forum dedicated to Prognostics and Health Management (PHM). The conference continues the tradition to bring together experts from industry, academia, and government in diverse application areas such as energy, aerospace, transportation, automotive, and industrial automation. The conference is sponsored this year by the newly founded PHM Society and technical sponsorship of the IEEE CIS.

The conference will feature
- keynote presentations by senior leaders in the field,
- panel discussions,
- hardware demonstrations,
- luminaries session,
- doctoral consortium,
- dedicated session on fielded systems,
- full day of tutorials free to all registrants.

Leading companies and research institutions will exhibit their products and demonstrate their technologies during the event. Several social events will provide opportunities for participants to connect with colleagues across the globe.