2016 Department Overview

Perry H. Leo, Department Head

Aerospace Engineering and Mechanics
Professional Advisory Board
Initiatives for 2015-2016

• Develop strategic plan encompassing research, teaching and service
  – small group with input from everyone
  – especially critical with new Dean coming in
• Continued discussion of the curriculum
• Implement plan to increase diversity
• Develop plan to improve communications
• Develop strategy for successfully increasing honors and awards
• Fund raising
The Mission of the Bachelor of Aerospace Engineering and Mechanics (BAEM) Program at the University of Minnesota is to produce graduates who are prepared to enter and sustain the practice of aerospace engineering and related fields, or to pursue advanced studies. This Mission is consistent with the Mission of the University of Minnesota in Learning and Teaching; with the Mission of the College of Science and Engineering to provide a rigorous and stimulating education for its undergraduate majors, and to provide programs of instruction in engineering that meet nationally accepted standards for practice of the profession of engineering.
AEM Degree Programs

The Aerospace Engineering and Mechanics (AEM) department offers a Bachelor's degree in Aerospace Engineering (BAEM) and Masters and PhD degrees in Aerospace Engineering and Mechanics.

- AEM Faculty teach courses at the undergraduate and graduate level.
- Core courses include fluid and structural mechanics and aerospace systems. Students gain experience in problem-solving techniques, experimental and computational methods, and engineering design.
- BAEM degree program is an engineering science based curriculum.
- Masters program is oriented towards students inclined to pursue a PhD degree in the fields of Aerospace Engineering and Mechanics.
Aerospace Systems

• William Garrard  
  – Dynamics and control of aerospace vehicles; stability and control of nonlinear systems; control of gas turbines; parachute dynamics.

• Demoz Gebre-Egziabher  
  – Sensor fusion; design of multi-sensor systems for navigation, guidance and control of aerospace vehicles; Global Position System (GPS), UAVs.
Aerospace Systems

• Bérénice Mettler
  – Autonomous guidance and control; trajectory planning; automated maneuvering; UAVs (on leave, 2014-2015)

• Peter Seiler
  – Aerospace flight control systems; fault detection and isolation for safety critical systems; nonlinear analysis; modeling and control for wind turbines

• Yohannes Ketema
  – Dynamics; dynamics of active materials; stability of formations; orbital mechanics
Aerospace Systems

• Maziar Hemati
  – Design techniques for modeling, dynamical analysis and control of large-scale systems; constructing models of aggressive aeroelastic aircraft flight maneuvers; formulating strategies for real-time control of uncertain large-scale nonlinear systems

• Richard Linares
  – State and parameter estimation; uncertainty quantification; space situational awareness; vehicle attitude estimation; small satellite systems
Fluid Mechanics

• Graham Candler
  – Hypersonic aerodynamics; computational fluid dynamics; high-temperature gas physics; thermo-chemical non-equilibrium flows

• Filippo Coletti
  – Experimental fluid mechanics; Turbulent mixing; Respiratory flow and particle transport in lungs; Particle-laden flows

• Ellen Longmire
  – Experimental fluid mechanics; particle-laden and multiphase flow; turbulence; vortex dynamics microscale flows
Fluid Mechanics

- **Krishnan Mahesh**
  - Numerical simulation and modeling of fluid flows; modeling and simulation of propeller crashback and helicopter blades

- **Joseph Nichols**
  - Aeroacoustics; Hydrodynamic stability analysis; Large eddy simulation; Turbulent reacting flows

- **Thomas Schwartzentruber**
  - Computational fluid dynamics; particle simulation of non-equilibrium flow; hypersonic flow
Solid Mechanics

• Ryan Elliott
  – Martensitic phase transformations; shape memory alloys; atomistic materials simulation; stability and bifurcation

• Richard James
  – Thermodynamics of solids; phase transformations; micromagnetics; active materials, especially shape memory materials; green energy
Solid Mechanics

• Perry Leo
  – Phase transformations; micromechanics of defects in solids; biological materials; composite materials

• Thomas Shield
  – Experimental solid mechanics; mechanics of materials; single crystal plasticity; shape-memory and magnetostrictive materials

• Ellad Tadmor
  – The Quasicontinuum Method; Peierls criterion for Deformation Twinning at Crack Tips; Reliability of MEMS Devices
Faculty Accomplishments

Professor Pete Seiler promoted to Associate Professor with tenure, effective fall 2016

Professor James Flaten was promoted from term Assistant Professor without tenure to term Associate Professor without tenure
Faculty Accomplishments

Professor Tom Schwartzentruber awarded Russell J. Penrose Faculty Fellowship

Professor Richard James wrote commentary articles in Nature and Science related to understanding hysteresis in materials. Research in this area has been carried out in AEM over the past few years.
Faculty Accomplishments

Professors Ellad Tadmor and Ryan Elliott sponsored a National Science Foundation Workshop on the “Rise of Data in Materials Research” in June 2015

−Purpose of the workshop was to discuss themes related to data in materials science, identify the most pressing issues to be addressed, and developing a way-forward program to facilitate emerging data in Materials Science research while fostering scientific excellence
Faculty Updates

Professor Emeritus Jerry Ericksen celebrated his 90th birthday at a symposium in Eugene, Oregon in October 2015.

Professor Emeritus William H. Warner passed away in December 2015 after a brief illness.
Faculty Updates

- Aerospace Systems faculty search ongoing
- Interviewed four candidates, one withdrew
- Uncertainty over Prof. Mettler’s return
Student Accomplishments

• Students from AEM 1905, Professor Flaten's Freshman Seminar on High-Power Rocketry, exhibited their rockets in the Balas Atrium in December 2015
Curriculum Review Update

• AEM Curriculum Similar to other top aerospace departments in country
• Two Areas Identified for Growth -- Computer Skills and Hands-on Projects
• No Consensus on What Topics to Drop Without Adding Program Credits
• Strategic Plan Development Will Provide Curriculum Guidance
Student Accomplishments

Senior Design Projects

– High Efficiency Hand Launched UAV
– AIAA Design, Build, Fly
– Subsonic/Supersonic Business Jet Design
– Low Cost GPS Denied Guidance for Munitions
– Design of a Low-Speed Wind Tunnel
– Design of UAV with One Control Surface
– CubeSat Design
– NASA Rascal
– Formula SAE Auto Racing
Student Fellowships

• Two incoming AEM graduate students received the Ken and Rosemary Anderson Graduate Fellowship for this year
  – Sally Keyes is pursuing a graduate degree in Aerospace Engineering and Mechanics after completing a bachelor’s degree in mechanical engineering at Purdue University
  – Kerry (Ke) Sun is studying aerospace dynamics and control after completing a bachelor’s degree in aerospace engineering and master’s degree in economics at California Polytechnic State University San Luis Obispo (Cal Poly)
Student Scholarships

• Chester Gaskell Aeronautical Engineering Scholarship – 3 students awarded
• John and Robert McCollum Memorial Scholarship – 2 students awarded
• Rose Minkin Scholarship – 3 students awarded
• Boeing Scholarship – 2 students awarded
• Richard & Shirley DeLeo Scholarship – 1 student awarded
• Eric W. Harslem Scholarship for Aerospace Engineering – 1 student awarded
• Richard G. Brasket AEM Scholarship – 2 students awarded
• Robert H. & Marjorie F. Jewett Scholarship – 3 students awarded
• AEM Program Initiatives Fund – 3 students awarded
Alumni Highlights

AEM alum Steve Cook was recently named a Fellow of the American Institute of Aeronautics and Astronautics (AIAA) – Mr. Cook is vice president for corporate development at Dynetics

AEM alum Dr. Ajit K. Roy was recently named a Fellow of the American Institute of Aeronautics and Astronautics (AIAA) – Dr. Roy is a Principal Materials Research Engineer and Computational Group Leader at the Nanoelectronic Materials Branch, the Materials and Manufacturing Directorate of the Air Force Research Laboratory (AFRL)
Alumni Highlights

AEM alum Adam Creuziger was named by President Obama as one of the 2016 recipients of the Presidential Early Career Award for Scientists and Engineers
– Mr. Creuziger has worked as a National Research Council post-doctoral associate at the National Institute of Standards and Technology (NIST) since 2008
Research Highlights

The Unmanned Aerial Vehicle (UAV) Laboratory is continuing development on its “Goldy” system, which serves as the brain of professional-grade UAVs used for scientific research:

- NASA is using the Goldy flight control system in the third version of Prandtl-D—a V-shaped glider designed to imitate how a bird flies.
Professor Joseph Nichols’ Research Group Works to Uncover New Physics in Jet Noise research

– High-fidelity simulations and analysis provide breakthrough understanding and modeling of noise generation
### Headcount: Students

*CSDy has one student not under AEM

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Course Trends

AEM 2301 Course Enrollment Trends

2004-05 to 2015-16

2301 is the best indicator of required UG class sizes
# Headcount: Faculty and Staff

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# Sponsored Funding

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<th>Expenditures ($)</th>
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<td>2015</td>
<td>8,138,583</td>
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<td>2014</td>
<td>7,138,103</td>
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<td>2013</td>
<td>6,932,793</td>
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<td>2012</td>
<td>7,019,527</td>
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<td>2011</td>
<td>9,311,318</td>
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*Data from OVPR External Support Expenditures: Departmental Type of Support*
## Fundraising

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Total Gifts &amp; Commitments</th>
<th>Gift Number Totals</th>
<th>Outright Gifts (includes pledge payments)</th>
<th>Matching Gifts</th>
<th>Matching Gifts Numbers</th>
<th>Realized Deferred Gifts</th>
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<td>YTD**</td>
<td>$165,685</td>
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<td>$111,790</td>
<td>$3,896</td>
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<td>FY15*</td>
<td>$210,012</td>
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<td>$146,047</td>
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<td>$111,150</td>
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<td>FY13</td>
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<td>192</td>
<td>$547,642</td>
<td>$4,205</td>
<td>15</td>
<td>$407,267***</td>
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<td>FY12</td>
<td>$710,326</td>
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<td>$179,638</td>
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<td>$570,363</td>
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<td>FY11</td>
<td>$357,036</td>
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<td>$6,257</td>
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<td>$33,654</td>
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<td>FY10</td>
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<td>192</td>
<td>$245,268</td>
<td>$2,950</td>
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<td>$30,466</td>
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* Includes 91 gifts totalling $58,694 to the Gary Balas Fellowship
** Includes a $50,000 pledge to be paid over 5 years
*** Richard DeLeo Estate Gift
CSE Updates

• Steve Crouch, dean of the College of Science and Engineering since 2005, announced in August 2015 that he has decided to step down from the deanship at the end of August 2016
• A national search for a new dean has been launched
• A search committee was named in October 2015
• Four candidates interviewed April 2016
UMN Updates

• President Eric Kaler’s Initiatives and Priorities
  – Campus Climate
  – Operational Excellence
  – Alignment of all University campuses
  – Students First - Teaching and Learning
    • Combine up-to-date, engaging teaching with a high-touch and high-tech learning experience that attracts diverse, qualified students and faculty
  – Discovery - Research and Innovation
    • Pursue new knowledge to advance human health and our economy
  – Stewardship - Funding and ROI
    • Advance Operational Excellence and a renewed partnership with the state to limit tuition increases and maximize the public’s return on investment
  – Champion our University - Impact and Reputation
    • Participate in relevant, vital public engagement and advocacy to solve our communities’ most vexing problems and compete globally
Challenges and Opportunities

• Financial situation continues to be an issue
  • CSE expects cuts of 1 – 2% next budget year
  • Salary increases continue to be fairly small
• Unionization
• Need to attract women and under-represented groups to both undergrad and grad programs
• Need to find other faculty to take on leadership roles
• Space for student projects and growing research programs
Challenges and Opportunities

• University not supporting freshman seminars—replaced by Grand Challenge Interdisciplinary focused courses
  • Academic year 2016-2017 AEM still offering two freshman seminars for first year students
    Fall -- Aircraft and Spacecraft: High Power Rocketry
    Spring – Model Aircraft Design, Flight Test, and Analysis
Bachelors of Aerospace Engineering and Mechanics

Prof. Tom Shield
Director of Undergraduate Studies
ABET Accreditation Process

- Collect Feedback from Constituents
  - Both Terms: Student (alternate years) and Instructor Course Surveys
  - Yearly: Senior Exit Surveys (BAEM and University)
  - Yearly Reports: Professional and Student Advisory Boards
  - Every 6 years: Alumni and Employer Surveys on Objectives
  - Every 6 years: External Visitor review

- Two year cycle of internal review by Faculty

- Next ABET visit Fall 2019
  - Evaluates how well we are following our process
  - Evaluates how well we are meeting outcomes and objectives

- Outcomes are specific learning achievements
- Objectives are overarching goals of the program
PAB Recommendations from last year

- Appreciate having the CSE data on job placement performance within the college (presented later)
- Tools and modeling experience is very important to industry, the department needs to continue to integrate more tools into the curriculum.
  - Consider these as potentially service classes within college
- Board would like to get a copy of the draft Student Advisory Board’s report prior to the meeting next year (emailed)
- Promote “life Long Learning” through enhanced support the engineering extra curricular activities (CANSAT, solar car, etc.)
- Board accepts the recommendations for changes to the ABET objectives
- Invite new industry partners to serve on the board; target Twin Cities metro companies and large aerospace firms
### AEM ABET Process Schedule

<table>
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<tr>
<th>Date Range</th>
<th>Event Description</th>
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<tr>
<td>Sept 29 - Oct 1 2013</td>
<td>ABET Visit</td>
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<tr>
<td>2014-8-8</td>
<td>2013 Final Statement Issued</td>
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<tr>
<td>Fall 2015</td>
<td>Even year review of years 2012-13 and 2013-14</td>
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<tr>
<td>2015-16</td>
<td><strong>AEM Graduates Employers Survey on Objectives – What to ask?</strong></td>
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<tr>
<td>2016-17</td>
<td>Even year review of years 2014-15 and 2015-16</td>
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<tr>
<td>Spring 2017</td>
<td>Student survey on Advising (after spring registration for fall)</td>
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<tr>
<td>2016-17</td>
<td>AEM Alumni Survey on Objectives</td>
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<tr>
<td>Spring 2018</td>
<td>External Visitor</td>
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<tr>
<td>2017-18</td>
<td>Collect Student work for classes not given 2018-19</td>
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<tr>
<td>2018-19</td>
<td>Even year review of years 2016-17 and 2017-18</td>
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<tr>
<td>2018-19</td>
<td>Collect Student Work for all UG Classes</td>
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<tr>
<td>Jan. 31, 2019</td>
<td>Request to ABET for review due</td>
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<tr>
<td>July 1, 2019</td>
<td>Self-Study Due</td>
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2013 ABET Review Feedback

- No Deficiencies, Weaknesses or Concerns
- Program Strengths
  - Professional and Student advisory boards: active and provide excellent feedback
  - Capstone design (4331) well supported by industry
  - Department Database System and On-line Advising very helpful
- Observations by Reviewer
  - 4303W spring 2013 – instructor poor and no controls
  - Materials course poor – current seniors, so was a while ago
  - Asked about ME 3324 and seemed ok
  - More “hands on” earlier in program
  - Program has more of a “research slant” than industry orientation
  - Asked about TAs and found no problems with AEM ones, physics ones are poor.
  - Desired “more proactive information about internships” – but students seem to want too much hand holding here
## Current BAEM Program

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<th>Freshman Year</th>
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<td>MATH 1371 — Calculus I</td>
<td>MATH 1372 — Calculus II</td>
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<td>CHEM 1061/65 — Chemistry I</td>
<td>PHYS 1301W — Physics I</td>
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<td>BIOL 1001 — Introductory Biology I</td>
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<td>WRIT 1301 — University Writing</td>
<td>CSCI 1113 — C/C++ Programming</td>
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**Sophomore year**

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<td>MATH 2374 — Multivariable Calculus and Vector Analysis</td>
<td>MATH 2373 — Linear Algebra and Differential Equations</td>
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<td>PHYS 1302W — Physics II</td>
<td>AEM 2012 — Dynamics</td>
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<td>AEM 2011 — Statics</td>
<td>AEM 2301 — Mechanics of Flight</td>
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<td>MATS 2001 — Materials Science</td>
<td>PHYS 2303 — Physics III</td>
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Liberal Education Elective

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## Current BAEM Program

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<td>AEM 4202 - Aerodynamics</td>
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<td>AEM 3031 - Deformable Body Mechanics</td>
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<td>AEM 4501 - Aerospace Structures</td>
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<td>AEM 3101 - Mathematical Modeling and Simulation in Aerospace Eng.</td>
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<td>AEM 4301 - Orbital Mechanics</td>
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<td>EE 3005/6 – EE Circuits with Lab</td>
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<td>AEM 4601 - Instrumentation Lab</td>
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<td>ME 3324 – Heat Transfer</td>
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<td>AEM 4203 - Aerospace Propulsion</td>
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<td>AEM 4331 - Aerospace Vehicle Design</td>
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<td>Technical Elective</td>
</tr>
</tbody>
</table>
BAEM Changes to Monitor

- First design course: *AEM 4331 – Aerospace Vehicle Design*
  - Covers both Air and Space Craft (mostly aircraft projects)
  - Given Fall 2008 as combined course for first time
- Admission to Upper Division is on a space available basis for Fall 2010 and later Freshmen and the decision has been moved up to after three semesters instead of four. (College-wide change)
- Addition of AEM 3101 (given fall 2013 and 2014)
- Moving AEM 4301 and 4303W later in program.
- AEM 4303W is now 3 credits (spring 2015 is first time offered as 3cr)
- AEM 4796 Professional Experience is no longer accepted as a technical elective starting Fall 2015.
AEM 2301 (sophomores) Enrollments

2016 Majors: 55 Jan admits, 16 May applicants, 10 transfers (81)

Women
2014-15 BAEM Graduates 6 months out

Responses/graduates: 50/59 BAEM 981/1118 CSE

Aerospace Engineering & Mechanics

- Employed: 64.0%
- Graduate School: 10.0%
- Military: 2.0%
- Seeking Employment: 1.0%

Responses/graduates:

- BAEM Starting Salary: 50/59 BAEM
- CSE: 981/1118

Department of Aerospace Engineering and Mechanics
ABET Mandated Outcomes

a) an ability to apply knowledge of mathematics, science, and engineering
b) an ability to design and conduct experiments, as well as to analyze and interpret data
c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d) an ability to function on multi-disciplinary teams
e) an ability to identify, formulate, and solve engineering problems
f) an understanding of professional and ethical responsibility
g) an ability to communicate effectively
h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i) a recognition of the need for, and an ability to engage in life-long learning
j) a knowledge of contemporary issues
k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
ABET Aerospace Program Criteria

- **Aeronautical Topics (complete coverage)**
  1. a knowledge of Aerodynamics
  2. a knowledge of Aerospace Materials
  3. a knowledge of Structures
  4. a knowledge of Propulsion
  5. a knowledge of Flight Mechanics
  6. a knowledge of Stability and Control

- **Astronautical Topics (partial coverage)**
  1. a knowledge of Orbital Mechanics
  2. a knowledge of Rocket Propulsion
  3. a knowledge of Space Structures
  4. a knowledge of Other Space Topics
Current BAEM Objectives

Consistent with the mission of the University of Minnesota, graduates of the BAEM program will be successfully employed in aerospace or other high technology industries.

Graduates admitted to graduate level studies in engineering and other professions will obtain an advanced degree.

Approved by the faculty 2016-2-25
Professional Advisory Board Charge

- As a constituent group, your feedback is an important part of our process for continual improvement
- You will meet with Student Advisory Board (SAB), at 11:15 (SAB is preparing a report as part of our process, you have last years by email)
- The report you prepare today should provide feedback on our program
- In particular:
  - Consider the Objectives of our program (note we need you to do this even though the new objectives are fairly trivial)
    - Are they appropriate?
    - Are our graduates achieving them reasonably well?
  - Have the previous changes to the program been effective and are the new changes appropriate?
  - Are there any new issues that need to be addressed?
  - Suggestions for questions on the: AEM Graduates Employers Survey on Objectives
2016 Graduate Program Overview

Prof. Demoz Gebre-Egziabher
Director of Graduate Studies

AEM Professional Advisory Board
# Headcount: Current Students

<table>
<thead>
<tr>
<th>Graduate Students</th>
<th>2014-2015</th>
<th>2015-2016</th>
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<tr>
<td>Masters</td>
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<tr>
<td>PhD</td>
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<td>71</td>
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<tr>
<td>CSDy PhD</td>
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</table>

*CSDy has one student not under AEM

<table>
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<tbody>
<tr>
<td>MS Degrees Awarded</td>
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<tr>
<td>PhD Degrees Awarded</td>
<td>6</td>
<td>11</td>
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</tbody>
</table>

**2015-2016 data is not yet available**
Fall 2016 Applicant Pool

• 195 Total Applications
  – 146 International, 49 Domestic
  – 95 Masters, 100 PhD
  – 17 Female

• 35 Admitted Students
  – 32 offers of funding made
  – 4 Female
  – 3 Received Graduate School Fellowships

• 13 Students Accepted Enrollment
  – 2 Female
  – 0 Graduate School Fellowships
## Fall 2016 Incoming Class

<table>
<thead>
<tr>
<th>Citizenship</th>
<th>2015-2016</th>
<th>2016-2017</th>
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<tr>
<td>Domestic</td>
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<td>11</td>
</tr>
<tr>
<td>Female</td>
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<td>Research Assistantship</td>
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<tr>
<th>Field</th>
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<td>Fluids</td>
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<td>CFD</td>
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<td>Systems</td>
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<tr>
<td>Solids</td>
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</tbody>
</table>

| Total                | 16        | 13        |
Maziar S. Hemati
Aerospace Engineering & Mechanics
University of Minnesota

Friday, April 29, 2016
A **Blind** Fish “Seeing”

Video courtesy of Michael Triantafyllou, MIT
A **Blind** Fish “Seeing”

Video courtesy of Michael Triantafyllou, MIT

Image adapted from S. Philip et al. (2012)
A Blind Fish “Seeing”

Video courtesy of Michael Triantafyllou, MIT

A model can be used to “reconstruct” a flow state or to classify various stimuli from sensor measurements.
A Dead Fish “Swimming”

Video courtesy of George Lauder, Harvard
Desirable Model Characteristics:

- **Accurate**: Reliable predictive performance.
- **Low-dimensional**: Suitable for real-time sensing and control.
- **“User-friendly”**: Ready for use with existing design/analysis tools.
- **Robust/Versatile**: Valid over many operating regimes.

Soap-film visualization of a sinusoidally flapping foil ($Re = 600$). Figures courtesy of Lentink et al. (2008).
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Soap-film visualization of a sinusoidally flapping foil ($Re = 600$). Figures courtesy of Lentink et al. (2008).

Modeling challenges:

- Nonlinearity
- High-dimensionality
- Uncertainty
Modeling Approaches:
- Physics-based
- Data-driven

F/A-18 scale model dye visualization in a water tunnel. 
Figure courtesy of NASA Dryden Research Center.
Bald Eagle performing a Perching Maneuver. Photo courtesy of gvisions.org.

Sukhoi Su-27 piloted through Pugachev’s Cobra Maneuver. Photo courtesy of Wikimedia Commons.
Video courtesy of Kenneth Granlund, NCSU.
Video courtesy of Kenneth Granlund, NCSU.

\[
(x_1(t), y_1(t), \Gamma_1(t)) \quad \Rightarrow \quad (x_2(t), y_2(t), \Gamma_2(t))
\]
α

Maziar S. Hemati

Video courtesy of Kenneth Granlund, NCSU.

\[ \ddot{\alpha} \quad C_l \]
Pablo Picasso
“Bull”
(1945–1946)
Draw a “cartoon” using a dynamical systems perspective of data.

Flow past a cylinder (Re=100)
Draw a “cartoon” using a dynamical systems perspective of data.

Flow past a cylinder (Re=413)
A “cartoon” of the system can be useful for both description and prediction.

- **Description** → Knowledge Discovery; Physical Insight; System Understanding
- **Prediction** → Sensing; Control; Optimization
The systems perspective generalizes to complex systems beyond fluid mechanics.

- Video Processing
- Neuroscience
- Epidemiology
- Robotics
- Sustainable Buildings
- Power Systems
- ...
Flight Systems
- Autonomy
- Agility
- Energy efficiency

Robotic Swimmers
- Gait optimization
- Hydrodynamic sensing
- Collective control

Energy & the Environment
- Wind turbine control
- Wind farm optimization
- Vortex-induced vibrations for marine energy harvesting

Formation flight of C-17 aircraft. Figure courtesy of www.wpafb.mil.

Collective coordination in fish school. Figure courtesy of NatGeo.

Wind farm wake interactions (LES). Figure courtesy of David Bock, NCSA