

# Unsettled Issues Regarding the Certification of Electric Aircraft

Ravi Rajamani, PhD  
Anna Mracek Dietrich

# Unsettled Issues Regarding the Certification of Electric Aircraft

**Ravi Rajamani, PhD**  
*drR2 consulting*

**Anna Mracek Dietrich**  
*AME Consulting*

## EDGE DEVELOPMENT TEAM

Mark DeAngelo, PhD, *SAE International*  
Tom Gunnarson, *Wisk Aero*  
Gary Horan, *Federal Aviation Administration*  
Ryan Naru, *Uber Elevate*  
Kevin Noertker, *Alcoa*  
Paulo C. Olericki, *Eviation Aircraft*

Norm Pereira, *Federal Aviation Administration*  
Joshua Portlock, *Electro.Aero*  
Luciano Serra, *magniX*  
Tine Tomažič, PhD, *Pipistrel*  
Mike Waller, *Avionic Instruments/Acme Aerospace*





## 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 lifelong 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 others. 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-the-industry examinations of the most significant

topics in mobility engineering. Contributors to SAE EDGE™ Research Reports are experts from academia, government, industry, and research 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® Powertrain Knowledge Hub**  
<https://saemobilus.sae.org/power/>

**SAE EDGE™ Research Report: Unsettled Domains Concerning Electric Propulsion Technology for Commercial Aircraft by Ravi Rajamani, PhD**  
<https://saemobilus.sae.org/concept/EPR2019006/>

## SAE Team

Frank Menchaca, Chief Growth Officer  
Michael Thompson, Director of Standards, Information and Research Publications  
Monica Ingulira, Director of Content Acquisition and Development  
Beth Miller Dibeler, Product Manager  
William Kucinski, Managing Technical Editor

Copyright © 2021 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: +1-724-776-4028; 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.

EPR2021007

ISSN 2640-3534

e-ISSN 2640-3542

ISBN 978-1-4605-3201-1

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 Editors



**Dr. Ravi Rajamani** is an independent consultant working on applying model-based and data analytics techniques to aerospace and other complex systems, especially in the areas of controls, prognostics and health management, and all forms of propulsion. He has published six books including *Electric Flight Technology: The Unfolding of a New Future*. In addition, Dr. Rajamani is the author of many book chapters, journal papers, conference proceedings, and patents. Prior to his current job, he worked at Meggitt, United Technologies Corporation, and General Electric. He has a PhD from the University of Minnesota; an MBA from the University of Connecticut; an MSc from the India Institute of Science, Bangalore; and a BTech from India Institute of Technology, Delhi. He is active within various SAE technical committees and serves as the chair of the Integrated Vehicle Health Management Steering Group. He currently serves as the Editor in Chief of the *SAE International Journal of Aerospace* and is part of the editorial board of two other journals. He has visiting research positions at the University of Connecticut and at Cranfield University.



**Anna Mracek Dietrich** is a leader in the urban air mobility and electric vertical takeoff and landing (eVTOL) industries with a focus on policy, regulatory affairs, government relations, and industry consensus standards. Working with private and public clients, she is at the forefront of laying the groundwork for a transportation future that is safe, reliable, and acceptable to communities and regulators alike. With experience as the founding Chief Operating Officer at Terrafugia, Anna brings a broad range of skills and an entrepreneurial spirit to whatever she does.

# contents

## About the Editors

## Unsettled Issues Regarding the Certification of Electric Aircraft

Introduction	4
<i>Aircraft Certification</i>	5
<i>Existing Certification Constructs</i>	6
Applicable Regulations and Relevant Perspectives	7
<i>Applicable Regulations across the Globe</i>	8
FAA and EASA	8
Others	9
<i>Relevant Perspectives</i>	10
Industry: Manufacturers	10
Industry: Operators and Maintainers	11
Industry: Infrastructure	11
Pilots (and Autonomy)	12
Public: Traveling and Nonparticipants	12
Regulators	12
Standards Development Organizations	13
<i>Airlines for America/Maintenance Programs Industry Group</i>	13
<i>ASTM International</i>	14
<i>EUROCAE</i>	14
<i>IMRBPB</i>	14
<i>RTCA</i>	14
<i>SAE/ARINC</i>	14
<i>Other SDOs</i>	15
<i>Recommendations</i>	15

Certification Challenges	16
<i>Areas of Maturity</i>	17
<i>Needs</i>	18
<i>Ongoing Efforts</i>	19
<i>Critical Next Steps</i>	20
<i>Propulsion Battery Certification Standards</i>	21
Battery Chemistries	21
Lithium Battery Design, Performance, and Testing Standards	21
Battery Charging Standards	22
<i>Motors and Generators</i>	23
<i>Distributed Electric Propulsion</i>	24
<i>Electric Avionics</i>	25
<i>Fuel Reserves</i>	25
<i>Different Aircraft Architectures and Issues Regarding Certification</i>	27
<i>Recommendations</i>	29
Process Level	29
Aircraft Level	30
Systems Level	30
Operational	31
Summary	31
<i>SAE EDGE Research Reports</i>	31
<i>Next Steps for EA Certification</i>	31
<i>Recommendations</i>	32
<i>Abbreviations/Definitions</i>	33
<i>Acknowledgments</i>	34
<i>References</i>	34
<i>Contact Information</i>	34

# Unsettled Issues Regarding the Certification of Electric Aircraft

## Abstract

The aerospace industry has begun to grapple with the reality of certifying electric aircraft (EA), signaling the maturing of the field. Many industry players are ramping up their activities to respond to imminent technical, safety, and regulatory challenges. In the foreground, manufacturers are working on new designs and innovative propulsion architectures for conventional and novel aircraft. While there are gaps in the understanding of the requirements as well as the processes for certification of these aircraft, some leading standards development organizations (SDOs) such as SAE International, ASTM International, and RTCA are stepping in to address many of these issues—often supported by representatives from regulatory agencies. These SDOs have representatives from aircraft and engine manufacturers, operators, and major suppliers. Even with active help from these experts, the question has not yet settled on all the rules and regulations that will guide the applicants in their quest for type certification. We believe this report is coming at an appropriate juncture in time to discuss the certification challenges faced by EA manufacturers in both the small (normal) and large (transport) categories. It will not cover autonomous vehicles, even though there is a tendency to conflate electric propulsion with autonomy. Autonomous flight is a rich topic that can best be served with a report dedicated to that topic alone.

The recommendations coming out of this document address technical, business, and process issues related to the certification of EA. Of special importance are the new rule changes in the normal category (Title 14 Code of Federal Regulations [14 CFR] Part 23, Amendment 64) that shift from a prescriptive philosophy to what is known as performance-based rules (PBRs); we will discuss how they affect the EA sector. In recent times, there has been a trend in the aviation sector of using electrical energy to power systems that have long used mechanical means such as hydraulics. But in EA, these components will be employed at criticality levels not previously witnessed in conventional aircraft. These components include motors, battery systems, actuators, auxiliary power units (APUs), and generators, among others. This report discusses many of the open issues with respect to certification of components and systems with the hope that the various stakeholders involved in this endeavor take note as they continue to move forward. We believe that with the first light-sport category EA certified in Europe in the summer of 2020, this is the right time to discuss some of the open issues regarding certification at all levels. The pace is only going to accelerate as other applicants present their various designs to the regulators and seek type certificates.

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. These reports are not intended to resolve the challenges they identify or close any topic to further scrutiny.

**RAVI RAJAMANI, PhD**  
*drR2 consulting*

**ANNA MRACEK DIETRICH**  
*AMD Consulting*

## Edge Development Team

Mark DeAngelo, PhD, *SAE International*

Tom Gunnarson, *Wisk Aero*

Gary Horan, *Federal Aviation Administration*

Ryan Naru, *Uber Elevate*

Kevin Noertker, *Ampaire*

Paulo C. Olenscki, *Eviation Aircraft*

Norm Pereira, *Federal Aviation Administration*

Joshua Portlock, *Electro.Aero*

Luciano Serra, *magniX*

Tine Tomažič, PhD, *Pipistrel*

Mike Waller, *Avionic Instruments/Acme Aerospace*

ISSN 2640-3536