Be Boulder.

AeroSpace Ventures
UNIVERSITY OF COLORADO BOULDER

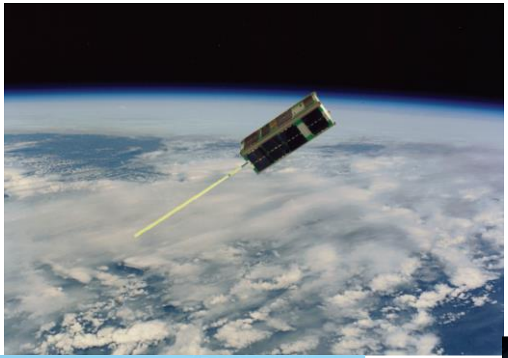
CU-Boulder AeroSpace Ventures Day
September 30, 2015
LASP Space Science Building
Boulder Campus

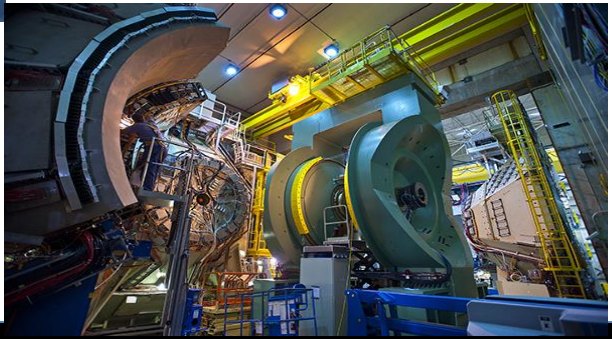
8:30AM – 9:00AM	**Welcome** Dr. Cora Randall, Professor and Chair, Department of Atmospheric and Oceanic Sciences
	AeroSpace Ventures Overview Dr. Penina Axelrad, Professor and Chair, Department of Aerospace Engineering Sciences
	College of Engineering Sciences & Applied Sciences Overview Scott Palo, Associate Dean for Research College of Engineering & Applied Science
9:00AM – 9:15AM	**Keynote Speaker** Gregg Burgess, Vice President of Technology & Engineering, Sierra Nevada Space Systems
9:15AM – 10:00AM	**Faculty Research Presentation Session #1**
10:00AM – 10:57AM	**Poster Networking Session #1**
10:57AM – 11:30AM	**Faculty Research Presentation Session #2**
11:30AM – 12:30PM	**Poster Networking Session#2**
12:30PM – 1:30PM	**Shuttle leaves for Lunch and the Career Fair at the UMC**
1:30PM	**Shuttle leaves the UMC to return to LASP**
3:30PM	**Shuttle leaves UMC to return to LASP**

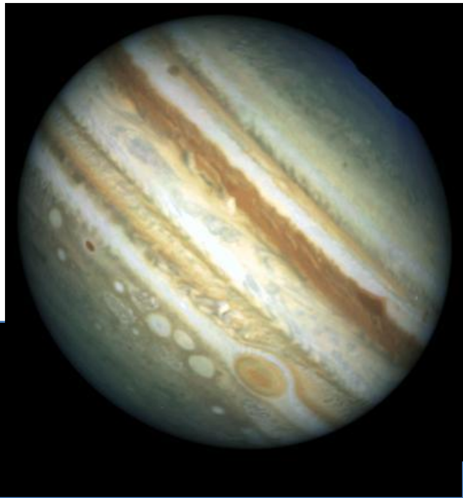
CU-Boulder
AeroSpace Ventures

Dr. Penina Axelrad, Chair
Aerospace Engineering Sciences

September 30, 2015

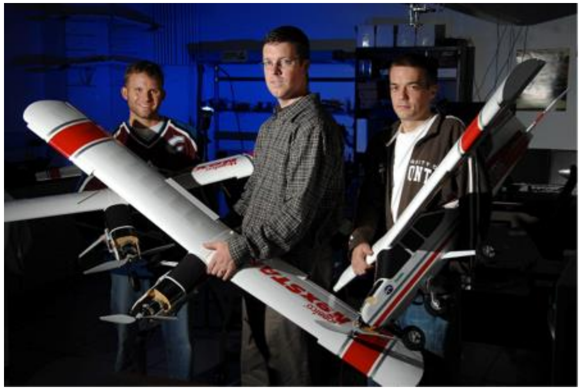


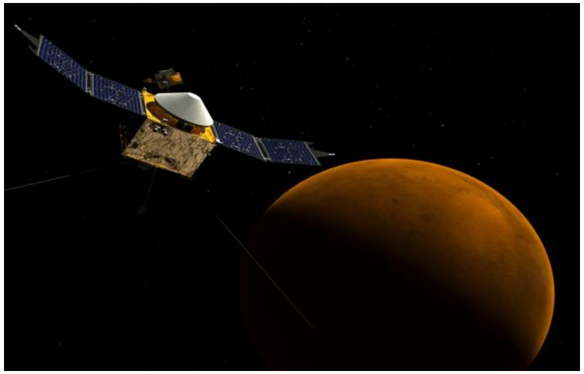




CU-Boulder is one of the nation’s leading aerospace universities

- **Over a dozen aerospace-related units on campus**
- **#1 public university recipient of NASA awards**
- **Over $100M in aerospace-related research expenditures**





CU-Boulder AeroSpace Ventures

Crossing the boundaries between
science and engineering & academia and industry

CU-Boulder AeroSpace Ventures is a collaboration among aerospace-related departments, institutes, centers, government laboratories and industry partners to create knowledge and develop new technologies specifically focusing on:

- Unmanned and autonomous aircraft
- Small satellites
- Earth and space sensors

CU-Boulder AeroSpace Ventures

Through CU-Boulder AeroSpace Ventures, these partnerships will:

- Accelerate discoveries in Earth and space science
- Broadly educate tomorrow's highly-skilled workforce
- Develop technologies that create new commercial opportunities
- Create collaborations that help industry grow

CU-Boulder AeroSpace Ventures…

…In Education

Hands-on learning; student projects targeted at corporate needs; multidisciplinary teams; professionally-prepared students

…In Research

Space situational awareness; severe weather and climate; global water cycle; space exploration

…In Industry

Create new innovations & technologies for new products; bring new funding into Colorado through joint research with industry; distance learning for working professionals

Industry Partnerships with CU-Boulder

Industry relationships are important components of CU-Boulder's aerospace research and education programs. Through CU-Boulder's AeroSpace Ventures, there are numerous opportunities to form partnerships with campus aerospace activities for mutually beneficial outcomes.

Research	Education
• Fundamental and applied • Joint research • Technology transfer • SBIR/STTR partnerships	• Student projects • Guest lectures • Interns, co-ops • Future employees • Distance professional development
Services	**Sponsorship**
• Facilities use • Special tests • Contract work	• Scholarships • Advisory boards • Endowed chairs • Endowed programs

CU-Boulder AeroSpace Ventures
Founding Corporate Partners

*Featured on CU-ASV website.

CU-Boulder Grand Challenge lets us ask:
"What's Next?"
Reinventing Discovery through Technological Innovation

Where are we starting? CU has made the investment of more than $4M for Year 1 of the Grand Challenge, including two Initiatives:

<u>The Integrated Remote and *In Situ* Sensing Initiative (IRISS)</u> will develop new sensing systems and strategies to gather previously unobtainable data that feeds science discovery.

<u>Earth Lab</u> will integrate Earth observations from space to answer outstanding questions about the pace and pattern of environmental change.

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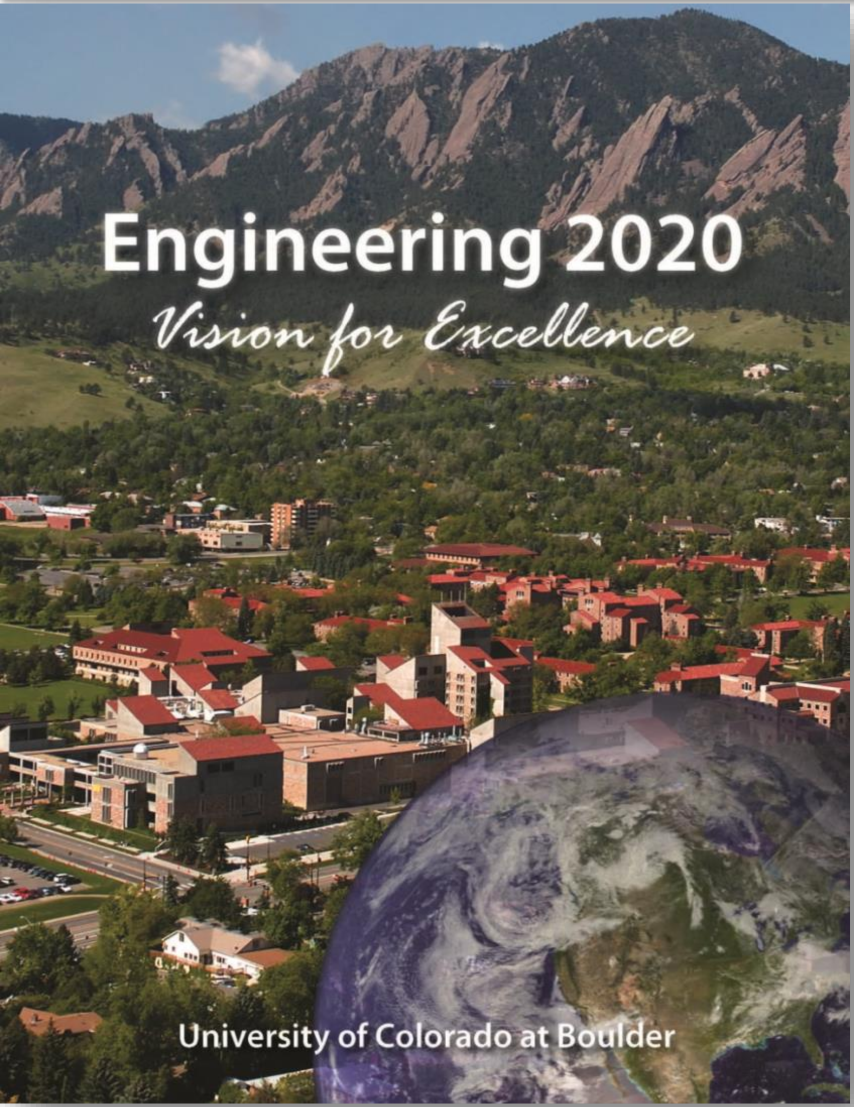
CU-Boulder Engineering Overview



Vision for Excellence:

- World leader in engineering research and education
- Inclusive excellence
- Engineering for global society
- Active, discovery-based learning

I hear . . . I forget
I see . . . I remember
I do . . . I understand

Confucius, c 500BC

University of Colorado Boulder

- Founded 1876 (Engineering started 1893)
- Eight Schools & Colleges
  - Arts & Sciences
  - Business
  - Education
  - Engineering & Applied Science
  - Graduate School
  - Law
  - Music
  - Media, Communication and Information
- Dynamic Community of Scholars
  - 25,000 undergraduates
  - 5,000 graduate students
  - 5 Nobel Prize winners
  - 6 federal research labs (NCAR, NIST, NOAA, NREL, USBR, USGS)
  - Strong corporate partners

CU-Boulder is the flagship campus of a four-campus system

CU Engineering by the Numbers – Fall 2015

6 Departments, 3 programs & 1 Institute
283 faculty

4253 Undergraduates
+46% in past 8 years

1062 Female undergraduates
+96% in past 8 years

552 URM undergraduates
+145% in past 8 years

19 Boettcher scholars
(in past 2 years)

1803 Graduate students
+50% in past 8 years

University of Colorado
Boulder

8000 students expected by 2020

CU Engineering Research

$83M in Research grant awards

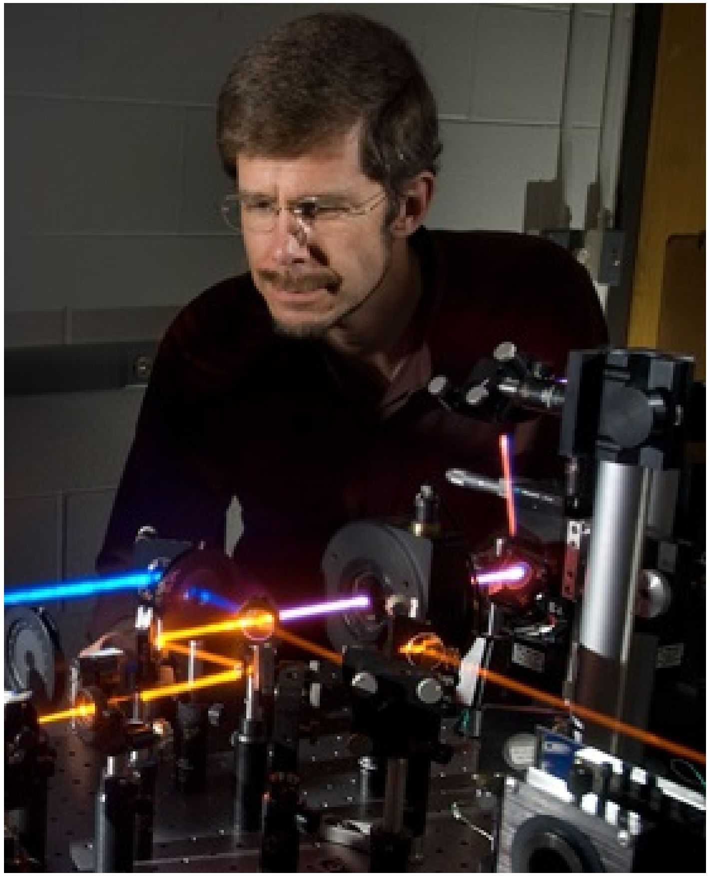
14 Research Centers

15 National Academy of Engineering Members

8 NSF Career Award Winners in 2015

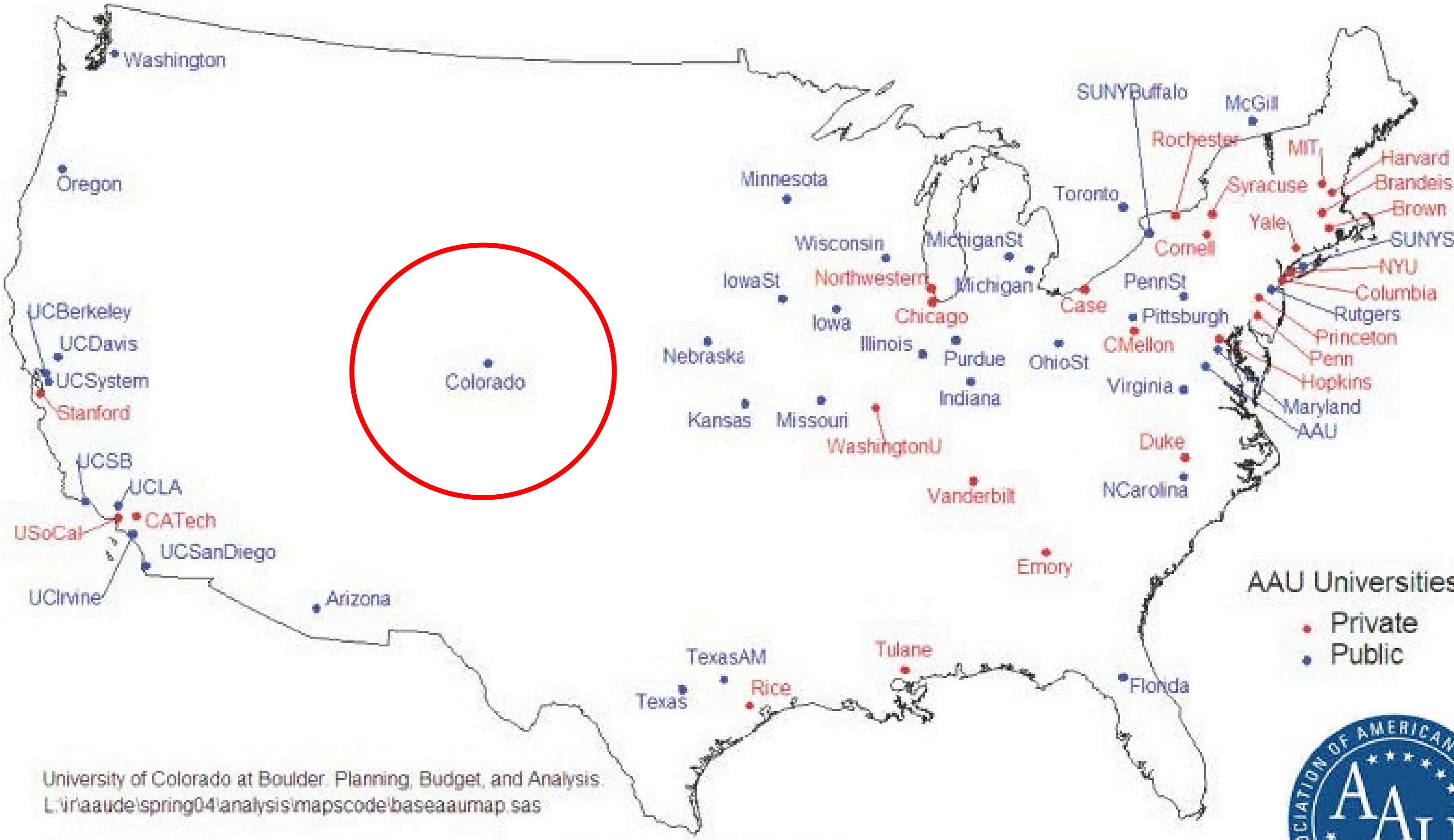
Unique Research Facilities

Increasing Focus on Industry Collaboration



108% growth in research awards over past 8 years

Association of American Universities



An association of 62 leading research universities

CU is a beacon in the mountain west

Ways to Engage

- Educational partnerships: Senior projects, innovative programs
- Research partnerships: Cooperative grants, research center membership
- Employment opportunities: Internships, co-ops, permanent jobs

- Volunteer service: Advisory committees, guest lectures, alumni events, mentoring
- Philanthropy: Scholarships, fellowships, student societies, programs, facilities, named faculty positions

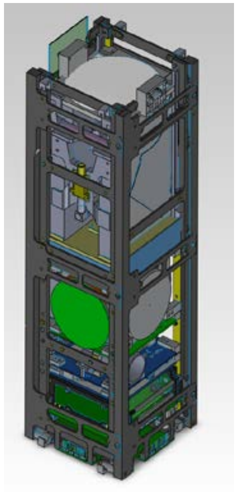
Thank you, and enjoy AeroSpace Ventures Day!

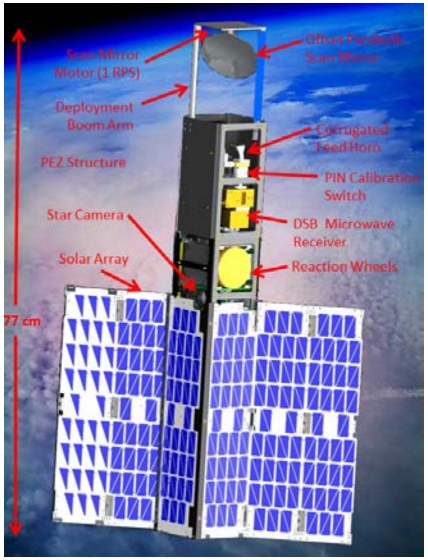
CUBESAT-BASED PATH ARRAY CONSTELLATION FOR ADVANCED WEATHER FORECASTING

Albin Gasiewski

Objectives and Description

- Demonstrate principal element of ~30 member 3U CubeSat constellation for weather forecasting and polar monitoring:
  - Sounding and sea ice edge detection in polar regions through clouds
  - Hydrometric tracking and forecasting of rapidly varying mesoscale convection and hurricanes
  - Radiance assimilation of thermodynamic variables for up to 7-day forecasting
- Achieve NRC Decadal Survey PATH objectives at a fraction of cost of geostationary microwave sensors
- Exceed JPSS/ATMS spatial resolution (2x) and repeat time (25x)
- Develop NIST SI traceable calibration in mass production
- Robust inexpensive 3-axis stabilized bus (CU ALL-STAR) with cross-track scanning mirror (16 km nadir resolution)
- 8-channel 118.75 GHz O_2 temperature imager/sounder with potential for 118/183 GHz payload
- Entire bus and payload designed and fabricated by CU student team





Status and Approach

- NASA ELaNa launch awarded (launch – ready mid 2016)
- USAF University Nanosat Program Phase I award
  - PDR August 2013
  - CDR February 2014
  - EDR Summer 2014
  - FCR/Engineering unit Dec 2014
- ALL-STAR/THEIA launch (bus S/N 001) April 2014
- Future S/C builds to focus on:
  - Downlink communications and latency
  - Additional bands (50-57, 183, 325, 670 GHz)
  - Deployable antennas

http://spacegrant.colorado.edu/allstar-projects/polarcube

Industry Application

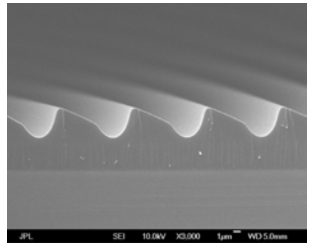
Strengths	Capability
Spaceborne remote sensing mission design, S/C and sensor development, calibration , demonstration, and data assimilation Advanced training of students for entry into the aerospace industry	• Passive microwave orbital system concept development •Microwave imaging system design and development • Forecast system integration • Precision traceable microwave radiometer calibration • Training for a world-class aerospace workforce

Be Boulder. AeroSpace Ventures UNIVERSITY OF COLORADO BOULDER · AIR FORCE RESEARCH LABORATORY · NASA · ORBITAL MICRO SYSTEMS · COSGC · CIRES · NSIDC National Snow and Ice Data Center · CET CENTER FOR ENVIRONMENTAL TECHNOLOGY

TECHNOLOGY DEVELOPMENT AND STUDENT TRAINING ON SOUNDING ROCKETS: NASA'S INVESTMENT IN FUTURE SPACE MISSIONS

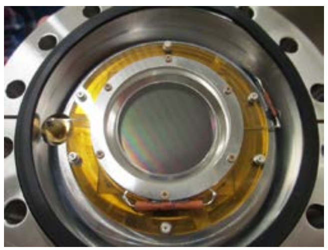
Kevin France

Objectives and Description



- **Develop and flight-test** cutting edge optical components to support future NASA missions

- Carry out unique **scientific investigations** into the birth of stars and planets



- **Train** and **mentor** the next generation of space scientists and engineers

Status and Approach

- NASA-supported program employing a team of undergraduate and graduate students from science and engineering departments

- Exposure to a *complete* NASA mission: from proposal to development to launch

- Reduce cost and schedule risk for future large missions

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Industry Application

Strengths	Application to Industry
Low-cost, technology development	Cost/Risk mitigation
Frequent launch opportunities	Multiple development milestones (lab & flight)
Student training with hands-on experience with NASA missions	Uniquely trained workforce and project leaders

University of Colorado Boulder

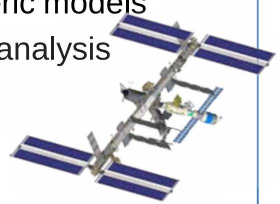
LASP

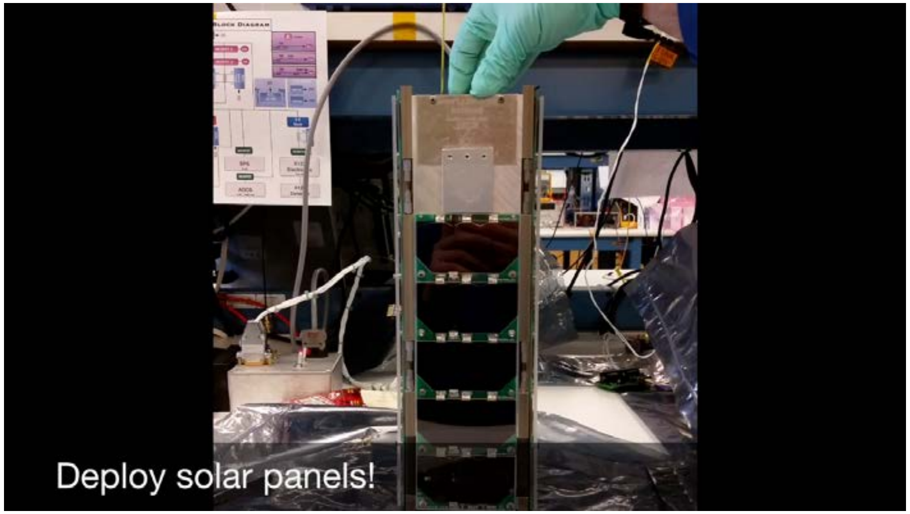
MINIATURE X-RAY SOLAR SPECTROMETER

James Paul Mason

Objectives and Description

- 3U CubeSat (34 cm x 10 cm x 10 cm, 3.5 kg)
- ISS LEO orbit, ~ 7 month expected lifetime before orbit decay
- Measure soft x-ray spectrum from Sun (~0.4 – 30 keV, 0.4 – 30 Å) at mid-high resolution (0.15 keV)
- Provide unique input to Earth atmospheric models and complementary data for solar flare analysis





Status and Approach

- AES graduate project started in Fall 2011
  - 41 students to date (37 graduate, 3 undergrad, 1 high school)
- Strong collaboration with LASP
- 2015/09/10: Delivered to NanoRacks in Houston
- 2015/12/03: Launch from Cape Canaveral
- ~2016 February: Deployment from International Space Station
- More info: lasp.colorado.edu/home/minxss

Industry Application

Strengths	Application to Industry
• High-precision 3-axis ADCS • Usage of COTS part for primary science (Amptek X123) • Potential space weather nowcasting	• Heritage for Blue Canyon Technologies XACT (first to fly) • Proof of publishable science on CubeSat platform • Space weather preparedness

BCT

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MinXSS CubeSat

LASP
Laboratory for Atmospheric and Space Physics
University of Colorado Boulder

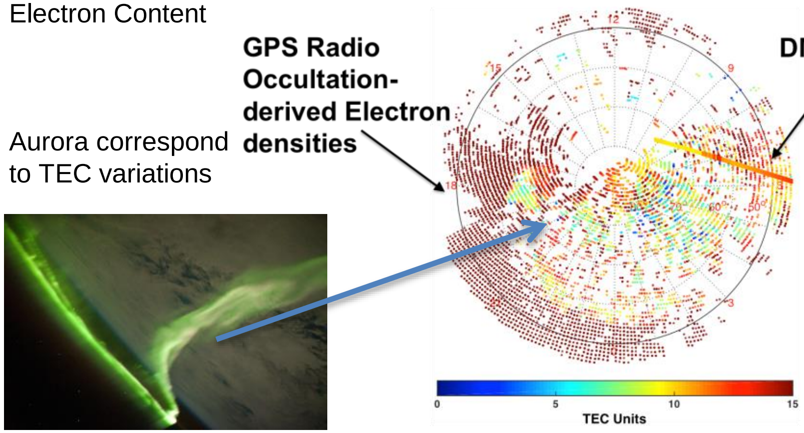
Aerospace Engineering

SPACE ENVIRONMENT DATA ANALYSIS (SEDA) GROUP
Dr. Delores Knipp

Objectives and Description

- Analyze, Understand, Predict the effects of aerospace environment on: humans; hardware; and signals
- Focus: global / local energy deposition in LEO
  - Energetic particle flux and characteristics
  - Electromagnetic energy flux
- What effect do changes in electric currents have on the space environment, as observed by spacecraft and on the ground

Merging GPS and DoD data



NASA

Status and Approach

Facilitate data and phenomena analyses:

- Space-based data transformed to common coordinate frame and altitude
- Statistical exploration of data from multiple platforms
- Advanced statistical techniques: data assimilation, to spread sparse satellite data to global distributions
- Benefit multiple communities via data com-parisons of DoD, NASA, & commercial satellites

Industry Application

Strengths	Application to Industry
New comparison technique for space-based LEO data Fields and Particles	Determine "coincidence" of measurements in the geomagnetic field
Reference frame analysis	Future application to spacecraft charging/geomagnetically induced currents
Statistical investigation of archives of space-based data	
Assimilation of multiple types of space data	Space situational analysis

SOLAR RADIATION PRESSURE MODELING WITH GPU

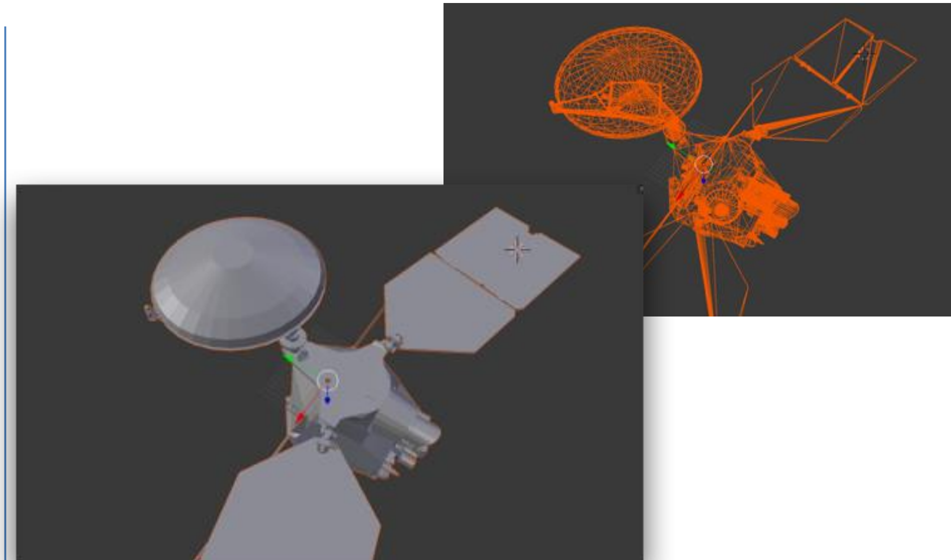
Hanspeter Schaub

Objectives and Description

- Solar Radiation Pressure (SRP) impacts the fine pointing ability, and the rate of momentum accumulation in deep space
- Fast numerical simulation of SRP is challenging, and is being done with sophisticated pre-processing

GOAL:

- **Develop custom GPU rendering pipeline which allows the SRP force and torque evaluations to be performed on general CAD models**



Status and Approach

- Basic custom OpenGL shader has been implemented
- Is able to read in a general CAD file of a spacecraft, and compute forces and torque
- Currently exploring
  - Enhancing the physics modeling of SRP
  - Including self-reflectance across the spacecraft
  - Create a simple tool chain to implement this in C-based numerical simulations

Industry Application

Strengths	Application to Industry
• Simplified setup to evaluate SRP forces and torques • Applicable to GEO and interplanetary missions • Allows complex SRP control research and design considerations	• High-fidelity hardware in the loop ADCS simulation • Rapid SRP modeling and prototyping • Increase robustness to SRP variations • Exploit SRP for momentum management

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AVS Laboratory

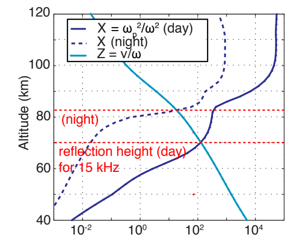
LIGHTNING GEOLOACTION FROM A SINGLE RECEIVER

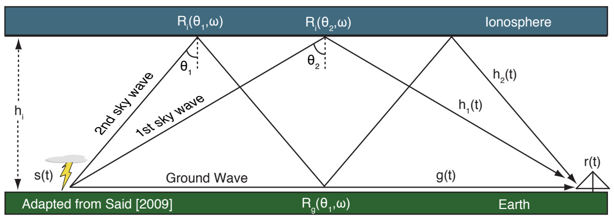
Dr. Robert A. Marshall

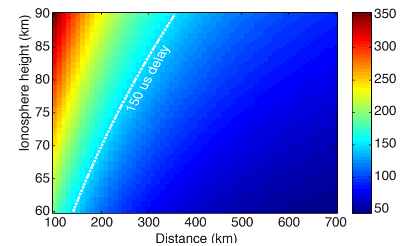
Objectives and Description

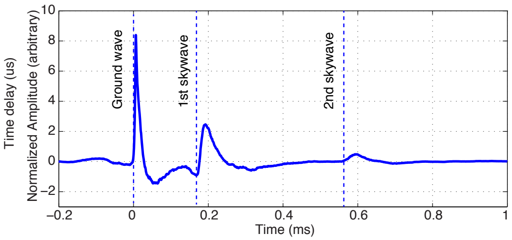
- Objective: Detect and locate lightning and thunderstorms in the absence of commercial lightning data (i.e. NLDN)
- We can use the reflection from the ionosphere to determine distance from a single receiver
- We wish to develop a compact receiver system that could be used in aircraft or other vessels without data access

Using the Ionosphere for Range-finding



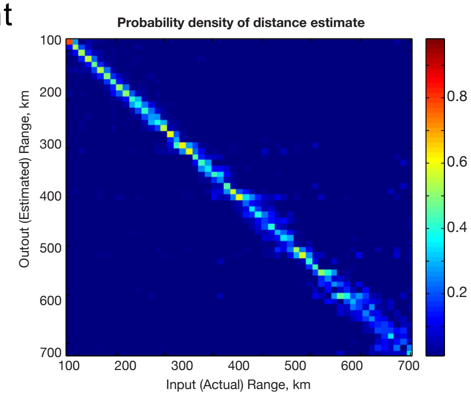






Status and Approach

- Status: Preliminary algorithm developed, tested on existing data
- Design for compact receiver complete – adapted from a CubeSat instrument
- Ongoing: algorithm refinement, sensor development, and error quantification



Industry Application

Strengths	Application to Industry
• Ability to locate lightning with a single receiver • Low cost • 5 km accuracy to 700 km range • Simple, low-cost, low-power system	• Air travel, especially intercontinental (no network access) • Ocean shipping • Private users • Airports and other stationary locations • Low cost compared to data access!

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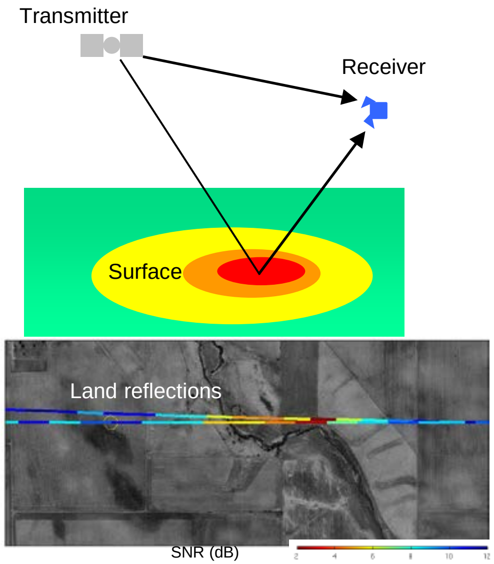
Aerospace Engineering

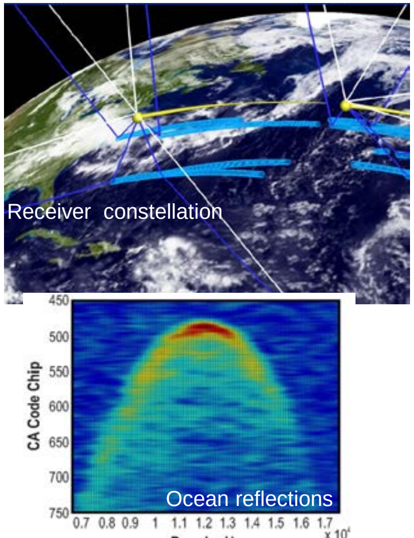
PASSIVE BISTATIC RADAR REMOTE SENSING

Dallas MASTERS

Objectives and Description

- Use transmitted satellite signals (GNSS, communications) as passive bistatic radar sources for remote sensing
- Large number and diversity (freq., bandwidths, etc.) of signals illuminating the Earth
- Bistatic radar receivers are lower power, size, cost than conventional monostatic radars
- CU pioneered GPS bistatic radar remote sensing of ocean, land, and sea ice surfaces
- Excellent opportunity to expand beyond GNSS and leverage ALL existing signals for bistatic radar

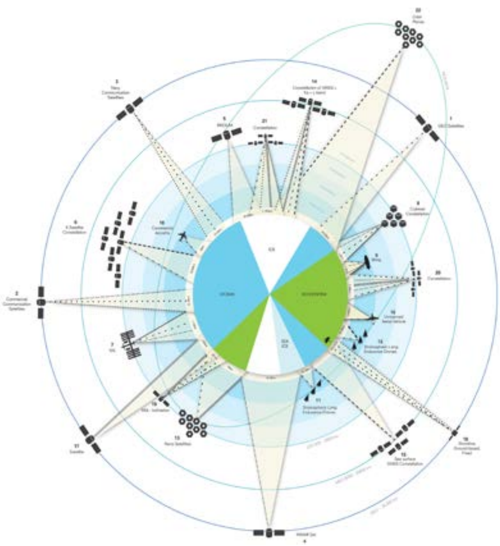




Gleason et al., 2005

Status and Approach

- Currently cataloging existing satellite transmitters
- Rank signals, collect samples using COTS software defined radio technology
- Needs: Reconfigurable radio technology, multi-frequency antennas



Industry Application

Strengths	Application to Industry
• Novel reuse of existing satellite signals • Lower cost, size, power remote sensing instruments • Inexpensive coverage with constellations of receivers	• Reconfigurable radio technology • Multi-frequency antennas • Instrument design • Bistatic radar remote sensing mission design

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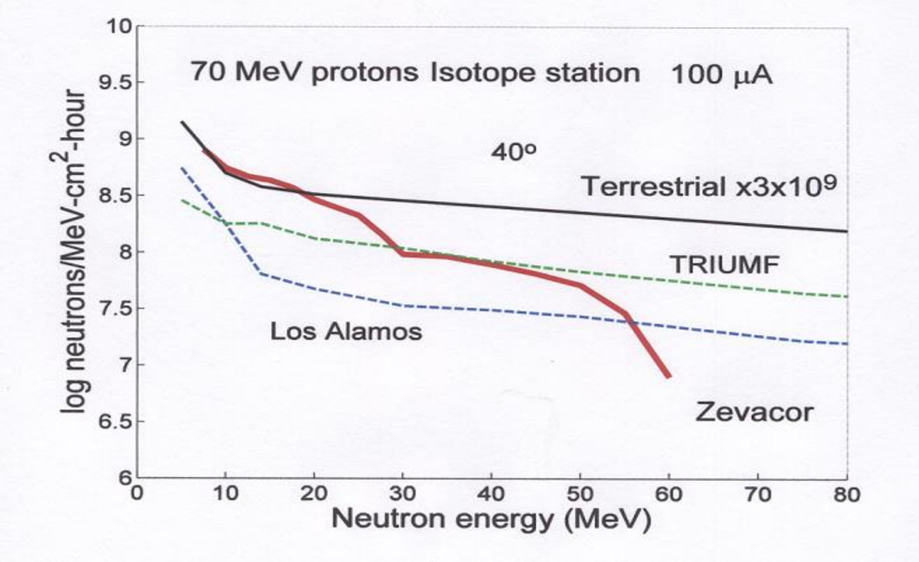
CCAR

TESTING NEEDS FOR RADIATION-INDUCED COMPUTING AND COMMUNICATION

Jerry Peterson

Objectives and Description

Energetic neutrons and protons from cosmic rays are an unavoidable source of errors and damage to electronic components and circuits. These devices can be tested in intense beams from accelerators to measure probabilities of failures . Smaller devices will have more scatter from device-to-device, needing more samples to be tested.



Status and Approach

- A new facility will produce byproduct neutrons in mid-2016, with much the same spectral shape as terrestrial and aircraft altitude neutrons, but several billion times more intense than in nature.
- Potential customers of this facility can get in on the ground floor for the design and construction of desired facilities, at any of four user stations.

Industry Application

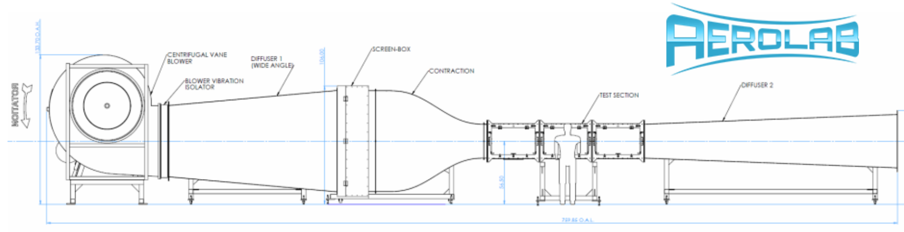
Strengths	Application to Industry
Accelerated measurement of neutron damage and errors in electronic systems, for terrestrial, aircraft, and space applications.	More reliable estimates of mean times to failure for vital systems

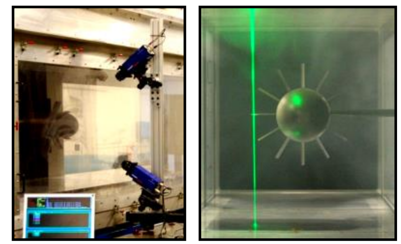
CU Low-Speed Research Wind Tunnel
John Farnsworth (AES)

Objectives and Description

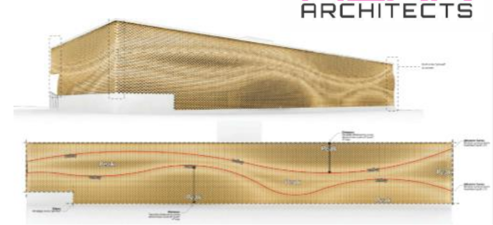
- **Constructing a Low-Speed Research Wind Tunnel**
  - Open-Return Configuration with upstream Wenham Blower
  - Test Section: **0.76m x 0.76m x 3.5m** (30in x 30in x 11.5ft)
  - Velocity Range: **0 – 65 m/s** (213 fps, 145 mph, 126.4 knots)

- **Variety of Aerodynamic Measurement Instrumentation:**
  - Stereo- Particle Image Velocimetry (SPIV)
  - Multi-Channel Pressure Scanners
  - Hot Wire/Film Anemometry
  - Potential for 6 Degree of Freedom Load Cells/Balances
  - Support for Maintenance and Growth…





Example of SPIV Experimental Setup from a similar facility.



Status and Approach

- Completing Final construction!
- Major Completion of the building construction: **October 9th**
- Installation of the wind tunnel: **October 13th -16th**
- Fully Operational: **January 2016**

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Industry Application

Strengths	Application to Industry
Facilities and Instrumentation Experience in Low Speed Aerodynamic Model Design and Testing Faculty and Student operated: • Available manpower • Inexpensive Costs • Extended student interaction	Applicable Fields: • Aviation • Unmanned Ariel Systems • Wind Energy • Naval Hydrodynamics Aerodynamic Testing Center 6.1 -6.3 R&D Activities • Focused on Basic and Applied Laboratory Research

Aerospace Engineering Sciences
UNIVERSITY OF COLORADO BOULDER

FISKE PLANETARIUM DIGITAL VIDEO PRODUCTION
Dr. Doug Duncan

Objectives and Description

- CU's Fiske Planetarium has the highest resolution digital theater in the US (8,000 x 8000 px. Video, 60 frames/sec)
- We produce video and animations to show science and engineering concepts.
- Our productions are shown worldwide

Status and Approach

We would like to work with you as we do with Lockheed and HP, to produce cool visuals.

Due to our extensive use of outstanding CU students guided by our professional staff our production costs are very low.

Industry Application

Strengths	Application to Industry
Low cost. Awesome quality. Distribution to domed theaters and planetariums or flat screens.	Lockheed loves our visuals and so will you.

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FISKE PLANETARIUM

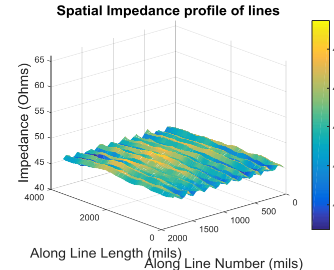
Signal Integrity Solutions

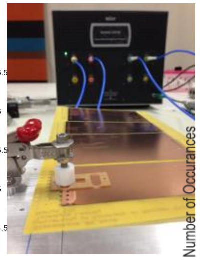
Eric Bogatin

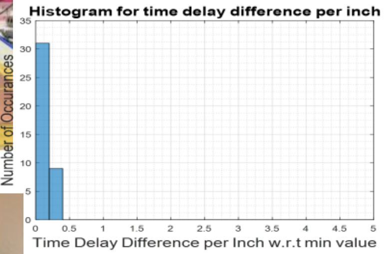
Objectives and Description

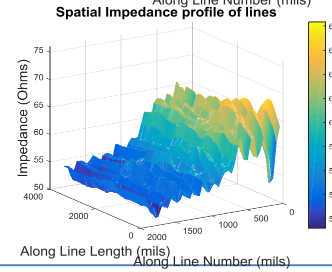
- Mission of my research programs: To train graduate students in:
- Developing, verifying and implementing Best Design Practices for High Speed Interconnect Design from DC to 50 GHz: for SI/PI/EMI
- Measurement techniques to characterize the electrical properties of interconnects and the correct interpretation of measurement and simulate results.

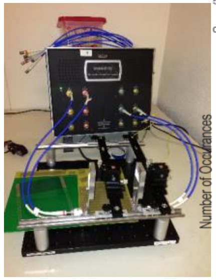
Research Programs

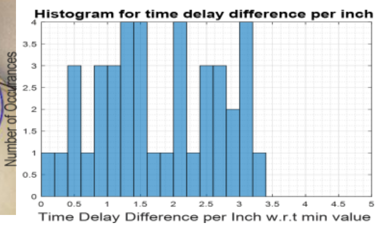












Status and Approach

- Students encounter the real world
- 7 current projects on measurement or simulation
- 13 MS students participated in my research projects so far
- 8 MS students worked as summer interns at Qlogic, National Instruments, Keysight, Sandisk, Qualcomm, NIST, Covidian, LeCroy, local startups

Industry Application

Strengths	Application to Industry
Gridded ground planes	Lighter weight circuit boards
Serpentines	Optimized design rules
ESR of capacitors	Accurate peak impedance predictions
Glass weave skew	Quality metric for glass yarn
Copper resistivity variations	Predictable PCB losses

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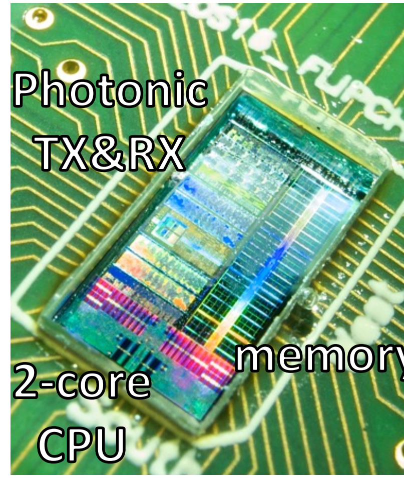
ECEE: Eric.Bogatin@Colorado.edu

Silicon Photonics in a Commercial Microprocessor Foundry

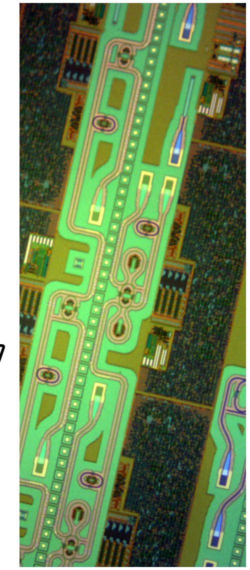
Prof. Milos Popovic – Dept. Electrical, Computer & Energy Engineering

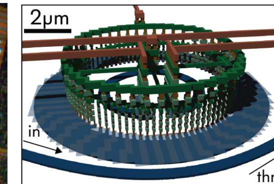
Objectives and Description

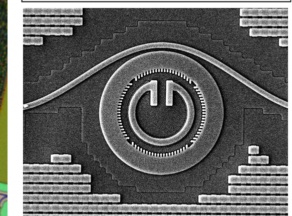
- **Electronic-photonic integrated circuits:** complex optical functions on a chip at low cost, size, weight and power (cSWAP)
- **Usually custom foundries and processes** – high cost, poor yield, challenging integration with state of the art electronics
- **Large barriers to commercialization**
- **Our vision:**
  - A photonic technology made in a commercial CMOS microelectronics fab
  - Photonics as a "More-than-Moore" CMOS technology

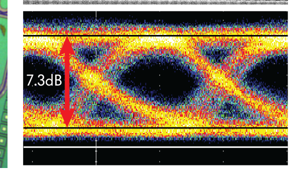


70M transistors, 1000's of photonic devices









Status and Approach

- **Our innovation:** "Zero-change CMOS" photonics
  - 300mm commercial foundry, state of the art 45nm SOI CMOS (used in 3 of top 5 supercomputers)
  - Millions of transistors & 1000s of photonic devices
  - Yield of a mature electronics process, immediate scale-up to production
- First demos of VLSI electronics-photonics
  - Datacom applications, >20 chips designed

New collaborations to push technology to new applications:

Founding co-PI:

Industry Application

Strengths	Application to Industry
Low-energy	CPU-memory, high performance SoC
5-200 GHz RF BWs	Communication, Remote sensing, Ultrawideband RF
Radiation hard SOI	Space applications
Photonic ASIC	Silicon imager/sensor, neuro-sensing, metrology, combs, quantum sensing/networks

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ECEE

INTEGRATED REMOTE & IN SITU SENSING (IRISS)

Brian Argrow

Objectives and Description

- **Vision:** Integrated space ⇔ ground column to collect new multi-scale data, provide new services
- **Aerospace mobility** extends spatial reach, temporal presence—to be at the right place at the right time
- **Multidisciplinary teams** will lead design, development, deployment of novel systems that exploit mobility to enhance integrated data collection
- **Students** will encounter unique experiences, be uniquely prepared for emerging careers

Status and Approach

- **Project Drought** couples satellite-based soil moisture observations with farm-scale UAS observations
- **Project Map** explores how ancient humans interacted with their paleo-environments
- **Project Storm** collects *in situ* data inside supercell thunderstorms for clues to tornadogenesis
- **Project Forest** seeks to understand widespread tree mortality by integrating ground, airborne, satellite data
- **Project Society** creates an multidisciplinary arena to understand social, ethical, political issues

Industry Application

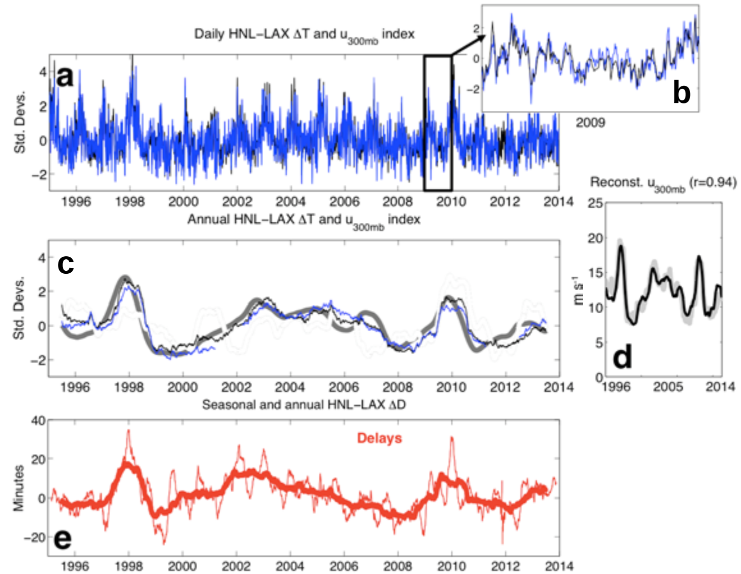
Strengths	Application to Industry
Small UAS for Networked Airborne Sensing/Comms	Unique Technologies, Applications, Strategies
Integrated Space-to-Ground Sensing/Services Column	Novel Information for Science, Industry Services
Multidisciplinary Programs & Industry Collaborations	Emerging Markets, Knowledgeable Workforce

CLIMATE VARIABILITY AND AIR TRAVEL

Kristopher B. Karnauskas

Objectives and Description

- Commercial flight durations on a day-to-day basis are influenced by flight-level winds.
- Flight-level winds are controled at seasonal-to-interannual timescales by natural climate variability (*e.g.*, El Nino), and on longer timescales by climate change.
- Variations in flight duration (due to persistent anomalous head/tailwind) lead to variations in fluel consumption and delays ($$).
- Observed and projected climate information (big data) can be used to predict flight duration variability months in advance.
- Over the course of this century, as the average atmospheric circulation ("climate") changes, the airline industry may contribute more or less radiative forcing (a feedback).



Status and Approach

- Past: NOAA global climate records (wind on pressure levels)
- Future: CMIP5 (IPCC AR5) global climate model simulations
- Idea / proof-of-concept published in *Nature Climate Change* (Karnauskas *et al.* 2015)
- Application to global airline route network underway
- Microsoft Azure supercomputing seed grant

Industry Application

Strengths	Application to Industry
Seasonal prediction of global wind patterns… → Seasonal prediction of round-trip travel time for each route Long-term projections of changes in flight-level winds	Improved on-time arrival Improved fuel efficiency and lower operating cost Improved resource allocation Efficiency and industry sustainability

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ATOC

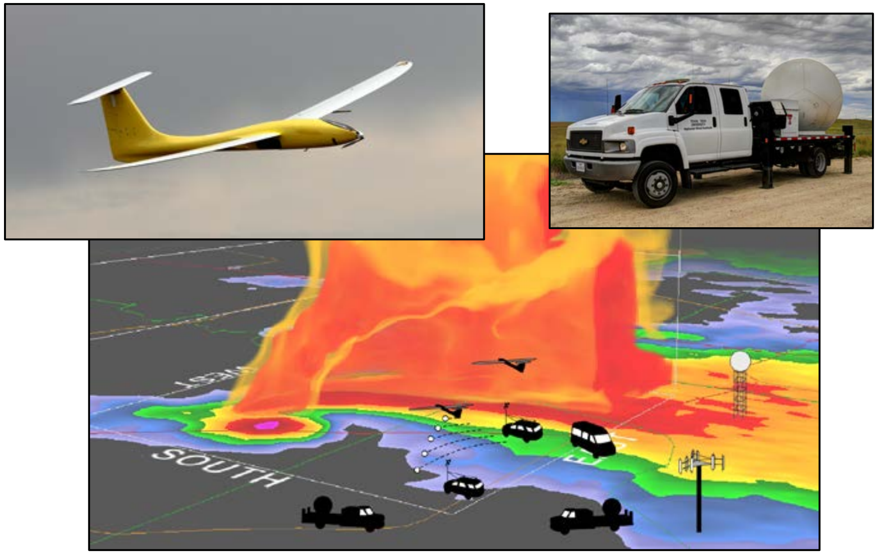
CIRES

SEVERE –STORM TARGETED OBSERVATION & ROBOTIC MONITORING (STORM)

Eric Frew

Objectives and Description

- Autonomous **self-deploying aerial robotic systems (SDARS)** will enable new in-situ atmospheric science applications through targeted observation.
- SDARS is comprised of:
  - multiple fixed-wing unmanned aircraft,
  - deployable Lagrangian drifters,
  - mobile Doppler radar,
  - distributed computation nodes in the field and in the lab,
  - a net-centric middleware connecting the dispersed elements
  - autonomous decision-making that closes the loop between sensing in the field and online numerical weather prediction



Status and Approach

- Proof of concept of end-to-end system in June 2015 in Lubbock, TX
- New effort focusing on atmospheric science application => add science goals into planning framework
- Deployable sensors to drift with wind to provide additional data along streamlines

Industry Application

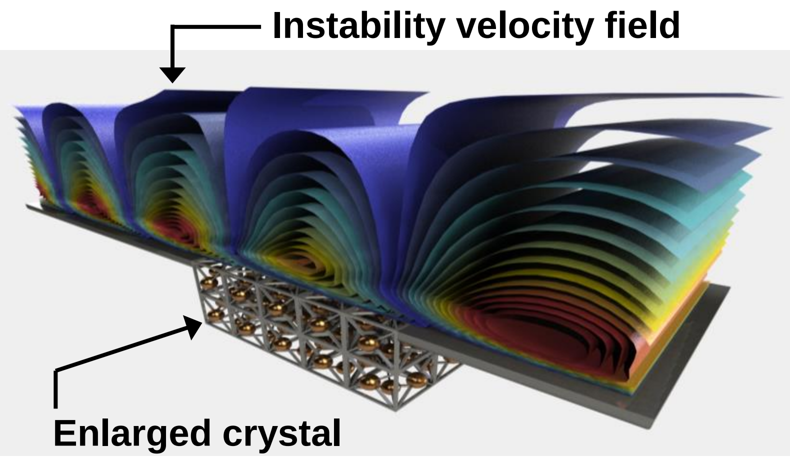
Strengths	Application to Industry
In-situ wind measurement	Atmos. science, wind turbines, beyond PBL
Onboard and cloud-based autonomy	Safe, robust operation of UAS in the NAS
Deployable sensors	
Wind energy extraction	Application-specific flight plan optimization
Online trajectory optimization	

FLOW CONTROL BY CRYSALS

Mahmoud I. Hussein*, Sedat Biringen**, Osama R. Bilal, Alec Kucala

Objectives and Description

- Develop a new technology for **flow control** to reduce drag for air, sea and land vehicles and other applications
- Proposed concept is to place an ***enlarged and carefully tuned crystal*** underneath a surface (e.g., of a wing) interacting with the flow
- Utilizing theories from condensed matter physics, the crystal is designed to passively **stabilize** the flow exactly above the location of its placement underneath the surface.



Status and Approach

- Concept has been demonstrated using direct numerical simulation of a plane channel flow
- A *theory of subsurface phonons* has been developed that enables precise prediction of flow behavior without the need for a coupled fluid-structure simulation
- Current research is exploring extension of the concept to drag reduction in *fully developed turbulent flow*
- Reference: Hussein, Biringen, Bilal and Kucala, *Proc. R. Soc. A*, **471**, 20140928 (2015)

Industry Application

Strengths	Application to Industry
Simple, passive, low-cost and low-maintenance technology for flow control	Drag reduction in aircraft, ships, cars, and other vehicles
Powerful means to stabilize, or destabilize, flows without sacrificing surface stability	Drag reduction in wind turbines and long-range liquid or gas pipelines
Provides precise spatial control of stabilization, or destabilization, regions	Enhancement of mixing in combustion and chemical reactions

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PHONONICS LABORATORY
University of Colorado Boulder

Aerospace Engineering

THE NATIONAL SOLAR OBSERVATORY

Kevin Reardon

Objectives and Description

- Advance our knowledge of the Sun, to better understand stars, magnetized plasmas, and the solar system space environment.
- Provide observational facilities and service to US and international solar physics research community.
- Partnership with CU/LASP to increase student engagement.
- Federally funded research laboratory (operated by AURA under agreement with NSF).
- Currently transitioning headquarters from Arizona and New Mexico to Boulder.

Daniel K. Inouye Solar Telescope

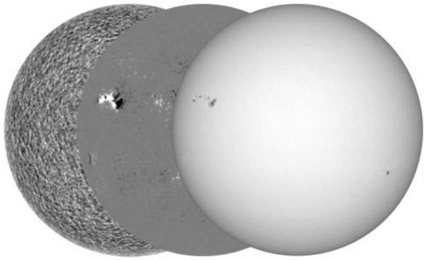
- 4-meter diameter, off-axis telescope to observe the solar atmosphere (photosphere, chromosphere, and corona) with a 20 km resolution.
- Under construction on Haleakalā, Hawaii.
- First observations in 2019.
- Will study fundamental magnetohydrodynamical processes to reveal the sources and variety of the Sun's behavior.

DKIST
DANIEL K. INOUYE SOLAR TELESCOPE

NSO Integrated Synoptic Program

NISP
NSO INTEGRATED SYNOPTIC PROGRAM

- Operates several facilities dedicated to collecting continuous and detailed observations of the whole Sun.
- Provides real-time information that is used in solar activity forecasts (NOAA) as well as to understand the long-term or solar-cycle, changes in the Sun's activity.



Industry Application

Strengths	Issues and Applications
Instrumentation and Optics	Multispectral, precision polarimetry, metrology
Big Data and Computing	5 PB/year, data mining and assimilation
Space Weather Predictions	Space environment, solar modeling
Adaptive Optics	Wavefront detection and correction
Thermal Control	13 kW heat load, minimize distortions
Image Analysis Algorithms	Spatiotemporal computer vision

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NSO

AURA

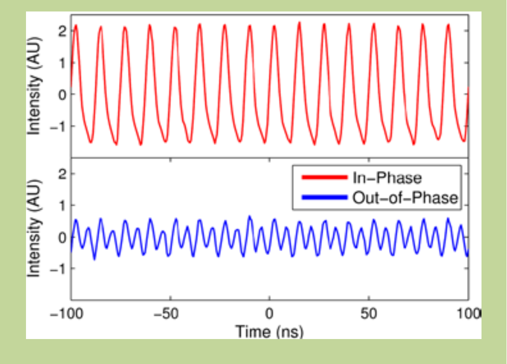
NSF

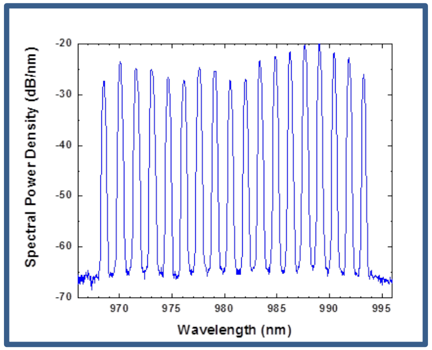
MINIATURE LASERS FOR SPACE APPLICATIONS

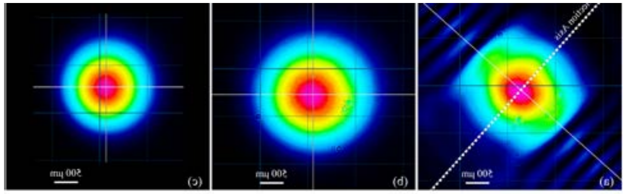
Juliet Gopinath

Objectives and Description

- **Study lasers and optical devices to make compact, cheaper, and robust optical systems with new capabilities**
- **Lasers**
  - **Compact pulsed laser systems suitable for space**
  - **Improved beam quality of multimode laser diodes and arrays**
  - **Beam combining of laser arrays**
- **Optical devices**
  - **Adaptive optics, new materials, miniature imaging systems, optical switching, fiber sensors and more**







Status and Approach

- **Multimode cw lasers**
  - **Beam combining with 'smile' compensation**
  - **Beam quality improvement with 'mode imaging'**
- **Pulsed lasers**
  - **Record pulse energy from electrically pumped modelocked semiconductor laser**
  - **New designs needed to scale up pulse energies further**
    - **Phase control implemented on an FPGA**
    - **'Synthesize' pulses with cw diode**

Industry Application

Strengths	Application to Industry
Efficiency	• Low-power applications and space
Large pulse energy	• Nonlinear optics, imaging & communications
High powers & good beam quality from multimode systems	• Pumps for other lasers, machining, LIDAR, space-based communications

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BIOASTRONAUTICS: THE STUDY AND SUPPORT OF LIFE IN SPACE

James A. Nabity

Objectives and Description

- Enable the safe and efficient human exploration and utilization of space
  - Study space physiology from microbes to humans
  - Research human-rated spacecraft design
  - Advance spacesuit and life support system technologies
- FAA Center of Excellence for Commercial Space Transportation
- BioServe Space Technologies: Commercial high-impact space life science research

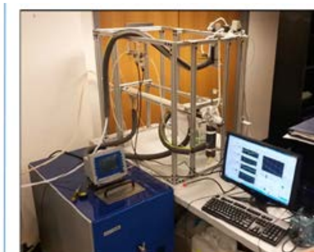
LifeLAB Facilities

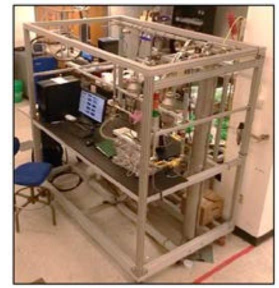
- TVAC chambers

- ***Investigate thermal control technologies***
- ***uTorr vacuum levels @ -180 °C***

- Atmosphere revitalization

- ***Simulate the respiration from mouse to crew member***





Status and Approach

- Research high risk, low TRL Spacecraft/Spacesuit Life Support technologies (Atmosphere, Thermal, Water, Waste & Food)
  - Variable Emissivity Electrochromic Radiator (NSTRF)
  - Ionic Liquid CO2 Reduction / Oxygen Recovery (NSTRF)
  - Self-Regulating Freezable Heat Exchanger (NASA STTR)
  - Gravity-dependent Freeze/Thaw Behavior of Water (NASA STTR)
  - Algal-based CO2 Reduction / Oxygen Recovery (MS Thesis)
  - Characterizing Biological Closed-Loop Life Support Systems (NSTRF)
  - Closed-loop Life Support System Analysis and Modeling
- Spacecraft Systems Design
  - Spacecraft human rating and risk analysis (FAA)
  - Spacecraft habitability for deep space exploration (NASA NextSTEP)
  - Space operability analysis (NASA Harriett Jenkins)
  - Protective Shielding of Habitats from Space Radiation

Industry Application

Strengths	Application to Industry
● Freezable Thermal Control Systems (TCS)	● Safe, simple TCS for spacecraft and habitats ● Enable high power cubesats
● Regenerable CO2 reduction technologies	● CO2 capture & reduction / O2 recovery
● Full-scale habitat mockups for human factors studies ● Radiation shielding	● Spacecraft systems design ● Astronaut comfort & health

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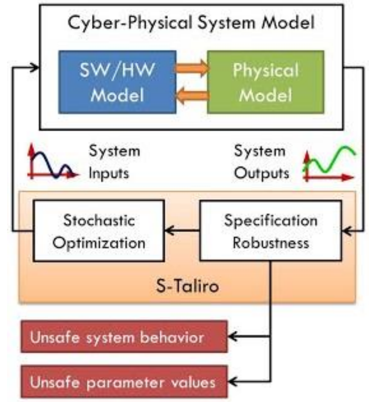
Aerospace Engineering

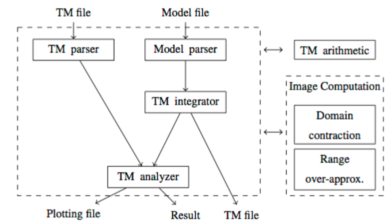
Software Assurance for Control Systems

Sriram Sankaranarayanan

Objectives and Description

- Software Assurance
  - Automated detection of bugs in software.
  - Certifying that software systems satisfy critical functions.
- Safety-Critical System Examples:
  - Engine control systems in automobiles.
  - Aircraft electric power systems.
- Research Thrusts:
  - S-Taliro: Automated testing of safety criticial systems.
    - https://sites.google.com/a/asu.edu/s-taliro/s-taliro
  - Flow*: Symbolic execution of hybrid control systems.
    - http://systems.cs.colorado.edu/research/cyberphysical/taylormodels/





Status and Approach

- S-Taliro: Automated Testing of Cyber-Physical Systems.
  - Robustness-guided blackbox testing of models.
  - Automates property-driven Software-in-the-loop tests.
  - Supports Simulink/Stateflow™ + easy to extend.
  - Status: Commercial users including support from Toyota motors.
- Flow*: Automated symbolic exploration of CPS.
  - Explore behaviors of systems that are difficult to observe through random tests.
  - Status: Research Prototype.

Industry Application

Strengths	Application to Industry
Exhaustive State-Space Exploration	Useful in obtaining high levels of code coverage.
Fully closed-loop functional verification.	Software bugs found are more likely to require fixes.
Simulink/Stateflow™ diagram support (S-Taliro)	Relevant to model-based development practices.

ADDRESSING TECHNOLOGY NEEDS IN AIRBORNE RADIATION SCIENCE

Sebastian Schmidt

Objectives and Description

Airborne Science

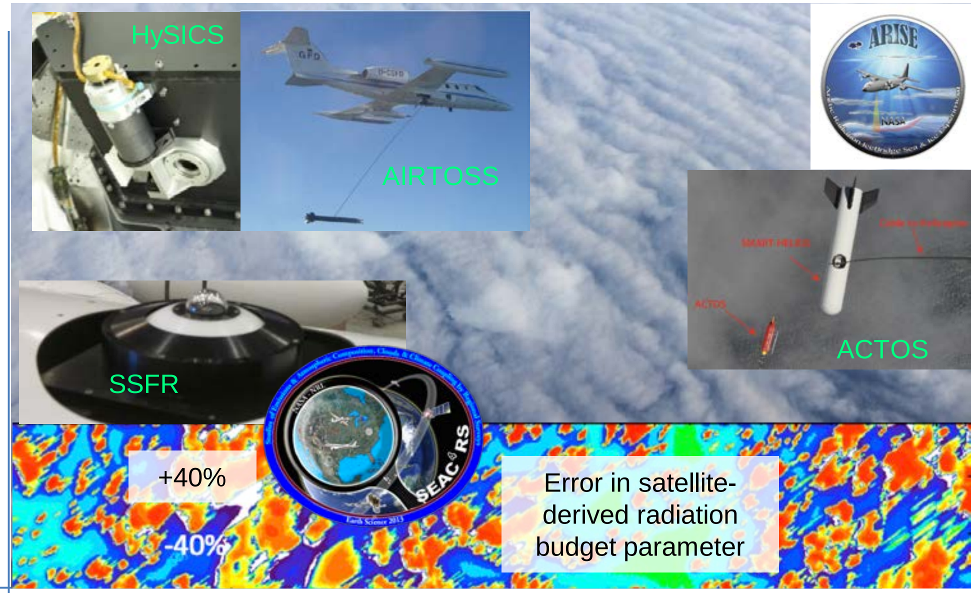
- Path finder and validation for satellite instrumentation used in Earth radiation budget assessment
- Challenges satellite-based estimates with "ground" truth, errors of 50% not uncommon

Airborne Radiation Science Workshop

- NCAR/CU March/2016 – emerging technology/needs

Most pressing current needs

- Need for sampling "first 500 feet", "ground" truth
- Formation flights to measure radiative effects costly/rare
- Near-surface measurements in Arctic and over oceans



Status and Approach

Instrumentation

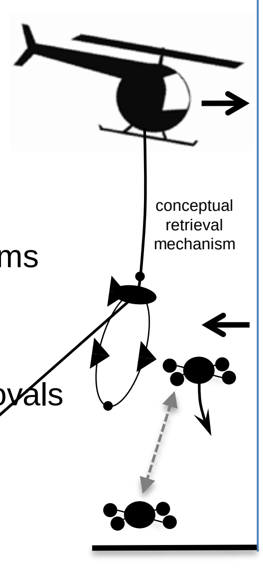
- In existence and (being) miniaturized

Existing collocation strategies

- towed platforms

Retrievable Quadcopter Sonde

- new type of UAV, based on towed platforms
- possibility to close gap to surface
- develop release/retrieve mechanism
- initially on helicopter to facilitate AT approvals



Industry Application

Strengths	Application to Industry
Hybrid manned/autonomous system: Drop – leave – measure – retrieve	Not limited to radiation: Sampling remote areas

Potential industry involvement

- Flight system & retrieval interface development
- Testing
- AT regulations compliance
- Seed funding for student involvement

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LASP ATOC

TECHNOLOGY TRANSFER SERVICES
Brynmor Rees

Corporate Relations

Access to university students + faculty

Access to intellectual property

Research collaboration

Business community engagement

Giving opportunities

Industry Contracts

Research collaboration agreements

Industry research agreements

Other industry contracts

Technology Transfer

Inventory unique research assets

IP management

Patentability assessment

Copyright management

License negotiation

Commercialization Support

Entrepreneurship education

Connect to innovation ecosystem: entrepreneurs, business advisors + mentors

Discover relevant market needs

SBIR/STTR support

Proof-of-Concept funding

Seed funding

Student engagement for market assessment, business planning

TTO Core Functions

TTO Support Areas

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University of Colorado
Boulder | Colorado Springs | Denver | Anschutz Medical Campus
TECHNOLOGY TRANSFER OFFICE

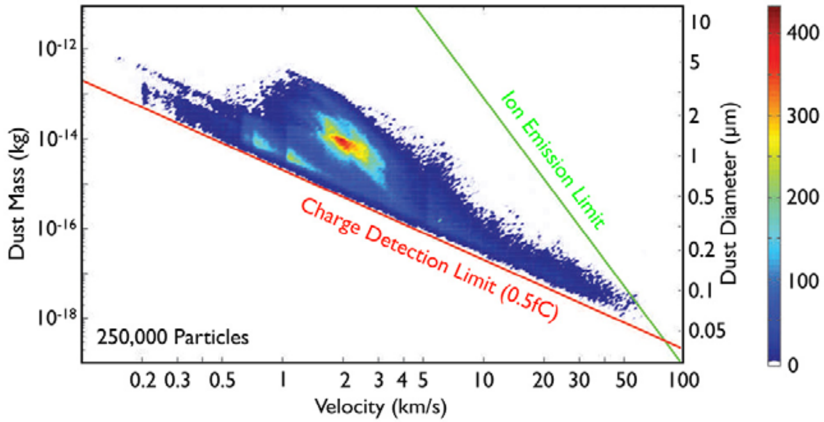
DUST ACCELERATOR FACILITY
Mihaly Horanyi

Objectives and Description

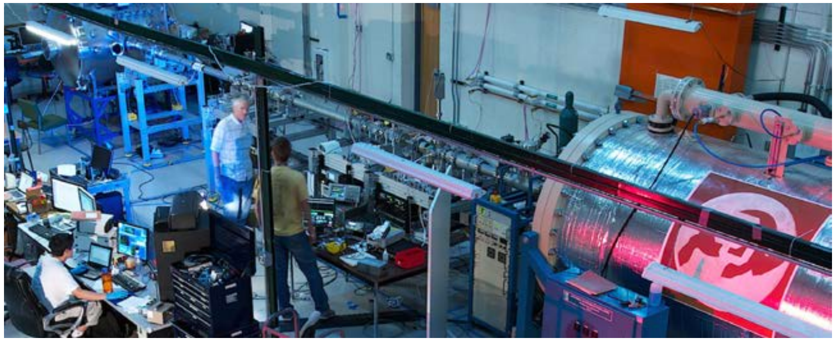
Hypervelocity Dust Impact Studies

– Spacecraft/mission safety
– Space debris effects
– Penetration studies
– Optical degradation studies
– Electromagnetic pulse generation
– Instrument test and calibration

Accelerator Performance



Status and Approach



3 MV Pelletron, fully operational since 2011

Industry Application

Strengths	Application to Industry
Basic impact physics	NASA, NSF, DOE, DOD Interest
Penetration/Degradation due to dust impacts	S/C safety and long duration performance
Planetary sciences contributions	NASA Exploration Missions: Mars, Phobos, Deimos, asteroids

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LASP

OFFICE OF INDUSTRY COLLABORATION (OIC)
Mike Traxler

Objectives and Description

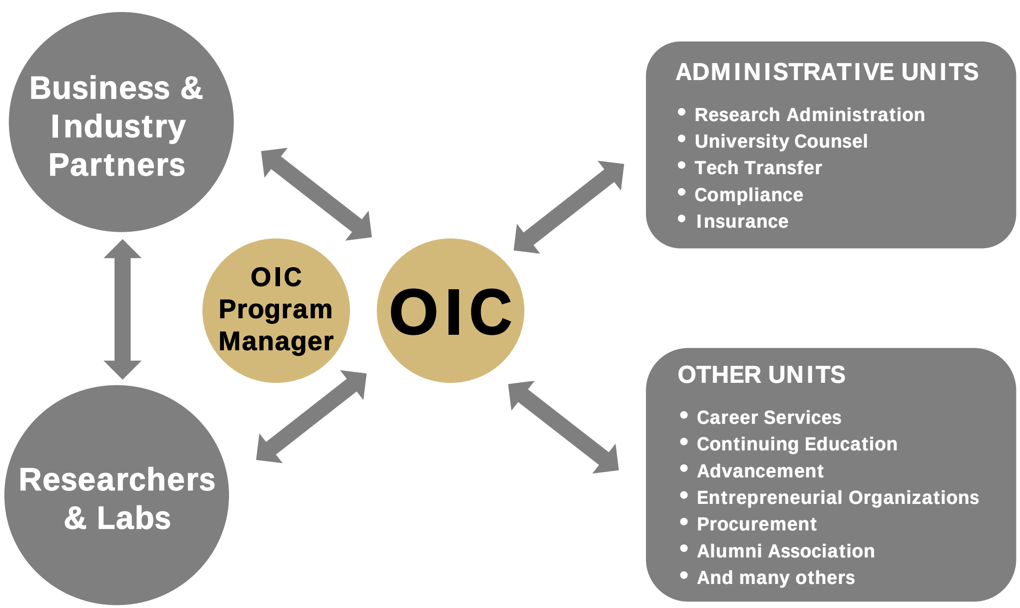
OIC serves as the portal to CU-Boulder Industry Opportunities

- **Connecting Industry partners to CU faculty/ researchers**
- **Supporting faculty collaboration with industry**
- **Promoting CU technical facilities and capabilities**
- **Streamlining processes for industry agreements**
- **Monitoring and supporting project completion**

Industry Opportunities at CU-Boulder

- **Improving Your Products and Services**
  - **Custom research & development**
  - **Licensing technology**
  - **Services: Facilities & Testing, consulting**
- **Building and Developing Your Workforce**
  - **Hiring/ Internships**
  - **Student projects**
  - **Employee development**
- **Engagement with CU Boulder**
  - **Promotion : advertising, sponsorship, philanthropy**
  - **Employee enrichment: workshops, special events**

How can CU-Boulder support your company?



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Thank you for attending.