https://youtu.be/CeLdivT7MvU

Penn State Vertical Lift Research Center of Excellence:
Educational Activities & Research Overview

Contact: Prof. Ed Smith
(814) 863-0966
ecs5@psu.edu

http://www.vlrcoe.psu.edu/

VLRCOE Overview
November 2023
Penn State University

Agenda – Day 1 (morning) Barron Innovation Hub, Monday, Nov 6, 2023

8:30– 8:45 AM	**Opening Comments and Introductions (Bhagwat)**
8:45– 9:30 AM	**VLRCOE Overview (Smith)**
9:30 – 10:00 AM	**Feature Project Briefing: Research Highlights from FAA ASCENT Programs (Greenwood, Brentner)**
10:00 – 10:45 AM	**1.1 Proprotor and Wing Interactional Aerodynamics for Performance and Acoustics (Lee, Brentner)**
10:45 – 11:00 AM	**Break**
11:00 – 11:30 AM	**3.3 Acoustically Aware Vertical Lift Autonomy (Greenwood, Langelaan, Brentner))**
11:30 – 12:00 AM	**8.2 Human Intuitable Collision Avoidance for Autonomous and Semi-Autonomous Rotorcraft (Wagner, Langelaan)**
12:00 AM – 1:00 PM	**Lunch**

Agenda – Day 1 (afternoon) Barron Innovation Hub, Monday, Nov 6, 2022

1:00 - 1:30 PM	**8.1 Semi-Passive Low-power Ice Protection Systems for EVTOL (Palacios, Wolfe)**
1:30 – 2:15 PM	**1.2 Scaling for Interactional Aerodynamics and Acoustics of Multi-rotor Systems (Palacios, Miller, Greenwood)**
2:15 – 2:45 PM	**1.11 Individual Blade Pitch Controls (IBC) for Vibration Reduction of Coaxial Rotor Vehicles with Pusher Propellers (Smith, Schmitz**
2:45 – 3:00 PM	**Break**
3:00 – 3:45 PM	**6.2 Hybrid Gas-Electric Rotorcraft Drivetrain Concepts for Enhanced Vehicle Performance (Hall, DeSmidt, Bill, Smith)**
4:00 – 4:40 PM	**1.12 Downwash-outwash of counter rotating coaxial rotors in-Ground Effect (Raghav, Schmitz)**
4:40 – 5:00 PM	**1.13. New UC Davis Task Kickoff. Design and Optimization of Airfoils in Compressible, Unsteady Flows at Moderate Reynolds Numbers (Badrya)**
5:00 – 5:15 PM	**1.11 (New expanded scope) High Speed Composite Rotor Optimization (Smith, Huang)**
5:15 – 5:30 PM	**Break**
5:30 – 6:00 PM	**Day 1 Review Team Caucus**
6:00 – 7:30 PM	**GRADUATE STUDENT - FACULTY - REVIEW TEAM MIXER EVENT**

Agenda – Day 2 (morning) Barron Innovation Hub, Tuesday, Nov 7, 2023

8:15 AM – 8:45 AM	**3.1 Adaptive Human Pilot Modeling for Shipboard Operations (Horn)**
8:45 – 9:30 AM	**3.2 State-Variable Implementation and Linearization of Simulations with Multi-Disciplinary Aeromechanics (Saetti, Horn, Brentner)**
9:30 – 10:10 AM	**1.4 Fundamental Interactional Aerodynamics of Low-drag Rotor/Hub/Pylon Flows (Schmitz, Jaffa, Reich, Coder)**
10:10 – 10:30 AM	**Break**
10:30 AM – 11:00 AM	**2.1 Cold Spray Deposition of polymer-Coating Metal/Ceramic Particles on CRFPs for Improved Erosion Resistance (Yamamoto, Wolfe)**
11:00 -12:00 PM	**Review Team Caucus**
12:00 PM - 12:30 PM	**Debrief**

Government/Industry Review team (on site*)

Army		
Mahendra Bhagwat	mahendra.j.bhagwat.civ@army.mil	Sr. Research Scientist, Aerodynamics & Design, TDD, DEVCOM AvMC, Moffett Field CA
Chris Cameron	christopher.g.cameron.civ@army.mil	Experimental Aeromechanics Branch, TDD/DSE, DEVCOM AvMC, Moffett Field CA
Lou Centolanza	louis.r.centolanza.civ@army.mil	Chief, Rotors Branch, TDD/DSE, DEVCOM AvMC, Ft. Eustis CA
Nelson Ciron	nelson.s.ciron.civ@army.mil	Rotors Branch, TDD/DSE, DEVCOM AvMC, Ft. Eustis VA
Steve Jamy	stephen.j.jamy2.civ@army.mil	Aeromechanics Division, SRD, DEVCOM AvMC, Redstone Arsenal AL
Henry Jia	zhongqi.jia.civ@army.mil	Computational Aeromechanics Branch, TDD/DSE, DEVCOM AvMC, Moffett Field CA
Anastasia Kozup	anastasia.j.kozup.civ@army.mil	Chief, Platforms Division, TDD/SID, CCDC AvMC, Ft. Eustis VA
Joon Lim	joon.w.lim.civ@army.mil	Computational Aeromechanics Branch, TDD/DSE, DEVCOM AvMC, Moffett Field CA
Jeff Lusardi	jeffery.a.lusardi.civ@army.mil	Sr. Research Scientist, Flight Controls, TDD, DEVCOM AvMC, Moffett Field CA
Will McNicholas	william.v.mcnicholas.civ@army.mil	Drives Branch, TDD/DSE, DEVCOM AvMC, Ft. Eustis VA
Marty Moulton	marvin.a.moulton.civ@army.mil	Chief Engineer for Aviation, TDD, DEVCOM AvMC, Redstone Arsenal AL
LTC Shawn Naigle	shawn.c.naigle.mil@army.mil	Deputy Associate Director, Design Simulation & Experimentation (DSE), TDD, DEVCOM AvMC, Moffett Field CA
David O'Brien	david.m.obrien48.civ@army.mil	Aeromechanics Division, SRD, DEVCOM AvMC, Redstone Arsenal AL
Jill Rich	jill.m.rich.civ@army.mil	Deputy Associate Director, System Integration & Demonstration, TDD, CCDV AvMC, Ft. Eustis VA
David Quinn	david.j.quinn.civ@army.mil	Aeromechanics Division, SRD, DEVCOM AvMC, Redstone Arsenal AL
Robert Scott	robert.c.scott154.civ@army.mil	Concept Design & Assessment Branch, TDD/DSE, DEVCOM AvMC, Moffett Field CA
Mat Thomas	mathew.l.thomas5.civ@army.mil	Rotors Branch, TDD/DSE, DEVCOM AvMC, Ft. Eustis VA
J Michael Vegh	julius.m.vegh.civ@army.mil	Concept Design & Assessment Branch, TDD/DSE, DEVCOM AvMC, Moffett Field CA
Allen Walker	allen.d.walker.civ@army.mil	Chief, Design & Test Division, TDD/DSE, DEVCOM AvMC, Ft. Eustis VA
MAJ Robert Walters	robert.walters@westpoint.edu	Dept of Civil & Mech Engg, US Military Academy, West Point NY
Oliver Wong	oliver.d.wong.civ@army.mil	Associate Director, Design Simulation & Experimentation (DSE), TDD, DEVCOM AvMC, Moffett Field CA
Navy		
Mookhram Basdeo	mookhram.basdeo@navy.mil	Propulsion Branch, NAWCAD (NAVAIR)
Ken Cahill	kenneth.m.cahill2.civ@us.navy.mil	Flight Dynamics Branch (AB21400), NAWCAD (NAVAIR)
Mike Fallon	michael.fallon@navy.mil	Vertical Lift S&T Portfolio Manager, NAWCAD (NAVAIR)
LtCol Tim Fenton	timothy.j.fenton2.mil@us.navy.mil	S&T Lead for the PEO(A) Advanced Development Team (ADT)
Bill Geyer	william.geyer@navy.mil	Naval Test Pilot School
Don Gaublomme	donald.p.gaublomme.civ@us.navy.mil	Manned Flight Simulator, H-1 Aero Model team lead, NAWCAD (NAVAIR)
David Gonzalez	david.r.gonzalez@navy.mil	Aerodynamics Program Officer, ONR
Samuel Hagner	samuel.t.hagner.civ@us.navy.mil	Structures Division, Airframe Technology Branch, NAWCAD (NAVAIR)
Scott Hromisin	scott.hromisin3@navy.mil	Experimental Aero Branch, NAWCAD (NAVAIR)
Richard Lavallais	richard.h.lavallais.ctr@us.navy.mil	Aerodynamics Program, ONR
Gabriel Murray	gabriel.murray@navy.mil	Structures Division, Airframe Technology Branch, NAWCAD (NAVAIR)
Chessie (James) Newbold	james.c.newbold.civ@us.navy.mil	Performance, NAWCAD (NAVAIR)
David Shane	david.a.shane6.civ@us.navy.mil	Applied Aerodynamics Branch, NAWCAD (NAVAIR)
Laura Slingerland	laura.a.slingerland.civ@us.navy.mil	Flight Controls Branch, NAWCAD (NAVAIR)
NASA		
Natasha Schatzman	natasha.schatzman@nasa.gov	Aeromechanics Office, ARC
Industry		
Loren Ahaus	lahaus@bellflight.com	Rotor Dynamics…, Ft Worth TX
Matt Hill	mjhill@bellflight.com	Computational Fluids Group Manager, Ft Worth TX
Ken Wittmer	kwittmer@bellflight.com	Sr Enginerr/ATF Flight Control Laws, Ft Worth TX
Bill Welsh	bill.a.welsh@lmco.com	Senior Tech Fellow- Dynamics
Nick Tomaine	nicholas.j.tomaine@boeing.com	Flight Controls, PSU VLRCOE Focal

Many other reviewers and TPOCs on TEAMS meeting

True Mastery of the Air

Vertical Flight Mobility REQUIRES Design, Operation, and maintenance of THE MOST COMPLEX machine human beings have ever created

But the payoff is in the capability

PENNSTATE

Rotorcraft Center
Goals and Technical Approach

Focus research personnel and facilities on **timely solution of 21st century technical barrier problems**

Provide an exciting and effective educational environment to **train the next generation of rotorcraft engineers**

Outline

- ***Educational Activities***
- ***Research Overview***
- ***Technology Transfer and Student Accomplishments***
- ***Strategic Plans***

Educational Activities @ VLRCOE

(graduate and undergraduate)

Vertical Lift Research Center Goals

1) **Focus research personnel and facilities on timely solution of 21st century technical barrier problems**

2) **Provide an exciting and effective educational environment to train the next generation of rotorcraft engineers**

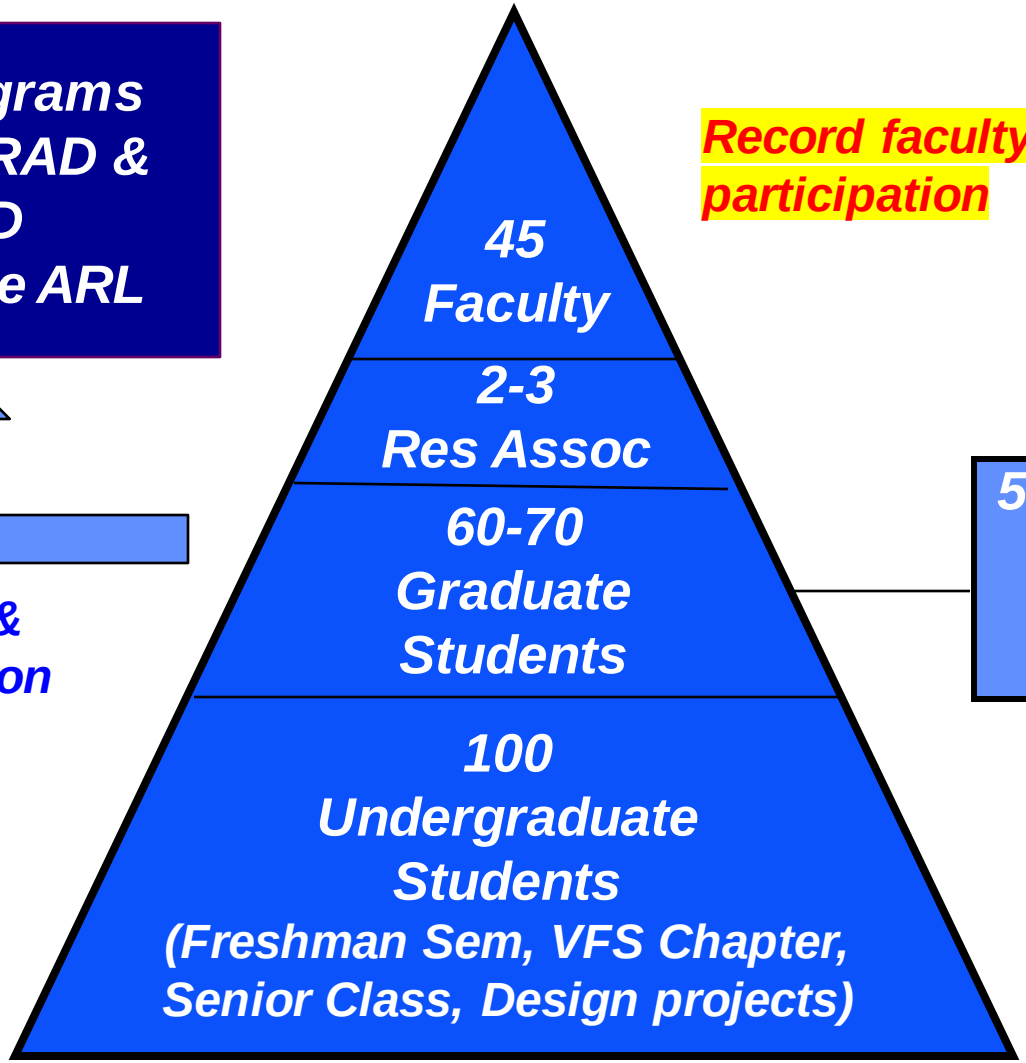
3) **Collaborate with industry and government agencies: stimulate vertical lift development & comm. acceptance**

4) **Form partnerships with outstanding universities around the country: to strengthen our technical scope and germinate**

PSU Vertical Lift Research Center Tech Base

SBIR Programs
Industry IRAD & CRAD
Penn State ARL

apply & transition



Record faculty participation

50-90 Continuing Education Students (Short course)

Vertical Lift Center Faculty @ PSU

PennState

Directors

Ed Smith	**Dynamics, aeromechanics, composites, drives**
Ken Brentner	**Aeroacoustics, CFD, VLRCOE Admin**

Deputy Directors

Joe Horn	**Flight mechanics, simulation, and control**
Sven Schmitz	**Applied and experimental aero, CFD, wind energy**
Ben Beck(ARL)	**Structural acoustics & dynamics, composites**

Administrative Assistants

Brenda Kasubick and Lindsay Moist (finance support)
bmk16@psu.edu, lnm3@psu.edu

Ben Enders (review IT support)
bre12@psu.edu

Debbie Mottin **(special finance support)**
daj122@psu.edu

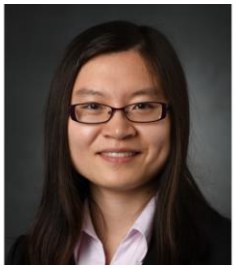
Vertical Lift Center Faculty @ PSU

Affiliated Faculty - Aerodynamics, Aeroacoustics, Flight Controls, Autonomy

Jack Langelaan	**Guidance, navigation, and controls**
Eric Johnson	**Autonomous aviation systems, avionics, controls**
Mark Maughmer	**Airfoil design, aerodynamics, icing**
Sean McIntyre (ARL)	**propulsion, CFD, aerothermodynamics**
David Reich (ARL)	**fluid dynamics**
Nick Jaffa (ARL)	**experimental fluid dynamics**
Dennis McLaughlin	**Experimental aerodynamics and aeroacoustics**
Eric Greenwood	**Rotorcraft Aeroacosustics**
David Hall	**Air breathing and electric propulsion**
Mark Miller	**Experimental aerodynamics**
Jim Coder	**CFD, aerodynamics**
Daning Huang	**aeroelasticity, optimization, HPC**

New Penn State
Assistant. Prof.

Junyi (Jenny) Geng	**Aerospace robotics,**
January 2023	**controls**



Vertical Lift Center Faculty @ PSU

Affiliated Faculty and Research Scientists - Structures, Dynamics, Drives

Jose Palacios	**Icing, smart structures, experimental mechanics**
Namiko Yamamoto	**nano-materials and composites**
Doug Wolfe (ARL)	**Coatings, materials and manufacturing**
Bob Bill	**Propulsion and powertrains**
Jianhua Zhang	**Rotor dynamics and design**
Aaron Isaacson (ARL)	**Drivetrain technologies, manufacturing**
George Lesieutre	**Structural dynamics, materials**
Chris Rahn (ME)	**Controls and structural dynamics**
Chuck Bakis (ESM)	**Composite materials and structures**
Cliff Lissenden (ESM)	**SHM, fatigue and fracture, composites, NDE**
Steve Hambric (ARL)	**Structural acoustics**
Ted Reutzel (ARL)	**additive manufacturing, laser processing**
Jogender Singh (ARL)	**advanced materials, sintering, coatings**
Micah Shepherd (BYU)	**interior noise and vibrations**
Caillin Ryan (ARL)	**coatings, metallurgy, ceramics, materials science**

Vertical Lift Center Faculty @ PSU

Teaching Faculty

Sara Lego	**vehicle design & systems engineering**

Affiliated Faculty and Research Scientists - Condition Based Maintenance

Karl Reichard (ARL)	**HUMS, signal, processing**
Jeff Banks (ARL)	**HUMS, system integration**
Sam Evans (USA ret. ARL)	**HUMS, CBM, Logistics**
Lewis Watt (USMC ret.)	**Logistics, flight operations**
Clark Moose (ARL)	**Acoustic Emissions and composites NDE**

https://www.arl.psu.edu

Vertical Lift Center Faculty Collaborators – outside PSU

VLRCOE 2021-2026 Partners:

Hans DeSmidt (U of Tenn)	**Drive system dynamics and control**
Seongku Lee (U of Cal Davis)	**Computational Aeroacoustics, CFD**
Vrishank Raghav (Auburn Univ)	**Exp. and Applied Aerodynamics**
Ehsan Taheri (Auburn Univ)	**Exp. and Applied Aerodynamics**
Umberto Saetti (Univ of Maryland)	**Flight controls and simulation**
Camli Badrya (U of Cal Davis)	**Experimental aerodynamics**

Educational Activities

- *1st Year: Hands-on Helicopters 101*

Now 2 sections = 100 students/year

- *Rotorcraft Aerodynamics*
- *Rotorcraft Dynamics*
- *Rotorcraft Stability and Control*
- *Rotorcraft Design*
- *Rotorcraft Advanced Aero and Acoustics (Greenwood)* *New Graduate Course*

- *Structural Dynamics*
- *Aeroacoustics & Structural Noise*
- *Applied Aerodynamics & CFD*
- *Composite & Smart Structures*
- *Control Systems & Navigation*
- *Autonomous Aerospace Systems*

- *Summer Short Course* *Record enrollment*
- *VFS Design Competition*
- *Educational programs for pre K-12 kids (e.g. Rotor Day)*

Professional Development Short Course

PennState

1 week Rotary Wing Tech Short Course at PSU

History	Stability & Control
Aerodynamics	Propulsion
Dynamics	Acoustics
Composites	Lab Tours & Demos

56th annual offering: July 2023

73 students
(10 from USAF)

3 new instructors
Dr. Al Brand
Dr. Bob Handschuh
Dr. Dave Hall

57th annual offering: July 2024

http://www.outreach.psu.edu/programs/rotary-wing/staff.html

"Good course, well run. very enjoyable experience especially coming in from Australia."

" Great job, will recommend to fellow workers."

"Overall I think this was an excellent course. Although a great deal of information was presented in a relatively short amount of time, I was able to learn a great deal, and very much enjoyed the course."

"This was a great program with terrific material. For the vast majority, don't change much, except new material and keep offering the program!"

"Great material presented by knowledgeable instructors, in a format that was easy to absorb."

"I thought the opportunities to interact with professors, instructors, and other students at the picnic and banquet were excellent."

VLRCOE Research Overview

VLRCOE Research Portfolio

- ***Rotor and airframe aeromechanics and dynamics***
- ***Flight control, handling qualities and simulation***
- ***Acoustics (aero and structural, simulation + test)***
- ***Propulsion and Drive Systems***
- ***Structures, materials, and manufacturing***
- ***Computational and experimental fluid dynamics***
- ***Icing and erosion: physics and protection***
- ***Autonomy, guidance, and navigation***

VLRCOE Research Themes

Improved Reliability, Maintainability, Affordability and Safety

- ***Condition Based Maintenance & Structural Health Monitoring***
- ***Flight Controls, Advanced Sim, Redundant systems, eVTOL***
- ***Advanced Coatings (erosion, thermal, icing)***
- ***Advanced Drive systems (fewer parts, longer lives)***
- ***Inspection and repair technologies, AM***

Enhanced Performance (range speed, payload, maneuver, noise, compactness)

- ***Advanced rotors (vibration, damping, performance, range)***
- ***Drag reduction and flow control***
- ***Advanced drive systems (light weight, variable RPM, hybrid electric)***
- ***Lightweight and low-cost advanced composite structures***
- ***Expanded vehicle autonomy***
- ***External noise characterization, control, and fundamental physics, eVTOL***

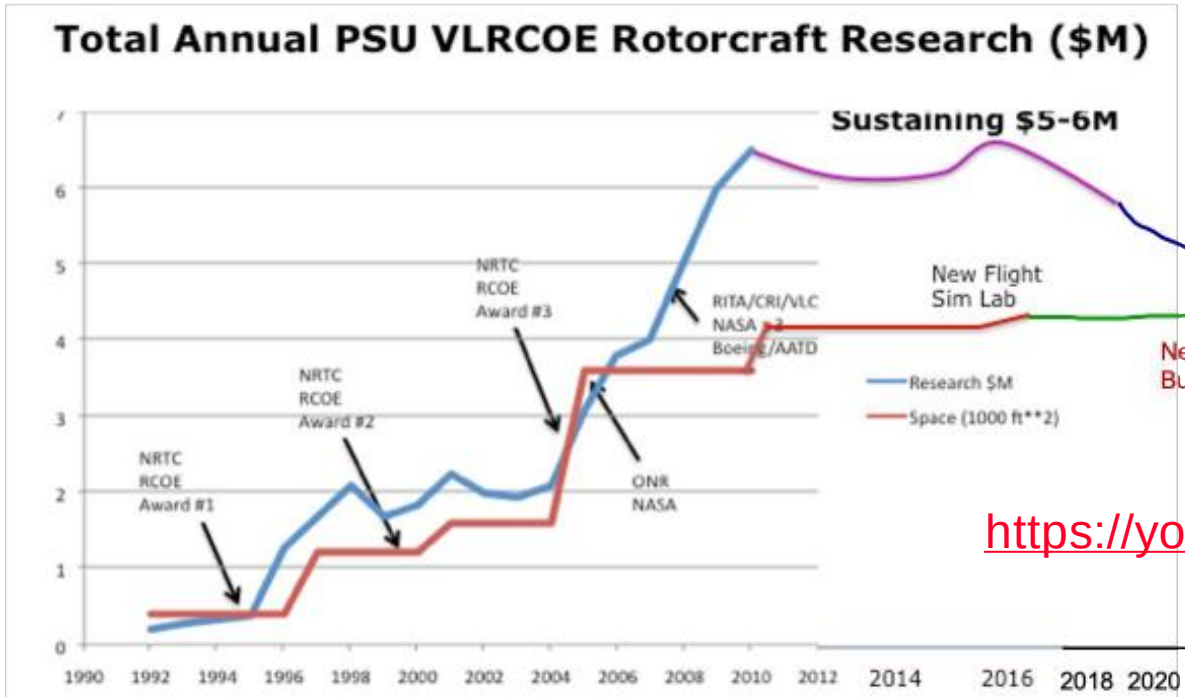
Interior Noise and Vibration Control (active and passive)

Adverse Environment (ice, sand, rain, wind, maritime)

Engineering Tool Development/Validation

Survivability –maneuver, crashworthy, HQ, autonomy

VLRCOE Maturation and Growth Chart

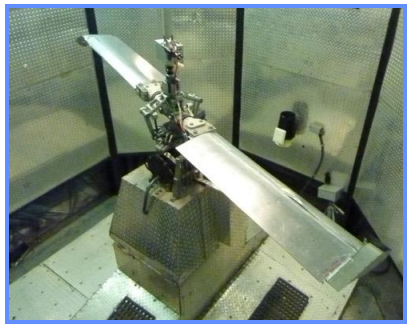


2022 2023

2021

https://youtu.be/CeLdivT7MvU

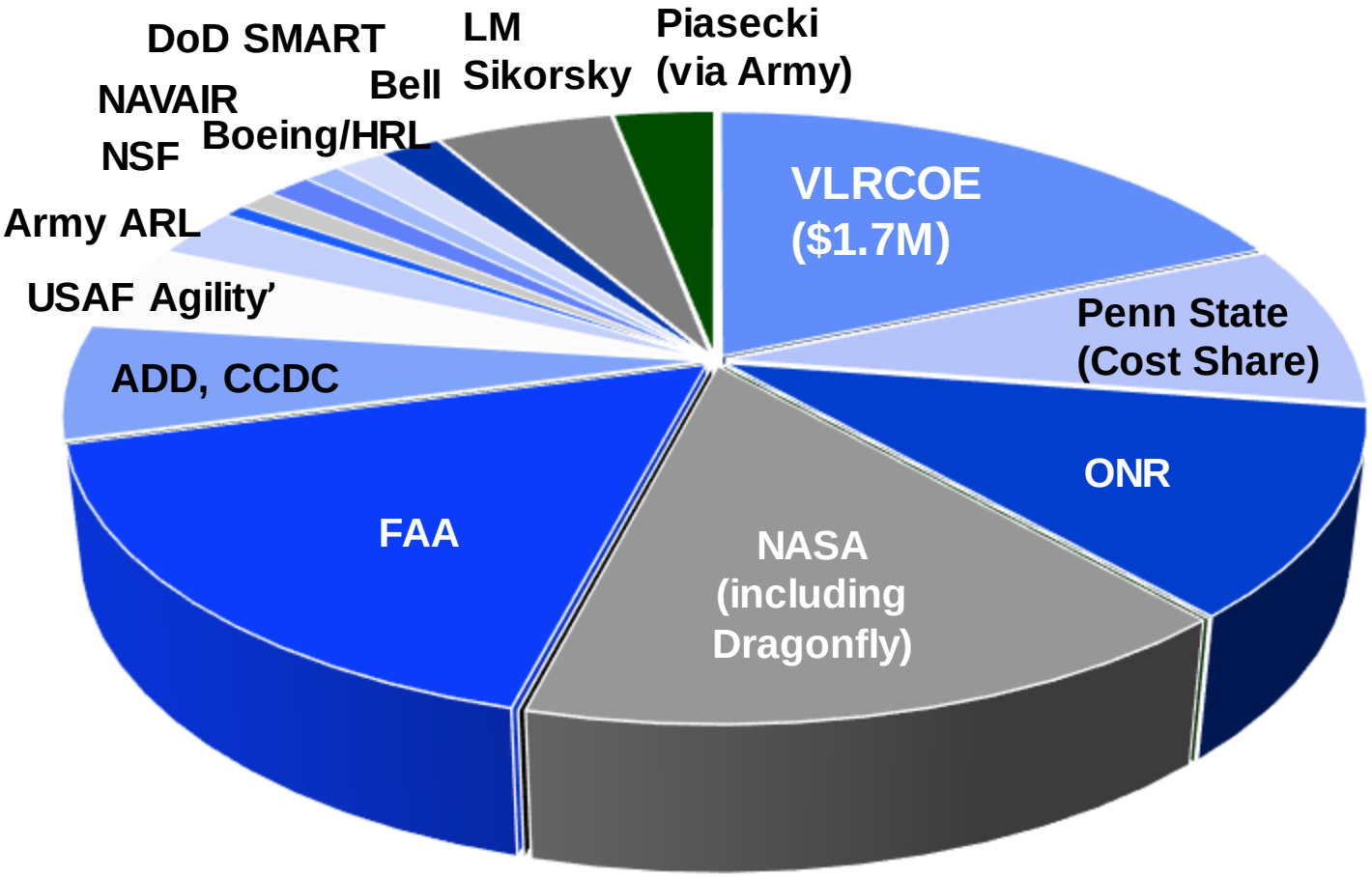
2021 2022 2023 2024



WE ARE! PENN STATE VLRCOE!

2023 VLRCOE funding profile

$.9.6M

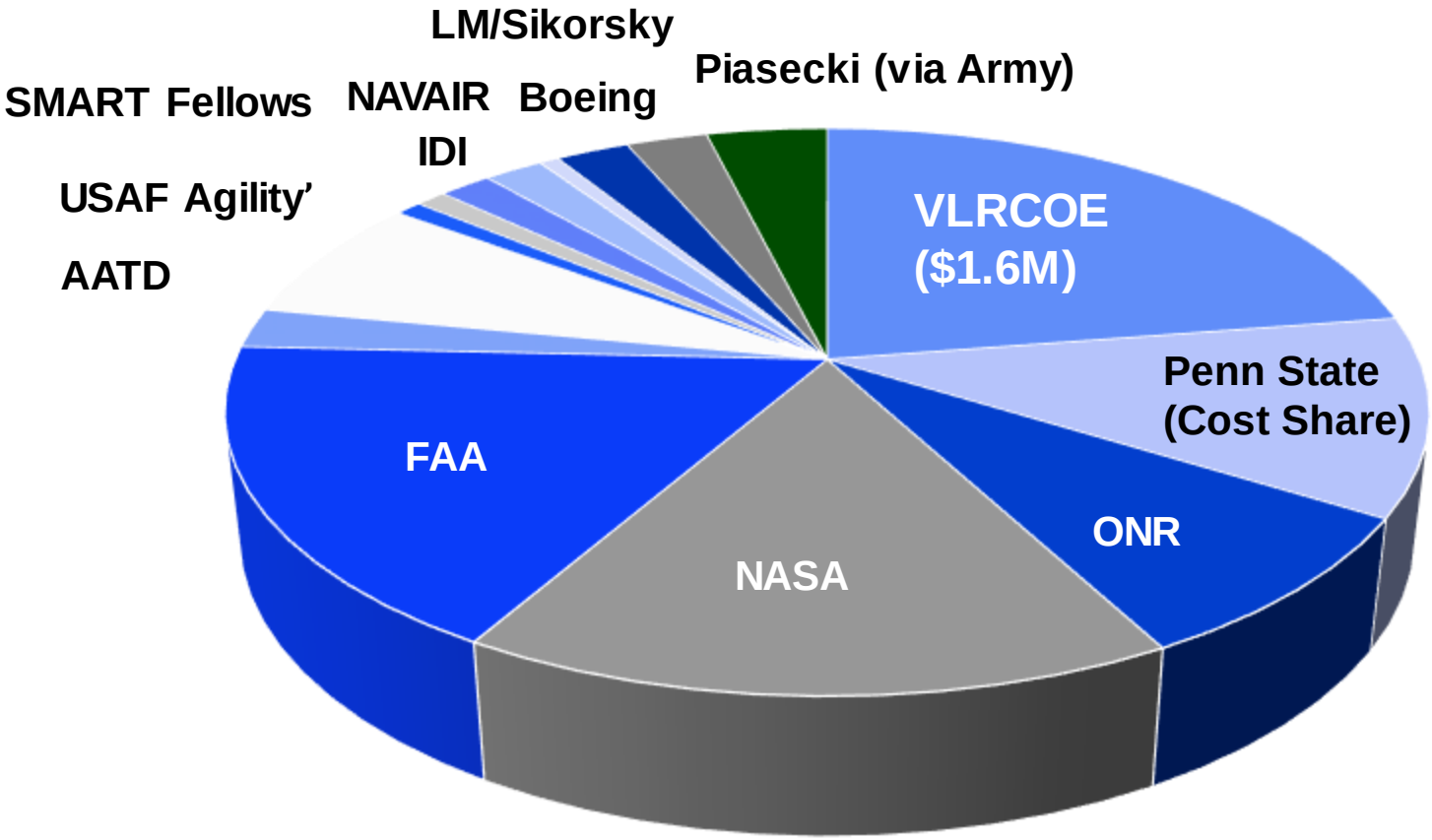


Continued strong growth despite challenging environment

(2022 funding: $7.6 M)

2022 VLRCOE funding profile

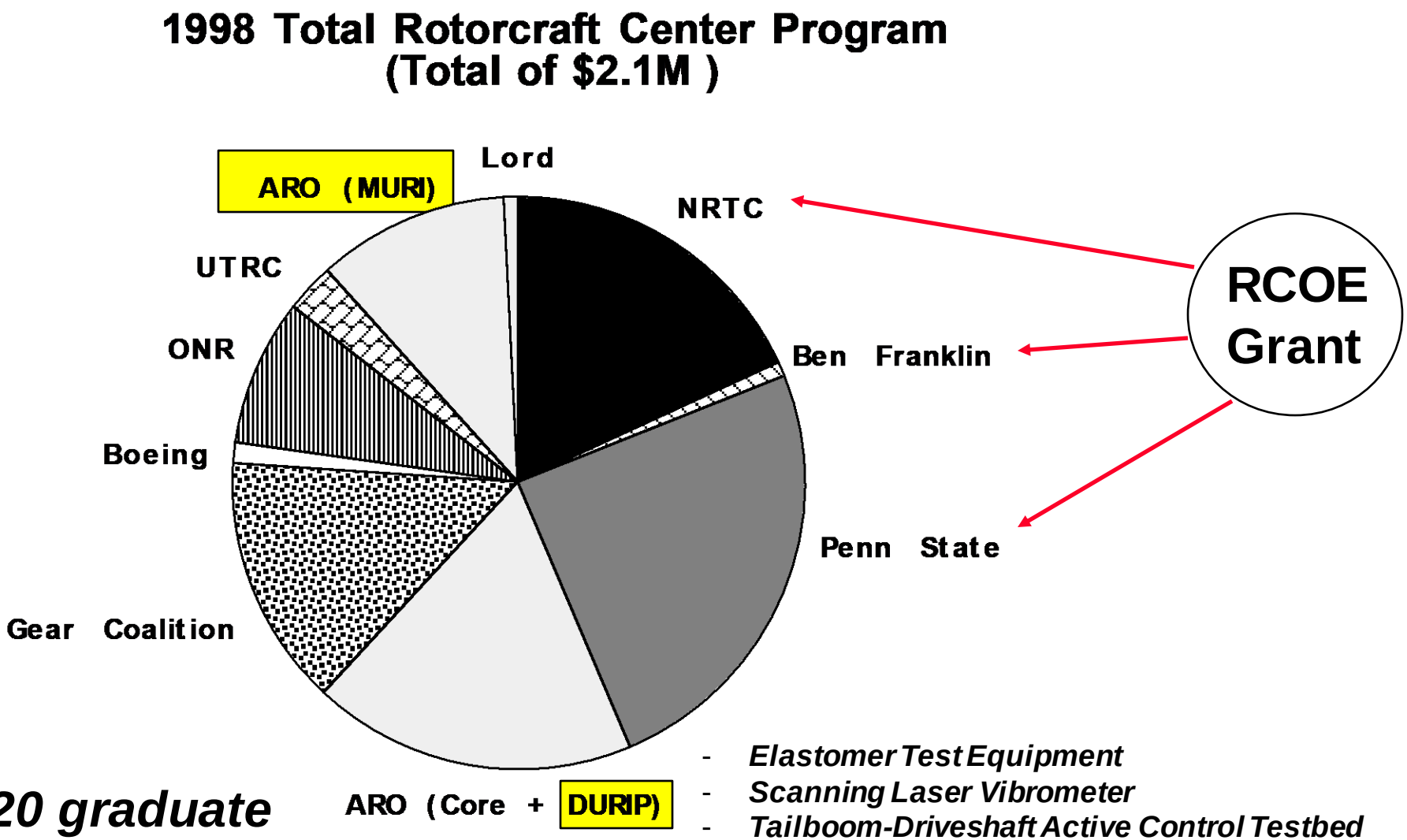
$7.6 M



10% growth despite challenging environment

(2021 funding: $6.9 M)

1998 Rotorcraft Research Budget



- *Elastomer Test Equipment*
- *Scanning Laser Vibrometer*
- *Tailboom-Driveshaft Active Control Testbed*
- *Computer and Network Upgrades*

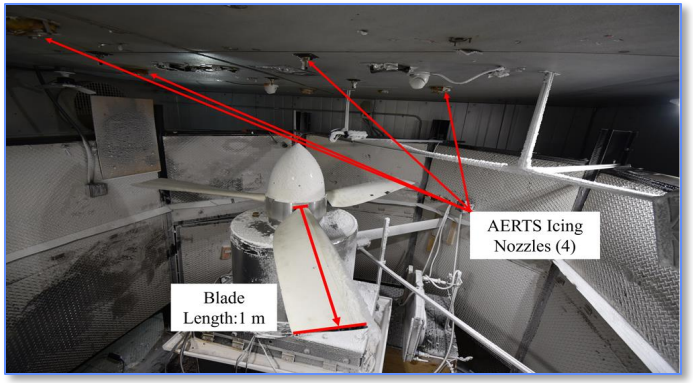
~ 20 graduate students

Other Current VLRCOE Projects

Federal Aviation Administration (FAA) ASCENT Program Tasks

- Rotorcraft Noise Abatement Operating Conditions Modeling and Procedures Development (Brentner, Horn, CDI)
- Measurements to Support Noise Certification for UAS/UAM Vehicles and Identify Noise Reduction Opportunities (Greenwood, Johnson, Brentner)
- Urban Air Mobility Noise Reduction Modelling (Brentner, Greenwood, Horn)

- eVTOL Ice Accretion Characterization (Palacios)



Other Current VLRCOE Projects

NASA New Frontiers Program (via Johns Hopkins Applied Physics Lab)

- **Dragonfly: exploration of Saturn's moon Titan via rotorcraft– Phase A (Langelaan, Schmitz, Palacios, Smith)**

  Phase B Awarded July 2019…..continuing

https://dragonfly.jhuapl.edu

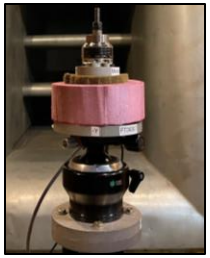
https://www.nasa.gov/press-release/nasas-dragonfly-will-fly-around-titan-looking-for-origins-signs-of-life

TDT rotor subsystem test

Other Current VLRCOE Projects

NASA

- ***Efficient Modeling Method to Capture Rotor-Rotor Interaction Noise (Greenwood, NASA LaRC)***
- ***Gust Load Alleviation for eVTOL Aircraft (Horn, STTR with CDI)***
- ***Full-Scale eVTOL Aircraft Performance and Aeroacoustic Test, Evaluation, and Modeling (STTR with CDI)***
- **Support for Comprehensive Acoustic Analysis for Urban Air Mobility Vehicles (Brentner, Greenwood, Horn, with CDI)**
- ***Anechoic Wind Tunnel Testing of NASA Langley 3D Printed Co-rotating Rotors (Palacios, Greenwood, NASA LaRC, NIA)***

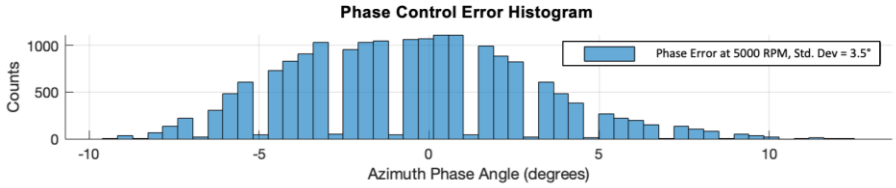


Other Current/Recent VLRCOE Projects

NASA

- *Performance and Acoustic Tests of Small UAS Scale Stacked Rotor Configurations (Greenwood & Palacios)*

- *VEATE- Electrified Multi-Spool Gas Turbine Engine for Enhanced Transient Performance (Hall, Smith, DeSmidt - UTK)*



Other Current VLRCOE Projects

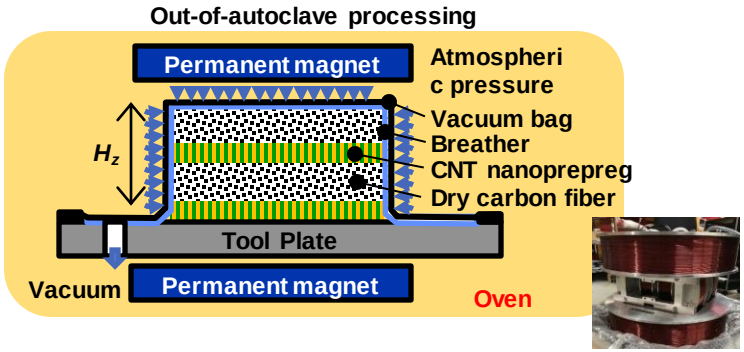
Office of Naval Research (ONR)

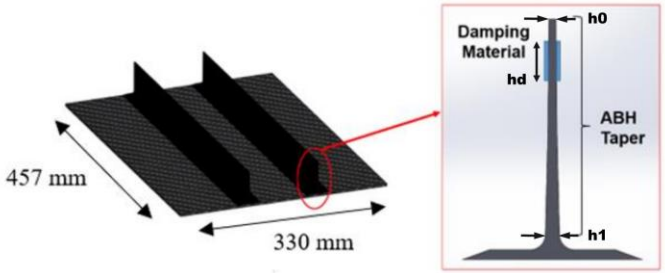
Experimental analysis of advanced control and estimation systems for autonomous shipboard landing (Horn, Langelaan)

Out-of-Autoclave Fabrication and Characterization of CNT-Reinforced Fiber Reinforced Plastics (Bakis, Yamamoto)

Advanced Damping System for Broadband Vibration and Interior Noise Control of Composite Airframes of Transport Rotorcraft (Smith, Shepherd, Bakis, Beck)

Global Stability and Receptivity Analysis of Transitional Rotor Boundary Layers" (Coder)

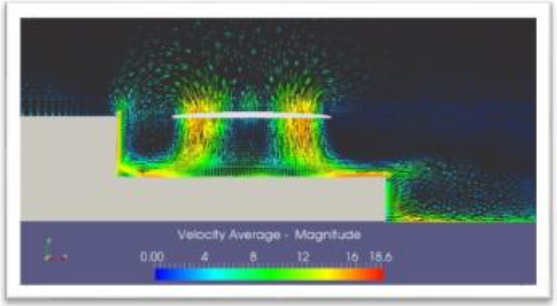




Other Current/Recent VLRCOE Projects

Office of Naval Research (ONR)

Passive Unmanned Aircraft Systems for Adaptive Sampling in a Riverine Environment (Johnson, Miller)



Other Current VLRCOE Projects

USAF (Agility Prime + SBIR/STTR)

- Acoustics Path Planning for UAM Vehicles
- eVTOL Simulation with Boulder Flight Systems
- eVTOL Simulation and Virtual Cert Tool with CDI (Horn, Brentner, Greenwood with CDI)
- eVTOL Quiet Coaxial Props with Harmony Aeronautics (Greenwood, Palacios)
- Energy-Dense, Fast-Charging Batteries to support Air Force Modernization and Electrification (with EC Power, Rahn)

Other Recent VLRCOE Projects

PennState

Army ADD and CCDC Ft Eustis, CCDC Huntsville

- **Coating Evaluation for Loss of Lube (SBIR with Acree Technologies)**
- **Ferrium Gear Testing (SBIR with Questek Innovations)**
- **Data Refinement and Reduction for Aviation Sustainment (Evans, with AVX)**

Army Research Lab (ARL)

- ***Next Generation e-VTOL Propulsion System Design, Optimization & Simulation (DeSmidt at UTenn)***

- ***Experimental evaluation of pericyclic transmission & design of hybrid-electric pericyclic drive (HyPER Drive) (Smith, Hall, Desmidt (UTenn)***

Other Current VLRCOE Projects

BellFlight & TEXTRON e-Aviation

- Gear Research Consortium (Isaacson)
- Simulation of Urban Air Mobility Aircraft for Support of Advanced Flight Control Design (Horn)

Boeing

- High Reduction Ratio transmissions (Smith et al)
- Scuffing Testing of Gear Steels (Isaacson)
- Gear Research Consortium (Isaacson)
- Undergraduate design-build-test projects

Sikorsky

- High-Speed Co-axial Hub System (Schmitz)
- Evaluation of the Effect of Reversed Bending on Gear Tooth Life
- Performance Evaluation of Ferrium C64
- Gear Research Consortium (Isaacson)

Piasecki Aircraft

- Damage Tolerant Control Design for a Winged Compound Rotorcraft (Horn and Johnson)

Other Current VLRCOE Projects

Hughes Research Lab/Boeing

- **Ice protective coating evaluations for rotorcraft (Palacios)**

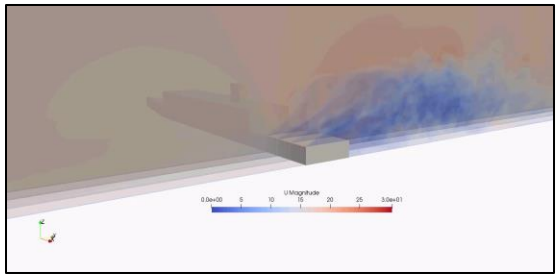
Innovative Dynamics Inc. - IDI

- **Electrothermal protection of Rotors using Sper Capacitors (Palacios)**

Other Current VLRCOE Projects

NAVAIR

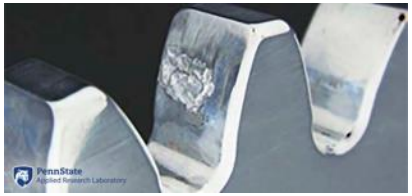
- *Coupled Atmospheric Turbulence / Ship Airwake Simulations for Launch & Recovery Flight Simulations (Schmitz, STTR with Craft Tech)*



Other Current VLRCOE Projects

Gear Research Institute (Aerospace Bloc) – Isaacson, PSU ARL

- **Avio Group (Italy), Bell Flight, Boeing (Mesa and Philadelphia), Carpenter Tech Corp, GE Aviation, GE Global Research, Pratt & Whitney, REM Surface Engineering, Rolls Royce, Sikorsky Aircraft, UTC Aerospace Systems**



PSU College of Engineering & Aerospace Engineering Dept

- **Fast Aeroacoustic Analysis for Complex Rotorcraft Configurations (Greenwood)**

- **Acoustics Scaling and Parametric Variations for Fixed Pitch Rotors in Edgewise Flight (Greenwood)**

Other Current VLRCOE Projects

National Science Foundation (NSF) Fellowships

- **Development and validation of Efficient CFD Approaches for Co-axial rotor systems for Terrestrial Aircraft Design and Planetary Exploration NSF Fellowship for Jason Cornelius)**

Department of Defense (DoD) Fellowships

- **Engine Icing CFD Simulations (NDSEG Fellowship for Belen Veras-Alba)**
- **Acoustically Insensitive Rotor Blades (Dan Weitsman SMART Fellowship)**

Army Contract; Penn State Applied Research Lab

PennState
Applied Research Laboratory

- $99.8M, 5 years, IDIQ, W91CRB-23-D-0005
- Uses terms/conditions of Navy (NAVSEA) contract and UARC sole source authorizations
- End date – 3 January 2028
- Minimum Task Order - $10K
- Maximum Task Order - $10M
- Classification – Up to Top Secret/Sensitive Compartmented Information (TS/SCI)
- Over $6M in Task Orders in first 10 months
- ARL POC is Sam Evans sse11@arl.psu.edu
- COR is Jeffrey Simmons, HQDA, G-4 (Logistics)

New US Army / PSU ARL Contract Mechanism

VLRCOE Facilities

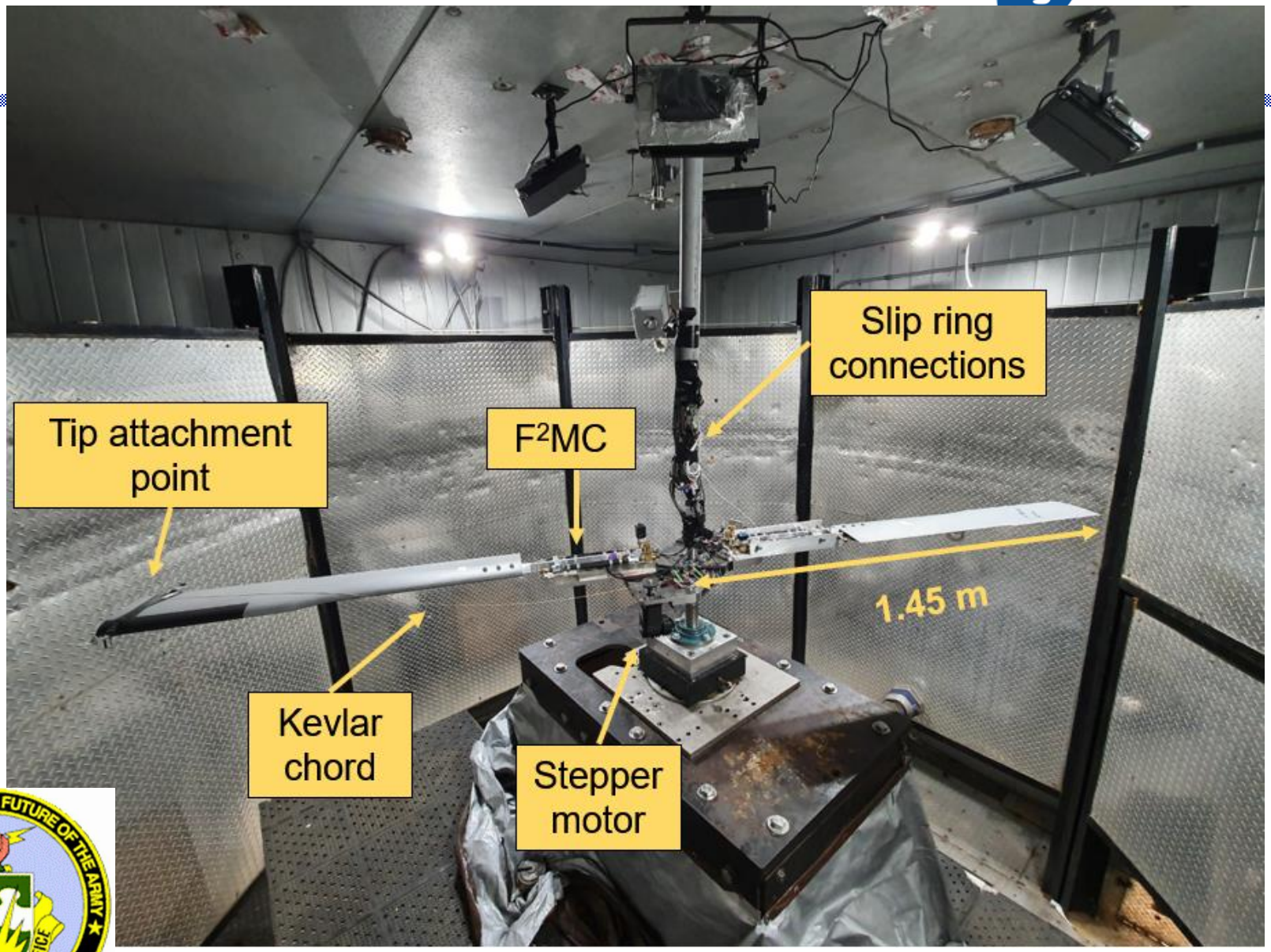
INSPIRE

CHALLENGE

EDUCATE

students and sponsors

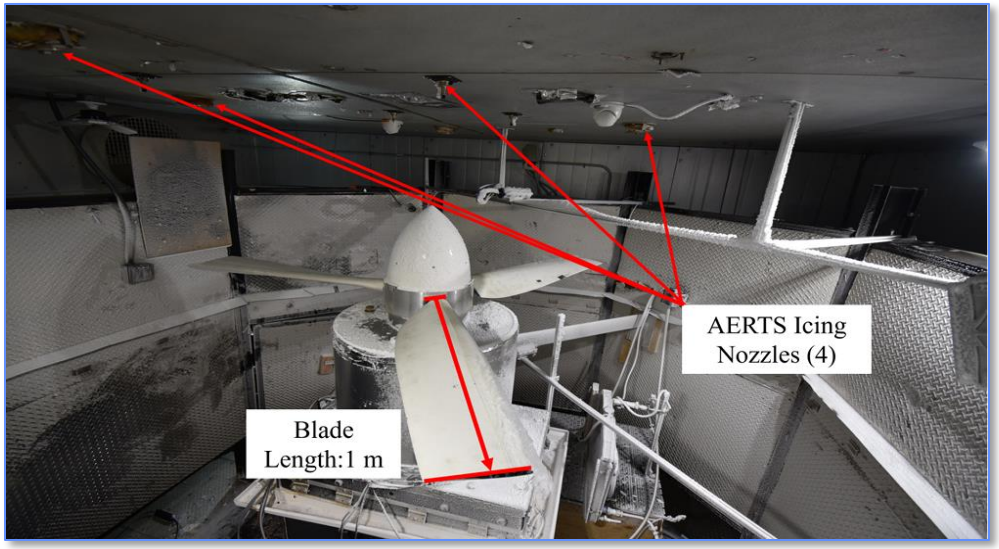
Rotating lag damping test – AERTS chamber



DURIP


VP of Black Hawk,
Sikorsky Aircraft
President,
Piasecki
Aircraft
Graduate student,
PSU VLRCOE
(now at US Army)
Principal Director
to the Deputy
Assistant
Secretary of
Defense for South
and South East
Asia
BG, USMC
Director of
R&D,
Boeing
Director,
PSU VLRCOE

AERTS Rotor Test Facility

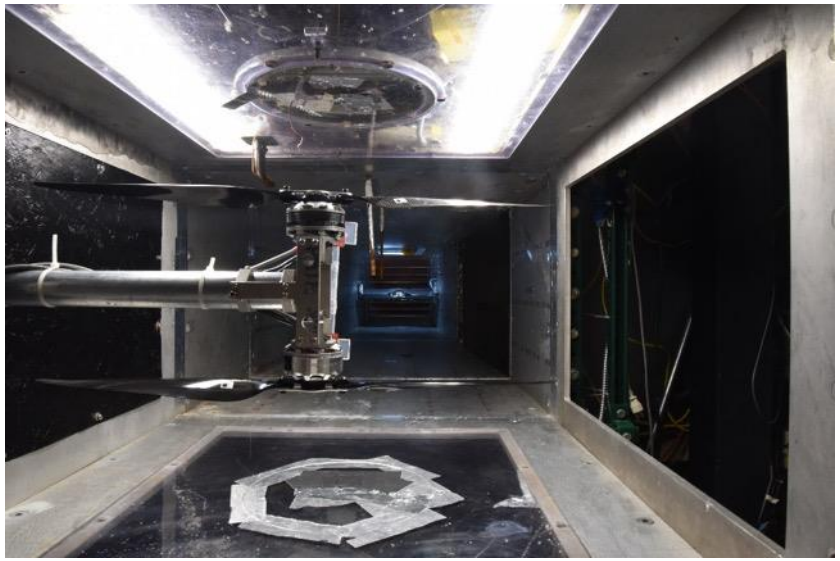


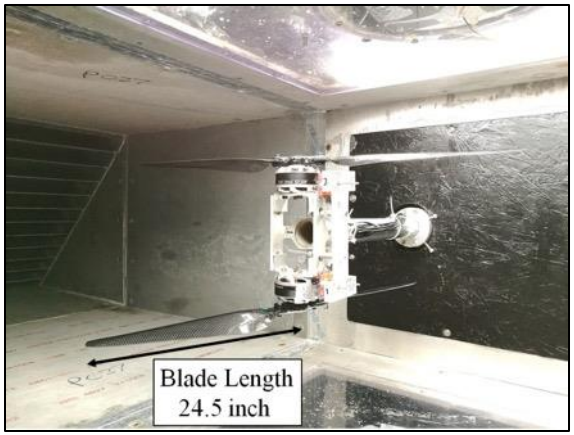
eVTOL rotor icing

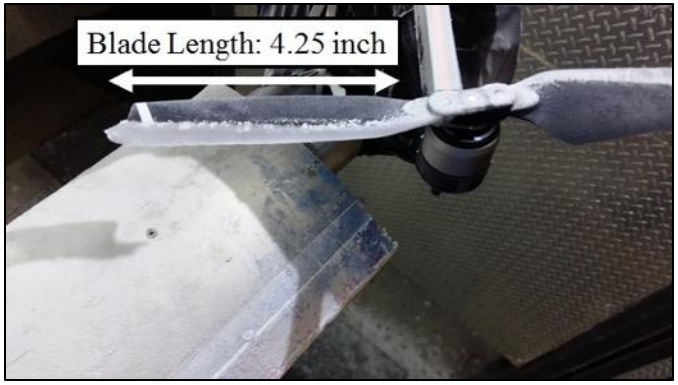
Ice protective coating evaluations

UAV Icing Testing

Icing and wind tunnel testing



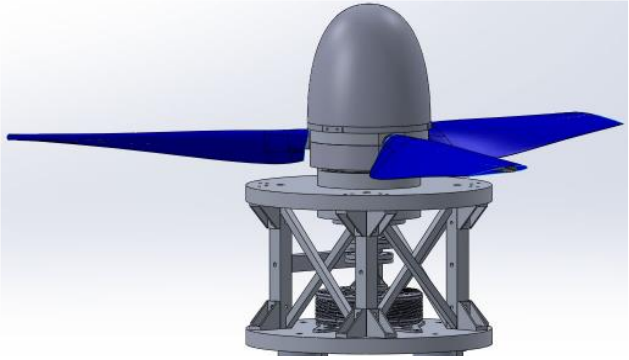


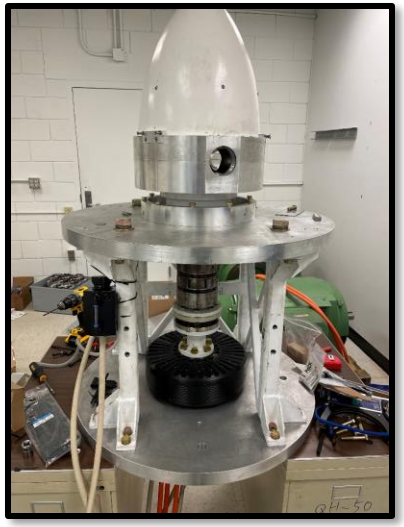


VLRCOE 2021-2026

Key Facilities

Outdoor Out-of-Ground Effect Hover Stand: A new facility is currently under construction and it will be available by August 2021. The outdoor hover stand spins a three bladed 7 ft. diameter rotor such that the downwash is pointed upwards, reducing ground effects. The rotor is powered by a 120 HP brushless motor. Thrust and torque sensors will quantify rotor performance. All components of the facility have been purchases and a custom hub is to be fabricated by May 2021. The rotor blades to be spun were donated to the Center by Joby Aerospace.





Outdoor Tiltrotor Download Test Stand

Designed and University Park Airport site plan in 2019 ($600K)

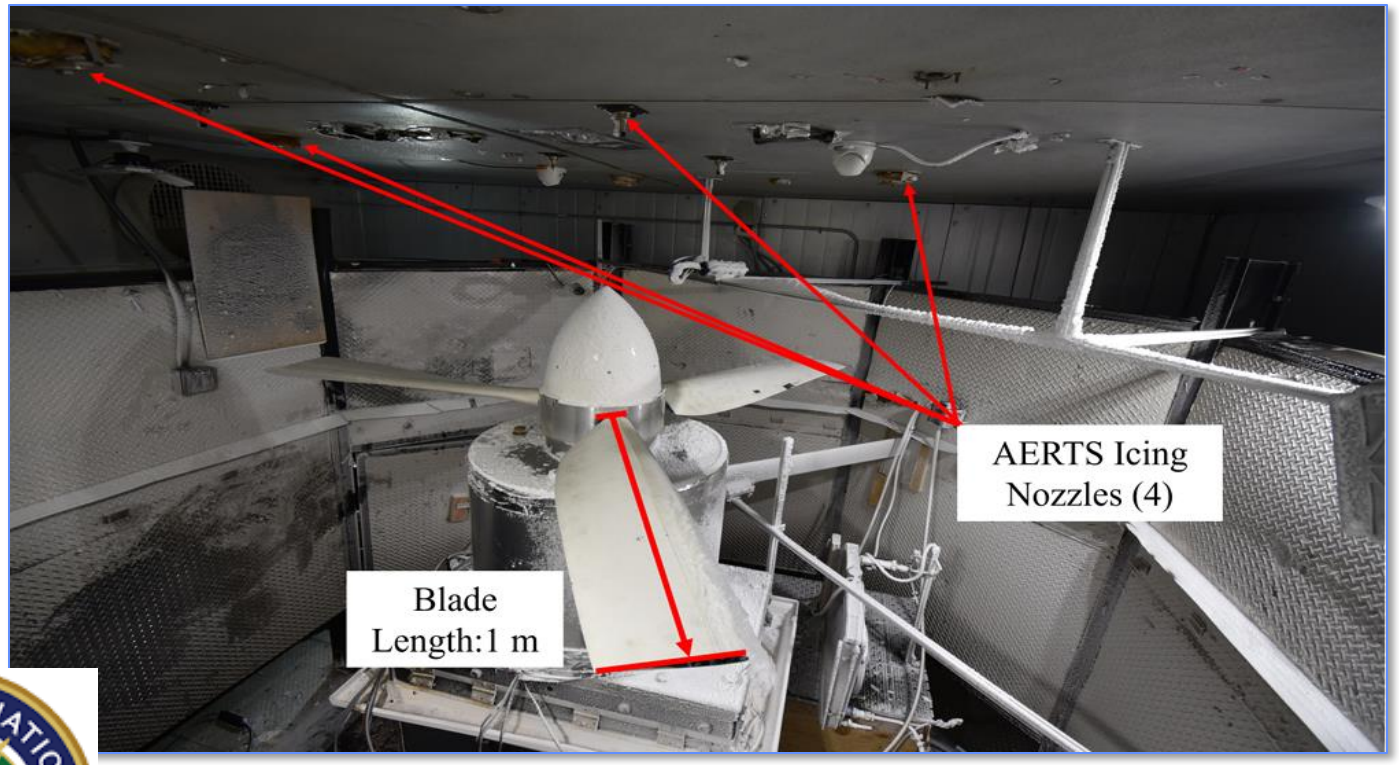
Model 247 UAV Concept (USMC)

¼ scale
2 x 300 HP electric motors
Instrumented rotor and wing

Anticipated Bell/Army/PSU Development and testing in 2024-2026

Full Scale Hover Stand in AERTS

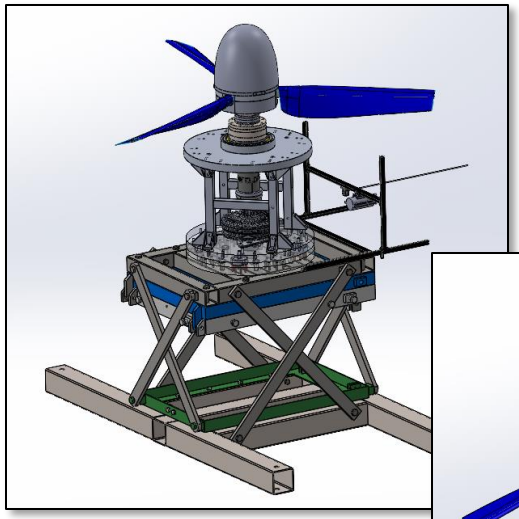
Preliminary Icing Testing



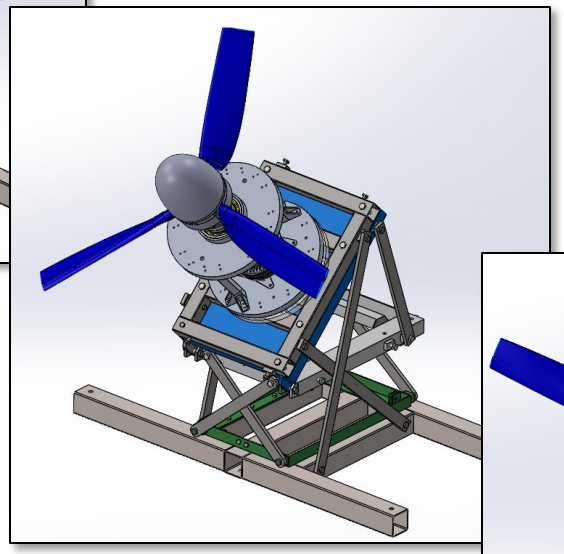
AERTS
Adverse Environment Research Test Systems
PennState

PennState

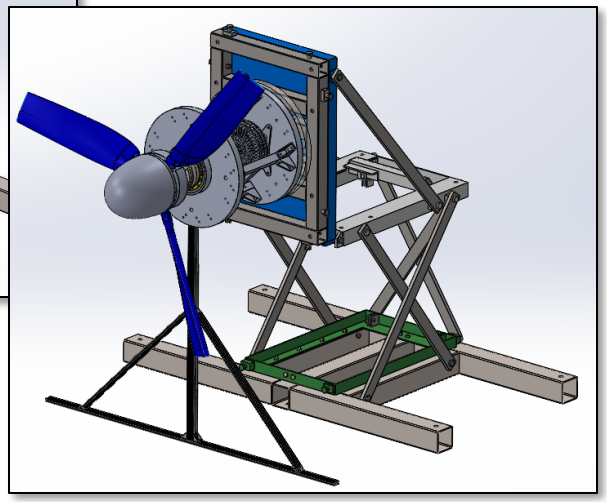
Hover



Transition



Cruise

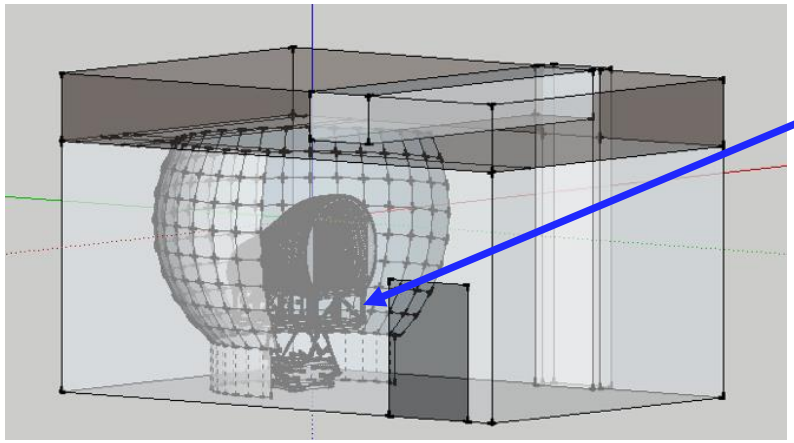


FEDERAL AVIATION ADMINISTRATION

Proprotor Icing test in Austria (May 2023)


DURIP
6 DOF MOTION SYSTEM
DEPARTMENT OF THE NAVY
USN
ONR
Science & Technology

Flight Simulator



+/- 30° deg roll / pitch / yaw motion
12" translations

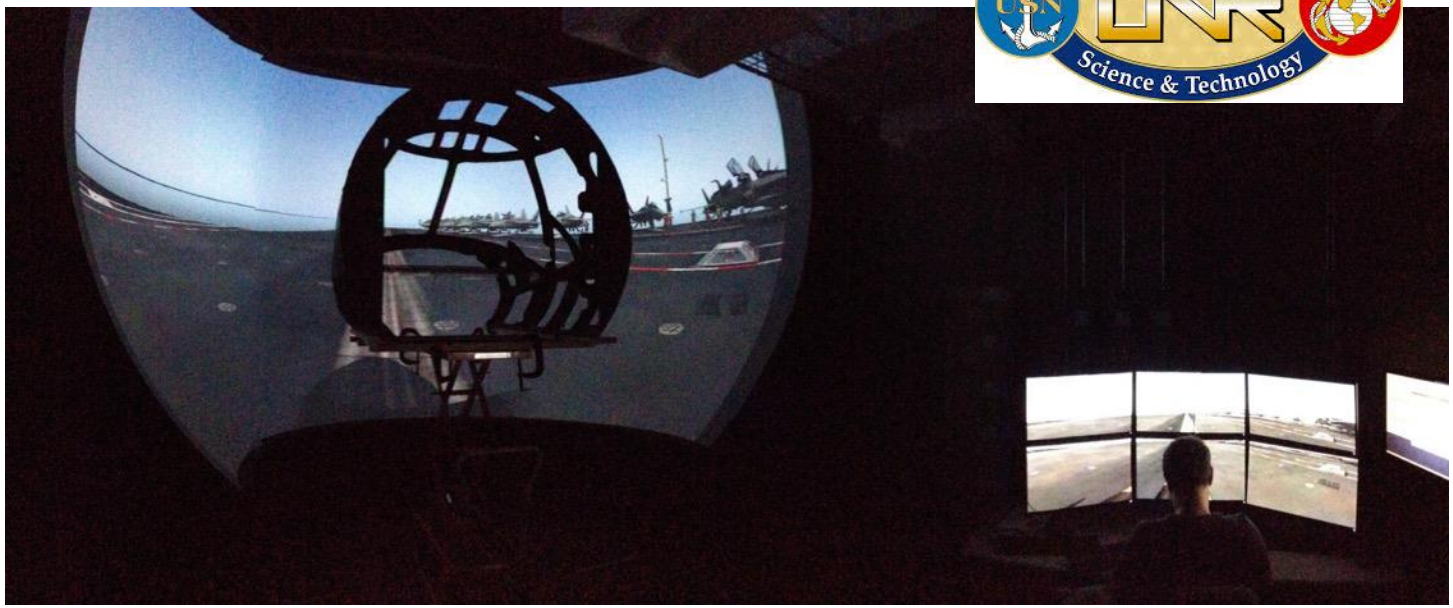
(MOTION SYSTEM FULLY FUNCTIONAL)

DURIP

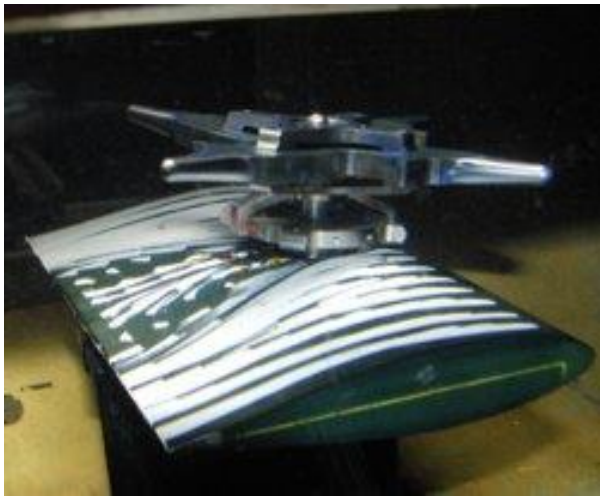
210° horizontal field of view

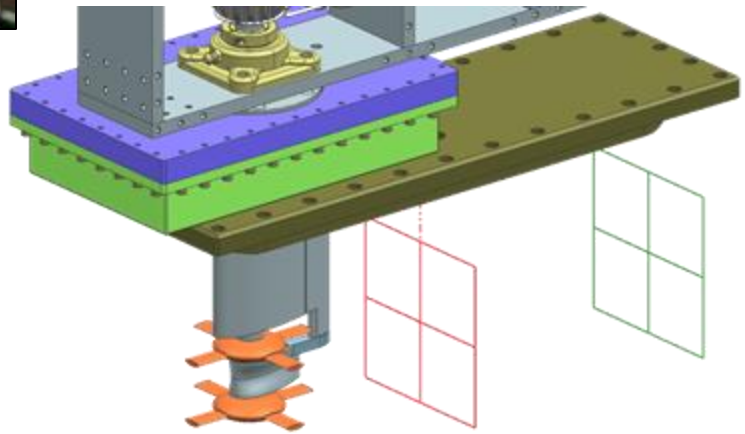
and

50° vertical field of view



12” – Penn State Water Tunnel





Coaxial Hub and Root Airfoil Testing

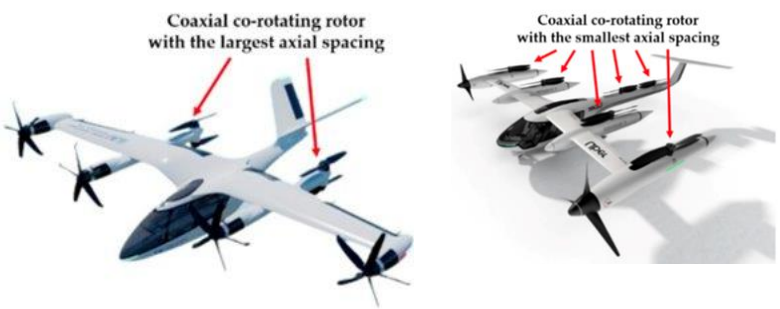
New rotor acoustics facilities
(Profs Greenwood & Palacios)

Flow through anechoic chamber

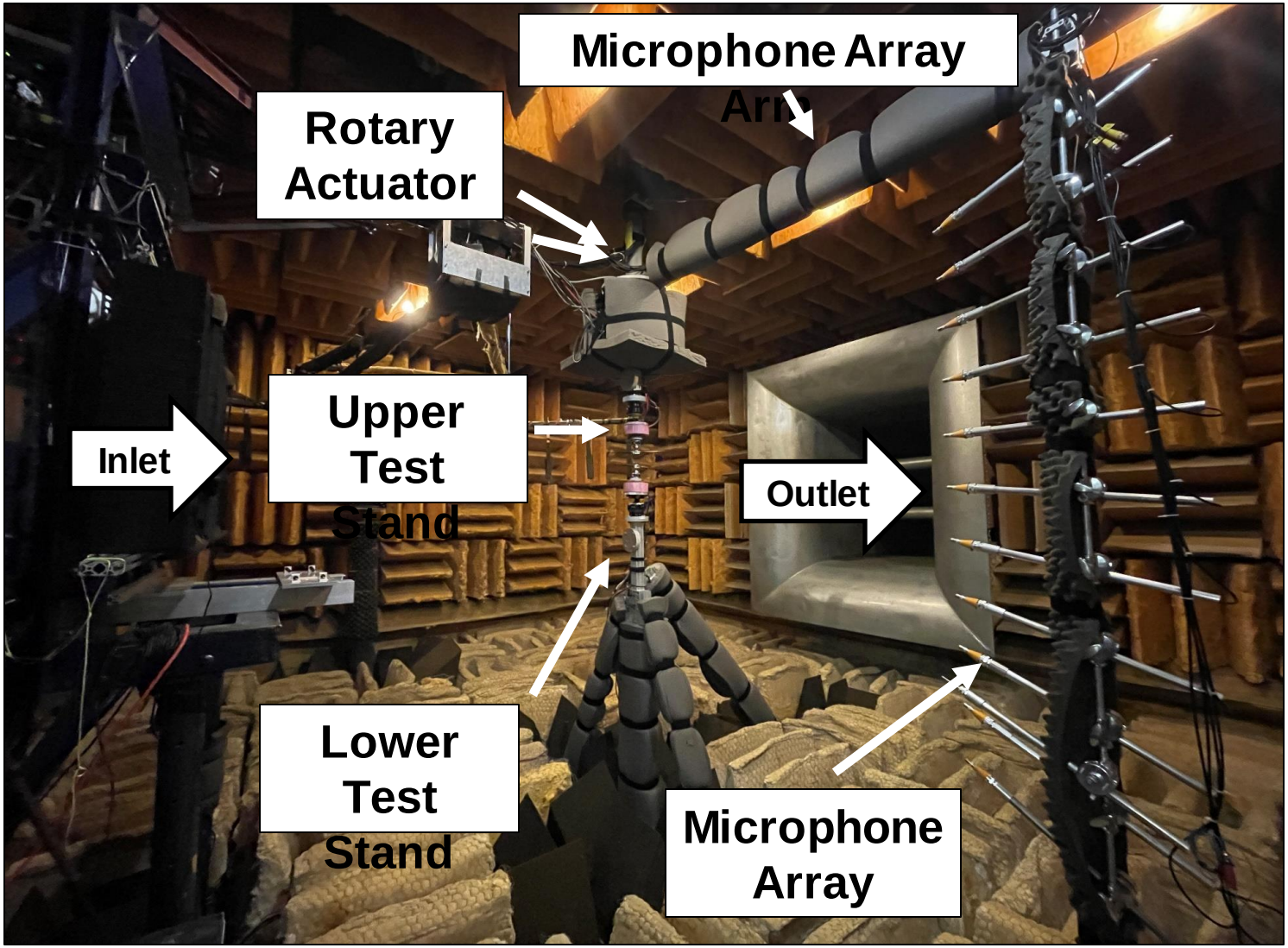
comprehensive microphone array

Co-axial rotors

Leveraging "Jet-noise facility" developed by Prof Dennis McLaughlin and his students



Acoustic Rotor Test Stand



New Setup: Coaxial Co-Rotating on Vertiq

Separated 2+2 with electronic phase control

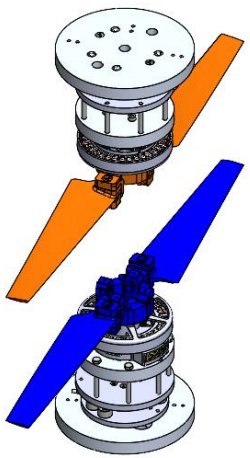
Physically Stacked 2+2

Switch to Vertiq IQ Motors

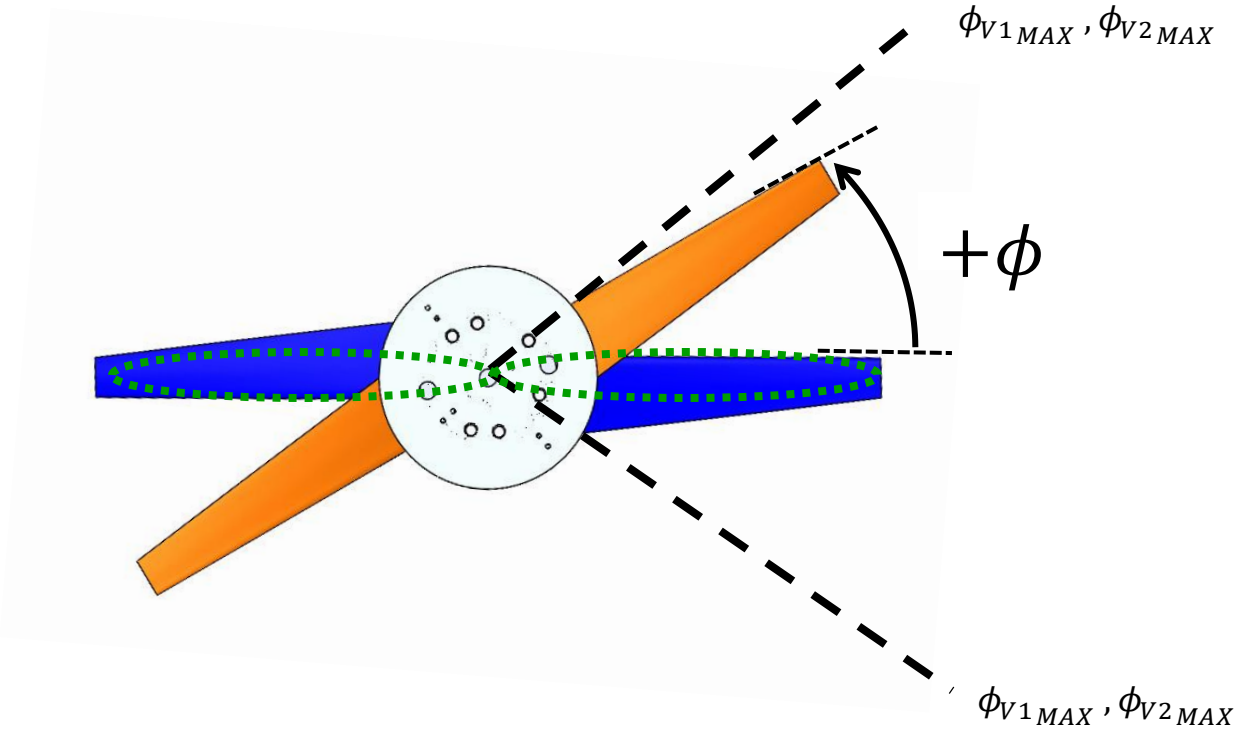
New Setup: PSU Phase Controller

Purpose: **Vary & hold azimuthal phase offset angle** **at any separation distance while not mechanically connected**

ISO VIEW



TOP VIEW

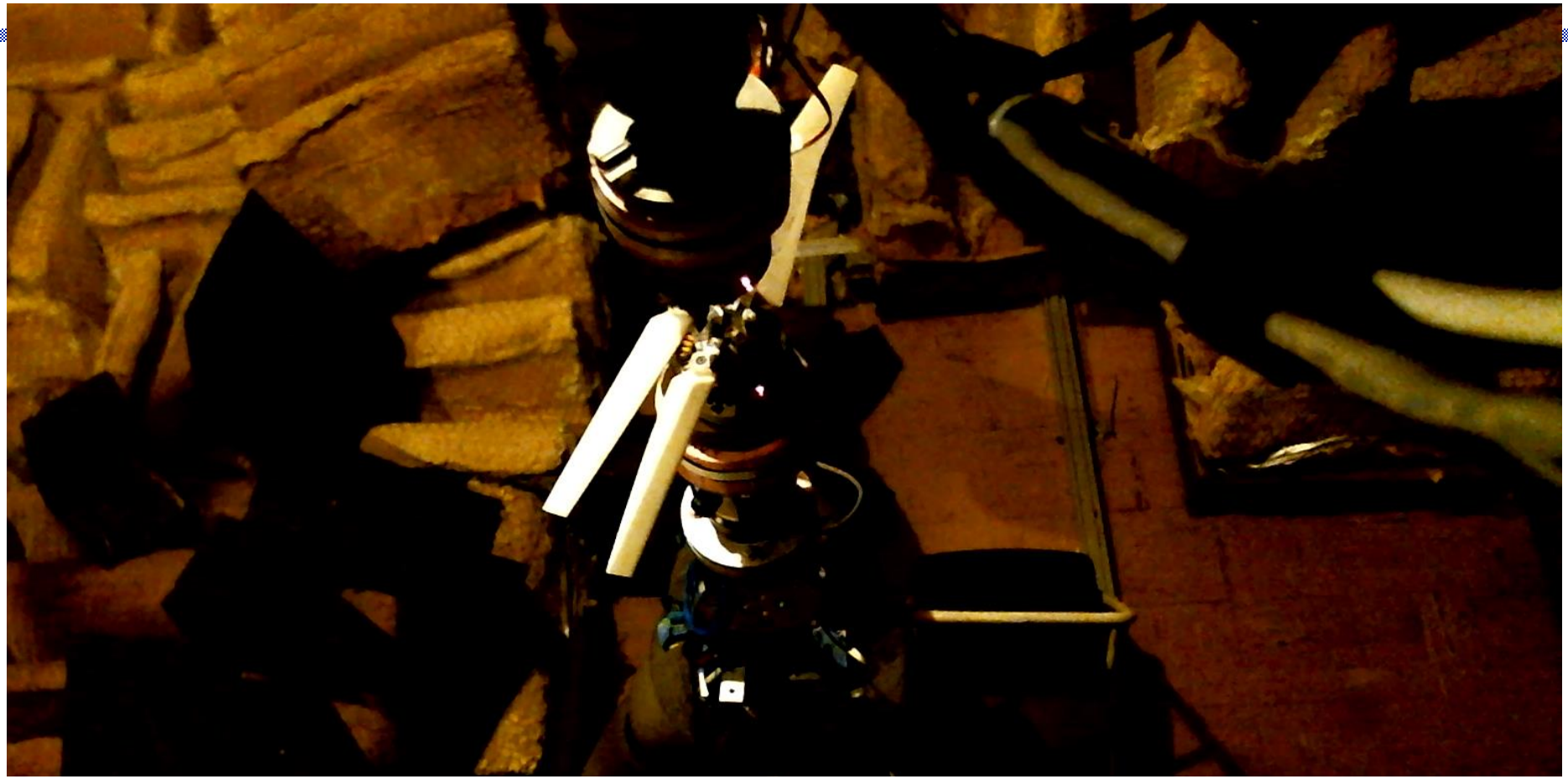


- Upper Rotor
- Lower Rotor
- Virtual Motor

Switch to Vertiq IQ Motors

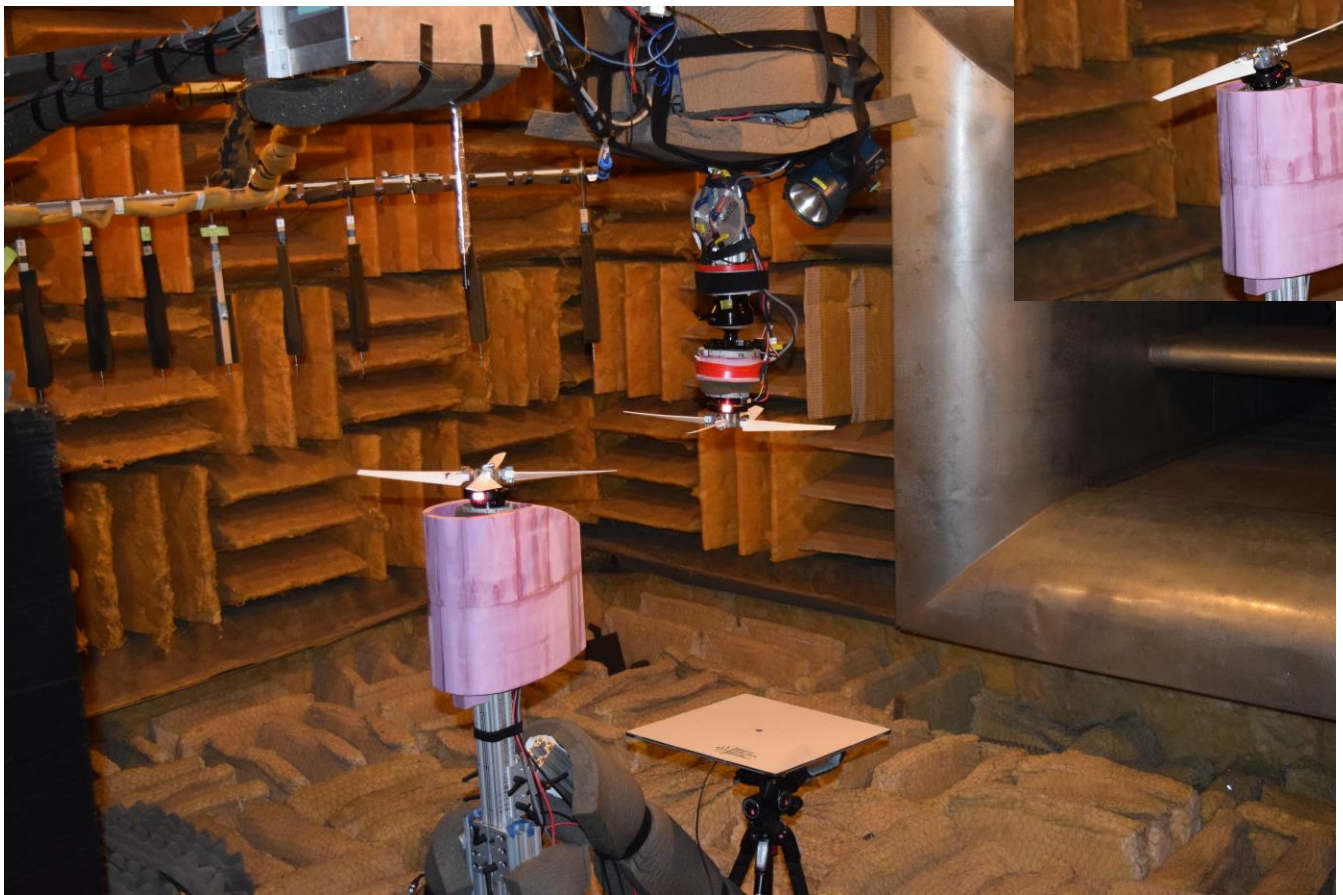
VPS Forum Paper 2023

PSU Phase Controller at 5000RPM

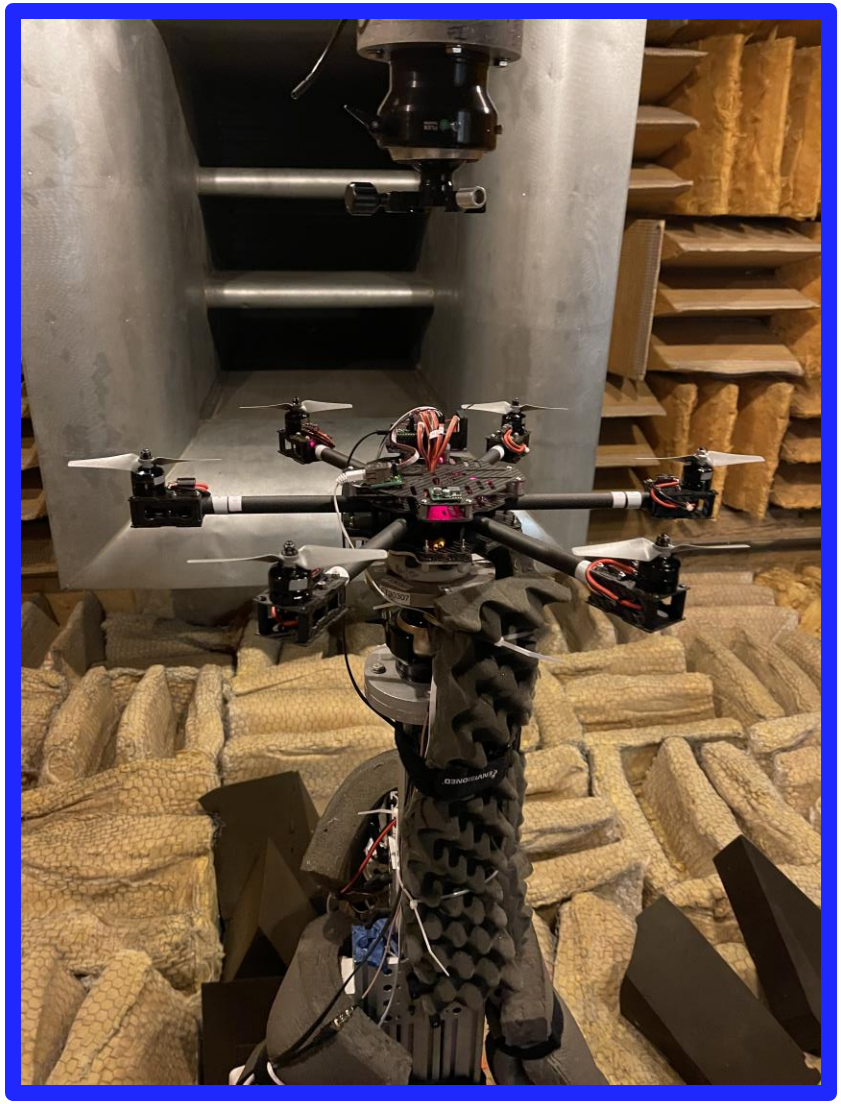


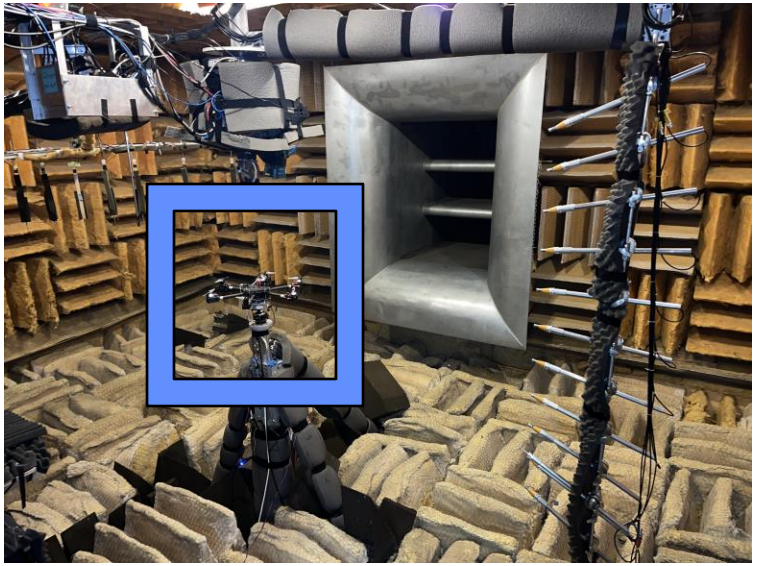
PSU Phase Controller

Tandem rotor descent



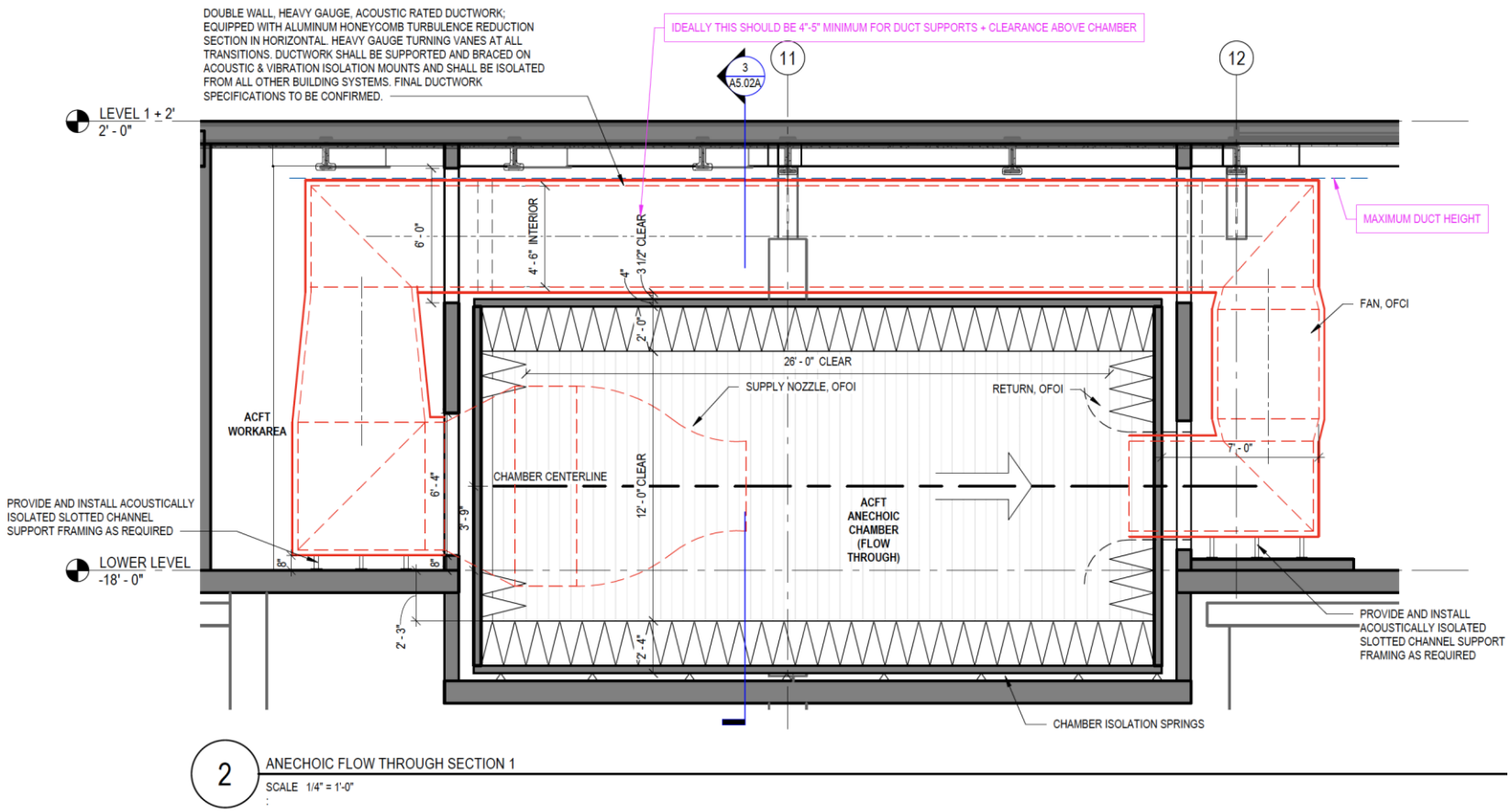
Multi-rotor flow-through tests





New rotor acoustics facilities

(Prof Eric Greenwood)



Anechoic wind tunnel section
nom. 4’ x 4’ open jet with 80 kts flow

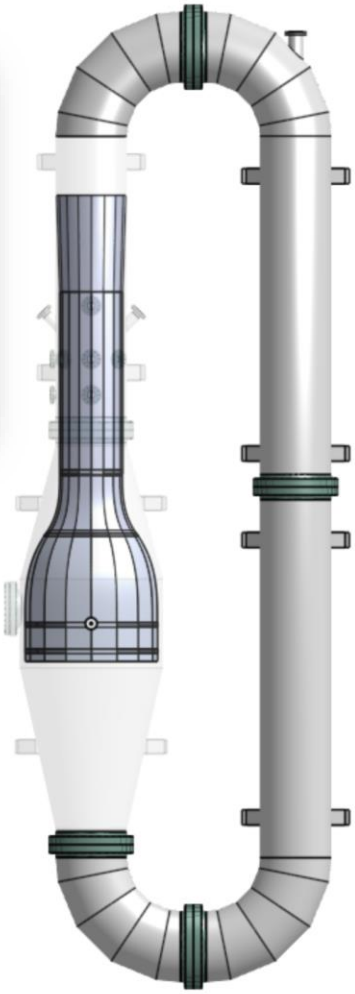
Outdoor Noise Measurements (electric multirotor UAS)

Outdoor Noise Measurements (hydrogen multirotor UUAM)

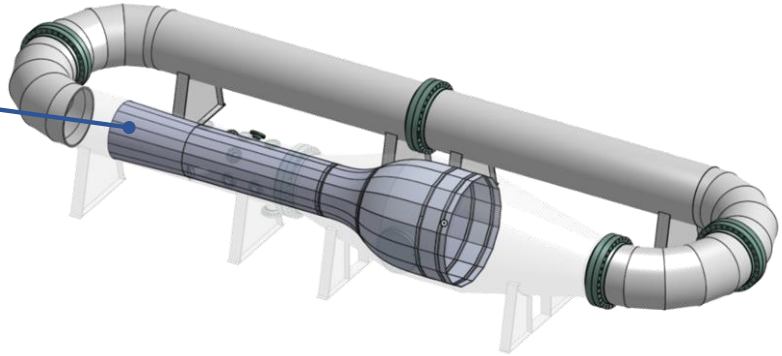
The Compressed Air Wind Tunnel (CAWT)

Mark A. Miller (Assistant professor, Aerospace Engineering)

Maximum Static Pressure	500 psi (34 atm.)
Max Model *Re*	9 million per foot
Model diameter at 7% frontal blockage	10″
Max. Wind Speed	31 mph (14 m/s)
Test section shape	Modular, nominally circular
Test section size	42″ (1.1 m) diameter, maximum
Facility Weight	100,900 lbs.

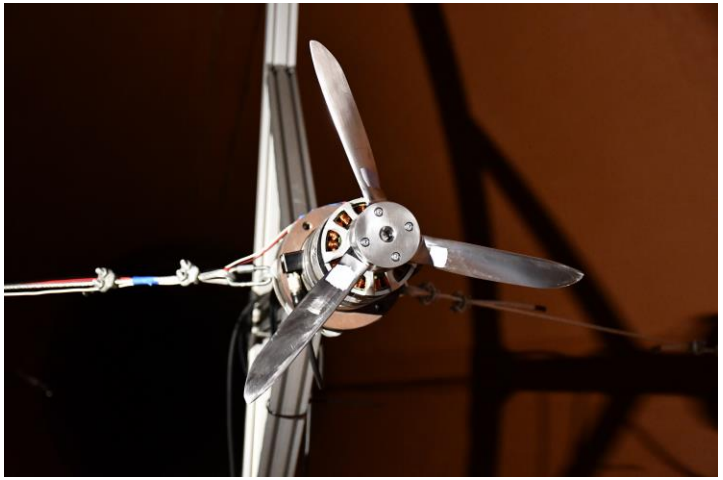


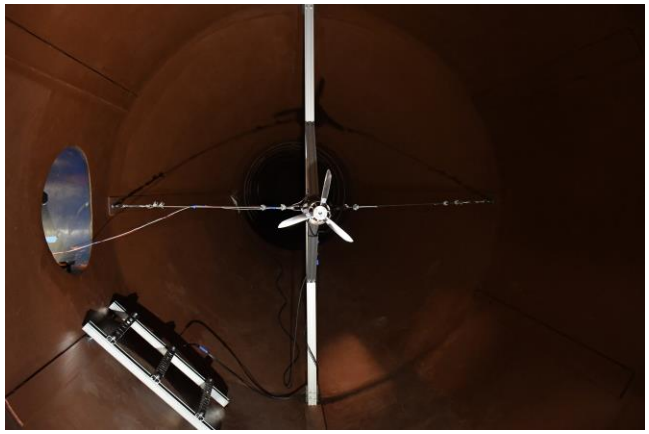
Interchangeable tunnel test section ductwork allows for a range of model sizes and velocities



The Compressed Air Wind Tunnel (CAWT)

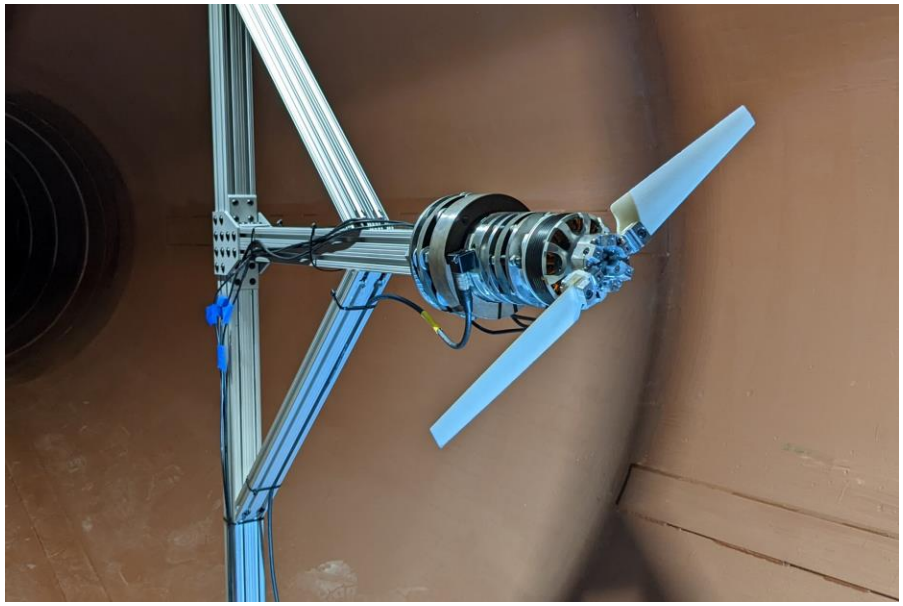
Mark A. Miller (Assistant professor, Aerospace Engineering)





The Compressed Air Wind Tunnel (CAWT)

Mark A. Miller (Assistant professor, Aerospace Engineering)



The Compressed Air Wind Tunnel (CAWT)

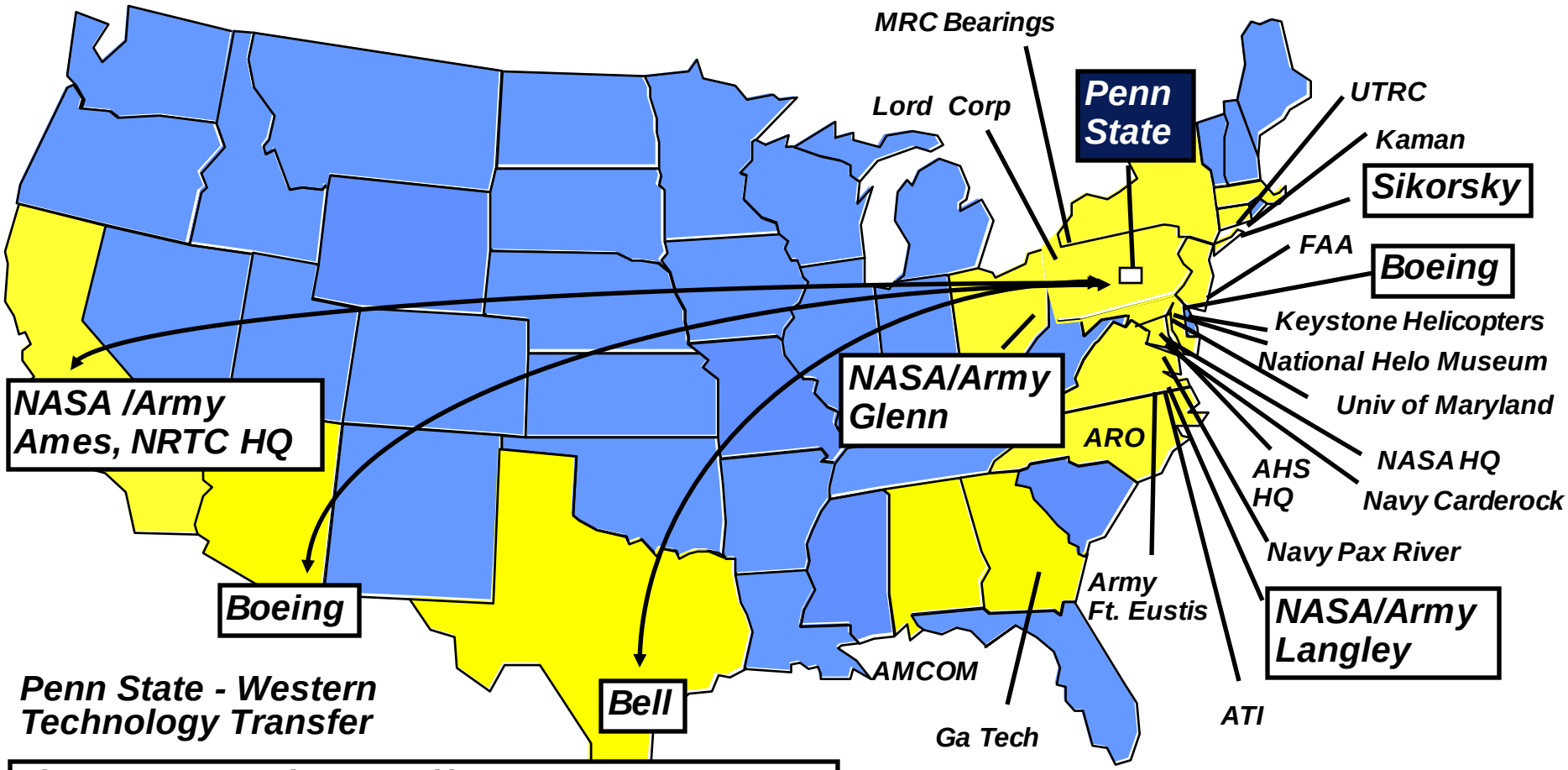
Mark A. Miller (Assistant professor, Aerospace Engineering)

Technology Transfer

and

Student/Faculty Accomplishments

Penn State Rotorcraft Center - technology transfer paths



Penn State - Western Technology Transfer

- Short Course graduates and instructors
- Graduate and undergraduate students
- Research consortia programs (elastomers, gears, etc)

Tech Transfer Highlights

- **Executable distribution of the PSU-WOPWOP code: approximately 37 separate requests during the past year; significant upgrades funded by CDI and FAA projects (Brentner)**

- **Acoustic flight testing with Beta Technologies (August 2022) (Greenwood)**

- **Transfer of rotor hub CAD files to Army group for hub testing in 7'x11' wind tunnel; transfer of hub & sail fairing CAD to Army, Sikorsky, Bell, U. Maryland, UT Knoxville (Schmitz)**

- **Penn State Research on Rotorcraft Ship Launch and Recovery: From Advanced Simulations to Flight Experiments, Seminar to the Auburn University Department of Aerospace Engineering, April 1, 2022. (Horn)**

- **Penn State Rotary Wing Short Course, (August 2022) Classroom instruction and lab tours for 72 students (Smith, Brentner, Hall)**

Tech Transfer Highlights

- **Transfer of atmospheric turbulence data from CFD simulations to NAVAIR and CraftTech (Schmitz)**

- **Invited Seminar: Sikorsky (Stratford CT) – "Interactional Aerodynamics for Rotorcraft & Wind Turbines" (Schmitz)**

- **Invited Seminar: ONERA (Paris-Meudon) – "Energy Methods for Rotorcraft Power Decomposition" (Schmitz)**

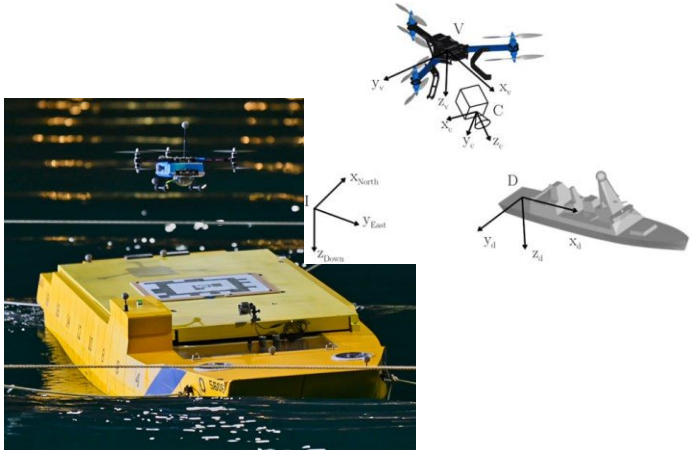
- **Patent App. 63/504,022 Passive Blade-Vortex Interaction Noise Reduction Using In-Blade Resonator Cavities, May 2023 (Greenwood)**

- **Open source release of OpenCOPTER multirotor aerodynamics code (https://github.com/PsuAeroacoustics/OpenCOPTER). (Greenwood)**
  Known users include:
  - **NASA Langley Research Center**
  - **Air Force Research Laboratory**
  - **University of Hartford**
  - **Blue Ridge Research and Consulting**

Tech Transfer Highlights

- **VLRCOE Overview Briefings (Smith)**
  - **USAFA , USN NSWC, SOCOM**
  - **Kaman, Bell**
  - **PSU COE**

- **UAV Shipboard Landing Model Scale Flight Testing at NSWC Carderock (Horn, Langelaan)**



- **Designed, fabricated, delivered and supported Dragonfly rotor for TDT Wind Tunnel Test at NASA LaRC (Palacios with JHUAPL staff)**

- **Extensive technical interactions with Sikorsky on Dragonfly program with NASA and JHUAPL (dynamics, aerodynamics, blade design)**

4th Rotor Hub Flow Prediction Workshop

Penn State VLRCOE - August 16 2022 (Hybrid In-Person/MS Teams)

PENNSTATE FLUID DYNAMICS RESEARCH CONSORTIUM

U.S. ARMY DEVCOM

ATTENDEE LIST

4th Rotor Hub Flow Prediction Workshop

Tuesday August 16th, 2022 Hybrid, Penn State & MS Teams

Vertical Lift Research Center of Excellence (VLRCOE)

The Pennsylvania State University

IP = In Person VI = Virtual

Name	Organization	Function	Email
Academia			
James Baeder (IP)	Prof., U. of Maryland	Modeler, HAMSTR	baeder@umd.edu
Bumseok Lee (IP)	Grad. Student, U. of Maryland	Modeler, HAMSTR	bslee@umd.edu
Aaron Crawford (IP)	Grad. Student, Georgia Tech	Modeler, HELIOS	acrawford48@gatech.edu
Yong Su Jung (VI)	Asst. Prof., Pusan Natl' University	Modeler, HAMSTR	yongsu.jung@pusan.ac.kr
James Coder (IP)	Assoc. Prof., Penn State AERSP	Modeler, OVERFLOW	jcoder@psu.edu
Robert Kunz (IP)	Prof., Penn State ME	Registered	rfk102@psu.edu
Edward Smith (IP)	Prof. & Director, Penn State VLRCOE	Registered	ecs5@psu.edu
Amy Pritchett (IP)	Prof. & Dept. Head, Penn State AERSP	Registered	apritchett@psu.edu
David Reich (IP)	Research Engineer, Penn State ARL	Experimentalist	dbr141@arl.psu.edu
Stephen Willoughby (IP)	Grad. Student, Penn State	Experimentalist	spw9@psu.edu
Nick Jaffa (IP)	Head, Fluid Machinery Penn State ARL	Experimentalist	naj15@arl.psu.edu
Sven Schmitz (IP)	Prof., Penn State AERSP	Host, Experimentalist	sus52@psu.edu

Government			
Dylan Jude (VI)	Army, DEVCOM	Modeler, HELIOS	dylan.p.jude.civ@army.mil
Louis Centolanza (IP)	Army, DEVCOM	Registered	louis.r.centolanza.civ@army.mil
Mathew Thomas (IP)	Army, DEVCOM	Registered	mathew.l.thomas5.civ@army.mil
David Schatzman (VI)	Army, DEVCOM	Registered	david.m.schatzman.civ@army.mil
Mahendra Bhagwat (VI)	Army, DEVCOM	Registered	mahendra.j.bhagwat.civ@army.mil
Nelson Ciron (IP)	Army, DEVCOM	Registered	nelson.s.ciron.civ@army.mil
Lev Hubbard (VI)	Army, DEVCOM	Registered	levi.s.hubbard.civ@army.mil
Rohit Jain (VI)	Army, DEVCOM	Registered	rohit.k.jain.civ@army.mil
Industry			
Kalki Sharma (IP)	Sikorsky	Modeler, StarCCM	kalki.j.sharma@lmco.com
Peter Lorber (IP)	Sikorsky	Registered	peter.f.lorber@lmco.com
Byung-Young Min (IP)	Sikorsky	Modeler, HELIOS	byung.young.min@lmco.com
Forrest Mobley (IP)	Boeing	Registered	forrest.j.mobley@boeing.com
Matthew Hill (IP)	Bell	Modeler, HELIOS	mjhill@bellflight.com

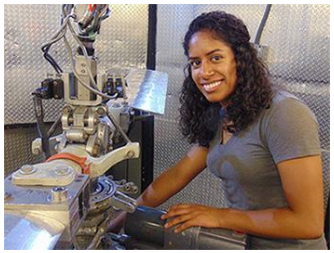
Student and Faculty Recognition/Service

2023 VFS Robert Lichten Award
Jess Beyer

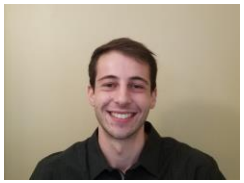
2023 VFF Fellows
Chris Axten
Isabella Mawry

DoD & SMART Fellows
Belen Bowman
Dan Weitsman

NSF Fellow
Jason Cornelius



John S. McCain Strategic Defense Fellowship
Jeffrey Lewis



Tony McVeigh Graduate Student Award
Chris Hendrick

Student and Faculty Recognition/Service

VFS Committees

Acoustics Brentner, Lee (UCD)
Education – Smith
Dynamics – Smith, Rahn
Handling Qualities – Horn
Test & Eval – Palacios, MIller
eVTOL – Langelaan
Unmanned VTOL - Langelaan
Propulsion – DeSmidt (UTenn)

VFS Deputy Director – Aeromechanics - Joe Horn

AIAA Applied Aero Comm Chair – Jim Coder

AIAA Fluid Dynamics Tech Comm - Sven Schmitz

Student and Faculty Recognition/Service

2023 VFS Technical Fellow – Joe Horn

2022 VFS Technical Fellow – Ken Brentner

2022 AIAA Aeroacoustics Award – Ken Brentner

AHS Journal Assoc Editor – Sven Schmitz

Penn State Lawrence J. Perez Memorial Student Advocate Award – Sven Schmitz

Boeing A.D, Welliver Chair Professor of Aerodynamics
- Sven Schmitz

Student and Faculty Recognition/Service

Promoted to Professor: Seongkyu Lee (UCD)

Promoted to Professor: Sven Schmitz

Promoted to Assoc Prof: Alan Wagner

AIAA Associate Fellow – Prof. Jim Coder

AIAA Associate Fellow – Prof. Jose Palacios

HAI Fly Neighborly Committee – Eric Greenwood

NASA UAM Noise Working Group – Eric Greenwood

VFS: Best Paper in Handling Qualities at FORUM 79 (Horn et al)

PENNSTATE

VLRCOE Home 2006-2023

40 graduate students

5 undergraduate students

5 Research Associates

Flight Simulation Lab

Benchtop Labs*

Vertical Flight Museum

*Additional Labs in Hammond (rotor tests, icing, vibrations), APB (wind tunnel), Research West (composites)

VLRCOE Home July 2024 and beyond!!

VLRCOE Students (50+)

Anechoic/reverb chambers and anechoic wind tunnel

VLRCOE Flight Sim, Motion Cap & UAS Labs

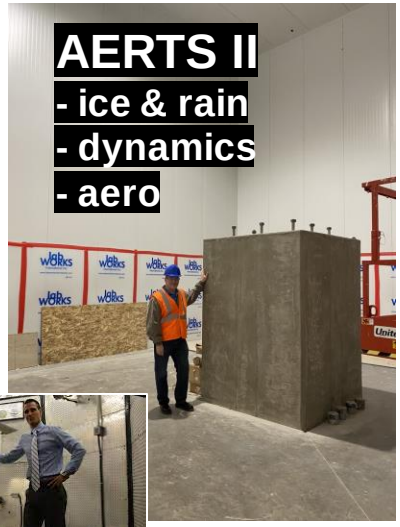
VLRCOE Labs (AERTS, new larger and more capable rotor test, icing wind tunnel, Benchtop labs,)

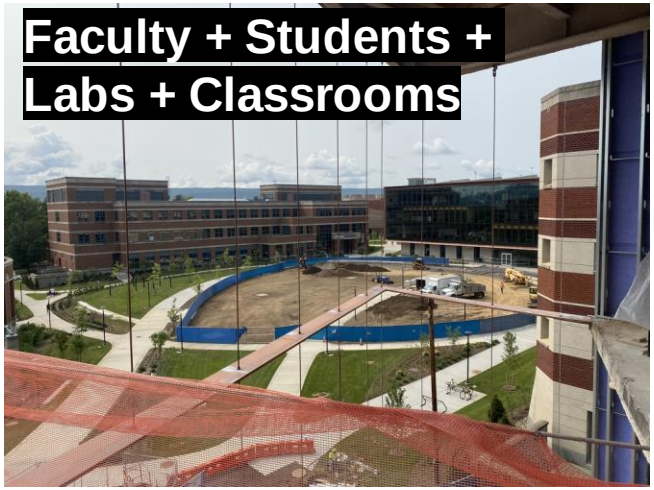
+ Additional large facilities throughout campus: UAV flight test, wind tunnels, composites lab, gear lab (PSU ARL)

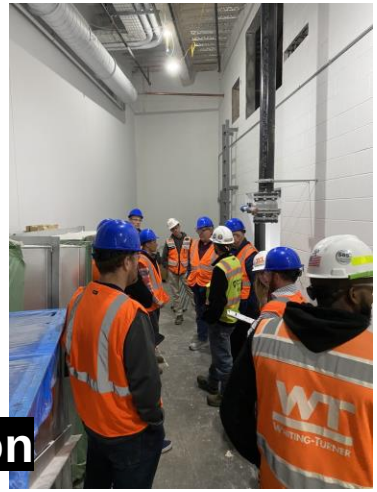
ECORE Building (c. OCT 2023)

Occupancy June 2024

Shared with AERSP, CE, ACOUSTICS, ARCH ENGR







200+ construction Workers per day

Recent VLRCOE Graduates (2021-2022)

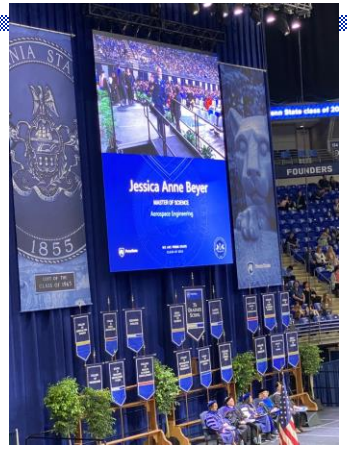
• Charis Lin, PhD	USAF Labs
• Sean Gaunnt. PhD	US Navy Labs
• Matt Waller, PhD	Penn State ARL
• Daniel Jaep, MS	Boeing Rotorcraft
• Grant Schneeberger, PhD	USAF Labs
• Avery Brown, MS	Penn State PhD
• Thomas Jaworsky, MS	NAVAIR
• Lauren Weist, MS	NASA Ames
• Jake Purzak, MS	Leonardo Helicopters
• Ted Gan, MS	Penn State PhD
• Demi Zachos, MS	Penn State PhD
• Bhaskar Mukherjee, MS	Penn State PhD
• Yu Xiong, PhD	Altair
• Gerald Boddie, MS	Timkin
• Chaitanya Bakre, PhD	Intel
• Sean Scrooger, MS	Lockheed Martin
• Blaise Konzel, MS	Boeing Rotorcraft
• Dalton Decerio, MS	Boeing

Recent VLRCOE Graduates (2021-2022)

• Sihong Yan, PhD	Ga Tech Research Faculty
• Kalki Sharma, MS	Sikorsky
• George Rai, PhD	Siemens, USA
• Sean Gauntt, PhD	JHU Applied Physics Lab
• Zhisheng Ai, MS, (UTK)	VLRCOE PhD student
• Ashwin Parwani, MS (UTK)	US Army Huntsville
• Evan Topper, MS	Boeing
• Hector Ortiz-Melendez, PhD (UTK)	Lockheed Martin Skunk Works
• Jared Carnes, PhD (UTK)	General Atomics
• Tristen Wall, PhD (UTK)	Joby
• Forrest Mobley, MS (UTK),	Boeing Rotorcraft
• Henry Jia, PhD, (UCD)	US Army Ames
• Nickolas Zhu, MS, (ERUA)	
• Kaijus Palm MS, (ERAU)	

Recent VLRCOE Graduates (2023)

- Jessica Beyer, MS — USAF helicopter pilot
- Eric McThane, MS
- Costa Kandias, MS — PSU VLRCOE PhD
- Chloe Zarader, MS — UIUC PhD
- Zhouzhou Chen, MS — PSU VLRCOE PhD
- Bianca Gonzalez, MS — Northrup-Grumman
- Jeffrey Lewis, PhD — US John McCain Fellow
- Jason Cornelius, PhD — NASA US



New VLRCOE grant students….
(<u>each year</u>, we will support & train
17+ graduate students and 3 Undergraduate
research assistants)

















Current VLRCOE funded students

- Demi Zachos, PhD — US
- Kail Yuan, MS — US
- Aniruddh Vashisth, PhD — India
- Zhouzhou Chen, PhD — China
- Kenny Chu, MS — US
- Tyler Ramsarran, MS — US
- Jessica Beyer, MS — US
- Isabella Mawry, MS — US
- Stephen Willoughby, PhD — US
- Neil Deore, MS — US
- Tyler Littmann, MS — US
- Ashish Mahnji, PhD — India
- Costa Kandias, PhD — Canada
- A. VanLandingham, PhD — US
- Nathan Alvarado, MS — US
- Junayed Hasan, PhD — Bangladesch
- Geoff Karli, MS — US
- Ashish Manjhi, PhD — India

- Batin Bugday, PhD (UMd) — Turkey
- Zhisheng Ai, PhD (UTK) — China
- Aditya Suvithiraj PhD, (AU) — India
- Lokesh Silwal, PhD (AU) — Nepal
- Zack Moore, MS (AU) — US
- P. Ayyanathan, PhD (AU) — India
- Nikos Trembois, PhD (UCD) — US
- Ethan Brown, PhD (UCD) — US
- Carlos Natividad, MS (UCD) — US

Undergraduate Research Assistants

Alex Duffy	US.
Jacob Lungin	US
Vincent Buffone	US
Sidd Porredy	US
Bhavya Patel	India
Ethan Landis	US
Nate Hoover	US
Bobby Kircheis	US
Miles Taylor	US

66 % US nationals

Current VLRCOE graduate students supported on other grants

• Tyler Rosenberger, MS, NASA	US
• Tomas Opazo: PhD, NASA	Chile
• Gracelyne Allred , MS, NASA	US
• Desirae Major , PhD, NAVAIR	US
• Belen Veras-Alba, PhD, DoD	US
• Jean-Pierre Theron, NASA/CDI	US / S. Africa
• Nicholas Morgan, MS, PSU Fellow	US
• Joel Rachaprolu, MS, FAA	India
• Bhaskar Mukherjee, PhD	India
• Ankit Agarwal, MS/PhD	US
• Jake Crouse, MS/PhD	US
• Oliver Dunbabin, MS/PhD	Australia
• Wen-Yu Chien, MS/PhD	Taiwan
• Robert Rau, PhD, NASA	US
• Daniel Weitsman, MS, Army SMART	US
• Darshankumar Zala, MS, NASA	India
• Sebastien Lopez, MS, FAA	US
• Geoff Karli, MS, FAA	US
• Joe Nangle, MS, FAA	US
• Vitor Valente, PhD, FAA	Brazil

58 %

US nationals

Current VLRCOE graduate students supported on other grants (continued)

• Jeremy McGovern, MS, Boeing, Army	US
• Chris Hendrick, PhD, ONR	US
• Sagar Peddanarappagari, MS, FAA	US
• Raja Zahirudin, MS, NASA	Malaysia
• Rupak Chaudary, PhD, FAA	Nepal
• Keon Wong Hur, MS, FAA	S. Korea
• Bhaskar Mukherjee, PhD, FAA	India
• Ze Feng (Ted) Gan, MS/PhD, FAA	Canada
• Nitya Singh, PhD, CDI	India
• Changik Cho, PhD, PSU	S. Korea
• Anna Moorhouse, MS, ONR	US
• Avery Brown, PhD, ONR	US
• Mariano Scaramal, PhD, USAF	Argentina
• Grant Li, PhD, NASA	Canada
• Micaela Crispen, MS, Textron Aviation	US

58 %

US nationals

Examples of Outstanding Students and Alumni

- ***University faculty members:***

UTenn: H. DeSmidt
Purdue: F. Semperlotti
UMd: U. Saetti
PSU: J. Palacios, J. Coder, J. Geng
UC Davis: S. Lee
USMA and Quinipiac: L. Byers
NC State: A. Howard
IIT Kanpur: T. Mathur
NUAA: H. Dong

- ***Numerous Industry and Government leaders throughout the US, Europe and Asia.***

Rotorcraft Center Strategic Goals: 2024

1) **Mature all new VLRCOE 2021-2026 tasks**

2) **Establish interactions for all tasks with government TPOCs on VLRCOE tasks**

3) **Continue VLRCOE Journal/Conf Publications and Theses**

4) **Fully develop and utilize new & existing VLRCOE facilities (new VLRCOE home in ECORE Bldg, UNV airport annex, etc.)**

5) **Expand collaborative research projects with government and industry partners (incl. student internships, as appropriate)**

~ Penn State ADSPIN Center ~

Aerospace
Dynamic
Systems
Performance
Industry
Network

~ Penn State ADSPIN Center ~

Aerospace
Dynamic
Systems
Performance
Industry
Network

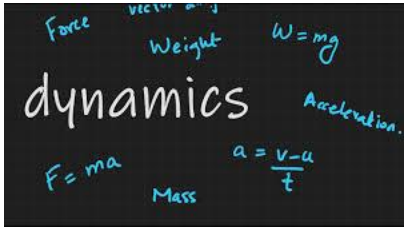
ADSPIN INTRODUCTORY BRIEFING
NOVEMBER 2023
Penn State University

Contact: Prof. Ed Smith
(814) 863-0966
ecs5@psu.edu

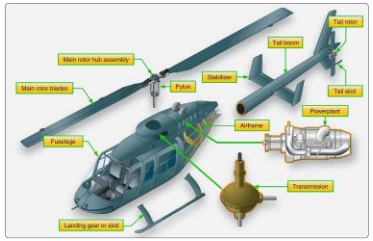
The efficient, elegant and exceedingly careful management of kinetic energy has always been at the core of aerospace vehicle development

Definitions

Dynamics: -the science of the motion of bodies and the action of forces in producing or changing their motion.



System: a set of things working together as parts of a mechanism or an <u>interconnecting</u> network.



Definitions

Performance (re: Dynamic systems)

- ✓ Low Vibration (transient and steady state)
- ✓ Dynamically stable (throughout operational envelope)
- ✓ Efficient (lightweight)
- ✓ Environmentally robust (ice, rain, sand, wind, temperature)
- ✓ Reliable and Maintainable
- ✓ Affordable (total lifecycle)
- ✓ Safe and robust to damage and failure modes

Required R&D Technology Areas:

- passive and active vibration control, and dynamic loads control
- advanced aerospace materials and structural concepts
- development and integration of next generation HUMS and CBM processes:
  - sensors, ML algorithms, prognostics
- "Super-low" levels of exterior noise ,AND interior cabin noise levels
  - innovative passive (device and design) and elegant (simple) active methods
- advanced low-power/high authority/lightweight ice protection systems
- robust erosion (sand and rain) coating materials
- full spectrum crashworthiness:
  - energy absorption, fire protection, ballistic/debris protection
- specialized enabling manufacturing methods

Emerging R&D Technology Areas:

- Autonomy – and it relates to constraints on *flight and vehicle dynamics/safety*, and Complex Unmanned Aerial System (C-UAS-O) operations.
- advanced vehicle flight controls and control redundancy management
- Dynamics of Electric and Hybrid Electric propulsion systems
  - robust dynamic stability of tightly coupled electromechanical systems
  - battery safety issues…ie thermal runaway, drop test survival
  - thermal management of PM motors/generators and inverters
- full spectrum UAM crashworthiness:
  - energy absorption, fire protection, ballistic/debris protection
- specialized UAM enabling manufacturing methods (lower cost, higher volume)

Aerospace Dynamic Systems:

- **Rotary Wing Aircraft**
  (helicopters, tiltrotors, drones, eVTOL air taxis, powered lift vehicles, etc)

- **Rotor system components**
  (blades, hubs, actuation, and on-blade control systems)

- **Advanced propellers**

- **Wind turbine blades and drive systems**

- **Fixed Wing Aircraft**
  - Subsonic, supersonic, hypersonic

- **Aeroelastic lifting surfaces**

Aerospace Dynamic Systems:

- Mechanical drivetrains (gearing, shafts, bearings)
- Turboshaft and reciprocating aircraft engines
- Electric and hybrid electric aircraft propulsion systems (including electric machines and battery systems)
- Missile and Rocket structural dynamic systems
- Spacecraft structural dynamic systems
- Spacecraft orbital dynamics and control

ADSPIN Vision

We see ADSPIN as a new Consortium and/or network

- ✓ filling a need for US Industry
- ✓ expanding Penn State's industry impact on education work force development, and research
- ✓ enabling multi-mechanisms for collaboration and funded activity

~ Penn State ADSPIN Center ~

Aerospace
Dynamic
Systems
Performance
Industry
Network

ADSPIN builds on strong existing PSU corporate relationships with key aerospace industry Stakeholders

ADSPIN leverages other PSU Multidisciplinary Technology PSU Centers:

- ***VLRCOE*** **(Vertical Lift Research Center of Excellence)**
  https://www.vlrcoe.psu.edu

- ***CAV*** **(Center for Acoustics and Vibration)**
  https://www.cav.psu.edu

- ***GTREO*** **(Gas Turbine Center)**
  https://sites.psu.edu/gtreo/

- ***BEST*** **(Battery and Energy Storage Technology Center)**
  https://best.psu.edu

- ***Applied Research Laboratory*** **(Drivetrain Center, Condition Based Maintenance Division, Composite Structures Division, Structural Vibration and Acoustics Division)**
  https://www.arl.psu.edu

ADSPIN builds on strong existing PSU corporate relationships with Key Industry Stakeholders:

US Rotorcraft and Aircraft Companies

- **Boeing (owns Boeing Helicopters in Philly and Mesa, AZ, Boeing Commercial in Seattle, and Boeing Defense St-Louis)**
- **Lockheed Martin (owns Sikorsky Aircraft in CT, etc)**
- **TEXTRON (owns BellFlight in Ft Worth, TX)**
- **Robinson Helicopter Company (CA)**
- **KAMAN Aerospace Corp. (CT)**

- **Collins Aerospace (Icing Detection and Protection Systems in MN and Ohio, and Drive Systems in Rome, NY)**
- **Parker-Hannifin (Cleveland, OH, Parker-LORD Corp in Erie, PA and Cary, NC)**
- **Timken Corp (N. Canton, Ohio)**

US Rotorcraft and Aircraft Companies

PennState

BOEING

LOCKHEED MARTIN

TEXTRON

BELL

SIKORSKY
A LOCKHEED MARTIN COMPANY

KAMAN

Collins Aerospace

TIMKEN

ROBINSON
HELICOPTER COMPANY

Parker

Parker
LORD

ADSPIN builds on strong existing PSU corporate relationships with Key Industry Stakeholders:

PennState

Rapidly Growing US EVTOL-sector companies:

- Joby - CA
- Archer - CA
- Supernal - CA
- Overair - CA
- Beta – VT
- Wisk - CA

US Specialty Aerospace Companies

- Piasecki Aircraft (Philadelphia, PA)
- Advanced Technologies Inc. (Newport News,VA) -blades
- Continuum Dynamics, Princeton, NJ
- Advanced Rotorcraft Technology, CA
- GPMS (Vermont) – HUMS systems
- EPS Power Systems(UT)

US Wind Energy Companies:

- GE Wind - South Carolina

What is needed to Take Off

- ✓ *Major ($15M+) College of Engineering investments in research infrastructure have been made and have been executed (occupancy July 2024)*

- ❑ *Approximately $3M in new research equipment, and engineering development support is needed to rapidly become fully operational (within 18 months)*

- ❑ *Numerous opportunities for industry-sponsored laboratories and kickoff research projects*

- ❑ *Opportunities for industry sponsored:*
  ADSPIN Industry Graduate Fellows (IGFs)
  and "Engineering Support Fellows (ESFs)",

~ Penn State ADSPIN Center ~

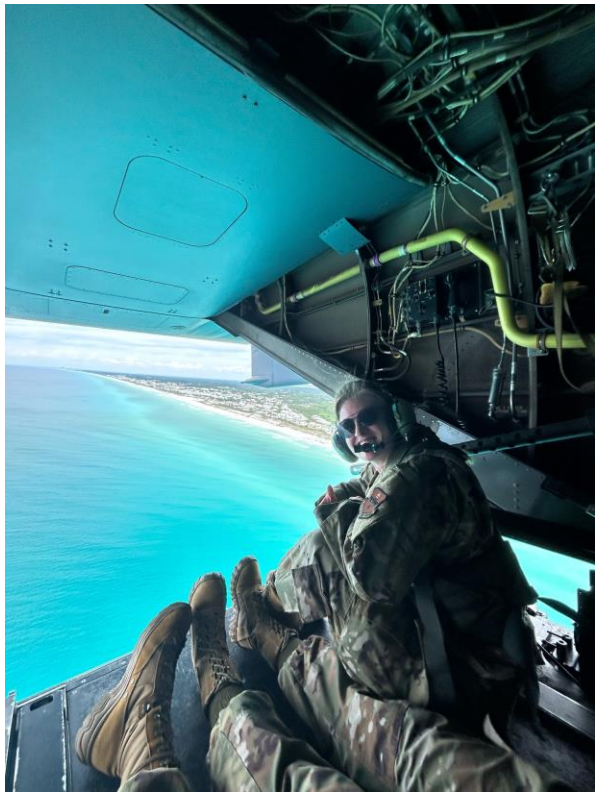
Aerospace
Dynamic
Systems
Performance
Industry
Network

Rotorcraft Center Strategic Goals: 2024

6) as always, DON”T FORGET TO HAVE SOME FUN!

Rotorcraft Center Strategic Goals: 2024

6) as always, DON”T FORGET TO HAVE SOME FUN!



2023 VFS Forum “team Photo”

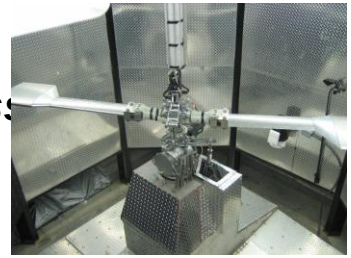
Vertical Lift Research Center of Excellence (VLRCOE)

https://www.vlrcoe.psu.edu

POC: Prof. Ed Smith ecs5@psu.edu

- *1 of 3 Vertical Lift research and education university centers in the US*
- *$7+M annual funding from DoD and industry: 60 graduate students, 30 faculty*
- Competitively awarded in 1996, 2001, 2006, 2011, 2016, 2021
- Since 1996: 10x growth in research funding
  5x growth in student & faculty engagement
- *Grad and Undergrad curriculum + Annual 1-week Short Course*

VLRCOE Research Themes



Enhanced Performance (range speed, payload, maneuver, compactness
Improved Reliability, Maintainability, and Safety
- *Condition Based Maint. & Structural Health Monitoring*
- *Advanced Coatings (erosion, thermal, icing)*
- *Advanced Drive systems (fewer parts, longer lives)*
- *Repair technologies*

Interior Noise and Vibration Control (active and passive)
Adverse Environment (ice, sand, rain, wind, maritime)
Engineering Tool Development/Validation
Survivability – noise signature,, maneuver, crashworthy
autoflare, HQ, autonomy

Vertical Lift Research Center of Excellence (VLRCOE)

https://www.vlrcoe.psu.edu

POC: Prof. Ed Smith ecs5@psu.edu

Key Technical Contributions

- *Development of world class rotorcraft icing and flight simulation facilities and research programs*

- *Sustained 27-year contribution to vibration control methods and devices, aeromechanical stability analysis, crashworthy systems, composite rotor blades for advanced helicopter and tiltrotor vehicles*

- *International leadership in rotorcraft noise computations ad experiemnts*

- *Development of high-fidelity shipboard flight simulation, controls, and aeroelastic analysis software for the US Navy*

- *Sustained 27-year contribution to advanced drive system material development (Drivetrain Materials Consortium), gearbox CFD and design analysis (NASA Awards), and condition based maintenance (CBM) methods.*

- *Extensive record of industrial research collaborations: (Bell, Boeing, Sikorsky, LORD, Goodrich, Piasecki Aircraft, GE, etc.)*

PENNSTATE

1855

Vertical Lift Research Center of Excellence

Contact:
Prof. Ed Smith
814-863-0966
ecs5@psu.edu

Contact (Admin):
Prof. Ken Brentner
814-865-6433
ksbrentner@psu.edu

https://youtu.be/CeLdivT7MvU