

Short Course on Electric VTOL Technology



COURSE DESCRIPTION / OVERVIEW:

The Vertical Flight Society's signature eVTOL class offers 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 (NASA Ames) 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 requires 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.

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 an illustrative example.

INSTRUCTORS

Seyhan Gul, Research Engineer, Science and Technology Corporation, NASA Ames
Joshua Stewart, Associate Chief Engineer, BAE Systems
Michael Ricci, Chief Technology Officer, LaunchPoint Electric Propulsion Solutions
Dilhara Jayasundara, Aerocoustics Engineer, MagLev Aero

COURSE CONTENTS

I. Fundamentals: Rotors, Aircraft, and Integrated Electric Power

Seyhan Gul, Science and Technology Corporation, NASA Ames
Research Center

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

Joshua Stewart, Associate Chief Engineer, BAE Systems

- Definitions
- Describe battery operations and management
- Fundamentals of safe management and control
- Detail elements of battery packaging
- Discuss battery modeling
- Discuss battery fuel gauge concepts
- 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.

Michael Ricci, CTO, 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

Dilhara Jayasundara, Aeroacoustics Engineer, MagLev Aero

- 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:



Seyhan Gul is a research engineer at Science and Technology Corporation at NASA Ames Research Center. He holds M.S. and Ph.D. degrees in Aerospace Engineering at the University of Maryland. His research focused on aeromechanics modeling of tiltrotor aircraft and prediction of high-speed aeroelastic stability and loads of hingeless hub proprotors. He developed Alfred Gessow Rotorcraft Center's new comprehensive analysis code UMARC-II. Gul also led a graduate team in 2018-2019 to design an extreme-altitude mountain rescue vehicle, which won the 36th VFS Student Design Competition. Before his Ph.D, he completed another Master's Degree at the Middle East Technical University in Ankara/Turkey and worked at Turkish

Aerospace. There, he focused on comprehensive analysis and rotor/airframe loads predictions of T625 Gökbey Helicopter. Gul is a recipient of the prestigious Vertical Flight Foundation Scholarship and best paper awards in dynamics session at VFS Forum 77 and AIAA SciTech Forum in 2021.



Joshua Stewart is an Associate Chief Engineer at BAE Systems and a member of the VFS. He has been working in the aerospace industry for over 10 years. Over the last 5 years, Josh has been a technical leader in the development of high-power, high-voltage battery systems for aircraft propulsion at BAE Systems. Josh is involved with the analysis and development of electric and hybrid electric aircraft propulsion systems, including Li-Ion battery storage, high-fidelity battery management systems, high voltage power distribution, motor drives and cables. He has played a critical role in the development of aircraft propulsion solutions for CTOL and eVTOL aircraft.

With a strong background in flight-critical avionics and energy storage for ground transit, Josh has been able to apply a broad systems approach to the design of battery systems, including design for thermal runaway propagation and containment. He holds a B.S. degree from Binghamton University and a M.S. degree from Worcester Polytechnic Institute in Mechanical Engineering.



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 halfbach 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.



Dilhara Jayasundara is an aeroacoustics engineer at MagLev Aero, an innovative company headquartered in Boston, Massachusetts that leverages magnetic levitation to create a quieter and safer fully electric VTOL platform. He holds M.S. and Ph.D. degrees in Aerospace Engineering from the University of Maryland. During that time, Jayasundara led a graduate team in 2020-2021 to design a high-speed, unmanned vertical lift concept suitable for delivering supplies to precise locations, which won the 38th VFS Student Design Competition.