AIR FORCE RESEARCH LABORATORY

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Applications of Small Satellites

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Outline

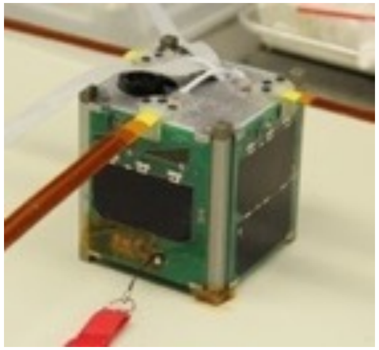
- Overview
- Small Satellite Applications for S&T
- Small Satellite Applications for Operational Use
- Small Satellite Applications for Workforce Development
- Limitation of Small Satellites
- Summary

AFRL Small Satellite Portfolio Objectives

- **Objective 1: Determine how small satellites can meet Air Force objectives (1kg-50kg)**
- **Objective 2: Workforce Development**

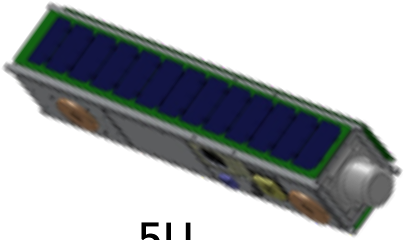
Objectives will be met through:

- researched performed at AFRL
- partnerships between AFRL and other government labs, industry, and academia
- At 2+ small satellites per year

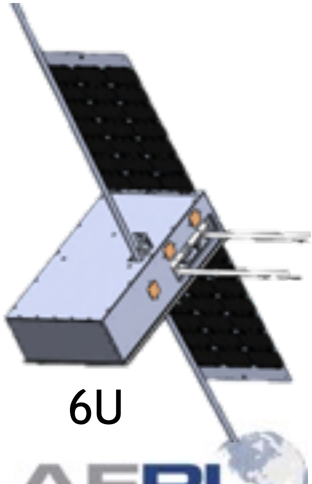


1U (10cm x 10cm)

3U



5U



6U

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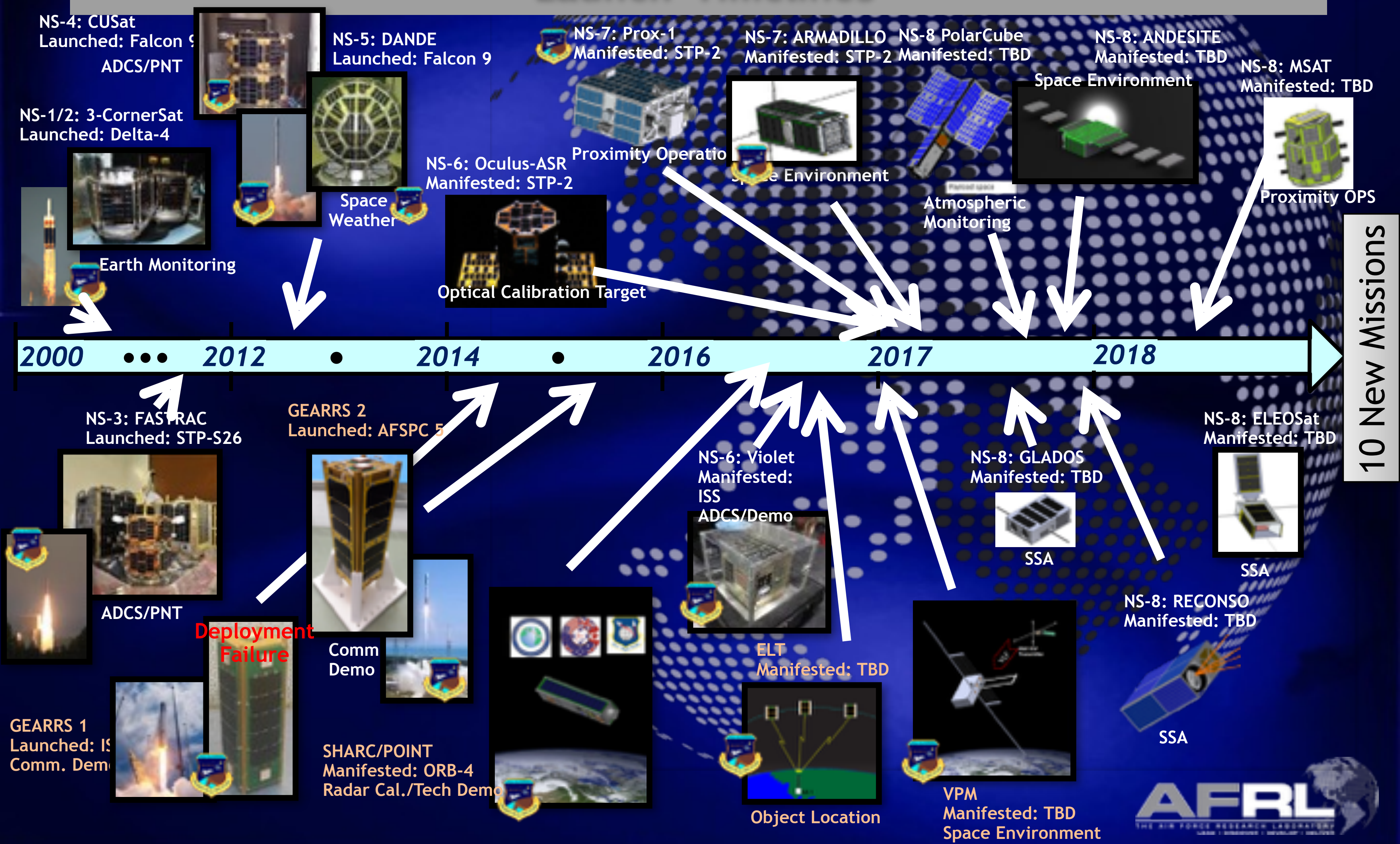
Small Satellite Portfolio

Launch Timelines



Small Satellite Applications:

Science and Technology

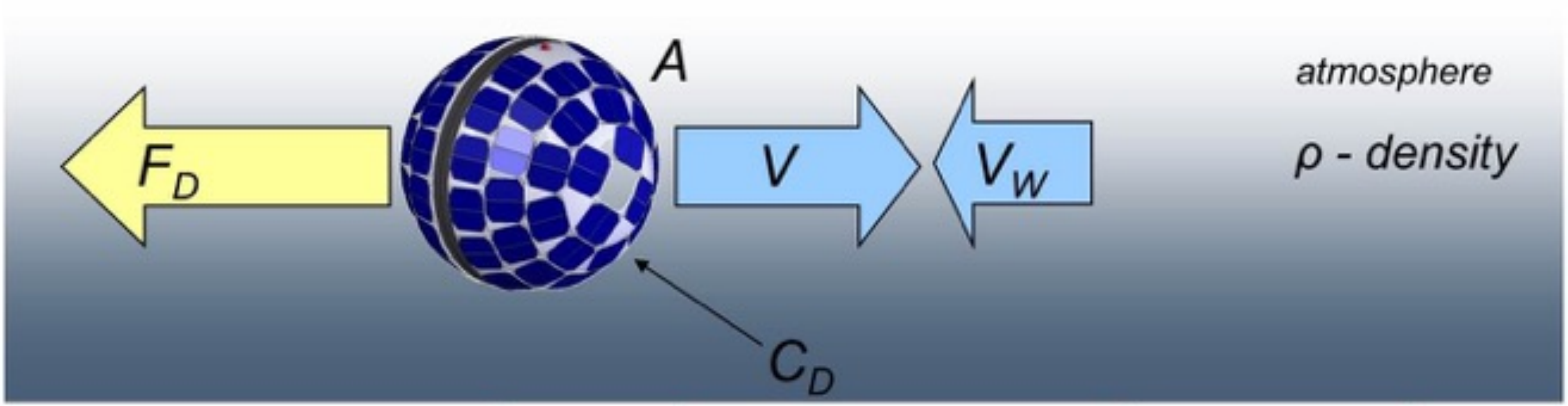
Science Investigations

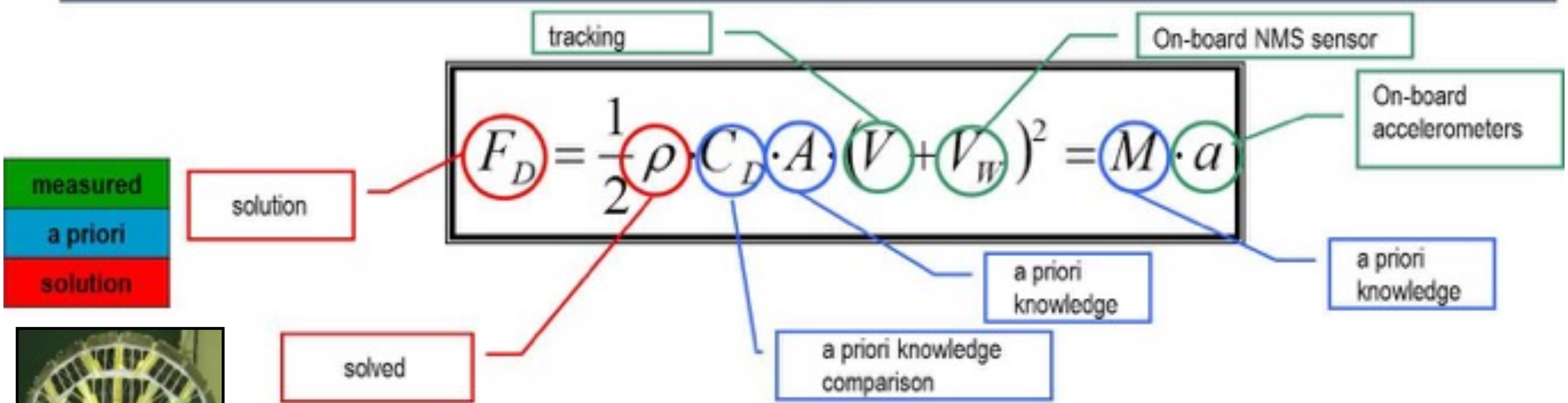
- Small satellites excel at examining a particular, well-defined, science investigation (***Case Study 1***)
- Small Satellites can meet the need for multiple, in-situ measurements (global scale) needed for many space weather models (***Case Study 2***)

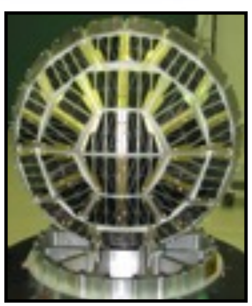
Case Study 1: DANDE	
Mission	Investigate atmospheric drag
Method	Spherical sat. with accels. and a neutral mass spectr.
Mass	43 kg

Case Study 2: VPM	
Mission	Multipoint VLF wave and particle measurements
Method	6U CubeSat with particle detector payload
Mass	8 kg
School	AFRL

Case Study 1: DANDE



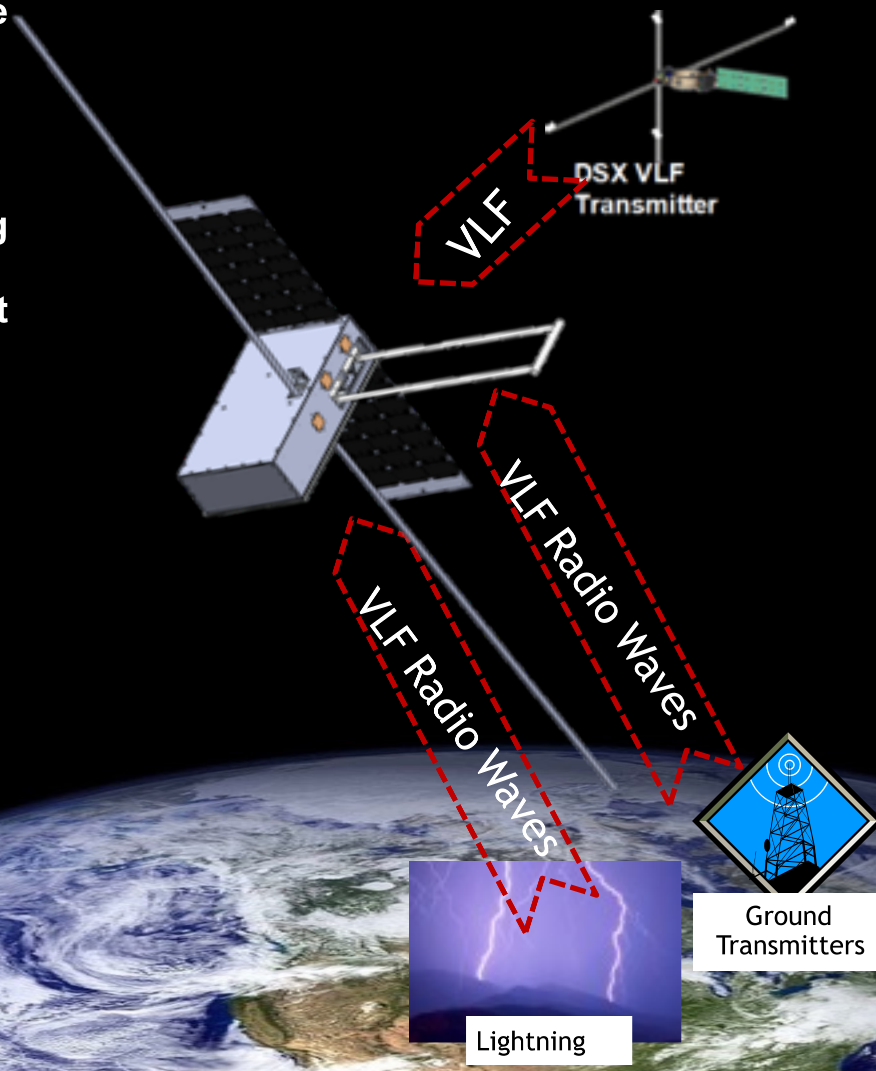




Able to investigate all aspects of the drag equation

Case Study 2: Very low frequency Particle Mapper (VPM)

- Critical augmentation for the AFRL Demonstration and Science Experiment (DSX) satellite
- Answers key DSX physics: Can we transmit VLF across the space plasma sheath into the far-field.
- Sensors to observe precipitating energetic particles induced by DSX
- Launch through DoD Space Test Program
- STATUS: 2017 Launch



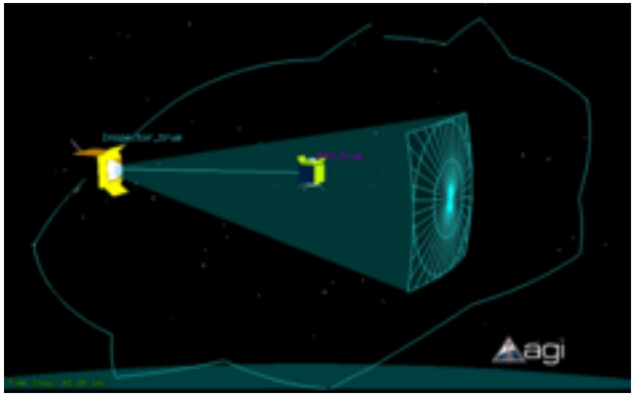
Technology Demonstrations

- Small Satellites provide a low-cost testbed for evaluating new algorithms (***Case Study 3***)
- Small Satellites provide opportunities for risk reduction of components for high value programs (***Case Study 4***)
- Small Satellites enable future missions

Case Study 3: Mr & Mrs Sat (MSAT)	
Mission	Circumnavigation of RSO
Method	Two small sats one with stereoscopic imager for prox-ops
Mass	~50 kg
School	Missouri S&T
Case Study 4: GEARRS	
Mission	Demonstrate Commercial C2
Method	3U CubeSat with Globalstar radios
Mass	3.9 kg
School	AFRL

Case Study 3: Mr. & Mrs. Sat (MSAT)

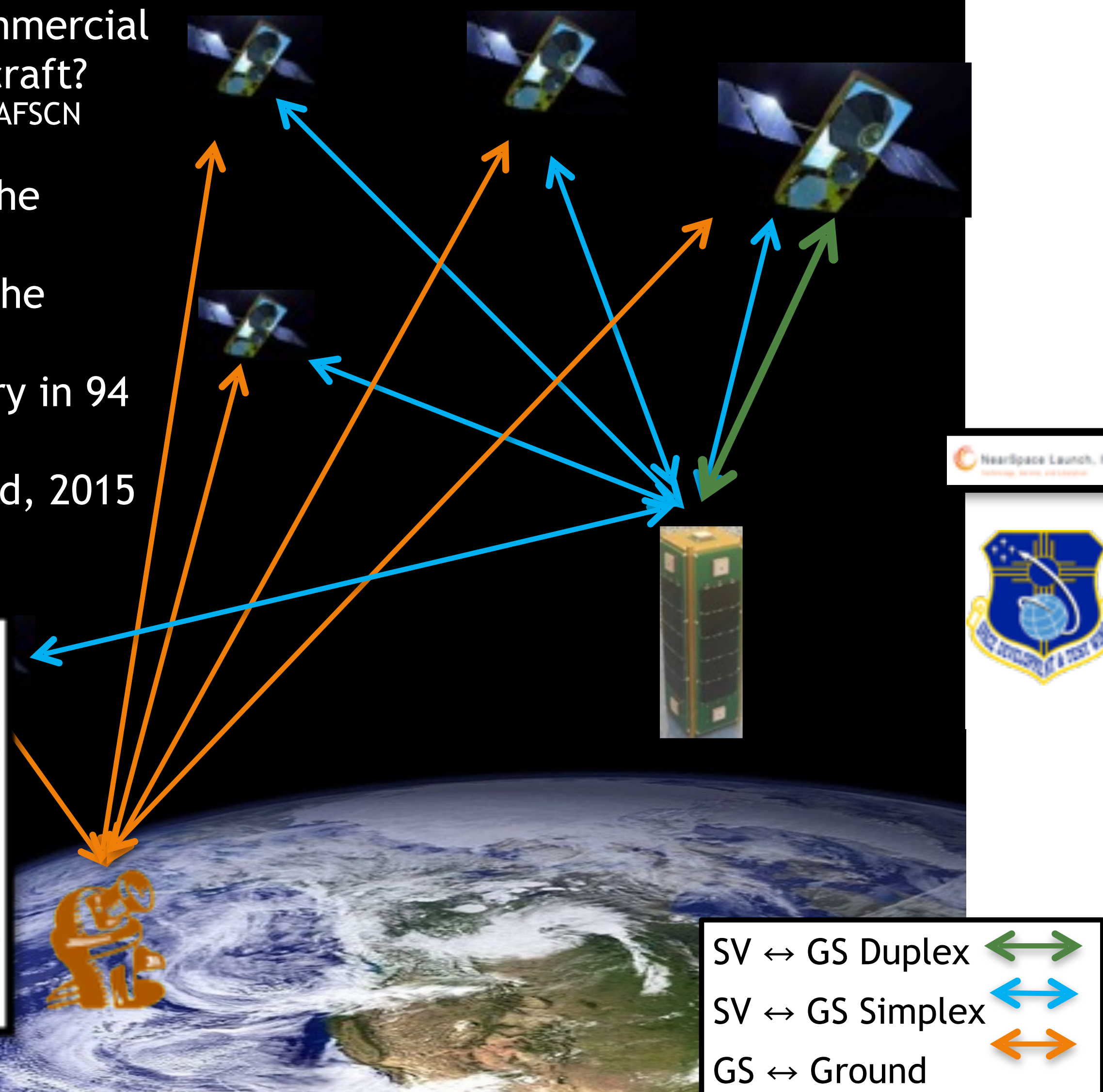
- Visual Based proximity operations to autonomously circumnavigate an RSO (Mrs. Sat)
- Investigating stereo imaging
- Investigate 3D reconstruction of objectives

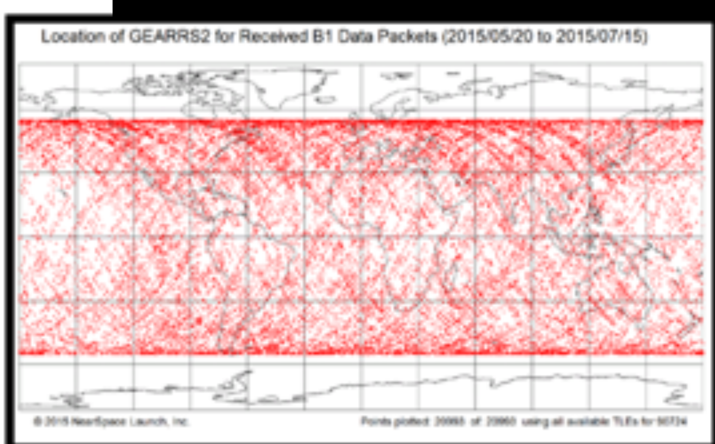


Allow research for on-orbit validation of next generation Prox-OPS

Case Study 4: Globalstar Experiment and Risk Reduction Satellite

- Challenge: Can we use commercial comm to operate AF spacecraft?
  - Potential lower cost than current AFSCN
  - 60% global coverage for duplex
- Experiment: Characterize the Globalstar network for LEO spacecraft comm for both the Duplex and Simplex radios
- Mission definition to delivery in 94 days!
- Status: Full Mission Achieved, 2015





Small Satellite Applications:
Operational Use

Operational Applications

- Small Satellites can offload some of the work from operational high value assets allowing them to be allocated to critical areas of interest (***Case Study 5***)
- Small Satellites can perform routine missions for operational customers (***Case Study 6***)

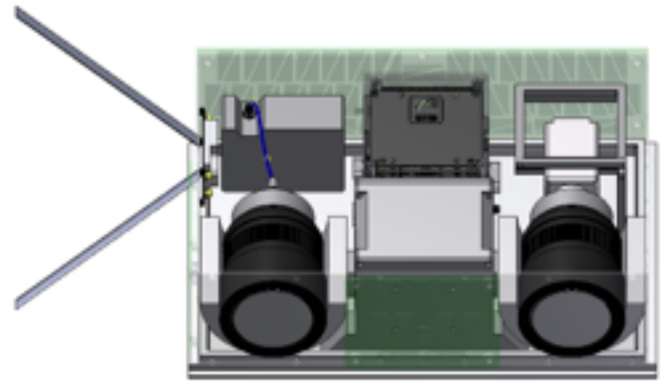
Case Study 5: GLADOS	
Mission	Investigate RSO characteristics via glint and spectroscopic analysis
Method	6U with imager and spectrometer
Mass	9 kg
School	University at Buffalo

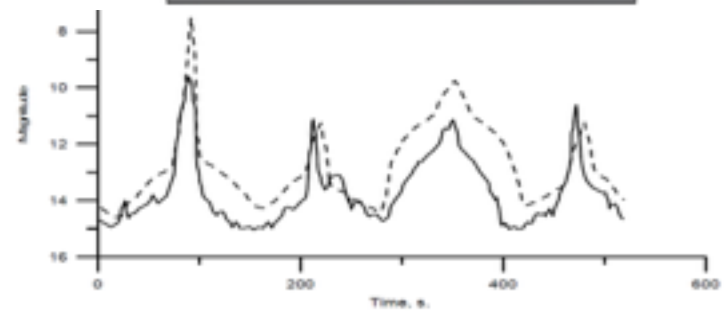
Case Study 6: SHARC	
Mission	Provide radar calibration for ground based radars
Method	5U Cubesat with transponder and GPS
Mass	5 kg
School	AFRL

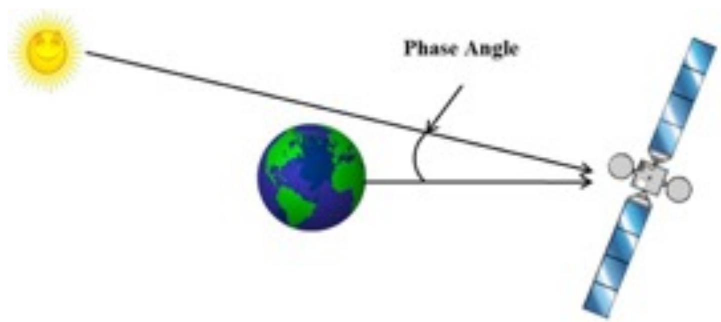
Note: Operational applications is not a goal of the University Nanosat Program or the Small Satellite Portfolio

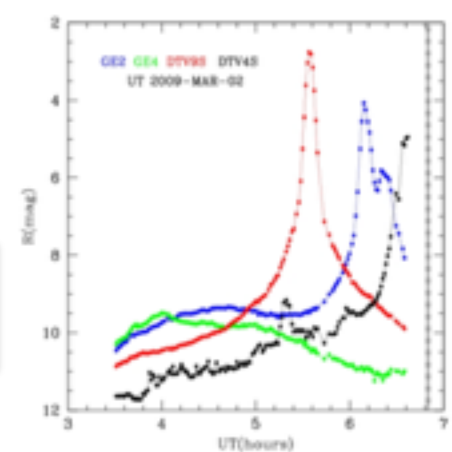
Case Study 5: GLADOS

- Operational augmentation
- Utilize multi-band photometric data of glinting space objects to identify their type, surface materials, and orientation
- GLADOS would allow for missions such as the Space Based Surveillance System (SBSS) to be dedicated to primary areas of interest







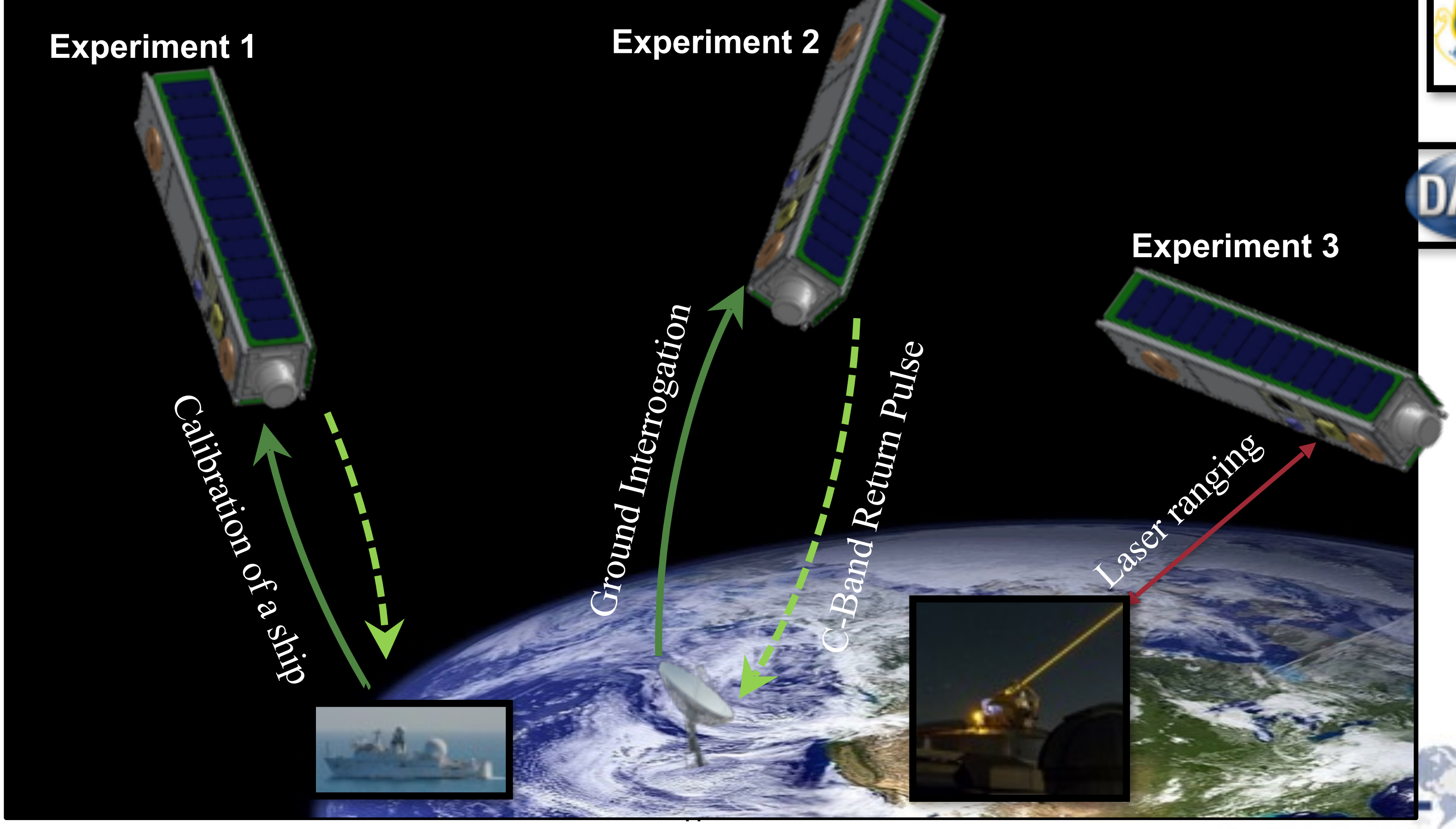


Low-cost missions such as GLADOS move us towards a persistent space based capability

Note: not actually operational

Case Study 6: Satellite for High Accuracy Radar Calibration

- **Demonstrate the capability to perform critical calibration of over 120 Tri-Service C-Band radars.**
- **Calibration is needed to meet tracking requirements of orbital objects**
- **Demonstrate low latency delivery of data (min vs days)**
- **Investigate the performance of Hypervisor on-orbit for DARPA**
- **Launch: December 2016**



Small Satellite Applications:
Workforce Development

Small Satellites and Workforce Development

- Small Satellite development efforts are a microcosm for large acquisition programs (still have BAA, hardware development, delivery, on-orbit operations)
- Small Satellites *typically* have
  - Shorter development lifetimes
  - Reduced set of requirements
  - Shorter lifetimes
- They provide an excellent opportunity for understanding the interrelated nature of requirements and how to trade them at the system level
- Programs are excellent for junior workforce development (both at the University level and the professional level)

The University Nanosatellite Program

- **University Nanosat Program**
  - Multi-year program to design, build, and fly a small satellite
  - Program has been around for 15 years
  - UNP provides an extremely high fidelity concept study to military relevant missions
  - Over 32 small satellite (50kg and down) missions have been investigated through the program
- **Roles and Responsibilities**
  - AFOSR: Funds $55k per year up to four years
  - AFRL Space Vehicles:
    - Executes program (regular design reviews with each school)
    - Performs Environmental Stress Screening
    - Works with the Space Test Program for launch integration
  - SMC/Space Test Program: Launch

Primary Objective: Education
- Systems engineering training
- Workforce development
- Foundation for all UNP decisions

Secondary Objective: Technology
- Innovative, low cost technology development
- Motivation for Gov. and industry sponsors
- DoD relevant

Tertiary Objective: University Development
- Develop space hardware laboratories
- Support university PI's

Federally Recognized
Supporting National STEM initiatives

THE FEDERAL SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) EDUCATION PORTFOLIO

A Report from the
Federal Inventory of STEM Education Fast-Track Action Committee
Committee on STEM Education
National Science and Technology Council

DECEMBER 2011

Obj 1 • **Learning:** Develop STEM skills, practices, or knowledge of students or the public.

Obj 1 • **Engagement:** Increase learners' interest in STEM, perception of its value to their lives, and/or their ability to participate in STEM.

• **Pre- and In-Service Educator/Education-Leader Performance:** Train or retain STEM educators (K-12 pre-service or in-service, postsecondary, and informal) and education leaders to improve their content knowledge and pedagogical skills.

Obj 1 • **Postsecondary STEM Degrees:** Increase the number of students who enroll in STEM majors, complete STEM credentials or degree programs, or are prepared to enter STEM careers or advanced education.

Obj 1 • **STEM Careers:** Prepare people to enter STEM workforce with training or certification (where STEM discipline specific knowledge and skills are the primary focus of the education investment; STEM educator training and development investments should select the Pre-and In-Service Educator/Education Leader Performance objective listed above).

Obj 2 • **Institutional Capacity:** Support advancement and development of STEM personnel, programs, and infrastructure in educational institutions such as universities, informal education institutions, state education agencies, and local education agencies.

• **STEM System Reform:** Improve STEM education through a focus on education system reform.

UNP • **Education Research and Development:** Develop evidence-based STEM education models and practices.

								Performance	
	Commerce	Total	59.20	65.06	72.79				
0128	Defense	University Nanosatellite Program	1.50	1.60	1.60	-	Agency Mission Workforce	Learning	No
0134	Defense	Awards to Stimulate and Support Undergraduate Research Experiences	4.50	4.50	4.50	-	Agency Mission Workforce	Post-Secondary STEM Degrees	No
0130	Defense	National Defense Education Program Science, Mathematics And Research for Transformation	19.00	33.00	47.00	-	Agency Mission Workforce	Post-Secondary STEM Degrees	No
0133	Defense	National Defense Science and Engineering Graduate Fellowship Program	33.09	36.34	36.81	-	Agency Mission Workforce	Post-Secondary STEM Degrees	No

UNP is recognized as a STEM program in the President's STEM educational portfolio

Small Satellite:
Limitations

Common Poor Approaches to Small Satellite Missions

- People attempt to cram a 500kg mission into a 50kg bus
  - Small satellite missions must be well scoped for the capability of the platform
- People assume just because it's small it's easy
  - Small satellites (especially Cubesats) are highly integrated systems
  - There are many interdependencies between systems
- People attempt to leverage big space approaches to small satellites
  - Small Satellites allow for new paradigms for acquisition, on-orbit operations and mission assurance

Conclusion

- Small Satellites can play a big part in meeting the needs of the Air Force S&T efforts

- Small Satellites can play a large role in helping to train the workforce to better manage large acquisition programs
  - We need individuals who are passionate about what they do
  - Universities are the perfect place to experiment with high-risk, novel missions
  - Universities have the freedom to approach problems in an untraditional way enabling new science, and new programmatic paradigms

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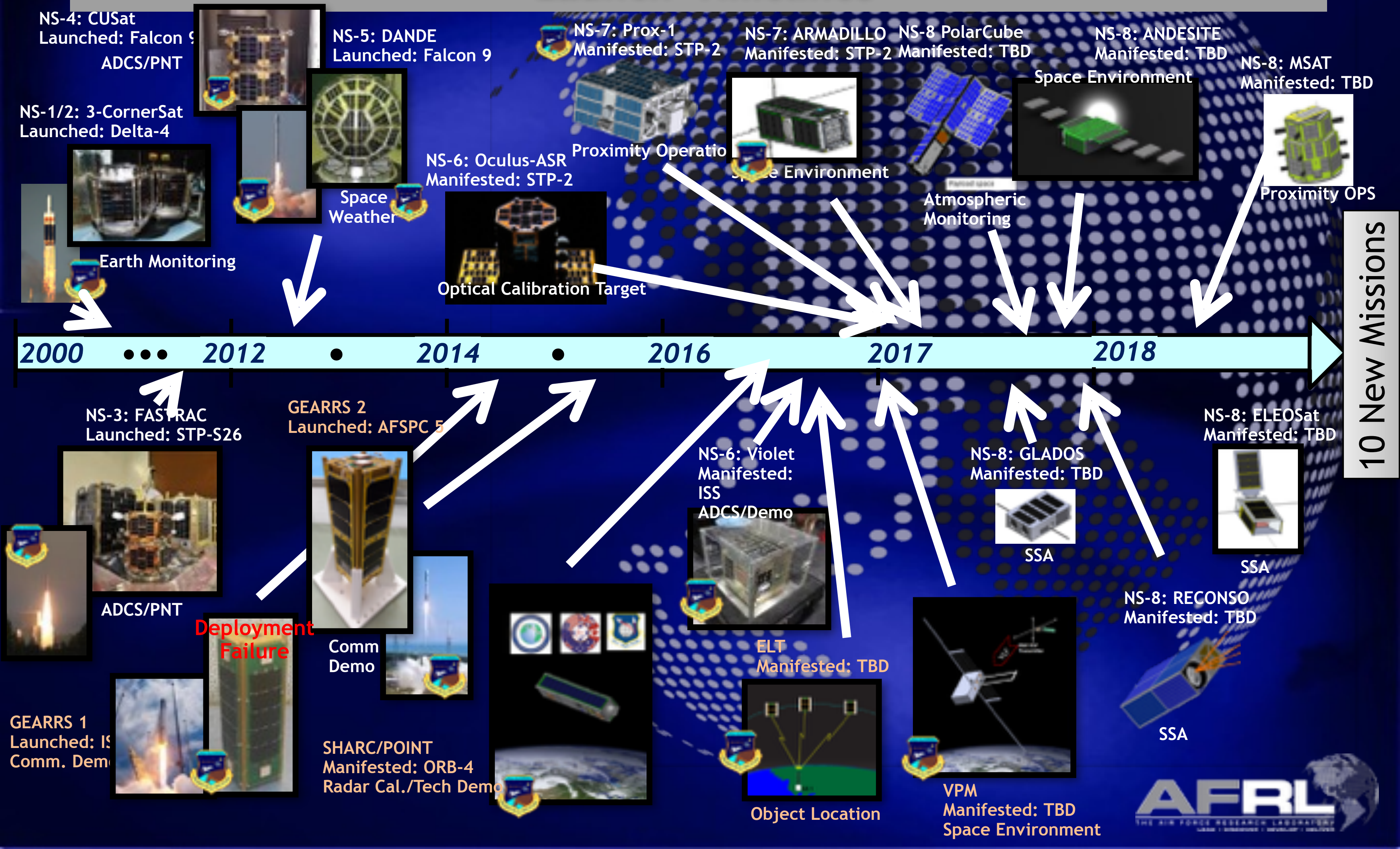
Small Satellite Portfolio

Launch Timelines



Small Satellite:
Back Ups

Technology Demonstrations

- Small Satellites provide a low-cost testbed for evaluating new algorithms (***Case Study 3***)
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- Small Satellites enable future missions (***Case Study 5***)

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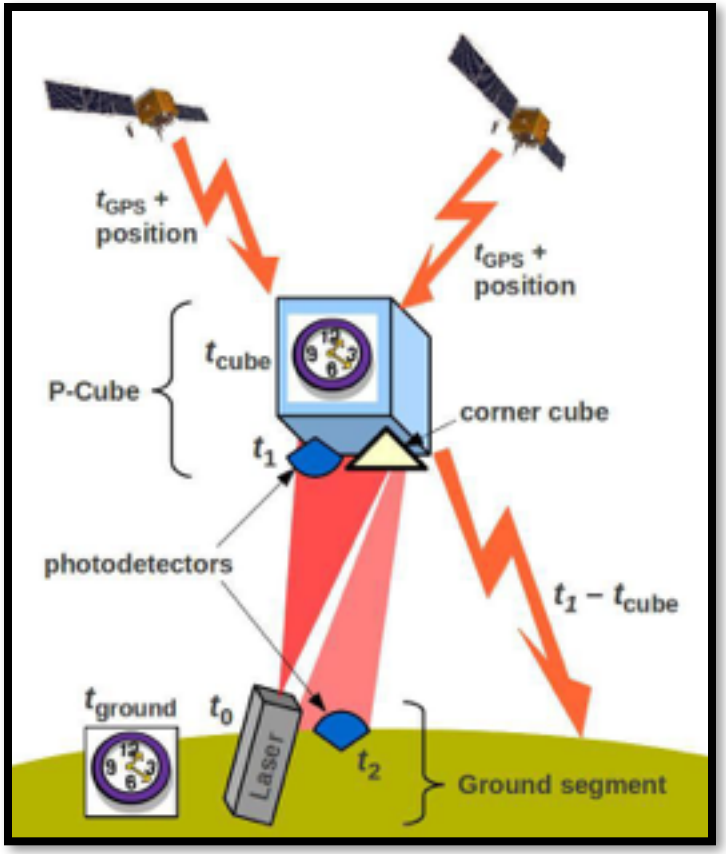
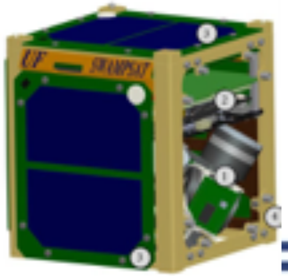
Mass	~50 kg
School	Missouri S&T
Case Study 4: GEARRS	
Mission	Demonstrate Commercial C2
Method	3U CubeSat with Globalstar radios
Mass	3.9 kg
School	AFRL
Case Study 5: P-Cube	
Mission	Demonstrate Precision Timing between ground and CubeSats
Method	1U flying atomic clock, corner cube
Mass	2 kg
School	University of Florida

Case Study 5: P-Cube

- Precision Time Transfer with CubeSats
- Enable high accuracy timing between CubeSats and the ground
- Flying Symmetricom's Chip Scale Atomic Clock
- Use laser pulses and a corner cube to determine timing difference between the CubeSat and the ground (frequency stability on the order of ~1.5×10^{-10})
- Formerly developed by the University of Florida in the NS-8 competition



Enabling technology for disaggregated architectures



Limitations of Small Satellites

- Power
  - Limitation: Typically are sub-50W with many missions sub-10W
  - Workaround: Duty Cycle payloads
- Communications
  - Limitation: Typically low baud rate communication systems
  - Workaround: Creative CONOPS or large dish on the ground
- Multiple measurements
  - Limitation: Due to the low power, reduced volume this restricts the number of payloads a small satellite can fly
  - Workaround: Reduced size of payloads where appropriate
- Environments
  - Limitation: Very rough random vibration environments which we typically do not know at the outset of the program
  - Approach: Use GEVS model and over design (where appropriate)

Workforce Development Needs

- **U.S. Space Policy (NSPD 49):** "… implement activities to *develop* and maintain highly skilled, experienced, and motivated space professionals within their workforce."

- **Rising above the Gathering Storm, Revisited (2010)**: "In 2000 the number of foreign students studying the physical sciences and engineering in United States graduate schools for the first time surpassed the number of United States students."

- **Preparing the next generation of STEM Innovators (NSF, 2010)**: "The identification and development of our Nation's human capital are vital to creating new jobs, improving our quality of life, and maintaining our position as a global leader in S&T."

Conclusion

- Small Satellites can play a big part in meeting the needs of the Air Force S&T efforts
- The technology is currently available for tackling many of the space challenges
- Small Satellites can play a large role in helping to train the workforce to better manage large acquisition programs
- We need individuals who are passionate about what they do
- Universities are the perfect place to experiment with high-risk, novel missions
- Universities have the freedom to approach problems in an untraditional way enabling new science, and new programmatic paradigms