EIGHT LEVEL DPHM SYSTEM DEVELOPMENT

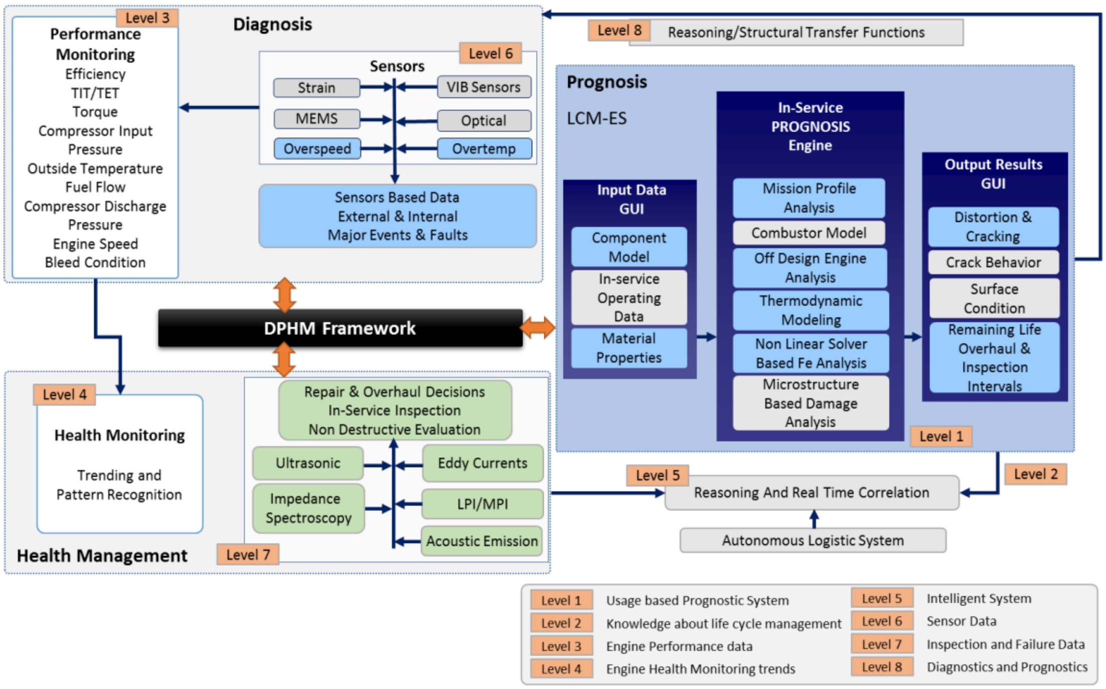

Figure 1: A system framework

The flow diagram essentially describes two interrelated packages of technology. The left hand side of the flow diagram shows sensor and inspection data based technologies that are routinely used for diagnostic purposes. These diagnostic tools are well known and are widely applied to initiate maintenance action. For example, performance monitoring is often used to detect compressor fouling to initiate compressor wash action, temperature data is monitored to detect over-temperature events, vibration sensors are used to detect gross structural integrity problems and inspection data are of course used to make decisions about component replacement. However, diagnostic tools are only able to detect the damage once it has reached a critical stage. On the right hand side of the diagram in the dashed square are the emerging technologies that can be used to initiate predictive maintenance or operation actions to maximize engine utilization with minimum down times and these technologies are also known as the prognosis technologies. LPTi has developed a number of such prognosis technologies that have largely been incorporated into a prognosis system called XactLIFE. Additional technology modules are currently under development will allow interpretation of data from existing diagnostic capabilities to be correlated with fundamental component level damage states predicted by the prognosis tools. This will provide a basis for the development of a life cycle management expert system. A detailed description of possible interrelationships between diagnostics and prognosis technologies is given later.

The flow diagram also delineates broad relationships between component level prognosis domain and system level health monitoring, diagnostics and inspection domains. It also shows how clear correlations can be developed among these fields of gas turbine engineering to develop an all-encompassing DPHM system that will enable a user to predict the state of components as a function of engine operation using sensor based health monitoring and diagnostics information in order to initiate appropriate corrective measures. Prior to describing the schematic in greater detail, it is important to understand the terminology used to describe the proposed DPHM schematic.

Any measured parameter for use in prognosis, performance and health monitoring or diagnostics is called “data” and trending of sensor data to discern meaningful patterns is called “information”. If the data is used in physics based prognosis or diagnostics analysis, the resulting prognosis and diagnostics information is referred to as “knowledge”. Any knowledge that is successfully correlated with field experience and can be used for predictive maintenance of the engine as a function of future engine operation is in turn classified as intelligence. Therefore, the entire aim of the schematic presented in the flow diagram is to lay down the foundation for creating an intelligent DPHM expert system.

In the proposed DPHM scheme, knowledge generated through the use of physics based predictive techniques, analysis of on-line sensor data, trending of the sensor data to generate correlating information and tying up the entire knowledge base and information with the field experience or overhaul based inspection results are assigned a level ranging between level 1 to level 8 on the basis of the sequence of events leading to component level changes and the consequent impact of these changes on engine performance and structural integrity. For example, Level 1 is assigned to identification and analysis of thermal-mechanical loads during service for use in conjunction with physics based damage algorithms to develop knowledge about various forms of component damage in different sections of the turbine. Knowledge about the manifested damage state and the prediction of its impact on remaining life, inspection and overhaul intervals is assigned Level 2 in the overall sequence of events and analysis. The combination of Level 1 and Level 2 knowledge constitutes the prognosis domain in the proposed DPHM scheme. The components in a damaged state (Level 2 information) may in turn influence the engine performance (Level 3 data) or the health monitoring trends (Level 4 information). Development of a real time correlation between Level 2 knowledge, Level 3 data and Level 4 information and the verification of the results using field experience will lead to the development of a real time intelligent system that is assigned Level 5 in Figure 1. This Level 5 intelligent system should in principle be capable of predicting the state of components using performance and health monitoring information and component level prognosis knowledge. Once component level damage exceeds certain limits and creates a fault that can be detected by trending a specific sensor data (Level 6 information) and verified through inspection (Level 7 data), the impact of the fault on the future structural integrity can be assessed using physics based damage growth algorithms to develop additional Level 2 knowledge. The development of this additional Level 2 knowledge base and its real time correlation with the sensor information can in turn be used to create structural transfer functions to assess the future structural integrity of the components containing growing faults. Development of verified structural transfer functions using field experience will lead to the development of another layer of intelligence (Level 8 in the flow diagram) that will be capable of predicting real time structural integrity of the engine in the presence of sustainable faults. The combined intelligence developed by training engine specific systems at Levels 5 and 8 in the flow diagram will form the basis of an real time DPHM expert system that can be used for making system level decisions for predictive maintenance.

The development of intelligent systems at Levels 5 and 8 fundamentally requires the availability of knowledge based prognosis systems at Levels 1 and 2 and the availability of performance and health monitoring information and diagnostics information including field experience. LPTi has thus far successfully developed and validated a prognosis system called XactLIFE that is capable of generating component level knowledge using actual engine usage about the damage state at Levels 1 and 2 for a specific engine and detect performance deteriorations using levels 3, 4 and 6. AI based interpolations are also available for level 1 for real-time applications.