Update on the Cubesat Program of the U.S. National Science Foundation

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National Science Foundation, USA

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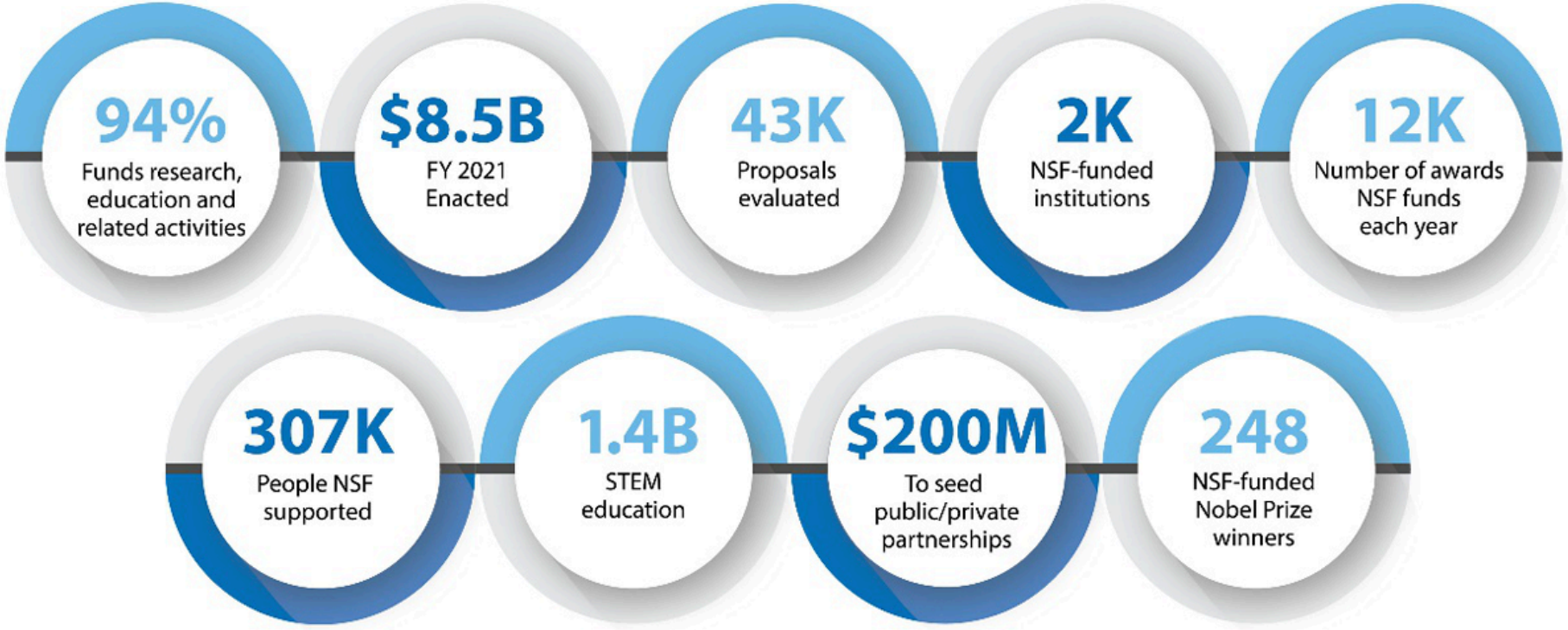
Weekend Session VIII: Next on the Pad - Research & Academia
36th Annual Small Satellite Conference

NSF invests in basic research and education across STEM disciplines

To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense …



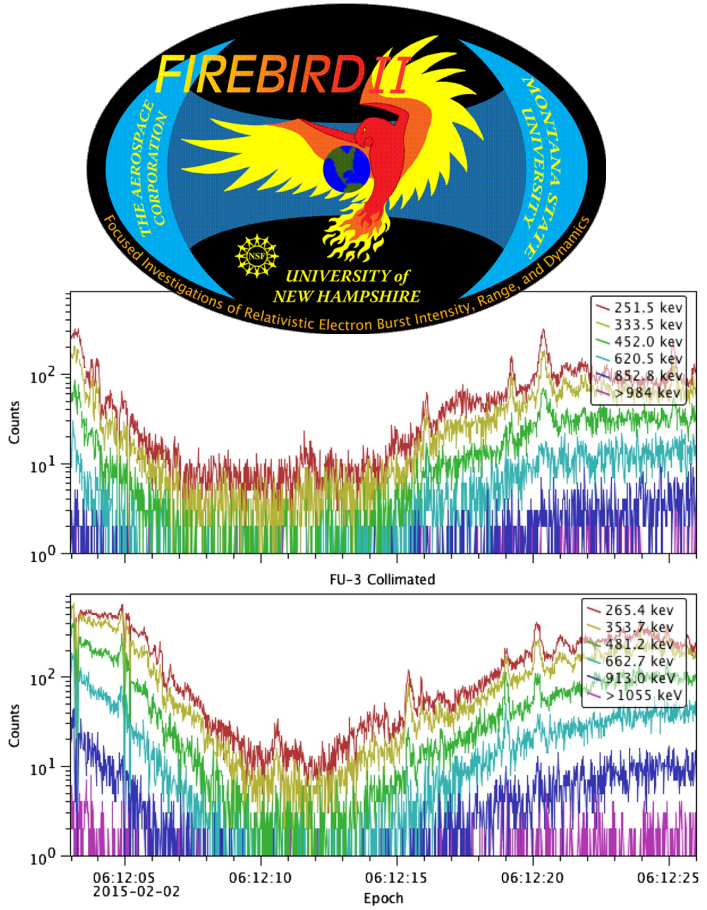
- Competitive proposal-driven grants for limited period, merit reviewed on intellectual merit and broader impacts

NSF not space agency – so why cubesats?

- Since 2008, support for nearly 20 university-led missions
  - $1-4.5M over 3-5 years
- Extramural funding via solicitations – **science, engineering**, and **educational advances proposed by researchers**
  - Atmospheric/geospace sciences, space weather research
  - Innovative wireless communication
  - Precision formation flying

- Key partners
  - NASA Wallops Flight Facility – technical advice
  - NASA CubeSat Launch Initiative
    - Previously—DoD, NRO

FIREBIRD-II (in orbit) ssel.montana.edu/firebird2.html

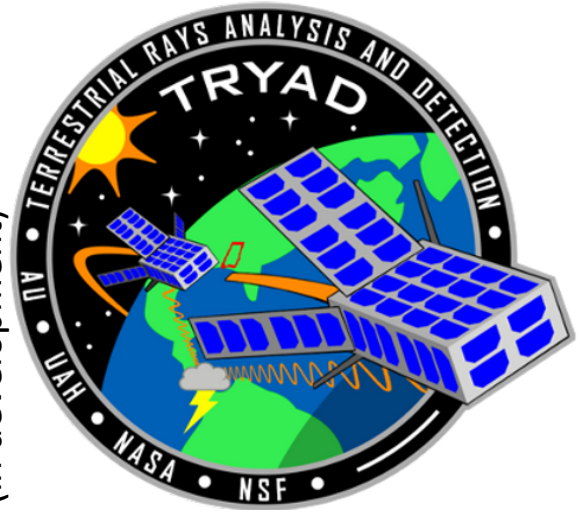


doi.org/10.1002/2016JA022485

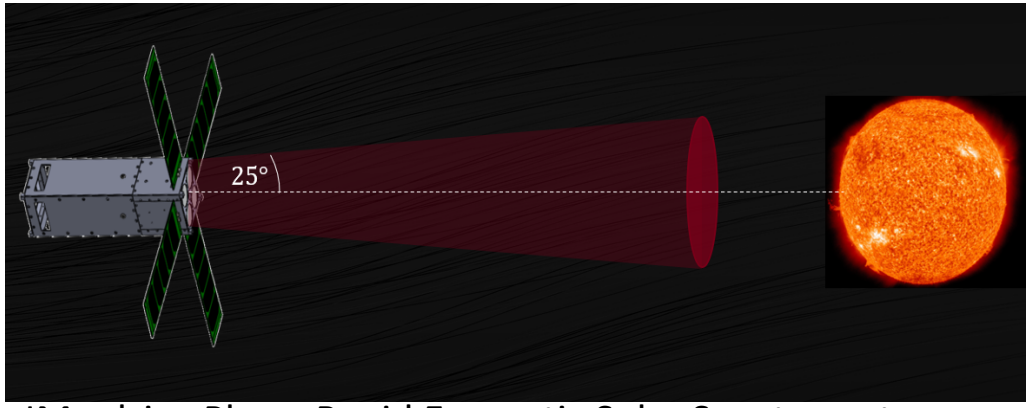
Advancing knowledge of the Sun and near-Earth space environment

NSF-sponsored cubesat missions next on the pad

www.space.auburn.edu/tryad
(in development)

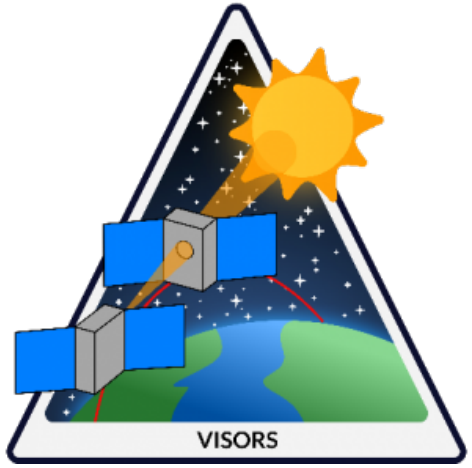


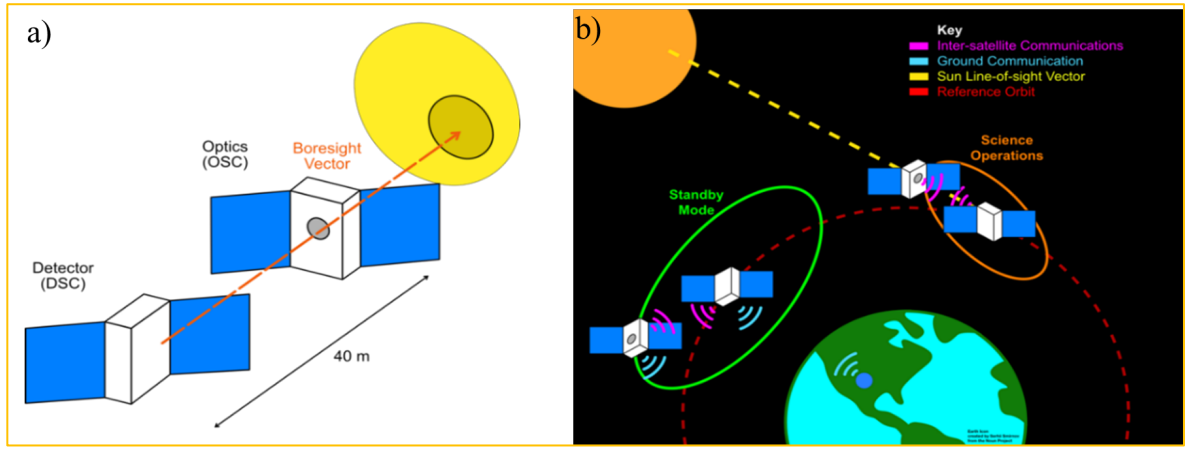
culair.weebly.com/canvas.html
(in development)



IMpulsive Phase Rapid Energetic Solar Spectrometer:
smallsat.umn.edu/impress (in development)

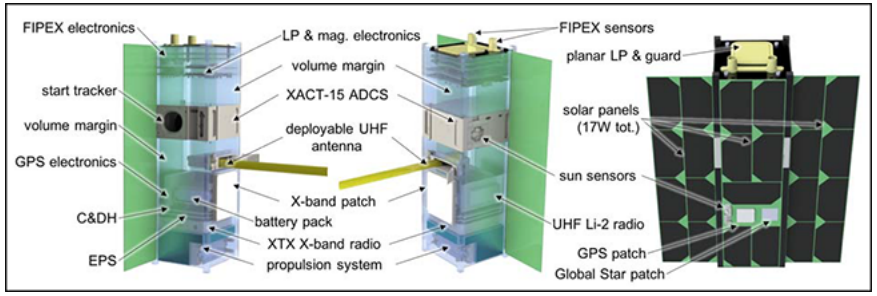
Innovations in communications and spacecraft operations





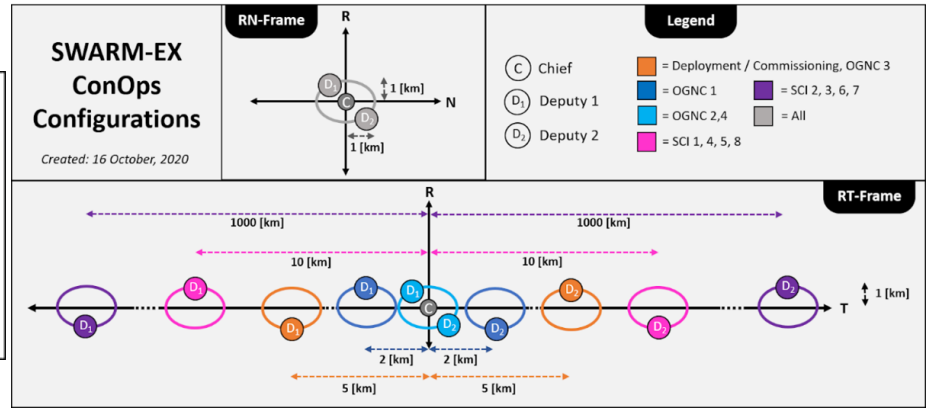
VISORS (in development)

ssdl.gatech.edu/index.php/research/projects/visors-virtual-super-resolution-optics-using-reconfigurable-swarms



SWARM-EX (in development)

www.colorado.edu/aerospace/research/cu-boulder-cubesats



Ideas Lab: Cross-cutting Initiative in CubeSat Innovations
www.nsf.gov/pubs/2019/nsf19530/nsf19530.htm

Advantages of and Challenges for Academic Cubesats

✓ Proven success at providing science measurements from space; can coordinate with ground-based scientific observations
  - Partial fulfillment of mission objectives due to technical challenges

✓ Short turn-around time, relatively low cost for unique science & innovation

  - Adequate funding to build, test, address preflight issues
  - Contracts with vendors

✓ Project management and reviews by university
  - Grantees must comply with regulations, incl. spectrum licensing, orbital debris, etc.

✓ Leadership opportunities for students

  - Student turnover / constant recruitment and training

- Ground station networks (frequencies, data download rates, protocols)

- Launch opportunities (current great support from CSLI) and costs

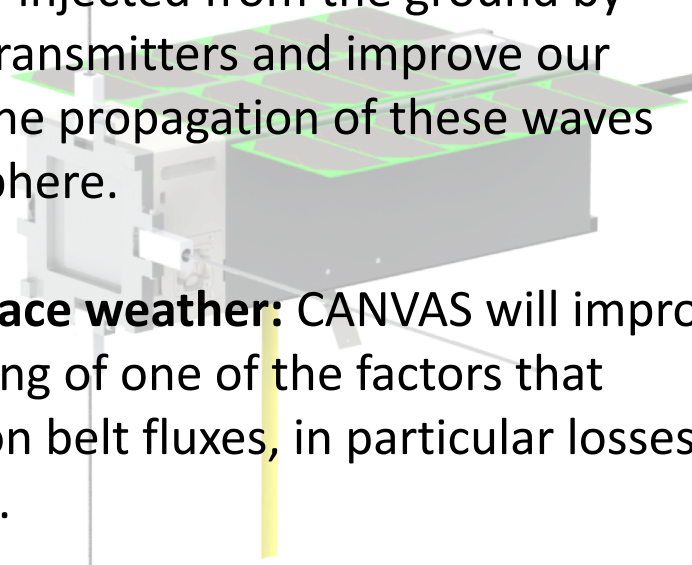
Climatology of Anthropogenic and Natural VLF wave Activity in Space

- **Mapping the VLF energy input from Earth to Space**

VLF (0.3—30 kHz) waves affect the Earth's radiation belts. CANVAS will provide the most complete picture of the wave energy injected from the ground by lightning and VLF transmitters and improve our understanding of the propagation of these waves through the ionosphere.

- **Relevance to space weather:** CANVAS will improve our understanding of one of the factors that controls radiation belt fluxes, in particular losses to the atmosphere.

- To be delivered for launch through CSLI in 2023



PI: Robert Marshall, CU Boulder, Aerospace Engineering Sciences
Co-PI: David Malaspina, CU Boulder / LASP
Co-PI: Scott Palo, CU Boulder, Aerospace Engineering Sciences

Partners:

- **CNRS (France): providing search coils**
- **Roboze (Italy): 3D printed PEEK components**
- **CTD (Colorado): composite deployable boom**
- **Blue Canyon (Colorado): XACT ADCS system**

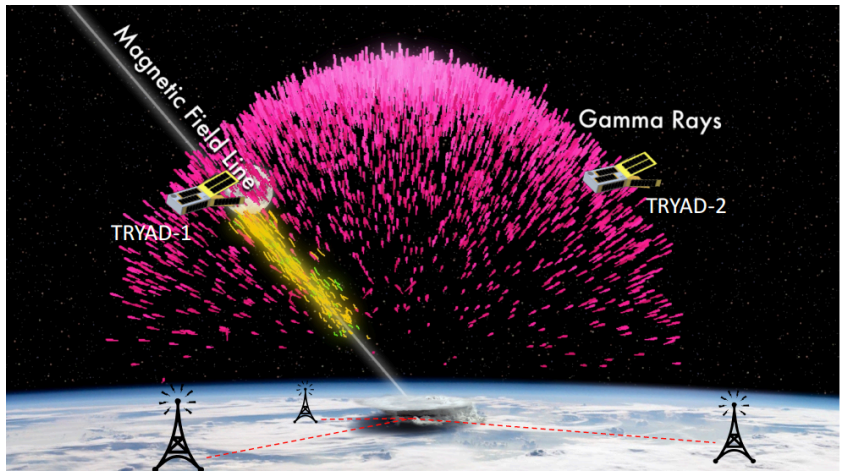
- **CANVAS involves PhD students, graduate students and undergraduate students.** Graduate students take part in spacecraft design, analysis, manufacturing, and test through a 2-semester Projects course sequence. To date, >30 graduate students have worked on the CANVAS mission.

Terrestrial Rays Analysis and Detection

- Terrestrial Gamma Ray flashes (TGFs) are short gamma ray bursts from electrons accelerated by strong electric fields in thunderstorms. TGF seed particles are thought to be relativistic electrons originating from cosmic rays
- TRYAD along with ground measurements, will measure TGF gamma ray beams in multiple locations, constraining beam parameters.
- TRYAD is two 6U spacecraft; flight hardware being built
- To be delivered for launch through CSLI in 2023

Key personnel & affiliation
Michael Briggs (overall and science PI, UAH)
Michael Fogle (engineering PI, Auburn)

Partners
Georgia De Nolfo (electrical engineering, GSFC)



- TRYAD project is an undergraduate student project. TRYAD provides funding for the students over the summer. Faculty and PIs provide guidance
- Many student go on to advanced degrees at prestigious universities and get hired by aerospace companies.

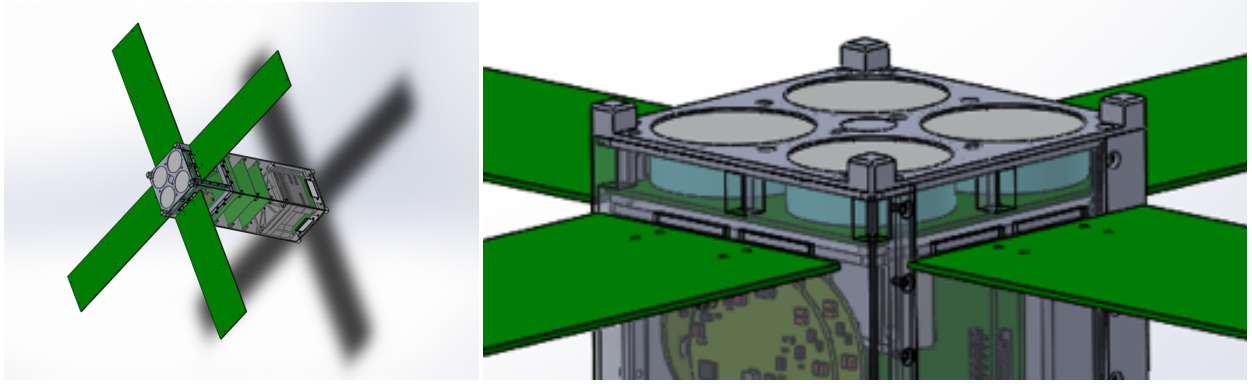
The IMpulsive Phase Rapid Energetic Solar Spectrometer

- **Primary Mission Goal**: Investigate **electron acceleration timescales in solar flares** by measuring short (subsecond) spikes in X-ray time profiles.
- **Relevance to space weather:** This mission investigates the timescales of magnetic reconnection and energy release for flares. This energy release powers the flares and coronal mass ejections that give rise to space weather.
- To be delivered for launch through CSLI in 2023

Key personnel:
Lindsay Glesener and **Demoz Gebre-Egziabher** at Univ. of Minnesota
John Sample at Montana State Univ.
David Smith at Univ. of California Santa Cruz
Amir Caspi at Southwest Research Institute

- **Broader impacts / student involvement / outreach**

IMPRESS is a student-run project, with students in Project Scientist, Project Manager, and Chief Engineer roles. 30+ UMN students each semester work on IMPRESS from the Physics/Astro dept and the Aerospace Engineering dept (led by Glesener and Gebre-Egziabher, respectively). Students also participate at MSU and UCSC.



- 3U, Sun-pointed CubeSat
- 4 scintillator detectors + 1 silicon drift detector → energy range ~1-100 keV (throughout soft and hard X-ray bands)

VIrtual Super-resolution Optics with Reconfigurable Swarms

- VISORS will image the Sun at an unprecedented angular resolution of 160 milliarcseconds to test theories of coronal heating
- Distributed UV telescope with diffractive optics; 2 6U CubeSats, 40 meters apart. Leading CubeSat hosts a photon sieve and the trailing one hosts a detector, in precision formation via low-interference propulsive maneuvers; navigation, control, and autonomy; and 5G-inspired inter-CubeSat communication.
- VISORS will advance space weather research by high-resolution imaging of coronal structures to constrain physical models of nanoflares.
- To be delivered for launch through CSLI in 2023

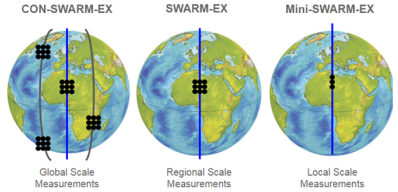
Key personnel & affiliation

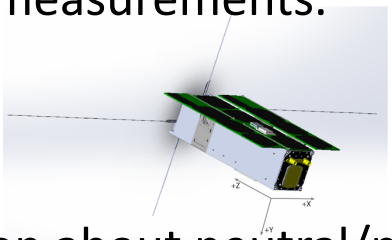
Participant	Institution
Farzad Kamalabadi	**Univ. of Illinois Urbana-Champaign**
Alina Alexeenko	Purdue University
Philip Chamberlin	Univ. of Colorado, LASP
Simone D'Amico	Stanford University
Adrian Daw	NASA GSFC
Kevin Denis	NASA GSFC
Eylem Ekici	Ohio State University
Subhanshu Gupta	Washington State University
John Hwang	Univ. of Calif. San Diego
James Klimchuk	NASA GSFC
Glenn Lightsey	Georgia Tech
Hyeongjun Park	New Mexico State Univ.
Douglas Rabin	NASA GSFC
John Sample	Montana State University
Thomas Woods	Univ. of Colorado, LASP

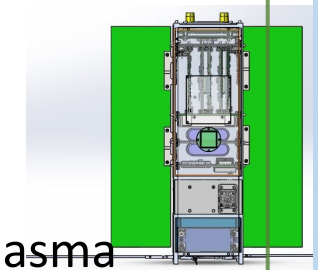
- Broader impacts: development of open-source modeling and design optimization toolkit for CubeSat swarms

Space Weather Atmospheric Reconfigurable Multiscale Experiment

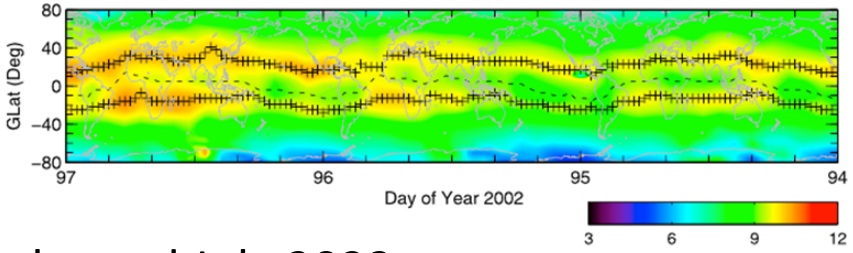
- SWARM-EX: 3x3U cubesat for multipoint collaborative in-situ measurements.







- Open science question about neutral/plasma coupling related to the equatorial ionization and thermospheric wind anomalies



- CSLI Launch planned July 2023

Key personnel & affiliation (8 faculty, 2 staff, 21 students)

Scott Palo, Jeff Thayer & Marcin Pilinski – U. Colorado Boulder
Whitney Lohmeyer – Olin College
Kristina Lemmer – Western Michigan
Glenn Lightsey – Georgia Tech
Saeed Latif – University of South Alabama
Simone D'Amico – Stanford University

Partners

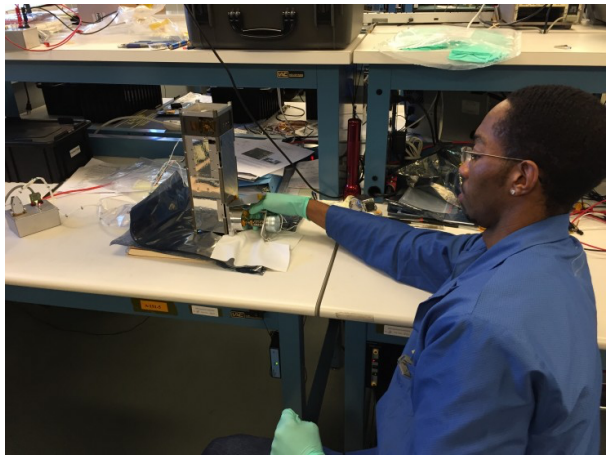
University of Stuttgart (FIPEX Instrument)
Astra LLC (Langmuir Probe)
Blue Canyon Technologies (Attitude Determination and Control)
Blue Cubed LLC (X-band CDMA Transmitter)

Broader impacts / student involvement / outreach

Integrated into project-based learning courses
Mentoring of new teams by experienced ones
Surveying and tracking student impact
Developing Slack Q&A space for new teams

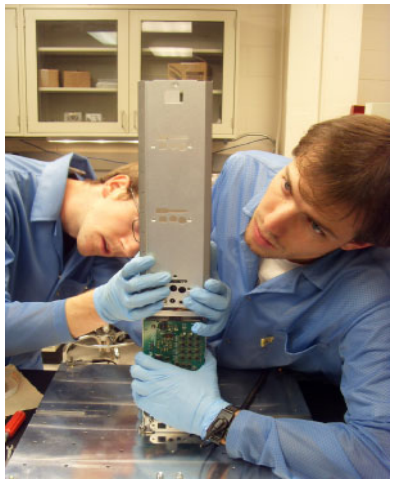
Education and Workforce Development through Cubesat Projects

- Broadens participation among underrepresented groups in STEM
- Hands-on, minds-on experience in end-to-end space mission development - students design, build and test cubesat systems *and* do science
- Develop skills and leadership in
  - ➢Problem Solving & Debugging
  - ➢Project Management
  - ➢Teamwork, collaboration
  - ➢Communication and Documentation
  - ➢Science Data Analysis
  - ➢Interdisciplinarity



Future leaders in aerospace and space science

SWARM-EX team
(photo: Olin College)



lasp.colorado.edu/home/csswe

IT-SPINS team
(photo: Montana State University)

elfin.igpp.ucla.edu

NSF was early advocate of science and engineering with smallsats, providing leadership roles for students

Will continue support, expanding utilization of smallsats into disciplines across NSF portfolio

Contact: Dr. Mangala Sharma <MSharma@nsf.gov>