Welcome to
School of Aeronautics and Astronautics
Purdue University

PURDUE™ AERONAUTICS & ASTRONAUTICS

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Graduate Program
School of Aeronautics and Astronautics
Purdue University

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What to do (academically)?

- Find your major area of study
- Find a faculty advisor
- Select classes (math, major, minor)
- Sign up for the classes (on-line, paper)
- Switch classes before 9/22
- Find financial support (TA, RA, Fellowship)

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Study/Research Areas in AAE (Major/Minor)

- Aerodynamics
- Aerospace Systems
- Astrodynamics and Space Applications
- Dynamics and Control
- Propulsion
- Structures and Materials

Aerodynamics

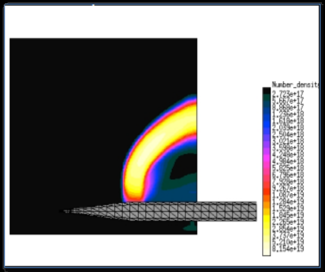
Alina Alexeenko

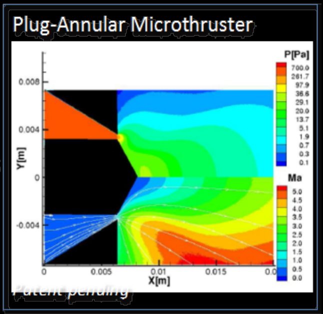
Methods

- DSMC for high-speed rarefied flows with chemistry and thermal non-equilibrium
- Deterministic Boltzmann methods for low-speed flows
- Uncertainty Quantification for computational models

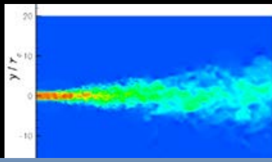
Applications

- High-altitude aerodynamics of satellites and space vehicles
- Micropropulsion
- Atmosphere/thruster plume interactions at high-altitudes
- Aerodynamic damping in MEMS
- Vacuum technology: ultra-high-vacuum deposition of thin-film materials; condensation pumping for pharmaceutical freeze-drying





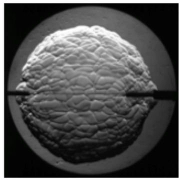
Greg Blaisdell



Sally Bane

Propulsion & Combustion

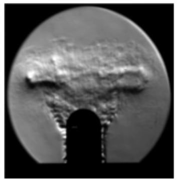
- High-Pressure Gaseous Combustion and Detonation
- Combustion Ignition and Safety
- Hydrogen Energy
- High-Speed Optical Visualization and Laser Diagnostics
- Combustion Instability



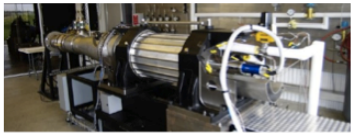
- Combustion Control Using Plasma Actuation / Plasma-Assisted Combustion
- Liquid rocket propulsion
- Pressure-Gain Combustion

Experimental Fluid Mechanics

- Active Flow Control
- Plasmas and Electrostatics

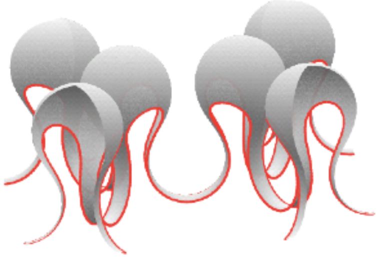


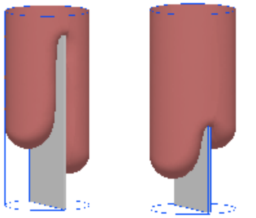
- Optical Flow Visualization & Measurements



Steven Collicott

- Capillary-dominated fluid physics
- Low-gravity fluid dynamics
- Liquid propellant control and gauging in spaceflight
- Low-gravity experimentation

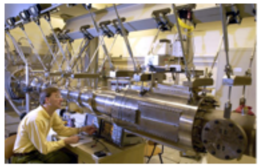




Aerodynamics

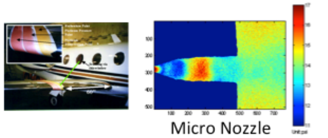
Steve Schneider

- hypersonic laminar-turbulent transition.
- only hypersonic tunnel in the world with laminar nozzle-wall boundary layers and low noise comparable to flight
- aeroheating on reentry vehicles (Space Shuttle, Orion manned capsule, Prompt Global Strike, Mars Science Laboratory, etc), on scramjet-powered vehicles (Air Force X-51), on ballistic interceptor missiles, etc.
- quiet-tunnel measurements have affected the design of the X-51 scramjet vehicle, the HiFire-1 flight vehicle (joint with Australia), and the DARPA/Lockheed-Martin HTV-2 gliding reentry vehicle.
- international cooperations with Germany, Japan, Belgium, and Italy.

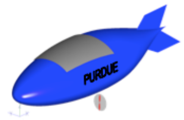


John Sullivan

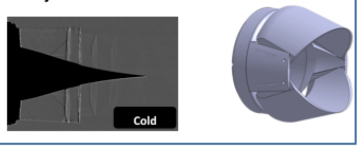
Molecular Sensors
TSP, PSP
For MEMS, Flight Test, M=.01-10., etc



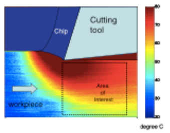
Vehicle Design
High Altitude Airships
UAV's



Nozzle Experiments
Supersonic Plug Nozzle
Ejector Nozzle



Manufacturing Experiments
PIV, TSP

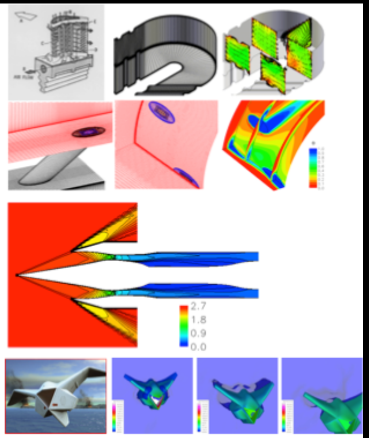


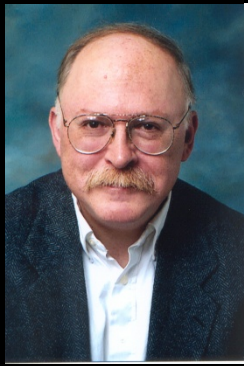
Tom Shih

CFD
- grid gen & flow solvers
- V&V and UQ in CFD

Aerodynamics
- control of shock-wave/ boundary-layer interactions
- aircraft icing

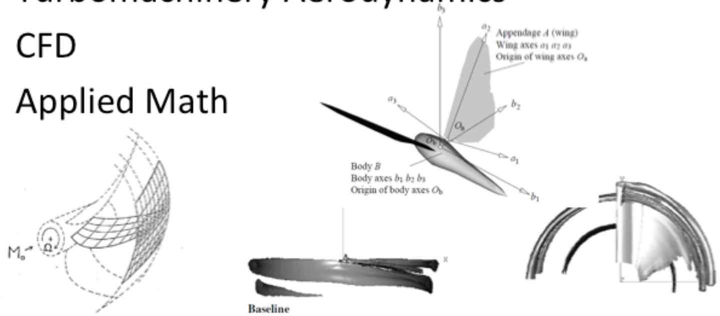
Propulsion and Power
- cooling of gas turbine components
- thermoelectric power gen
- automotive torque converters





Marc Williams

- Unsteady Aerodynamics and Aeroelasticity
- Turbomachinery Aerodynamics
- CFD
- Applied Math



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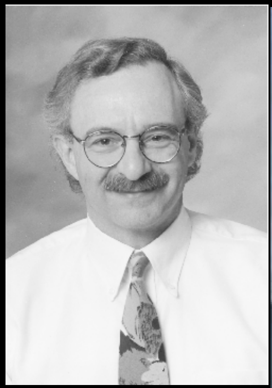
Aerospace Systems



Dominick Andrisani

Barrett Caldwell

Bill Crossley

Dan DeLaurentis

Mike Grant

Inseok Hwang

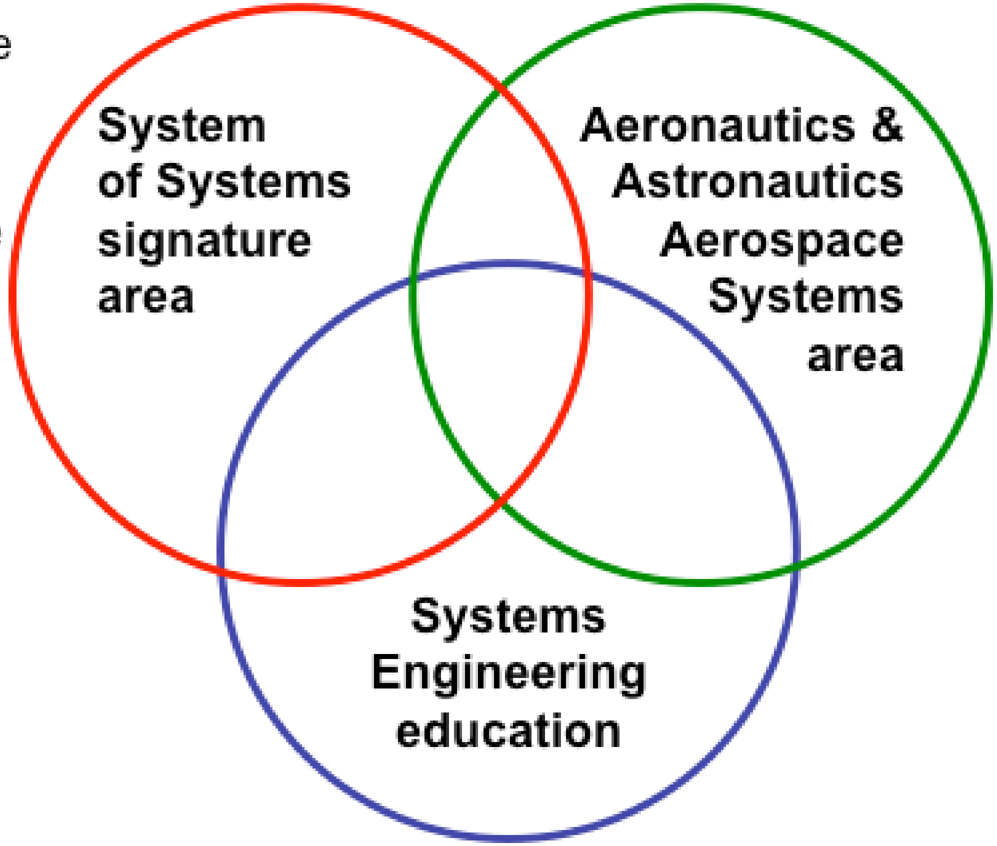
Karen Marais

John Sullivan

Dengfeng Sun

AeS in Context at Purdue

- System of Systems signature area
  - "Trans-disciplinary" research initiative originated by AAE faculty member
  - College-level, involves faculty in several schools & colleges
- Aeronautics & Astronautics Aerospace Systems area
  - Research and curriculum for design, development, operation of aerospace systems (aircraft, spacecraft, etc.)
  - Within AAE; involves plans of study, shared research interests, PhD qualifying examination
- Systems Engineering education
  - Educational support to SoS research
  - Address external stakeholder needs for graduate education in SE
  - Currently IE / AAE led effort to establish graduate concentration

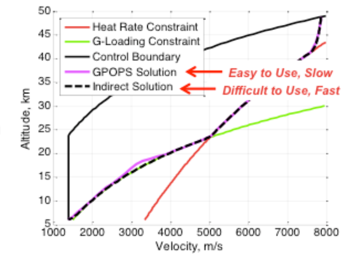


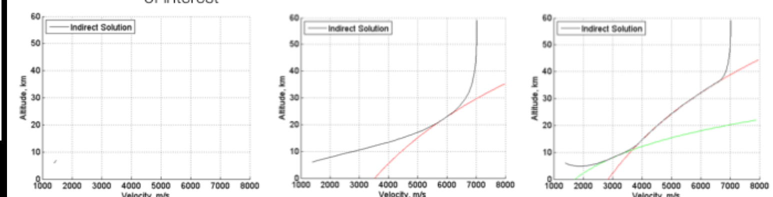
Aerospace Systems

Mike Grant

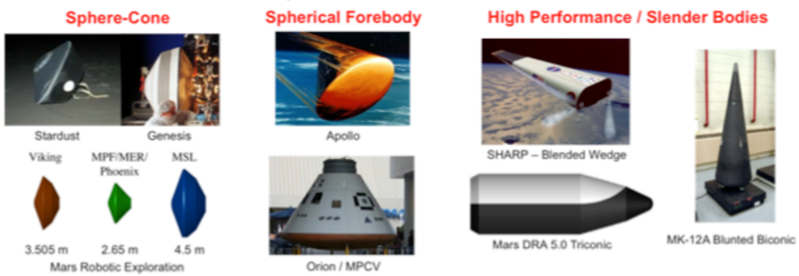
- Rapid Simultaneous Design
  - The conceptual design of complex aerospace systems generally involves computationally intensive iteration among various disciplinary analyses
    - Disciplinary advancements often performed in isolation
  - Recent research focused on collapsing the iterative design framework into a single, unified mathematical framework
    - Enables rapid simultaneous hypersonic aerodynamic and trajectory optimization for conceptual design
  - Framework constructed from two enabling advancements:
    - Analytic hypersonic aerodynamics
    - Rapid trajectory optimization

- Rapid Trajectory Optimization
  - Due to challenges of determining an optimal trajectory, general (slow) methods are often used
    - Fast optimization methods have disappeared from hypersonic design
  - Recent research has capitalized on the fundamental connectedness of optimal hypersonic design solutions
    - Enables optimal solutions to be rapidly evolved to new solutions of interest





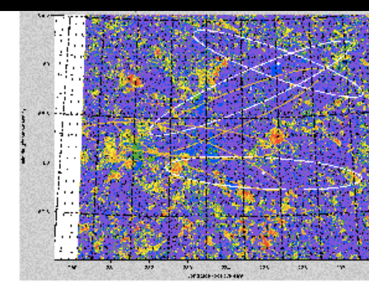
- Analytic Hypersonic Aerodynamics
  - Conceptual hypersonic aerodynamics of vehicles are often computed numerically
    - Likely required for complex geometries (Space Shuttle Orbiter, X-38)
  - However, many vehicle geometries are not complex

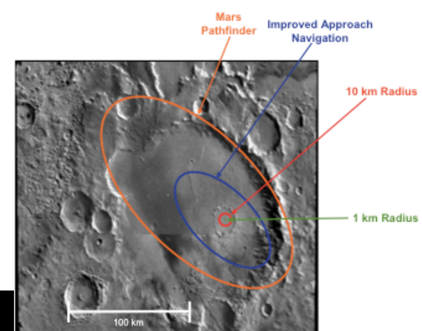


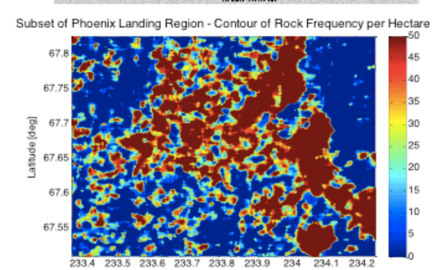
The analytic geometries of these hypersonic vehicles enable the construction of analytic hypersonic aerodynamic coefficients

- Database of analytic solutions created for many hypersonic vehicles of interest
  - Evaluation nearly instantaneous
  - Provides exact solutions approximated today by numerical methods
  - Enables vehicle shape to be incorporated into rapid trajectory optimization methods

- Game-changing EDL architecture design
  - Phoenix landing site selection dominated by safety concerns
  - What if want to travel to more dangerous regions?
    - Place footprint over dangerous regions if vehicle had capability to Smart Divert







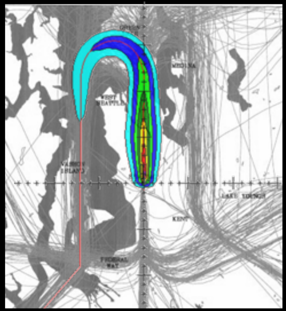
Aerospace Systems

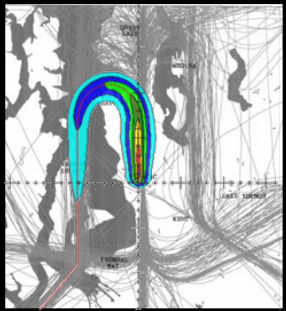
Develop and operate complex engineering systems safely, sustainably, and profitably.

Karen Marais

Aviation Environmental Impact

- System-level trade studies
- Aircraft Operations
- Airport Operations





Financial Aspects of Engineering Design

- Reliability and Maintenance
- Aircraft Design
- Wind Energy

Engineering Levers
- Performance
- Location
- **Reliability & Maintenance Strategy**
- …

Cost of Energy
- Construction cost
- Operating cost
- …

Market Levers
- Contract design
- Intentional downtime
- …

Operating Conditions
- Uncertain Weather
- Variable Energy Demand
- Government Policies
- …

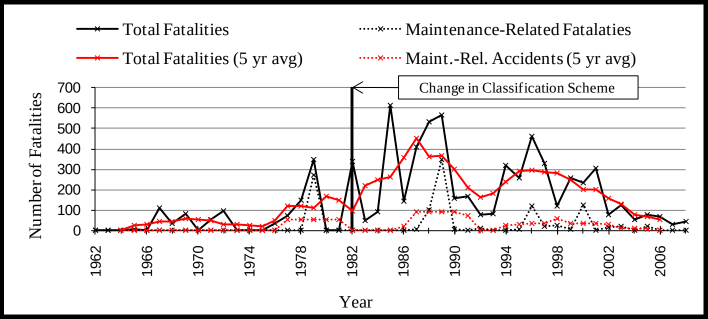
Energy Requirement/ Capacity

Energy Price

Market Conditions

Safety and Risk Management

- Aviation Safety
  - Maintenance
- Risk Assessment in Complex Socio-Technical Systems



Astrodynamics and Space Applications

Dave Filmer

Spacecraft and Subsystem Design

Satellite Ground Station at Zucrow (uplink+downlink)
- Tracking antennas
- Radio – send/receive
- Auto Doppler correction for radio
- Control for antennas+Doppler
- Capability for different modulation and demodulation techniques on uplink/downlink

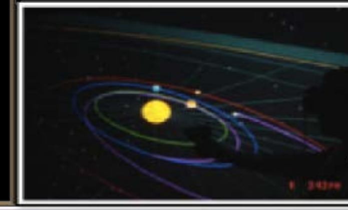
Satellite Systems
- AAE 590Z (spring)
- Mission analysis (includes sizing, environment, materials)
- Vehicle and subsystem design (includes launch, ops, comm, thermo,…)

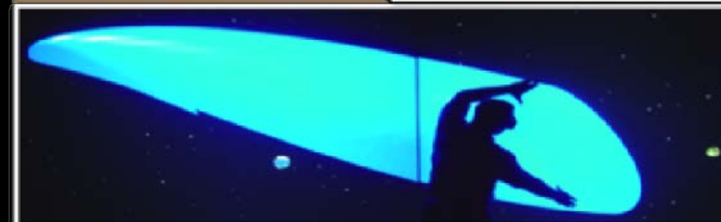
Kathleen Howell

Visualization Lab (Envision

Supports Projects
- dynamical structure of the solar system
- mission design
- astronomy applications

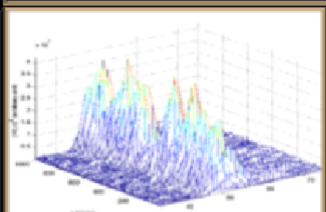
Future
- interactive partners
- spacecraft dynamics and control
- other researchers



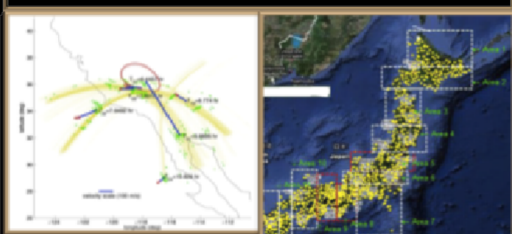


Jim Garrison

GNSS Reflection and occultation measurements for Earth remote sensing

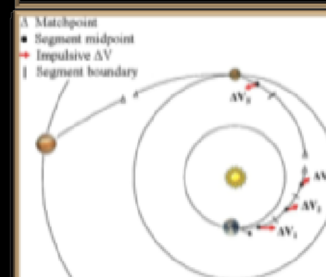


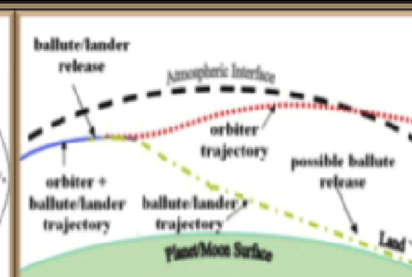
GNSS sensing of seismically-induced ionospheric disturbances



Jim Longuski

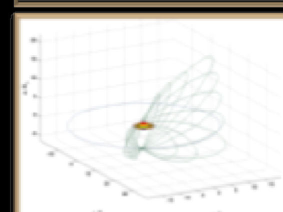
Trajectory Design and Optimization

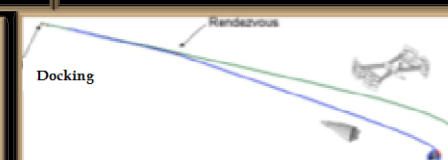




Dual-Use Ballute for Aerocapture and Landing

Optimization of Low-Thrust Gravity-Assist Trajectories

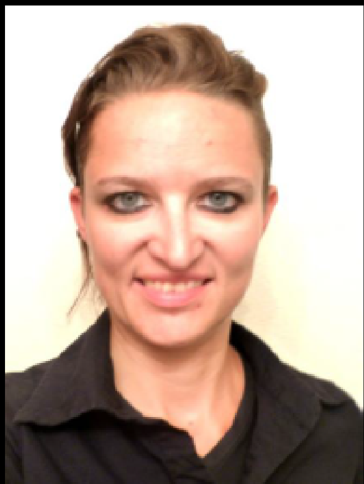




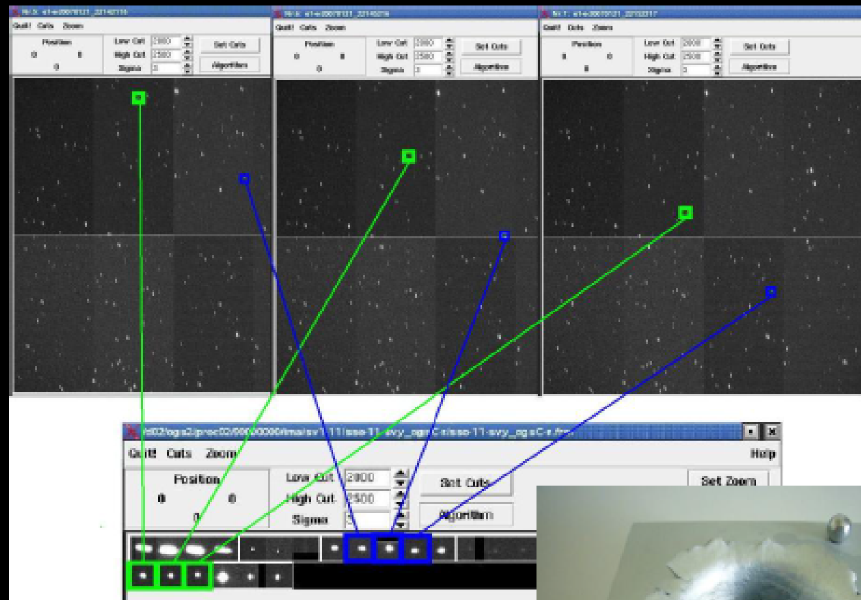
Encore and End of Life Studies for Cassini Mission

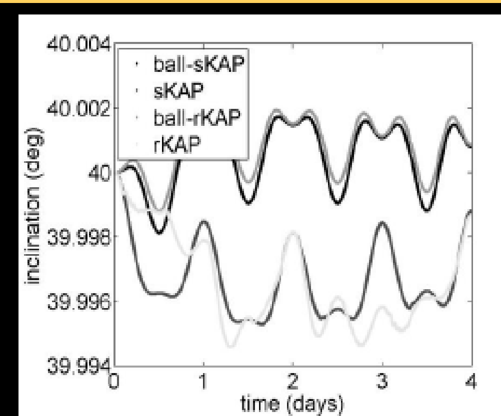
Hyperbolic Rendezvous with Cycler Vehicle

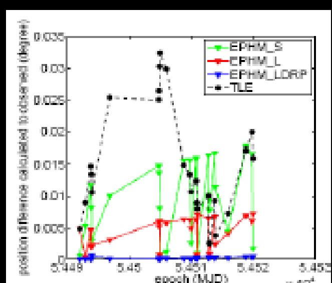
Astrodyamics and Space Situational Awareness

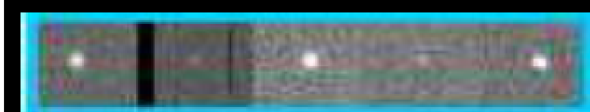


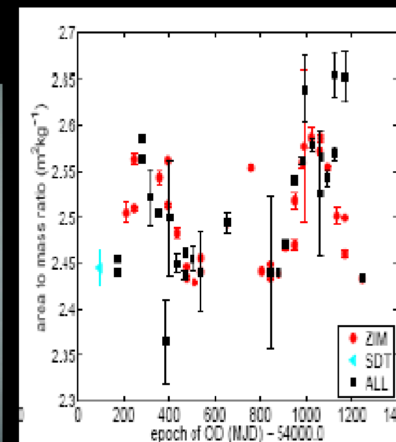
Carolin Frueh

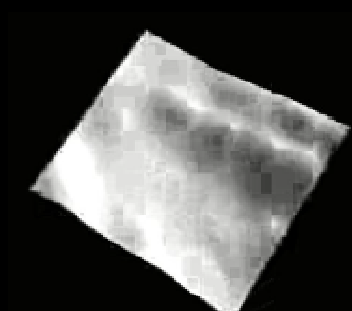


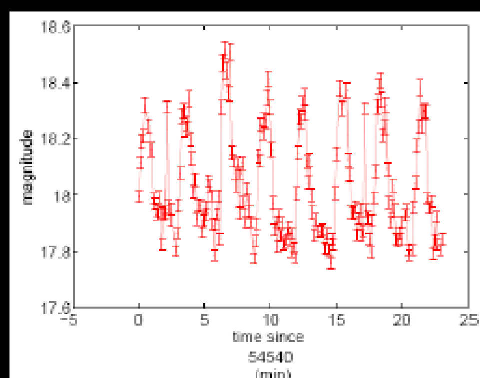






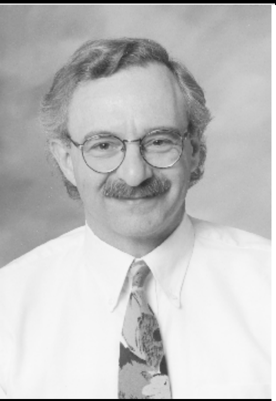






- Coupled orbit-attitude dynamics,
- Perturbation modeling,
- Optical characterization of unknown RSO,
- Man-made object taxonomy,
- Semi-coupled corrector step integration

Dynamics and Controls



Dominick Andrisani

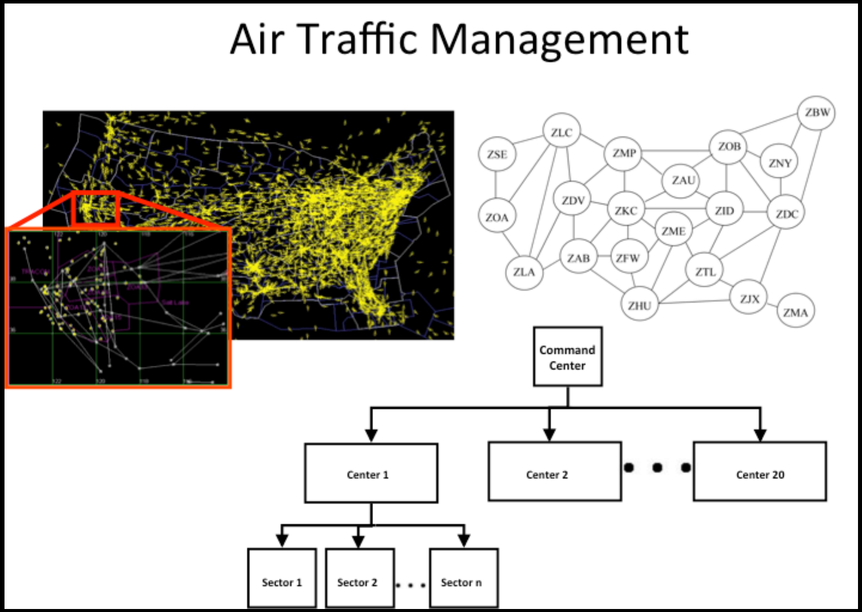
- **Air Traffic Management**
  - Aircraft travel in virtual tubes (highway-in-the-sky)
  - Tube network adjusts hourly to traffic and weather
  - Airspace capacity and schedule reliability are enhanced
- **Precision Navigation and Targeting**
  - Inertial Navigation
  - Optical sensors for navigation
  - Optical sensors improve navigation and targeting accuracy

Martin Corless

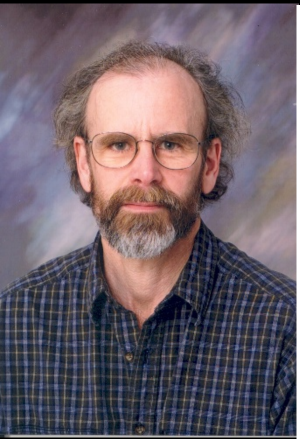
- **Analysis and robust control of uncertain systems**
- **Nonlinear systems** (applications to robotics, vehicles)
- **Networked dynamical systems**
- **Vehicle rollover**
- **Continuous control of spacecraft trajectories**
- **Congestion avoidance** especially in communication networks.

Dan DeLaurentis

- **Dynamics of networks**
  - Developing network topologies to enhance the performance of transportation system-of-system
  - Command, control and communication architectures
- **Dynamics on networks**
  - Control of vehicle swarms using shared autonomy (human and machine)
  - Modeling processes that take place on networks
    - Risk propagation in networks of engineered systems
    - Disease propagation models
- **Dynamic performance of new aircraft configurations** especially in NextGen (Next Generation Air Transportation System)



Dynamics and Controls

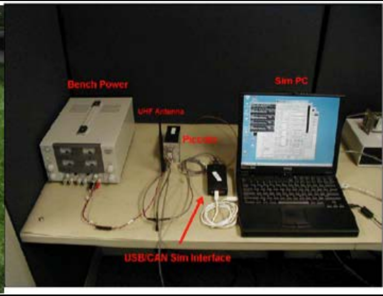


Art Frazho

- **Control Systems**
  - Robust and H-infty control
  - Delay and infinite dimensional control
- **Signal Processing**
  - Filtering theory
  - Filter banks and data compression
  - System identification and sinusoid estimation
- **Network Analysis**
  - Search algorithms, Google PageRank

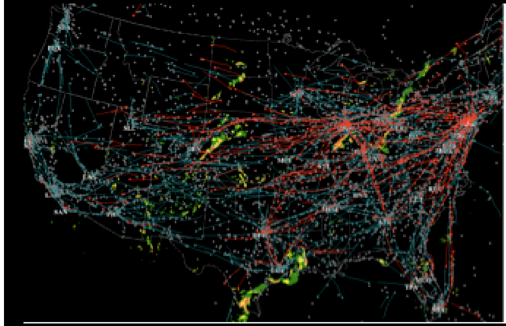
Inseok Hwang

- **Modeling, information inference, and decision making for networked dynamical systems with uncertainty**
  - Air traffic control
  - Navigation/control of autonomous systems/ combined human-machine systems (e.g., UAVs, UGVs, etc)
- **Safety monitoring for safety critical embedded systems (e.g., aircraft/ spacecraft, transportation systems)**
- **Space applications: control and tracking of low-thrust spacecraft**



Dengfeng Sun

- **Air Traffic Management**
  - Modeling and optimization for strategic (global long-term) traffic flow management
  - Modeling and optimization for tactical (local short term) traffic flow management
  - Airspace capacity estimation using weather translation
  - Application of modeling and optimization techniques to practical air traffic control
- **Intelligent Transportation Systems**
  - Optimal metering of highway ramps
  - Multi-modal transportation systems



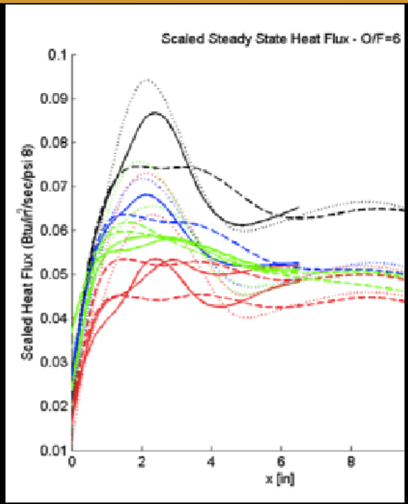
Total # flights	56,653
Total Delay	200,000 minutes
Delay < 2 hours	7408 flights
Delay > 2 hours	1899 flights

Propulsion

Bill Anderson

combustion instability, heat transfer, advanced propulsion cycles for space transportation, propellants, combustor design theory

1st time- and space-resolved measurements of heat flux in large rocket combustor



- Benchmark tests in high-pressure LOX/H2 combustor provide validation data for SOA CFD models of Constellation upper stage engine
- Test configuration mimicked actual rocket engine combustors
- Data shared with NASA, contractors, and other researchers

Steve Heister

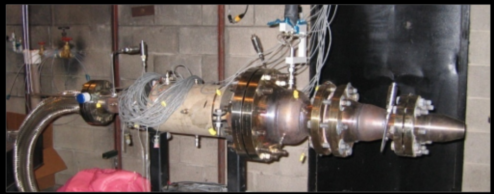
aerospace propulsion systems, airbreathing and rocket engine combustors, liquid propellant injection systems, two-phase and capillary flows

Thermal Imaging and Analysis of Combusting Flows

David Blunck, Jay Gore, Steve Heister, Scott Meyer, and Yuan Zheng

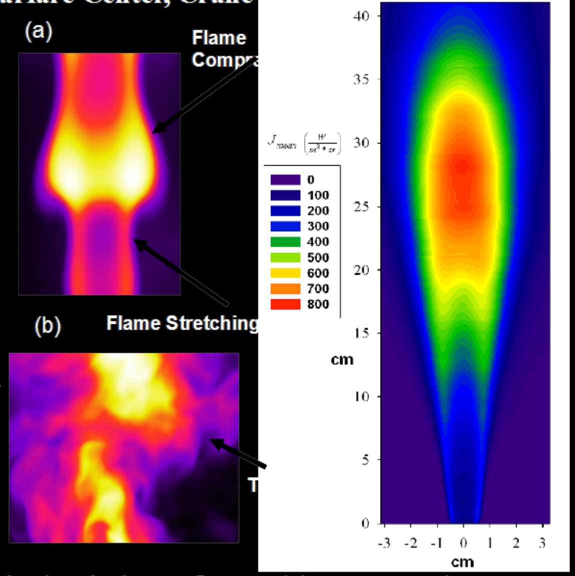
Sponsor: Naval Surface Warfare Center, Crane Division

Objective 1: Measure and compare the infrared signature of advanced gas turbine nozzle designs.



Objective 2: Use infrared measurements of flames to calculate scalar values, capture combustion phenomena, and provide insights into the global radiating nature of the flame.

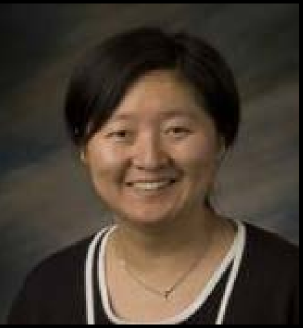
(c)



Figures: (a) instantaneous image of an unsteady laminar hydrogen flame, **(b)** instantaneous images of the Sandia H3 flame (turbulent), **(c)** averaged radiance measurements of the Sandia H3 flame.

Propulsion

Tim Pourpoint



Li Qiao

Haifeng Wang

aerospace propulsion systems, rocket engine combustors, liquid propellant injection systems, hypergolic propellants, high pressure and hydrogen storage systems

- **Novel fuels and propellants:** To understand the rheology and combustion characteristics of alternative fuels and high-performance fuels (for hypersonics).
- **Chemically reacting flows**: To understand the complex interactions between chemistry and turbulence in propulsion systems.
- **High-speed imaging techniques and advanced laser diagnostics**
- **New combustion concepts**

Interests

> Turbulence and combustion modeling

> Fluid mechanics and computational modeling

> Multi-phase flows

> Propulsion and energy systems

Hydrogen storage in metal organic frameworks can provide a means of portable energy storage.

Challenges

- Develop a porous media model with hydrogen flow to characterize the heat transfer in a test bed
- Experimentally verify model results under cryogenic and high pressure conditions

MOF Physics

- Physisorption is the primary means for adsorption of hydrogen into metal organic frameworks (MOFs).
- Hydrogen is stored in the structural gaps and held within the voids with Van der Waals forces.
- Other solid compounds store hydrogen through a chemisorption process which chemically bonds hydrogen to the adsorbing material. In general, chemical bonds require more energy to form and/or break than covalent bonds.

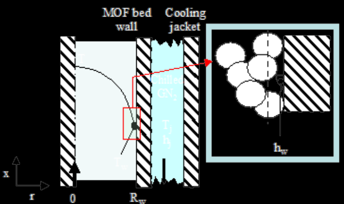


Figure 1: Two-dimensional sketch of the model test bed which shows possible MOF bed wall boundary conditions.

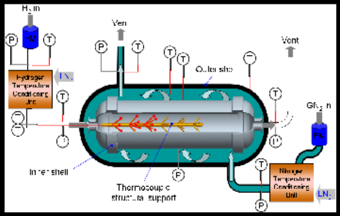
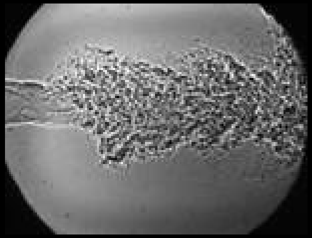
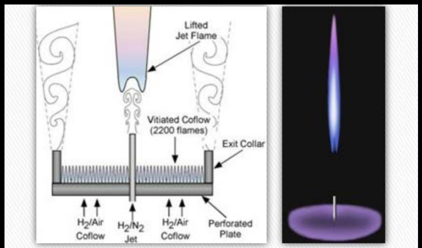


Figure 2: Physical component of the experimental system.

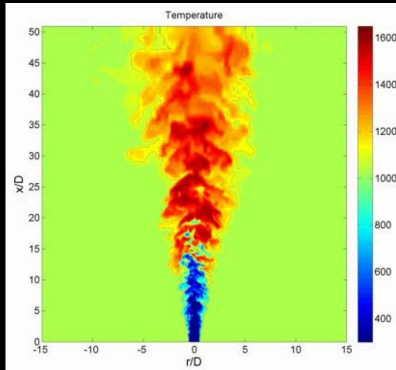
Approach

- Models must be developed to include convection effects of hydrogen flow through voids, adsorption site availability/ occupancy, and the reaction rate dependency on temperature and pressure
- The models will be developed to facilitate parameter estimation
- Develop a test vessel that allows a variety of tests including continuous hydrogen flow under pressure, single port pressurization, near adiabatic boundary, isothermal boundary, cryogenic, and ambient temperatures
- Cryogenic conditions will be achieved with careful consideration of the test bed thermal boundary condition
- Results from the experiments will be used to quantify MOF properties and reaction characteristics





Lifted jet flame
- LES/PDF method



Structures and Materials

Wayne Chen

Research

- Develop novel experimental methods for material characterization
- Determine material and structural responses under severe conditions
- Relate mechanical response to microstructure evolutions

Laboratory

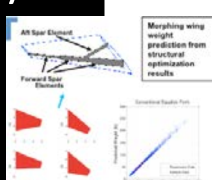
- Focus on Impact Mechanics
- Located in ARMS B130 and Bowen
- 15 graduate students, 4 undergrads
- Study impact response of materials and structures ranging from MEMS structures to armor ceramics

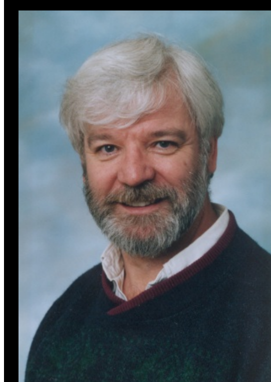
Skip Grandt

- **General Technical**
  - Damage tolerant analysis (fatigue & fracture)
  - Structural analysis and design
  - Nondestructive inspection
  - Aging Aircraft
- **Recent Research**
  - Damage tolerance of unitized construction
  - Fiber metal laminates
  - Interacting cracks
  - Residual stress effects on fatigue
- **Continuing Education**
  - Teach AAE 552 and 554 via Engineering Professional Education
  - Last 5 years have taught over 15 short courses on damage tolerance analysis and nondestructive inspection to industrial and government sites in US, Australia, and New Zealand

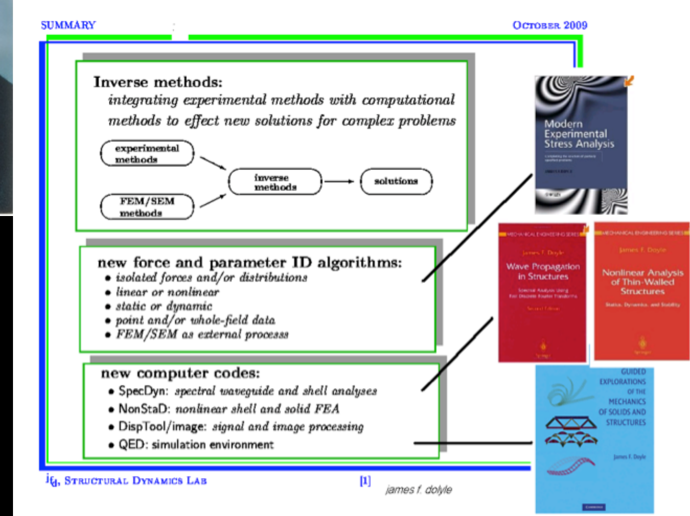
Bill Crossley

- Member Aerospace Systems and Structures area committees
- Structures research interests
  - Structural optimization
    - Multi-objective structural optimization
    - Combinatorial (mixed discrete, continuous) optimization
    - Topology and combined topology / shape optimization
  - Design under uncertainty
    - Simple uncertainty propagation methods for conceptual design
    - Discrete optimization under uncertainty
  - Morphing aircraft
    - Optimization approach for structures with multiple geometric configurations (i.e. changing stiffness matrix for each load set)
    - Surrogate models (parametric equations) for wing weight prediction





James Doyle



Structures and Materials

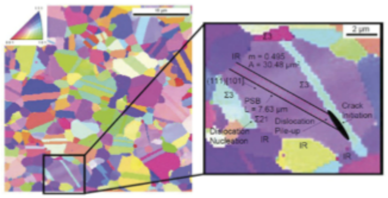
Mike Sangid

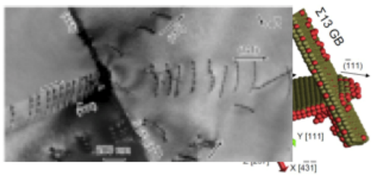
Research Interests:

- composite materials analysis
- characterization and manufacturing
- Nanomaterials

Byron Pipes

- Build materials models to relate structure to property
  - Reduce time and cost of material development
  - Certification by simulations
- Develop multi-scale material models
  - Primarily aerospace alloys
  - Failure mechanisms: fatigue, fracture, creep
- Quantify deformation at atomistic scale and build insights into mesoscale
- Transform life prediction of components and ultimately design
- Linking model predictions to experiments



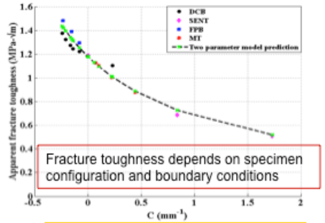


Vikas Tomar

C.T. Sun

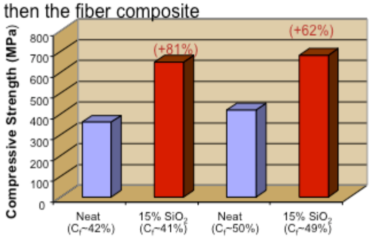
Fracture Mechanics

Why the toughness of a brittle material is not constant



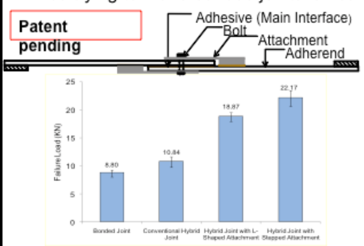
Nanocomposites

Use nanoparticles to enhance the matrix and then the fiber composite



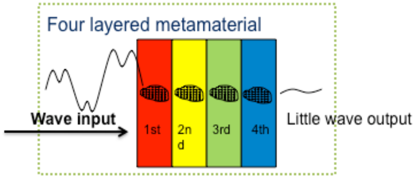
Improving Hybrid Joints

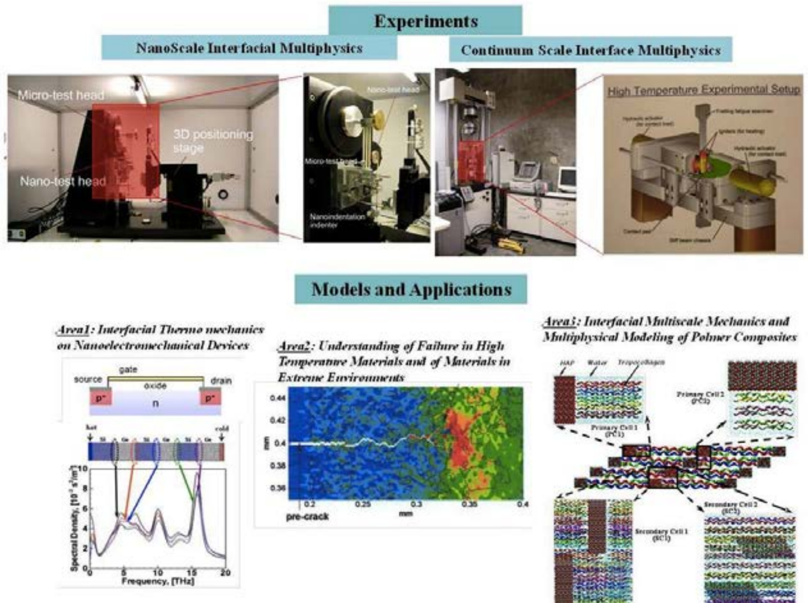
Also trying to make bonded joints fail-safe



Acoustic Metamaterials

Composite materials having man-made microstructures distributed in a host material. Unusual dynamic properties such as negative effective mass result

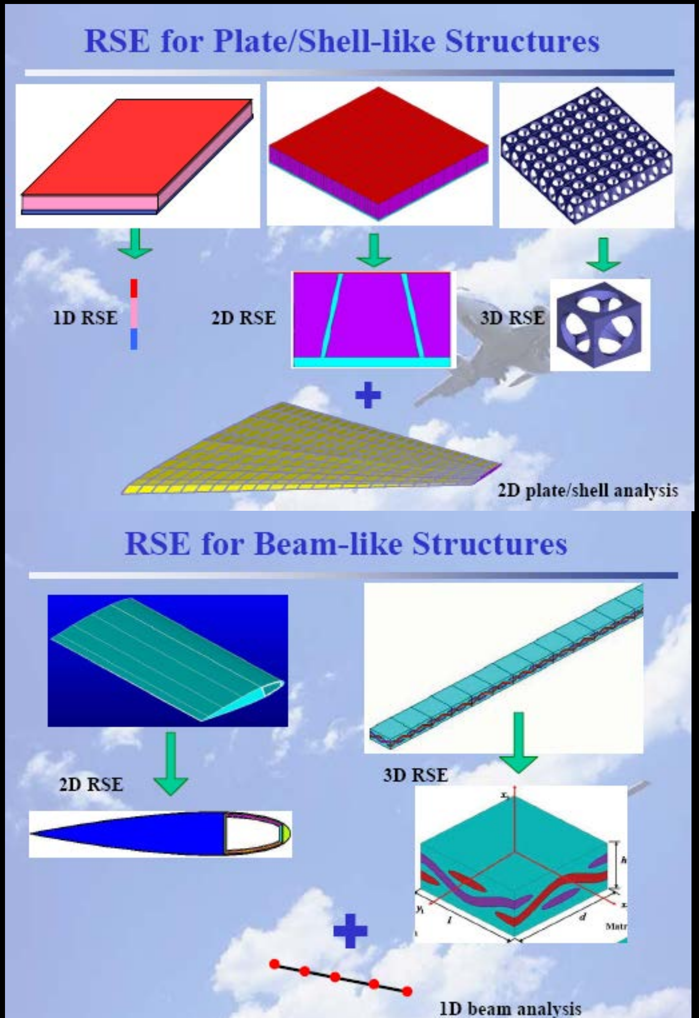


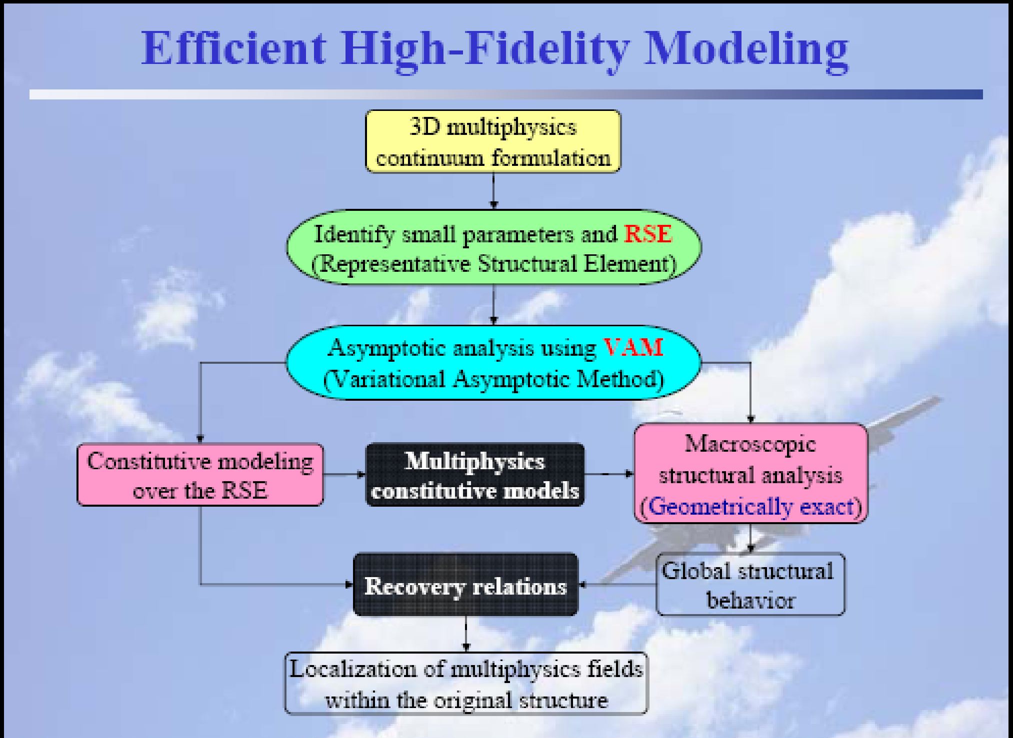


Structures and Materials

Wenbin Yu

- Structural Mechanics (Composite/Smart/Multifunctional Structures)
- Micromechanics (Composite/Smart/Multifunctional Materials)
- Multiphysics modeling
- Flexible Multibody Dynamics
- Multiscale Modeling





Course Registration

- Find a research advisor:

- Research is a good experience for MS and a must for PhD
- Start to work with an advisor early if you know what you want to do
- File a Plan of Study with the approval of advisor
- Course registration signed by advisor

- Typical load:

- Three courses plus RA or TA
- For first semester, three courses in math, major, and minor

- PhD Qualify:

- Contact Linda for access to old problems
- No later than 3rd semester if your MS is not from Purdue
- No later than 2nd semester for Purdue MS
- Three subjects: Math, Major, and Minor
- May take two related classes with B or better instead of taking minor

Financial Support

- RA:
- Talk to professors directly

- TA:
- Must have advisor nomination except new recruits
- Maximum time: Two (2) years
- Must maintain GPA > 3.0
- Must have oral English (OEPT) certification or TOEFL Speaking score 27 or higher

- Fellowship:
- **https://engineering.purdue.edu/Engr/Academics/Graduate**

- Other TAs on campus:
- Math Department
- Engineering Education

TAs in Other Departments

- Math Department:
- http://www.math.purdue.edu/jobs/ta
-
- Engineering Education:
- https://engineering.purdue.edu/ENE/AboutUs/Employment

Fellowship Opportunities

Government Funded Fellowships	
DOE Computational Science Graduate Fellowship	$36,000/year, tuition, fees for up to 4 years/US citizens/January
Science, Mathematics, And Research for Transformation (SMART)	$25,000 - $38,000 per year, tuition/US citizens willing to accept post-graduate employment with the DoD/December 1
NSF Graduate Research Fellowship	3-year $30,000 stipend, tuition, fees/US citizen or permanent resident students who completed no more than 1-year of graduate studies/November
NASA GSRP Fellowship	

Fellowship Opportunities

NDSEG Fellowship	3 years of $30,500+ stipend, tuition, fees/US citizens in their final year of undergraduate studies, or have completed less than two years of graduate study in the discipline in which they are applying/November
Sandia Excellence in Science, & Engr. Research Fellowship	up to 3 years of stipend, tuition and fees/Purdue first-year doctoral students/determined by CoE

Information on fellowships can be found at:
www.gradschool.purdue.edu/funding/