K. Todd Lowe
Professor, Kevin T. Crofton Department of Aerospace and Ocean Engineering
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Education and training:

B.S.	2001	Aerospace Engineering, Virginia Tech
M.S.	2004	Aerospace Engineering, Virginia Tech
Ph.D.	2006	Aerospace Engineering, Virginia Tech

Research and professional experience:

2021-present, Professor, Aerospace and Ocean Engineering, Virginia Tech
2017-present, Co-Director, Advanced Propulsion and Power Laboratory, Virginia Tech
2016-2021, Associate Professor, Aerospace and Ocean Engineering, Virginia Tech
2016-2017, Associate Director, Advanced Propulsion and Power Laboratory, Virginia Tech
2010-2016, Assistant Professor, Aerospace and Ocean Engineering, Virginia Tech
2006-2010, Vice President for Research and Development, Applied University Research, Inc.

Prof. Todd Lowe leads a research team focused on experimental aerodynamics and aeroacoustics, often addressing applications on propulsion inlets and exhausts. His fundamental contributions have provided insights for understanding turbulence transport and noise in turbulent shear flows, such as the role of large-scale turbulence in supersonic jet noise. His instrumentation research has resulted in several notable impacts, including 250 kHz planar vector velocimetry and methods for quantitative flow imaging without particles. He is co-inventor of seven US utility patents, with one additional patent pending, and has co-authored more than 190 publications in the areas of advanced diagnostics for fluid dynamics, turbulent shear flow and jet noise physics, propulsion and power, and signal processing. Since 2007, he has been the P.I. or co-P.I. for research contracts and awards amounting to $24M ($13M of that total being his credited share) from government and industry sponsors including the Office of Naval Research, NASA, US Air Force, Pratt & Whitney, Rolls-Royce, GE, and several small businesses. He is the Co-Director of the Advanced Propulsion and Power Laboratory at Virginia Tech (https://www.aoe.vt.edu/research/multidisciplinary-centers-labs/appl.html) and the Director of the Pratt & Whitney/Virginia Tech Center of Excellence.

Selected professional service and activities:

- AIAA Aerodynamic Measurement Technology Technical Committee (2010 - present)
  - Past Chair (2022-present)
  - Chair (2020-2022)
  - Vice Chair (2018-2020)
  - Conferences subcommittee chair (2016 – 2018)
  - Conference co-chair, 2015 Aerodynamic Measurement Technology/Ground Test Conference in Aviation 2015
  - Webmaster (2013 – 2016)
- Co-Director of the Virginia Tech Advanced Propulsion and Power Laboratory (2017-present)
- Director of the Pratt & Whitney/Virginia Tech Center of Excellence (2019-present)

- Inaugural member of the Rolls-Royce Technology Centre at Virginia Tech (2013-present)
- ASME IGTI Aircraft Engine Committee (2019-present)
    - Point Contact for Turbo Expo 2023 and 2024
    - Turbo Expo session co-chair (2018, 2019)
- NATO AVT Technical Team Member (2019-present)
    - AVT-349 "Non-Equilibrium Turbulent Boundary Layers at High Reynolds Numbers": Leading a team developing three-dimensional boundary layer flow cases for improved modeling and understanding of high Reynolds number wall flows.
    - Member of AVT-306 "Overview of Modern Instrumentation Technology Concerning Prognostics and Health Management and Control in Aero Turbine Engines"
- Advisory committee member for the *International Symposium on Applications of Laser Techniques and Imaging to Fluid Mechanics*

Awards and honors:

- Fellow, Royal Aeronautical Society (2023)
- Virginia Tech College of Engineering Dean's Award for Excellence in Teaching (2023)
- Fellow, ASME (2022)
- SAE International Ralph R. Teetor Educator Award (2018)
- Virginia Tech College of Engineering Dean's Award for Excellence in Research (2018)
- Keynote speaker, Second International Symposium on Image based Metrology (2017)
- Associate Fellow, AIAA (2015)
- National Institute of Aerospace Visitors Research Program (2014)
- Virginia Space Grant Consortium New Investigator Award (2012)

Peer-reviewed journal articles:

Note: * Indicates advisee.

1. Powers SW*, Byun G and **Lowe KT** 2024 "Validation of Filtered Rayleigh Scattering Optical Rake Measurement Techniques in Turbomachinery Applications and Boundary Layers," *ASME Journal of Turbomachinery*, 146(1), https://doi.org/10.1115/1.4063562.
2. Antous B*, Byun G, **Lowe KT** and Smith CF 2024 "Virginia Tech Optical Inlet Sensor for Particle Detection: Rolls Royce M250 Turboshaft Demonstration," *ASME Journal of Engineering for Gas Turbines and Power*, 146, pp.031010-1, https://doi.org/10.1115/1.4063584.
3. Hayden AP*, Gillespie J*, Hefner C, Untaroiu A and **Lowe KT**, 2024 "High Throughflow StreamVane Swirl Distortion Generators: Design and Analysis," *ASME Journal of Engineering for Gas Turbines and Power*, 146(4), https://doi.org/10.1115/1.4063709.
4. Fritsch DJ, Vishwanathan V*, Roy CJ, **Lowe KT**, and Devenport WJ 2023 "Modeling the Surface Pressure Spectrum on Rough Walls in Pressure Gradients," *ASME Journal of Fluids Engineering*, 145(12), https://doi.org/10.1115/1.4062821.
5. Acharya AS*, **Lowe KT**, and Ng WF 2023 "Mean Flow Characteristics Downstream of a Vortex Tube Separator Array," *AIAA Journal*, 61(11), 4990-5008, https://doi.org/10.2514/1.J062556.

6. Gargiulo A*, Duetsch-Patel JE*, Borgoltz A, Devenport WJ, Roy CJ, and **Lowe KT** 2023 "Strategies for Computational Fluid Dynamics Validation Experiments," *ASME Journal of Verification, Validation, and Uncertainty Quantification*, 8(3), https://doi.org/10.1115/1.4063639.
7. Duetsch-Patel JE*, Gargiulo A*, Borgoltz A, Roy CJ, Devenport WJ, and **Lowe KT** 2023 "Boundary Layer Flow Over a Bump and the Three-Dimensional Law of the Wall," *Journal of Turbulence*, 24(3-4), 2202404, https://doi.org/10.1080/14685248.2023.2202404.
8. Vishwanathan V*, Fritsch DJ, **Lowe KT**, and Devenport WJ 2023 "History effects and wall-similarity of non-equilibrium turbulent boundary layers in varying pressure gradient over rough and smooth surfaces," *International Journal of Heat and Fluid Flow*, 102, 109145, https://doi.org/10.1016/j.ijheatfluidflow.2023.109145.
9. Duetsch-Patel JE*, Gargiulo A*, Borgoltz A, Devenport WJ, and **Lowe KT** 2023 "Structural aspects of the attached turbulent boundary layer flow over a hill," *Experiments in Fluids* 64(2), 38, https://doi.org/10.1007/s00348-023-03580-4.
10. Moon CY*, Edwards C*, Byun GB, and **Lowe KT** 2022 "Particle characterization using optical measurements and neural networks," *Measurement Science and Technology*, 34(3), 035202, https://doi.org/10.1088/1361-6501/aca423.
11. Olshefski K*, Collins A*, Coulon T*, **Lowe KT**, and Ng W 2022 "Development of an Anisokinetic Particle Sampling Probe for Use in a Gas Turbine Engine Compressor," *Frontiers in Mechanical Engineering*, https://doi.org/10.3389/fmech.2022.951986.
12. Gillespie J*, Ng W, **Lowe KT**, Crook L, and Oechsle V 2022 "Acoustic thrust estimation on turbofan engines," *AIAA Journal of Propulsion and Power,* 39(1), 130-140, https://doi.org/10.2514/1.B38794.
13. Fritsch DJ, Vishwanathan V*, Roy CJ, **Lowe KT**, and Devenport WJ 2022 "Turbulence and pressure fluctuations in rough wall boundary layers in pressure gradients," *Experiments in Fluids,* 63(9) 140, https://doi.org/10.1007/s00348-022-03476-9.
14. Fritsch DJ, Vishwanathan V*, **Lowe KT**, and Devenport WJ "Fluctuating pressure beneath smooth wall boundary layers in non-equilibrium pressure gradients," accepted to *AIAA Journal*, 60(8), 4725-4743, https://doi.org/10.2514/1.J061431.
15. Daniel KA*, Mayo Jr. DE*, **Lowe KT**, and Ng WF 2022 "The density near-field of a non-uniformly heated supersonic jet," *Experiments in Fluids,* 63, 67, https://doi.org/10.1007/s00348-022-03413-w.
16. Devenport WJ and **Lowe KT** 2022 "Equilibrium and non-Equilibrium Turbulent Boundary Layers," *Progress in Aerospace Sciences*, 131, 100807, https://doi.org/10.1016/j.paerosci.2022.100807.
17. Acharya AS*, **Lowe KT**, and Ng WF 2022 "Fluorescent particle image velocimetry using atomized liquid particles," *Meas. Sci. Technol.*, 33 065301, https://doi.org/10.1088/1361-6501/ac543b.
18. Saltzman AJ*, **Lowe KT**, and Ng WF 2021 "50 kHz Doppler global velocimetry for the study of large-scale turbulence in supersonic flows" *Experiments in Fluids*, 62, 192, https://doi.org/10.1007/s00348-021-03286-5.
19. Powers SW*, Schetz JA, **Lowe KT**, and Kapania RK 2021 "Analysis of Stresses in Metal Sheathed Thermocouples in High-Temperature Flows," *AIAA Journal*, 59:9, https://doi.org/10.2514/1.J060239.
20. Saltzman AJ*, **Lowe KT**, and Ng WF 2021 "Finite control volume and scalability effects in velocimetry for application to aeroacoustics," *Experiments in Fluids*, 62:33, https://doi.org/10.1007/s00348-021-03138-2.

21. Readon JP*, Schetz JA, and **Lowe KT** 2021 "Computational Analysis of Unstart in a Variable-Geometry Inlet," *AIAA Journal of Propulsion and Power*, 37:4 https://doi.org/10.2514/1.B38214.
22. Turner EJ, Bogdan MF, O'Connell TM, Ng WF, **Lowe KT**, Crook L, Stevenson R, and Roberts J 2021 "Measurement drift in 3-hole yaw pressure probes from 5 micron sand fouling at 1050°C," *ASME J. of Turbomachinery*, 143:3, 091009, https://doi.org/10.1115/1.4050069.
23. Moon CY*, Byun G, Panda A*, Smith CF, and **Lowe KT** 2020 "Non-intrusive optical measurements of gas turbine engine inlet condensation using machine learning," *Measurement Science and Technology*, 32, 044001, https://doi.org/10.1088/1361-6501/abcf63.
24. Vincent T*, Schetz JA, and **Lowe KT** 2020 "Analysis of pin fins including radiation and transients," *Computational Thermal Sciences, 12:5, 429-451,* https://doi.org/10.1615/ComputThermalScien.2020026224.
25. Saltzman AJ*, **Lowe KT**, and Ng WF 2020 "250 kHz three-component Doppler velocimetry at 32 simultaneous points: a new capability for high speed flows," *Measurement Science and Technology,* 31, 095302, https://doi.org/10.1088/1361-6501/ab8ee9.
26. Moon CY*, Gargiulo A*, Byun G, and **Lowe KT** 2020 "Non-spherical particle size estimation using supervised machine learning," *Applied Optics,* 59:1, 3237*,* https://doi.org/10.1364/AO.385750.
27. Boyda M*, Byun G, Saltzman A*, and **Lowe KT** 2020 "Geometric scattering removal in cross-correlation Doppler global velocimetry by structured illumination," *Measurement Science and Technology,* 31:6, 064004, https://doi.org/10.1088/1361-6501/ab6b4f.
28. Daniel K*, Mayo DE*, **Lowe KT**, and Wing WF 2019 "Use of Thermal Non-Uniformity to Reduce Supersonic Jet Noise," *AIAA Journal (express article),* 57:10*, 4467-75,* https://doi.org/10.2514/1.J058531.
29. Zhang D, Cadel DR*, Paterson EG, and **Lowe KT** 2019 "Hybrid RANS/LES Turbulence Model Applied to a Transitional Unsteady Boundary Layer on Wind Turbine Airfoil," *Fluids 4:3, 128,* https://doi.org/10.3390/fluids4030128
30. Otero Jr R*, **Lowe KT**, Ng WF, and Silas K* 2019 "Coupled Velocity and Temperature Acoustic Tomography in Heated High Subsonic Mach Number Flows" *Measurement Science and Technology,* 30, 105901, 17pp, https://doi.org/10.1088/1361-6501/ab24a3
31. Mayo DE*, Daniel K*, **Lowe KT**, and Ng WF, 2019 "Mean Flow and Turbulence of a Heated Supersonic Jet with Temperature Non-Uniformity," *AIAA Journal*, 57:8, https://doi.org/10.2514/1.J058163.
32. Stuber M*, **Lowe KT**, and Ng WF, 2019 "Synthesis of Convection Velocity and Turbulence Measurements in Three-Stream Jets," *Experiments in Fluids,* 60:83*,* https://doi.org/10.1007/s00348-019-2730-5*,* View-only access: https://rdcu.be/bxAHy.
33. Vincent T*, Rolfe E*, **Lowe KT**, and Schetz JA, 2019 "Aerodynamic Analysis of Total Temperature Probe Thermal Performance Using Conjugate Heat Transfer," *AIAA Journal of Thermophysics and Heat Transfer*, 33:3, 830-43, https://doi.org/10.2514/1.T5635.
34. Guimarães T*, **Lowe KT**, and O'Brien WF, 2019 "Vortical Flow Development in Round Ducts Across Scales for Engine Inlet Applications," *Experiments in Fluids,* 60:52, https://doi.org/10.1007/s00348-019-2702-9, View-only access: https://rdcu.be/bo9RO.
35. **Lowe KT**, 2019 "Laser Velocimetry for Turbofan Inlet Distortion Applications," *Aeronautical Engineering and Aerospace Technology* , 92:1, 20-26, for special issue on NATO Specialists' Meeting AVT-306, https://doi.org/10.1108/AEAT-11-2018-0285.

36. Otero Jr R*, **Lowe KT**, and Ng W, 2019 "In-flight thrust monitoring: an acoustics-based approach," *Aeronautical Engineering and Aerospace Technology,* 92:1, 15-19, for special issue on NATO Specialists' Meeting AVT-306, https://doi.org/10.1108/AEAT-11-2018-0287.
37. Boyda M*, Byun G, and **Lowe KT** 2019 "Investigation of Velocity and Temperature Measurement Sensitivities in Cross-correlation Filtered Rayleigh Scattering (CCFRS)," *Measurement Science and Technology,* 30, 044004, 15pp, https://doi.org/10.1088/1361-6501/ab0350.
38. **Lowe KT**, Silas K*, Boggs G*, Ng WF, 2019 "An experimental study on the coupling between adjacent Hartmann whistles," *International Journal of Aeroacoustics,* 18(2-3), 299-316, https://doi.org/10.1177/1475472X19834525.
39. Cadel DR*, Zhang D, **Lowe KT**, and Paterson EG, 2018 "Unsteady boundary layer development on a wind turbine blade: an experimental study of a surrogate problem," *Experiments in Fluids,* 59:72, https://doi.org/10.1007/s00348-018-2526-z. View-only access: http://rdcu.be/JQGw
40. Vincent T*, **Lowe KT**, and Schetz JA, 2018 "Enhanced low-order model with radiation for total temperature probe analysis and design," *SAE International Journal of Aerospace,* 11:1, 1-13*,* https://doi.org/10.4271/01-11-01-0003.
41. Frohnapfel D*, **Lowe KT**, and O'Brien WF, 2018 "Experimental quantification of fan rotor effects on inlet swirl using swirl distortion descriptors," *ASME Journal of Engineering for Gas Turbines and Power,* 140(8), 082603*,* https://doi.org/10.1115/1.4039425.
42. Guimarães T*, **Lowe KT**, and O'Brien WF, 2018 "Complex Flow Generation and Development in a Full-Scale Turbofan Inlet," *ASME Journal of Engineering for Gas Turbines and Power,* 140(8), 082606, https://doi.org/10.1115/1.4039179.
43. Guimarães T*, **Lowe KT**, and O'Brien WF, 2017 "The StreamVane turbofan inlet swirl distortion generator: mean flow and turbulence structure," *AIAA Journal Propulsion and Power*, https://doi.org/10.2514/1.B36422.
44. Otero R*, **Lowe KT** and Ng W 2018, "Non-Intrusive Acoustic Measurement of Flow Velocity and Temperature in a High Subsonic Mach Number Jet," *Measurement Science and Technology*, 29(1), 015106, https://doi.org/10.1088/1361-6501/aa92a9.
45. Otero R*, **Lowe KT**, Ng W 2017, Ma L and Kim C-Y 2018 "Nonintrusive Gas-Turbine Engine-Exhaust Characterization Using Acoustic Measurements," *AIAA Journal Propulsion and Power,* 34(3), pp. 730-738 , https://doi.org/10.2514/1.B36579.
46. Reardon J*, Schetz JA and **Lowe KT**, 2017 "Computational Modeling of Total-Temperature Probes," *AIAA Journal of Thermophysics and Heat Transfer*, https://doi.org/10.2514/1.T4991.
47. Otero R*, **Lowe KT** and Ng W 2017 "Extension of sonic anemometry to high subsonic Mach number flows," *Measurement Science and Technology*, 28(3), 035306, https://doi.org/10.1088/1361-6501/aa54ed.
48. Ecker TE*, **Lowe KT** and Ng WF 2017 "On the distribution and scaling of convective wavespeeds in the shear layers of heated supersonic jets," *Flow, Turbulence and Combustion*, 98, 355-366, https://doi.org/10.1007/s10494-016-9752-3.
49. Cadel D* and **Lowe KT** 2016 "Investigation of measurement sensitivities in cross-correlation Doppler global velocimetry," *Optics and Lasers in Engineering*, 86, 44-55, https://doi.org/10.1016/j.optlaseng.2016.05.003.
50. Xue S, Guillot S, Ng WF, Fleming J, **Lowe KT**, Samal N* and Stang UE 2016 "An experimental investigation of the performance impact of swirl on a turbine exhaust diffuser/collector for a series of diffuser strut geometries," *ASME Journal of Engineering for Gas Turbines and Power*, 138(9), 092603, https://doi.org/10.1115/1.4032738.

51. Barboza K, Ma L, **Lowe KT**, Ekkad S and Ng W 2016 "A diagnostic technique for particle characterization using laser light extinction," *ASME Journal of Engineering for Gas Turbines and Power*, 138(11), 111601, https://doi.org/10.1115/1.4033468.
52. Wohl CJ, Kiefer JM, Petrosky BJ*, Tiemsin PI, **Lowe KT**, Maisto PM* and Danehy PM 2015 "Synthesis of Fluorophore-Doped Polystyrene Microspheres: Seed Material for Airflow Sensing," *ACS Applied Materials & Interfaces*, 7(37), 20714-20725, https://doi.org/10.1021/acsami.5b05584.
53. Petrosky BJ*, **Lowe KT**, Danehy PM, Wohl CJ and Tiemsin PI 2015 "Improvements in laser flare removal for particle image velocimetry using fluorescent dye-doped particles," *Measurement Science and Technology*, 26(11), 115303, https://doi.org/10.1088/0957-0233/26/11/115303.
54. Ecker T*, **Lowe KT** and Ng WF 2015 "Eddy Convection in Developing Heated Supersonic Jets," *AIAA Journal*, 53(11), 3305-3315, https://doi.org/10.2514/1.J053946.
55. Cadel DR* and **Lowe KT** 2015 "Cross-correlation Doppler global velocimetry (CC-DGV)," *Optics and Lasers in Engineering,* 71, 51-61, https://doi.org/10.1016/j.optlaseng.2015.03.012.
56. Ecker T*, **Lowe K T** and Ng W F 2015 "A rapid response 64-channel photomultiplier tube camera for high-speed flow velocimetry," *Measurement Science and Technology*, *26*(2), 027001, 6pp, https://doi.org/10.1088/0957-0233/26/2/027001.
57. Guillot S, Ng, W, Hamm HD Stang U and **Lowe KT** 2015 "The experimental studies of improving the aerodynamic performance of a turbine exhaust system," *ASME Journal of Engineering for Gas Turbines and Power,* 137(1), 012601, 13pp, https://doi.org/10.1115/1.4028020.
58. Ecker T,* Brooks DR* , **Lowe KT** and Ng W 2014 "Development and application of a point Doppler velocimeter featuring two-beam multiplexing for time-resolved measurements of high speed flow," *Experiments in Fluids*, 55, 1819-1833, https://doi.org/10.1007/s00348-014-1819-0.
59. Blanchard R, Ng W, **Lowe KT** and Vandsburger U 2014 "Simulating Bluff Body Flameholders: On the Use of Proper Orthogonal Decomposition for Wake Dynamics Validation." *ASME Journal of Engineering for Gas Turbines and Power,* 136(12), 122603, Paper No. GTP-14-1119, 12pp, https://doi.org/10.1115/1.4027556.
60. **Lowe KT**, Maisto P*, Byun G, Simpson RL, Verkamp M, Danehy PM, Tiemsin PI and Wohl CJ 2013 "Laser velocimetry with fluorescent dye-doped polystyrene microspheres," *Optics Letters*, *38*(8), 1197-1199, https://doi.org/10.1364/OL.38.001197.
61. **Lowe KT** and Simpson RL 2009 "An advanced laser-Doppler velocimeter for full-vector particle position and velocity measurements," *Measurement Science and Technology*, 20(4), 045402, 16pp, https://doi.org/10.1088/0957-0233/20/4/045402.
62. **Lowe KT** and Simpson RL 2008 "Turbulence structural measurements using a comprehensive laser-Doppler velocimeter in two- and three-dimensional turbulent boundary layers," *International Journal of Heat and Fluid Flow,* 29(3), 820-829, https://doi.org/10.1016/j.ijheatfluidflow.2008.03.003.
63. Tian Q, **Lowe KT** and Simpson RL 2007 "A three-velocity-component laser-Doppler velocimeter for measurements inside the linear compressor cascade," *Experiments in Fluids,* 43, 487-499, https://doi.org/10.1007/s00348-007-0311-5.

64. **Lowe K T**, and Simpson, R L 2006 "Measurements of velocity–acceleration statistics in turbulent boundary layers," *International Journal of Heat and Fluid Flow*, 27(4), 558-565, https://doi.org/10.1016/j.ijheatfluidflow.2006.02.003.

Articles in conference proceedings:

Note: * Indicates advisee.

1. Antous B*, Byun G, **Lowe KT** and Smith CF 2023 "Virginia Tech Optical Inlet Sensor for Particle Detection: Rolls Royce M250 Turboshaft Demonstration," *ASME IGTI Turbo Expo: Power for Land, Sea, and Air*, Vol. 87103, p. V13CT31A010.
2. Vlach T, Olshefski KT*, Bunin DJ, Ehlers AM, Caddick MJ, **Lowe KT** and Ng WF 2023 "Analysis of C-Spec Particle Breakage in a Turbine Engine Particle Ingestion Test Cell," *ASME IGTI Turbo Expo: Power for Land, Sea, and Air*, Vol. 87103, p. V13CT31A002.
3. Hayden AP*, Gillespie J*, Hefner C, Untaroiu A and **Lowe KT** 2024 "High Throughflow StreamVane Swirl Distortion Generators: Design and Analysis," *Turbo Expo: Power for Land, Sea, and Air*.
4. Powers SW*, Byun G and **Lowe KT** 2023 "Validation of Filtered Rayleigh Scattering Optical Rake Measurement Techniques in Turbomachinery Applications and Boundary Layers," *ASME IGTI Turbo Expo: Power for Land, Sea, and Air,* Vol. 86977, p. V004T05A012.
5. Tang JV, **Lowe T** and Ng W 2023 "The Effect of Thermal Non-Uniformity on Coherent Structures in Supersonic Free Jets," *AIAA AVIATION 2023 Forum*, paper AIAA 2023-3352.
6. Butt H*, Damani S, Srivastava S*, Chaware SS, Szoke M, Devenport WJ, **Lowe T**, Hales A, Colbrook M and Ayton LJ, 2023 "Pressure Gradient Effects on Boundary Layer Superstructures," *AIAA AVIATION 2023 Forum*, paper AIAA 2023-3337.
7. Roy CJ, **Lowe T**, Devenport WJ, Borgoltz A, Grzyb A*, Patil AH, Jordan WA, Binu D, Gargiulo A* and Duetsch-Patel JE* 2023 "A Blind Validation CFD Challenge Case for 3D Smooth-Body Turbulent Separation," *AIAA AVIATION 2023 Forum*, paper AIAA 2023-3986.
8. Pitt G and **Lowe T** 2023 "Ultraviolet (UV) Laser Implementation and Measurement Sensitivities in Filtered Rayleigh Scattering for Aerodynamic Flows," *AIAA AVIATION 2023 Forum*, paper AIAA 2023-4381.
9. Roy CJ, **Lowe T**, Devenport WJ, Borgoltz A, Grzyb A*, Hoge-Pail A, Jordan WA, Binu D, Gargiulo A*, Duetsch-Patel JE* 2023 "A Blind Validation CFD Challenge Case for 3D Smooth-Body Turbulent Separation," AIAA Aviation 2023 Forum, paper AIAA 2023-3986.
10. Tang JV*, **Lowe T**, and Ng W 2023 "The Effect of Thermal Non-Uniformity on Coherent Structures in Supersonic Free Jets," AIAA Aviation 2023 Forum, paper AIAA 2023-3352.
11. Pitt G* and **Lowe T** 2023 "Ultraviolet (UV) Laser Implementation and Measurement Sensitivities in Filtered Rayleigh Scattering for Aerodynamic Flows," AIAA Aviation 2023 Forum, paper AIAA 2023-4381.
12. Butt H*, Damani S, Srivastava S, Chaware SS, Szoke M, Devenport WJ, **Lowe T**, Hales A, Colbrook M, and Ayton LJ 2023 "Pressure Gradient Effects on Boundary Layer Superstructures," AIAA Aviation 2023 Forum, paper AIAA 2023-3337.

13. Warner EP* and **Lowe T** 2023 "Machine-Learned Background Quantification for Filtered Rayleigh Scattering Measurement Processing," AIAA SCITECH 2023 Forum, paper AIAA 2023-1373.
14. Gargiulo A*, Duetsch-Patel JE*, Roy CJ and **Lowe T** 2023 "Direct Investigation of Nonlinear and Nonlocal Turbulent Constitutive Relations in a Three-Dimensional, Non-Equilibrium Boundary Layer," AIAA SCITECH 2023 Forum, paper AIAA 2023-0444.
15. MacGregor DA, Gargiulo A*, Duetsch-Patel JE*, Lavoie P, and **Lowe T** 2023 "Mean and Unsteady Surface-Pressure Measurements on the BeVERLI Hill," AIAA SCITECH 2023 Forum, paper AIAA 2023-0468.
16. Hefner C, Hayden AP*, Gillespie J*, **Lowe T**, and Untaroiu A 2023 "Flutter Testing Methodology for Swirl Distortion Generators," AIAA SCITECH 2023 Forum, paper AIAA 2023-2573.
17. Hayden AP*, Hefner C, Gillespie J*, Untaroiu A, and **Lowe T** 2023 "A Computational and Experimental Analysis of Vortex Shedding from Complex Turning Vanes," AIAA SCITECH 2023 Forum, paper AIAA 2023-0049.
18. Acharya A*, Kurian J*, **Lowe T**, and Ng W 2023 "Spectral Proper Orthogonal Decomposition Downstream of a Vortex Tube Separator Array," AIAA SCITECH 2023 Forum, paper AIAA 2023-2354.
19. Sundarraj V*, MacGregor DA, Gargiulo A*, Duetsch-Patel JE*, Ozoroski TA, Hallock T, **Lowe T**, Roy CJ, Devenport WJ, Borgoltz A, Lavoie P 2023 "Estimation of Skin Friction on the NASA BeVERLI Hill using Oil Film Interferometry," AIAA SCITECH 2023 Forum, paper AIAA 2023-0988.
20. Acharya A*, **Lowe T**, and Ng W 2022 "Experimental Measurements on a Vortex Tube Separator Array," AIAA Aviation 2022 Forum, paper AIAA 2022-3260.
21. Butt H*, Damani S, Srivastava S*, Banks JT, Vishwanathan V*, Devenport WJ, **Lowe T**, Glegg SA 2022 "Pressure Gradient Effects on Low-Wavenumber Wall-Pressure Fluctuations in Turbulent Boundary Layers," 28th AIAA CEAS Aeroacoustics 2022 Conference, paper AIAA 2022-2803.
22. Fritsch D, Vishwanathan V*, **Lowe T**, Roy CJ, Devenport WJ, Croacker P, Tkachenko O, Pook D, Yasunari N, Knopp T, Stroeer P, Krumbein A, Sandberg R, Lav C, Shubham S, Bensow R 2022 "Experimental and Computational Study of the Turbulence and Pressure Fluctuations Generated by Smooth Wall Boundary Layers in Pressure Gradient," AIAA SCITECH 2022 Forum, paper AIAA 2022-0696.
23. Acharya A*, **Lowe T**, Ng W, Danehy PM, Edquist KT, Burns RA, Pham H, "Seeding Method for Velocimetry and Visualization of Supersonic Retropropulsion Nozzle Plumes," AIAA SCITECH 2022 Forum, paper AIAA 2022-0915.
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Book chapters:

1. Cutler AD and **Lowe KT** 2023 "Laser Rayleigh Scattering, Filtered Rayleigh Scattering, and Interferometric Rayleigh Scattering," in *Optical Diagnostics for Reacting and Non-Reacting Flows: Theory and Practice*, eds. Adam Steinberg and Sukesh Roy, AIAA Progress in Astronautics and Aeronautics Series, pp. 75-136, https://doi.org/10.2514/5.9781624106330.0075.0136.
2. **Lowe KT,** Bradner M and Emerson LP 2017 "Flow-rate measurement," *AccessScience,* McGraw Hill Education, New York, https://doi.org/10.1036/1097-8542.261700.

Intellectual property:

Patents

1. Kyritisis V, **Lowe KT**, Bristow M, and Loftus P, "Flow measurement for a gas turbine engine," US Patent US-11821771-B2.
2. Kyritisis V, **Lowe KT**, Bristow M, and Loftus P, "Flow measurement for a gas turbine engine," US Patent US-11796358-B2.
3. Kyritisis V, **Lowe KT**, Bristow M, and Loftus P, "Flow measurement for a gas turbine engine," US Patent US-11747236-B2.
4. Frohnapfel D*, O'Brien WF, and **Lowe KT**, "A flow distortion generator for combined swirl and pressure distortion," US Patent 10,865,818.
5. **Lowe KT**, Ng WF, and Otero Jr R* "System and method of non-intrusive anemometry," Patent No.: US 10,281,307 B2.
6. Simpson, R.L. **Lowe, K. T.**, Tian, Q. Q. "Low drag asymmetric tetrahedral vortex generators," US Patent 8,434,723.
7. Simpson, R.L. **Lowe, K. T.**, Tian, Q. Q. "Bridge pier and abutment scour preventing apparatus with vortex generators," US Patent 8,348,553.

Software

1. Gillespie J, Copenhaver W, Frohnapfel DJ*, Hoopes K, O'Brien WF and **Lowe KT**, "StreamVane design software," Proprietary design software, MATLAB, active development period: 2013-present, support ongoing.

Invited talks:

Keynote presentation

1. **Todd Lowe** 2017 "Fluorescent Particle Flow Imaging," Second International Symposium on Image based Metrology, Maui, HI, 16-21 December.

Seminars

1. **Todd Lowe** 2023 "Virginia Tech Advanced Propulsion and Power Laboratory Capabilities Overview," GE Aerospace aeromechanics discipline group. Virtual.
2. **Todd Lowe** 2023 "Enriching validation datasets: cutting-edge flow field measurements for inlet distortion," Roll-Royce, CFD+ Seminar Series. Virtual.
3. **Todd Lowe** 2023 "Cutting edge experimental techniques for inlet distortion," SAE International S-16 Committee, Summer Meeting.
4. **Todd Lowe** 2023 "In 3D aerodynamics, is it the forest or the trees? Local and large-scale aspects of turbulent flow over three-dimensional bodies," Penn State Fluid Dynamics Research Center Seminar Series.
5. **Todd Lowe** 2022 "Local and Large-scale Aspects of Turbulent Flow over Three-Dimensional Bodies" In LaRC Turbulence & Transition seminar. Virtual.
6. **Todd Lowe** 2019 "Benchmark Experiments for CFD Modeling and Validation," Seminar: George Washington University, Mechanical and Aerospace Engineering, 7 March.
7. **Todd Lowe** 2019 "Benchmark Experiments for CFD Modeling and Validation," University of Toronto Institute for Aerospace Studies, Toronto, Ontario, 5 September.
8. **Todd Lowe** and Chi Moon 2019 "Particulate Measurements for Turbine Engines: The State-of-the-Art and Beyond," Rolls-Royce, Indianapolis, IN, 7 November.
9. **Todd Lowe** 2018 "Experimental Propulsion Research at Virginia Tech: Using Thermal Non-uniformity for Supersonic Jet Noise Reduction," Seminar, University of California Irvine, April 2018.
10. **Todd Lowe** 2018 "Applied Flow Diagnostics at Virginia Tech: Enabling Advanced Propulsion and Vehicle Aerodynamics Research," Seminar, Fluid Dynamics Research Consortium, Penn State, October 4.
11. **Todd Lowe** 2016 "Applied Flow Diagnostics at Virginia Tech: Enabling Advanced Propulsion and Power Research," Seminar, Department of Mechanical and Aerospace Engineering, North Carolina State University, 1 April.
12. **Todd Lowe** 2015 "Applied Flow Diagnostics at Virginia Tech: Enabling Advanced Propulsion and Power Research," Lehigh University, Host: Prof. Justin Jaworski, 25 September 2015.
13. **Todd Lowe** 2014 "Turbulence Research by Laser Measurements," TU Dresden, Germany, Host: Prof. Jürgen Czarske, 11 December.
14. **Todd Lowe** 2013 "Time resolved diagnostics for hot supersonic jet noise," The Pennsylvania State University, Host: Prof. Dennis McLaughlin, 6 May 2013.
15. **Todd Lowe** 2013 "Time resolved Optical Diagnostics for Supersonic Shear Flow Research," AFRL, Dayton, OH.
16. **Todd Lowe** 2012 "Small scale turbulence measurements using Comprehensive Laser Doppler Velocimetry," Cambridge University, UK, Host: Prof. Nondas Mastorakos, October.

Invited talks at conferences

1. **Todd Lowe**, William Devenport, Christopher Roy, Aurelien Borgoltz, Vidya Vishwanathan, Aldo Gargiulo, Danny Fritsch, and Julie Duetsch, "Smooth Wall Separation over Bumps: Benchmark Experiments for CFD Validation" AIAA Aviation Forum, in Special Session: Experiments for Turbulence Model Validation and Evaluation, Dallas TX, 18 June 2019.
2. **Todd Lowe** and William Copenhaver "Measuring Propulsion Engine Aerodynamics using Filtered Rayleigh Scattering", IEEE RAPID Conference, Invited Session: Applications of Photonics, 21 August 2019.
3. **Todd Lowe** and Poland S "Inlet Distortion Measurement System Development," Propulsion Instrumentation Working Group conference, Jupiter, FL, Oct 2018.
4. Otero,R., **Ng, W.**, and Lowe, T., 2018 "Non-intrusive thrust detection: an acoustics-based approach", DoD Turbine Engines Technical Symposium, Dayton, OH, Sept.
5. **Todd Lowe** 2018 "Development of a benchmark problem for modeling transitional unsteady flows," UMich/NASA Symp. on Advances in Turbulence Modeling, Ann Arbor, MI, 12 July.
6. **Todd Lowe** 2012 "Novel resolved velocimetry for augmentor aeroacoustics," Augmentor Design Systems Conference, March.
7. **Todd Lowe** and Simpson RL 2012 "Recent advances in laser Doppler velocimetry: measuring more than just velocity," 50th AIAA Aerospace Sciences Meeting, Nashville, TN, 6-9 January.

Research funding:

More than $24M total, $13M credited share from sponsors including NASA, Office of Naval Research, NAVAIR, Air Force Research Laboratory, DARPA, Pratt & Whitney, Rolls-Royce.

Highlighted projects

1. Lowering Emissions and Environmental Impact from Civil Supersonic Transport (LEAN-CST), NASA University Leadership Initiative, USD 582, 148, Todd Lowe (50%), Gwibo Byun (50%), August 15, 2022 – August 14, 2025. Note: subcontract to Georgia Tech as lead. Lead P.I. Prof. Adam Steinberg.
2. Particle Ingestion Research on a Turboshaft Engine, Office of Naval Research, USD 1,759,562, Wing Ng (50%), Todd Lowe (50%), May 1, 2021 – April 30, 2025.
3. DURIP: Development of an engine test cell for investigations on impact of particle ingestion, Office of Naval Research, USD 653,359, Wing Ng (40%), Todd Lowe (40%), and Jaideep Pandit (20%), May 18, 2020 – May 17, 2021.
4. Smooth Wall Separation Over Bumps: Benchmark Experiments for CFD Validation, NASA, National Aeronautics & Space Administration, USD 600,000, Principal Investigators: Aurelien Borgoltz (25%), William J Devenport (25%), Todd Lowe (25%), Christopher J Roy (25%), 10/01/2018-09/30/2021
5. Turbulence Development in Non-Uniform Supersonic Jets for Supersonic Jet Noise Reduction, ONR, USD 517,749, 6/1/2016 – 5/30/2018, Candidate's Role: P.I., 50% credit, co-P.I.: W. Ng (50%).

Graduate advising:

PhD dissertations

	Student	Degree	Title	Date
1.	Tobias Ecker	PhD	Turbulence statistics and eddy convection in heated supersonic jets	3/20/2015
2.	Daniel Cadel	PhD	Advanced Instrumentation and Measurements Techniques for Near Surface Flows	9/20/2016
3.	Raul Otero Jr.[3]	PhD	Compressible Flow Characterization Using Non-Intrusive Acoustic Measurements	10/10/2017
4.	Tamara Guimarães	PhD	Fluid Dynamics of Tailored Swirl Distortions for Turbofan Engine Research	4/25/2018
5.	Dustin Frohnapfel[2]	PhD	Investigation of Turbofan Engine Response to Simultaneous Inlet Total Pressure and Swirl Distortion	4/8/2019
6.	Tyler Vincent[1]	PhD	Total Temperature Probe Performance for Subsonic Flows using Mixed Fidelity Modeling	4/8/2019
7.	David Mayo Jr.[3]	PhD	The Turbulence Structure of Heated Supersonic Jets with Offset Total Temperature Non-Uniformities	9/10/2019
8.	Jonathan Reardon[1]	PhD	Computational Analysis of Transient Unstart/Restart Characteristics in a Variable Geometry, High-Speed Inlet	11/26/2019
9.	Kyle Daniel[3]	PhD	Space-time Description of Supersonic Jets with Thermal Non-uniformity	12/4/2019
10.	Ashley Saltzman[3]	PhD	Spatiotemporally-resolved velocimetry for the study of large-scale turbulence in supersonic jets	1/8/2021
11.	Chi Young Moon	PhD	Optical Measurements of Gas Turbine Inlet Ingested Particles Using Machine Learning	1/19/2021
12.	Julie Duetsch-Patel[5]	PhD	Structure and Turbulence of the Three-Dimensional Boundary Layer Flow over a Hill	12/8/2022
13.	Vidya Vishwanathan[5]	PhD	The Resolution and Structure of High Reynolds Number Turbulent Boundary Layers Over Rough and Smooth Walls in Pressure Gradient	12/2/2022

14.	Sean Powers[1]	PhD	Filtered Rayleigh Scattering with an Application to Force Component Decomposition	3/22/2023
15.	Aditya Acharya[3]	PhD	Aerodynamic Interactions in Vortex Tube Separator Arrays	4/5/2023
16.	Kristopher Olshefski[3]	PhD	Development of diagnostic tools for use in a gas turbine engine undergoing solid particulate ingestion	4/19/2023
17.	Aldo Gargiulo[6]	PhD	Direct Assessment and Investigation of Nonlinear and Nonlocal Turbulent Constitutive Relations in Three-Dimensional Boundary Layer Flow	5/3/2023
18.	John Gillespie[3]	PhD	Acoustic Tomography and Thrust Estimation on Turbofan Engines	12/1/2023
19.	Andrew Hayden[7]	PhD	A Comprehensive Three-Dimensional Analysis of the Wake Dynamics in Complex Turning Vanes	11/8/2023

MS theses

	Student	Degree	Title	Date
1.	Nihar Samal	MS	A wind tunnel facility for the evaluation of a land-based gas turbine diffuser-collector	12/2011
2.	Brian Boehm	MS	Performance optimization of a subsonic Diffuser-Collector subsystem using interchangeable geometries	11/30/2012
3.	David Owens	MS	Wall Features of Wing-Body Junctions: Towards Noise Reduction	7/8/2012
4.	Donald Brooks	MS	Development of Specialized Laser Doppler Velocimeters for High Resolution Flow Profile and Turbulence Spectral Measurements	5/2014
5.	Pietro Maisto	MS	Experimental analysis and prospective flow diagnostic applications for fluorescence dye-doped microparticles	2/21/2014
6.	Nicole Heersema	MS	A Low Order Aerodynamic Model of Embedded Total Temperature Probes	10/9/2014
7.	Michael Nelson	MS	Stereoscopic Particle Image Velocimetry Measurements of Swirl Distortion on a Full-Scale Turbofan Engine Inlet	8/14/2014
8.	Tyler Englerth[1]	MS	An Experimental Conduction Error Calibration Procedure for Cooled Total Temperature Probes	2/23/2015
9.	Alex Schneider[1]	MS	Computational Modeling of High-Temperature Total Temperature Probes	1/30/2015

10.	Brian Petrosky	MS	Particle Image Velocimetry Applications of Fluorescent Dye-Doped Particles	6/21/2015
11.	Jonathan Reardon[1]	MS	Computational Modeling of Radiation Effects on Total Temperature Probes	1/29/2016
12.	Dustin Frohnapfel[2]	MS	Experimental Investigation of Fan Rotor Response to Inlet Swirl Distortion	6/7/2016
13.	Chuyoung Kim[3]	MS	Algorithms for Tomographic Reconstruction of Rectangular Temperature Distributions using Orthogonal Acoustic Rays	9/9/2016
14.	Kara Crosser	MS	Behavior of Aluminum Alloy Corrugated Naval Ship Deck Panels under V-22 Osprey Nominal Thermal Loads	9/14/2016
15.	Marcia Stuber[3]	MS	Investigation of Noise Sources in Three-Stream Jets using Turbulence Characteristics	3/28/2017
16.	Eric Rolfe[1]	MS	Impact of Total Temperature Probe of Geometry on Sensor Flow and Heat Transfer	3/28/2017
17.	Nicholas Pera[4]	MS	Development of a Method for Analysis and Incorporation of Rotorcraft Fluctuation in Synthesized Flyover Noise	6/16/2017
18.	William George	MS	Extension of Particle Image Velocimetry to Full Scale Turbofan Engine Bypass Duct Flows	7/10/2017
19.	John Gillespie[3]	MS	Aerodynamics of a Transonic Turbine Vane with a 3D Contoured Endwall, Upstream Purge Flow, and a Backward-Facing Step	8/9/2017
20.	Sean Shea	MS	Measurements of Convection Velocity in Heated and Unheated High-Speed Jets	11/14/2018
21.	Rueben Quickel[1]	MS	Mount Interference and Flow Angle Impacts on Unshielded Total Temperature Probes	6/12/2019
22.	George Boggs IV[3]	MS	Turbine engine thrust measurements using a non-intrusive acoustic technique	6/18/2019
23.	Kevin Silas[3]	MS	Phase Transform Time Delay Estimation to Counteract Spectral Haystacking Effects in Jet Exhaust Flow Measurements	8/13/2021
24.	Addison Collins[3]	MS	Development of a Novel Probe for Engine Ingestion Sampling in Parallel With Initial Developments of a High-speed Particle-laden Jet	9/12/2021
25.	Vignesh Sundarraj[6]	MS	Overview of the Skin Friction measurements on the NASA BeVERLI Hill using Oil Film Interferometry	12/14/2022

26.	Surabhi Srivastava[5]	MS	Mean Flow Characteristics and Turbulent Structures of Turbulent Boundary Layers in Varying Pressure Gradients and Reynolds Numbers	12/8/2022
27.	Brittney Antous	MS	Application of a Non-intrusive Optical Non-spherical Particle Sizing Sensor at Turboshaft Engine Inlet	2/10/2023
28.	Garrett Pitt	MS	Ultraviolet (UV) Laser Implementation, Signal Model, and Measurement Sensitivities in Filtered Rayleigh Scattering for Aerodynamic Flows	3/3/2023
29.	Joanne Tang	MS	The Effect of Thermal Non-Uniformity on Coherent Structures in Supersonic Free Jets	3/22/2023

For the PhD dissertation and MS theses tables above, superscripts indicate 50% co-advising with a colleague, as follows:
[1]Prof. Joseph Schetz
[2]Prof. Walter O'Brien
[3]Prof. Wing Ng
[4]Prof. Christopher Fuller
[5]Prof. William Devenport
[6]Prof. Christopher Roy
[7]Prof. Alexandrina Untaroiu

Instruction:

Prof. Lowe's experiences with small business and industry lend perspective for contemporary relevance in the classroom, where he teaches undergraduate and graduate courses in propulsion and fluid dynamics. He takes a great deal of care to foster a lecture atmosphere where students routinely and actively participate in classes of 150 or more students. Through his role as Co-Director of the Advanced Propulsion and Power Laboratory, he has established laboratory modules in which over 200 students annually participate. As part of the expansive Undergraduate Curriculum Redesign in AOE, he proposed a three-credit-hour course, AOE 3164 Aerothermodynamics and Propulsion, combining material from two courses required in the old curriculum and opening space for technical electives. Incorporating the required propulsion materials into the new course allowed significant revisions to AOE/ME 4234 Aerospace Propulsion Systems, increasing the value of this course as an elective, which maintains high enrollments despite no longer being required. He has also developed a three-credit-hour graduate course, AOE 5154 Data Analysis in Fluid Dynamics, addressing a need shared by several research groups at Virginia Tech for skills in applied statistics methods for turbulence. In each class taught, he employs a hybrid, "flipped" class style in which course content is delivered via lecture videos, while class experiences are reserved for interactive problem solving and programming exercises. These activities are further enhanced by incorporating industry hardware and research facilities for demonstrations and hands-on assignments, including the use of actual jet engines that students can access at Virginia Tech.

In partnership with Pratt & Whitney, and in collaboration with Dr. David Gray of Engineering Education, Prof. Lowe led the establishment of a new undergraduate engagement program focused on sustainability in aerospace propulsion. The "English-to-Engineering", or E2E, program aims at exposing diverse groups of students of all levels of undergraduate study to contemporary issues in the propulsion industry, while supporting the students' development of industry-relevant communication skills, as well as skills for research and technical project execution. E2E students routinely engage with technical fellows and executive leadership at Pratt & Whitney, receiving detailed feedback on devising and executing projects with industry relevance. The initiative has gained annual grant funding from Pratt & Whitney of $100k per year for its sustainment. This program began from experiences in AOE 3164 with an inaugural cohort of 10 juniors in spring 2022 and expanded in fall 2022 to include 26 students from all levels of undergraduate study and including at least 8 students from underrepresented or underserved groups. The original 10 students proposed and established the project areas that are now mainstays of the program covering topics such as sustainable aviation fuel adoption and wildfire ash mitigation. The program has further expanded to 30 students in fall 2023, with nearly half the participants being from underrepresented or underserved groups in aerospace engineering. Alumni of the program now hold roles in the aerospace industry and graduate school.

Courses taught

- AOE 3164 Aerothermodynamics and Propulsion
  Semesters taught: Spring 2019 – 2022
  Average Enrollment: 160 students, Average Student Evaluation: 5.2/6.0
- AOE/ME 4234 Aerospace Propulsion Systems

Semesters taught: Fall 2011 – 2019
Average Enrollment: 132 students, Average Student Evaluation: 5.2/6.0

- AOE 4814: Special Topics in Propulsion
  Semesters taught: Spring and Fall 2023
  Enrollments: 6 (Spring 2023), 30 (Fall 2023), Average Student Evaluation: 5.6/6.0
- AOE 5154: Data Analysis in Fluid Dynamics
  Semesters taught*:* Spring 2015-2018, 2020, Fall 2021, Fall 2022
  Average Enrollment: 17, Average Student Evaluation: 5.4/6.0
- AOE/ME 5135 Vehicle Propulsion
  Semester taught: Fall 2014, 2017 – 2019
  Average Enrollment: 31, Evaluation: 5.7/6.0
- AOE 6114 Transonic Aerodynamics
  Semesters taught: Spring 2012, 2014, 2016
  Average Enrollment: 8, Average Student Evaluation: 5.0/6.0
- AOE 4984 SS: Aero Engine Design Modeling
  Semesters taught: Spring 2012, Spring 2013
  Average Enrollment: 11, Average Student Evaluation: 5.7/6.0

Courses developed and listed in university course catalogs

- AOE 5154 Data Analysis in Fluid Dynamics*:* 3 credit hour graduate course covering data analysis techniques and their role in fluid dynamics research.
- AOE 3164 Aerothermodynamics and Propulsion Systems: 3 credit hours undergraduate course on fundamental principles of aerothermodynamics applied to aerospace propulsion system performance analysis and design.