AHS International — The Vertical Flight Society
Short Course on Electric VTOL Technology
May 14, 2018

COURSE DESCRIPTION

There has been a dramatic resurgence of interest in man-rated (2-5 seat) electric vertical takeoff and landing (eVTOL) aircraft in recent years — driven by advances in electric power and drone technology. Man-rated aircraft are more than drones, however; a safe, sound, and successful design requires a clear understanding of the underlying principles and technologies that enable this new class of aircraft. The objective of this course is to describe these principles and technologies.

Session I is focused on the principles, in particular: aeromechanics of high disk loading props, trim and transient characteristics of VTOL aircraft, electrochemical power, and permanent magnet machines and drives.

Session II is focused on technologies, in particular: NASA’s integrated design tool for VTOL/eVTOL, detailed design examples, and flight-worthy power-train construction, integration and testing. Session I will equip the audience with the necessary background for Session II.

INSTRUCTORS

Anubhav Datta, University of Maryland
Wayne Johnson and Chris Silva, NASA
Michael Ricci, LaunchPoint Technologies
Reed Danis and Colin Wilson, ESAero

CONTENTS

Session I

8:00-10:30 AM
Fundamentals of eVTOL
Anubhav Datta, University of Maryland

Introduction
- Why eVTOL? Why now?
- Mission and Aircraft Requirements
- Classification of electric / hybrid-electric power-train
- Survey of current concepts
- Review of AHS/AIAA/GAMA/ASTM standards/regulatory activities

Propeller aeromechanics
• Basic rotor aerodynamics and dynamics
• Performance metrics in hover, helicopter and airplane modes
• Prop-rotors, Coaxial, and shrouded/ducted rotors

**VTOL aircraft**
• Aircraft trim solution
• Aircraft L/D
• Sizing with piston, turbo-shaft and electric power plant
• Sample calculations for Uber-like intra and inter-city missions

**Li-ion and Sulphur Batteries**
• Steady-state I-V characteristics
• Effect of temperature and rate of discharge
• ECN models for transient dynamics
• Li Sulphur – fundamentals, advantages and limitations
• Fabrication
• Weights

**PEM fuel cells**
• Steady-state I-V characteristics
• Effect of pressure, temperature and humidity
• ECN models for transient dynamics
• Impedance spectroscopy; Warburg and CPE elements
• Hydrogen storage
• Balance of Plant
• Weights

10:45-12:00 AM
**Brushless Permanent Magnet Machines for Aircraft**
**Michael Ricci, LaunchPoint Technologies**

• Basic PM motor physics for aeronautical engineers
• PM motor types and geometries (radial and axial flux)
• Motor performance metrics (size, mass, efficiency, torque, speed)
• Motor sizing, mass, and efficiency
• Drives and gearboxes
• Electric tail rotor example

**Session II**

12:45-2:30 PM
**Conceptual Design of a eVTOL Aircraft**
Wayne Johnson and Chris Silva, NASA
- Modeling with NDARC – NASA Design and Analysis of Rotorcraft
- Principle design drivers of eVTOL

2:45-4:15 PM
Envisioning urban mobility with 10 years of eAirplane Development
Reed Danis and Colin Wilson, ESAero
- Design as an enabling technology
- Integrated power-trains
- Hybrid-electric XV-15
- X-57 Maxwell Project
- Integrated traction bus, inverters and motors
- Flight batteries – lessons learned

Instructor Biographies

Anubhav Datta is an Associate Professor of Aerospace Engineering at the University of Maryland at College Park. Prior to joining Maryland, he worked at the U.S. Army Aviation Development Directorate (ADD) at NASA Ames Research Center from 2007-2016, on full-scale rotor testing, aeromechanics code development, and eVTOL. He is the author of the 3D rotor aeromechanics stress analysis software X3D. His research at Maryland is focused on modeling and testing of new electric propulsion concepts for eVTOL and improving dynamic loads and stability of high-speed tilting prop-rotors through wind-tunnel testing and RANS/FEA simulations. He is the chair of the AHS Integrating Technical Team (ITT) on eVTOL, leads NARI's inter-city eVTOL working-group, chair of the AIAA Structural Dynamics Conferences Subcommittee, a member of AHS Dynamics Committee, Associate Fellow of AIAA, and an Associate Editor of the Journal of the AHS. The research conducted by Datta and his colleagues and students have been recognized over the years by AHS's Alfred Gessow, Grover E. Bell, and François-Xavier Bagnoud Awards, NASA's Technical Excellence in Publications Award, and Group Achievement Awards from the US Army and NASA.

Wayne Johnson worked at the U.S. Army Aeromechanics Laboratory from 1970 to 1981, assigned to the 40- by 80-Foot Wind Tunnel branch of Ames Research Center. He was with NASA from 1981 to 1986, including a couple years as Assistant Branch Chief. In 1986, Dr. Johnson founded Johnson Aeronautics, and from 1986 to 1998 developed rotorcraft software. Since 1998 he has worked at the Aeromechanics Branch of NASA Ames Research Center. Dr. Johnson is author of the comprehensive analysis CAMRADII and the rotorcraft design code NDARC; and the books "Helicopter Theory" (1980) and "Rotorcraft Aeromechanics" (2013). He is a Fellow of AIAA and AHS, and an Ames Fellow, and has received the U.S. Army Commander's Award for Civilian Service, NASA Medals for Exceptional Engineering Achievement and Exceptional Technology Achievement, the AHS Grover E. Bell Award, the Ames H. Julian Allen Award, the AIAA Pendray Aerospace Literature Award, the 2010 AHS Alexander Nikolsky Honorary Lectureship, and the 2014 Alexander Klemin Award of the American Helicopter Society.

Chris Silva is a Research Aerospace Engineer at NASA Ames Research Center, Moffett Field, California, performing conceptual design, tool development, and technology assessment for advanced vertical lift
vehicles. Prior to joining NASA, he was at the U.S. Army AMRDEC at Moffett Field, performing conceptual design and assessment for Department of Defense rotorcraft programs. Chris has also worked on numerous radio control aircraft development projects as a hobbyist and been involved with dozens of electric aircraft national and world records, including both fixed-wing and rotary-wing types of aircraft.

Michael Ricci is the Vice President of Engineering, LaunchPoint Technologies, and the driving force behind LaunchPoint Technologies “Propulsion By Wire” electric aircraft propulsion effort and spent the last 6 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, and eVTOL vehicles. During Mike’s 17-year tenure at LaunchPoint Technologies 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.