COLLEGE OF ENGINEERING

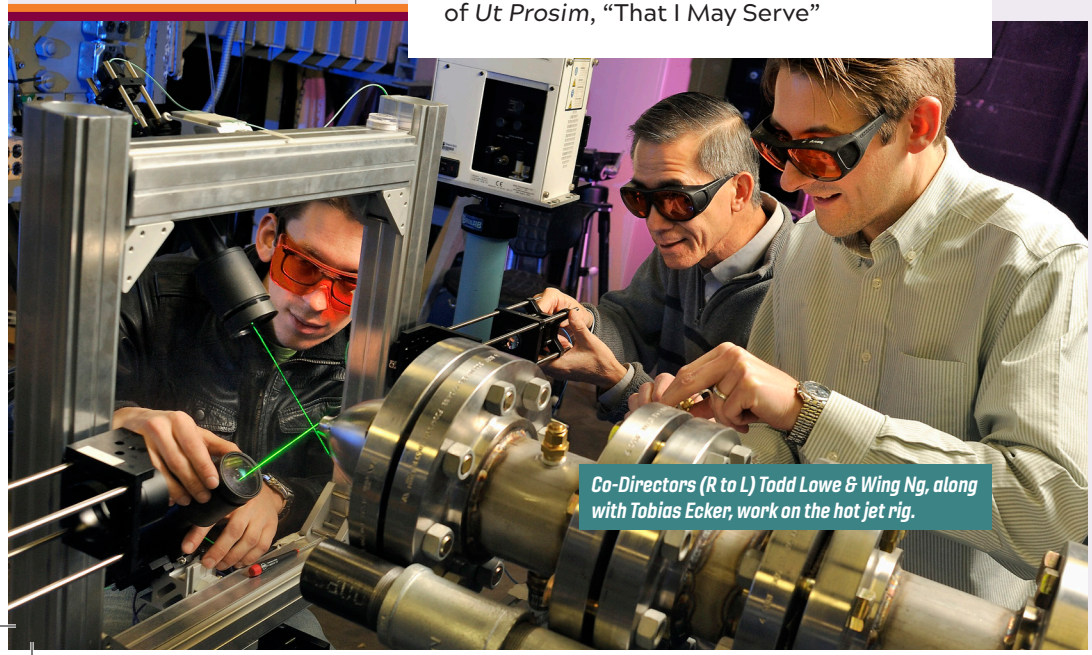
THE ADVANCED PROPULSION AND POWER LAB

VIRGINIA TECH™

DEPARTMENT OF MECHANICAL ENGINEERING //

KEVIN T. CROFTON DEPARTMENT OF AEROSPACE AND OCEAN ENGINEERING

The Advanced Propulsion and Power Lab provides hands-on learning experiences, unique technology applications, educational opportunities, and innovative ideas to serve (or collaborate with) our clients and to uphold Virginia Tech's motto of *Ut Prosim*, "That I May Serve"



Co-Directors (R to L) Todd Lowe & Wing Ng, along with Tobias Ecker, work on the hot jet rig.

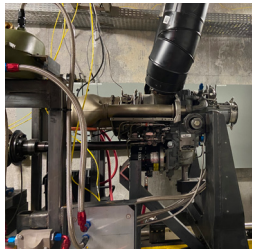
FACILITIES

APPL is equipped with several state of the art experimental rigs, diagnostic instrumentation, and infrastructure.

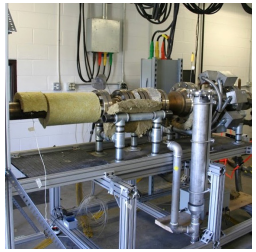
Compressed air to the lab is supplied by two BOGE industrial compressors, capable of supplying air at up to 1200 kPa (175 psi) at a flow rate of 1.2 kg/s. The air is dried to remove water vapor prior to being stored in the 5,000 gallon storage tank.

The lab's professional **machine shop** includes two milling machines, lathe, saws, drill press, and welding equipment. The shop is staffed by a professional machinist with over 30 years experience.

Honeywell TFE731-2B and Pratt & Whitney Canada JT15D-1A **turbofan engines** are available for research. These turbofans support a variety of projects, including inlet distortion research, advanced sensor development and validation, and laser-based flow measurement techniques.

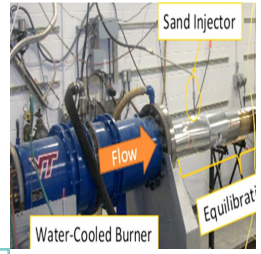


A **Rolls-Royce model 250-C20B turboshaft engine** is focused on sand ingestion research. A Pratt & Whitney Canada PT6A-20 turboshaft engine has been used to support sensor development and validation, alternative fuels research, and education for both graduate and undergraduate students.

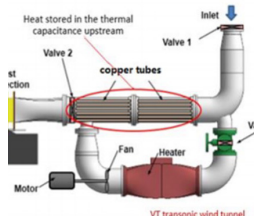


The **heated free jet rig** is capable of continuous operation at up to supersonic Mach numbers. This electrically heated jet maintains stagnation temperatures of up to 700 K. Experiments performed include studies of noise reduction, acoustic thrust estimation, effects of VTOL on ship decks, and stereo PIV and IR thermography.

The **high-pressure combustion rig** supports reacting experiments up to 8 bara, optical accessibility. It operates with exhaust temperatures up to 1700C on compressed natural gas and has a modular design. It is currently being modified for supersonic jet noise experiments with total temperatures up to 1850C, with Mach number of 1.65.

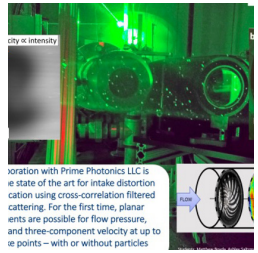


The lab's **aerothermal rig** studies sand ingestion in aircraft engines and interaction with engine hardware. It operates at temperatures of up to 1500 K, at atmospheric pressure, produces sand velocities of 100 m/s, and measures sand deposition and restitution.

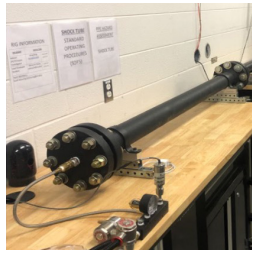


The **transonic blowdown tunnel rig** enables studies in heat transfer and aerodynamic performance of engine hardware. This linear cascade tunnel operates at flow rates of up to 4.5 kg/s, for durations of 30 seconds. It can reach exit Mach Number from 0.8 to 1.2 at inlet Turbulence Intensity of 16%, using IR thermography to measure heat transfer on blade surface and endwall.

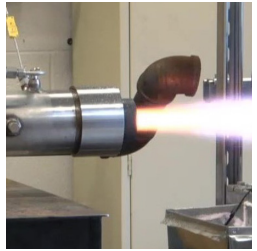
The **hypersonic wind tunnel rig** operates at Mach 2-7 (nominal) with a runtime of approximately 8s. The tunnel has a 15-20 kW electric heater and provides stagnation temperature of up to ~800 K and stagnation pressures up to ~2200 psia. It is instrumented for pressure transducers/ thermocouples with a 250 kHz data acquisition system. Configuration is amenable to Schlieren imaging, and it is suited for both research and instruction.



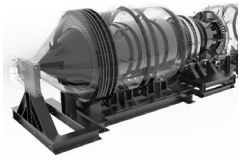
The **high-speed wind tunnel rig** operates continuously at up to Mach 0.5, with a 6" diameter test section, powered by Hoffmann centrifugal blower. Experiments include: validation of inlet distortion generators, development of laser technique (filtered Rayleigh Scattering) to measure 3D flow fields without requiring particles, and risk-reduction experiments prior to testing on turbofan engines.



The **shock tube tunnel rig** is used for quick and repeatable production of transonic and supersonic shock waves. Maximum driver section pressure is 600 psia, with a minimum driven section pressure of 1.5 psia. Mach number of a shock wave is measured. Varying diaphragm thickness with the pressure difference across the diaphragm allows the Mach number to be adjusted up to Mach 4.

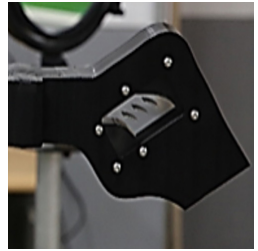


The **solid fuel ram jet rig** operates simulating flight Mach numbers up to ~ Mach 4. A 192Kw heater provides heated clean dry air, and the device explores flammability limits and performance of novel solid fuels and grain designs. Traditional and bypass air flow operational characteristics are possible. Parameters of interest include fuel type, ingredients, and additives; air flow rate; inlet temperature; combustor pressure; and fuel grain geometry.

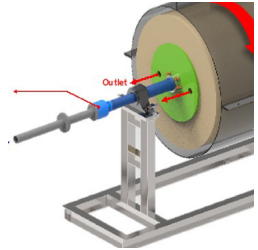


The **generic turbine test facility rig** is equipped with a scaled model of 1.5 stage turbine and rotates up to 3600 rpm. A short-duration blowdown test can simulate transonic flow and heat transfer, and experiments can include combustor-vane clocking, air system and cooling air.

The **annular sector cascade rig** is equipped with annulus section (6 passages) of scaled turbine vanes or blade airfoils. Short-duration blowdown test can simulate transonic annulus flow. Experiments can include loss characterization of lean and sweep design, profiled endwall and blade tip leakage flow.



The **mini cascade rig** is equipped with a 2D scaled model of compressor and turbine airfoils. Continuous blowdown test can simulate transonic flow, and experiments can include incidence angle effect, and shock interaction.



The **soft disc rotating rig is** equipped with Soft Disc (Rohacell material) and rotates up to 1000 rpm. This material is lighter, safer, and easy to repair and offers low-cost rotating test capability. Experiments can include radial and axial rotating duct of air system and cooling air.

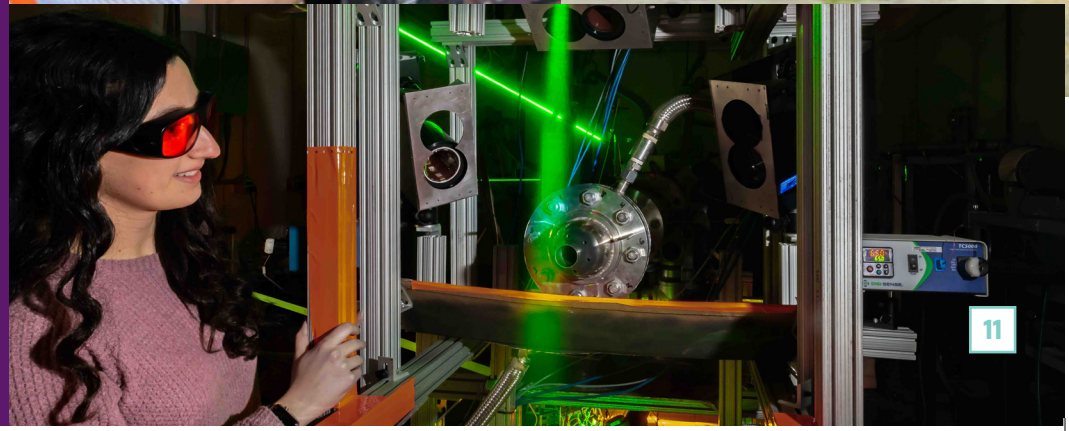
LEGACY

Propulsion-focused research at Virginia Tech began in the early 1970's, with founding faculty members Henry Wood, Joseph Schetz, Hal Moses, and Walter O'Brien.

In the 1970's, Randolph Hall housed a supersonic wind tunnel. The Turbomachinery and Propulsion Research Laboratory (TurboLab) at the Virginia Tech airport began research operations in the late 1970's. Turbine engines used for research in the TurboLab included T-64, F109, and JT15D-1. Now, PT6A-20 and TFE731 engines have been added.

The Advanced Power and Propulsion Laboratory facility opened in 2015, adding additional capability to one of the largest propulsion-related research activities in the United States. TurboLab soon began doing cooperative projects with the APPL and became a lab fully under the APPL umbrella in 2020.

Sponsors for past research have included Pratt & Whitney, Rolls-Royce, Honeywell, Air Force Research Laboratory, NASA, Naval Air Systems Command, and Prime Photonics. Projects for these sponsors have included turbine engine performance, turbine engine inlet distortion, StreamVane™ distortion generators, flow measurement diagnostics, and non-intrusive flow measurement.



PEOPLE

CORE FACULTY

Wing Ng is co-director of APPL. He is an Alumni Distinguished Professor and the Chris C. Kraft Professor in the Department of Mechanical Engineering at Virginia Tech. His primary research interests are aeroacoustics of drones and unmanned air vehicles, aeroacoustics of jet noise, development of advanced diagnostics techniques for flow measurements in turbine engines and for flight tests, transonic turbine blade aerodynamics and heat transfer studies, evaluation of gas turbine diffuses/collector performance, and aerotherma particle studies for gas turbine components.

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Todd Lowe is co-director of APPL and professor with the Kevin T. Crofton Department of Aerospace and Ocean Engineering at Virginia Tech. His primary research interests are novel flow instrumentation, supersonic jet noise reduction and engine/airframe integration. He serves as the director of the Pratt & Whitney Center of Excellence and has been active with the Rolls-Royce University Technology Center since its founding.

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Changmin Son

Joseph Meadows

Joseph Schetz

Colin Adams

Greg Young

PROPULSION RESEARCH PIs

Scott Case

Rakesh Kapania

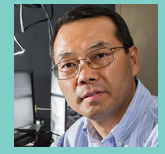
William Devenport

Tom Diller

Gary Pickrell

Danesh Tafti

Alex Untaroiu



Anbo Wang

Bill Copenhaver, Senior Research Engineer

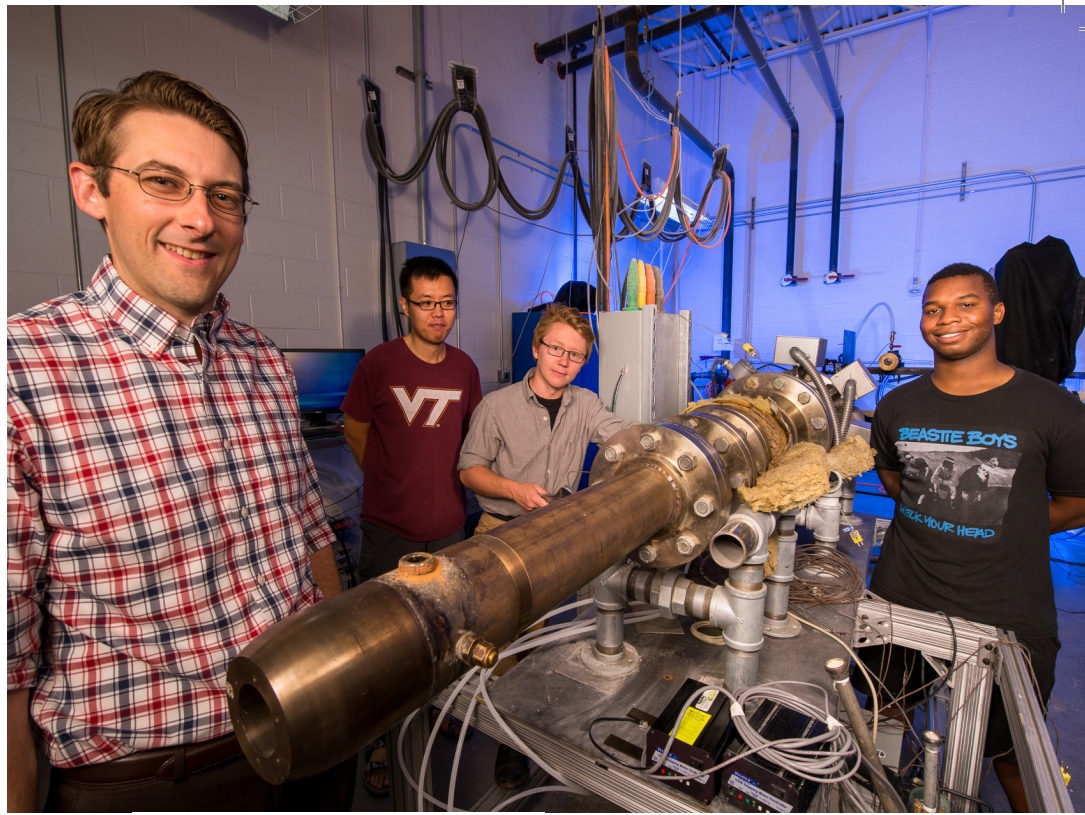
Jason Doby is the APPL Lab Manager. Jason joined the APPL in March 2022, having previously worked nearly 15 years in the fields of research and education.

Gwibo Byun is a research scientist with the Kevin T. Crofton Department of Aerospace and Ocean Engineering at Virginia Tech. He plays an active role in assisting the students in planning and conducting experiments. Gwibo has been active with the Rolls-Royce University Technology Center and the Pratt & Whitney Center of Excellence.

John Gillespie is a research associate with the Kevin T. Crofton Department of Aerospace and Ocean Engineering at Virginia Tech. He is involved in projects that span multiple areas such as aerodynamics, turbine engine based testing and validation of instrumentation, etc. and is active in the Rolls-Royce University Technology Center as well as the Pratt & Whitney Center of Excellence.

Randall Monk is in charge of the machine shop at the APPL. He supports various projects' manufacturing needs including machining, custom client needs, and contributes to rig development and safety.

Diana Israel supports the administration and operations of APPL through financial planning, billing, and purchasing. She serves as a key liaison among the faculty members and students involved with the lab and is dedicated to continuously improving APPL's operational efficiency and effectiveness.



Co-Director Todd Lowe works with students.

FACULTY ADVISORS

The APPL has seven faculty advisors with a combined 100+ years of expertise in their respective fields. Co-directors Wing Ng and Todd Lowe are available in addition to the five facutly listed here to consult with students, clients, and other constituents.

Colin Adams is an assistant professor with the Kevin T. Crofton Department of Aerospace and Ocean Engineering at Virginia Tech. His primary research interests are in spacecraft propulsion, fusion energy, and plasma in high-speed flows.

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Joseph Meadows is an assistant professor in the Department of Mechanical Engineering at Virginia Tech. His primary research interest is combustion for propulsive and power generating applications.

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Joseph Schetz is an endowed professor with the Kevin T. Crofton Department of Aerospace and Ocean Engineering at Virginia Tech. His primary interests are in skin friction and heat flux measurements, aerodynamics and multidisciplinary design optimization for advanced aircraft, and injection, mixing and combustion in supersonic flow.

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Changmin Son is the Rolls-Royce Commonwealth Professor of Mechanical Engineering and Director of Rolls-Royce University Technology Center at Virginia Tech. His industrial experience focused on turbine system and future technologies. He broaden the research interest in radical design of turbomachinery, gas turbine system, integrated aircraft & engine modeling, energy system design and engine prognostics.

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Greg Young is an associate professor in the Kevin T. Crofton Department of Aerospace and Ocean Engineering at Virginia Tech. His interests are Advanced Diagnostics and Experimental Testing, Energy Systems, and Propulsion.

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PARTNERS

We are a modular facility with the ability to customize to our customers needs and the ability to adapt quickly. New capabilities can be quickly added, and existing capabilities can be expanded.

We work successfully with a wide range of partners, including:

- Large corporations, including several aircraft engine OEMs
- National research organizations (NASA, AFRL, ONR)
- Small businesses (often through the SBIR and STTR programs)

The team can develop low-technology readiness level (TRL 1-2) technologies on our rigs, and then transition to engine tests for higher TRL (up to TRL 4) testing.

Collaborations provide great opportunities for our students and partners alike. Students get connected to prospective employers, and are exposed to real-world practices. Employers get access to large graduating classes from highly regarded BS, MS and PhD programs.

Our facilities are also available on a for-hire basis, where external users can perform work directly. If you would like to schedule a block of time to operate in our facility, please contact Todd Lowe at kelowe@vt.edu or (540)231-7650.

LAB EXPERTISE

The lab also has several advanced diagnostics capabilities:

Laser diagnostics, including:

- Stereoscopic Particle-Image Velocimetry (PIV), including 25 kHz high-speed operation
- Filtered Rayleigh Scattering (FRS)
- Doppler Global Velocimetry (DGV)
- Phase Doppler Particle Analysis (PDPA)
- Laser Doppler Velocimetry (LDV) measurements (Laser Doppler Velocimetry, Filtered Rayleigh Scattering)
- Particle characterization based upon laser scattering and attenuation

Infrared imaging applications including:

- High resolution thermography, including heat transfer measurements
- 12-inch diameter schlieren imaging for flow visualization
- 48-inch background-oriented schlieren (BOS) flow visualization
- High-speed imaging for quantitative and qualitative flow diagnostics

Combined expertise spans a broad base of disciplines:

- Thermofluids
- Acoustics
- Combustion
- Aeromechanics
- Materials
- Photonics
- Sensors
- Multidisciplinary Design Optimization

Virginia Tech - Rolls-Royce University Technology Center

The Virginia Tech Rolls-Royce UTC in Advanced Systems Diagnostics is working to enhance product understanding, control, and life-cycle management through innovation in measurement system technology and to provide effective transition of data to knowledge, delivering the company measurement system and diagnostics capability strategy.

The UTC is the center of excellence for measurement systems and diagnostics and to inform the design system, develop deep knowledge and enable rapid design iterations and deliver robust product, structured as an agile hub to enable rapid evaluation, fast learning, and to provide forward-looking capability ahead of need and build a partnership biased towards collaboration and provide measurements standards and technology to the UTC network.

Pratt & Whitney Center of Excellence

Built upon the long standing relationship between Pratt & Whitney and Virginia Tech, the College of Engineering works with Pratt & Whitney on fundamental research initiatives that support the design and development of advanced gas turbine engine propulsion and composite materials. The partnership enables Pratt & Whitney to leverage its substantial technology investments and furthers Virginia Tech's expertise in fundamental and applied research.

Students Rose Stanphill and Eszter Anna Varga in Prof. Todd Lowe's junior level Aerothermodynamics and Propulsion course inspect the PW6000 engine, which was recently donated to the university by Pratt & Whitney. Photo by Jama Green for Virginia Tech.

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