Wearable Brain Machine Interface Architectures for Cognitive Stress

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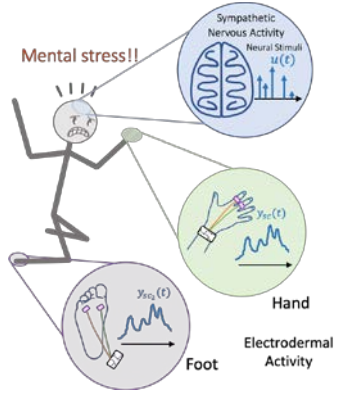
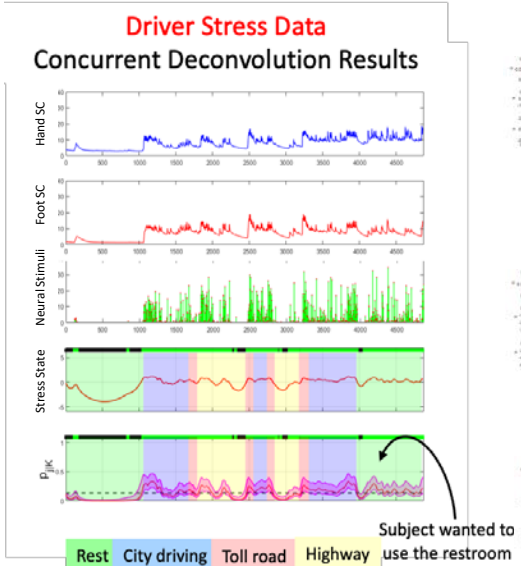
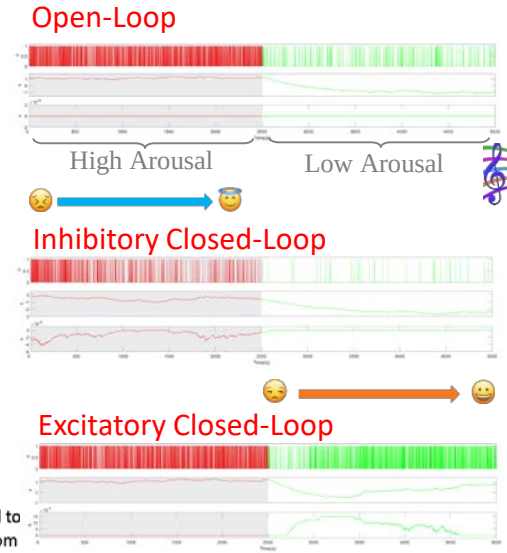
COLLEGE of ENGINEERING
Computational Medicine Laboratory

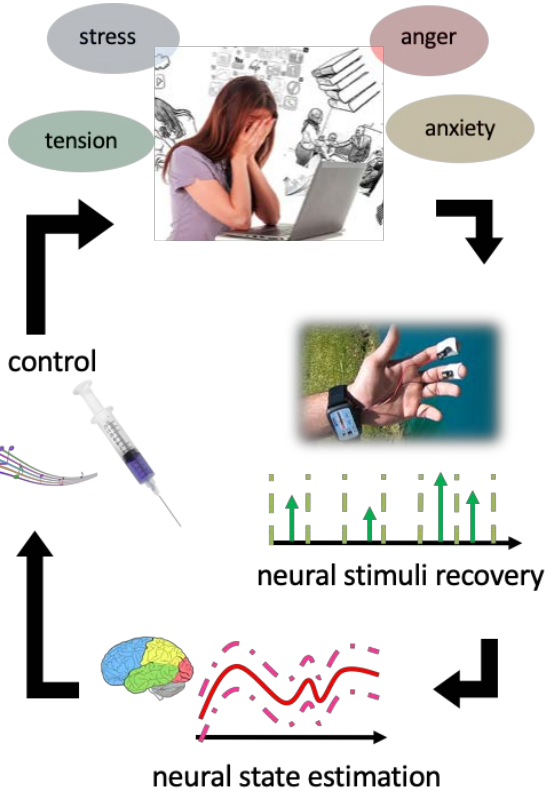
Wearable devices to infer brain activity from peripheral physiological signals

- Infer neural stimuli underlying pulsatile physiological signals (e.g. skin conductance, blood cortisol levels)
- Estimate an unobserved state from underlying pulsatile stimuli
- Apply control mechanism to maintain neural state within a desired range





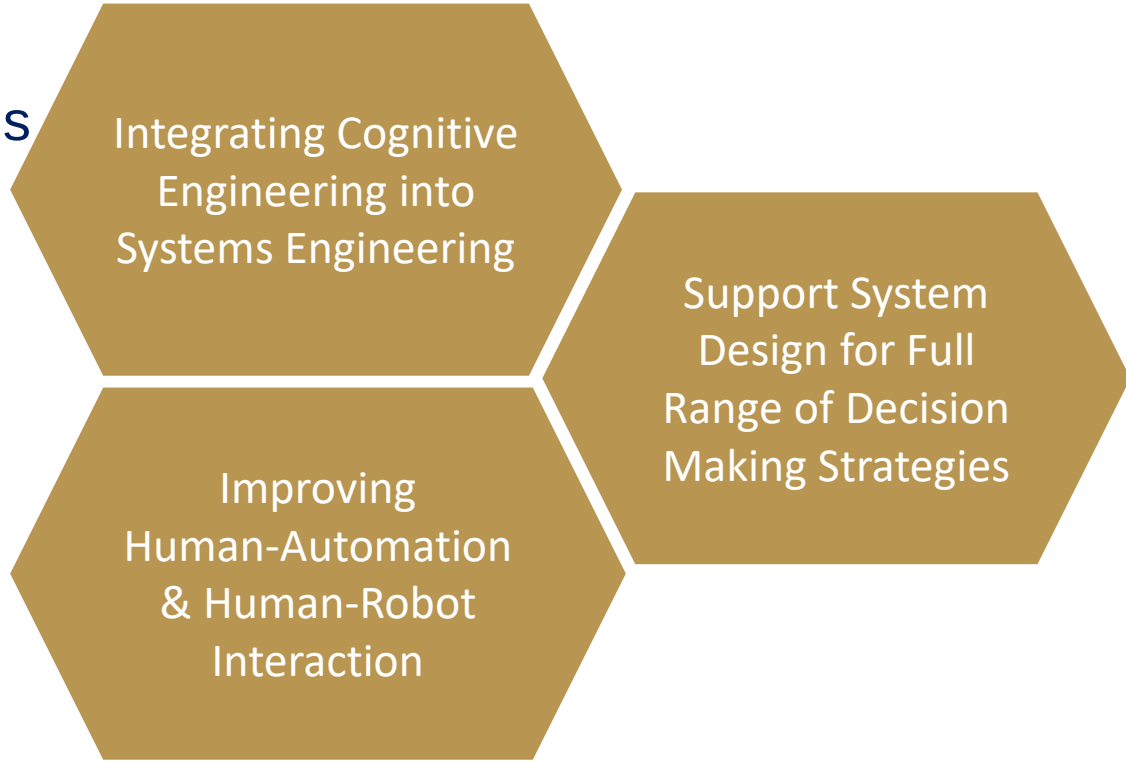




Improving Human – Autonomy Teaming

Three Themes & Many Methods

- Ethnographic and Knowledge Elicitation
- Work Modeling
  - Cognitive Work Analysis
  - Contextual Inquiry
  - Cognitive and Hierarchical Task Analysis
- Requirements Derivation
- Analytical Modeling
- Computational Modeling & Simulation
- Human Subject Experimentation
- Inferential Statistics
- Machine Learning



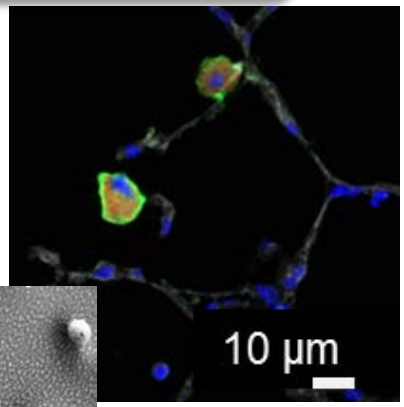
Catherine Fromen

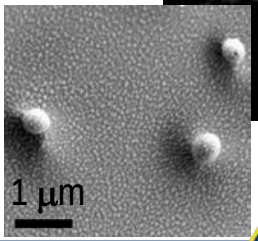
Assistant Professor, Chemical & Biomolecular Engineering

University of Delaware

Fromen Lab

Polymeric Nanoparticle Formulations to Direct Lung Immune Responses





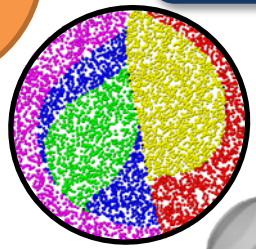
Mucosal Immunology

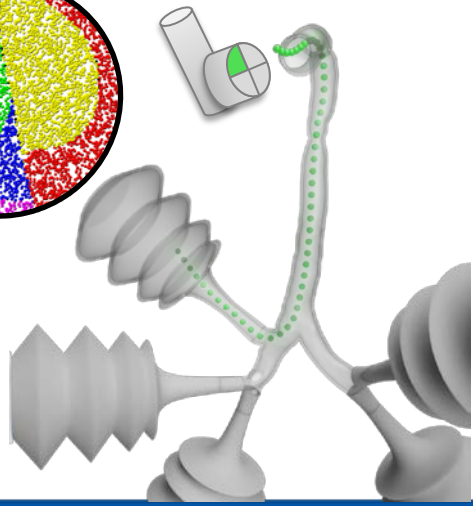
Engineering Design Principles

Engineering Respiratory Tools and Therapeutics

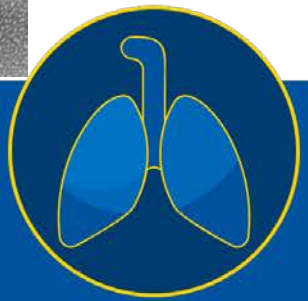
Novel Biomaterials

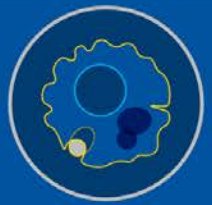
Anatomically-Accurate 3D-Printed Lung Models to Improve Deposition





Chemical & Biomolecular Engineering





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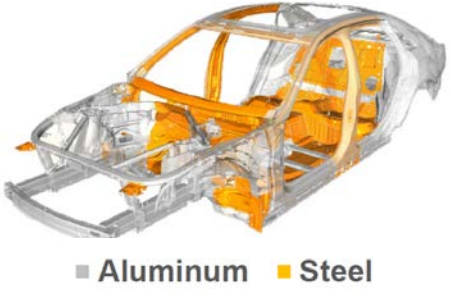
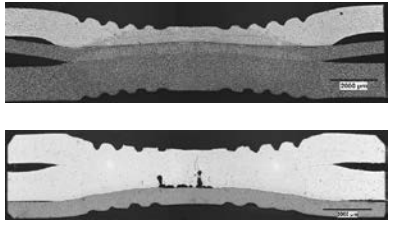
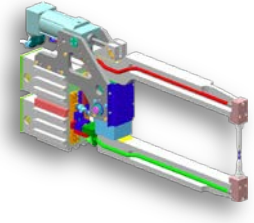
Joining Lightweight Automotive Body Structures

Amberlee Haselhuhn, Ph.D. Senior Researcher, General Motors R&D Amberlee.Haselhuhn@gm.com

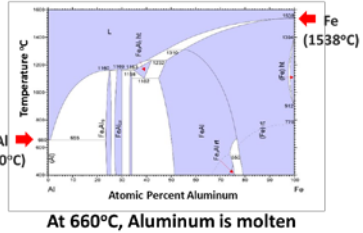
Put the right material in the right form in the right application → Lightweighting for zero emissions goal





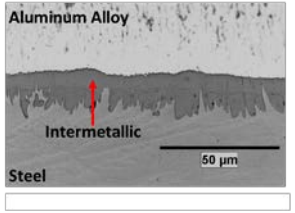


900°C Melting Point Difference



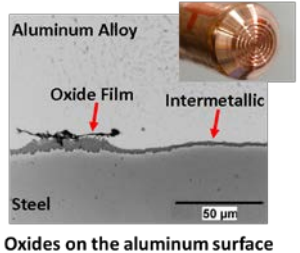
At 660°C, Aluminum is molten but steel is only getting warm

Intermetallic Layer



Intermetallic compound layer can cause brittle failure

Aluminum Oxides



Oxides on the aluminum surface can cause premature weld failure

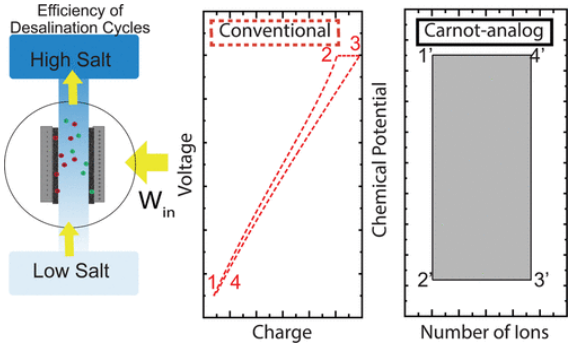
GM RESEARCH & DEVELOPMENT

Marta C. Hatzell
Assistant Professor
School of Mechanical Engineering
Georgia Institute of Technology

The Hatzell labs investigates the thermodynamics and interface science of next generation electrochemical technologies for sustainable food, energy and water production.

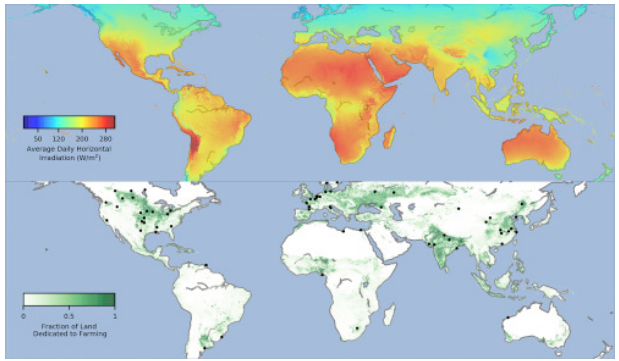
Motivation: The decreasing price of renewable energy motivates the need for technologies that are capable of up converting and storing this energy in higher value products, such as fuels, fertilizers, and water.

Electron-driven separations



Moreno, Daniel, and Marta C. Hatzell. "Efficiency of Carnot and Conventional Capacitive Deionization Cycles." *The Journal of Physical Chemistry C* (2018).

Solar-driven fertilizer production

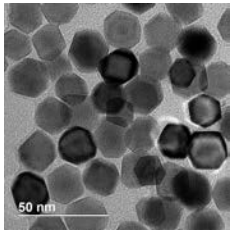


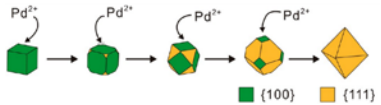
Comer, Benjamin M., et al. "Prospects and Challenges for Solar Fertilizers." *Joule* (2019).

Electrochemical Water Treatment

$$NO_{3\ aq}^{-} \rightleftharpoons NO_{3\ ads}^{-} \rightarrow NO_{2\ ads}^{-} \rightarrow NO_{ads} \rightarrow N_2O \rightarrow N_2$$

$$NO_{2\ aq}^{-} \rightarrow NO_{ads} + NH_{x\ ads}$$

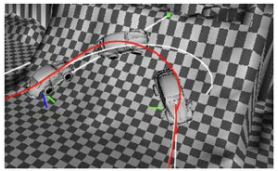




Christoffer Heckman
University of Colorado, Boulder

OPPORTUNITY

- *Robotic autonomy* for challenging one-shot tasks.
- Low-cost, robust perception in challenging environments, including *underground*, in automated *agriculture*, and *indoors*.
- Human-directable lifelong learning through natural la



COLLABORATORS

- Robotics: Humbert, Frew, Correll, Rentschler
- Machine learning: Hayes, Roncone, Palmer
- Sponsors: DARPA, NSF, DoD, NASA, industry

APPROACH

- **Large-scale, long term** simultaneous localization and mapping (SLAM) for long-term autonomy.
  - Bayesian estimation and **sensor fusion**.
  - 3D reconstruction using **stereo** cameras, mmwave **RADAR**, and LiDAR.
  - **Visual-inertial** navigation for rapid feedback.
- Online uncertainty-aware **model-predictive control**.
- Natural language and semantic perception.
- Deep learning in perception-action loops.

IMPACT
(Industry, Government, Society)

- Ubiquitous perception, natural language interactions and lifelong machine learning combined can accomplish a lot without any embodiment.
- Autonomy has implications in many of the other cases:
  - Enhanced productivity in du repetitive tasks
  - Safety-critical operation in dangerous environments

Cathleen Hoel

Materials Scientist – Ceramic Processing

General Electric Research

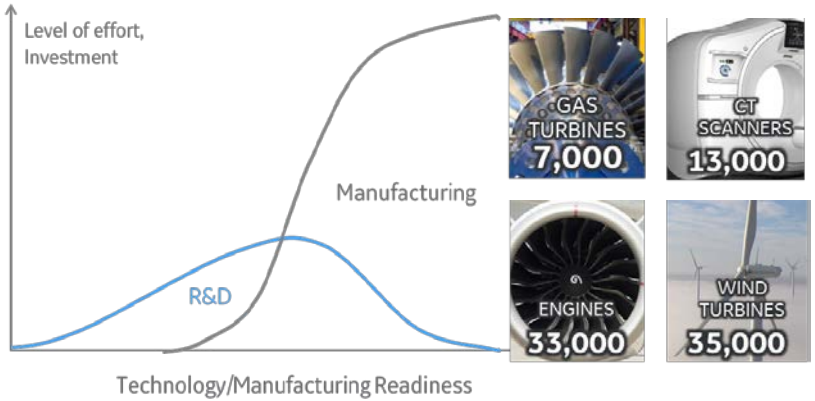
Where research meets reality

Feasibility Testing

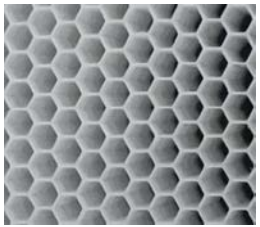
Lab-to-Pilot Transitioning

Root Cause Analysis

Project Management

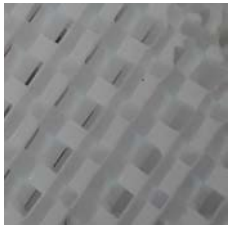


Additive Manufacturing Ceramics



< 200 um walls

Curved & straight internal channels



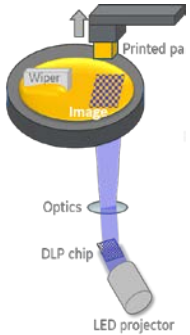
Trifurcating channels

Material development

Prototyping and Feasibility

Collaborating with Designers

Education and Promotion



https://www.linkedin.com/in/cathleen-hoel/

Discovering High Thermal Conductivity Materials to Revolutionize Thermal Management Technologies

Yongjie Hu
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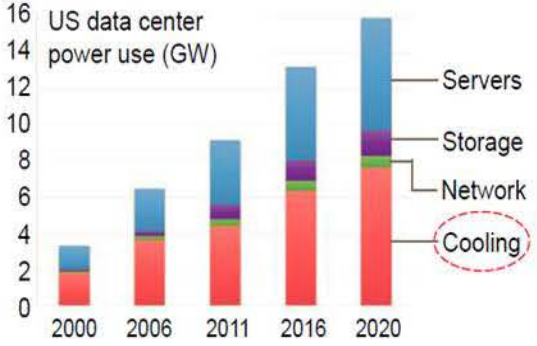
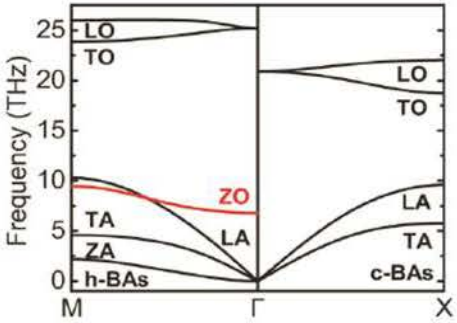
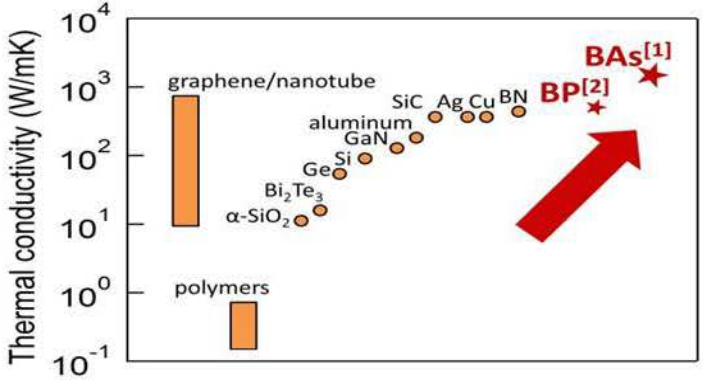
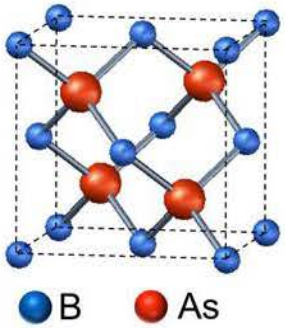
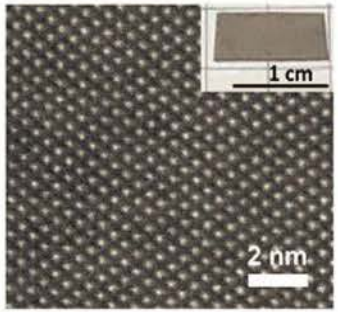
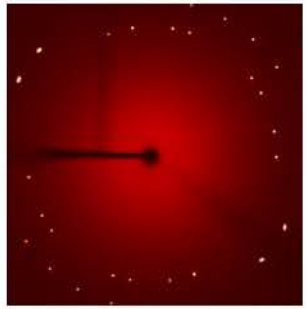


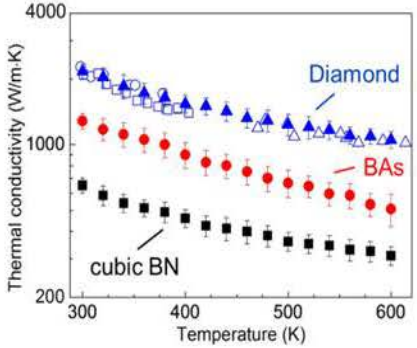


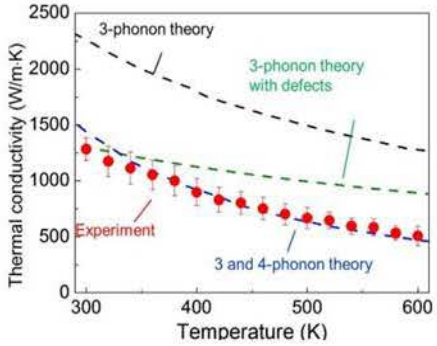








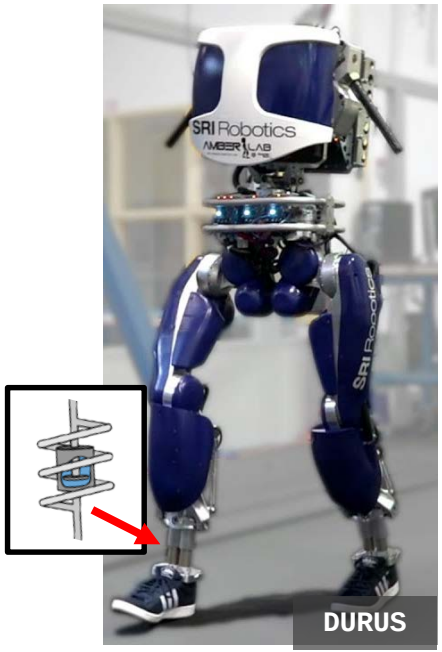




References: [1] *Science* 361, 575 (2018). [2] *Nano Letters* 17, 7507 (2017). [3] *Phys. Rev. B* 100, 085420 (2019). [4] *Appl. Phys. Lett.* https://doi.org/10.1063/1.5116025 (2019).

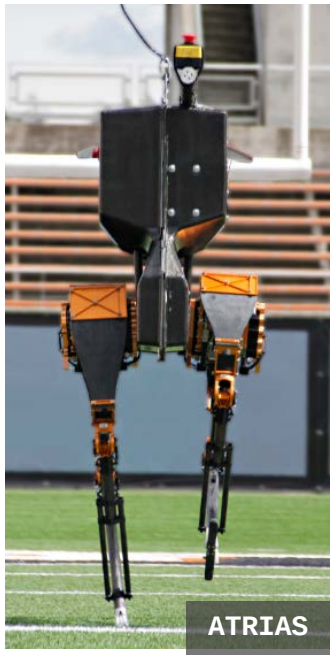
Lessons from Legged Robotics and Applying them to Manufacturing

Christian Hubicki, Florida State University, FAMU-FSU College of Engineering

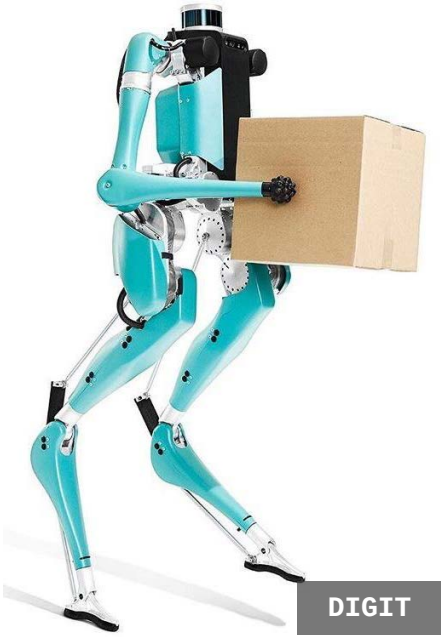


Physical Compliance and Passive Dynamics

Robustness to Environments



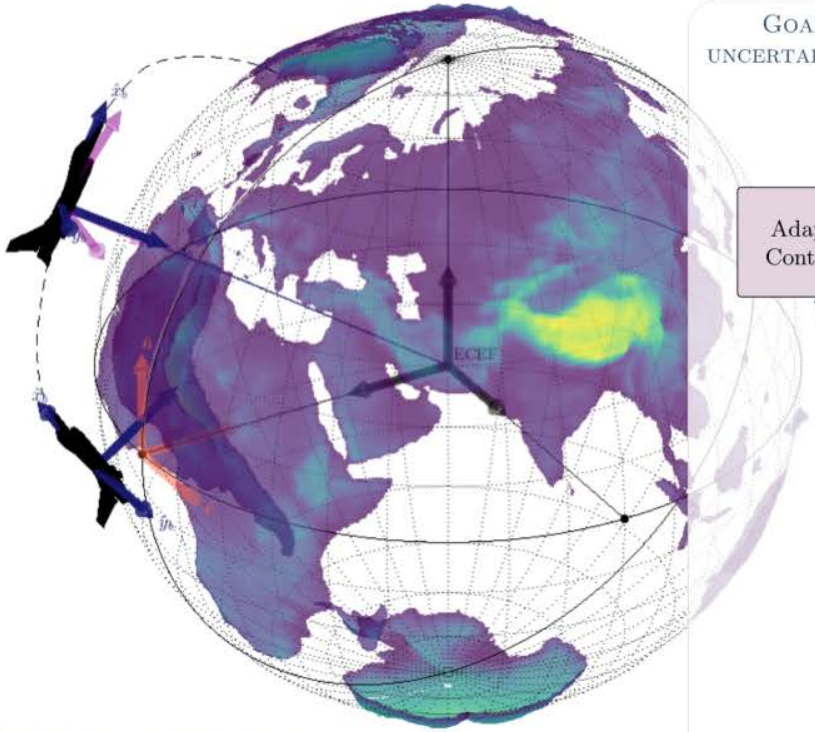
Self-stable Control and Emergent Behaviors



Task-flexible Control Algorithms

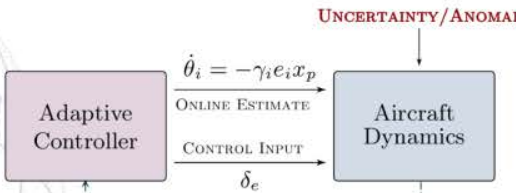
Heather Hussain, Sc.D.

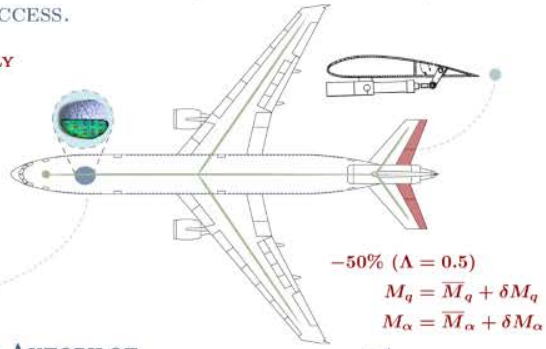
Guidance, Navigation, Controls, & Autonomy (GNC&A)

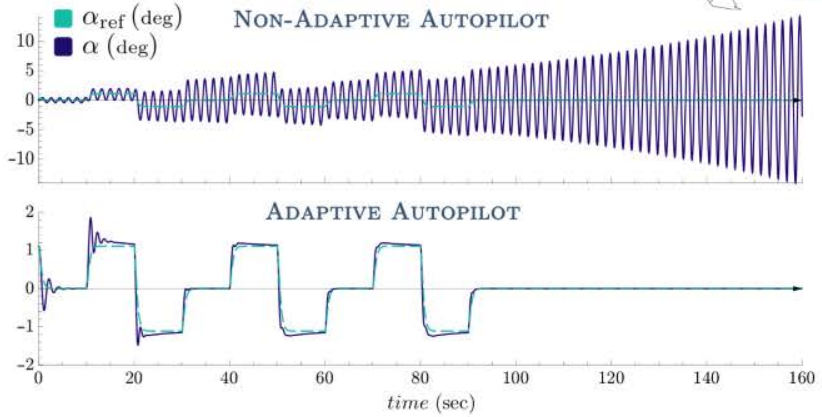


Robust & Adaptive Flight Control ✓

Goal: Design a flight controller that robustly adapts to & compensates for uncertainties that would adversely affect performance, maneuverability, and mission success.







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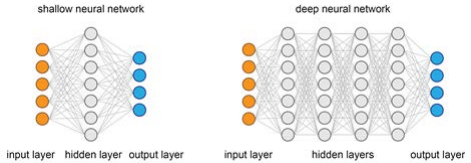
Boeing Research & Technology, Tukwila, WA

Towards theoretically-founded learning

Shirin Jalali, Math and Algorithms Group, Nokia Bell Labs



A Theory of Deep Learning

Is there a theory of Deep Learning that explains its success? Why Deep NNs are much more powerful that Shallow NNs?

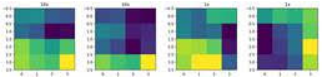
Theoretically-founded Structure Learning

- Phase retrieval
- Compressive imaging
- OCT imaging
- Compression
- Denoising

Data processing algorithms heavily rely on exploiting structure of data, which is usually discovered either by

- domain experts (via diligent time-consuming work), or
- hard-to-interpret potentially sub-optimal tools such as NNs.

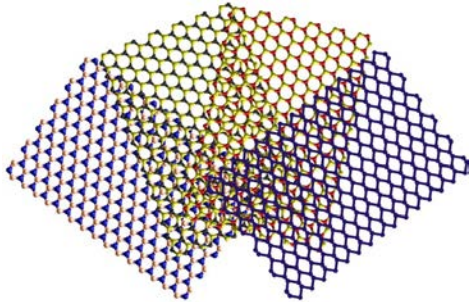
Question: Could we have an efficient, theoretically-founded structure learning method?



Theoretically-founded learning is possible and impactful.

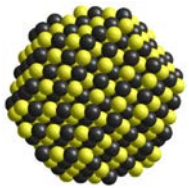
New Semiconductors for Known (and new) Challenges

Materials with Passivated Surfaces and Interfaces



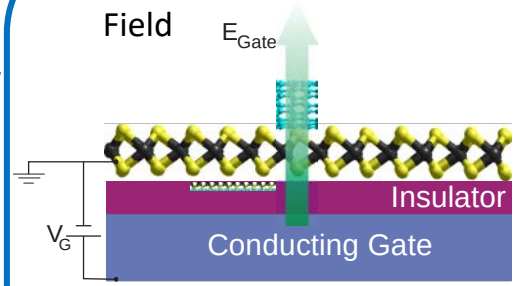
Van der Waals Materials

Carbon Nanotubes

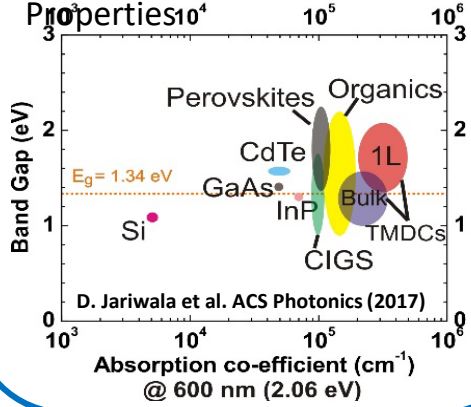


Organics and Nanocrystals

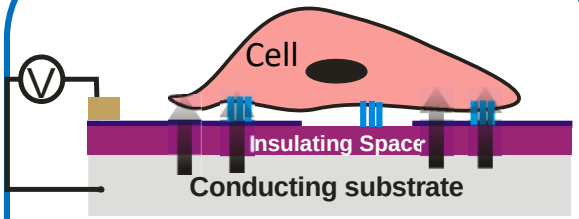
Semi-Transparency to E-Field



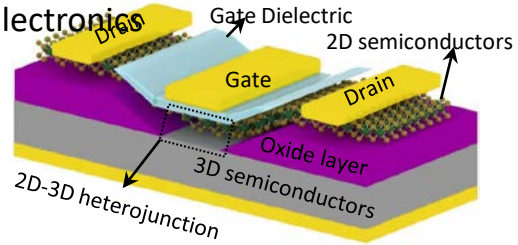
Extraordinary Optical Properties



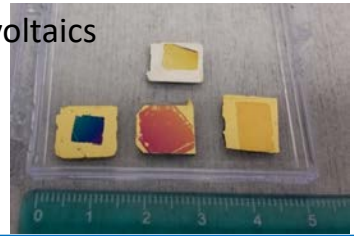
Cell/Tissue-Recording/Stimulation



Hybrid/Augmented Si/III-V Electronics



Ultrathin Photonics and Photovoltaics



Deep Jariwala, PI
Device Research and Engineering Laboratory

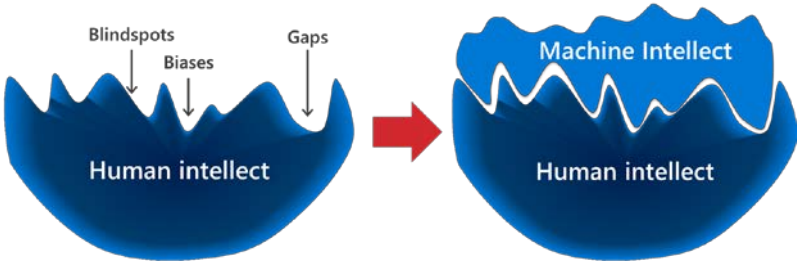
Dr. Edward Jimenez
Sandia National Labs

- Hyperspectral Computed Tomography
- Computational Imaging
- High-Performance Computing for Big Data
- Algorithm Development

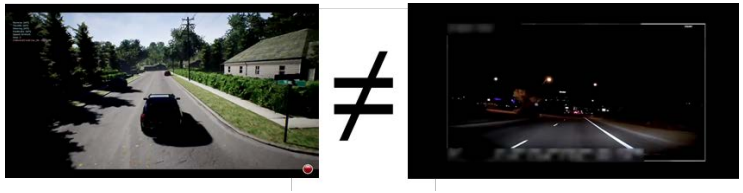
Microsoft Research AI

Human-centered AI

Ece Kamar, Principal Researcher, TA to Aether Committee



human-AI collaboration



AI in the real-world

biases and blind spots

fairness and ethics

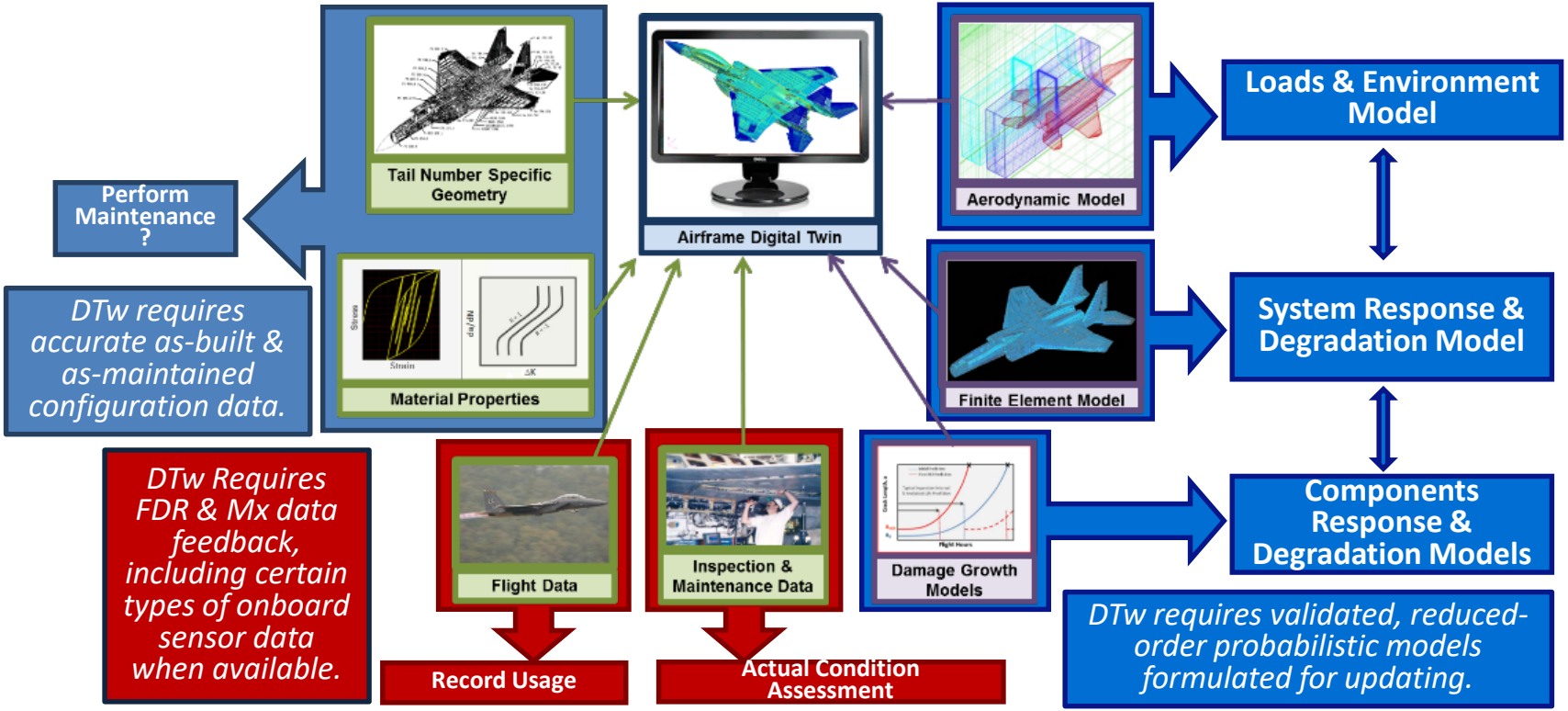
Aether Committee

Microsoft

AI, Ethics and Effects
in Engineering & Research

Airframe Digital Twin

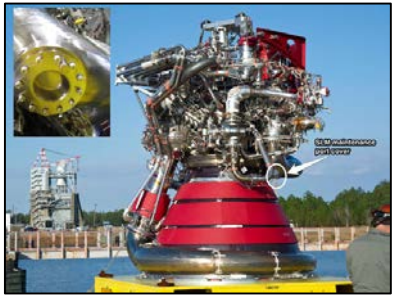
Dr. Pam Kobryn
Air Force Research Laboratory



88ABW-2018-2960

Computational Materials for the Design and Qualification of Additively Manufactured Components

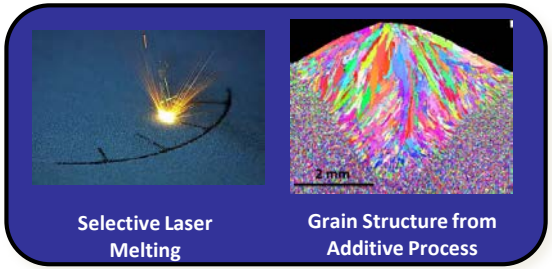
Aeronautics Research

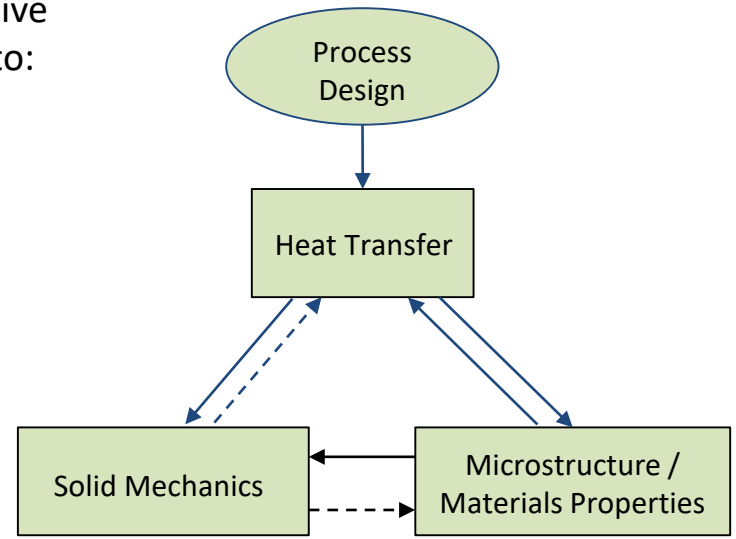


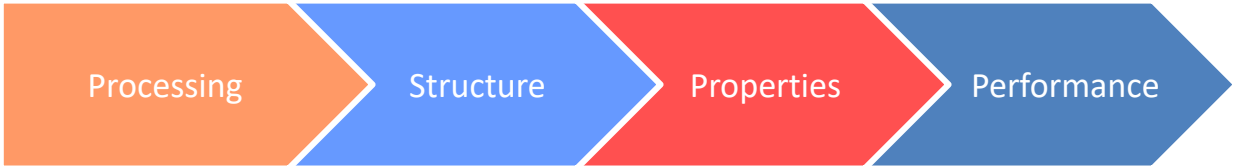
Space Exploration

Physics-based modeling of the additive manufacturing process contributes to:

- Process Design/Optimization
- Defect Formation/Mitigation
- Certification
- Component Design







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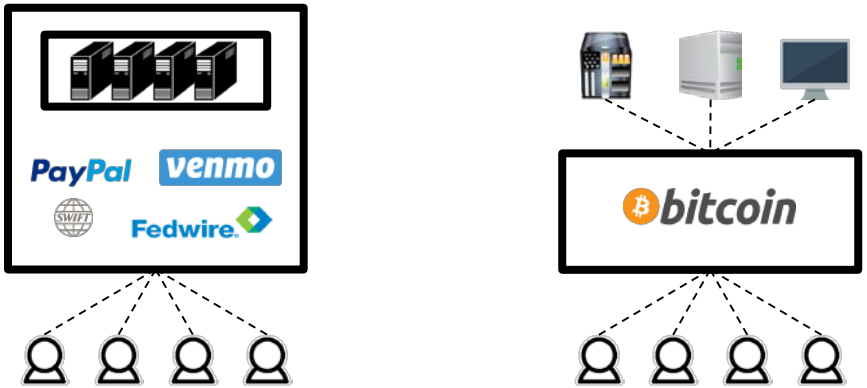
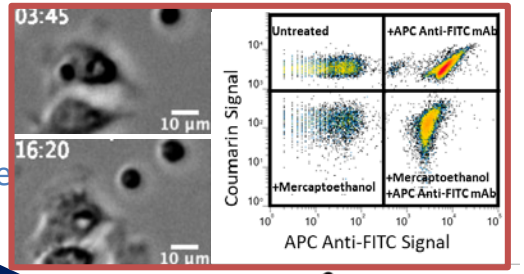
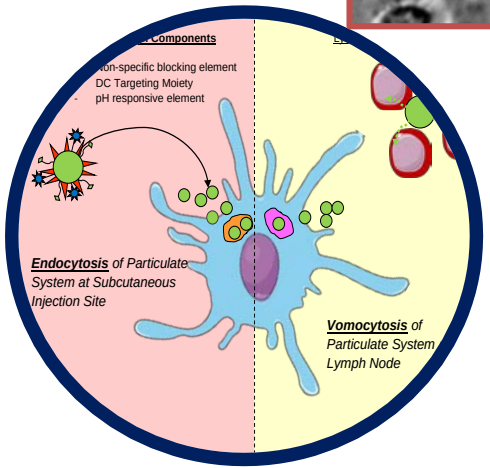
Traditional Payment Systems vs. Bitcoin

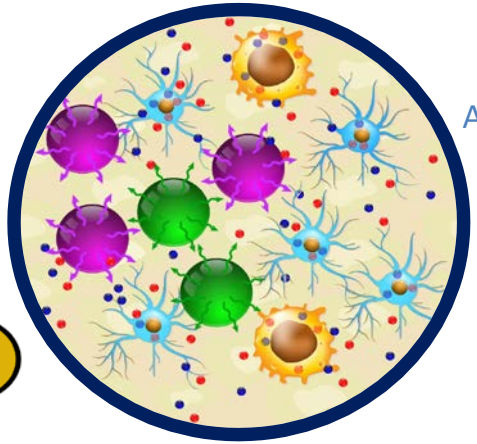


Rules	Set by firm/org	Fixed by protocol
Infrastructure	Procured by firm/org	*Entry/Exit, Revenue*
Pricing	Fees set by firm/org	*Equilibrium congestion pricing,* *Miners do not set prices*
Balancing supply and demand	Firm's incentives	*??*

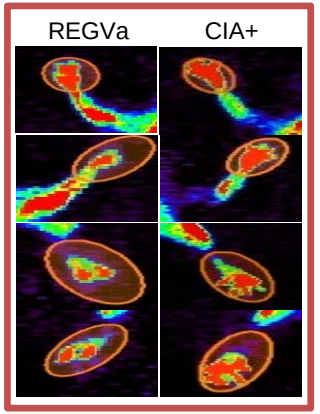
Deciphering Vomocytosis from Phagocytic Immune Cells



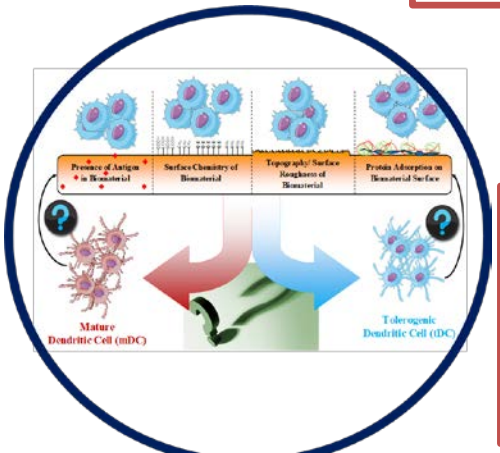




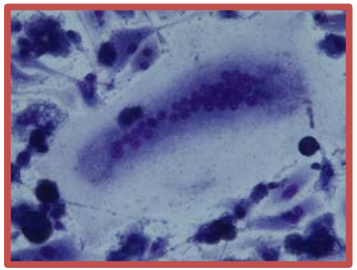
Particulate-based immunotherapy for Autoimmune Diseases



IMBL
Immunomodulatory Biomaterials Laboratory



Understanding the role of DCs in the FBR



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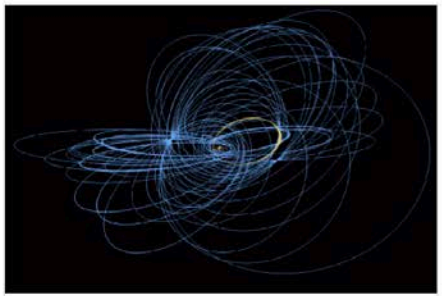
Charles Stark Draper Assistant Professor,

Department of Aeronautics and Astronautics

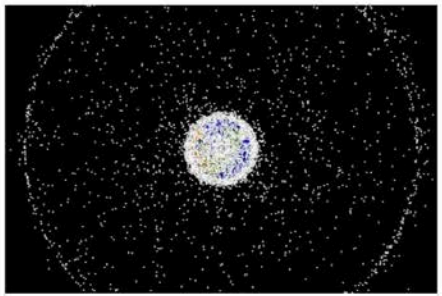
Massachusetts Institute of Technology

Massachusetts Institute of Technology
Space Systems Laboratory



Astrodynamics

Autonomous Space Systems



Space Traffic Management

Optimally utilize information from **models** and **observations** to **estimate and control the state** and forecast **uncertainty of physical systems**