# Integrated System Health Management (ISHM) for Test Stand and J-2X Engine: Core Implementation

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## Abstract

ISHM capability enables a system to detect anomalies, determine causes and effects, predict future anomalies, and provides an integrated awareness of the health of the system to users (operators, customers, management, etc.). NASA Stennis Space Center, NASA Ames Research Center, and Pratt & Whitney Rocketdyne have implemented a core ISHM capability that encompasses the A1 Test Stand and the J-2X Engine. The implementation incorporates all aspects of ISHM; from anomaly detection (e.g. leaks) to root-cause-analysis based on failure mode and effects analysis (FMEA), to a user interface for an integrated visualization of the health of the system (Test Stand and Engine). The implementation provides a low functional capability level (FCL) in that it is populated with few algorithms and approaches for anomaly detection, and root-cause trees from a limited FMEA effort. However, it is a demonstration of a credible ISHM capability, and it is inherently designed for continuous and systematic augmentation of the capability.

The ISHM capability is grounded on an integrating software environment used to create an ISHM model of the system. The ISHM model follows an object-oriented approach: includes all elements of the system (from schematics) and provides for compartmentalized storage of information associated with each element. For instance, a sensor object contains a transducer electronic data sheet (TEDS) with information that might be used by algorithms and approaches for anomaly detection, diagnostics, etc. Similarly, a component, such as a tank, contains a Component Electronic Data Sheet (CEDS). Each element also includes a Health Electronic Data Sheet (HEDS) that contains health-related information such as anomalies and health state.

Some practical aspects of the implementation include: (1) near real-time data flow from the test stand data acquisition system through the ISHM model, for near real-time detection of anomalies and diagnostics, (2) insertion of the J-2X predictive model providing predicted sensor values for comparison with measured values and use in anomaly detection and diagnostics, and (3) insertion of third-party anomaly detection algorithms into the integrated ISHM model.

ISHM capability is implemented based on an ISHM model that is organized as a hierarchical network of intelligent processes (Figure 1). This architecture encapsulates data, information, and knowledge (DIaK) of a system, and enables management of DIaK

that is fundamental to implementation of ISHM functions. The elements at the lowest level include intelligent sensor process models that can be encapsulated in sensors/actuators and components (e.g. valves, tansk, etc.). These include algorithms and procedures for sensor/data validation. It does not mean that one has to have a physical intelligent sensor in which to encapsulate DIaK; it can be done virtually in software (this was the case for the implementation described in this paper). The next level up includes intelligent element process models such as pressurization of a tank, opening of a valve, etc. These models usually involve multiple sensors. The next level up includes subsystem process models. These are models that involve multiple elements (e.g. tanks, valves, etc.) such as flow of fluid from a tank through a valve, pipes, etc.

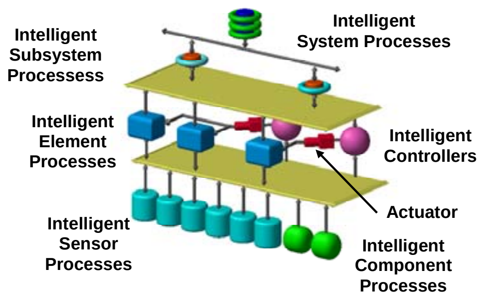


**Figure 1. Architecture to build ISHM Models of Systems.**

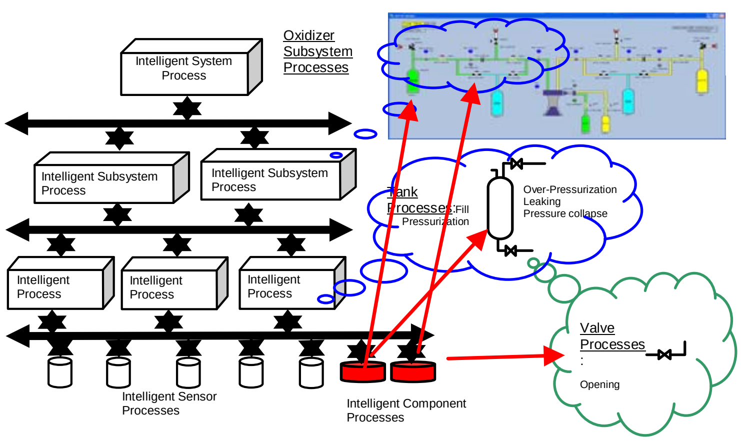


**Figure 2. Encapsulation of process models at various levels of the architecture.**

Figure 2 shows pictorially examples of DIaK that might be encapsulated within the process objects of the architecture. The general thought is that processes at higher levels allow consistency checks with higher level information, to detect events that can only be visible through models involving multiple elements (e.g. a leak within the fuel subsystem). Events detected at each level are sent down to improve health assessment at lower level process models, and up to help assess overall system health.

The architecture and implementation are modular and allow systematic augmentation of ISHM capability as new process models become available. This is crucial to develop sustainable and affordable systems. The paper will describe the ISHM implementation and provide results of its performance during J-2X testing.

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