The Scientific Promise of Small Satellite Missions:
Mindset change and research utilization of CubeSats

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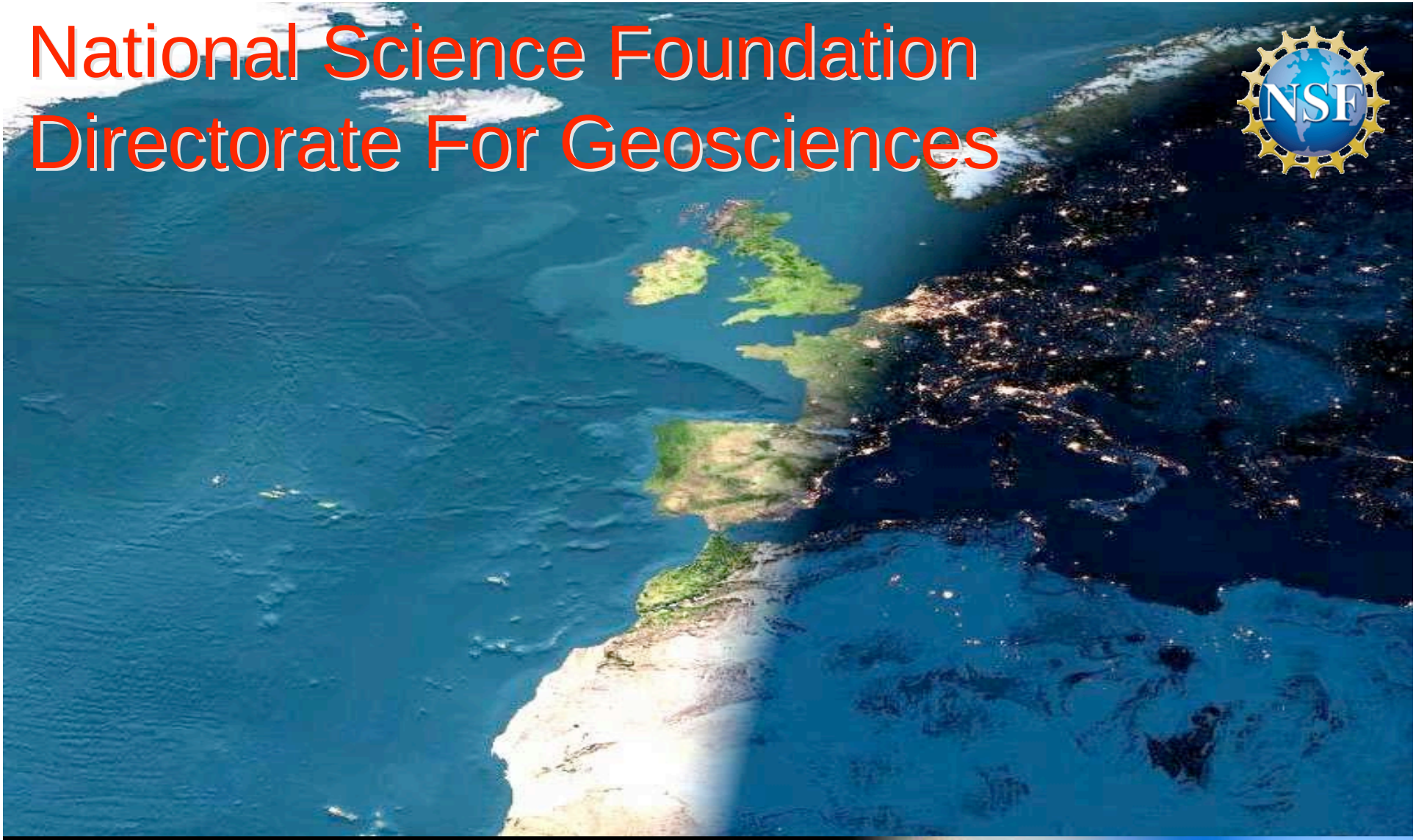
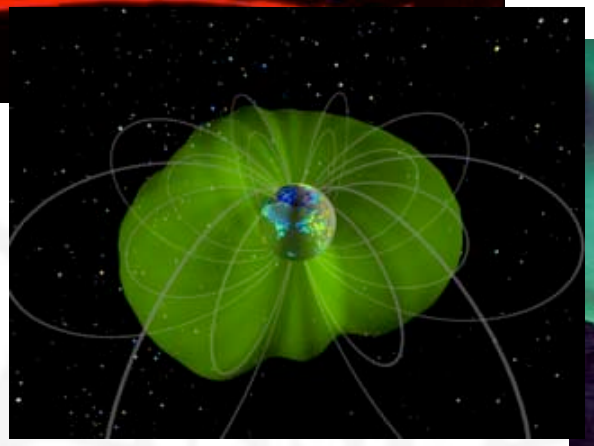


Advancing scientific knowledge of
Earth's environment

Geo

Space Physics at NSF

- Division of Atmospheric and Geospace Sciences
  - Solar Physics
  - Magnetospheric Physics
  - Aeronomy
  - Upper Atmospheric Facilities
  - Space Weather
  - CubeSat program



Why are we doing it: science

- We need space based measurements
- Low-cost, focused small satellite missions can help provide these
- Doing things in new ways will spur innovation, creativity and technology development

Why are we doing it: Education

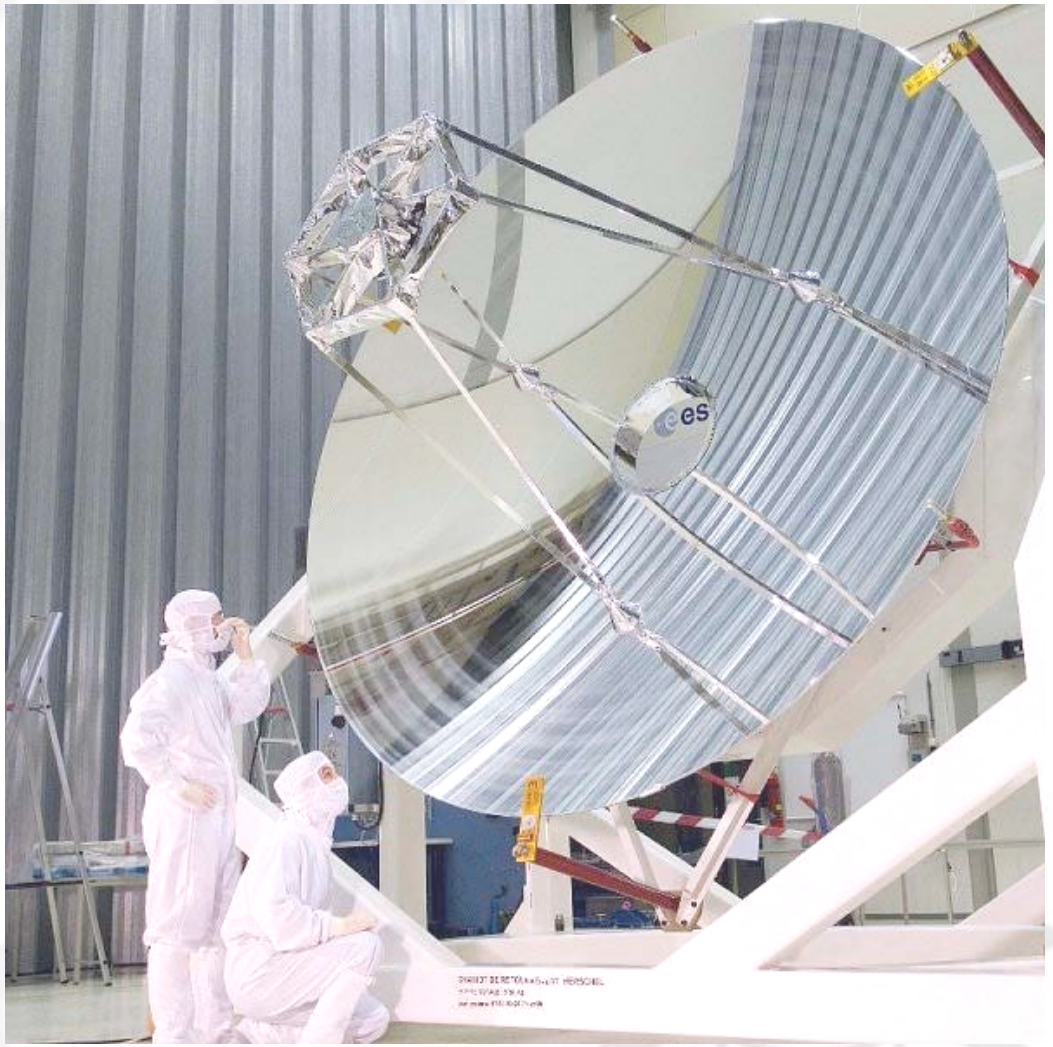
- We need space based experimental opportunities to train the next generation of space scientists and engineers
- Small satellite missions offer end-to-end participation for students; full mission experience
- Will help spur new excitement for space science

The need for observations

- Explore and explain phenomenon
  - New discoveries are still being made
- Initiate, constrain, and validate models
  - Data assimilation
- Data sparseness
  - Remote sensing
  - Networks or constellations

Small Satellites: Obvious Limitations

- Physical size (optics; booms; antennas)
- Power, data rate downlink
- Pointing, maneuvering
- Limited control of orbits



Small Satellite Trade-offs

- Large missions:
  - Single satellites
  - Comprehensive measurements
  - Long lead-times
- Small missions:
  - Multi-point simple measurements
  - Fast turn-around
  - Narrowly focused science investigations
  - Try out new experimental approaches

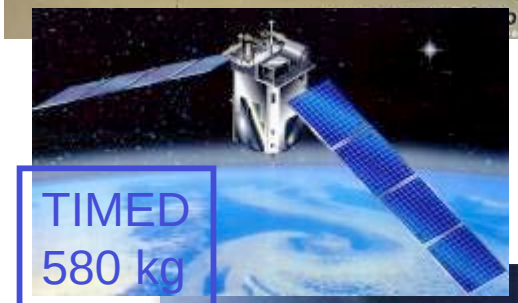
Small Satellites: What can they contribute?

- Fill-in gaps in coverage
  - geographic, local time, sky-view, long-time monitoring
- Small-scale structure
  - Multi-point measurements to avoid space-time aliasing
- Interferometry & Tomography
  - Satellite constellations
- New measurements
  - Technology experiments

Satellite Sizes

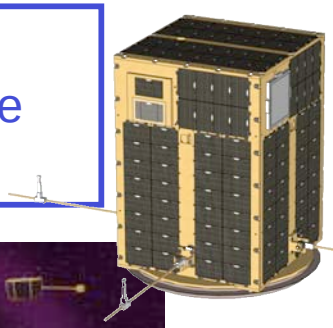
Class	Mass(kg)	Cost($M)	Time(y)
Large-satellite	2,000+	1,000	10+
Small-satellite	750	100	2-3
Mini-satellite	250	75	2
Micro-satellite	100	50	1-2
Nano-satellite	1-10	1-5	1
Pico-satellite	<1	<500	<1

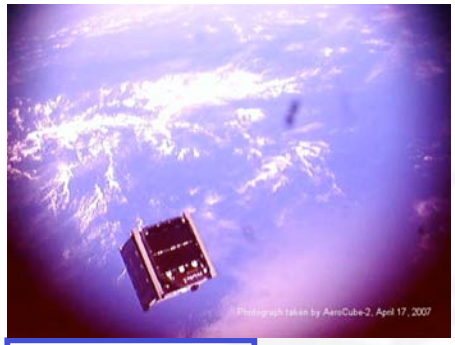
NOAA-N
1400 kg



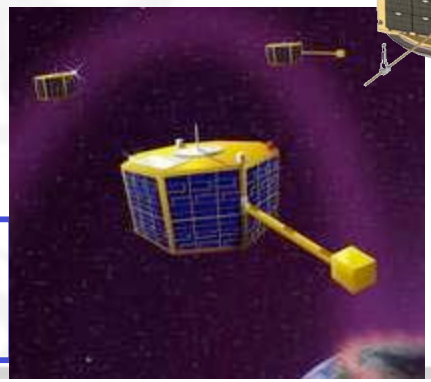
TIMED
580 kg

University
Nanosatellite
25 kg





Cubesats
1 - 3 kg



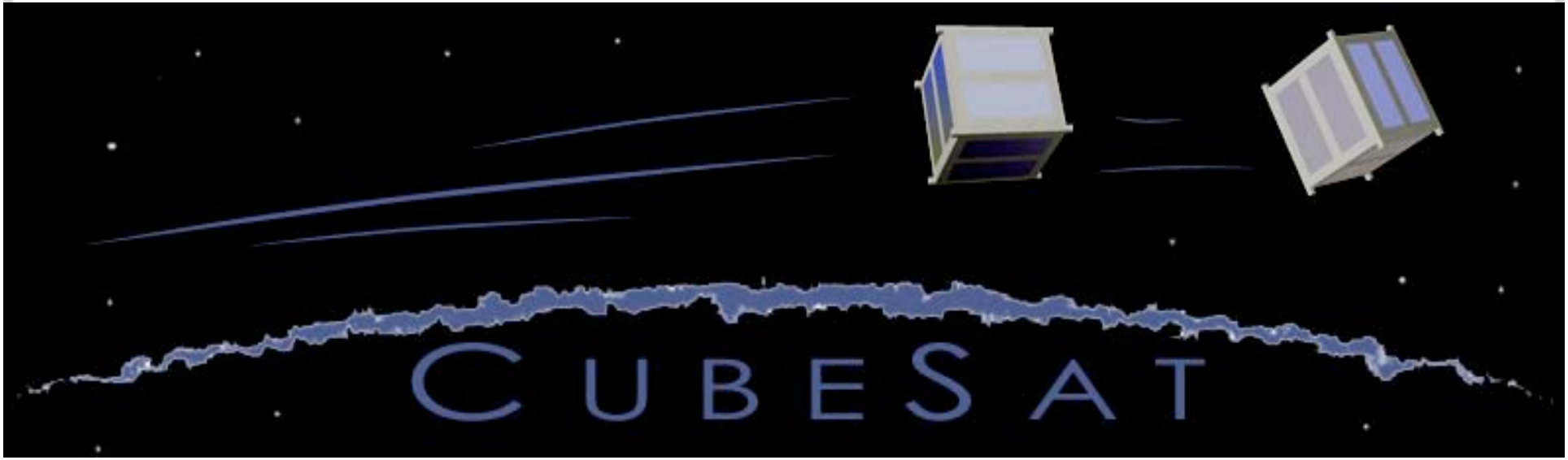
ST5
25 kg

SSTL MicroSat-70
70 kg

AIM
210 kg

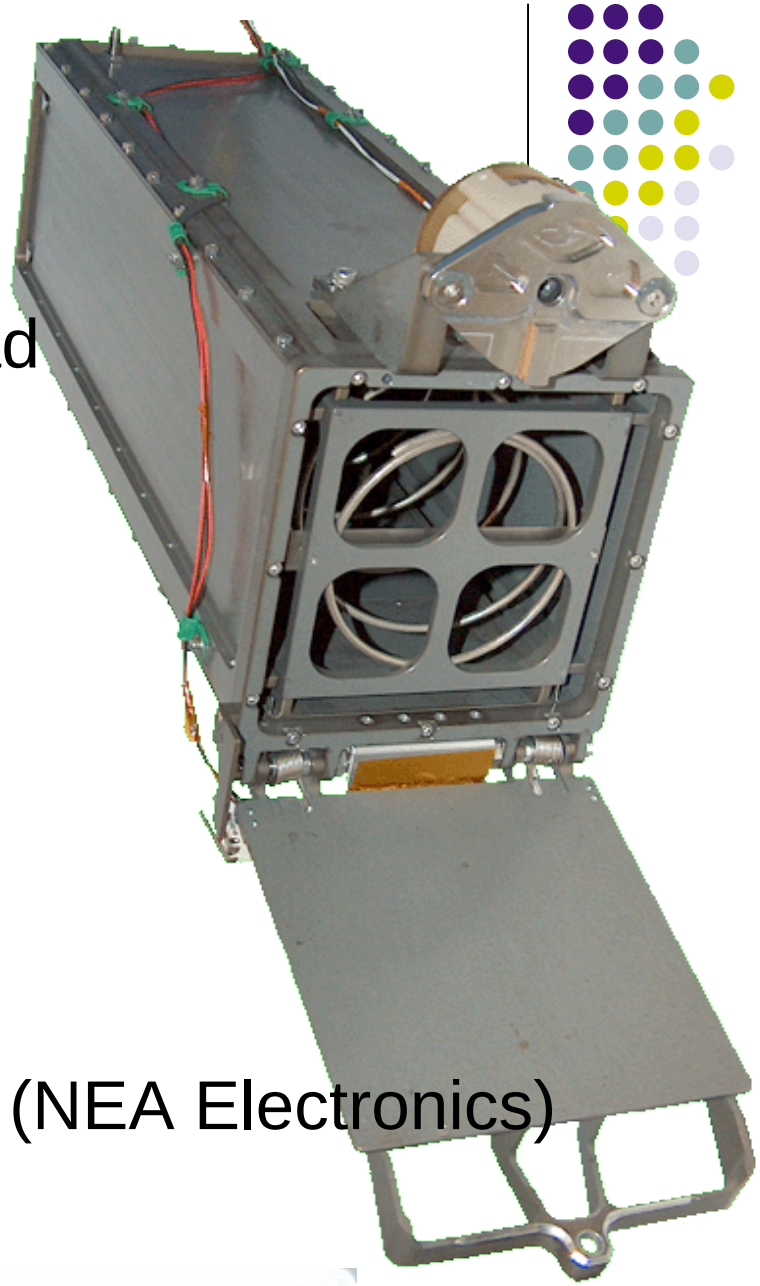
What is a CubeSat?

- A pico-satellite Standard
  - 1999 by Puig-Suari, CalPoly and Twiggs, Stanford
- Drivers
  - Simple but safe
  - Available COTs components
  - P-POD deployer system

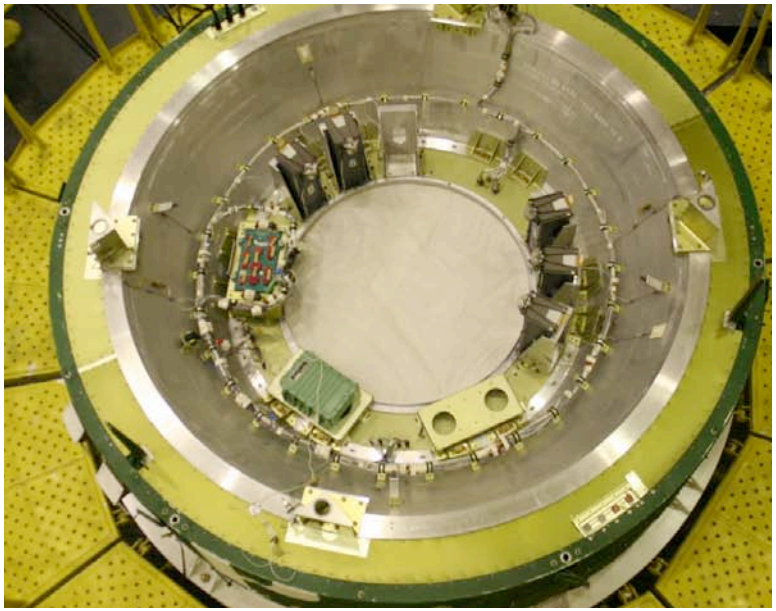


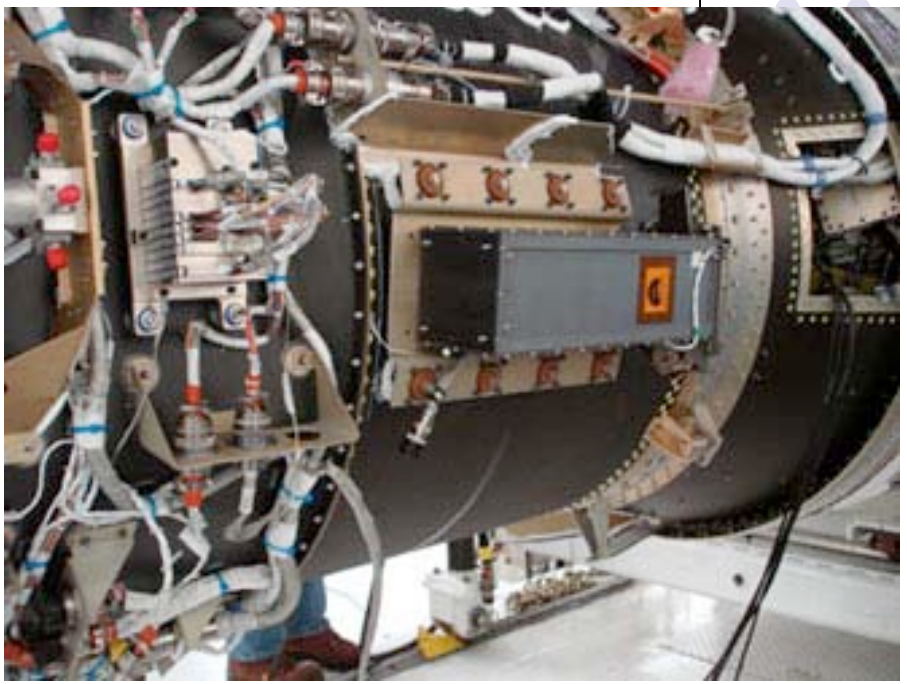
The P-POD

- Mission Objectives
  - Protect LV and primary payload
  - Safe/reliable deployment
  - Compatibility with many LV
  - Simplicity
- Payload: 3 Single CubeSats
- Main Features
  - Tubular Frame
  - Spring Assisted Ejection
  - Standard Deployment System (NEA Electronics)
  - Deployment Detection Switch



P-POD Flight Heritage





- Rockot 2003
- Dnepr 2006 (Launch Failure) & 2007
- Minotaur 1 2006 & 2009
- Falcon 1 2008 (Failure) & 2009?
- Minotaur 4 2010

Some CubeSat Facts

- Over 100 Developers Worldwide
  - Including Government, Industry & Academia
- 28 CubeSats in LEO (44 Launched)
- Dedicated Workshops/Meetings
- CubeSat Industrial Suppliers

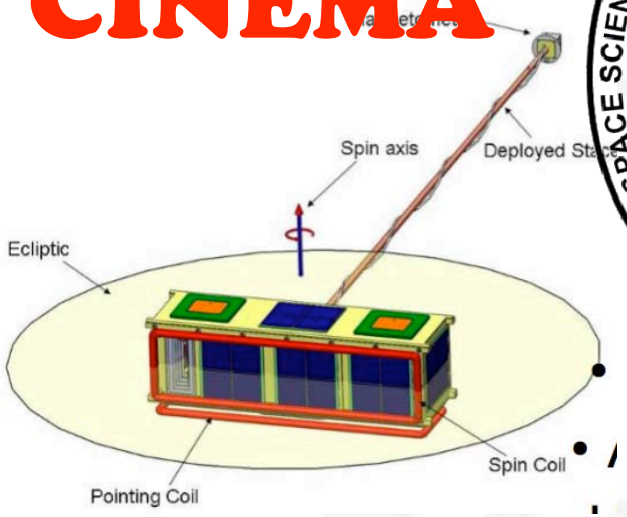
Cube-sat based science missions: A new NSF program

- Space weather & atmospheric research and education
- 2-3 new science missions/ year
- Utilize CubeSat and P-POD technology development
- Collaboration with NASA WFF on comisioning and launch services
- Collaborate with DOD, NASA, Industry on launch opportunities
- Five projects so far

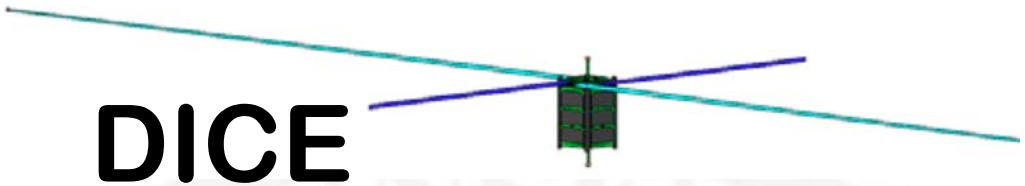
Photograph taken by AeroCube-2, April 17, 2007

Current NSF CubeSat Projects

CINEMA



DICE



FIREFLY

NATIONAL SCIENCE FOUNDATION · SIENA COLLEGE · NASA/GSFC · USRA · HAWK INSTITUTE FOR SPACE SCIENCES

RAX

Radio Aurora Explorer

FIREBIRD

THE AEROSPACE CORPORATION

MONTANA STATE UNIVERSITY

BOSTON UNIVERSITY

Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics

Message from one of the CubeSat fathers:

CubeSat's limitation is **mindset** not resources

- Need change in approach to scientific satellites that is compatible with CubeSat
- Limited Options + Limited Resources + Significant need = High Risk Unconventional Solutions

"Guerrilla Space"

Great science with limited resources is not new

Patent Office Clerk
Albert Einstein