The Prognostics and Health Management Digital Hierarchy of Needs

Joseph Barta[1], Ethan Erlhoff[2], and Dania Alfeerawi[3]

[1,2, 3] *Northrop Grumman Aeronautics Systems, San Diego, CA, 92127, United States of America*

Joseph.Barta@ngc.com
Ethan.Erlhoff@ngc.com
Dania.Alfeerawi@ngc.com

ABSTRACT

In today's modern world, with the abundance of digital data, data science identified as a rigorous discipline, and the common use of machine learning (ML) techniques, the Prognostics & Health Management (PHM) field can successfully be executed utilizing a foundational approach where a digital hierarchy of needs is established for successful implementation of PHM on a large-scale system. This paper rationalizes the digital hierarchy of needs as it applies to PHM, explains how each foundational concept is essential, and builds upon the base-level concepts through analysis and implementation.

First, this paper expounds how the integration of digital data from the lower-level components to the system level is critical for the success of PHM-enabled Systems. Once established, a description is provided on mapping the appropriate fault data to the corresponding components for the purpose of correlating failures to fault data. Next, a discussion on the PHM System Characterizations of Fault Detection, Fault Isolation, and simple prognostics analyses is presented. This is then followed by a discussion on how advanced PHM analyses can then be conducted utilizing data science and machine learning techniques with the intent of predictive maintenance analysis. Lastly, a dialogue is presented for an approach to implement real-time predictive activities once the complex analysis is validated and verified.

This concept can be seen graphically in Figure 1. Data integration is the foundation of the pyramid, supporting the identification of fault and parametric data, and followed by Fault Detection, Fault Isolation, and Simple Prognostics. The top tiers of the pyramid can then integrate complex analysis such as ML, and real-time implementation.

For each of these elements in the PHM Digital Hierarchy of Needs, a hypothetical case study of an aircraft system is used to show what happens when each level is successfully implemented, and when it is not successfully implemented.

1. INTRODUCTION

Problem Statement: Many traditional programs view the discipline of Prognostics and Health Management (PHM) as an add-on activity to the discipline of Reliability and Maintainability (R&M). However, the successful implementation of PHM requires a systematic process that deviates from the traditional activities to R&M. The activities for the PHM efforts start with the foundation of ensuring the data is available and then all other activities build upon this. This paper provides a Digital Hierarchy of Needs by which PHM can be built upon (Figure 1).

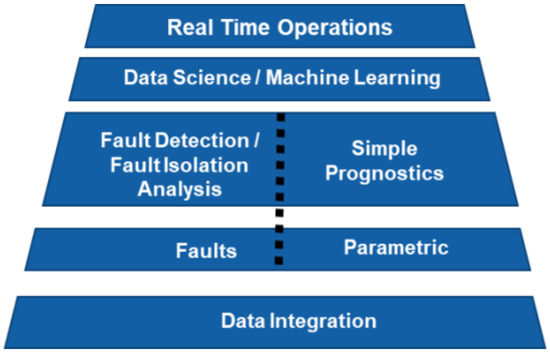

Figure 1. PHM Digital Hierarchy of Needs

Problem Motivation: Through this identification of a Digital Hierarchy of Needs, a PHM practitioner can begin to systematically walk through the foundational activities required to implement PHM on a large-scale system with a set of prioritizations. This paper provides an order of precedence to these activities and can serve as a reference point for the development of a PHM Program Plan. It should be noted that the concepts described in the PHM Digital Hierarchy of Needs are not new concepts. However, the novelty of this paper is to show how each concept builds upon

---

the other so that a PHM effort can successfully be implemented

Problem Background: Traditionally, with most aviation programs where PHM activities are required, the segmentation of activities is divided such that data integration is driven by hardware and software development needs, fault detection/isolation is conducted through the Testability Analysis using a Failure Mode & Effects Criticality Analysis (FMECA) and Prognostics are an afterthought. The PHM Plan is typically a subset of the R&M Program Plan and little thought is applied to the systematic needs to fully implement PHM.

However, as activities such as Condition Based Maintenance Plus (CBM+) become more critical to support complex systems, the PHM effort should be more rigorous from a bottom-up approach starting at data collection. And as, "*the incorporation of CBM+ on aviation programs requires careful consideration due to the unique challenges evident during all aspects of an aviation program life cycle*" (Crooks, Plawecki, 2021), PHM activities should be more methodical for the practitioner.

Subsequently, using the PHM Digital Hierarchy of Needs, the key foundational activities can be developed and built on to successfully implement PHM and apply the complex diagnostics and analysis in areas of the system where cost benefits can be fully optimized. Note that this hierarchical approach is focused on the Data Driven (DD) prognostics method which "*comprise two major approaches, statistical and Machine Learning (ML), that use acquired data to statistically and probabilistically produce prognostics information such as decisions, estimates, and predictions*" (Goodman, Hofmeister, & Szidarovszky, 2019). The aim of this approach is to provide an affordable PHM solution on what can be used from the existing design as "*the DD approaches make health decisions and predictions based purely on the data available*" (Pecht, 2008)

Technical Introduction: The PHM Digital Hierarchy of Needs, consists of five (5) elements which build upon another leading to a cost-effective solution to the implementation of PHM in a large-scale system.

The first (1st) element is Data Integration. The foundation element focuses on the development of the data pipelines from the lower components to the system level components. This allows for the effective reporting of PHM data.

Building upon this, the second (2nd) element is the identification and documentation of the data reported at the system level. This allows for an adequate understanding of the PHM data. Note that in the second element of the hierarchy, "faults" are defined as diagnostic data identifying when a component as failed, and "parametric data" is defined as additional data (such as voltage, current, temperature) to identify the existing health of a component.

The third (3rd) element is the characterization of the PHM Data's capability through Fault Detection/Isolation Analysis. Also, the development of simple prognostics and trending can be considered in this element. This element allows for a better understanding on the performance of the PHM data.

Building upon the third element, the fourth (4th) element of Data Science and Machine Learning applications can be considered in the appropriate areas where the performance of the PHM data may require additional refinement and advanced capabilities to detect a failure prior to occurrence.

Lastly, the fifth (5th) element, and at the top of the PHM Digital Hierarchy of Needs is the implementation of the Real-Time Operation for PHM. Once an algorithm/approach has been developed from the fourth element, is verified to work, and is proven to be valid in the intent, then it can be considered for Real-Time implementation such that identification of a failure prior to occurrence is fully automated.

To supplement the concept of the PHM Digital Hierarchy of Needs a hypothetical case study of an Aircraft System is used to demonstrate the importance of each element, from a Supplier-to-Subsystem-to-System Level integration, and how it builds upon the upper elements shown in Figure 1. For each element in the case study, a "Major", or "Minor", quantitative impact assessment is provided to articulate the importance of the element against the hypothetical case study.

2. DATA INTEGRATION

PHM Data integration focuses on ensuring that the system has "*Built-in Fault or Data logs that store parametric and fault code data to mature the Health Management System (HMS) design*" (Beshears & Butler, 2005). The integration of the PHM data from the lower-level components to the system level diagnostics reporting is the foundational element to the PHM Digital Hierarchy of Needs. Success to this element is critical for the success of the remaining elements. Additionally, it is critical that this element has a high level of focus during the development phase of the program.

To succeed in this element, software documentation with respect to diagnostics requires attention and review. It is critical to know what type of data is available and reported out the higher levels of a system. Ideally, if one has a good understanding of the PHM dataflow in the early phases of design, corrections can be easily made. Conversely, if these issues are identified in later phases of the system design, corrections cannot be easily made as this may require software, and potentially hardware updates.

It is recommended that PHM Dataflow diagrams be developed to articulate and communicate data paths and identify any gaps in the development of PHM Data. The development of PHM Dataflow Diagrams allows for the concept of "*transparent data integration*" (O'Donovan, Leahy, Cusack, Bruton, & O'Sullivan, 2015) to be realized in that one can identify all the originating data sources utilized for PHM reporting. A sample PHM Dataflow diagram can be seen below in Figure 2.

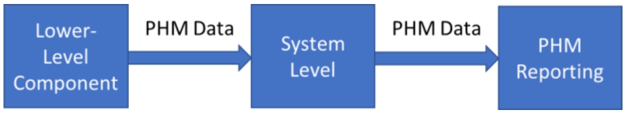

Figure 2. Sample PHM Dataflow Diagram

2.1. Hypothetical Case Study: Integration of PHM Data on an Aircraft System

In the first phase of the hypothetical case study, for the Aircraft System, the focus is on effectively integrating data from the lowest level of components up to the System Level where PHM data can effectively be reported. In this hypothetical study, the assumption is that Lower-Level Components are developed by a Supplier, and then integrated into an Aircraft Subsystem, which is then integrated at the Aircraft System Level for Reporting of the PHM data. In this situation it is critical to ensure that the Suppliers have the appropriate diagnostics requirements where the data can be accessed at the subsystem level.

Once at the subsystem level, PHM data can be integrated, and standardized, so that the System Level has adequate reporting of PHM Data. It should be noted that "*Implementing an effective PHM strategy for an entire system will involve integrating different health monitoring approaches*" (Vichare & Petch, 2006). Subsequently, all of these approaches may present the data in different fashions at the Subsystem Level. At the System Level it is important to standardize this data so that it can effectively be reported.

Successful Implementation: For this hypothetical case study, the successful implementation of this element of the hierarchy will allow the PHM Engineer to effectively articulate reported PHM Data and communicate any gaps of coverage in the Aircraft System where Prognostics and Diagnostics are not implemented.

Unsuccessful Implementation: In the hypothetical case study, if the Data Integration element is not successfully implemented, PHM data will not be available leading to a lack of Prognostic and Diagnostic coverage in the Aircraft System. Without the availability of PHM Data, Faults and Parametric data cannot be characterized. Basic PHM metrics cannot be developed to determine the PHM performance of the Aircraft System. Lastly, any advanced PHM capabilities cannot be developed. Subsequently, development of any of the other elements are limited because the data is not available. Moreover, System failures could go unnoticed leading to potentially severe consequences.

For this hypothetical case study, in the context of a Supplier-to-Subsystem-to-System Level integration, failure to implement this element of the hierarchy would have a "Major" impact on the Aircraft Systems PHM capability because no other element could effectively be developed.

3. IDENTIFICATION OF FAULT/PARAMETRIC DATA

Building upon the foundation, once the PHM Data has been integrated from the lowest levels reporting data up to the system level, it is critical to identify what that data is and what it represents. Ideally, a PHM Data Dictionary should be developed which articulates the subsystem, components, data that is reported, and the medium by which that data is communicated. The development of the PHM Data Dictionary provides a single source location of the identification of the fault data and any parametric data associated with the PHM Data of the system.

It is recommended that documentation be started in text document, tabular spreadsheet, or a database. Any of these methods will suffice if the PHM Data Dictionary is available to all stakeholders involved in the development of a system required to utilize the PHM Data, e.g.: System Engineering, Test Engineering, or Software Engineering.

3.1. Hypothetical Case Study: Identification of Fault/Parametric Data on an Aircraft System

In the second phase of the hypothetical case study, for the Aircraft System, the assumption is that the Supplier-to-Subsystem-to-System Level data has been effectively integrated. This then leads to the next element of the hierarchy, which is developing a clear definition of the faults and parametric data for the Aircraft System.

At this point, the PHM engineer can develop a PHM Data Dictionary to categorize all the PHM data, identifying how each piece of data correlates to the Aircraft System. This can provide traceability at the System level all the way down to the Supplier Level.

Successful Implementation: For this hypothetical case study, the successful implementation of this element of the hierarchy allows for a clear understanding of the Aircraft PHM data at the System level. Under the assumption that a Failure Mode, Effects, and Criticality Analysis (FMECA) has been completed for the Aircraft System, the Fault and Parametric data can be correlated to the various failure modes to determine what data is critical to the Aircraft System. Moreover, having a clear definition of the fault and parametric data allows for ease of characterizing how well the diagnostics of the system can perform (fault data). And it allows the PHM engineer to identify data for basic prognostics on potential failure trends (parametric data).

Unsuccessful Implementation: In the hypothetical case study, if the Fault/Parametric Data is not effectively identified, or documented, the delineation from the System Level Aircraft data to the Subsystem Data to the Supplier data will be limited. As a result, the PHM engineer will not have limitations for correction at the Supplier level if there is no defined correlation of data at the System Level. Not having this element correctly in place will impact the next element of Fault Detection/Isolation, False Alarm Mitigation and Simple Prognostic development, in that documented source data from the design will be limited and will be dependent only on the field data collected.

For this hypothetical case study, in the context of a Supplier-to-Subsystem-to-System Level integration, failure to implement this element of the hierarchy would have a "Major" impact on the Aircraft Systems PHM capability because the ability to articulate updates at the Supplier level would be limited.

4. FAULT DETECTION/ISOLATION, FALSE ALARM MITIGATION AND SIMPLE PROGNOSTICS

Once the PHM Data has been successfully integrated, and the data is clearly articulated, it can be assessed for performance. In this case, the PHM data is assessed for how well it detects a failure, how well it isolates a failure, and how accurate the data report is (e.g.: minimization of false alarms, and fault isolation to the right component). Also, the data can be used to conduct Simple Prognostics which in this case is the identification of data trends prior to the occurrence of a failure.

4.1. Fault Detection

Once the data has been integrated and identified, PHM data can be mapped to components for failure detection. At this point, it is appropriate to correlate fault data to failure data. The system should be characterized for its performance to conduct fault detection. This characterization is typically expressed in terms of a fault detection percentage where the number of failures detected by the system PHM capability is divided by the failures in the system. This can be seen in Eq. (1).

$$Fault\ Detection\ \% = \frac{\sum Failures\ Detected}{\sum Failures} \quad (1)$$

Fault Detection Percentage is also referred to as "*Fraction of Faults Detected (FFD)*" (Quanterion Solutions Incorporated, 2015).

This PHM system characteristic element supports the identification of a failure once it has occurred.

4.2. Fault Isolation

Once fault data to failure data has been formulated, it is appropriate to identify how well the fault data can successfully point to the correct component. This is often referred to as fault isolation. Building upon a system's ability to detect a failure, fault isolation characterizes how well that system can isolate the correctly failed component. This characterization is typically expressed in terms of a fault detection and isolation percentage where the number of failures isolated to the correct component by the system's PHM capability is divided by the failures detected through the system's PHM capability. This can be seen in Eq. (2).

$$Fault\ Isolation\ \% = \frac{\sum Failures\ Isolated}{\sum Failures\ Detected} \quad (2)$$

Fault Isolation Percentage is also referred to as "*Fraction of Faults Isolatable (FFI)*" (Quanterion Solutions Incorporated, 2015).

This PHM system characteristic element supports how to correct the failure once it has occurred.

4.3. Simple Prognostics

After the system has been characterized for fault detection and fault isolation capability, the system should be assessed for simple prognostics. This can be considered the single variable linear trend which will lead to the depiction of a symptomatic characteristic to a failure prior to its occurrence.

This is the simplest form of prognostics where a particular data element of the system can be tracked against an acceptable tolerance. The data element can be tracked against the identified tolerance and when the data goes out of the tolerance level, a potential for a failure can be identified.

This PHM system characteristic element supports how to identify a failure before it has occurred.

4.4. Hypothetical Case Study: Tracking of Fault Detection/Isolation, False Alarms, and Simple Prognostics on an Aircraft System

In the third phase of the hypothetical case study, for the Aircraft System, the assumption is that the Supplier-to-Subsystem-to-System Level data has been effectively integrated, and the Fault Code and Parametric data has been effectively identified. At this point, the PHM Engineer can move toward the next element of the hierarchy which is the characterization of the diagnostic capability of the Aircraft System (Fault Detection/Isolation metrics) and develop simple prognostics to trend the health of the Aircraft System.

Successful Implementation: For this hypothetical case study, the successful implementation of this element of the hierarchy allows for the PHM engineer to identify deficiencies in the capability of this Aircraft System, and with the successful implementation of the two elements, the Suppliers can be corrected such that deficiencies can be addressed. Moreover, Simple Prognostics can be developed to identify single parametric health elements of the Aircraft System. This would then segway into the more complex applications which can consider Data Science and Machine Learning techniques to evaluate multiple health parameters of the Aircraft System.

Unsuccessful Implementation: In the hypothetical case study, if the Fault Detection/Isolation, and False Alarm, metrics cannot be developed for the Aircraft System, then the PHM Engineer will not be able to characterize the performance of the Aircraft System. This will limit the ability to articulate any issues for Supplier corrections. In addition, if Simple Prognostics cannot be developed with single parametric elements, then incorporating Data Science, and Machine Learning, techniques with multiple parameters will not be feasible either. And any Data Science based visualization of the Aircraft PHM data will not be feasible either.

For this hypothetical case study, in the context of a Supplier-to-Subsystem-to-System Level integration, failure to implement this element of the hierarchy would have a "Major” impact on the Aircraft Systems PHM capability because the ability to identify issues with the Aircraft System performance would be unknown.

5. THE APPLICATION OF DATA SCIENCE AND MACHINE LEARNING TECHNIQUES TO PHM

Once the data has been effectively integrated, adequately articulated and the performance has been characterized, advanced concepts can be considered for development, building upon the three previous concepts.

At this point in the PHM Digital Hierarchy of Needs, Data Science concepts can be applied, and Machine Learning (ML) techniques should be considered. Data visualizations should be considered for identifications of trends and machine learning algorithms can be applied to the PHM data to predict failures prior to occurrence. At this point, common prognostic algorithms such as “*Neural Networks (NN), Gaussian Process (GP), Particle Filter (PF), and Bayesian Methods (BM)*” (An, Ho, Kim, & Choi, 2013) can be considered for application.

5.1. Hypothetical Case Study: The Application of Data Science, and Machine Learning, Techniques to PHM on an Aircraft System

In the fourth phase of the hypothetical case study, for the Aircraft System, the assumption is that (1) the Supplier-to-Subsystem-to-System Level data has been effectively integrated, (2) the Fault Code and Parametric data has been effectively identified, and (3) Fault Detection/Isolation metrics, and processes, have been establish and Simple Prognostics have been implemented.

For this hypothetical case study, the assumption is that there is a Data Science/Machine Learning (ML) organization which the PHM Engineer can work with. Under this premise, the PHM Engineer can work with the Data Science/ML team to establish more complex methods to support advanced fault isolation, false alarm mitigation, data visualizations, and ML based prognostics techniques that use multiple parameters of the Aircraft System PHM Data.

Successful Implementation: For this hypothetical case study, the successful implementation of this element of the hierarchy allows for the PHM engineer to develop advanced fault isolation methods which would provide a shorter troubleshooting time for the Aircraft maintenance team. It would minimize the number of unwarranted maintenance events by reducing the false alarm rate of the Aircrafts diagnostic system. Also, it would provide a more “advanced prognostics” capability without the need to work with the Aircraft System Suppliers for additional sensors; this could prove to provide a cost saving benefit. In addition, if the “advance prognostics” proved to be consistently correct in predicting failures, this could be implemented in the software of the Aircraft to provide Real-Time prognostics to the system.

Unsuccessful Implementation: In the hypothetical case study, if this is not implemented the PHM Engineer would potentially be limited to adding additional sensors at the Supplier level for improved prognostics. Any implementation of Real-Time prognostics from a “software only” prospective may not be available.

For this hypothetical case study in the context of a Supplier-to-Subsystem-to-System Level integration, failure to implement this element of the hierarchy would have a "Minor” impact on the Aircraft Systems under the assumption that not all Subsystems would require advanced PHM analysis.

6. REAL-TIME IMPLEMENTATION OF PROGNOSTICS

Lastly, if warranted, the complex analysis developed can be considered for real-time implementation in a system to provide advanced prognostics. At this point, for real-time implementation, it would be required for the algorithms to be functioning correctly and validated to function as required.

Once these algorithms have been confirmed to successfully identify failure prior to occurrence, they can then be applied for further development to full operation of the system. At this point, the PHM system can focus on the ability to “*achieve critical fault monitoring and early warning during the mission, based on real-time status data and pre-set rules*” (Zhou, Hu, & Yang, 2019).

6.1. Hypothetical Case Study: The Implementation of Real-Time Prognostics to an Aircraft System

In the fifth, and final, phase of the hypothetical case study, for the Aircraft System, the assumption is that (1) the Supplier-to-Subsystem-to-System Level data has been effectively integrated, (2) the Fault Code and Parametric data has been effectively identified, (3) Fault Detection/Isolation metrics, and processes, have been established and Simple Prognostics have been implemented, and (4) the PHM Engineer successfully collaborated with the Data Science/ML team to establish more complex methods such as advanced fault isolation and ML based multiple parameter prognostics techniques on the Aircraft System.

In this final phase of the hypothetical case study, the PHM engineer can build a case to implement any of the proven advanced prognostics on the Aircraft System without the need of any additional overhead analysis. This can help identify failures prior to occurrence, and/or support any advance fault isolation techniques. In this part of the hypothetical case study, the PHM engineer may need to work with any Suppliers responsible for the components under analysis in the Aircraft System.

Successful Implementation: For this hypothetical case study, the successful implementation of this final element of the hierarchy allows for the PHM engineer to influence the diagnostics and prognostics characteristics of the system with an anticipated limited amount of Supplier reach back under the assumptions that the proven ML prognostics algorithms utilize all the existing data.

Unsuccessful Implementation: In the hypothetical case study, if this final phase is not implemented, the Aircraft System would be limited to the time it takes to conduct the analysis off-board of the Aircraft. Depending on the advanced prognostics needs of the Aircraft System, this may or may not be acceptable.

For this hypothetical case study in the context of a Supplier-to-Subsystem-to-System Level integration, failure to implement this element of the hierarchy would have a "Minor" impact on the Aircraft Systems under the assumption that not all Aircraft Subsystems would require Supplier reach back support for successful operation.

7. CONCLUSION

As systems continue to become more complex, and harder to diagnose, implementing a systematic approach to the development of PHM will be more relevant than ever. Subsequently, the PHM Digital Hierarchy of Needs provides a PHM practitioner with the big picture vision to successfully implement PHM on a large-scale system. With a firm understanding of data integration, documentation, and performance characterization, more advanced PHM activities can be implemented that are geared toward data science and machine learning techniques. Once these advanced techniques have been verified and validated, they can be automated for a real-time solution to minimize maintenance down time and catch failures prior to occurrence.

Additionally, the Aircraft System hypothetical case study, in the context of a Supplier-to-Subsystem-to-System Level integration, shows the importance of each of these elements and the level of impact provided if not considered. The hypothetical case study, under the specified ground rules and assumptions, shows that the first three elements (1) Data Integration, (2) Identification of the Fault and Parametric Data, and (3) Fault Detection/Isolation Characterization and Simple Prognostics have a major impact to the success of a PHM effort. And the remaining two elements (4) Data Science/ML and (5) Real Time Implementation, have a minor impact to the success of a PHM effort. Note that while these two elements ranked as minor in the hierarchy, they have potential to reduce any reach back Supplier cost.

REFERENCES

Crooks, K., & Plawecki, N. (2021). Novel Approach to CBM+ Implementation on Aviation Systems. *2021 Annual Reliability and Maintainability Symposium (RAMS)*, pp. 1-6, doi: 10.1109/RAMS48097.2021.9605703.

Goodman, P., Hofmeister, J., P., & Szidarovszky, F., (2019). *Prognostics and Health Management: A Practical Approach To Improving System Reliability Using Condition-Based Data*. Hoboken, New Jersey: John Wiley & Sons Ltd.

Pecht, M., G. (2008). *Prognostics and Health Management of Electronics*. Hoboken, New Jersey: John Wiley & Sons Ltd.

O'Donovan, P., Leahy, K., Og Cusack, D., Bruton, K., & O'Sullivan, D. T. J. (2015). A data pipeline for PHM data-driven analytics in large-scale smart manufacturing facilities. *Annual Conference of the PHM Society*, 7(1). doi: 10.36001/phmconf.2015.v7i1.2772

Beshears, R., & Butler. L. (2005). Designing for health: a methodology for integrated diagnostics/prognostics. IEEE Autotestcon, 2005., 2005, pp. 90-95. doi: 10.1109/AUTEST.2005.1609108

Vichare, N., M., & Pecht, M., G. (2006). Prognostics and health management of electronics. *IEEE Transactions on Components and Packaging Technologies*, vol. 29 (no. 1), pp. 222-229. doi: 10.1109/TCAPT.2006.870387

An, D. ., Ho Kim, . N. ., & Choi, J.-H. . (2013). Options for Prognostics Methods: A review of data-driven and physics- based prognostics. Annual Conference of the PHM Society, 5(1). doi: 10.36001/phmconf.2013.v5i1.2184

Quanterion Solutions Incorporated (2015). *System Reliability Toolkit-V: New Approaches and Practical Applications*. Utica, New York: Quanterion Solutions Incorporated.

Zhou, Y., Hu, T., & Yang, J. (2019). Design and Implementation of PHM System Framework for Unmanned Surface Vehicles. Prognostics and System Health Management Conference (PHM-Qingdao), 2019, pp. 1-5. doi: 10.1109/PHM-Qingdao46334.2019.8942844

BIOGRAPHIES

Joseph Barta earned a Bachelor of Science Degree in Electrical Engineering (B.S.E.E.) from the University of Washington in 2002, and is currently in pursuit of a Master of Engineering Degree in Systems Engineering with the expected graduation date of January 2023 at the Stevens Institute of Technology. Currently, he works at Northrop Grumman as a System Engineer focusing on the field of Prognostics and Health Management (PHM), Reliability and Maintainability (R&M) and Supportability Engineering. His previous working experience has been with The Boeing Company and the U.S Government holding multiple positions.

Ethan Erlhoff earned a Bachelor of Science Degree and Master of Science Degree in Aerospace Engineering from the California Polytechnic State University, San Luis Obispo in 2012. Currently, he works at Northrop Grumman as a Manager of Engineering focused on the discipline of Prognostics and Health Management (PHM). His previous work experience has been in the disciplines of Quality Engineering, Systems Engineering, Reliability Engineering, and Maintainability Engineering in various positions.

Dania Alfeerawi earned a Bachelor of Science Degree in Mechanical Engineering from University of California, Irvine in 2019, and is currently in pursuit of a Master of Science Degree in Mechanical Engineering with an expected graduation date of May 2022 at University of Southern California (USC). Currently, she works at Northrop Grumman as a System Engineer focusing on Prognostics and Health Management (PHM). Her previous work experience has been with NASA Jet Propulsion Laboratory (JPL) and PBF Refinery as a Mechanical Engineer and Reliability Engineer.