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RESEARCH INTERESTS

Unmanned Aircraft Systems (UAS); computational, experimental, and analytical aero-gas dynamics/thermophysics, specifically dense gas dynamics and high-speed aerodynamics, Monte Carlo simulation (rarefied gas dynamics)

EDUCATION

Ph.D., Aerospace Engineering, University of Oklahoma, 1989, NSF Fellow, GEM Fellow.

M.S., Mechanical Engineering, University of Oklahoma, 1986.

B.S. with distinction, Aerospace Engineering, University of Oklahoma, 1983.

PROFESSIONAL EXPERIENCE

Look Professor of Engineering, Department of Aerospace Engineering Sciences, University of Colorado, 7/06-present

Co-Founder and Director, Research and Engineering Center for Unmanned Vehicles, 1/04-present

Associate Chair, Department of Aerospace Engineering Science, University of Colorado, 8/01-8/04

Associate Professor, Department of Aerospace Engineering Sciences, University of Colorado, 4/99-present

Assistant Professor, Department of Aerospace Engineering Sciences, University of Colorado, 8/92-4/99

AFOSR Summer Faculty Researcher, Wright Lab, Wright-Patterson AFB, OH, 5/92-7/92

Assistant Professor, School of Aerospace and Mechanical Engineering, University of Oklahoma, 5/89-8/92

Instructor, School of Aerospace and Mechanical Engineering, University of Oklahoma, 8/86-5/89

Tutor/Counselor, Minority Engineering Programs, University of Oklahoma, 8/82-8/88

Member of the Technical Staff, Summer Intern, Fluid Mechanics Dept., The Aerospace Corp., El Segundo, CA, 1983 and 1984

REVIEW BOARDS AND PANELS

USAF Scientific Advisory Board (2005-pres.)

NASA Academy of Program and Project Leadership, Management Operations Working Group (2003-pres.)

USAF Scientific Advisory Board (ad hoc member), UAV Study, Vehicles Panel (Feb.-Jun. 2003)

NASA LaRC Peer Review Panel (Jan. 2003)

Defense Science Study Group (IDA, DARPA) (Sept. 1999 – Dec. 2001)

NASA Advisory Council, Aeronautics and Space Transportation Technology Advisory Committee, Airframe Systems Subcommittee, 1997-2000

Manufacturing Technology & Aerospace Proposal Review Panel, Texas Advanced Research/Advanced Technology Programs, Texas Higher Education Coordinating Board 1995-1997

TEACHING AWARDS

University of Colorado Marinus Smith Award, 2003

2003 Subaru Teaching Spotlight Award

University of Colorado President's Teaching Scholar, 2000 (lifetime guild appointment)

University of Colorado Boulder Faculty Assembly 1996-1997 Teaching Excellence Award

University of Colorado 1996 Charles A. Hutchinson Teaching Award

W. M. Keck Foundation's 1995 Engineering Teaching Excellence Award

PUBLICATIONS

1. Archival Journals

- 1.1. Guardone, A., Argrow, B., "Nonclassical gasdynamic region of selected fluorocarbons," *Physics of Fluids*, **17**, 116102 (2005).
- 1.2. Farhat, C., Argrow, B., Nikbay, M, and Maute, K., "Shape Optimization with F-Function Balancing for Reducing the Sonic Boom Initial Shock Pressure Rise," *International Journal of Aeroacoustics*, **3**, 361-378 (2004).
- 1.3. Guardone, A., Vigevano, L., and Argrow, B., "Assessment of thermodynamic models for dense gas dynamics," *Physics of Fluids*, **16**, 3878 (2004).
- 1.4. Ferguson, S., Guardone, A., and Argrow, B., "Construction and Validation of a Dense Gas Shock Tube," *J. Thermophysics and Heat Transfer*, **17**, 326 (2003).
- 1.5. Ferguson, S. H., Ho, T. L., Argrow, B. M., and Emanuel, G., "Theory for Producing a Single-Phase Rarefaction Shock Wave in a Shock Tube, *Journal Fluid Mechanics*, **445**, 37 (2001).
- 1.6. Brown, B. P. and Argrow, B. M., "Application of Bethe-Zel'dovich-Thompson Fluids in Organic Rankine Cycle Engines," *Journal of Propulsion and Power*, **16**, 1118 (2000).
- 1.7. Graves, R. E. and Argrow, B. M., "Bulk Viscosity: Past to Present," *J. Thermophysics and Heat Transfer*, **13**, 337 (1999).
- 1.8. Brown, B. P. and Argrow, B. M., "Characteristic Calculation of Equilibrium Flow in Minimum Length Nozzles," *Inverse Problems in Engineering*, **7**, 65 (1999).
- 1.9. Brown, B. P. and Argrow, B. M., "Nonclassical Dense Gas Flows for Simple Geometries," *AIAA Journal*, **36**, 1842 (1998).
- 1.10. Brown, B. P. and Argrow, B. M., "Two-Dimensional Shock Tube Flow for Dense Gases," *Journal Fluid Mechanics*, **349**, 95 (1997).
- 1.11. Argrow, B. M., "Shock Tube Flow for Dense Gases," *Shock Waves*, **6**, 241 (1996).
- 1.12. Aldo, A. C. and Argrow, B. M., "Dense Gas Flow in Minimum Length Nozzles," *Journal of Fluids Engineering*, **117**, 270 (1995).
- 1.13. Rohrs, H. W., Wickham-Jones, T., Ellison, G. B., Berry, D., and Argrow, B. M., "FTIR Absorption Spectroscopy of Jet-Cooled Radicals," *Review of Scientific Instruments*, **66**, 2430 (1995).
- 1.14. Emanuel, G. and Argrow, B. M., "Linear Dependence of Bulk Viscosity on Shock Wave Thickness," *Physics of Fluids*, **6**, 3203 (1994).
- 1.15. Argrow, B. M. and Cox, R. A., "A Quantitative, Second-Law Based Measure of Numerical Accuracy," *Thermodynamics and the Design, Analysis, and Improvement of Energy Systems*, AES-30/HTD-266, ASME, 49 (1993).
- 1.16. Cox, R. A., and Argrow, B. M., "Entropy Production in Finite-Difference Schemes," *AIAA Journal*, **31**, 210 (1993).
- 1.17. Borth, C. J. and Argrow, B. M., "Evaluation of Entropy Production and Numerical Entropy Change in Flowfield Solutions," *Second Law Analysis: Industrial and Environmental Applications*, AES-25/HTD-191, 101 (1991).
- 1.18. Argrow, B. M. and Emanuel, G. "Computational Analysis of the Transonic Flow Field of Two-Dimensional Minimum Length Nozzles," *Journal of Fluids Engineering*, **113**, 479 (1989).
- 1.19. Argrow, B. M. and Emanuel, G., "Comparison of Minimum Length Nozzles," *Journal of Fluids Engineering*, **110**, 283 (1988).
- 1.20. Argrow, B. M., Emanuel, G., and Rasmussen, M. L., "Entropy Production in General Nonsteady Coordinates," *AIAA Journal*, **25**, 1629 (1987) (Errata, **27**, 986 (1989)).

2. Editorial

- 2.1. Argrow, B. M., "A Survey of Facilities for High-Temperature, High-Pressure Fluids Experiments," Special Feature, *Measurement Science and Technology*, **16** (2006)

3. Conference Proceedings

- 3.1. Argrow, B., "Cooperative Mobile Sensing Systems for In Situ Measurements in Hazardous Environments," AGU Fall Meeting, San Francisco, 5-9 Dec 2005. (Invited)
- 3.2. Elston, J., Argrow, B., and Frew, E., "A Distributed Avionics Package for Small UAVs," AIAA Paper 2005-6984, Infotech@Aerospace, Sep. 2005.
- 3.3. Dixon, C., Frew, E., and Argrow, B., "Radio Leashing of an Unmanned Aircraft," AIAA Paper 2005-7030, Infotech@Aerospace, Sep. 2005. (Invited)
- 3.4. Frew, E., Dixon, C., Argrow, B., and Brown, T., "Radio Source Location by a Cooperating UAV Team," AIAA Paper 2005-6903, Sep. 2005.
- 3.5. Argrow, B., Rasmussen, E., and Lawrence, D., "UAV Systems for Sensor Dispersal, Telemetry, and Visualization in Hazardous Environments," AIAA Paper 2005-1237, 43rd AIAA Aerospace Sciences Meeting and Exhibit, Jan. 2005.
- 3.6. Bateman, T., Argrow, B., Sheek, M., Hanft, J., Dean, A., and Blakeley, B., "USAS, A Stability Augmentation System," AIAA Paper 2004-6587, AIAA 3rd Unmanned Unlimited Technical Conference, Workshop and Exhibit, Sep. 2004.
- 3.7. Brown, T., Argrow, B., Dixon, C., and Doshi, S., "Ad Hoc UAV Ground Network (AUGNet)," AIAA Paper 2004-6321, AIAA 3rd Unmanned Unlimited Technical Conference, Workshop and Exhibit, Sep. 2004.
- 3.8. Argrow, B., Farhat, C., Maute, K., and Nikbay, M., "Linear-Theory-Based Shape Optimization for Sonic Boom Minimization," IUTAM Symposium Transsonicum IV, Göttingen, Germany, Sep. 2002. (Invited)
- 3.9. Farhat, C., Argrow, B., Maute, K., and Nikbay, M., "A Shape Optimization Methodology with F-Function Lobe Balancing for Mitigating the Sonic Boom," AIAA Paper 2002-5551, 9th AIAA/ISSMO Symposium and Exhibit on Multidisciplinary Analysis and Optimization, Atlanta, GA, Sep. 2002.
- 3.10. Argrow, B. M., "Proactive Teaching and Learning in the Aerospace Engineering Curriculum 2000," Proceedings of the ASEE Annual Conference and Exposition, Montreal, June 2002.
- 3.11. Argrow, B. and Curry, J., "Integration of UAV Senior Projects into the Curriculum 2000," AIAA Paper 2002-3485, 1st AIAA Unmanned Aerospace Vehicles, Systems, Technologies, and Operations Conference and Workshop, Portsmouth, VA, May 2002.
- 3.12. Dixon, C., Eheim, C., Argrow, B., and Palo, S., "Tornado Chaser: A Remotely Piloted UAV for In Situ Meteorological Measurements," AIAA Paper 2002-3479, 1st AIAA Unmanned Aerospace Vehicles, Systems, Technologies, and Operations Conference and Workshop, Portsmouth, VA, May 2002.
- 3.13. Farhat, C., Maute, K., Argrow, B., and Nikbay, M., "Shape Optimization Methodology for Reducing the Sonic Boom Initial Shock Pressure Rise," AIAA Paper 2002-0145, 40th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, Jan. 2002.
- 3.14. Ferguson, S. H. and Argrow, B. M., "Simulation and Experimental Verification of Rarefaction Shock Waves in a Single-Phase Vapor," 23rd International Symposium on Shock Waves, Ft. Worth, TX, July 2001.
- 3.15. Ferguson, S. H. and Argrow, B. M., "Construction and Operation of a Dense Gas Shock Tube," AIAA Paper 2001-2747, 35th AIAA Thermophysics Conference, Anaheim, CA, June 2001. (Invited Paper)
- 3.16. Ferguson, S. H. and Argrow, B. M., "Simulations of Nonclassical Dense Gas Dynamics," AIAA Paper 2001-2752, 35th AIAA Thermophysics Conference, Anaheim, CA, June 2001. (Invited Paper)
- 3.17. Brown, B. P. and Argrow, B. M., "Application of Bethe-Zel'dovich-Thompson Fluids in Organic Rankine Cycle Engines," AIAA Paper 99-0462, 37th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, Jan 1999.
- 3.18. Brown, B. P. and Argrow, B. M., "Nonclassical Dense Gas Flows for Simple Geometries," AIAA Paper 97-1881
- 3.19. Seebass, A. R. and Argrow, B. M., "Sonic Boom Minimization Revisited," AIAA Paper 98-2956, 2nd AIAA Theoretical Fluid Mechanics Meeting, Albuquerque, NM, June 1998.

- 3.20. Graves, R. E. and Argrow, B. M., "Bulk Viscosity: Past to Present," AIAA Paper 98-2576, 7th AIAA/ASME Joint Thermophysics and Heat Transfer Conference, Albuquerque, NM, June 1998.
- 3.21. Miller, R. W., Argrow, B. M., Center, K. B., Brauckmann, G. J., and Rhode, M. N., "Experimental Verification of the Osculating Cones Method for Two Waverider Forebodies at Mach 4 and 6," AIAA Paper 98-0682, 36th Aerospace Sciences Meeting & Exhibit, Reno, NV, January, 1998.
- 3.22. Miller, R. W. and Argrow, B. M., "Subsonic Aerodynamics of an Osculating Cones Waverider," AIAA Paper 97-0189, 35th Aerospace Science Meeting & Exhibit, Reno, NV, January, 1997.
- 3.23. Aldo, A. C. and Argrow, B. M., "Dense Gas Flow in Minimum Length Nozzles," NASA CP-10122, 1995.
- 3.24. Argrow, B. M. and Emanuel, G. "Computational Analysis of the Transonic Flow Field of Two-Dimensional Minimum Length Nozzles," AIAA Paper 89-1822, 1989.

4. Special Reports

- 4.1. USAF Scientific Advisory Board (contributing author), "Unmanned Aerial Vehicles in Perspective: Effects, Capabilities, and Technologies, Vol. 1," SAB-TR-03-01, Sept. 2003.
- 4.2. Argrow, B. M., "Assessment of the Impact of Low-Cost Robotic Aircraft to National Security," IDA Paper-3704, Institute for Defense Analysis, Defense Science Study Group, Feb. 2002, pp.79-101.

RESEARCH FUNDING

PI: Small UA Prototype Construction and Test Project, EIM Corp., 9/06-12/06, \$11,091.

PI: Design, Fabrication, and Test of a Wing-Integrated Antenna, Phase-1 SBIR with First RF Corp., 9/06-12/06, \$15,384.

Co-PI: UAV Sensor Data Collection, L3 Communications, 1/06-6/06, \$258,727.

Co-PI: Sea Ice Freeboard, Roughness and Topography from UAV Laser Profilometry, Satellite and Surface Observations: Relationships to Ice Dynamical and Thermodynamical Properties, NSF, 10/05-4/08, \$333,064.

PI: SNC Spartan UAV Prototype: Design, Fabrication, Assembly, and Test, Sierra Nevada Corp., 6/05-12/05, \$40,994

Co-PI: Ad Hoc UAV-Ground Networking (AUGnet) Project and Networked UAV C3: Integration, Deployment, and Test Plan, L3Communications, 7/03-6/05, \$590,000.

Co-PI: Supersonic Aircraft Shaping Technology for a Constrained Shock Pressure Rise, NASA, 10/1/02-9/30/03, \$150,000

PI: Vertical Integration in the Aerospace Engineering Curriculum 2000, Lockheed Martin, 6/1/2002-5/31/2005, \$150,000

Co-PI: Shape Optimization for Sonic Boom Minimization, DARPA, 1/1/01-12/31/01, \$350,000

PI: Supplemental Equipment for a Dense Gas Shock Tube, NSF, 3/15/00, \$18,270

Co-PI: Applications of Aerosondes to Long Term Measurements of the Atmosphere and Sea Ice Surface in the Beaufort/Chukchi Sector of the Arctic Ocean, NSF, 6/99-5/04, \$3,997,402

PI: Experimental Investigation of Dense Gas Dynamics, NSF, 6/99-6/02, \$260,000

Co-PI: A Workshop on Dense Gas Dynamics, NSF, 2/99-1/00, \$10,100 (\$2,600 CU, \$7,500 Institute for Advanced Physics)

Co-PI: Optimization and Analysis of a Waverider Vehicle for Global Spaceplane Trajectories, AFOSR, 1/98-12/98, \$25,000

PI: Engineering Applications of Dense Gases, Phase 1: Advanced Computational Methods, NSF, 7/96-6/97, \$50,000

PI: Subsonic and Supersonic Testing of Osculating-Cones Derived Waveriders, NASA, 7/96-6/98, \$44,000.

Co-PI: Measurements of Vertical Air Velocities from Radar (ARMAR) and DC-8 Aircraft, NASA, 7/94-6/95, \$22,000

PI: Numerical Entropy Production in Navier-Stokes Solutions, EPSCoR/NSF, 1/90-3/92, \$60,000

SELECTED TALKS & SEMINARS

NOAA: *Cooperative Mobile Sensing Systems for In Situ Measurements in Hazardous Environments*, Dec. 2005

Lockheed Martin: *Ad Hoc UAV Ground Network (AUGNet)*, Lockheed Martin, Nov. 2004

Dept. Aerospace Engineering and Mechanics, University of Minnesota *Research and Engineering Center for Unmanned Vehicles*, May 2004

DARPA 2003 QSP Technology Exchange Meeting: *Linear Theory Based Optimization for Sonic Boom Minimization*, Nov. 2003

University of Colorado Faculty Teaching Excellence Program Symposia on Teaching and Learning: *Pro-Active Teaching & Learning*, Sept. 1999, Feb. 2003.

Computer Science Dept., Colorado State University *Pro-Active Teaching & Learning*, June 2001

DARPA QSP Kickoff Meeting: *Supersonic Aircraft Shaping Technology for Constrained Shock Pressure Rise*, Dec. 2000

University of Colorado, College of Engineering and Applied Sciences Excellence in Teaching Series: *Pro-Active Teaching & Learning in the AES Curriculum 2000*, Feb. 1999

COURSES TAUGHT

Undergraduate: Introduction to Thermodynamics and Aerodynamics, Aerodynamics, Thermodynamics, Gas Dynamics, Space Science and Systems, Dynamics, Introduction to Engineering Computing.

Graduate: Unmanned Aircraft Systems in the National Airspace System, Real Gas Dynamics, High-Speed Aerodynamics, Rarefied Gas Dynamics, DSMC Gas Dynamics, Spaceflight Dynamics, Advanced Engineering Analysis.

GRADUATE STUDENTS

Graduated Ph.D.: Brady Brown (1997), Rick Graves (1999), Stephen Ferguson (2001)

Graduated M.S. with thesis: Alok, Gautam (1992), Charles Aldo (1993), Brady Brown (1994), Gregory Melvin (1995), Rolf Miller (1998)

Current Ph.D candidates: Cory Dixon, Jack Elston, Eric Paulson

PROFESSIONAL MEMBERSHIPS

American Institute of Aeronautics and Astronautics (Senior Member)

Technical Program Committee Infotech@Aerospace Conference, Washington, DC (2005)

Technical Program Committee, Unmanned Unlimited Conference, Workshop, and Exhibit, Chicago (2004)

Technical Program Co-Chair, 2nd Unmanned Unlimited Conference Systems Technologies, and Operations—Aerospace, Land, and Sea Conference, Workshop, and Exhibit, San Diego (2003)

Technical Program Co-Chair, 1st Unmanned Aerospace Vehicles, Systems, Technologies, and Operations Conference and Workshop, Portsmouth, VA (2002)

American Physical Society

American Society for Engineering Education

Society of Automotive Engineers

CONSULTING

Lockheed Martin, “Aerocapture Inflatable Decelerator” (2004-pres)

Williams Professional Services, LLC (2002)

“Kaiser-Hill Independent Safety Assessment,” Contract No. WPS-SUB02-003

“Evaluation of DOE Standard 3013-2000,” Contract No. DE-AT01-01EW07005

Krispin Technologies, Inc., “Innovative Organic Rankine Cycle Engines,” National Science Foundation SBIR Contract No. 9860391 (1998)

ITT Industries, Systems Division, “High Altitude Scoping,” Contract No. DASG6098-C-0099 (1999-2000)

Research Statement

After receiving my Ph.D. in 1989, my research was initially focused on computational gas dynamics. This evolved into general computational fluid dynamics and eventually to dense gas dynamics, where I have made my most significant research contributions. My high-speed aerodynamics research included a 1995 wind tunnel study that verified the method of osculating cones [3.21, 3.22]; a method that was developed at the University of Colorado. My high-speed aerodynamics research continues in the area of sonic boom. My current research focus is unmanned vehicle systems. The following is a more detailed summary of my research projects and future research plans.

Dense Gas Dynamics was the focus of my research from 1993-2000. My initial interest was to model dense gas behavior with state-of-the-art computational fluid dynamics (CFD). At the time most “advanced” CFD was focused on modeling the aerodynamics of ideal gases such as air, or combusting gases that can still be considered as thermally perfect gas mixtures. To model a dense gas, i.e., a single-phase vapor near the liquid-vapor coexistence curve, the gas must be modeled as both thermally and calorically imperfect. For the high-molecular-weight molecules of interest, this means very complex thermal and caloric state equations must be incorporated. My graduate students and I first applied the nozzle design methods used in my graduate work to the design of supersonic nozzles for dense gases [1.12]. Following a review of the experimental methods of other researchers in related areas, I developed a shock tube design to study dense gas phenomena. My 1996 paper was the first to show CFD results for the complete unsteady, one-dimensional shock tube wavefield for a dense gas [1.11]. With NSF funding, my graduate students and I designed and built a prototypical dense gas shock tube for experiments [1.4]. Parallel to the experimental effort, we continued to use CFD with increasingly more advanced equations of state [1.10, 1.9, 1.6, 1.5]. In the spring of 2001, Alberto Guardone, a Ph.D. candidate from the Dipartimento di Ingegneria Aerospaziale, Politecnico di Milano, Italy spent six months in my research group. He brought an advanced flow solver that we integrated with our equation of state models to produce a new level of computational modeling with simulation results that reproduced all of the important features observed in the experiments [1.4]. In 2004, a team led by Professor Piero Colonna, with Dr. Guardone as a co-investigator, started the construction of a new dense gas shock tube facility at Delft University of Technology. The shock tube is based on my original design. I am a member of the steering committee for this team and continue to collaborate with Dr. Guardone and the Delft-Milano Team to apply complex equations of state to the computational dynamics of dense gases [1.3, 1.1].

Sonic Boom Minimization. During the late 1950s through the early 1970s, NASA led the international focus on sonic boom research. The goal was to understand the origins of sonic boom and the development of aircraft technologies to mitigate its effects. In 1998, Prof. A Richard Seebass and I co-authored a paper that revisited the sonic boom work of the earlier decades [3.19], thus my introduction to the field. At that time Prof. Seebass was the leading international authority on sonic boom. In 2000, national sonic boom research was resurrected with DARPA’s Quiet Supersonic Platform (QSP) Program and the AES team of Professors Seebass, Charbel Farhat, Sedat Biringen, and Brian Argrow, was one of the university teams to receive a DARPA QSP grant. We proposed to couple linear-theory-based aerodynamic optimization, pioneered by Prof. Seebass and his former colleague Alfred George, with the advanced computational optimization methods developed by Prof. Farhat and his research group. Initially, mine was a secondary role, but with the death of Prof. Seebass in November 2000, one month prior to the kickoff of the QSP Program, I became responsible for the development of the aerodynamic and acoustic propagation theories. In December 2000 I delivered our Team’s briefing at the QSP kickoff meeting. Following our DARPA work, we received additional funding from NASA to flesh out some of the ideas we had developed. My most significant contribution is the theory of *F-Function Lobe Balancing to Produce Multiple-Shock Signatures*; I introduced this theory in an invited session of the 2002 Transonicum IV meeting in Göttingen, Germany [3.8]. An early form of the theory is employed in our 2004 *International Journal of Acoustics* publication [1.2]. I believe lobe balancing will be a key component of future sonic boom minimization research.

There is much to be done in sonic boom minimization. The origins of sonic boom were well understood by the late 1960s, however the computational requirements for aircraft shape optimization were too great. Since that time, computational capability, in terms of computer speed and algorithm efficiency, has increased several orders of magnitude, yet the understanding of the basic flow physics and appropriate models has (in my opinion) atrophied as experts have retired, died, or been ignored. I believe that the linear-theory-based aircraft shape optimization will prove to be the key to the design of a supersonic business jet with an acceptable sonic boom signature. Evidently, sonic boom

research will be one of the focuses of the renewal of NASA aeronautics funding.¹ With my current research and ideas I believe I will be competitive for this funding.

Unmanned Vehicle Systems. In 2002, the AES External Advisory Board expressed concern that the balance of the Department was too much on the side of aeronautics and space science. Concurrent with this observation was the growing national interest in unmanned aerial vehicles (UAVs). At that time I made the decision to redirect my research focus to unmanned vehicle systems. I had a long-standing interest in the use of unmanned aircraft to obtain *in situ* measurements in severe thunderstorms and starting around 2000, in collaboration with Dr. Erik Rasmussen from NOAA's National Severe Storms Laboratory (NSSL), I began to sponsor senior projects to develop a small unmanned aircraft system to penetrate severe storms. I saw an opportunity to address my growing research interest and to simultaneously bring a renewed aeronautics focus to the Department. In 2002, I was a Technical Program Co-Chair of the 1st AIAA Unmanned Aerospace Vehicles, Systems, Technologies, and Operations Conference and Workshop. In the spring of 2003, I began to organize a nucleus of about 10 faculty members from throughout the College to start a research center for unmanned vehicles. During the summer of 2003, I and Professor George Morgenthaler co-founded the Research and Engineering Center for Unmanned Vehicles (RECUV) and since January 2004 I have been the Center Director. RECUV currently rosters 20 faculty and has two Corporate Sponsors, Lockheed Martin and Raytheon, and one Associate Sponsor, NAVSYS. Center research contracts currently total about \$2.5M. The vision I share with my RECUV colleagues is to develop an infrastructure for Cooperative Mobile Sensing Systems to do *in situ* sensing in environments that are too dangerous, or too hard to reach for manned systems.

During the summer of 2003, with USAF funding through L3 Communications, Professor Timothy Brown and I began the development of the AUGNet (Ad Hoc UAV and Ground Network) test bed. Over the past 2-1/2 years, we have received about \$850k to develop an experimental test bed to investigate WiFi mobile ad hoc networks. Our first experimental campaign concluded in October 2004 with successful experiments and demonstrations that involved as many as three UAV-borne radio nodes in a network with automobile-mounted and fixed ground nodes. The scope of this research continues to expand as we now deploy fully autonomous unmanned aircraft systems (UAS) [3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7]. In the spring of 2003 Prof. Eric Frew was hired into AES and RECUV and he is now a full AUGNet Co-Investigator. Integration of communications and control in UAS design is now our current focus. I am sponsoring an AY 2005-06 senior project to deploy a "smartsonde" proof-of-concept vehicle. Smartsonde is a term I recently introduced to describe a small sonde instrument package integrated into a micro aerial vehicle (MAV). The project will demonstrate the feasibility of using a UAV mothership to deploy several smartsondes that will then fly to a designated GPS waypoint to return meteorological data as they descend to the Earth. Organizers of the proposed VORTEX-II (Verification of Origins in Rotation in Tornadoes Experiment) Field Experiment have proposed that RECUV UAVs be part of the experiments planned for 2007-08. I recently visited Dr. Stephan Nelson, the NSF Program Director of Physical and Dynamic Meteorology to discuss this opportunity. We will be notified by his office in June 2006 if NSF funds will be allocated for the VORTEX-II campaign. If this announcement is positive, I will finally begin to realize my dream of designing and building a UAS to penetrate severe storms. This project will integrate the autonomous UAVs we have developed in the AUGNet program with the smartsondes to be deployed into developing storms.

¹ <http://www.aiaa.org/pdf/industry/presentations/revital05romanowski.pdf>

Teaching Statement

I believe I have had a significant influence on education, particularly undergraduate education, in the Department and the College and, as a President's Teaching Scholar, in the University. The following are some of the highlights of how my thesis on knowledge and curriculum, and teaching and learning, have helped to change the direction of undergraduate education in the Department. I have conducted teaching workshops for the College and the University's Faculty Teaching Excellence Program, and many of my teaching methods are implemented on a daily basis throughout the University.

Proactive Teaching and Learning. The Pro-Active Philosophy emerged from my own learning and teaching experiences, and from observing the interactions of instructors, teachers, and students. Much of the philosophy is based upon my learning experiences from two award-winning teachers *and* researchers from the University of Oklahoma: Professor Maurice Rasmussen, from the School of Aerospace and Mechanical Engineering, and Professor Michael Morrison, from the Department of Physics and Astronomy. Professor Rasmussen was the first to make me aware of the importance of conceptual knowledge relative to operational knowledge. Professor Morrison was the first I observed to use daily reading assignments with individual and group quizzes to reinforce reading comprehension. These professors are *teachers*—a distinction to be made from instructors. Instructors give instructions (usually by lecturing), i.e., they generally emphasize rote procedures. Teachers supplement instructions and *enable* students to learn. The intent is not to imply that instruction is wrong, it is simply not enough. The teacher's primary objective is to enable students to master the components of knowledge. Thus, a teacher must develop a set of enabling tools and must be able to assess their effectiveness. Enabling students to learn necessarily requires active participation and increased responsibility for their learning experiences. This is the essence of my Pro-Active Philosophy:

Proactive Teaching & Learning: Instruction and learning begin with instructor and student preparation. The classroom is not a place for instructors to show how much they know—the classroom is the place to learn what students do not know so those things become known.

In the Fall of 1997, I introduced the Proactive Philosophy for Teaching and Learning with the inception of the Aerospace Curriculum 2000 (C2000) [3.10]. I was one of the three untenured, junior faculty members who led the complete overhaul of the AES curriculum. The C2000 is the result of a complete reformation of curricular content, and a new teaching and learning paradigm, based on my Proactive Philosophy. The Integrated Teaching and Learning Laboratory enabled the new teaching and learning paradigm to be horizontally integrated with the focus on the engineering sciences, hands-on experiments, and product design in a teaming environment. In 1999, this curriculum passed its initial ABET review at the highest level. The preliminary findings from the second visit in the fall of 2005 indicate the same level of ABET assessment. My thesis on knowledge and curriculum, and how it is implemented in the C2000 is presented in Ref. [3.10].

An Emergent Engineering Systems Curriculum. In 2003, as AES Associate Chair, I created a Senior Projects Committee to review the senior projects sequence. The original implementation of the C2000 in 1997 focused primarily on the sophomore and junior reorganization. The senior projects course sequence did not fully leverage the potential for our faculty and students to create a unique capstone experience. The senior projects course sequence is now an appropriate capstone experience. (My colleague Professor Lee Peterson refers to it as a “prototypical engineering experience.”) With the project course now in place, an emergent outcome of the C2000 are students well-versed in the concepts and practices of systems engineering without a single course in the C2000 that labeled systems engineering. A secondary benefit of teaching this curriculum is that the entire AES faculty is more educated in systems engineering. References [3.2, 3.6, 3.11, 3.12] document the development of the capabilities of the AES C2000 as verified by the complexity and quality of several projects.

In each of the projects previously cited, several of the students chose to continue their graduate work in my research group, thus verifying the continuum of research and education. Two of my current PhD candidates began working with me with independent study projects, followed by a senior project, and now to dissertation topics. The distributed computing system and virtual cockpit described in [3.2, 3.12] is now forms the basis for our AUGNet [3.1, 3.2, 3.3, 3.4, 3.5, 3.7, **Error! Reference source not found.**] research. I am heavily involved with undergraduate research programs, with at least two or three projects per year sponsored through the Undergraduate Research Opportunities Program. In 2003, I also created our team that competes in the annual AIAA Design, Build, and Fly Competition. The current team is composed of about 30 students from several of the College's engineering departments and the Physics Department. This team has proved to be a fertile “proving ground” from which I harvest students for senior projects or direct

involvement in my funded research. These activities exemplify my ideal that students should come to a research university to become educated in the professional practice and research with an integrated experience.

Service Statement

My commitment to service, in the name of the University, is evident through the local, national, and international activities. Much of this service has been associated with teaching and learning initiatives and includes my ongoing K-12 outreach commitment to middle- and high-school teachers, and underrepresented students of color in the Denver Public Schools. My service is also administrative, as former AES Associate Chair, and Co-Founder and current Director of the Research and Engineering Center for Unmanned Vehicles. Most of my national service has been with the NASA and USAF Advisory Boards. My international current international service is as a member of the Steering Committee for dense gas dynamics research at the Delft University of Technology. The following summary emphasizes the breadth of my service activities, and hopefully imparts some sense of the degree to which I consider the importance of these and future service activities.

Administration. As AES Associate Chair (2000-2004) one of my most important accomplishments was to lead the overhaul of our Sr. Projects capstone courses so that our students could fully utilize the systems engineering experience from earlier portions of the Curriculum 2000. As the current chair of the AES Curriculum and Teaching Committee, I am leading the implementation of our new plan, presented during last year's ABET visit, that closes the assessment loop for the Curriculum 2000. This loop is closed with an outcomes assessment of the capstone sequence that is fed back for the annual overall curriculum evaluation and planning. By measuring what the seniors can do in a design, build, test, and verify capstone experience, we fine-tune the preceding curriculum to address the assessed needs.

As Director of the Research and Engineering Center for Unmanned Vehicles I have two goals. The first is to develop an infrastructure for *Cooperative Mobile Sensing Systems*. Such an infrastructure would enable the deployment of cooperative unmanned vehicles (air, ground, and sea) into environments that are too hazardous for manned systems, or require persistence that exceeds human capabilities. Many of the components for the mobile sensing system are in development through the RECUV funded research programs on vehicle platform, communications, command and control, and sensors. The second goal is to develop an unmanned systems graduate curriculum. A strawman curriculum has been vetted; it will be refined with a target date for implementation within one year. In addition to these efforts, I continue to pursue opportunities for corporate sponsors (current sponsors include Lockheed Martin, Raytheon, and Navsys), SBIR/STTR opportunities, and other efforts for center-wide research/education funding.

Engineering Education Reform. My involvement in the development and implementation of the AES Curriculum 2000 is discussed in the Teaching Statement. I continue to realize the ideals of hands-on, design, and systems-oriented curricula through opportunities supported by the ITLL and more recently, the Discovery Learning Center. The original Integrated Teaching and Learning Initiative (ITLI) was supported by seven disciplinary committees, after the ITLL was opened in 1997, all the disciplinary committees dissolved, except for the Fluid and Thermal Science Focus Group that I chaired. With the multidisciplinary (and multidepartmental) collaboration that started with the ITLI, our group developed a prioritization procedure that allowed us to continue the development of experimental modules and equipment that supports the aero-fluid mechanics, thermodynamics, and heat transfer. This group was also the first to pilot a multidisciplinary fluid dynamics course team taught by faculty from several departments. I continue to collaborate with faculty from several of the College's departments to develop multidisciplinary modules used in the ITLL.

In 2003 I organized the first CU Design, Build, and Fly Team. Since then my teams have competed in the annual competition. The teams are self organized; this year's team started with about 40 students last fall, ranging from freshman physics majors to AES M.S. and Ph.D. candidates. As we approach the competition in April 2006, the team still numbers about 30. The DBF Team is an excellent "proving ground" for students who might become involved in RECUV undergraduate research. All of the graduate students involved in the project, including the PhD candidate, started as undergraduate team members. DBF is an excellent avenue for the early involvement of students in a multidisciplinary (and multidepartmental) systems engineering experience. In addition to the horizontal integration of the disciplinary topics, it also teaches students to work in a vertically integrated team. I believe both types of integration are an essential to my continuous efforts in engineering education reform and implementation.

K-12 Education and Outreach. Each summer I participate in one or two of the outreach programs sponsored by the College or the ITLL. This includes organizing sessions, curriculum modules, and teaching. Examples include the *Success Institute*, a two-day immersion of underrepresented students of color, particularly rising juniors and seniors from the Denver Public Schools, into a multidisciplinary engineering experience and a taste of university life. The *High School Honors Institute*, is an annual program in which rising seniors from the state of Colorado are introduced to the

disciplines and programs of the College through a series of workshops and tours. I have organized many of the AES programs and conducted workshops to illustrate the fundamentals of aircraft flight, traditionally concluded with a popular Whitewings® competition that I introduced about a decade ago. *Go with the Flow* is a 3-4 day workshop for middle- and high-school teachers in which I teach an aero-fluid dynamics curriculum, jointly developed with the ITL K-12 program, that helps the teachers integrate engineering into their K-12 curricula. At the conclusion of the *Go with the Flow* workshop these teachers receive professional development continued education credit.

National Service. As a Technical Co-Chair, I participated in the organization of the 1st AIAA Unmanned Vehicle Systems, Technologies, and Operations Conference and Workshop in 2002, and for two subsequent annual conferences. I am currently a member of the Unmanned Systems Program Committee and continue to chair sessions for the annual conferences.

From 1997-2001 I served three years on the NASA Advisory Council Aeronautics and Space Transportation Technology, Airframe Systems Subcommittee. I also served on the NASA Aerospace Missions and System Analysis Peer Review in 2003, and since 2003, I continue to serve as a member of the NASA Academy of Program and Project Leadership, Management Operations Working Group.

As a member of the Institute for Defense Analyses (IDA) 2000-2001 Defense Science Study Group (DSSG) my focus was on the threat that unmanned aircraft pose to national security as described in my 2002 report: “Assessment of the Impact of Low-Cost Robotic Aircraft to National Security” [4.2]. In 2003, I was appointed an ad hoc member of the USAF Scientific Advisory Board (AFSAB) as part of the Vehicles Panel for the 2003 study of Unmanned Vehicles; in 2005 I was appointed a full member of the AFSAB. I am currently a member of the Surveillance and Identification Panel for the study “Defense Against Foreign UAVs”.