

# **Unsettled Topics on the Use of IVHM in the Active Control Loop**

**Rhonda D. Walthall**

# Unsettled Topics on the Use of IVHM in the Active Control Loop

**Rhonda D. Walthall**  
*Collins Aerospace*

---

**EDGE DEVELOPMENT TEAM**

---

Dr. Shreeder Adibhatla, *General Electric Aviation*

Carina Birgersdotter, *SAAB, retired*

Andy Hess, *The Hess PHM Group*

Dr. Ian Jennions, *Cranfield University*

Dave Larsen, *Collins Aerospace*

Linda O'Flarity, *Pratt & Whitney*

Steve O'Flarity, *Pratt & Whitney*

Dr. Ravi Rajamani, *drR2 consulting*

Douglas Felipe Rodrigues da Silva, *Embraer S.A.*

Dr. Antonios Tsourdos, *Cranfield University*

Dr. George Vachtsevanos, *Georgia Institute of Technology, retired*





## About the Publisher

SAE International® is a global association of more than 128,000 engineers and related technical experts in the aerospace, automotive and commercial-vehicle industries. Our core competencies are life-long learning and voluntary consensus standards development. Visit [sae.org](http://sae.org)

## SAE EDGE™ Research Report Disclaimer

SAE EDGE™ Research Reports focus on topics that are dynamic, in which knowledge is incomplete, and which have yet to be standardized. They represent the collective wisdom of a group of experts and serve as a practical guide to the reader in understanding unsettled subject matter. They are not meant to provide a recommended practice or protocol. The experts have assembled as a community of practitioners to contribute and collectivize their thoughts and points of view; these are not the positions of the institutions or businesses with which they are affiliated, nor is one contributor's perspective advanced over other contributors. SAE EDGE™ Research Reports are the property of SAE International and SAE alone is responsible for their content.

## About This Publication

SAE EDGE™ Research Reports provide state-of-the-art and state-of-industry examinations of the most significant topics in mobility engineering. SAE EDGE™ contributors are experts from research, academia, and industry who have come together to explore and define the most critical advancements, challenges, and future direction in areas such as vehicle automation, unmanned aircraft, cybersecurity, advanced propulsion, advanced manufacturing, Internet of Things, and connectivity.

## Related Resources

**SAE MOBILUS® Automated & Connected Knowledge Hub**  
<https://saemobilus.sae.org/automated-connected/>

## SAE Team

Frank Menchaca, Chief Growth Officer  
Michael Thompson, Director, Standards, Information and Research Publications  
Monica Nogueira, Acquisitions Director  
Beth Ellen Dibeler, Product Manager  
William Kucinski, Managing Technical Editor

---

Copyright © 2020 SAE International. All rights reserved.

No part of this publication may be reproduced, stored in a retrieval system, distributed, or transmitted, in any form or by any means without the prior written permission of SAE International. For permission and licensing requests, contact SAE Permissions, 400 Commonwealth Drive, Warrendale, PA 15096-0001 USA; e-mail: [copyright@sae.org](mailto:copyright@sae.org); phone: +1- 724-772-4028; fax: +1- 724-772-9765.

Printed in USA

Information contained in this work has been obtained by SAE International from sources believed to be reliable. However, neither SAE International nor its authors guarantee the accuracy or completeness of any information published herein and neither SAE International nor its authors shall be responsible for any errors, omissions, or damages arising out of use of this information. This work is published with the understanding that SAE International and its authors are supplying information but are not attempting to render engineering or other professional services. If such services are required, the assistance of an appropriate professional should be sought.

**EPR2020011**

**ISSN 2640-3536**

**e-ISSN 2640-3544**

**ISBN 978-1-4686-0185-5**

**To purchase bulk quantities, please contact: SAE Customer Service**

E-mail: [CustomerService@sae.org](mailto:CustomerService@sae.org)

Phone: 877-606-7323 (inside USA and Canada)  
+1-724-776-4970 (outside USA)

Fax: +1-724-776-0790

<https://www.sae.org/publications/edge-research-reports>

## About the Editor



Rhonda D. Walthall, photo by SAE International

**Rhonda D. Walthall** is a Technical Fellow at Collins Aerospace in Charlotte, NC, a division of Raytheon Technologies Corporation (RTX). In her role, she focuses on Design for Prognostics and Health Management (PHM) and Digital Thread initiatives. She is an industry-recognized leader in the development of standards and best practices for PHM and Integrated Vehicle Health Management (IVHM).

Walthall earned her Bachelor of Science Degree in Aeronautical and Astronautical Engineering from Purdue University and her Master's degree in Business Administration from Pepperdine University. She began her career as a Flight Test Engineer for the McDonnell Douglas Aircraft Company before working for Northwest Airlines as a Powerplant Engineer. In 2003, she joined Hamilton Sundstrand and has held positions of increasing responsibility, leading to her role today as a Technical Fellow.

Walthall is a member of the SAE International Board of Directors and is the Vice President of the PHM Society Board Directors. She has been actively engaged in SAE standards development and leadership since 2004. She was recognized by SAE as a Top Contributor of the Year (2019) and received the Rodica Baranescu Award for Technical Excellence & Leadership (2018) and the James M. Crawford Technical Standards Award for Outstanding Achievement (2016).

She holds three patents and has contributed significantly to numerous SAE documents and authored chapters in SAE and IEEE publications. She has presented technical papers and has participated as a keynote speaker, invited speaker, or panelist at numerous PHM-related conferences.

In 2020, Walthall received the Outstanding Aerospace Engineer Award from Purdue University, where she is a member of the Industrial Advisory Council to the School of Aeronautics and Astronautics.

# contents

**About the Editor**

**Unsettled Topics on the Use of IVHM in the Active Control Loop . . . . . 3**

Introduction . . . . . **4**  
*State of the Industry* . . . . . **4**

**Challenges to Implementing IVHM Capabilities into Active Control Systems. . . . . 6**  
*Large Transport Aircraft* . . . . . **8**  
*VTOL Aircraft* . . . . . **9**  
*Unmanned Aircraft* . . . . . **10**  
*Summary* . . . . . **11**  
*Recommendations* . . . . . **11**

**Challenges to Implementing IVHM Capabilities into Aircraft Control Systems. . . . . 12**  
*Data Interoperability for Vehicle-Level Reasoners* . . . . . **12**

**Certification . . . . . 13**  
Uncertainty in Prognostics . . . . . **14**  
Human-Machine Teaming . . . . . **15**  
**Summary . . . . . 16**  
**Recommendations . . . . . 17**

**Summary . . . . . 17**  
**SAE EDGE™ Research Reports . . . . . 17**  
**Next Steps for the Use of IVHM in the Active Control Loop . . . . . 17**  
**Recommendations . . . . . 18**  
**Acronyms . . . . . 18**  
**Acknowledgements . . . . . 19**  
**Bibliographic References . . . . . 19**  
**Contact Information . . . . . 20**

# Unsettled Topics on the Use of IVHM in the Active Control Loop

## Abstract

The growth in global economies has led to a world that has become much more mobile in the last few decades. The number of enplanements has increased and is expected to continue to do so at an annual average rate of 1.8% through 2039 [1]. Prior to the COVID-19 pandemic, the number of aircraft in service was expected to increase annually to meet the travel demand. Next-generation, more-complex aircraft were scheduled to replace the older aircraft at a pace that still allowed sufficient capacity to meet the increasing demand. The events of 2020 have driven the industry to accelerate retirement of older aircraft while deferring the introduction of new aircraft. While the length of the industry recovery period cannot be predicted, most analysts believe that demand for travel will return once a vaccine is widely available. The impact to the design of next-generation aircraft will likely be shaped by technologies that are being accelerated for the post-COVID world as well as for new mobility platforms. Technologies, such as artificial intelligence and fault-tolerant and self-adapting control, will use integrated vehicle health management (IVHM) capabilities as part of the decision-making processes. This SAE EDGE™ Research Report seeks to explore the unsettled issues surrounding embedding IVHM information into the active control loops of modern aircraft systems and in future generations of aircraft designs.

NOTE: SAE EDGE™ Research Reports are intended to identify and illuminate key issues in emerging, but still unsettled, technologies of interest to the mobility industry. The goal of SAE EDGE™ Research Reports is to stimulate discussion and work in the hope of promoting and speeding resolution of identified issues. SAE EDGE™ Research Reports are not intended to resolve the challenges they identify or close any topic to further scrutiny.

**RHONDA D. WALTHALL**  
*Collins Aerospace*

## Edge Development Team

Dr. Shreeder Adibhatla,  
*General Electric Aviation*  
Carina Birgersdotter, *SAAB, retired*  
Andy Hess, *The Hess PHM Group*  
Dr. Ian Jennions, *Cranfield University*  
Dave Larsen, *Collins Aerospace*  
Linda O'Flarity, *Pratt & Whitney*  
Steve O'Flarity, *Pratt & Whitney*  
Dr. Ravi Rajamani, *drR2 consulting*  
Douglas Felipe Rodrigues da Silva,  
*Embraer S.A.*  
Dr. Antonios Tsourdos, *Cranfield University*  
Dr. George Vachtsevanos,  
*Georgia Institute of Technology, retired*

ISSN 2640-3536