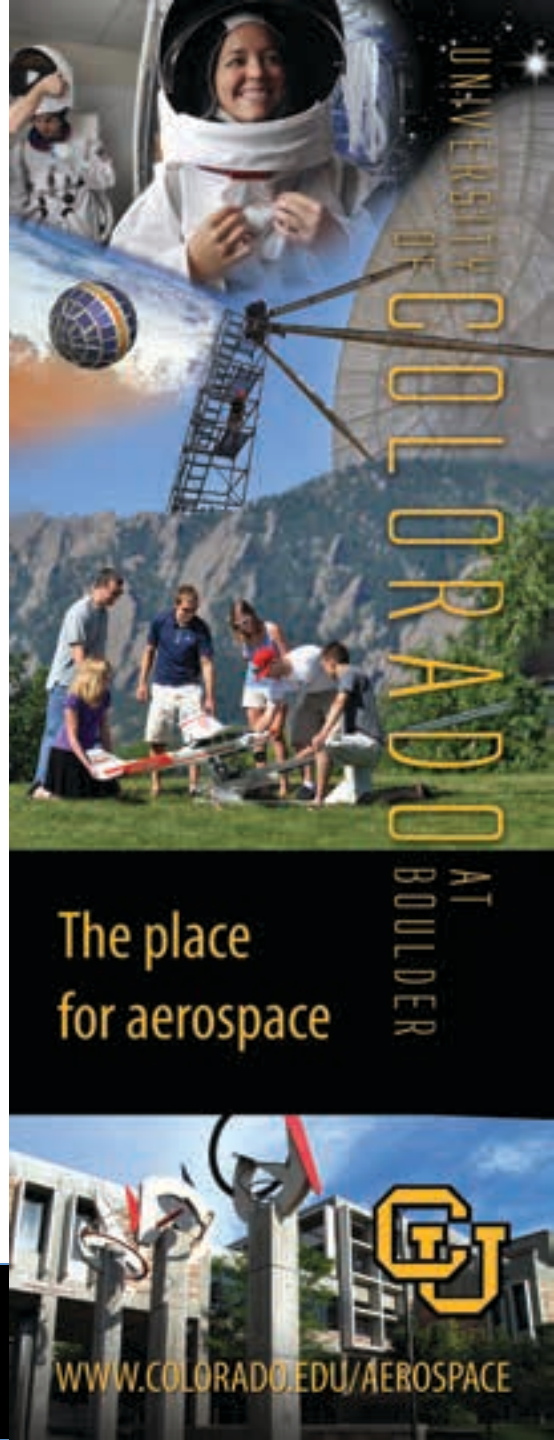
CU-Boulder AeroSpace Ventures

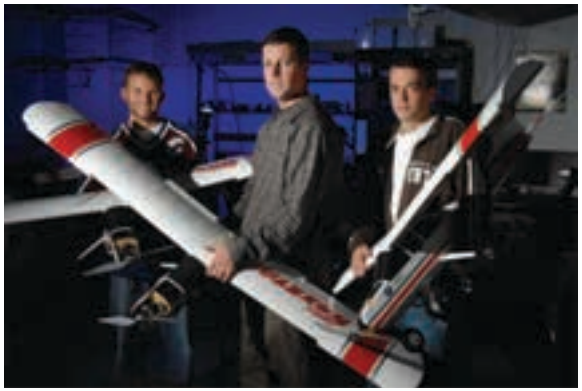
Dr. Dan Baker
Director, LASP
April 17, 2014



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

www.colorado.edu/aerospace/cu-aerospace-ventures



CU-Boulder AeroSpace Ventures

Crossing the boundaries between
science and engineering & academia and industry

CU 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

Industrial Partnerships with CU-Boulder

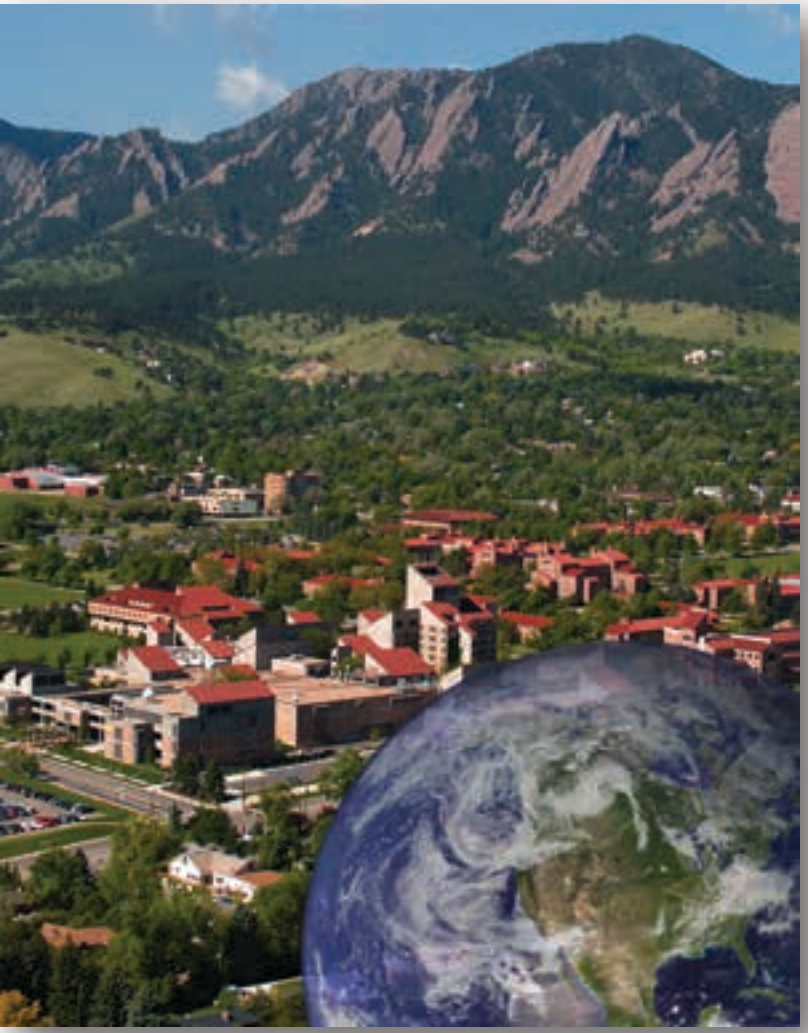
Industrial relationships are important components of CU-Boulder's aerospace research and education programs. Through CU AeroSpace Ventures, there are numerous opportunities to form partnerships with campus activities for mutually beneficial outcomes.

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 • Target acquisitions through eSpace	• Scholarships • Advisory boards • Endowed chairs • Endowed programs

CU-Boulder AeroSpace Ventures
Founding Corporate Partners

*Featured on CU-ASV website.

CU-Boulder Engineering Overview



Vision for Excellence:

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

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

Confucius, c 500BC

- Inclusive excellence

University of Colorado Boulder

- Founded 1876 (Engineering started 1893)
- Seven Schools & Colleges
  - Arts & Sciences
  - Business
  - Education
  - Engineering & Applied Science
  - Graduate School
  - Law
  - Music
- 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 Engineering by the Numbers – Fall 2013

6 Departments
16 degree subjects

3657 Undergraduates
+25% in past 6 years

875 Female undergraduates
+56% in past 6 years

421 URM undergraduates
+87% in past 6 years

33 Boettcher scholars & semifinalists
(among current freshmen)

1623 Graduate students
+35% in past 6 years

$72M Research grant awards
+80% in past 6 years

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!

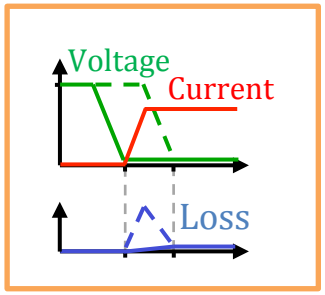
CU-Boulder AeroSpace Ventures

Faculty Presentations
April 17, 2014

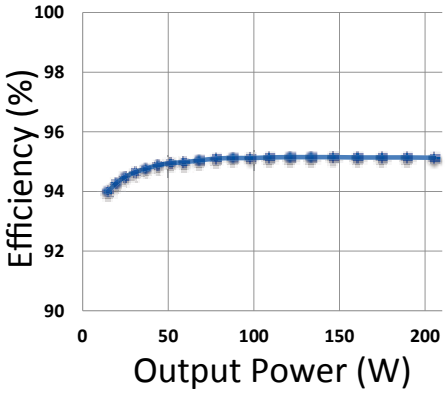
Ultra-Efficient Compact Power Converters: Dr. Khurram Afridi (ECEE)

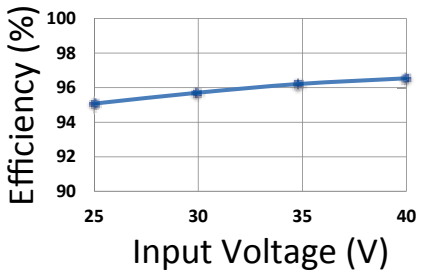
Objectives

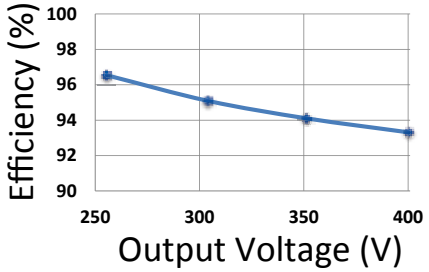
- High power density needs high switching frequency
- Losses increase with frequency
- Soft-switching a must
- Conventional soft-switched converters cannot maintain high efficiency across wide operating range



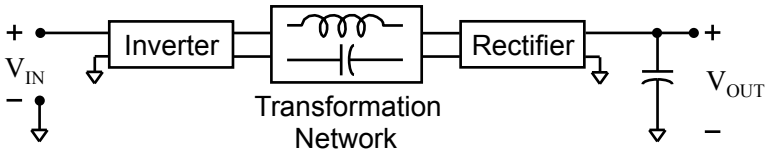
Results

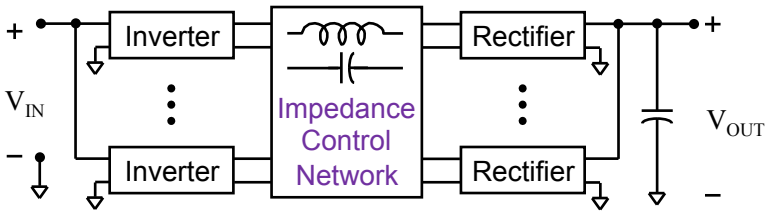






Conventional versus ICN Approach





Industry Application

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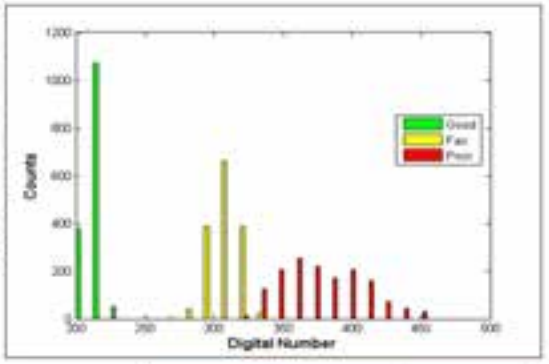
CoPEC

Quality Assessment of Roads in Colorado Based on Satellite Imagery: Dr. William Emery (AES)

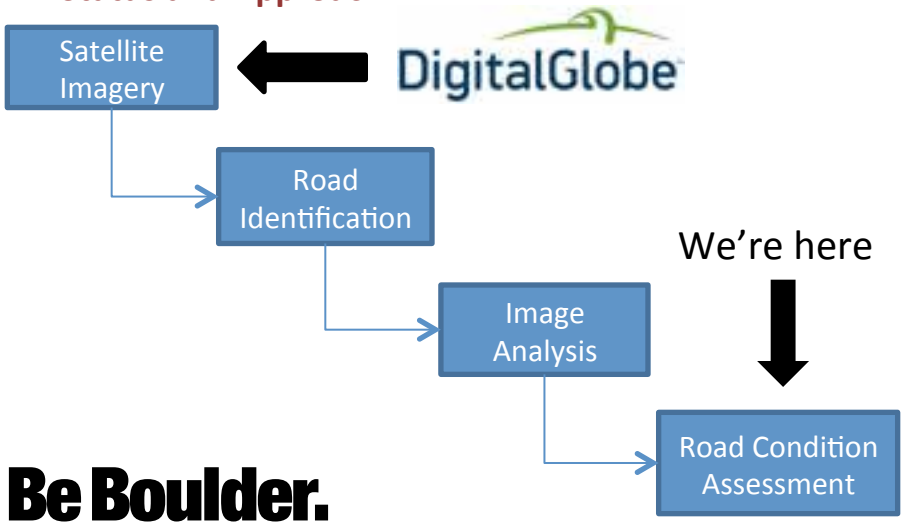
Objectives and Description

- Road condition surveillance is a tedious task which requires manual inspection of thousands of miles of road length
- Our study has determined that an automated satellite remote sensing based method can be established for this task
- We are now working towards designing and developing such a solution



	Good	Fair	Poor
Mean	214.3	307.7	377.7
STD	5.2	10.3	29.5

Status and Approach



Industry Application

Strengths	Capability
• Decrease the cost of road survey and quality assessments • Increase the speed of these traditionally tedious processes	

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Aerospace Engineering Sciences
UNIVERSITY OF COLORADO BOULDER

Research and Engineering Center for Unmanned Vehicles (RECUV): Dr. Eric Frew (AES)

Objectives and Description

RECUV draws faculty and students from across the College of Engineering and Applied Science to address technical challenges in a collaborative environment that integrates the traditional aerospace engineering disciplines of aerodynamics, structures, propulsion, navigation, control, and platform design with networking, telecommunications, robotics, information science, and security.

Status and Approach

Mission-Derived sUAS Design
Mobile Ad Hoc Communications
Vehicle-Sensor Integration
Mobile Sensor Networks and Cooperative Control
Advanced Propulsion Systems
Airspace Integration
Intelligent Human-UAS Interaction

Industry Application

Applications	Capabilities
Polar science	Nomadic CONOPs
Severe weather	Supersonic UAS
Precision agriculture	Wind / turbulence
Wind energy	Ad-hoc networking
Search and rescue	FAA COAs
National defense	Multi-vehicle ops

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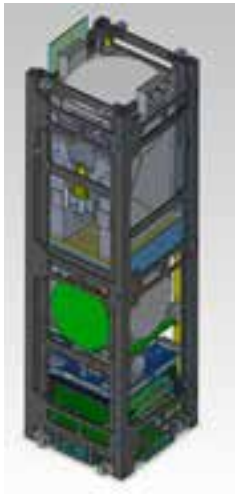
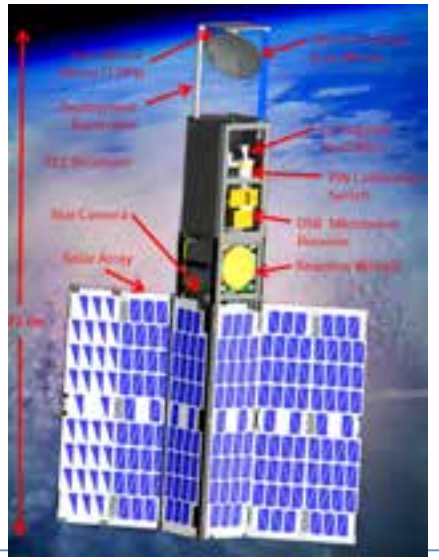
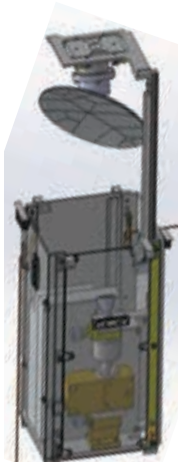
CubeSat-based PATH Array Constellation for Advanced Weather Forecasting: Dr. Al Gaswieski

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 2015)
- 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

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NASA

COSGC

CIRES

NSIDC
National Snow and Ice Data Center

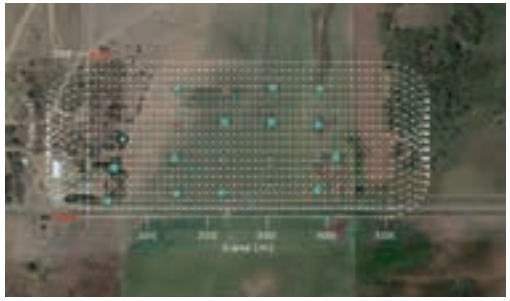
CET
CENTER FOR ENVIRONMENTAL TECHNOLOGY

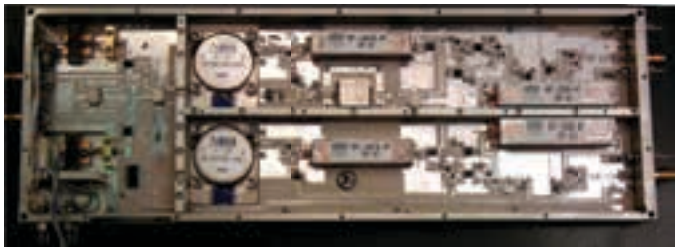
UAS-based Soil Moisture Mapping in Precision Agriculture: Dr. Al Gasiewski

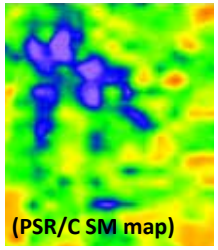
Objectives and Description

- Remote aerial mapping of soil moisture and NDVI for
  - Agriculture
  - Drought monitoring
  - Trafficability assessment
  - Flood runoff prediction
  - NASA SMAP Satellite algorithm validation/SM scaling studies
- Achieve unprecedented spatial resolution (15 m) and local area coverage (1 ha/hr) determined by altitude
- Based on NASA WMAP radiometer architecture
- Use cell-phone manufacturing technologies to achieve unprecedented SWAP reduction
- Secondary application to coastal salinity mapping

Joint project between CU/ECEE Center for Environmental Technology (CET) and Black Swift Technologies







Status and Approach

- NASA Phase II SBIR awarded March 2014 to BST
- Lobe Differencing Correlation Radiometer (LDCR) fabricated and under testing, NDVI sensor developed
- CoCo antenna integration into Tempest UAS underway
- 250 MS/s TB solid state recorder and FPGA digital correlators in development
- New RFI mitigation and signal detection algorithms under development
- NASA SMAP mission validation and spatial scaling studies planned for early-mid 2015
- Proposed for use in future NASA Aquarius coastal validation studies in 2015-16

Industry Application

Strengths	Capability
Airborne remote sensing system design, development, field demonstration, and data product development Support of custom business models to commercialize RS systems	• Suborbital system concept development in remote sensing • Precision microwave radiometer and radar prototyping • Massive high rate data acquisition and processing • Aircraft integration of novel antennas

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Black Swift TECHNOLOGIES

NASA

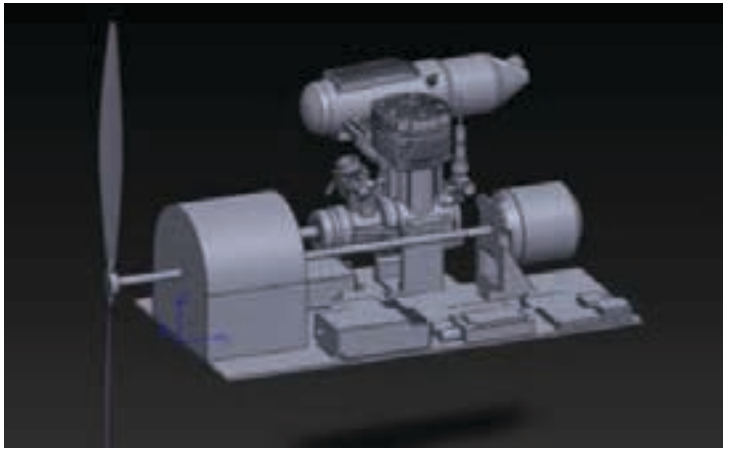
CET
CENTER FOR ENVIRONMENTAL TECHNOLOGY

HELIOS Torque Fusion, Inc.: Dr. Jean Koster (AES)

Objectives and Description

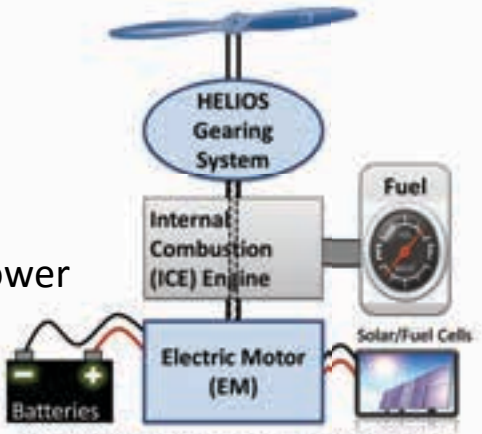
- HTF is developing a line of hybrid-electric propulsion systems for aircraft which allow greater fuel efficiency, higher dispatch reliability, and improved stealth.
- Utilizing a proprietary patent-pending **lightweight clutchless gearsystem**, HTF is able to offer customers a novel, reliable alternative to liquid-fuel-only, all-electric, and series-hybrid systems.

Parallel Hybrid Solution



Status and Approach

- Clutchless Power Blending
- US Patent Pending
- Interchangeable Power Sources



Schematic showing coaxial shaft input into gear box. Other arrangements with additional gears are possible.

Industry Application

Strengths	Capability
•Reduced fuel consumption •Diesel/biodiesel ready •Increased reliability •Quiet mode cruise operation •Cruise altitude above ICE capabilities	HPS can switch seamlessly between any or all torque being generated from one source, to any or all torque being generated from another source.

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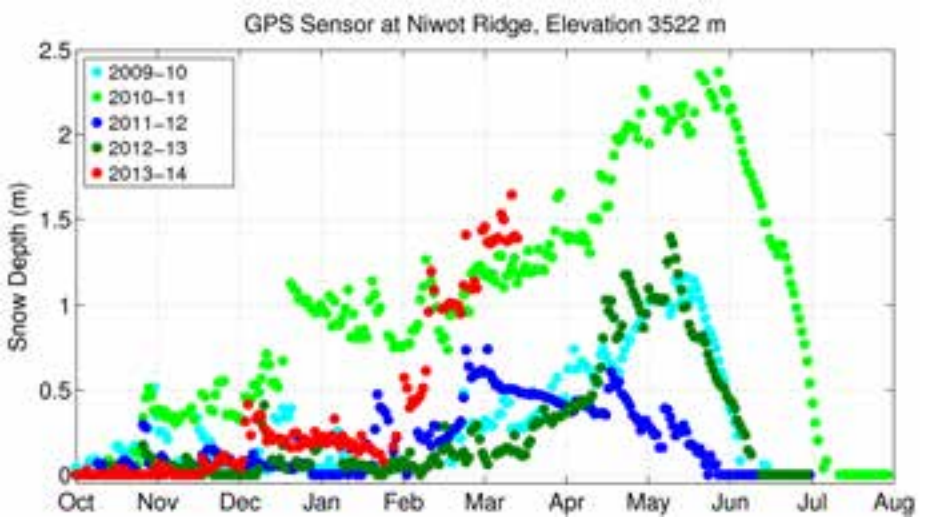
HELIOS Torque Fusion, Inc.

GPS Environmental Sensing: Dr. Kristine Larson (AES)

Objectives and Description

- Measurements of soil moisture, vegetation water content, and snow depth (and snow water equivalent) are needed for climate studies and to predict/mitigate effects of drought/flooding.
- Reflected GPS signals are sensitive to these environmental parameters. Existing GPS sites (installed by geoscientists and surveyors) can be used to simultaneously measure location, timing, and reflection quantities.



Status and Approach

- NSF and NASA has funded development of the GPS reflection technique; it is operational for a network of ~400 sites in the western United States.
- Daily results: http://xenon.colorado.edu/portal .
- Can be extended world-wide.
- Next: GPS reflections on UAS platforms or from satellites.

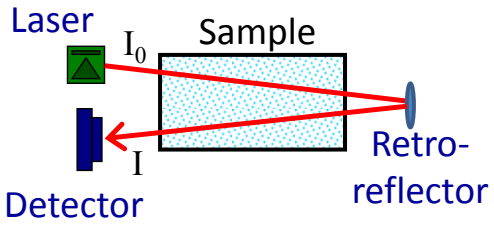
Industry Application

Strengths	Capability
•Robust measurement •Off the shelf components •Existing datastreams	Subdaily measurements in near-real-time. Currently GPS; should expand to all GNSS constellations in next decade.

Sensors for Atmospheric, Combustion, and Industrial Systems
Dr. Greg Rieker (ME)

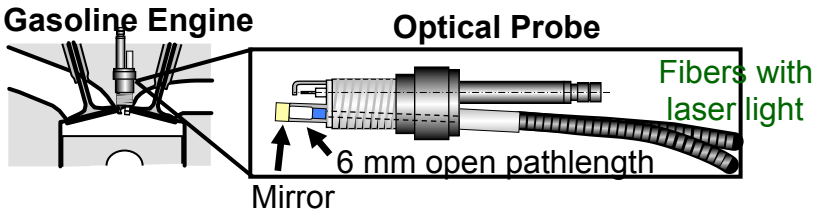
Objectives and Description

Non-intrusive detection of temperature, pressure, velocity, and concentration in harsh environments



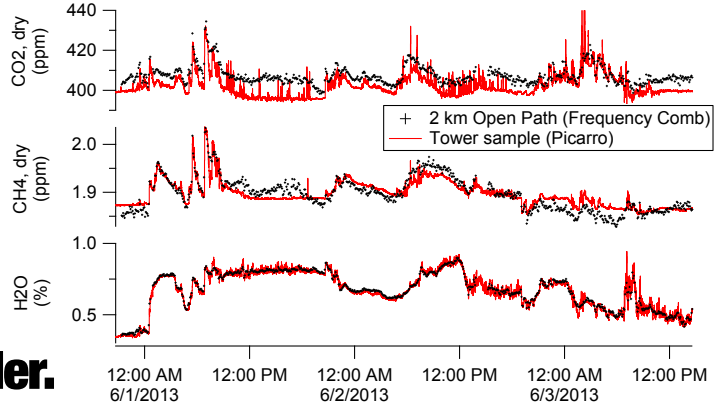
Light absorption is related to sample properties

Temperature and H_2O Concentration @ 5 kHz in a Fired Engine



Status and Approach

Methane, CO_2, and H_2O Concentration over a 2km Outdoor Laser Path



Industry Application

Strengths	Capability
Lasers: •Diode to frequency comb **Spectroscopy:** •Fundamental to applied **Systems:** •Combustion •Atmospheric	**R & D of novel sensors for measurements that are not currently possible** **Combustion & atmospheric research using laser-based measurements** **Fundamental spectroscopic studies**

Unmanned Aerial Systems for Atmospheric Science: Drs. Lundquist, Friedrich & Cassano (ATOC)

Objectives and Description

- Critical questions in atmospheric science demand **data that cannot be acquired** using conventional meteorological towers or remote sensing instruments
  - –atmospheric flow in complex terrain
  - –complex flows like wind turbine wakes
  - –offshore environments
- ATOC faculty join forces with AE faculty to test UAS for collecting the required data

Aerosonde UAV being launched from the top of a pickup truck at the Pegasus ice runway, Antarctica

(Cassano group)

Status and Approach

- The Cassano research group is using small UAVs (Aerosonde, SUMO, and DataHawk) to observe atmospheric boundary layer processes in Antarctica during the late-Antarctic winter
- The Cassano, Friedrich, and Lundquist research groups (ATOC) are collaborating with the Lawrence research group (AE) to observe wakes around wind turbines
- The Friedrich (ATOC) and Lawrence (AE) groups have proposed using UAS to measure mountain flow recirculations

Industry Application

Strengths	Capability
• Detailed measurements of complex and heterogeneous flow in the atmospheric boundary layer at varying heights and locations independent of expensive and restricted fixed measurements	• Understand previously unobserved or inadequately observed phenomena such as flow in complex terrain or over complex surfaces like polar oceans or polynyas • Quantify wind turbine wake behavior to optimize wind farm design and operations

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ATOC

Office of Industry Collaboration
Caroline Himes, Director

Objectives and Description

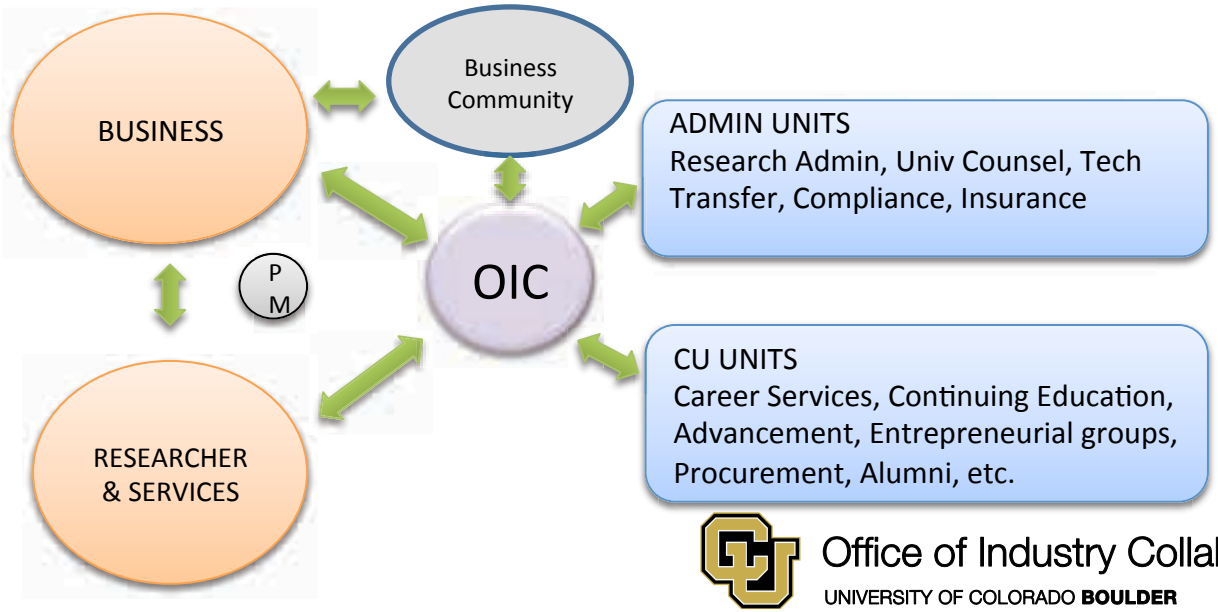
Increase the interactions between industry and CU-Boulder for the benefit of the companies, students, the economy, and CU.

- Support industry partners interested in connecting to CU Boulder
- Support faculty and researchers interested in working with industry
- Provide information on CU offerings and capabilities
- Facilitate administrative implementation
- Monitor and support project completion

Types of Connections

- Workforce
  - Hiring
  - Internships
  - Enrichment of workforce
- Product Support
  - Custom development & research
  - Licensing Technology
  - Services
    - Facilities & Testing
    - Consulting
- Engagement / Promotion
  - Seminars
  - Advertising

How can CU Boulder support your company?



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Office of Industry Collaboration
UNIVERSITY OF COLORADO BOULDER

Technology Transfer Services: MaryBeth Vellequette, Director

Corporate Relations

Access to university students + faculty

Access to intellectual property

Research collaboration

Business community engagement

Giving opportunities

Technology Transfer

Inventory unique research assets

IP management

Patentability assessment

Copyright management

License negotiation

Industry Contracts

Research collaboration agreements

Industry research agreements

Other industry contracts

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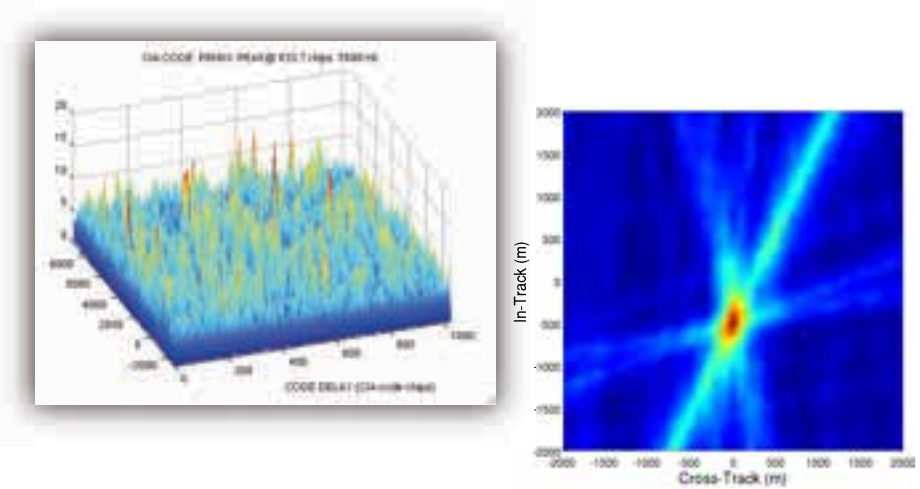
University of Colorado
Boulder | Colorado Springs | Denver | Anschutz Medical Campus
TECHNOLOGY TRANSFER OFFICE

Collective GPS+ Positioning
Dr. Penny Axelrad & Graduate Student Ben Bradley (AES)

Objectives and Description

Provide GPS-based position and time solutions:

- Without continuous tracking or nav data decoding
- Instantaneous with < 10 ms of antenna exposure
- Robust to interference by enforcing consistency among contributions from multiple transmitters
- Ability to incorporate new GNSS and SBAS signals
- Determine solution by direct search in the position and time domain, rather than acquiring and tracking
- Use predicted orbit & clock models from the internet



Status and Approach

- Algorithms coded in MATLAB demonstrated using simulated and live sample data recordings.
- Currently in SBIR Phase 1 for small satellites
- Next - leverage DSP and efficient search algorithms to reduce memory usage and increase speed
- Customize approach for new application scenarios & requirements

Industry Application

Strengths	Capability
• Reduces SWaP • Reduces specialized HW & SW • Can be extended to new signals of opportunity • Robust solutions in challenging environments	Leverage knowledge from other sensors and via alternate communications links to find most likely location using all available GPS signals directly.

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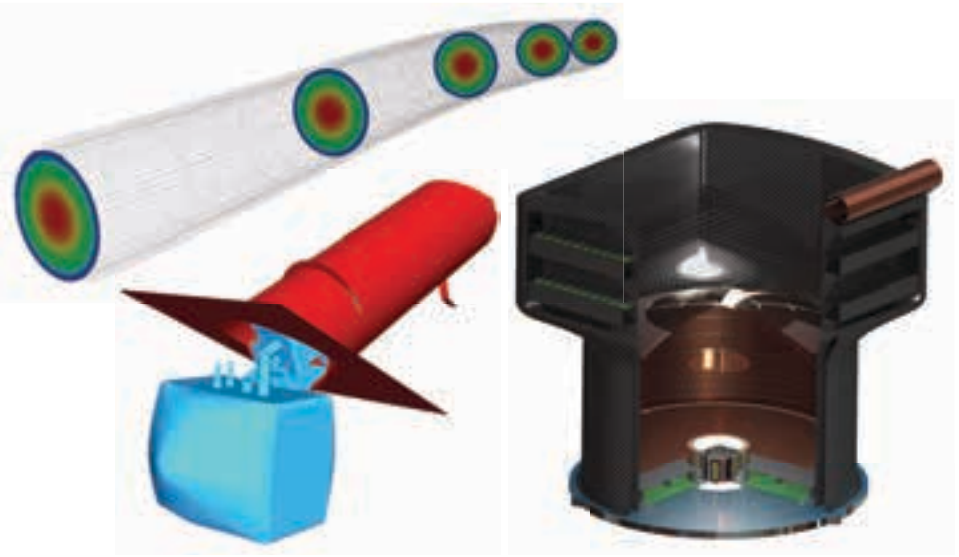
Aerospace Engineering Sciences
UNIVERSITY OF COLORADO BOULDER

Advanced Simulation and Design of Instruments: Dr. Kurt Maute (AES)

Objectives and Description

Analysis and Design of Complex Engineering Systems via High-Fidelity Numerical Simulation and Optimization.

- Hyperdust
  - Detailed design of instrument for in-situ analysis of cosmic dust for mass, velocity, charge, and composition.
- CULPIS
  - Perform structural analysis for flight safety of sea ice observation platform for US Coast Guard C-130 flights over arctic waters.
- Flow Sensor
  - Analysis of complex fluid-structure interaction behavior in Coriolis-effect flow sensors



Status and Approach

- Hyperdust
  - Completed initial design. Developing novel shape and topology optimization tools to achieve low structural mass, large target area, better mass resolution, and improved trajectory resolution.
- CULPIS
  - Completed analysis of local aircraft structural behavior due to static inertial and dynamic aero loads on instrument package.
- Flow Sensor
  - Developed fully-coupled 3-D fluid-structure interaction FE model of instrument for exploration of low Reynolds number flows.

Industry Application

Strengths	Capability
• Simulation & Optimization of coupled multi-physics systems	• Provide High-Fidelity Analysis & Optimized Designs for Complex Load Environments

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Aerospace Engineering Sciences
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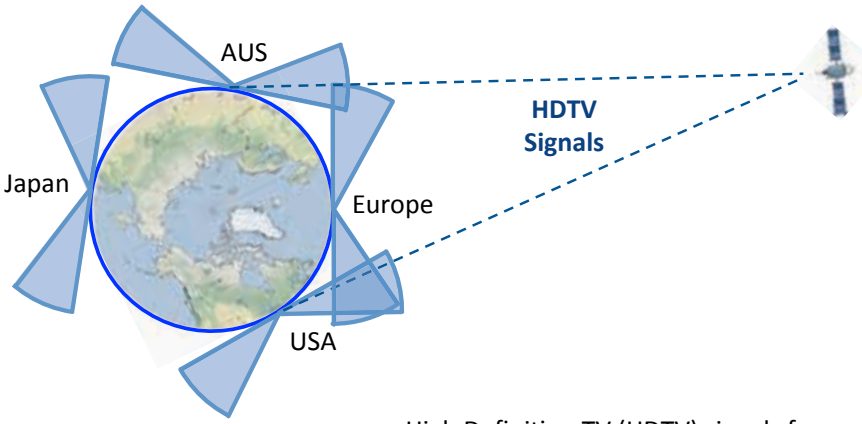
Spacecraft Navigation Using HDTV: Dr. Jeff Parker (AES)

Objectives and Description

- Over **8800 HDTV towers** broadcast with enough power to be easily received at the **Moon** or beyond.
- These signals may be converted into navigation data for spacecraft, from Earth orbit out to the Moon.
- One tower is sufficient, but we can uniquely identify dozens of towers at any given time.
- Objective of research: to demonstrate autonomous spacecraft navigation using these ***Signals of Opportunity*** **(*SoOps*)**.



Towers broadcast up to 15° above the horizon, and up to 1.3 MW in power

High Definition TV (HDTV) signals from over 8800 towers may be used to navigate satellites and spacecraft as far away as the Moon.

Status and Approach

- Working with Loctronix's ASR-2300 radio, which can pick up any HDTV tower transmissions, GNSS, and even S-Band.
- Demonstrating SoOps navigation on the ground.
- Preparing to demo SoOps on an aircraft (July).
- Preparing to demo SoOps on a high-altitude balloon.
- This work will support a 6U-cubesat mission to be deployed on Orion's EM-1 mission to the Moon in 2017.

Industry Application

- **Low-Cost Navigation**: HDTV transmissions can be received using COTS hardware and omni-antennae.
- **Autonomous Spacecraft Navigation**: SoOps navigation does not require active ground tracking.
- **Improved Navigation Accuracy**: There is an immense amount of free tracking data available to be used stand-alone or to supplement ground tracking.
- **Applications**: GPS updates, GEO navigation, autonomous operations, Orion navigation.

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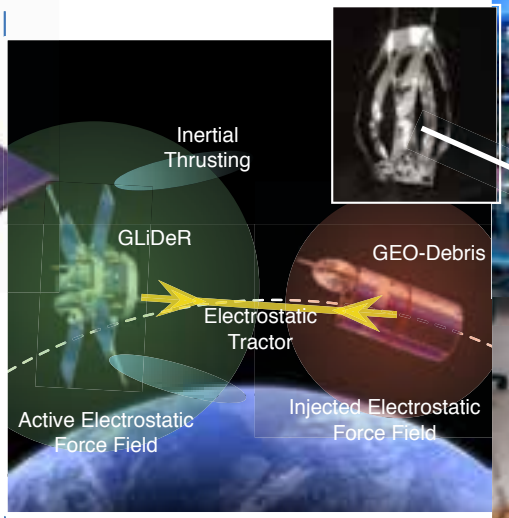
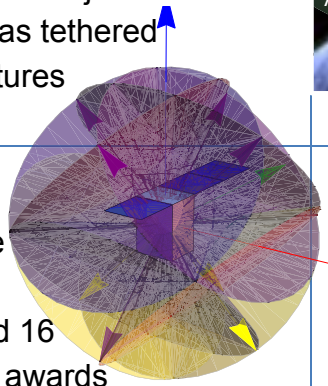
CCAR Colorado Center for Astrodynamics Research

Dr. Schaub's Research Group
Autonomous Vehicle Systems (AVS)Lab

Objectives and Description

- Spacecraft formation flying and rendezvous and docking
- Nonlinear dynamics and control
- Attitude dynamics and control
- Fault tolerant, autonomous control
- Space debris mitigation and remediation
- Visual relative motion control
- Touchless despinning of passive space objects
- Gossamer structure dynamics such as tethered tugging or charged membrane structures





Status and Approach

- Research has led to 137 conference and 91 journal papers
- Graduate researchers have received 16 national fellowships, plus numerous awards
- Internationally recognized program for:
  - spacecraft control developments
  - hardware-in-the-loop simulations
  - complex dynamic simulations
  - experimental research on space actuation and sensing

Industry Application

Strengths	Capability
• Nonlinear dynamics, estimation and control • Advanced spacecraft attitude and relative motion control • Sensor modeling and estimation integration • Experimental astrodynamics	• Dynamic analysis of complex space concepts • Fast numerical simulations in C and OpenCL • Hardware experiments and simulations • Virtual reality dynamic simulations • Force/torque modeling due to spacecraft charging

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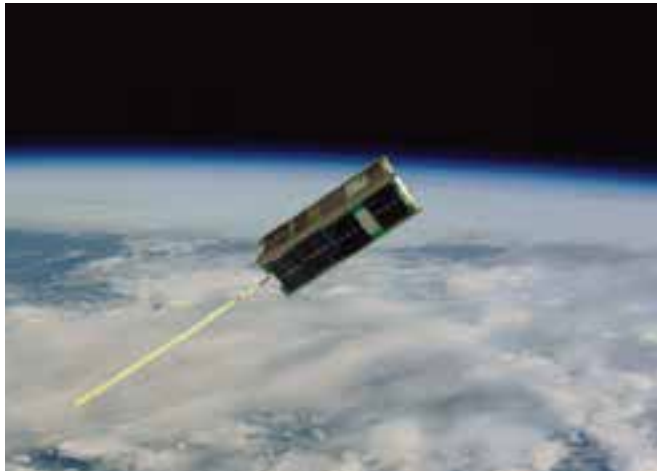
The CSSWE CubeSat:
Dr. Xinlin Li and Graduate Student Quintin Schiller (AES/LASP)

Objectives and Description

- Design, build, and operate a 3U CubeSat to investigate harmful electrons and protons in near-Earth space
- Student led with advisement from professionals from the Laboratory for Atmospheric and Space Physics (LASP) and AES
- Over 60 students involved
- Launched from Atlas V-401 (NRO-L36) September 13th, 2012
- Funded by NSF for < $1M

(Research Demonstration or Graphic)



Status and Approach

- Full success reqs: 120/90 days of ops/science
- Currently: 564/356 days of ops/science
- **Still operational**

- Major challenges include low budget, student turnover, and student inexperience
- Approach: thorough design, analysis, and documentation with a keep-it-simple paradigm

Industry Application

Strengths	Capability
• Inexpensive space weather monitor	• Accurate measurements of harmful particles
• Low budget, yet robust and reliable	•Exceeding expectations
• Provides valuable science data	• Nearly 5x nominal mission lifetime

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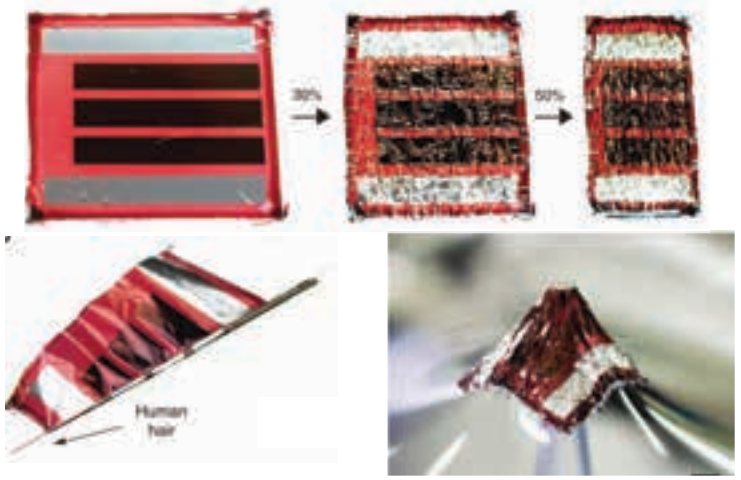
Organic Electronics for Lightweight Photovoltaics and Transistor Devices: Dr. Sean Shaheen

Objectives and Description

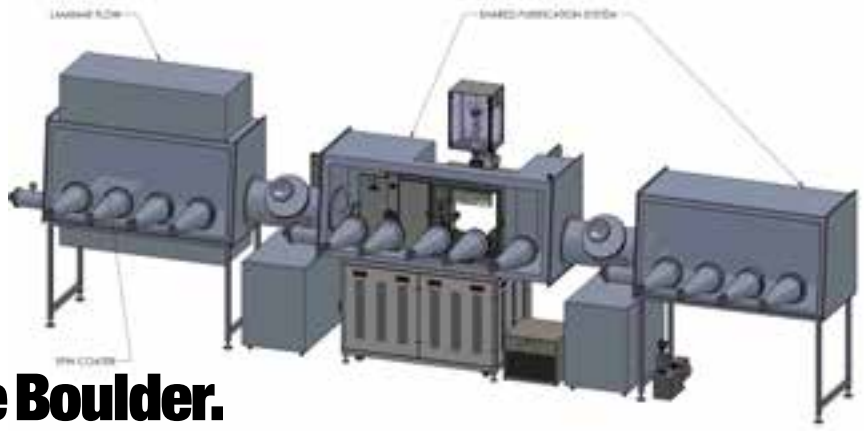
- Organic, aka "plastic", electronics (OEs) are emerging as an innovative technology that is complimentary to conventional electronics in many ways.
- Current devices being researched or commercially manufactured include OPVs, OLEDs, and OFETs.
- The aim of OEs is to take advantages of their low-cost, fast design-to-fabrication cycle, and desirable mechanical properties.

An example of the mechanical properties of an ultra-lightweight organic photovoltaic device[1]



Status and Approach

- Device performance is reaching commercially viable levels for several applications.



Industry Application

Strengths	Capability
• OPV on ultrathin substrate exhibits the highest power-to-weight ratio (10 W/g) of any PV technology. • OFETs have demonstrated excellent radiation hardness of hundreds of krad[2].	• The Shaheen group has capabilities to design, build, and test OEs for a variety of applications.

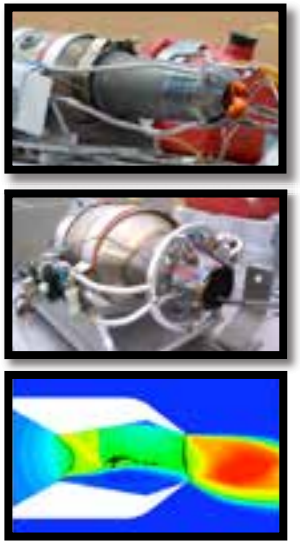
[1] Ultrathin and lightweight organic solar cells with high flexibility, M. Kaltenbrunner et al., *Nature Communications* **3**, 770 (2012).
[2] X-ray irradiation effects in top contact, pentacene based field effect transistors for space related applications, R.A.B. Devine, et al., *Appl. Phys. Lett.* **88**, 151907 (2006).

Efficient Small Scale Propulsion: Dr. Ryan Starkey (AES)

Objectives and Description

- Develop the next generation of efficient small scale propulsion systems for use in:
  - Unmanned aircraft
  - Gliders (take-off/sustainer propulsion)
  - Decoy and missile systems
  - Research aircraft
- Enables new systems due to advanced capabilities compared to state-of-the-art:
  - 2X efficiency, >20X time-between-overhaul

Turbojet Engines



Status and Approach

- Eliminate lubrication and starter systems
  - Advanced bearings and overall engine design
- Reduce system part count
- Improve component design/interoperability
- Improved compression and combustion
- Unique capabilities include: articulating nozzle, afterburner, power generation, thrust vectoring

Industry Application

Strengths	Capability
High Thrust	200+ lbf
Highest Fuel Efficiency (~2X)	0.7 lbm/(lbf hr)
Expanded Operability	40+ kft, 1000+ mph, 1000+ hrs TBO
Ease of starting	Wind-Milling
Storability, Reliability	No oil/pyro systems
Light Weight	< 14 lbs
Low Cost	TBD

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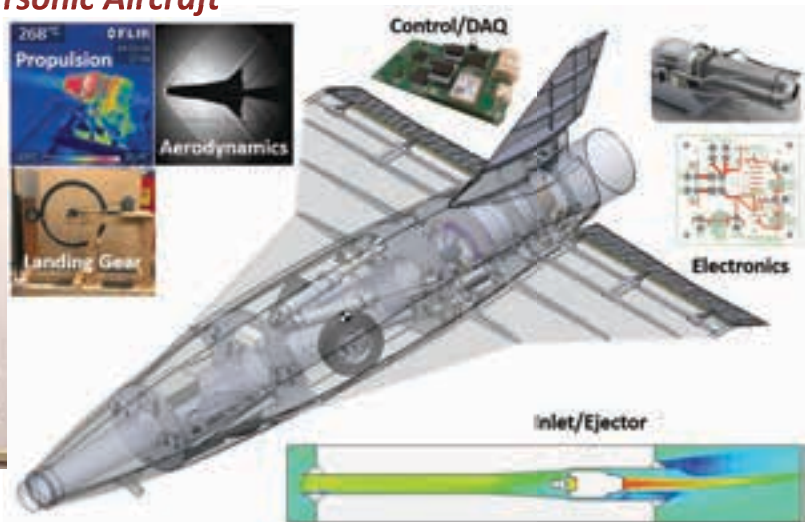
High-Speed Unmanned Aircraft: Dr. Ryan Starkey (AES)

Objectives and Description

- Develop technology for low cost, unmanned aircraft for high-speed flight testing:
  - Novel configurations/control systems
  - Sonic boom reduction
  - Hurricane penetration
  - Transonic/supersonic testing
  - Missile, ISR applications
  - Advanced engine testing (combined-cycles)
  - Component testing/qualification in relevant environments

Supersonic Aircraft



Status and Approach

- All major components designed, built, verified
- Integration beginning Spring 2014
- Low-speed flight testing (250 mph) Fall 2014 at New Mexico UAS Flight Test Center
- Data to be used to finalize supersonic design Spring 2015
- Supersonic flight testing Fall 2015

Industry Application

Strengths	Capability
High Speed	Mach 1.4 (~1000 mph)
Low Cost	$50,000
Light Weight	100 lbs
High Thrust-to-Weight	2 (vertical take-off?)
Small scale	6 ft long x 5 ft span
Long range	~200 miles @ M=1.4 500+ miles @ M=0.9

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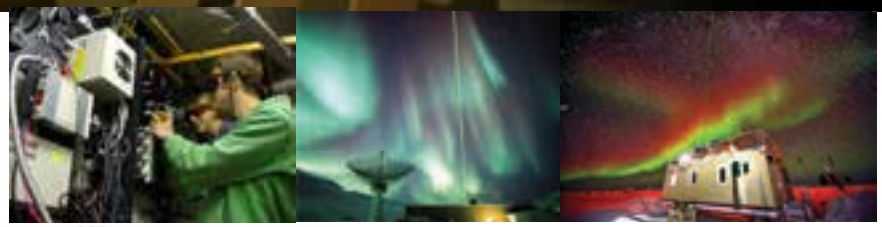
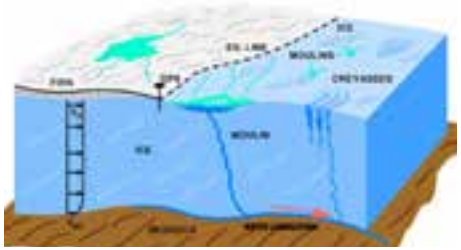
Active Remote Sensing Lab: Novel Lidar Techniques
Dr. Jeff Thayer

Objectives and Description

- Develop new lidar techniques based on fundamental scattering processes for broad applications
  - Rayleigh, Mie, Raman, Resonance, Polarization
- Applied to atmospheric and ocean remote sensing
  - Tropospheric water vapor
  - Cloud thermodynamic phase and ice particle orientation
  - Aerosol detection and shape estimation
  - Meteoric Alkali metal resonance
  - Shallow water lidar bathymetry
- Innovative use of polarization to isolate intrapulse phase modification induced by scattering (INPHAMIS)





Status and Approach

- Field deployed lidar systems in Kangerlussuaq and Summit Camp, Greenland
- Prototype INPHAMIS lidar bathymetry system with demonstrated ability to measure shallow water regimes with 1-cm depth accuracy and 4-mm precision
  - Patent-pending technology
  - Exclusive license agreement with ASTRALiTe Inc.
  - Developing a portable system for deployments in the field

Industry Application

INPHAMIS

Strengths	Capability
• Enhanced Range Resolution • Precise Measurement • No Contact with Media • Distance Sampling • Low Cost Solution • Accurate and Scalable • Differential Measurement not requiring platform position	• Shallow water depths • Water floor topography maps • Submerged object detection • Semitransparent media thickness measurement • Surface roughness characterization

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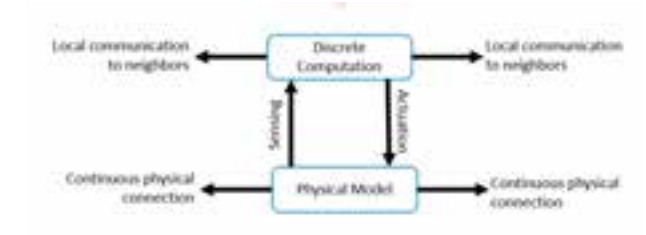
CCAR

Cyber-physical Materials: Dr. Nikolaus Correll (CS)

Objectives and Description

- Novel class of composite materials that tightly embed
  - Sensing
  - Actuation
  - Computation
- Applications
  - Non-destructive evaluation
  - Morphing capabilities
  - Appearance change



Status and Approach

- Multiple approaches to stiffness change
  - Sheet jamming
  - Low melting point metal/polymers
- High-bandwidth sensing
  - Real-time spectral analysis of sensor input within the material
  - High-frequency NDE
- Standardized hardware infrastructure, nation-wide collaborations on materials and NDE

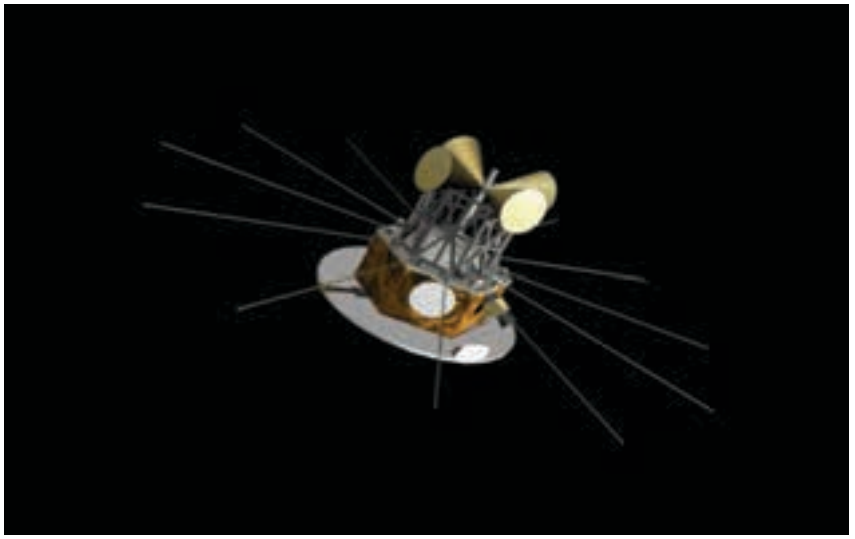
Industry Application

Strengths	Capability
•Increased reliability and reduced downtime due to in-situ measurements •Increased performance and efficiency due to adaptive shape change	CPMs enable high-bandwidth sensing *inside the composite*, from kHz to GHz and active control of polymer properties at high resolution.

Dark Ages Radio Explorer (DARE): Dr. Abhirup Datta

Objectives and Description

- The science objectives of DARE include formation of first stars, first accreting black holes, beginning of reionization and end of the Dark Ages.
- Measure the sky-averaged 21-cm signal using a single radiometer between **40-120 MHz** (z=11-35).
- DARE will orbit the Moon for **~2 years** and take data only above the lunar far side, where it is shielded from the Earth's intense RF Interference.
- Absence of Ionosphere will help to achieve the **10^{-6}** dynamic range to detect the faint cosmic signal.



Status and Approach

- Mission will be proposed for the upcoming SMEX opportunity (end of 2014)
- Extensive Laboratory Tests to demonstrate the feasibility of high dynamic range (**10^{-6}**) calibration.
- Engineering Prototype testing to demonstrate the integrated instrument is at TRL 6.
- Demonstrate that the effect of RF Interference and the Ionosphere will be severe limitations for a DARE-like experiment from the ground.

Industry Application

Strengths	Capability
• Unique science case & wavelength for a SMEX mission. • Efficient, low cost, high science return mission	Low-risk instrument design that can achieve 1 ppm calibration High heritage space-craft (BALL), launch innovation (secondary payload).

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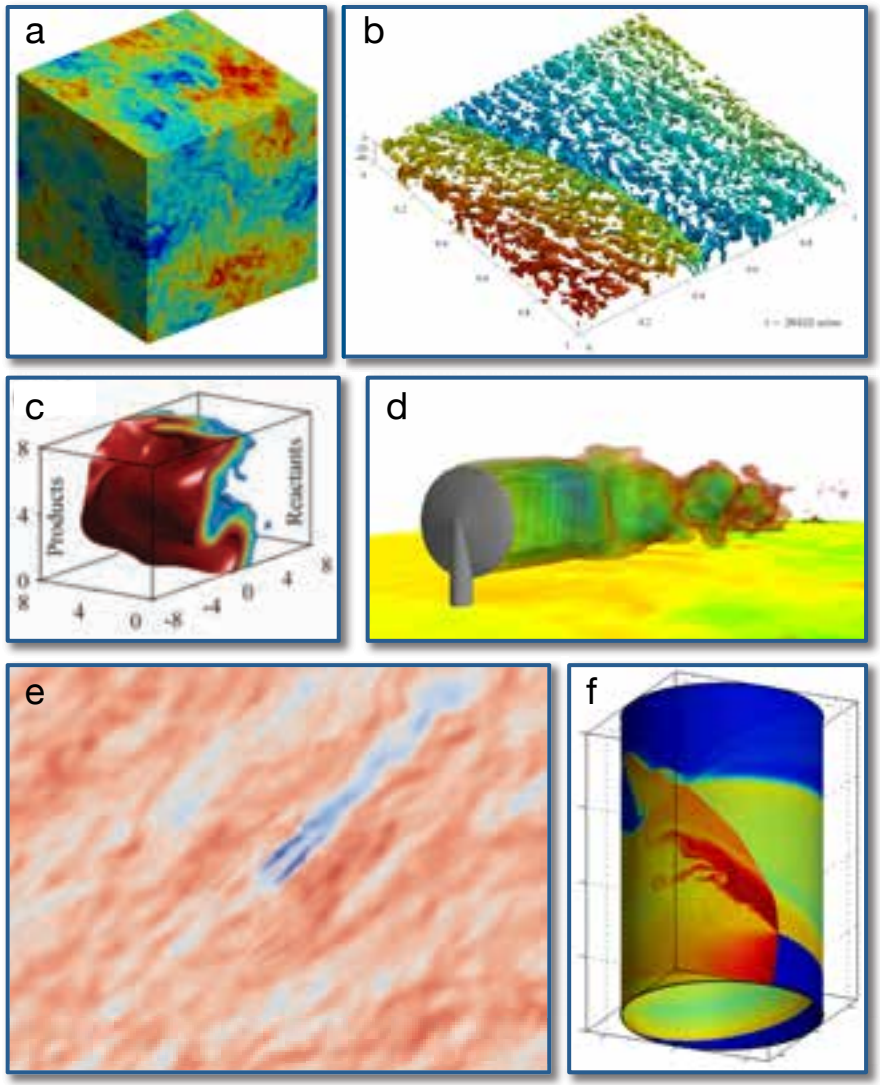
DARE

CASA
CENTER FOR ASTROPHYSICS AND SPACE ASTRONOMY

Turbulence and Energy Systems Laboratory: Dr. Peter Hamlington (ME)

- The Turbulence and Energy Systems Laboratory (TESLa) focuses on numerical simulations of turbulent flows
- The simulations are used for fundamental flow studies, model development, design optimization, and performance analysis
- There are three core areas of research at TELSa:
  1. Turbulence modeling (e.g. vorticity dynamics and nonequilibrium modeling, panel a)
  2. Geophysical turbulence (e.g. upper ocean dynamics, panel b)
  3. Reacting flows and combustion (e.g. flame-turbulence interactions, panel c)
- Applied research topics are examined at the intersections of the three core areas:
  1. Wind and ocean renewable energy (e.g. ocean and wind current turbines, panels d and e)
  2. Ocean carbon cycle and contaminant transport (e.g. chemical species, plankton, oil)
  3. Propulsion and transportation (e.g. rotating detonation engines, panel f)
- Funding from NSF, NREL, AFOSR
- Contact: Prof. Peter Hamlington at peh@colorado.edu or 303-492-0555.



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Aerospace and Defense Industry

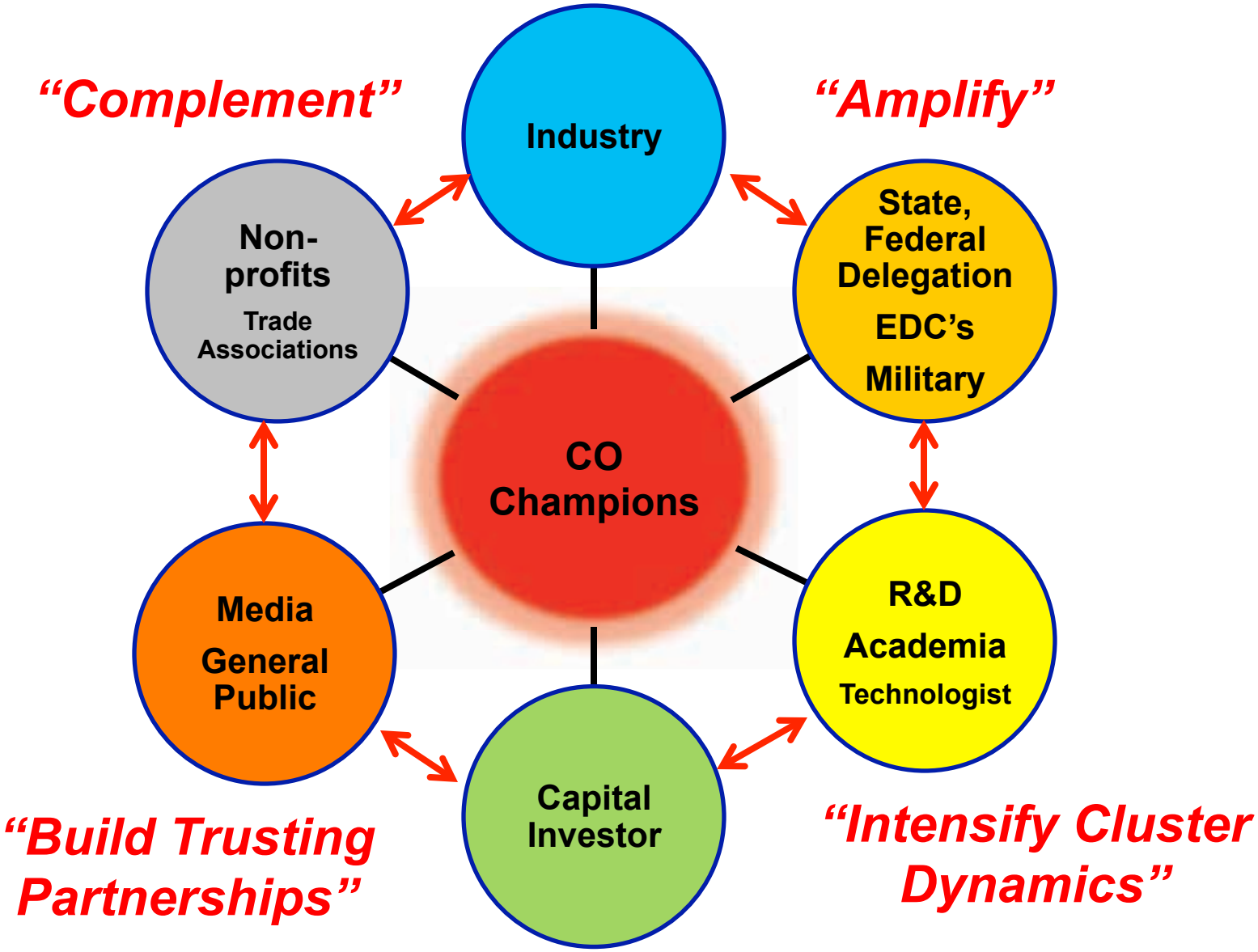
Leading Colorado To The Next Level

AeroSpace Ventures

Jay Lindell

CO Aerospace & Defense Industry Champion; 17 Apr 2014

Ecosystem Catalyst



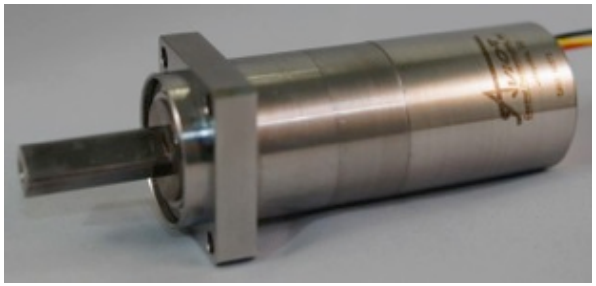
Colorado Aerospace Economy

- 400 + companies provide space-related products, services; most small business tier 2/3 suppliers
- 1st in nation per capita in aerospace employment; 24,990 employees; $3B payroll
- Colorado 3rd in nation in private aerospace direct employment
  - 170,000 + in related jobs (telecomm, IT)
  - 17.3% CO aerospace growth in past 10 years (6.1% nationally)
- Colorado 3rd in nation in science & technology investments
- Anchored in government R&D & procurement programs

"The space economy is an outsized driver of Colorado's economy"
Brookings Institute, Launch Report , Feb 2013

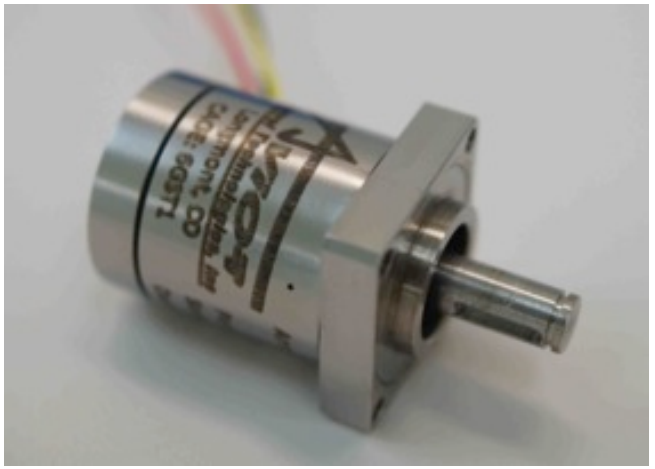
Aerospace Small Business
Avior Control Technologies

Solar Array Deployment Actuator



Eddy Current Adapter

Actuator for NASA Lunar Robotic Mission



Rotary Switch for NASA Lunar Robotic Mission

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Small Business

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GPS – Key Enabling Technology

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Unmanned Aerial Systems

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Unmanned Aerial Systems

CU RECUV

Research and Engineering Center for Unmanned Vehicles

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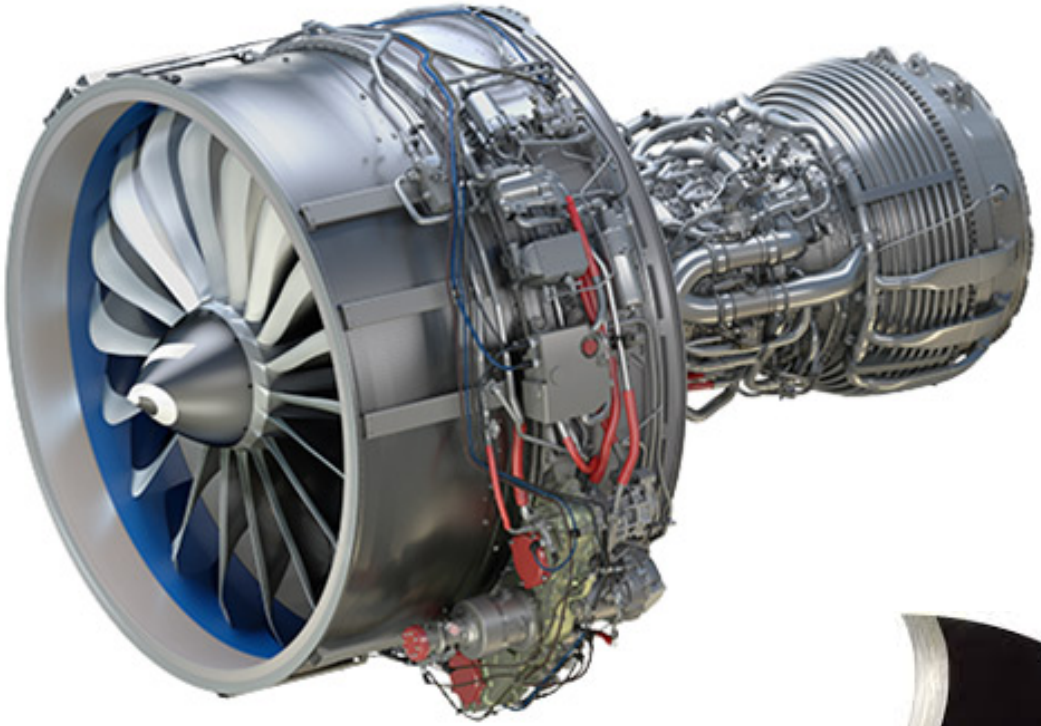
Additive Manufacturing



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Additive Manufacturing

Leading CO To The Next Level

"Colorado is 1 of 10 States poised to create new jobs & see an economic boom in 5 to 10 years." **National Chamber Foundation, 2012**