Now a Fully Virtual Conference
November 29 – December 2, 2021

Two Optional Online Short Courses:

1.	Analytics for PHM – Advanced Course	November 15 – 16 & 18 – 19, 2021	1:00 – 5:00 EST
2.	PHM Fundamentals and Case Studies	January 12 – 14 & 17 – 18, 2022	1:00 – 5:00 EST *(Tentative)*

After careful consideration, given the current COVID-19 situation the PHM Society has made the difficult decision to adjust our 2021 Annual Conference to a fully virtual event. This virtual event will be held over four days from Nov. 29 – Dec. 2, and will include all of the features conference registrants are accustomed to – Speaker and Panel sessions, Keynote speakers, a Diversity event, three tutorials, a Technical Language Processing workshop, and optional Short Courses. Papers will be presented live and additionally will be pre-recorded and available prior to, during, and after the actual conference dates.

We will bring together the global community of PHM experts from industry, academia, and government in diverse application areas, such as, but not limited to, energy, aerospace, transportation, automotive, human health & performance, smart manufacturing, and industry AI.

Here's some of what we have planned for 2021:

- A choice of two dedicated Short Courses focused on fundamental PHM concepts and techniques, as well as data analytics (separate registration required),
- A full-day Technical Language Processing Workshop,
- Keynote Speakers each day
- Technical Paper Sessions,
- Three free Tutorial Sessions,
- Ten Panel Sessions,
- A Data Analysis Challenge (with prizes!) held prior to the conference open to everyone, with winning teams presenting their approaches in an Invited Paper Session,
- Student Posters, and
- Networking, diversity outreach, and award presentations!

We hope that you will be able to join us this year and look forward to seeing you in the fall!

Dave Larsen (Collins Aerospace),
Sankaran Mahadevan (Vanderbilt University), and
Scott Clements (Lockheed Martin), chairs

chair@phmconference.org

Topics of Interest:

- Advanced Sensing & Embedded Devices
- Adaptive Control & Fault Accommodation
- Automotive Systems
- Autonomous / Robotic / Unmanned Systems
- PHM in Aviation Systems
- CBM RoI & Business Case Analysis
- Cloud Analytics
- Corrosion
- Cybersecurity PHM
- Data Driven Approaches
- Decision Support Systems
- Detection, Diag. & Prog. Methods
- Digital Twin and Digital Thread
- Electronic Transaction and Blockchain
- Energy (e.g., Nuclear, Smart Grid, Wind)
- Enterprise-wide PHM Applications
- Human-centric PHM
- PHM for Human Health and Performance
- Marine, Mining, and Railway Applications
- PHM for Precision Agriculture
- Oil & Gas
- Physics of Failure & Model Based Prediction
- Predictive Analytics
- Smart cities
- Smart Grid
- Smart Manufacturing
- Smart Cities
- Space Technologies and Systems
- Standards, Metrics, and V&V

www.phmconference.org

Keynotes

Keynote 1: CBM+ .... The Future is Now!
Tuesday, November 30, 2021, 10:00 – 10:55 EST
Presenter: Maj. Gen. H. Brent Baker Sr. (USAF, Retd.) (Worldwide Vice-President for Federal Aerospace and Defense, PTC)

Keynote 2: Cyberthreat of Adversarial AI
Tuesday, December 1, 2021, 10:00 – 10:55 EST
Presenter: Dr. Edmon Begoli (AI Systems R&D Section Head, Oak Ridge National Laboratory)

Keynote 3: From Monitoring to Mitigation in an Autonomous Vehicle Future
Tuesday, December 2, 2021, 10:00 – 10:55 EST
Presenters: Prof. Daniel Work and Prof. Jonathan Sprinkle (Vanderbilt University)

TLP Workshop

Technical Language Processing Workshop
Monday, November 29, 2021, 10:15 – 3:00 EST
Session Chair: Michael Brundage (National Institute of Standards and Technology (NIST))

This Technical Language Processing (TLP) workshop will guide you through the analysis of text data and how maintenance decisions can be improved with this information. Each presenter will demo their methodology step-by-step to give an in depth look into the world of TLP! For more information on TLP, please visit: https://www.nist.gov/el/tlp-coi

Opening Remarks
10:15 – 10:30 EST
Presenter: Michael Brundage (NIST)

A technical language processing-based solution to automatically calculating lubrication-related costs from maintenance work orders
10:30 – 11:15 EST
Presenters: Michael Stewart and Melinda Hodkiewicz (University of Western Australia)

Description: Lubrication plays a critical role in the reliable functioning of rotating assets such as pumps, motors, gearboxes, compressors, fans, wheels and so on. Manufacturing sites can use over 50 lubricants on hundreds of pieces of equipment. Lapses in quality control of lubricants and lubrication systems such as filters, breathers and pumps, can lead to catastrophic failure of critical equipment. However, trying to identify how much is being spent on maintenance of the lubrication systems and the direct costs of failure requires significant manual input from subject matter experts. This is due to, for example, the myriad of ways various lubricants (grease, oil, lube etc.) are identified in historic work order data. In this presentation we demonstrate a technical language processing-based solution to this challenge. MWO2KG is an end-to-end pipeline for constructing knowledge graphs from maintenance work orders. The deep learning model behind the MWO2KG pipeline is trained on annotated data created through collaborative annotation using Redcoat, our open source web-based annotation tool, and can be interacted with by domain experts using Echidna, our open source knowledge graph visualization platform. We show how we have utilized MWO2KG to automate calculation of the direct cost of lubrication-related work orders. Direct cost is the sum of the cost on executing lubrication work identified in maintenance strategies and the cost of unplanned failures based on the time and materials involved. The MWO2KG pipeline is being used on real industry data although anonymized examples and simulated cost data are used in this example.

From data collection to decision making: a step by step tutorial using maintenance work order data
11:15 – 12:00 EST
Presenters: Anna Conte, Lynn Phan, Coline Bolland, and Thurston Sexton (NIST)

Description: Historical data analysis provides a core foundation for optimized decision-making in maintenance management. To contextualize natural language text as a data source within this process, Technical Language Processing (TLP) provides a framework for gleaning additional knowledge from this often-overlooked type of historical data. In this workshop, we focus on how the TLP paradigm informs the analysis of maintenance work orders (MWOs), which are a widely available source of data for industrial organizations to better inform their decision making. This step-by-step tutorial illustrates several applications of TLP from within different stages of the data analysis process. We present tools, schemas, and data cleaning strategies for data collection and preprocessing stage, along with a selection of Exploratory Data Analysis (EDA) and feature-selection methods relevant to text-based MWO data. More generally, we cover how to identify and mitigate common pitfalls faced by analysts when making use of MWOs for decision support data.

12:00 – 12:45 EST *Lunch Break*

RedShred: Extract, Enrich, and Reshape
12:45 – 1:30 EST
Presenter: Jim Kukla (RedShred)

Description: The demise of paper and the rise of the paperless office has been predicted since before the invention of the fax machine. Paper's limitations

are well known to those accustomed to the tools of today's digital world. Unfortunately, paper analogs such as PDF inherit most of paper's weaknesses due to a dizzying variety of internal representations for equivalent visual output. Even today, paper remains the universal "lowest common denominator" format for technical reference material that is critical in maintenance operations. In this demo we introduce RedShred, a platform that enables teams to liberate document-hosted knowledge more effectively by combining computer vision and natural language processing. This platform is built on three principles: extract, enrich, and reshape. Using RedShred, teams can collaborate on reshaping valuable content that was previously trapped in paper and paper analogs. In this demonstration we will show how users can load technical documentation and configure the platform to extract and enrich the content and reformat its content for a smaller-than-printed-page interface such as the ubiquitous mobile or tablet devices carried by field service personnel. We will also show how RedShred enrichments include useful artifacts for downstream usage such as fine-tuning language models with specific kinds of content from the documents that were ingested. We also discuss the underlying principles and mental model we use to unify these capabilities into a coherent platform

Modeling in R
1:30 – 2:15 EST
Presenter: Maria Seale (US Army Engineer Research and Development Center)

Description: Natural language processing techniques are often applied to labeled text data to produce numeric vectors that can inform classification models. However, a wealth of information can reside in text data that is not labeled. In these cases, statistical techniques can be used to determine groups of documents that are semantically similar, effectively "labeling" the documents and providing important information on composition and relevance. This presentation will provide a background on topic modeling and examine a use case implemented in the R programming language.

Utilize CMMS data in practical ways despite data quality issues with Asset Answers
2:15 – 3:00 EST
Presenter: Manjish Naik (GE Digital)

Description: Asset Answers is a cloud diagnostic application that eliminates poor data quality using benchmarked standards and provides continuous data improvement recommendations. The included asset performance analytics, dashboards, and reporting tools deliver accurate metrics to qualify the asset strategy, drive better reliability and make data-driven maintenance decisions. The Data Quality Module encourages accurate data entry and accountability by pinpointing the correlation between data improvement and metric impact. Asset Answers provides an accurate asset performance assessment by analyzing the Computerized Maintenance Management System (CMMS) data for completeness, accuracy, and standards. Data quality analysis provides a list of data inconsistencies and prioritized actions to effectively resolve challenges – backed by GE Digital industry leadership, equipment expertise, and performance metrics.

Tutorials

Tutorial Session 1: A Guide to the NASA Python Prognostics Packages
Monday, November 29, 2021, 10:15 – 12:15 EST
Presenter: Chris Teubert (NASA Ames)

Description: This year, NASA Released the Prognostics Python Packages, a collection of research tools for developing prognostic models, simulating degradation of systems, performing prognostics, analyzing results, and developing new prognostic algorithms. The Prognostics Python Packages encapsulate design improvements based on experience gained with the previously open-sourced Generalized Software Architecture for Prognostics (GSAP) and Prognostics Matlab Libraries. The tools have been extended to include new features such as approaches for resource-constrained prognostics (e.g., sample shedding), hybrid models, model validation tools, online system identification, and surrogate model generation. This tutorial is a hands-on overview of these tools, including how to use and extend them. This tutorial will also include examples about how the tools are used at NASA.

Tutorial Session 2: Methodology and Case Studies for Fielding PHM Systems – Successes, Challenges, and Lessons Learned
Tuesday, November 30, 2021, 11:00 – 1:00 EST
Presenter: David Siegel (Predictronics)

Description: With recent advancements in sensors, IOT, and machine learning-based analytics, it's an exciting time for leveraging the promising new developments and research in prognostics and health management for fielding solutions in various industrial applications. This tutorial will discuss some of the challenges that arise in deploying solutions, including data quality, training data requirements, maintaining algorithm accuracy/re-training, and how to make better decisions from the fielded system. A

methodology on how to approach the development and deployment of a PHM solution for each application will be presented, along with best practices and lessons learned. Case studies in manufacturing, heavy industry, and aerospace, among others will be presented. Lastly, new developments and ideas will be shared, exploring thoughts on the improvement of existing PHM fielded solutions and addressing the current unmet challenge.

Tutorial Session 3: Hybrid Physics-Informed Neural Networks for Cumulative Damage Modeling
Tuesday, November 30, 2021, 2:45 – 4:45 EST
Presenter: Felipe Viana (Univ. of Central Florida)

Description: We present a modeling framework that allows for the simultaneous use of physics-informed and machine learning by implementing recurrent neural networks for cumulative damage modeling. The main advantage of this approach is the compensation of limitations in physics-informed kernels as well as labeled data. This framework handles highly unbalanced datasets formed by few output observations and data-lakes containing time series used as inputs. This tutorial will focus on both formulation and computational implementation. There will be two hands-on examples on model identification of dynamic systems as well as fatigue crack growth modeling written in the TensorFlow using the Python programming language API. The participants will have direct access to the Python scripts and will be able to run them on their personal laptop.

Panel Sessions

Panel Session 1: Standards
Tuesday, November 30, 2021, 1:30 – 2:45 EST
Session Chair: Jeff Bird (TECnos)
Moderator: Karl Reichard (Penn State University)

Description: Standards have proven invaluable to the industries for which they are developed. Some standards may be regulatory while others may be voluntary. Regardless of their requirement, standards can be invaluable to an organization's growth and sustainability. These documents can offer a range of value including reducing the risk of technological adoption, anticipating technical requirements of emergent technologies, protecting health and safety, increasing productivity, promoting efficiency, and reducing costs. Documents can range from prescriptive standards, to guidelines, to suggested best practices offering a range of flexibility in their deployment. Published by standards development organizations with input from industry practitioners, academics, research institutes, and government organizations, these documents can take years to produce.

The PHM community has benefited from published standards and continues to support their development to increase industry's ability to adopt emerging and advanced PHM technologies. Numerous PHM Society members are active in several standards committees whose focus is on developing PHM-focused documents. This panel features leaders and members of several PHM-focused committees including ASME, ISO, and SAE. The standards generation process will be discussed including how topics are defined, documents are developed, and standards are ultimately approved for public usage.

Questions to be addressed:
1. What new existing and new standards are coming from the main standards developing organizations?
2. How to contribute and identify gaps?
3. How is the PHM Society tying to integrate access?

Outcomes
1. Summary of access methods – PHM Society website – standards page; dedicated sites
2. Priorities on gaps in knowledge & processes

Panelists:
Rhonda Walthall *(Collins Aerospace)*
Brian Weiss *(NIST)*
Tim Felke *(Garrett Motion)*

Panel Session 2: Cybersecurity and PHM: Securing the OT and PHM Data Streams
Tuesday, November 30, 2021, 2:30 – 3:45 EST
Session Chair: Radu Pavel (TechSolve)
Moderator: Brian Weiss (National Institute of Standards and Technology (NIST))

Description: The COVID-19 pandemic has led to an accelerated digitalization of the work environment and adoption of remote supervision of manufacturing assets and production. In this new digital manufacturing ecosystem, the Prognostics and Health Management (PHM) approach is becoming the strategy of choice for the advanced manufacturing enterprise. The value of real-time data from various functions, and the benefits of new technologies fuel the desire to connect production and non-production devices on the factory floor. However, the appetite for advanced technology is rapidly exceeding the organizations' ability to protect it, and this connectivity and data rich environment raise significant concerns and challenges associated with cybersecurity.

This panel will explore the latest trends regarding standards, regulations, strategies, and technologies

aiming to secure the operational technology (OT) and PHM data and information. The panel also aims to reveal perceived challenges faced by the developers, implementers, and providers of PHM technology, and their current strategies for mitigation.

Panelists:
David Carter *(CyManII)*
Berardino Baratta *(MxD institute)*
Michael Powell *(National Cybersecurity Center of Excellence at NIST)*

Panel Session 3: Applying Artificial Intelligence & Machine Learning for Predictive Maintenance and Analytics
Wednesday, December 1, 2021, 11:00 – 12:15 EST
Session Chair: Andrew Harper (Georgia Tech Research Institute)

Description: With the increasing prevalence of Artificial Intelligence and Machine Learning (AI/ML), and the widening adoption of Model Based Systems Engineering practices (MBSE), applied AI/ML and MBSE are having a significant impact on the PHM community. From predictive maintenance planning through neural net data training and digital twin development to distributed enterprise level systems engineering, these cutting-edge capabilities are impacting all operational domains across the public and private sectors.

Panelists will discuss lessons learned and best practices leveraging these emerging technologies. Topics will include integrating and leveraging SME expertise jointly with data science, system level challenges to real world MBSE implementation, and demystifying considerations when applying AI/ML to fielded challenges in the field.

Panelists:
Chris Shumeyko *(JAIC)*
Derrick Kozlowski *(SOCOM)*
Sean Ducker *(NAWCAD)*

Panel Session 4: PHM for Space Applications
Wednesday, December 1, 2021, 12:15 – 1:30 EST
Session Chair: Derek DeVries (Northrop Grumman)
Moderator: Andy Hess (The Hess PHM Group)

Description: The planned use of manned and long-term crewed space platforms, as well as quick to launch and reusable space vehicles, is increasing at a very accelerating rate. After the legacy NASA developed Space Shuttle and LEO ISS; among many things, there are near term NASA plans for: a lunar Gateway station, a permanent lunar base, asteroid present, and Mars bases. Vehicles and platforms to accomplish these far-reaching goals will include: crewed space and surface based stations and habitats; various types of launch, long range transportation, and orbit to surface vehicles; and all kinds of support subsystems and technologies. Beside NASA and other government directed organizations; commercial based entities are aggressively developing systems to achieve these same and additional space related goals. These commercial focused applications include tourist to space and LEO, space-based hotels, and lunar and deep-space resource mining. This panel will focus on issues and challenges associated with these applications; and how PHM capabilities can be applied to reduce risks, increase efficiencies, and ensure resilient sustainment of these vehicles, platforms, habitats, and systems.

Panelists:
Morteza Safai *(Boeing)*
Homer (Heath) Dewey *(Northrop Grumman)*
Sudipto Ghoshal *(Qualtech Systems)*

Panel Session 5: Digital Twin
Wednesday, December 1, 2021, 2:00 – 3:15 EST
Session Chair: Antonios Kontsos (Drexel)
Moderator: Sarah Malik (Drexel)

Description: The motivation for this panel is two-fold. First, the number of applications where the digital twin concept is used, in the context of digital enterprise and digital transformation, increases continuously. The main reason for this trend can be found on the growing and in some cases mandated process of digitally threading an increasing number of systems in which sensor data is interfaced with archiving, processing, computing and decision-making tools. Second, the associated hardware and software components used to design such digital twins provide increasing capabilities. From Internet of Things (IoT) workflows to machine learning and artificial intelligence methods, the range of options that are available to construct digital twin paradigms is practically vast.

In this context, the objective of this panel is to invite the PHM community in a focused discussion related to the concept of digital twins. Experts from industry, government and academia will provide their views while there will be sufficient time for a live discussion and exchange of ideas. More specifically, this panel will focus on and discuss the following related topics and challenges in this field: a) efforts to standardize digital twin processes or at least validate parts of them using traceable, repeatable and effective ways; b) issues related to creating validated dataset repositories which could assist model and processing approach development, independent of a given application and of case-specific data acquisition, and contributing towards demonstrations of successful

alignments of the physical and digital spaces; c) benchmark problems tailored to a PHM-related hierarchy of detection, classification and prediction, similar to other domains e.g. in nondestructive evaluation, material characterization, as well as inspection and maintenance; d) modeling including knowledge-based, deep learning, probabilistic, analytical, physics-based etc., which could be leveraged in digital twin workflows; e) efforts to use digital twinning not only in forward flows that involve steps from data to decision but are also creating dynamic adaptations capable of evolving as monitoring occurs, providing feedback to sensors as data is processed and ultimately even creating real autonomy via e.g. data and model-driven adaptive control.

Panelists:
Benjamin L. Grisso *(NSWC)*
Tom Wiegele *(Collins Aerospace)*
Yolanda Mack *(Raytheon)*
Sankaran Mahadevan *(Vanderbilt University)*

Panel Session 6: PHM for Manufacturing: Assessing Operations to Advance PHM Capabilities
Wednesday, December 1, 2021, 3:15 – 4:30 EST
Session Chair: Brian A. Weiss (NIST)
Moderator: Gregory Vogl (NIST)

Description: Manufacturing has evolved over the last few decades to leverage emerging and advanced technologies. Many of these technologies enable the growth of PHM capabilities including the advancement of monitoring, diagnostics, and prognostics to enhance decision-making and maintenance strategies. Manufacturers recognize that these emergent PHM capabilities can enhance their maintenance strategy - optimize planned downtime and minimize unplanned downtime - to achieve more reliable, and ultimately, more profitable operations. For manufacturers to realize advanced PHM within their facilities, they face a challenging reality - How do they assess their PHM capabilities and the value it obtains? And, more importantly, what is the value they want to achieve and the corresponding PHM capabilities to be added?

This panel will focus on how manufacturers can assess their current PHM capabilities and how they can determine what levels of PHM are most desired by their organization. This will be paired with individual value propositions in terms of the expected return on investment of additional PHM capabilities along with a discussion of current maintenance expenses.

Panelists:
Adam Simpson *(Atlas Roofing)*
Douglas Thomas *(NIST)*
Matt Malloy *(EWI/Buffalo Manufacturing Works)*
Graham Immerman *(Machine Metrics)*

Panel Session 7: Unlocking the Potential of Automotive PHM
Thursday, December 2, 2021, 11:00 – 12:15 EST
Session Chair: Steve Holland (VHM Innovations)
Moderator: Tim Felke (Garrett Motion)

Description: The automotive industry has proven to be one of the most fertile application domains for PHM technology in terms of financial impact, analytics sophistication and sheer scale. Successful examples have been implemented for both manufacturing systems and the automotive vehicles themselves. The case has been made for even greater opportunity in coming decades as the continuing electrification of vehicles takes place. Similarly, the potential impact for fleets is anticipated to be huge. This applies to conventional automotive and trucking fleets as well as for future autonomous fleets. But the pace of PHM introduction continues to lag behind what it might be. This panel seeks to understand the key enablers for recent industry successes as well as the barriers that have limited more rapid progress. The discussion will be centered on strategies that effectively exploit those enablers while mitigating the barriers.

Panelists:
Troy Shilling *(Bosch)*
Joe Klesing *(Nexteer)*
Rex Struble *(SafeRide Technologies)*
Shiming Duan *(GM)*

Panel Session 8: An Integrated Architecture for Cyber-Physical Systems Health Management
Thursday, December 2, 2021, 12:15 – 1:30 EST
Session Chair: Frank Zahiri (US Air Force)
Moderator: Scot Hudson (ALAE Solutions)

Description: As the complexity of modern manufacturing, transportation and industrial systems increases, the need for improved system resilience, reliability, and safety, follows an increased trend. Technologists attempting to develop and introduce integrated process/system methods for such complex systems must introduce new and novel system engineering concepts that integrate facets of modeling, testing, analysis, and algorithm development. The Cyber Physical Systems community has an expressed interest in the health status of integrated processes/systems, i.e., questions are raised as to whether specific processes are available to perform the next work tasks, or a sequence of pro-

cesses is not suffering individual process losses that might compromise the operational objectives of the whole system of systems. It is of interest to investigate technologies that can address such questions. Large scale systems (industrial and manufacturing processes, transportation systems) are subjected to fault/failure modes at the component level. They might propagate to other healthy components and, eventually, migrate to the subsystem (inspection station, repair/overhaul, etc.) and system levels. High-fidelity models at the subsystem level are difficult and time consuming to develop. Moreover, sensing modalities at the component level monitoring their health status are mostly absent. It is imperative, therefore, that investigations of the health status at the integrated process level must rely on simple methods that take advantage of the structural and functional properties of such complex systems.

This panel will discuss the following topics:

- We will begin with a definition and typical examples from Cyber-Physical Systems (CPS) domain
- Determining the health status of integrated CPS
- Modeling of CPS at the system and subsystem levels
- Reasoning paradigms for determining diagnostic and prognostic approaches at the subsystem level
- Examples from the industrial and manufacturing areas

Panelists:

WenZhan Song *(University of Georgia)*
Mehrdad Pakmehr *(ControlX, Inc.)*
Peng Liu *(Penn State)*

Panel Session 9: Qualifying Data and Data Use – Assuring Data Capability for Intelligent Systems and Beyond

Thursday, December 2, 2021, 1:45 – 3:00 EST
Session Chair: Michael Sharp (NIST)
Moderator: Vincenzo Ferrero (NIST)

Description: Reliable information and quality data are the foundations of the PHM philosophy. Qualifying that data for a range of applications can build trust in end users by providing expectations and limits to how the data should be used. This can also aid developers and solution providers who need understanding of the data to make best use of its capabilities. Understanding information, such as where the data comes from and how it can be used, is integral to the creation of optimal intelligent systems, viable models, and trustworthy information capable of providing actionable decision support.

This panel seeks to discuss the mechanisms for qualifying data collection, documentation, and use as it applies to specific domain applications within the PHM community. Although some qualifications of data are agnostic of application, other questions such as 'how much data do I need' or 'is this an acceptable level of uncertainty', can only be answered within the context of the end goals and application. Some data collection and storage methods may also dictate the capabilities of that data. Ex. just because a data set is appropriate to build a time series model - it may not work for frequency. Can metadata or data provenance help to communicate this type of information? The goal of this panel is to present and discuss mechanisms for measuring quality of collection, use, and return on investment for data and any associated models primarily with current goals in mind, while leaving room for potential expansion in the future.

Panelists:

Radu Pavel *(TechSolve)*
Lou Zhang *(Machine Metrics)*
Anna Connte *(NIST)*
Coline Bolland *(NIST)*

Panel Session 10: Fireside Chat—Experience and Lessons Learned over the Multiple Eras of PHM Development and Implementation

Thursday, December 2, 2021, 1:45 – 3:00 EST
Session Chair: Andy Hess (The Hess PHM Group)
Moderator: Derek Devries (NGC)

Description: This panel will we made up of several "seasoned" experts who have been developing and implementing PHM related capabilities and technologies for a great number of years. This panel will use their experiences and stories to explore the issues, barriers, and lessons learned that have evolved across the many eras of PHM related activities, development, expanding applications, and implementation.

Panelists:

Mark Redding *(Poseidon Systems)*
Dave Daniszewski *(Army DEVCOM)*
Mark Walker *(D2K Technologies)*

Want to be a part of next year's PHM2022 Conference (in Nashville, TN)? Join us Friday (after the conference) for an online meeting!

chair@phmconference.org

Optional Online Short Courses

For more information contact
shortcourse@phmconference.org
Separate Registration(s) Required

Short Course 1: Analytics for PHM Online Short Course – Advanced Course
November 15 – 16 & 18 – 19, 2021 *(Tentative)*
1:00 – 5:00 EST each day
Course Presenter: Neil Eklund (PARC)
Course Administrator: Jeff Bird (TECnos)

Overview

This course is intended for engineers, scientists, and managers who are interested in data driven methods for asset health management. You will learn how to identify potential data driven projects, visualize data, screen data, construct and select appropriate features, build models of assets from data, evaluate and select models, and deploy asset monitoring systems.

By the end of the course, you will have learned the essential skills of processing, manipulating and analyzing data of various types, creating advanced visualizations, detecting anomalous behavior, diagnosing faults, and estimating remaining useful life.

Note that this course is an advanced course with only a brief, high-level overview of PHM presented – students are expected to know the basics of PHM already. New practitioners are encouraged to take fundamentals course or contact the course leader to examine their background and skills.

Course Credit

A PHM Society Certificate will be provided for nominally 1.6 (2.4) Continuing Professional Development Units to each participant completing the course (and exercises).

Course Details

1. This course will be delivered virtually to a limited group of registrants, expected to be 25-30.
2. Course notes will be available to be printed and shipped to students. (Details to follow for the registered participants.)
3. Optional exercises will be presented in python in Google Colab.

phmsociety

Who Should Attend

This advanced course is designed for two primary types of students:

- Managers who oversee asset health management projects, and want to know more about the technical details behind the process.
- Practitioners who want to know the theory and get hands-on experience for data driven PHM, including:
  - Students
  - New engineers and scientists
  - Experienced engineers and scientists looking to update their skills and understanding data driven methods
  - Project managers who incorporate data driven PHM in their projects
  - Individuals with a general understanding of analytics who want to see how it is applied to PHM

Topics include

- Overview of Data-Driven PHM
- Review of Fundamental Statistics
- Data Visualization
- Introduction to Machine Learning
- Anomaly Detection (AD)
- Decision Trees
- Random Forest (RF)
- Boosting (XGBoost)
- Intro to Neural Networks
- Deep Autoencoders for Vibration Analysis
- Diagnosis and Prognosis
- Feature Extraction
- Feature Selection
- Model Evaluation and Characterizing Performance
- Model Selection
- Data-Driven and Hybrid Diagnosis
- Data Fusion
- Machine Learning for PHM Model Maintenance
- Case Study: DARPA Collective Mind Prognosis Project
- Practical Issues
- Case Studies in Aviation
  - Real-Time Fault Prediction and Avoidance for Commercial Aircraft Engines
  - A Hybrid Approach to Bearing Spall Prognostics in Military Aircraft
- Introduction to Deep Learning
  - Overview and examples
  - Self-taught learning
  - Deep learning for PHM
  - Promising application areas for innovation
  - Application area: Time series

Short Course 2: PHM Fundamentals: PHM Fundamentals and Case Studies Online Short Course

January 12 – 14 & 17 – 18, 2022
1:00 – 5:00 EST each day

Course Leaders: Karl Reichard (Penn State) and Jeff Bird (TECnos)

Course Presenters: Jeff Bird (TECnos), José R. Celaya (Schlumberger), Neil Eklund (PARC), Karl Reichard (Penn State), and Abhinav Saxena (GE Global Research Center)

Course Administrator: Jeff Bird (TECnos)

Overview

The PHM Society offers this updated intensive short course titled **PHM Fundamentals and Case Studies—From Monitoring/Sensing to Fault Diagnosis/Failure Prognosis and Case Studies**, on PHM tools, methods, applications and case studies as an on-line course spread over 18 hours over five days. This follows from the first offering at the PHM14 conference in Fort Worth, TX with 48 attendees and regular ratings of 4/5. It was also run in 2015 in San Diego, 2016 in both Bilbao, Spain and Denver USA, in St. Petersburg, USA in 2017, Philadelphia in 2018, Utrecht, Netherlands in July 2018 and Scottsdale at PHM19. Content fully updated for PHM21 based on offerings over the past 9 years.

As in the previous offerings, the course will be taught by recognized international experts in the PHM field and will cover the current state of the art in PHM technologies, sensors and sensing strategies, data mining tools, CBM+ technologies, novel diagnostic and prognostic algorithms as well as a diverse array of application examples/case studies. It is addressed to engineers, scientists, operations managers, educators, small business principals and system designers interested to learn how these emerging technologies can impact their work environment.

Through a lecture (with Q&A), networking and workshop format with specialist experts, participants will:

1. Establish a baseline for defining the extent and capabilities of PHM, specifically needs and organization
2. Identify specific details of PHM Applications (metrics, sensors, cost benefits, reliability) and PHM Methods (diagnostics, prognostics, data driven methods and uncertainty)
3. Identify issues and needs and a way forward including Continuing Professional Development
4. Examine case studies of PHM applications across diverse domains to identify solutions and impacts
5. Plan a PHM application in two mini workshop settings with expert group leaders

Course Credit

A PHM Society Certificate can be provided for 1.8 Continuing Professional Development Units to each participant completing the course, on request.

Course Details

1. Background reading and references: http://www.phmsociety.org/references/documents/recommended-reading
2. Course notes will be available to be printed and shipped to students. (Details to follow for the registered participants.)
3. Workshop topic: We will work in small groups on small realistic problems. Participants are asked to submit a problem statement from their organization: Problem definition, asset of interest, health management objectives, and customer(s).
   - Segment 1: developing PHM requirements—needs, stakeholders and metrics
   - Segment 2: data and modeling approaches, operational issues.

Topics include

- Introduction to PHM (Taxonomy, scope, basics, standards – for all talks)
- Deriving Requirements for PHM
- Case Study for Requirements/Metrics
- Diagnostics Methods
- Case Study for Diagnostics
- Failure Prognostics
- Case Study for Prognostics
- Data Analytics Methods
- Case Study for Data Analytics
- Sensors and Sensor Strategies
- PHM Project Workshop – Problem, Stakeholders, Metrics
- CBM+ and IVHM Technologies
- PHM Performance Metrics
- PHM Cost Benefit Analysis
- Reliability and Life Cycle Management
- Fielded Systems Case Study for Reliability
- PHM Planning Workshop Introduction – Models and Operational Issues
- Fielded Systems Case Study for CBM
- Fielded Systems Case Study for Cost Benefit Analysis Bearings
- PHM Project Planning Workshop – Models and Operational Issues
- Plenary – Issues and Needs and Priorities
- Way forward (Paths, Resources, Continuing Professional Development)

PHM2021 Tentative Schedule
(All Times EST)

Monday, November 29, 2021	10:00 – 10:15	Opening Remarks		10:00 – 10:15
	10:15 – 3:00	Technical Language Processing Workshop (with Breaks)	Tutorial Session 1: *A Guide to the NASA Python Prognostics Packages*	10:15 – 12:15
			NEW: Mentoring for the PHM Community	12:15 – 1:00
			Paper Session 1	1:00 – 2:00
			Paper Session 2	2:00 – 3:00
	3:00 – 4:00	Paper Session 3	Paper Session 4	3:00 – 4:00
	4:00 – 5:00	Invited Session: *Data Challenge Winners*	Invited Session: *IJPHM Papers*	4:00 – 5:00
Tuesday, November 30, 2021	10:00 – 11:00	Keynote 1: *CBM+ .... The Future is Now!* Maj. Gen. H. Brent Baker Sr., (USAF, Retd.), *PTC*		10:00 – 11:00
	11:00 – 12:00	Paper Session 5	Tutorial Session 2: *Methodology and Case Studies for Fielding PHM Systems*	11:00 – 1:00
	12:00 – 1:00	Paper Session 6		
	1:00 – 1:30	*Break*		1:00 – 1:30
	1:30 – 2:30	Paper Session 7	Panel Session 1: *Standards*	1:30 – 2:45
	2:30 – 3:45	Panel Session 2 *Cybersecurity*	Tutorial Session 3: *Hybrid Physics-Informed Neural Networks*	2:45 – 4:45
	3:45 – 4:45	Paper Session 8		
Wednesday, December 1, 2021	10:00 – 11:00	Keynote 2: *Cyberthreat of Adversarial AI* Dr. Edmon Begoli, *Oak Ridge National Laboratory*		10:00 – 11:00
	11:00 – 12:00	Paper Session 9	Panel Session 3: *AI and Machine Learning*	11:00 – 12:15
	12:00 – 1:00	Paper Session 10	Panel Session 4: *Space Applications*	12:15 – 1:30
	1:00 – 1:30	*Break*		
	1:30 – 2:30	Paper Session 11	*Break*	1:30 – 2:00
	2:30 – 3:30	Paper Session 12	Panel Session 5: *Digital Twin*	2:00 – 3:15
	3:30 – 4:30	Paper Session 13	Panel Session 6: *PHM for Manufacturing*	3:15 – 4:30
Thursday, December 2, 2021	10:00 – 11:00	Keynote 3: *From Monitoring to Mitigation in an Autonomous Vehicle Future* Prof. Daniel Work and Prof. Jonathan Sprinkle, *Vanderbilt*		10:00 – 11:00
	11:00 – 12:00	Paper Session 14	Panel Session 7: *Automotive PHM*	11:00 – 12:15
	12:00 – 12:30	*Break*		
	12:30 – 1:30	Paper Session 15	Panel Session 8: *Cyber-Physical Systems*	12:15 – 1:30
	1:30 – 1:45	*Break*		1:30 – 1:45
	1:45 – 3:00	Panel Session 9: *Qualifying Data and Data Use*	Panel Session 10: *Experience and Lessons Learned*	1:45 – 3:00
	3:00 – 3:20	The PHM Community – Inclusion and Mentoring Programs		3:00 – 3:20
	3:20 – 4:00	Awards Presentation & Conference Closing		3:20 – 4:00
Dec. 3	10:00 – 11:00	ijPHM Meeting (*invitation only*)		10:00 – 11:00
	11:00 – 12:00	PHM22 Organizational Committee Volunteers Meeting (*all welcome!*)		11:00 – 12:00

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