Expanding the Boundaries of Test and Diagnostics : Prognostics and Health Management (PHM) for Complex Systems

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I. ABSTRACT

Prognostics, or predictive diagnostics, offers substantial promise to reduce the life-cycle costs of critical systems. When linked with comprehensive Prognostics and Health Management (PHM) or Integrated Vehicle Health Management (IVHM) architectures, prognostics offers significant benefits. Applications range from aerospace to industrial machines on the factory floor. These systems include electronic and mechanical components that are subject to wear-out and eventual failure.

Standard test and diagnostics can serve to confirm the quality of the manufactured device or system at time zero but also can be used to monitor the health of the part throughout its lifetime. This is done by linking diagnostics with parameter extraction to determine on-going state-of-health (SoH). Algorithms can analyze the SoH to determine the Remaining Useful Life (RUL) as well. Key benefits are that prognostics enable impending failures to be found before they occur, with improvements to safety and serviceability, along with life cycle cost reduction. On-line tests or periodic tests during the components'/systems' lifetime or burn-in tests and diagnosis serve to provide useful input data for the prognostic process.

The historical basis for prognostics began with vibration monitoring of mechanical systems. It was found that unique signatures could be detected, extracted, and then correlated with wear on bearings or gears. These unique signatures, in turn, could be used to build fault dictionaries, to alert service personnel and trigger a host of autonomic logistical actions. In recent years, PHM has expanded to the electronics world, where users have raised concern about the robustness of systems when the key components such as ICs may have reduced lifetimes.

While conventional mean-time-between-failures (MTBF)-type reliability estimates offer some initial measure of statistical lifetime, the individual system's lifetime is affected by its actual use environment, possible "Black Swan" events, or damage while in service. The basic process of prognostics involves an orderly sequence of steps:

- - Sensing and observability
- - Anomaly Detection
- - Cross reference against a fault dictionary
- - Algorithmic processing of data
- - State of Health (SoH) and Remaining Useful Life (RUL) calculations

As with any process or method, the business case has to be examined involving Return on Investment (ROI). Often the ROI calculations transcend organizational boundaries. Some of the early findings have been very encouraging on life-cycle cost reductions. The advent of advanced Internet of Things (IoT) technologies has also introduced promising avenues for further growth in this area. Additional future trends involve the development of key standards for interoperability and tool development.

The current state of prognostics, PHM/IVHM, Condition-based Maintenance and new areas of R&D will be discussed, and their future impact on society.

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