



Small Satellites for Space Weather: ION-F & TOROID

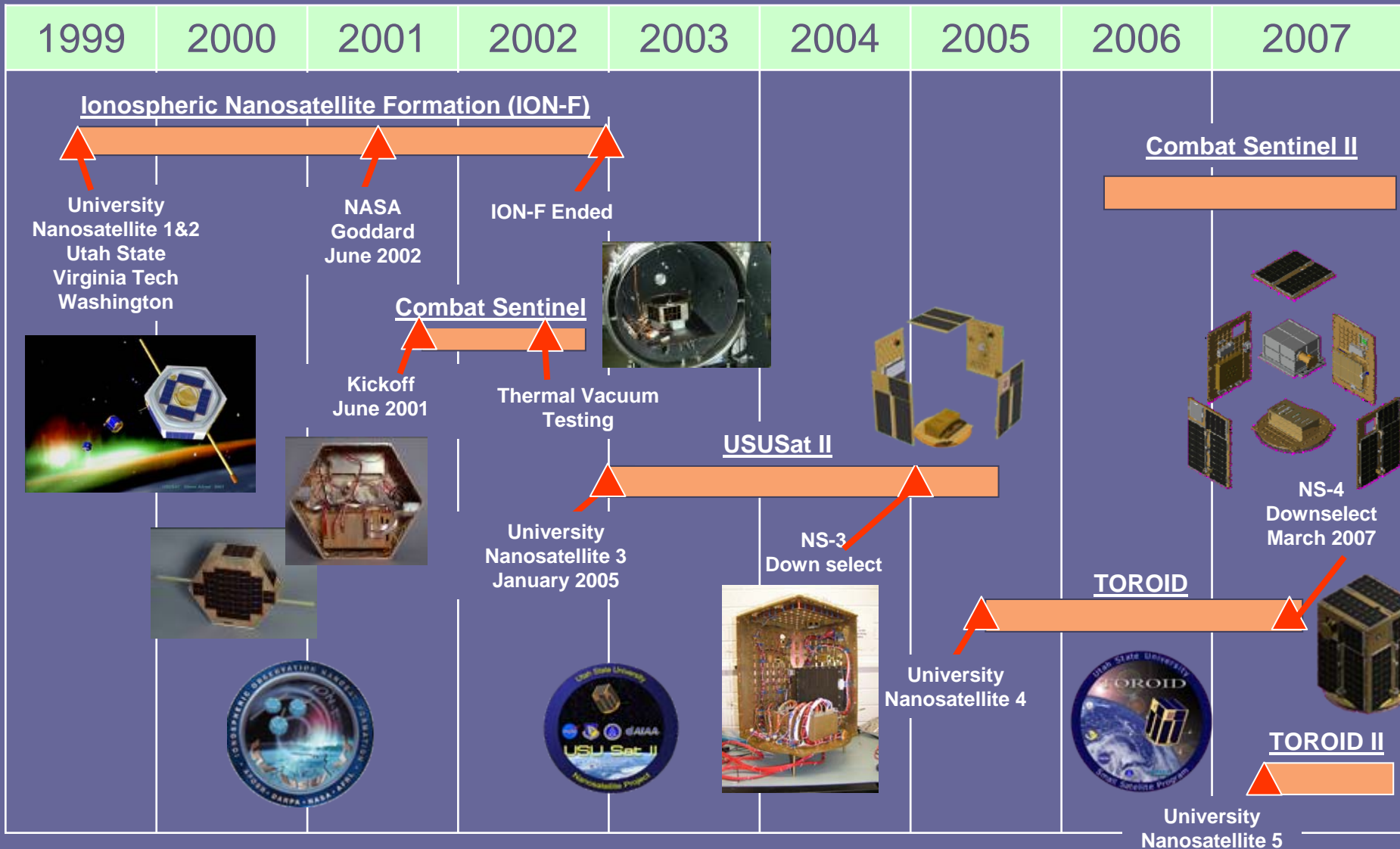
CEDAR 2007 – Small Sat Workshop

Charles M. Swenson, Chad Fish, Aroh Barjatya

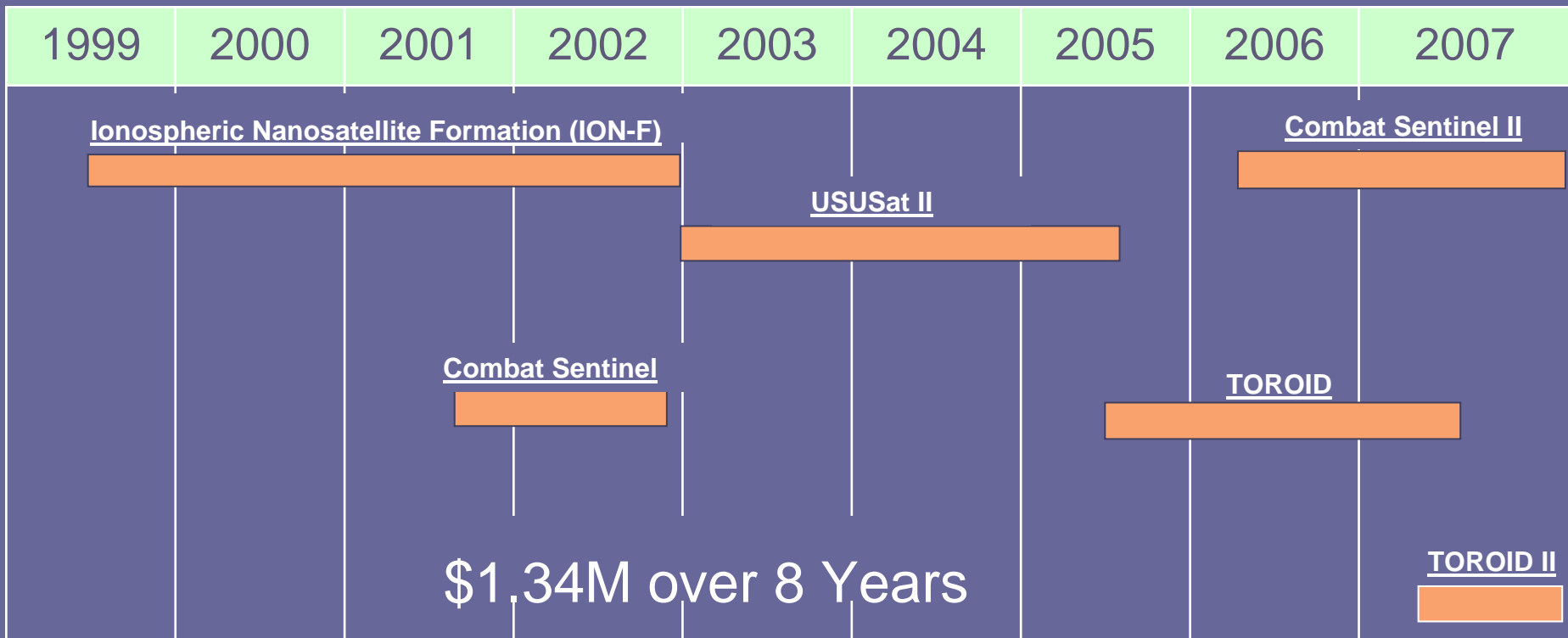
UtahState
UNIVERSITY



USU Nanosatellite (USUSAT) Lifetime Overview



USUSAT Funding & Educational Impact



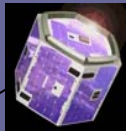
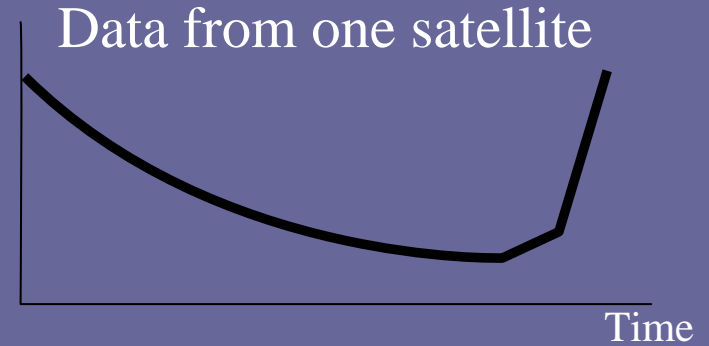
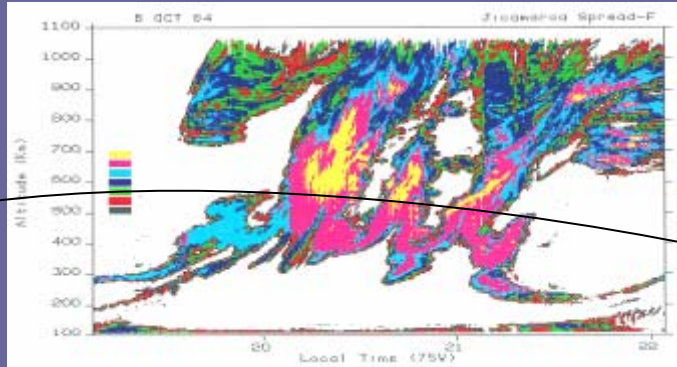
- Student Involvement

- 154 Core team members
- 70 Extra
- <http://ususat.usu.edu/>

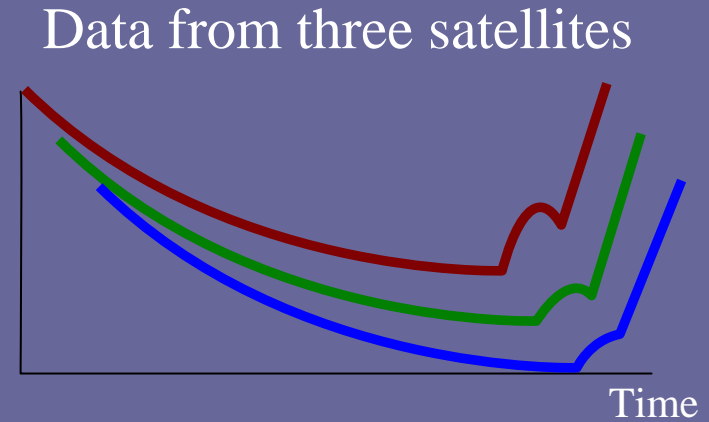
- Research

- 2 PhD Dissertations
- 35 MS Thesis
- 27 ME Projects
- 45 Senior Projects

ION-F Space Science Mission [*Past*]



Spacing varies from 200 m to 200 km along same orbital track

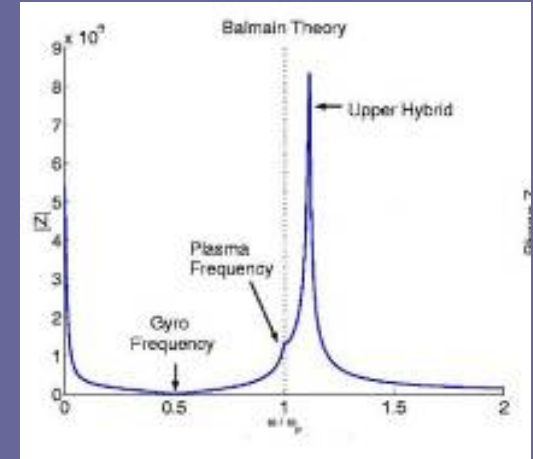
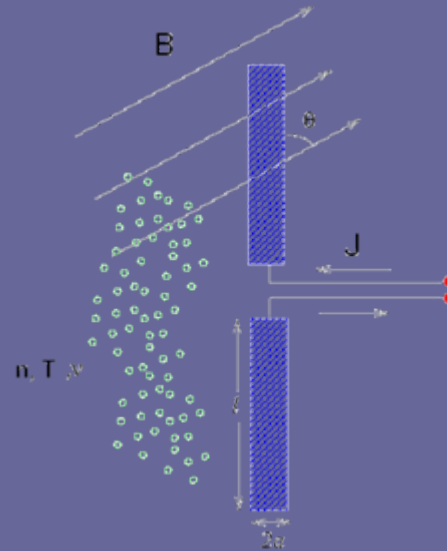


Principal Diagnostics:

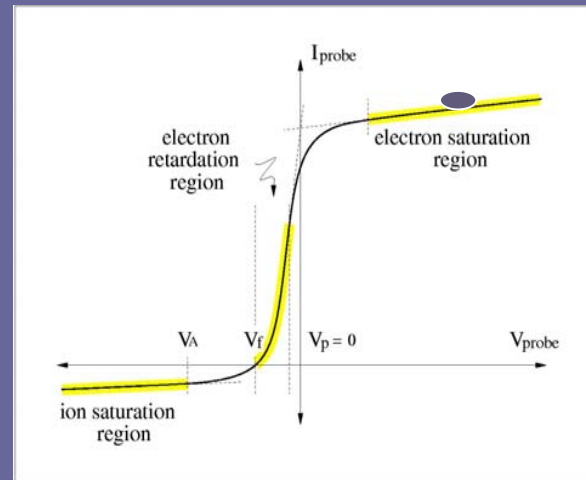
- Electron Density - 200 m/sample
- GPS Scintillation - 7.5 km/sample

ION-F Science Sensor Instrumentation

- A sweeping impedance probe (PIP) to have measured absolute ionospheric plasma density



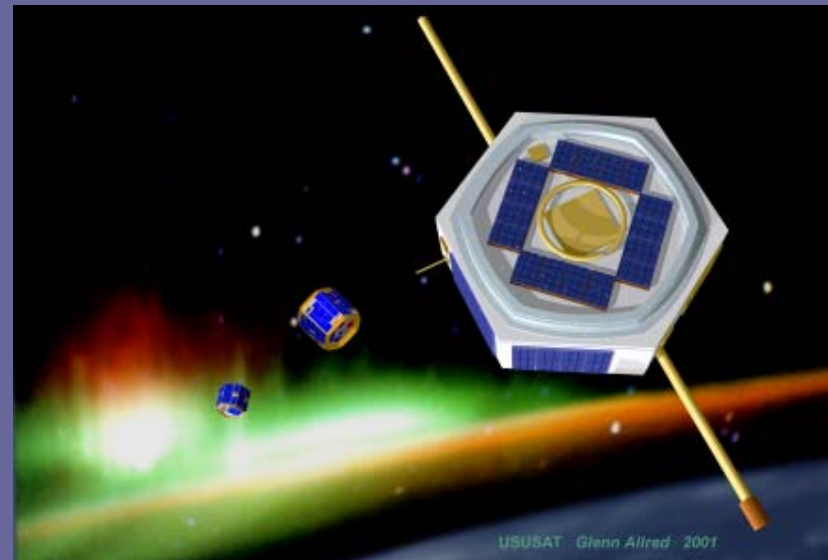
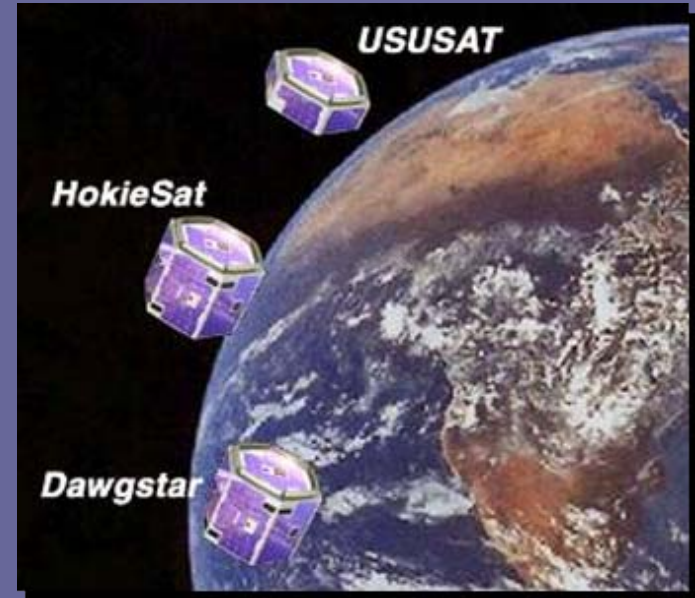
- A fixed voltage Langmuir probe (DCP) to have measured local relative plasma density



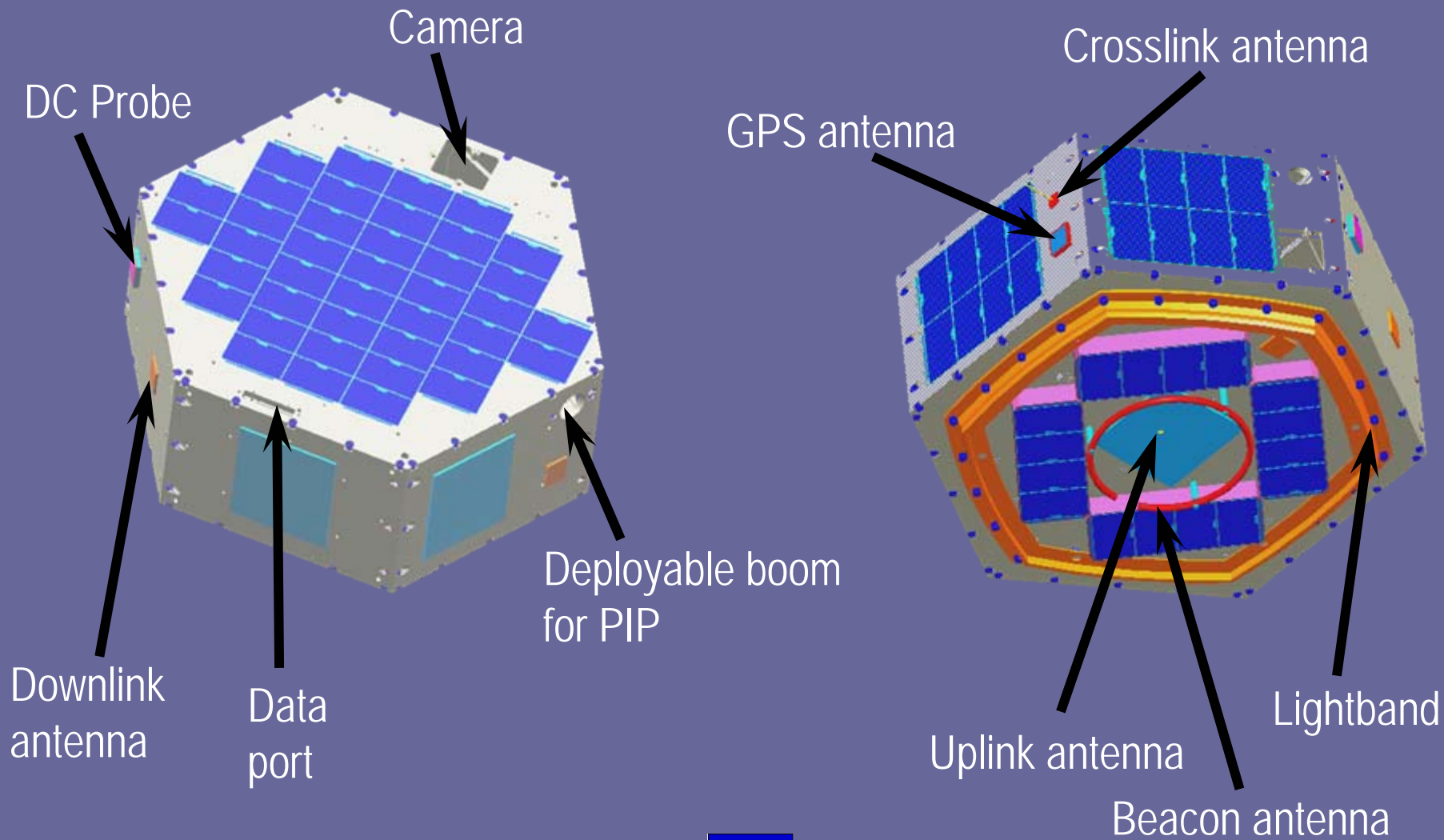
- GPS receiver

ION-F Formation Flying Demonstration

- Phase I (first two months)
 - 22 m/sec ΔV required
 - “String of beads” leader-follower formation
 - 200 m -200 km separation
- Phase II (second two months)
 - 45 m/sec ΔV required
 - Orbit maintenance to extend satellite lifetime
 - 500-5000 km separation

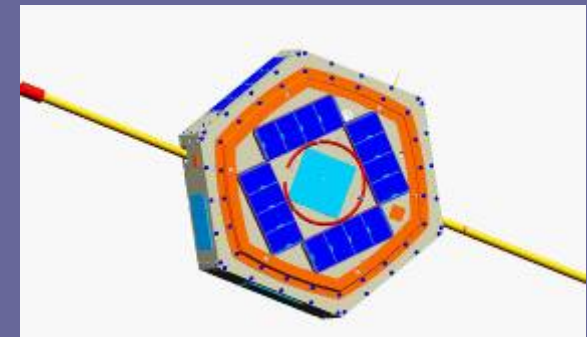
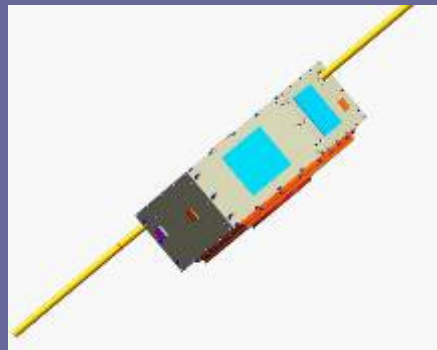
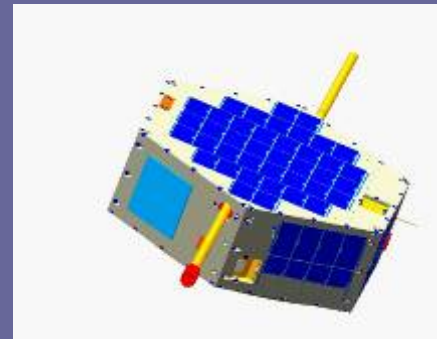
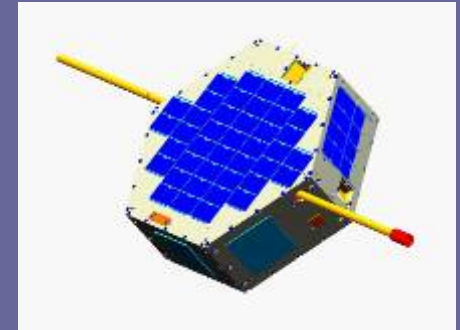


ION-F USUSAT Design

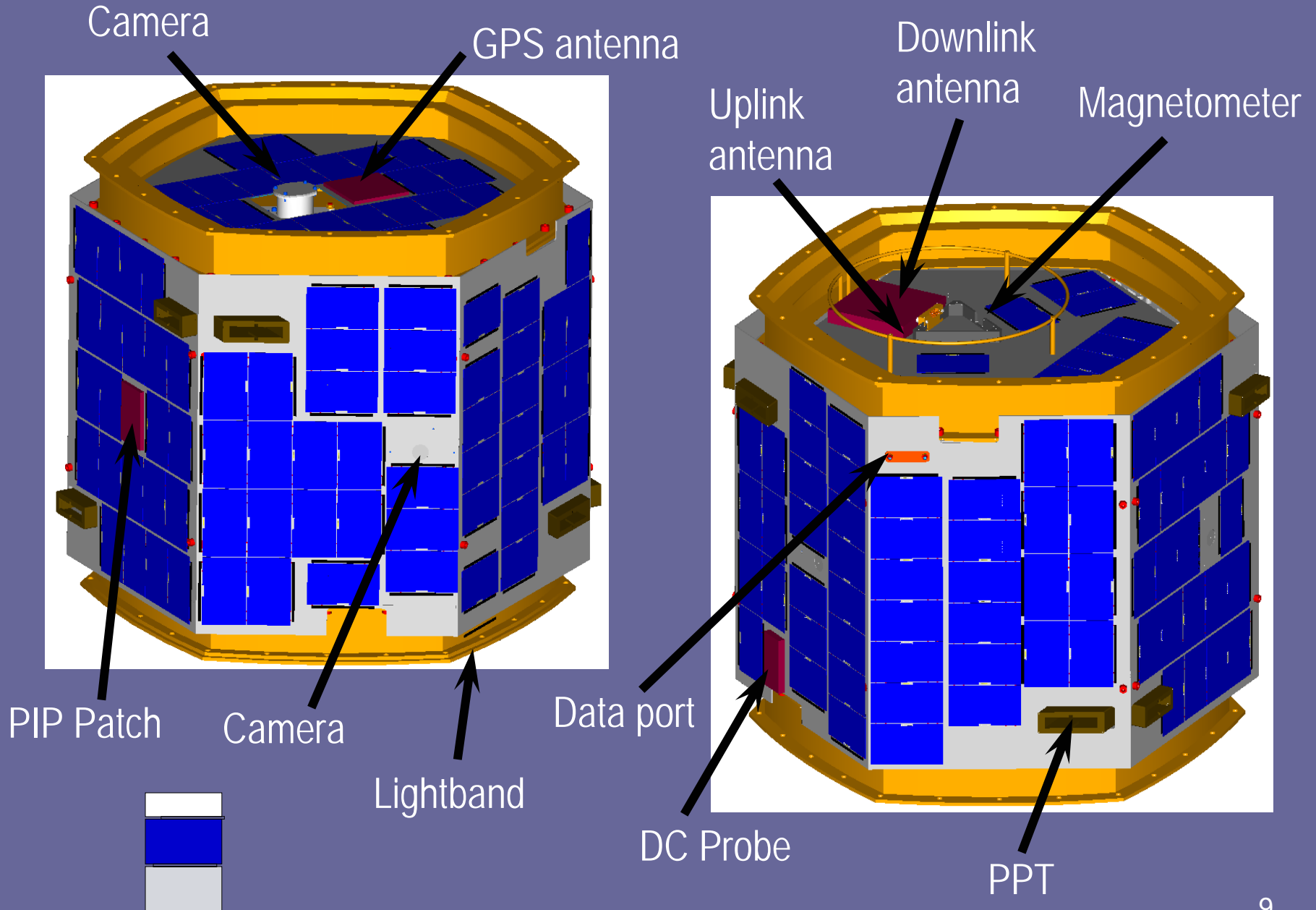


ION-F USUSAT Design

- Structure
 - 19.75 inch (MD), 6 inch Depth
- Operating Temp
 - Electronics (Industrial Grade)
 - -40 to 85° C
- Orbital Power
 - 11 W Orbit Average
- Spacecraft Mass
 - 15 kg



ION-F Dawgstar Design



ION-F HokieSat Design

GPS Antenna

Crosslink antenna

Lightband

PPT

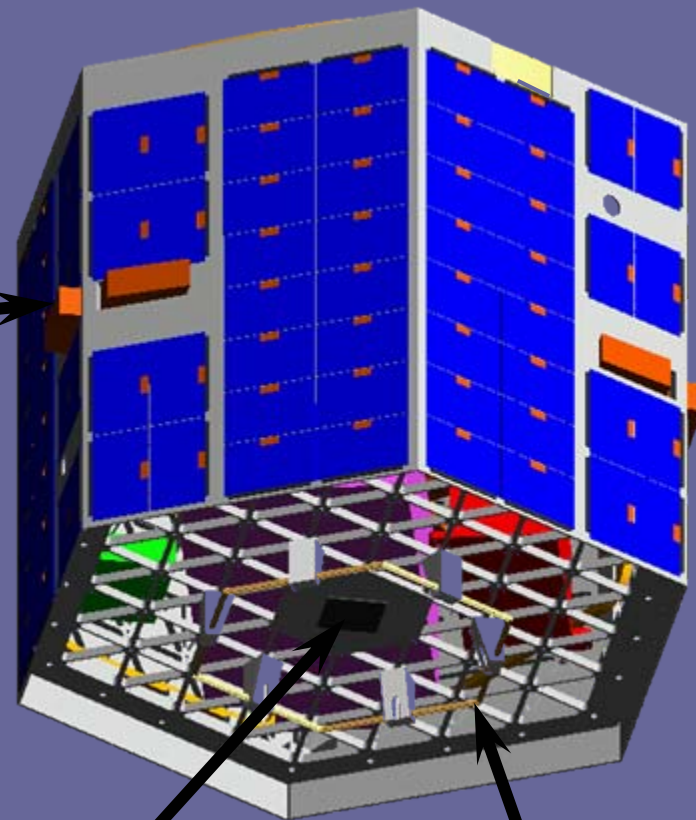
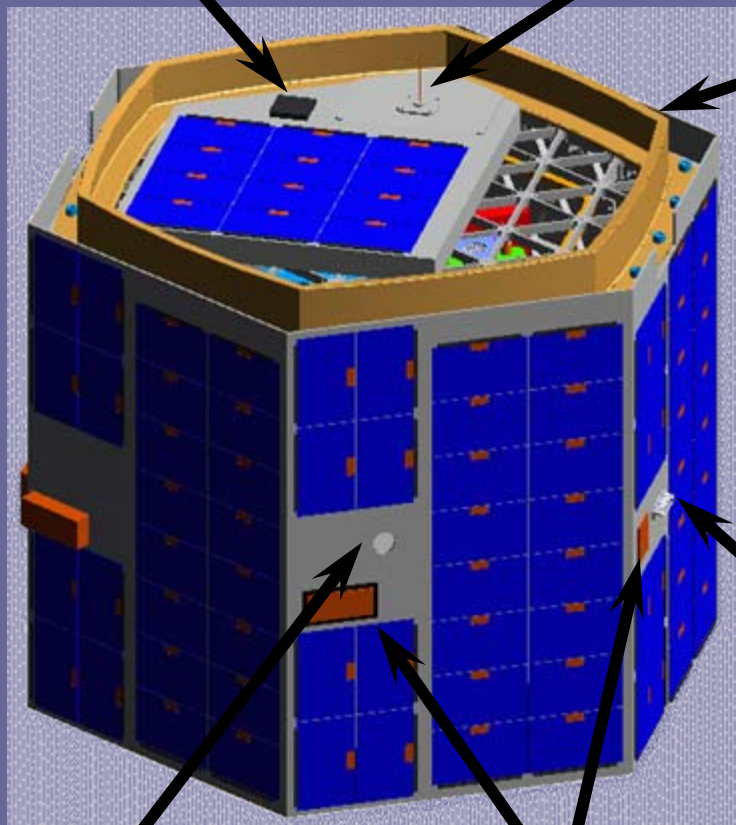
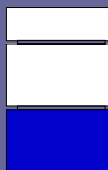
Data Port

Camera

DC and PIP

Downlink antenna

Uplink antenna



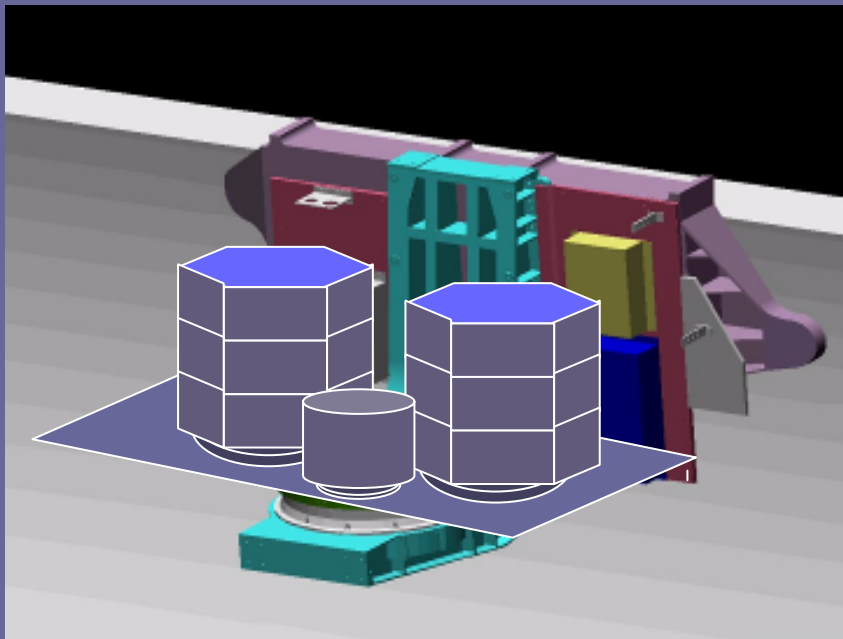
ION-F C&DH Design

- Physical Characteristics
 - Main components
 - Hitachi SH3 7709 Microprocessor
 - **VxWorks Operating System**
 - Actel 42MX FPGAs
 - 256 KB EEPROM
 - 6 MB SRAM
 - 32 MB Flash Memory
 - Interfaces w/ other subsystems through CEE backplane and various external connectors
- Performance Characteristics
 - **2.5 W of power consumption**
 - Fault tolerant hardware and software design
 - 32-bit 80-MIPS processing power
 - 64 ADC channels
 - 71 Digital inputs/outputs
 - Two RS232 ports, one RS422 port
 - SPI bus with 32 connections
 - 1-Wire® bus
 - DMA oriented telemetry and camera image buffers
 - **Designed, built, and tested by students**



ION-F Stack Deployment System

- SHELS
 - Shuttle “canless” hitchhiker ejection system
- Stack Separation System
 - Lightband by Planetary Systems Corporation

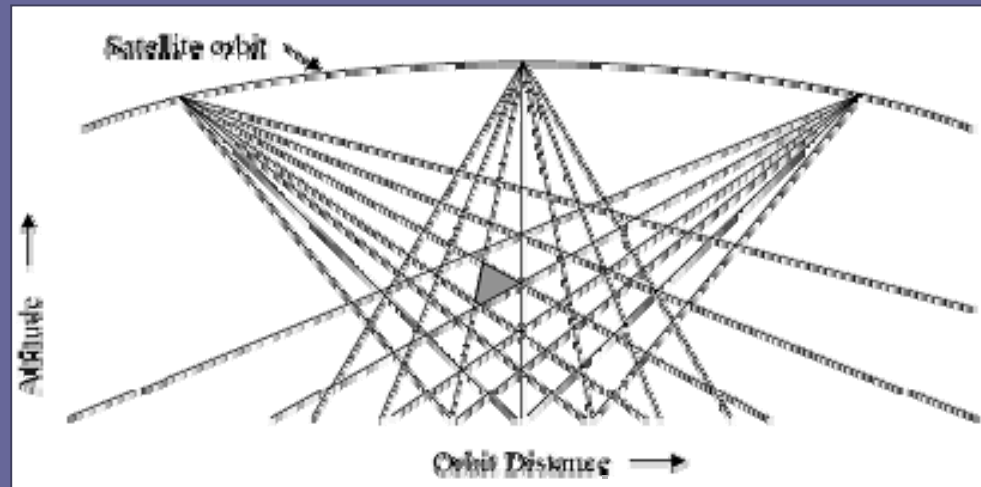
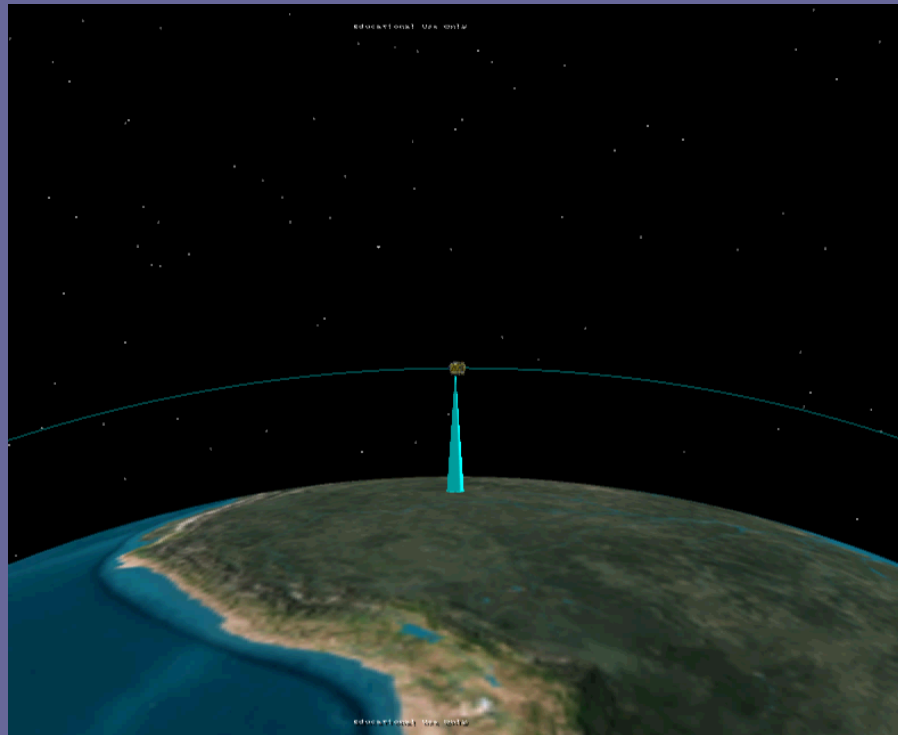
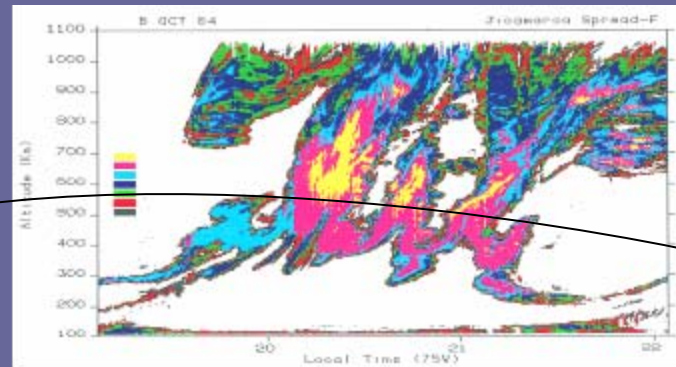


USUSAT



TOROID Space Science Mission [Current]

Single satellite

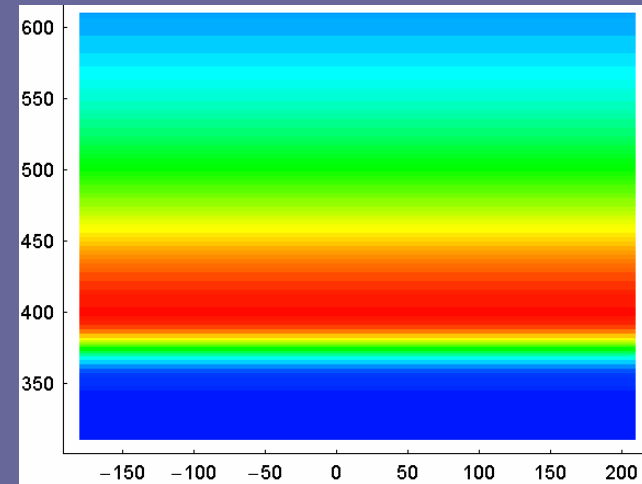


Principal Diagnostics:

- Electron Density - 200 m/sample
- Airglow – 1 rev/second, 180 samples

TOROID Space Science Mission

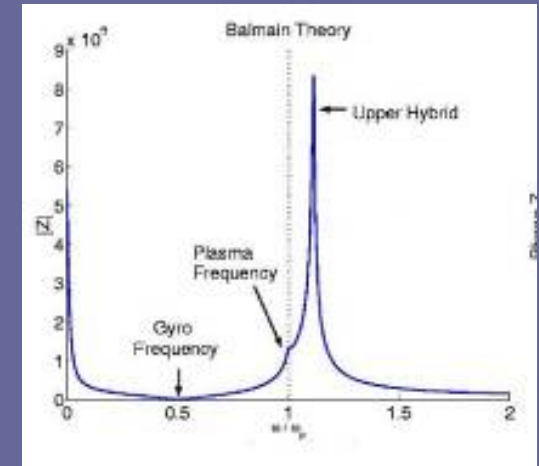
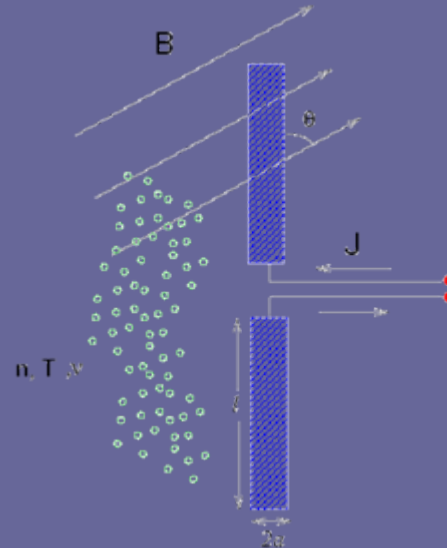
- Science topics to be addressed by TOROID
 - Measure vertical density profiles of the night time ionosphere near the magnetic equator of the Earth
 - Global distribution of equatorial ionospheric plasma structures and irregularities
- Instrumentation
 - Plasma Impedance Probe (PIP) to make electron density measurements
 - Scanning Photometer (TOROID) to make airglow (electron density) measurements
- Airglow data will be sent to the ground and vertical density profiles will be generated using tomographic reconstruction techniques. The PIP absolute plasma density measurements will be used to calibrate the airglow data
- Complement collected data with ground based radar operations and concurrent observations from other satellites



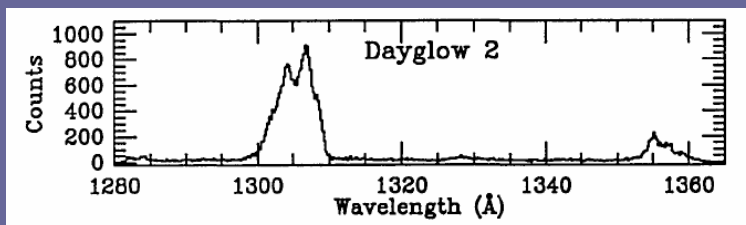
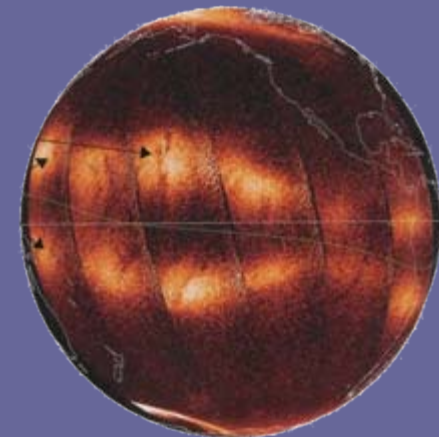
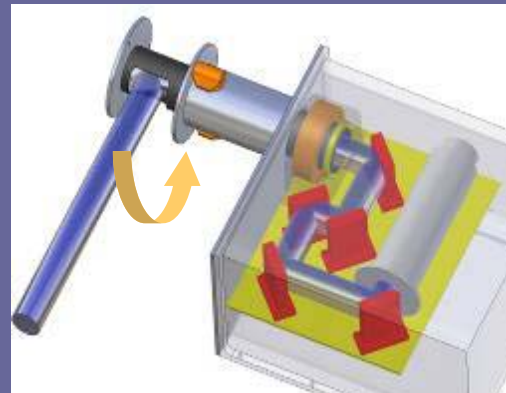
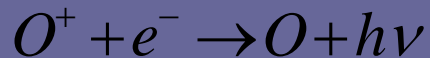
[Courtesy of P. Bernhardt, NRL]

TORIOD Science Sensor Instrumentation

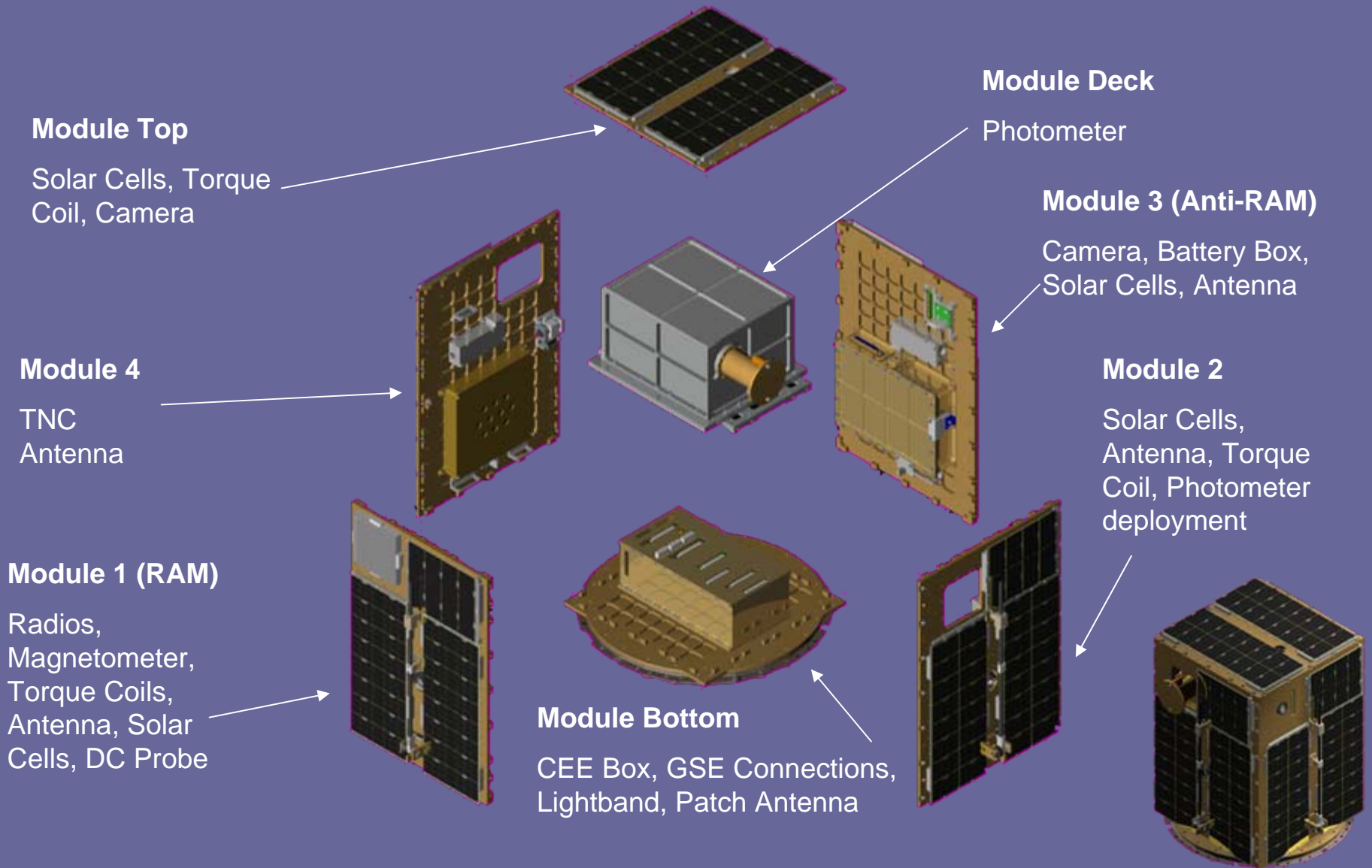
- A sweeping impedance probe (PIP) will measure local ionospheric density



- A scanning photometer (TOROID) will measure ionospheric airglow (EUV)



TOROID USUSAT Design



TOROID USUSAT Design

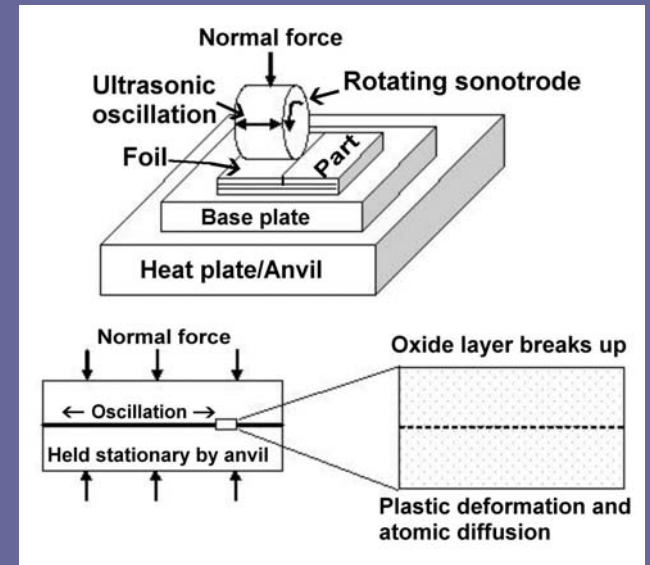
Size & Mass	33 x 33 x 48 cm, Current Mass: ~28kg
Power	Bus: 17 W orbit Average Payload: ~5 W Triple Junction GaAs body mounted arrays w/ series regulated NiCAD 4Ah Battery
Comm.	450 MHz Command & Control link, S-Band Data downlink (115.2 kbps)
Attitude	Accuracy: better than 1° control Sensors: 3-axis Magnetometer, star, sun and horizon imagers Actuators: Momentum Wheel, torque coils
Thermal	Passive Design, supplemented with Heaters, viable for LEO & GTO

C&DH	Hitachi SH3 7709 Microprocessor, 80 MIPS, radiation tolerant architecture. VxWorks real-time operating system. Interfaces: A/D, Digital, SPI & Serial (RS-422)
Structure	Seven orthogrid panels Standard Bolt Pattern
Mechanism	Antenna Hinge and Release Lightband Deployment System Photometer
Launch	TBD
Mission Life	~ 6 months to 1 year
Science Objective	Measure Intensity of 1356Å FUV photons in F region of ionosphere for tomographic reconstruction of vertical density profile
Technology Demo	Additive Manufacturing

Additive Manufacturing - Ultrasonic Consolidation

[Courtesy of Q. Young & B. Stucker, USU]

- SOLIDICA Formation
 - Rapid prototyping technology
 - Additive manufacturing
 - Computer controlled process
 - Low temperature metallurgical bonding
 - Room temperature to 300 F
 - Highly localized plastic flow
 - Atomic diffusion
 - True metallurgical bond
 - Integrated 3-axis milling machine
 - Trimming edges
 - Shaping parts



CENTER FOR
ADVANCED
SATELLITE
MANUFACTURING

Experimental Vision - Conclusion

- Future progress In aeronomy will be tied to multipoint measurements in space
 - Deconvolve temporal/spatial ambiguities of *in-situ* sensing techniques
 - Differentiate the integrated line-of-site quantities from remote sensing techniques
 - Sufficient observations for predictive space weather models
- There is a need for small satellites in aeronomy to provide multi point measurements
 - Create satellite clusters and constellations
 - University-based programs can be a significant contributor to the development and implementation of low-cost small satellite constellations

Small Satellite Conference

IT'S THE **MISSION** THAT MATTERS

- August 13 to 16, 2007
- Utah State University
- Logan, Utah
- 21st Annual Meeting
- <http://smallsat.org/>

DATE... AUG. 8-11, 2005... **SMALL SATELLITE STANDARDS**
PLEASE VISIT



"Breakthrough Technologies"
The Foundation of the Future

*The Sixteenth Annual
AIAA/USU Conference on Small Satellites*



Small Satellites
"Coming of Age"

Aug 13 - 16, 2001

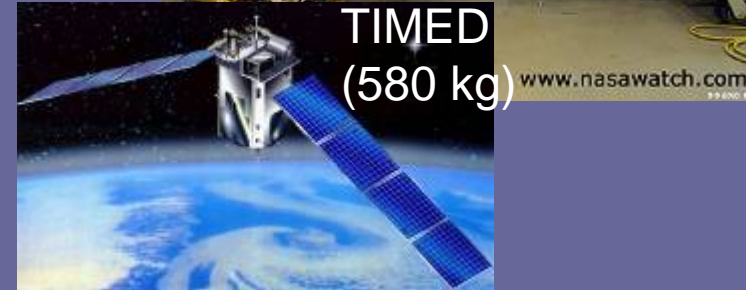


Supplemental Information

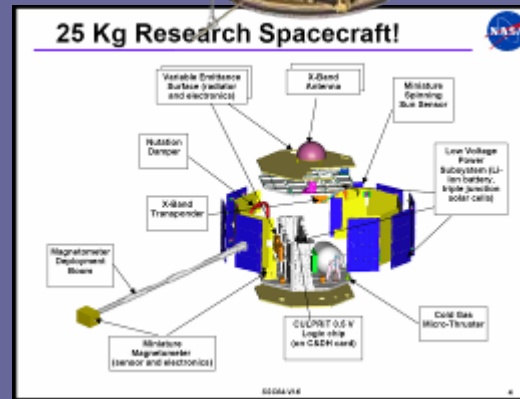
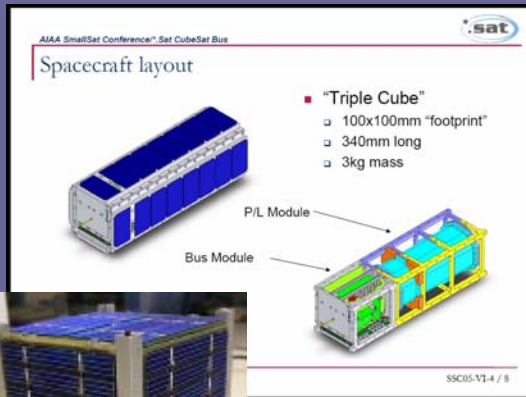
Satellite Sizes

Class	Mass (kg)	Cost (\$M)
Large satellite	> 1000	> 100
Small satellite	500 - 1000	50 - 100
Mini-satellite	100 - 500	10 - 40
Micro-satellite	10 - 100	4 - 8
Nano-satellite	1 - 20	0.5 - 2
Pico-satellite	< 1	< 0.2

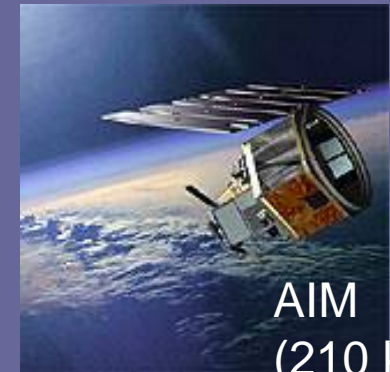
NOAA-N
Prime
(1400 kg)



University
Nanosatellite
Program
(25 kg)



SSTL MicroSat-70
(70 kg)



Cubesats
(1 to 3 kg)

ST5

