



### Short Course on Electric VTOL Technology

Taught: Mon-Tues, Jun 14–15, 2021

10am–3pm ET (GMT-4), both days

Virtual | Go-To-Webinar | Two-part course

Cost: US\$300.00

Organized by the VFS eVTOL Technical Committee

#### COURSE DESCRIPTION / OVERVIEW:

The Vertical Flight Society's signature eVTOL class is **now expanded over 2-days with in-depth coverage** of **industry-standard battery** systems development (BAE), advanced high-power **hybrid-electric hardware** (LaunchPoint), PEM fuel cells and **hydrogen** propulsion and as always, the fundamentals of Vertical Lift and rotor aeromechanics from design to state-of-the-art in **acoustics** (Alfred Gessow Rotorcraft Center, University of Maryland).

Electric Vertical Take Off and Landing aircraft – or eVTOL – are aircraft propelled by electric power and capable of carrying people. There has been a dramatic resurgence of interest in these aircraft, driven by advances in electric-propulsion, digital manufacturing, high-fidelity simulations, and drone technologies (mobile computing and deep-learning). However, man-rated aircraft are more complex than drones, and require more than a clever combination of scaled-up components from consumer electronics and automobiles. Maturation of eVTOL into a safe, sound, and sensible aircraft require a clear understanding of rotary-wing fundamentals, principles of enabling technologies and timely resolution of its major barriers. The objective of this course is to introduce these fundamentals, technologies and barriers.

Led by Anubhav Datta, Alfred Gessow Rotorcraft Center, University of Maryland, this multi-presenter course will provide an overview of the unique challenges and opportunities of this new class of vehicles. Both electric and hybrid-electric passenger carrying vertical flight aircraft will be covered for a variety of missions ranging from personal/private use to urban air taxis to regional electric VTOL bizjets.

#### WHO SHOULD TAKE THE COURSE:

Aerospace engineers interested in electric power. Electrical / Mechanical engineers interested in VTOL aircraft. The content will be presented in a simplified and practical manner to allow innovators, entrepreneurs, and non-VTOL experts to be able to make useful calculations and build their own design / simulation tools. The content will be presented in a simplified and practical manner aimed to engage a wide audience of mixed aerospace and non-aerospace background. A simplified multi-rotor VTOL aircraft will be designed and analyzed in class, progressively, as a illustrative example.

Power point course notes will be emailed to all registered participants two weeks before the class.





## COURSE CONTENTS

### I. Fundamentals: Rotors, Aircraft, and Integrated Electric Power Anubhav Datta, Associate Professor, Alfred Gessow Rotorcraft Center

2.0 hrs

#### Introduction

- Why eVTOL? Why now? A brief history
- State-of-the-art in aircraft, battery, and motor
- Single vs. distributed
- Sizing an example eVTOL
- The connection to infrastructure

#### Rotor aeromechanics

##### VTOL aircraft

- Basic aerodynamics and performance
- Rotors vs. propellers vs. prop-rotors
- Coaxial and shrouded rotors
- Blade structural dynamics and loads
- eVTOL controls and trim
- Example Quadrotor and Tiltrotor

#### Electric power

- Power architecture
- Brushless permanent magnet motors
- Engine-generator hybrid
- Lithium ion and Sulfur batteries
- PEM fuel cells and hydrogen storage

### II. Sizing Advanced Battery Systems for eVTOL Application Robert Hess, Systems Engineering Manager, BAE Systems

3.0 hrs

- Definitions
- Describe battery operations and management
- Fundamentals of safe management and control
- Detail elements of battery packaging
- Discuss battery modeling
- Relate electrical and thermal elements to basic first principles
- Detail how systems are sized
- Assess battery performance (example)
  - Power
  - Energy
  - Size
  - Weight
  - Life
  - Cost
- Review development standards and testing



### **III. Brushless Permanent Magnet Machines and motor drives for Aircraft.**

**3.0 hrs**

**Michael Ricci**, LaunchPoint Electric Propulsion Solutions

- Basic PM motor physics for aeronautical engineering
- PM motor types and geometries (radial and axial flux)
- Motor performance metrics: size, weight, efficiency, torque, speed
- Characteristics and performance
- Designing a PM motor: sizing, weights and efficiencies
- Gearboxes
- Operating modes: motor vs generator
- Fundamental operation principles and sizing of Motor Drives
- Introduction to EMI concerns and mitigation
- Electric Tail rotor example

### **IV. eVTOL and UAM noise**

**2.0 hrs**

**James Baeder**, Samuel P. Langley Distinguished Professor, Alfred Gessow Rotorcraft Center

- Definitions
- Fundamentals of rotor acoustics
- Types of noise: broadband, rotational, and impulsive noise
- Ffowcs Williams and Hawkings Model
- Method to calculate noise
- Lifting-line versus CFD inputs
- Single versus multiple rotors
- Hover and forward flight
- Active control of noise
- Fundamental limits
- How quiet is quiet enough?

## INSTRUCTORS

**Anubhav Datta**, Associate Professor, University of Maryland

**Robert Hess**, BAE Systems

**Michael Ricci**, LaunchPoint Electric Propulsion Solutions

**James Baeder**, Samuel P. Langley Distinguished Professor, University of Maryland



**Anubhav Datta** is a member of the Alfred Gessow Rotorcraft Center (AGRC) and an Associate Professor of Aerospace Engineering at the University of Maryland at College Park. He holds a M.S. and Ph.D. in Aerospace Engineering from Maryland. He re-joined AGRC as faculty in 2016 after nine years at the U. S. Army Aviation Development Directorate (ADD) at NASA Ames Research Center. At Maryland, Datta and his students are focused on future vertical lift barriers through Mach-scale wind-tunnel tests and HPC-based high-fidelity simulations. The research conducted by Datta and his colleagues have led to new fields in VTOL such as Mars Helicopter (2000), CFD/CA (2004), and eVTOL (2012). Over the years his work has been recognized by the VFS Grover E. Bell and Alfred Gessow Awards, NASA Technical Excellence in Publications

Award, and U.S. Army and NASA Group Achievement Awards. Datta is the founder and inaugural chair of the VFS eVTOL Technical Committee, Chair of the AIAA Structural Dynamics Sub-committee on Conferences, and Associate Editor of the *Journal of the American Helicopter Society*.



**Robert Hess** is a Systems Engineering Manager at BAE Systems. He has been working in the aerospace industry for over 35 years. He currently leads the development of high-power, high-voltage battery systems for vehicle propulsion at BAE Systems where he leverages a multidisciplinary design team to advance battery solutions. Over the last 10 years, Bob has been involved with the analysis and development of Li Ion, ultra-capacitor and LiS battery concepts for all-electric and hybrid-electric propulsion. He holds several patents in the area of battery systems. As he has many years' experience in vehicle avionics systems, Bob has is able to apply a broad systems approach to the design of battery systems, including design for safe

operations and sustainability. Prior to his work with battery systems, Bob was involved in the development of helicopter HUMS as well as aircraft aerodynamic analysis. He published a number of papers in the fields of battery systems, diagnostics, prognostics and aircraft aerodynamic modeling and simulation. He hold a B.S. degree in Mechanical Engineering from Western New England University as well as a M.S degree from the George Washington University. Bob is a member of VFS and SAE International.



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**Robert Hess**, BAE Systems

**Michael Ricci**, LaunchPoint Electric Propulsion Solutions

**James Baeder**, Samuel P. Langley Distinguished Professor, University of Maryland



**Michael Ricci** is the Chief Technology Officer of LaunchPoint Electric Propulsion Solutions, and the driving force behind LaunchPoint's "Propulsion By Wire" electric aircraft propulsion effort. He spent the last 8 years as PI on a number of projects to develop electric aircraft propulsion technologies. These projects have included the development of highly efficient and powerful dual halbach array motors, high specific power wide bandgap semiconductor motor drives, and hybrid-electric gen-sets and bus power management systems. Applications have included HALE vehicles, helicopter electric tail rotors, multi-rotors, eVTOL vehicles, and turbogenerators. During Mike's 17 year tenure at LaunchPoint he has worked on flywheel energy storage, implantable heart assist pumps, medical oxygen concentrators, engine valve actuators, and a magnetically-levitated freight transportation system. Prior to joining LaunchPoint, Mr. Ricci worked as a mechanical engineer with Spectra F/X, a theme park engineering company, where he served as Project Engineer on several very large custom systems with high cycle rates, intimate man-machine interfaces, and high human-safety concerns.



**James Baeder** is a member of the Alfred Gessow Rotorcraft Center as a Professor of Aerospace Engineering at the University of Maryland at College Park. He is currently the Samuel P. Langley Distinguished Chair at the National Institute for Aerospace. He holds a M.S. and Ph.D. in Aeronautics and Astronautics from Stanford University. He joined the AGRC in 1993 after nine years at AFDD. His research interests are in developing and applying Computational Fluid Dynamic methods to better understand rotor aerodynamics, acoustics and dynamics. He is a pioneer in the development of high-fidelity CFD and aeroacoustics methods and tools for rotorcraft. Currently he is focused on the development of improved CFD algorithms on GPGPU technology, to: capture the details of laminar/turbulent transition; dynamic stall; as well as tip vortex formation, convection and interaction with other surfaces including fuselages, towers or the ground and including adjoint capabilities. Dr. Baeder's research has been funded by Excelon, NASA Ames and Langley, the Army Aeroflightdynamics Directorate, the Army Research Office, the National Rotorcraft Technology Center, NAVAIR and DARPA, with support from the various helicopter companies. Dr. Baeder is a Technical Fellow of the Vertical Flight Society, member of the Acoustics Technical Committee (1996-present), member of the Aerodynamics and Propulsion Area Committee, and Chairs the Innovation and Commercialization Committee of the Business Network for Offshore Wind as well as the National Offshore Wind Innovation Center.