



UNIVERSITY OF
ILLINOIS
URBANA-CHAMPAIGN

Department of Aerospace Engineering

Astrofest 2023

Siegfried Eggli

April 28, 2023

AE by the numbers:

- ~30 faculty
- ~650 undergraduate students
- ~300 graduate students

Research Domains:

- Aerodynamics, Fluid Mechanics, Combustion and Propulsion
- Controls and Dynamical Systems
- Space Systems
- Structural Mechanics and Materials



Department Head: Jon Freund



Examples of Centers with substantial AE involvement

- [Center for UAS Propulsion \(CUP\)](#)
- [Center for Sustainable Aviation](#)
- [Center for Cryogenic High-Efficiency Electrical Technologies for Aircraft \(CHEETA\)](#)
- [Center for Exascale-enabled Scramjet Design](#)
- [Center for AstroPhysical Surveys \(CAPS\)](#)
- [IAU Centre for the Protection of the Dark and Quiet Skies \(CPS\)](#)

Saxton-Fox receives College Award for Leadership or Institutional Impact on Diversity, Equity, and Inclusion

Diversity, Equity and Inclusion

- Aero's Space to Belong
- Women in Aerospace
- Cultural exchange events
- Alumni Board

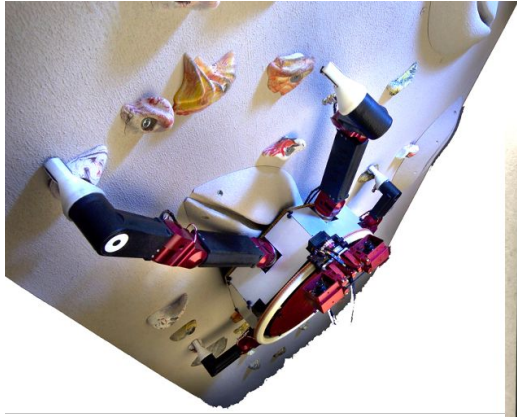


Tess Saxton-Fox

Space Systems



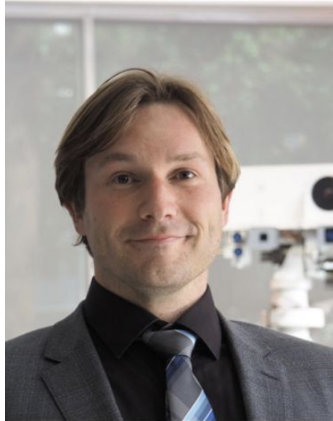
Tim Bretl



BRETL

Aerospace Robotics

- Planning, control, and optimization of robot motion
- Manipulation
- Rehabilitation
- Perception



Siegfried Eggli



Planetary Defense

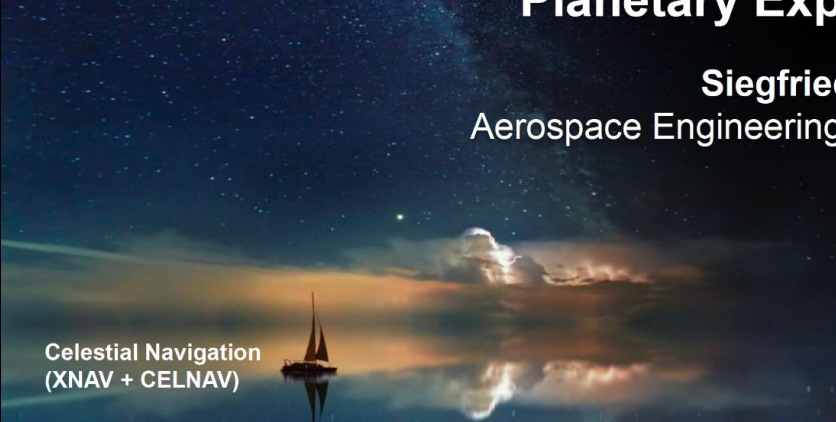


Sustainable Space Exploration

APEX

Astrodynamics and Planetary Exploration Lab

Siegfried Eggl
Aerospace Engineering / Astronomy / NCSA



Celestial Navigation (XNAV + CELNAV)



Habitability of Planets in Binary Star Systems



Mike Lembeck



LASSI

Laboratory for Advanced Space Systems at Illinois



Programs

Low-cost Small Satellite Radio



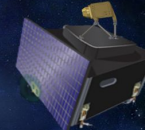
Provide UHF satellite uplink and downlink capability for small satellites in a compact, low-cost package

iEDU



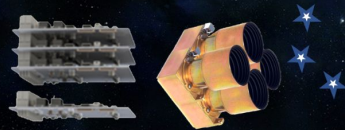
IlliniSat Educational Development Unit allows middle and high school students to participate in the design, assembly, and operation of a CubeSat payload

COSSMo



Carruthers Geocoronal Observatory Student Solar Monitor will monitor solar activity from the L1 Lagrange Point

Low-cost Small Star Tracker



Tracker intelligently combines images from camera array using a scalable AI-based compute platform to obtain high signal-to-noise ratio star images for accurate attitude determination

SEAQUE



JPL's Space Entanglement and Annealing QUAntum Experiment demonstrates 'integrated optical' source of entangled photon and extends photodiode lifetime via optical annealing

DarkNESS



Fermilab's X-ray observations of the galactic center using a cryo-cooled sensor in search of a 3.5 keV signal that may be the signature of dark matter decay.



Robyn Woollands

• High-fidelity Orbit Propagation

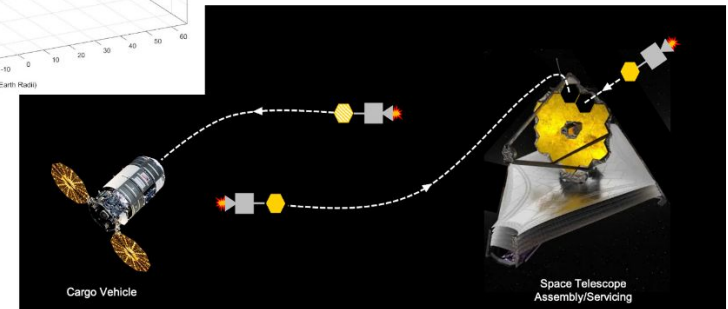
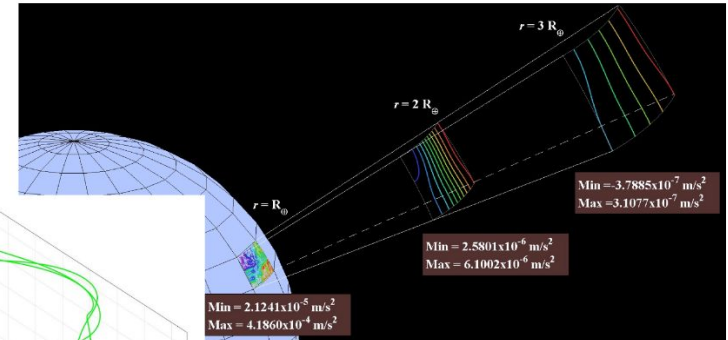
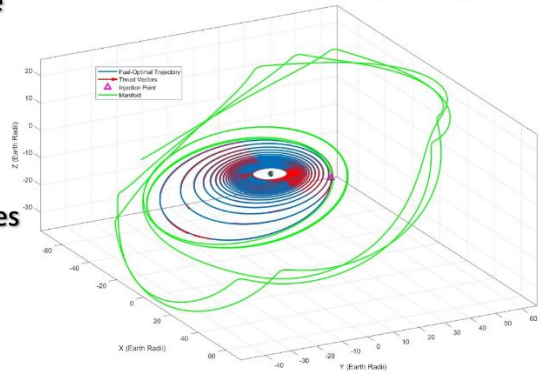
- Adaptive Picard-Chebyshev (APC) High-Fidelity Orbit Propagation
- Variable fidelity force model, radially adaptive gravity
- Neighboring trajectories computed economically using “gravity offset”

• Low/Medium Thrust Trajectory Optimization

- Smoothing thruster and eclipse on/off switches
- Thruster pointing & anti-collision constraints
- Smart eclipse continuation

Applications

- Satellite refueling and servicing (LEO & SEL2)
- Cislunar low-thrust trajectory optimization
- Space situational awareness
- Cloud Tomography Mission Design



Aerodynamics, Fluid Mechanics, Combustion and Propulsion



Francesco Paneri

Department of Aerospace Engineering / Grainger College of Engineering

Plasma flows

Surface oxidation

1000 °C 1400 °C 1600 °C

Micro- and meso-structures

t = 0.000 s

Ablation and

Image-based material analysis

Breakup and decomposition of meteorites

20 °C 850 °C 1000 °C

200 μm

High attenuation grains (meteoritic iron)

Parachute fluid structure interactions

The central image shows a glowing, ablated meteorite tip. Arrows point from this central image to six surrounding panels, each representing a different research area. The panels include: 1. Plasma flows (three portraits of researchers). 2. Surface oxidation (three images of a metal sample at 1000 °C, 1400 °C, and 1600 °C, with a portrait of a researcher). 3. Micro- and meso-structures (a micrograph of a material structure and a 3D model of a cylindrical structure at t = 0.000 s). 4. Ablation and (three portraits of researchers). 5. Image-based material analysis (a 3D visualization of a material structure with a color scale). 6. Breakup and decomposition of meteorites (three images of meteorite cross-sections at 20 °C, 850 °C, and 1000 °C, with a portrait of a researcher and a legend for high attenuation grains). 7. Parachute fluid structure interactions (a 3D model of a parachute structure and a portrait of a researcher).



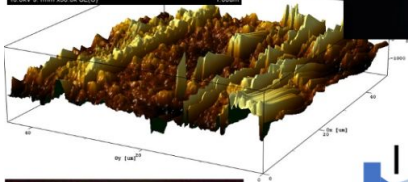
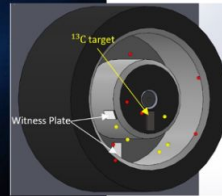
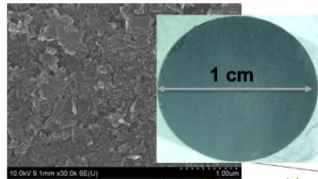
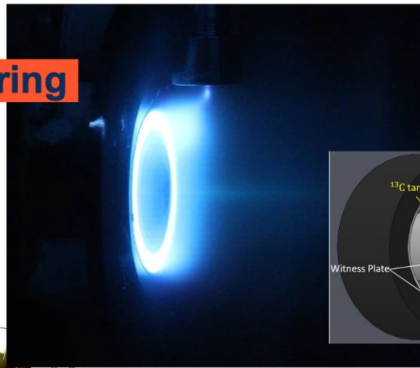
Josh Rovey

Electric Space Propulsion Lab



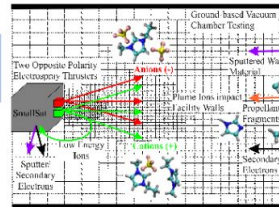
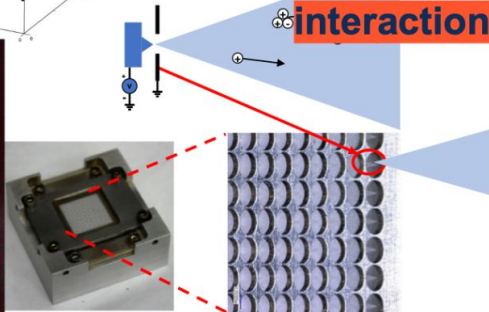
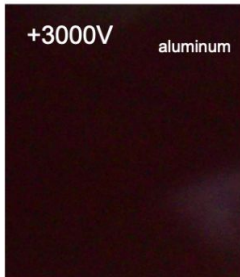
Hall Thruster:

- **Carbon sputtering & transport**

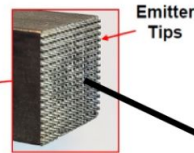
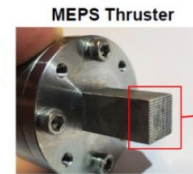
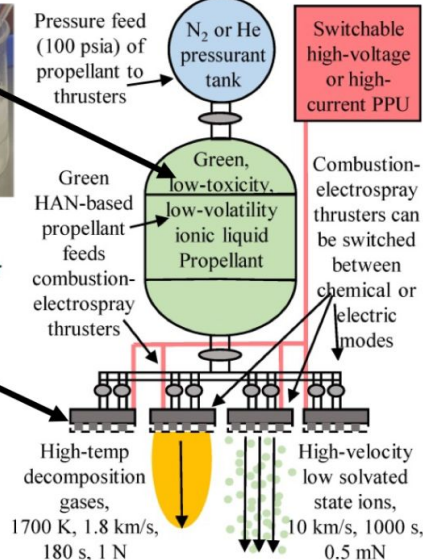
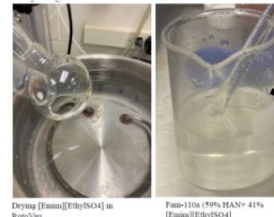
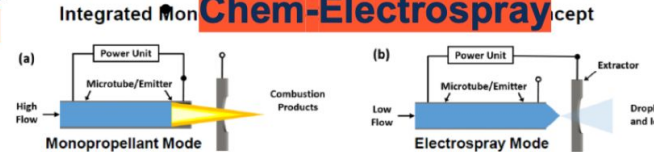


Electrospray:

- **Plume-material interactions**



Multimode Propulsion: Chem-Electrospray





Laura Villafane-Rocha

Particle-laden and complex flows

Turbulent particle-laden flows

Air flow Particles

Talbot

Turbulence modulation

Topology simplification and tracking algorithms

Plume surface interactions

Mach 5 Mars landing

Granular bed Solid substrate

Mars New instrument Moon

P. Concentration t (s)

Vision

Lander Radar Reflector Radar

Natural radar landmark Crater

Flow velocimetry via MRI (@Beckman)

AEROSPACE ENGINEERING

Parachute fluid and structural mechanics

Increasing permeability

0.5 mm

GRAINGER ENGINEERING



Deborah Levin

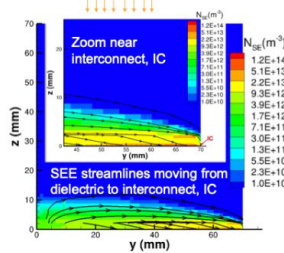


Why high performance particle-in-cell for space plasmas?

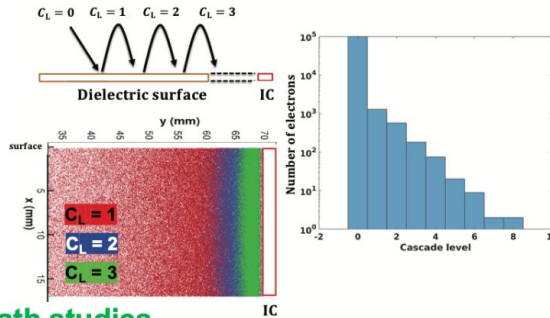
- **Electrons have non-Maxwellian behavior.**
- **3-D effects important in characterizing plasma instabilities**
- **Use massively parallel heterogenous CPU/GPU strategies.**

(2) Solarcell arrays – parasitic current snapover

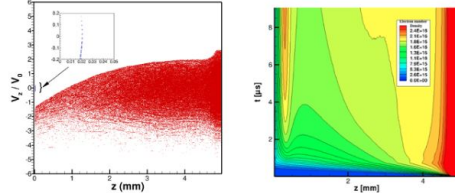
LEO Free stream O^+ , e^-



e^- s cascading along dielectric surface changes its surface conductivity

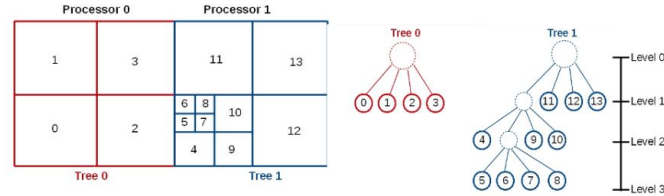


(3) ETC Plasma sheath studies



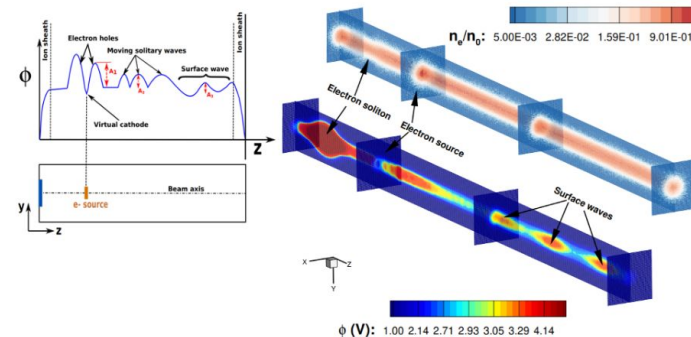
Low energy thermionic electrons accumulate near $z = 0$ mm surface because of repulsion from virtual cathode

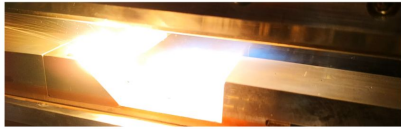
(1) Numerical approach – AMR/Octree



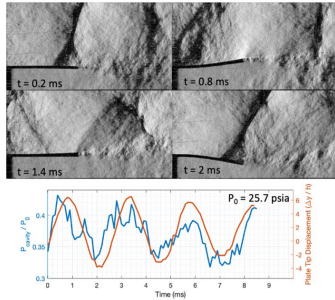
- **3-D CHAOS codes use two linearized Morton-ordered FOTs with own, λ or λ_D for DSMC and PIC simulations**

(4) Role of Electrostatic Solitary Waves in Beam Neutralization

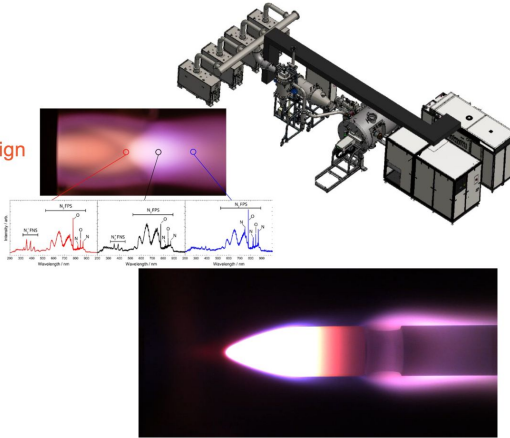




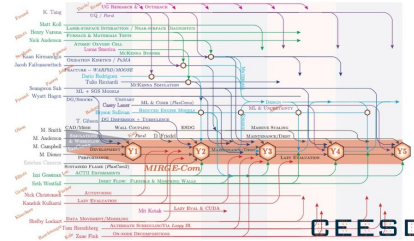
The Center for Exascale-enabled Scramjet Design



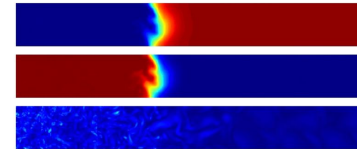
Fluid/Thermal Structure Interactions in High-Speed Flows



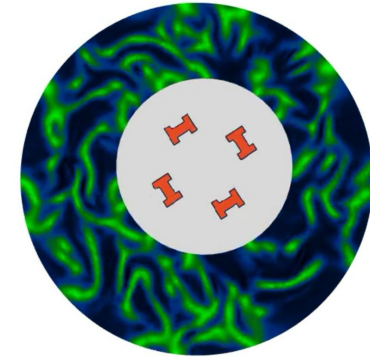
CHESS (Plasmatron X) TPS and Thermal/Chemical Non-equilibrium Flows



The Center for Exascale-enabled Scramjet Design



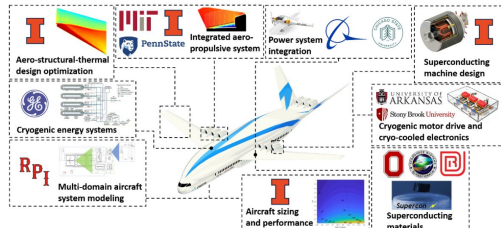
Gov. equation constrained ML training for SGS coupled physics



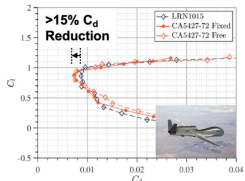
Active suspension dynamics

Greg Elliot

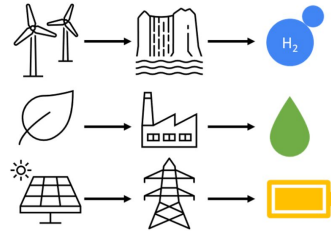
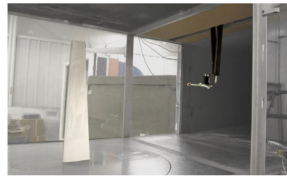
Jon Freund



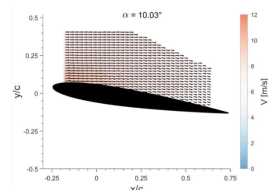
Aircraft Technology Integration and Design



Air Vehicle Aerodynamics



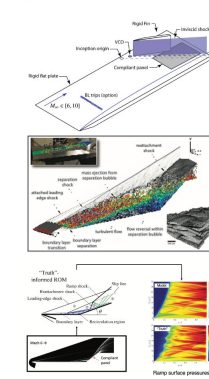
Sustainable Aviation



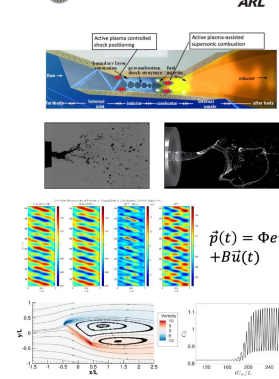
Unsteady Aerodynamics

Professor Daniel J. Bodony
University of Illinois at Urbana-Champaign
bodony@illinois.edu
<http://acoustics.ae.illinois.edu>

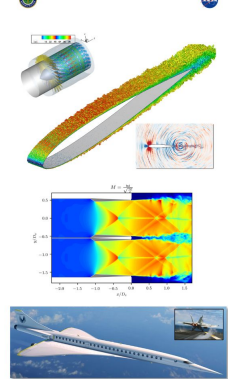
High-speed aerodynamics and aerothermoelasticity



Model- and data-driven flow control



Aeroacoustics and aircraft noise reduction

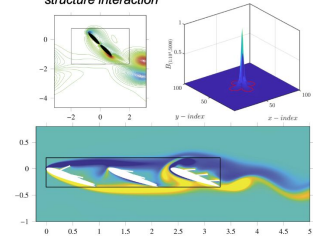


$$\vec{p}(t) = \Phi e^{At} \Phi^T \vec{e}_0 + B \vec{u}(t)$$

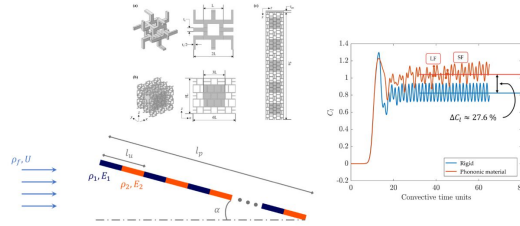
Phil Ansel

Dan Bodony

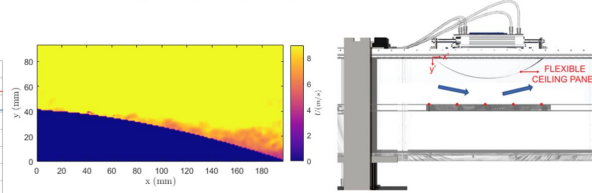
Better numerical methods for fluid-structure interaction



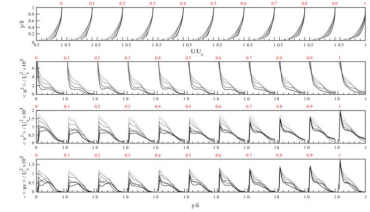
Harness modern materials in passive flow control



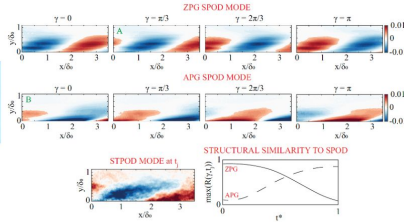
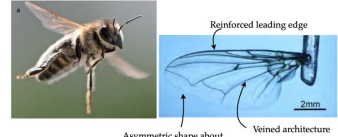
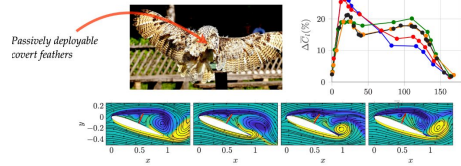
Separating and globally unsteady turbulent flows



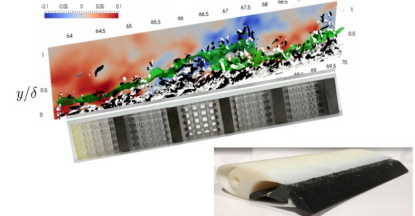
Massive data collection for computational validation, machine learning



Understand bio-inspired flow control/locomotion mechanisms



Coherent structure physics and analysis



Flow, (meta)material interaction for flow control

Andres Goza

Tess Sexton-Fox

Structural Mechanics and Materials



Jeff Baur

Novel Materials

Novel Reactive Polymers

- Structural Resins
- Shape Memory Polymers
- Frontal Polymerized
- Radiation/Snap Cured

Structural Reinforcement

- Fibers
- Nanofillers
- Printed lattices

Multifunctional

- Sensors / Hardening
- Autonomous Response
- EM/Thermal Transport
- Microvascular
- Power/Computation

Printed Composites

Fundamental Understanding



Topology Optimization



Bio-inspired Morphogenesis

Emerging Industry



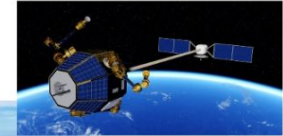
Continuous Fiber Printed Composites



Rapid Model Validation of Adaptive Structures

Multi-functional Structures

Space-based Printing



Active Thermal Management



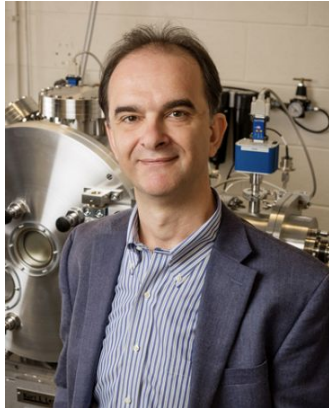
New Adaptive Structures



Low-Cost Attritable Aircraft



Sustainable Aircraft Structures

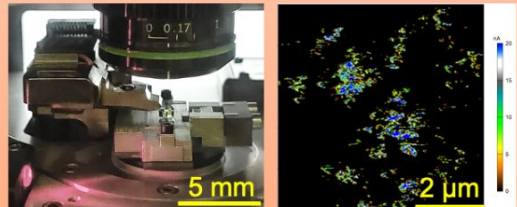
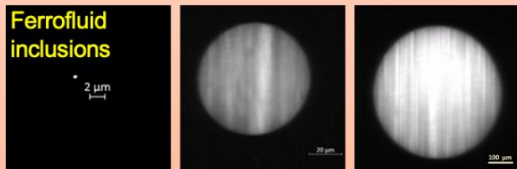
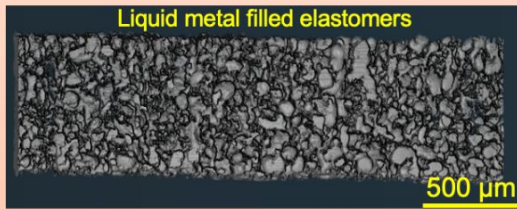


Ioannis Chasiotis

SOFT COMPOSITES WITH LIQUID INCLUSIONS

NSF DMREF MATERIALS FOR OUR FUTURE

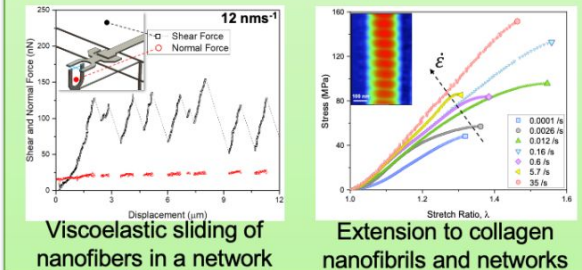
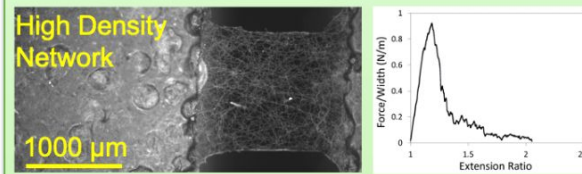
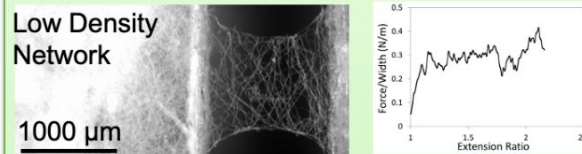
OBJECTIVE: Investigate multiphysics phenomena in elastomer matrix composites with electrically or magnetically active liquid inclusions.



RANDOM NANOFIBER NETWORKS

NSF NIH

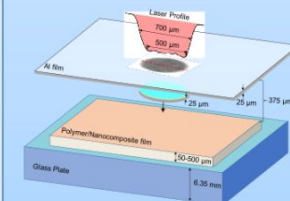
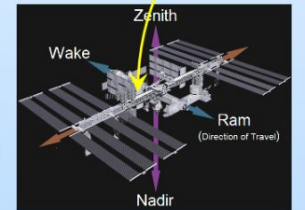
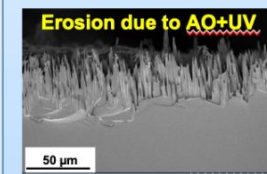
OBJECTIVE: Understand fiber-to-fiber interactions and their effects on global mechanical response of random nanofiber networks and their composites.



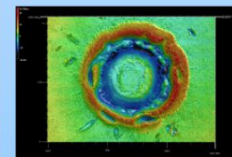
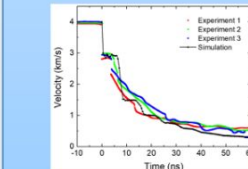
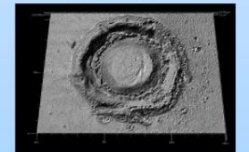
SELF-HEALING MATERIALS FOR LEO

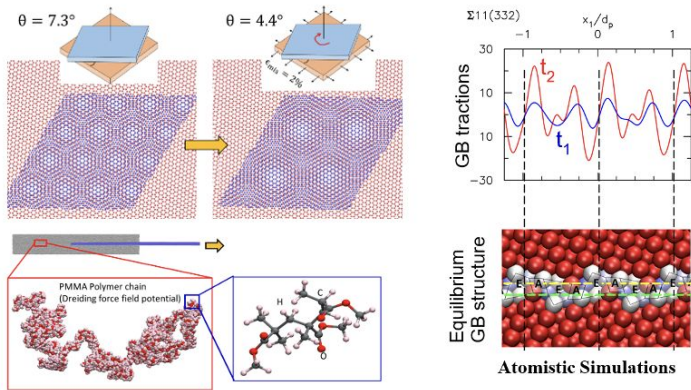
NSF

OBJECTIVE: Develop strategies for AO+UV erosion mitigation and orbital debris damage repair of polymers in situ in LEO.



Laboratory debris impact experiments





Nanoscale Mechanics of Interfaces

Huck Beng Chew

Philippe H. Geubelle

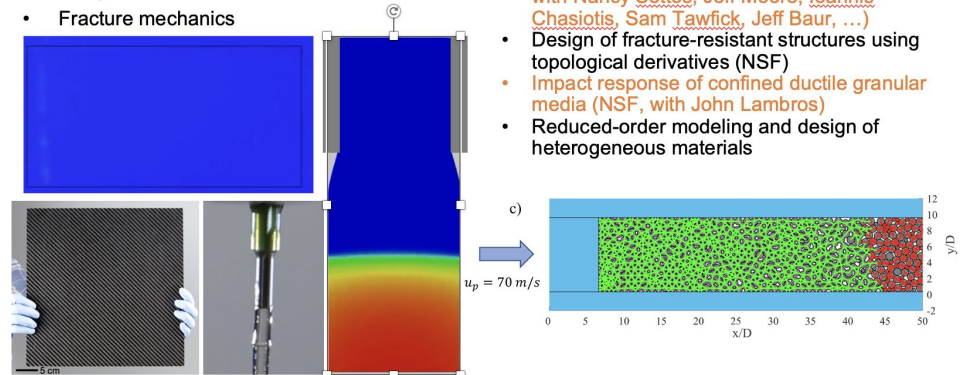
<http://aerospace.illinois.edu/directory/profile/geubelle>
<http://geubelle.aerospace.illinois.edu>
geubelle@illinois.edu

Research Interests

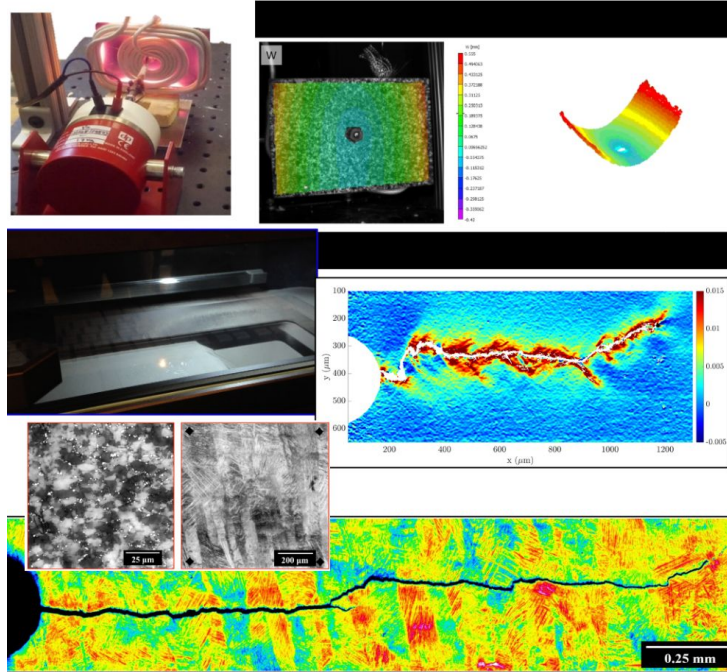
- Faster, energy-efficient manufacturing process for thermoset composites
- Computational design of biomimetic materials
- Development of novel finite element methods
- Multi-scale and multi-physics modeling and design of advanced materials
- Fracture mechanics

Current Projects

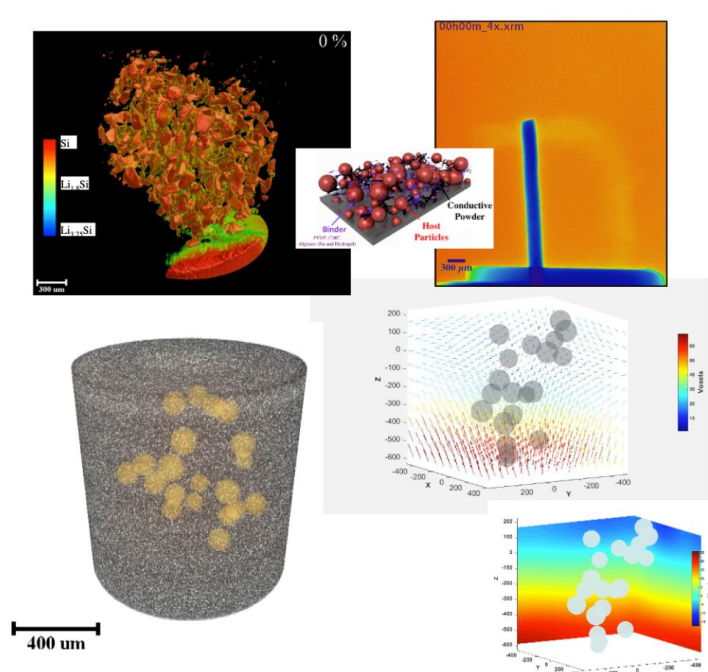
- Rapid, energy-efficient manufacturing of composites using frontal polymerization (FP); 3D printing of thermoset polymer composite; space manufacturing of large composite structures; machine learning-based discovery of new recyclable thermoset polymers made with FP (AFOSR, NSF, DARPA, DOE EFRC, with Nancy Sottos, Jeff Moore, Ioannis Chasiotis, Sam Tawfik, Jeff Baur, ...)
- Design of fracture-resistant structures using topological derivatives (NSF)
- Impact response of confined ductile granular media (NSF, with John Lambros)
- Reduced-order modeling and design of heterogeneous materials



Thermoacoustic response of AM metals



Tomographic investigation of composites



John Lambros

Controls and Dynamical Systems

Security and privacy in control

How to ensure stability/performance guarantees of a controlled system when communication network, sensors, and actuators may be under cyber-attack?

An artist's view of Stairwell (from NYT)

How to control systems without revealing private information about models and data?

Smart-city applications

How to design information-based influencing mechanisms that persuade users to act for a greater good?

Waze - Drive Social!

...while respecting privacy and acting fairly?

Human-robot collaboration

Where is it going to land?

What makes the motion of a UAV or robot legible to a human co-worker or passerby?

How to plan for both efficiency and (correct) belief shaping?

Strategic Information Transmission

Infrastructure for the people

Network information dynamics & "fake news"

What prompts a newsreader to further propagate a message?

Data markets

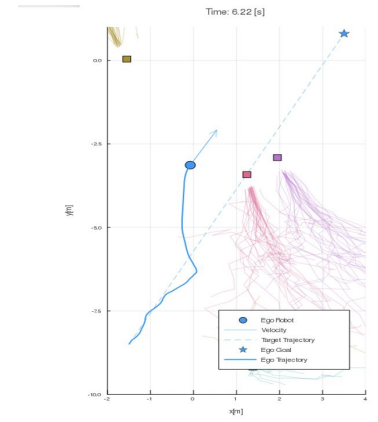
What tactics are used for manipulation and to counter it?

In contested space like an airport, who should get access to more data (about airport-operation caused delays)? At what price? At what granularity?

Cedric Langbort

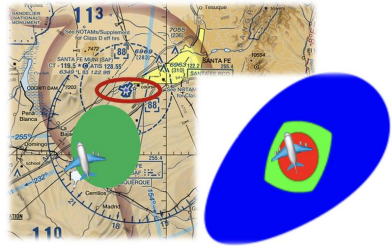
ICON

Risk-Aware Robots

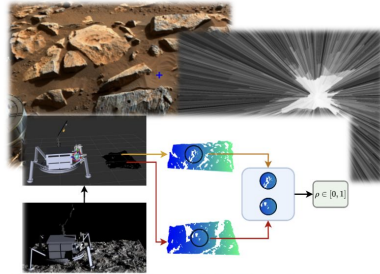


Multi-Agent and System Level Interactions

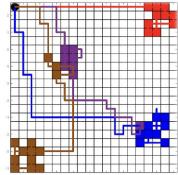
Negar Mehr



**Resilience and
Guaranteed Mission Completion**



Faster Learning with Side Information



**Multi-Agent
Mission Decomposition**



Behavior Inference and Belief Manipulation

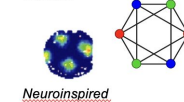
Melkior Ornik



Multi-agent Learning



**Connected and automated
vehicles**



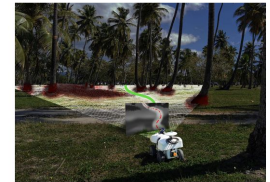
Neuroinspired



**Human
teammate(s)**
AI teammate



Human-agent Teaming



Robotics and Formal Methods

Hui Tran

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