

DEEP SPACE

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Aramco Technology and
Operational Excellence Forum

Prognostics & Health Management: A NASA Perspective

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Objective

How can advanced automation techniques developed by NASA to perform Fault Detection, Isolation, and Recovery (FDIR) in space missions be used here on Earth in the Oil & Gas industry?

Whether on a Mars orbiter or an oil platform, having an intelligent machine to back up the crew/operators to help monitor and diagnose the systems for possible problems and aid in determining a corrective action/response is an important and useful attribute for multiple industries.



The Solution

The analytic process is the same, just applied to different situations.

- Develop an understanding of what can go wrong,
- Determine how it looks from a sensor or instrumentation view,
- Develop a process for down selecting from multiple possibilities to one or a couple, and
- Determine what follow-on or recovery steps are needed to return the situation to a safe or stable state.

Various techniques can be used in combinations to perform this function. For example, a rule-based approach can be utilized to perform simple, straightforward assessments. More advanced or complicated assessments may combine model-based reasoning with rule-based and statistical / probabilistic approaches. Subject Matter Experts (SMEs) on both advanced automation techniques and the system domain (such as the offshore rig, subsea ops, remote Artic facility, etc) would work together to build the Fault Detection, Isolation, and Recovery (FDIR) system for the specific application.

Some Potential Examples

Space Related

- Human missions to Mars
 - Complex, quick response ops
 - Rendezvous & docking
 - Landing & take off from Mars
- Deep space robotic missions
- Space Station
 - Nominal ops
 - Off-nominal ops

Oil & Gas Related

- Off shore well operation
 - Subsea ops
 - Topside ops
 - Integration
- Arctic / Antarctic operations
- Piping and transportation
- Robotic applications
 - Construction
 - Maintenance

Prognostics Overview

- **Prognostics** is an engineering discipline focused on predicting the time at which a system or a component will no longer perform its intended function. This lack of performance is most often a failure beyond which the system can no longer be used to meet desired performance. The predicted time then becomes the **remaining useful life (RUL)**, which is an important concept in decision making for contingency mitigation.
- Prognostics predicts the future performance of a component by assessing the extent of deviation or degradation of a system from its expected normal operating conditions. The science of prognostics is based on the analysis of failure modes, detection of early signs of wear and aging, and fault conditions.
- An effective prognostics solution is implemented when there is sound knowledge of the failure mechanisms that are likely to cause the degradations leading to eventual failures in the system. It is necessary to have initial information on the possible failures (including the site, mode, cause and mechanism) in a product. Such knowledge is important to identify the system parameters that are to be monitored. Potential uses for prognostics is in condition-based maintenance.

Prognostics Overview (Cont'd)

- The discipline that links studies of failure mechanisms to system lifecycle management is often referred to as:
 - **prognostics and health management (PHM)**,
 - **system health management (SHM)** or
 - **vehicle health management (VHM)** or **engine health management (EHM)** — in transportation applications
- Technical approaches to building models in prognostics can be categorized broadly into:
 - data-driven approaches,
 - model-based approaches, and
 - hybrid approaches.

NASA FDIR Overview

- From the beginning of NASA, each mission has used some level of automation or machine (artificial) intelligence.
- As NASA moved forward, it realized that advanced automation and robotic devices (using machine intelligence) will play a major role in all future space missions. Such systems will complement human activity in space, accomplishing tasks that people:
 - cannot do,
 - are too dangerous,
 - too laborious, or
 - too expensive.

Accident Precursor Analysis (APA) Overview

- NASA's APA process provides a systematic means of analyzing candidate accident precursors by evaluating anomaly occurrences for their system safety implications and, through both analytical and deliberative methods used to project to other circumstances, identifying those that portend more serious consequences to come if effective corrective action is not taken.
- APA builds upon existing safety analysis processes currently in practice within NASA, leveraging their results to provide an improved understanding of overall system risk. As such, APA represents an important dimension of safety evaluation; as operational experience is acquired, precursor information is generated such that it can be fed back into system safety analyses to risk-inform safety improvements.
- APA utilizes anomaly data to predict risk whereas standard reliability and PRA approaches utilize failure data which often is limited and rare.

JSC Software, Robotics, And Simulation Division

The Spacecraft Software Engineering Branch provides leadership and technical expertise in spaceflight software development and Vehicle Systems Management (VSM).

- Technical support to major human spaceflight programs/projects (e.g. ISS, Orion, Altair) includes both contractor oversight and government furnished equipment software development.
- Systems engineering is performed to assess flight vehicle operations, the appropriate application of automation and autonomy, and the performance of flight processor architectures.
- VSM includes Fault Detection, Isolation and Recovery (FDIR), Vehicle Re-initialization, Mode Management, Resource Management, Onboard Checkout, and Management of Health and Status Data.

Forward Plan

Proactively devise a plan of attack to implement over the long-run, starting now (“Be the Ball”):

- Propose specific applications needed by both industries
- Identify gaps in technology where our industries can collaborate to get solutions via “Faster, Cheaper, Better” (Pick Two)
- Implement collaboration
- Solve the problems
- Celebrate the fact that we really are in the 21st Century.... 😊