Design of the Local Ionospheric Measurements Satellite

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LionSat

PENNSTATE

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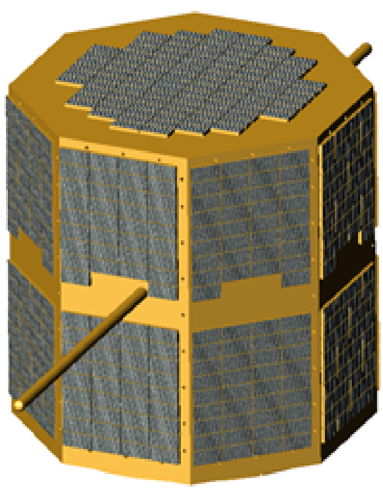
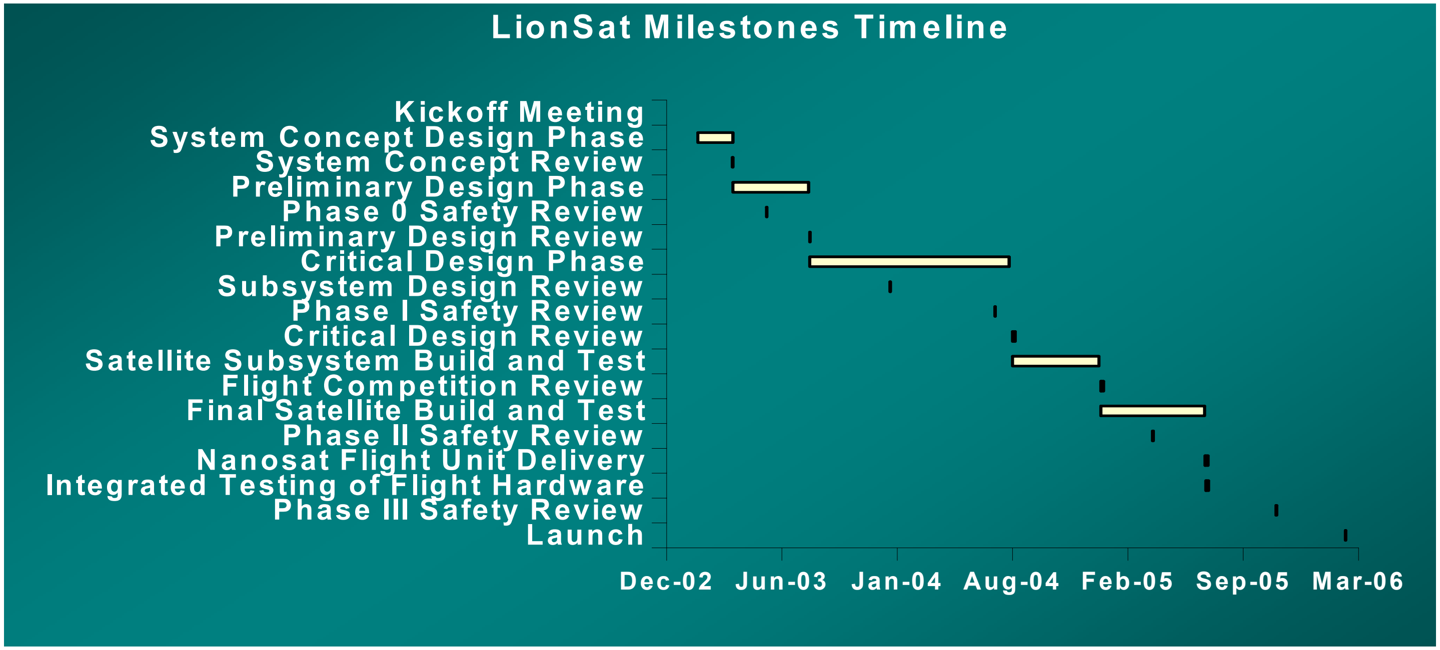
Overview

LionSat

- Local Ionospheric Measurements Satellite
  - Funded by Nanosat-3 program sponsored by AFOSR/NASA/AIAA
- Scientific goals
  - Explore ram/wake structure via probes as spacecraft spins
  - Obtain ambient measurements of undisturbed ionospheric plasma environment via two probes mounted on deployed booms
  - Correlate ambient to ram/wake measurements
- Engineering goals
  - Test a miniature RF ion thruster system that will augment satellite spin
  - LionSat will use IP communications for return of prime science data and uploading new campaign scenarios
- Educational goals
  - Prepare students at undergraduate and graduate levels for productive careers in technical and nontechnical fields relating to space systems



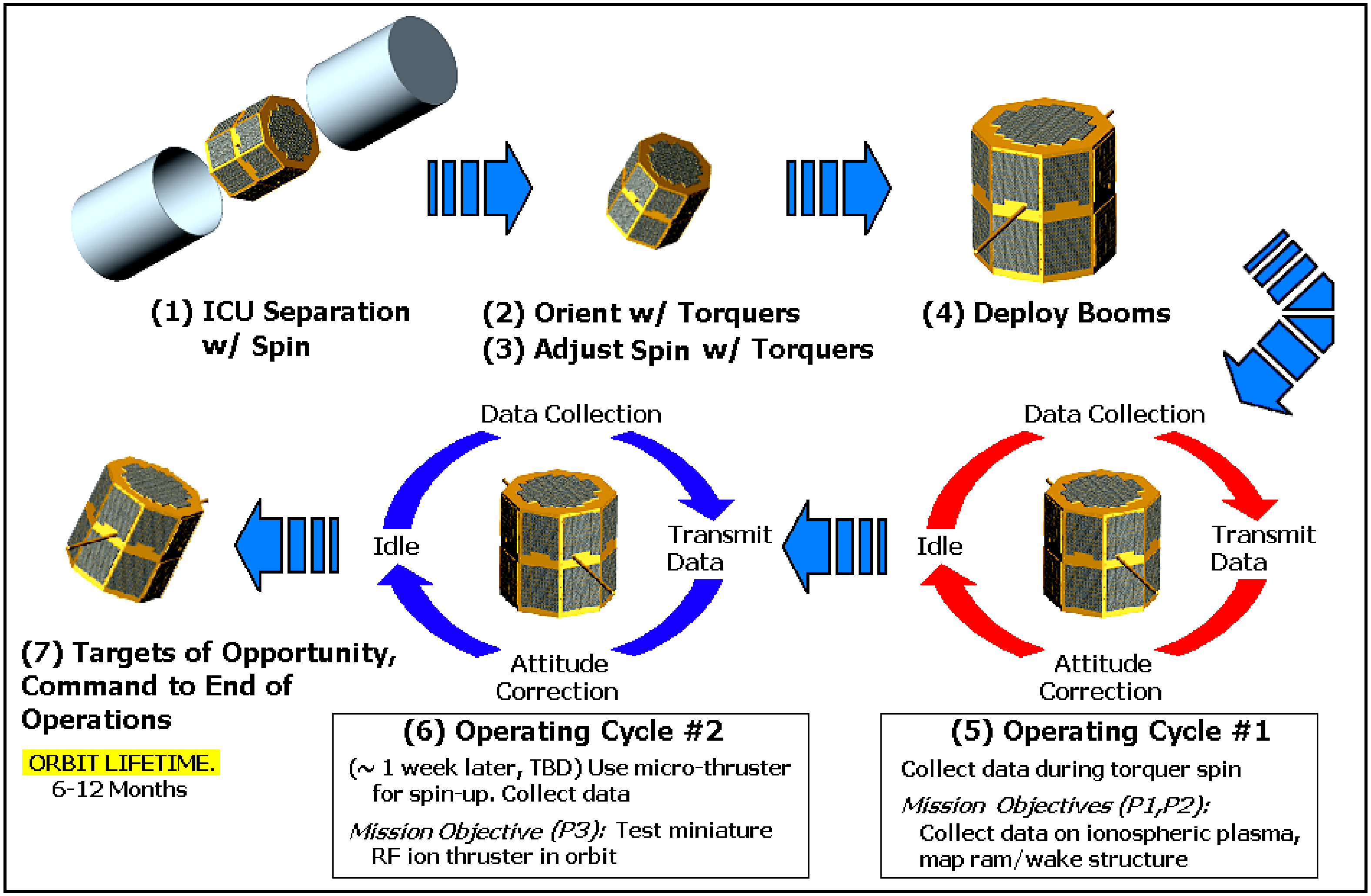
Methodology



- Top-down approach to design
- 11 subsystems
- Formal documentation process
- Margin of flexibility in design
  - Due to uncertainties (e.g., launch vehicle currently unknown, baseline is Shuttle in CAPE)
- Educational goals are met through public outreach (grades K–12) and integration of LionSat design into design courses

Mission Timeline

LionSat



Spacecraft Overview

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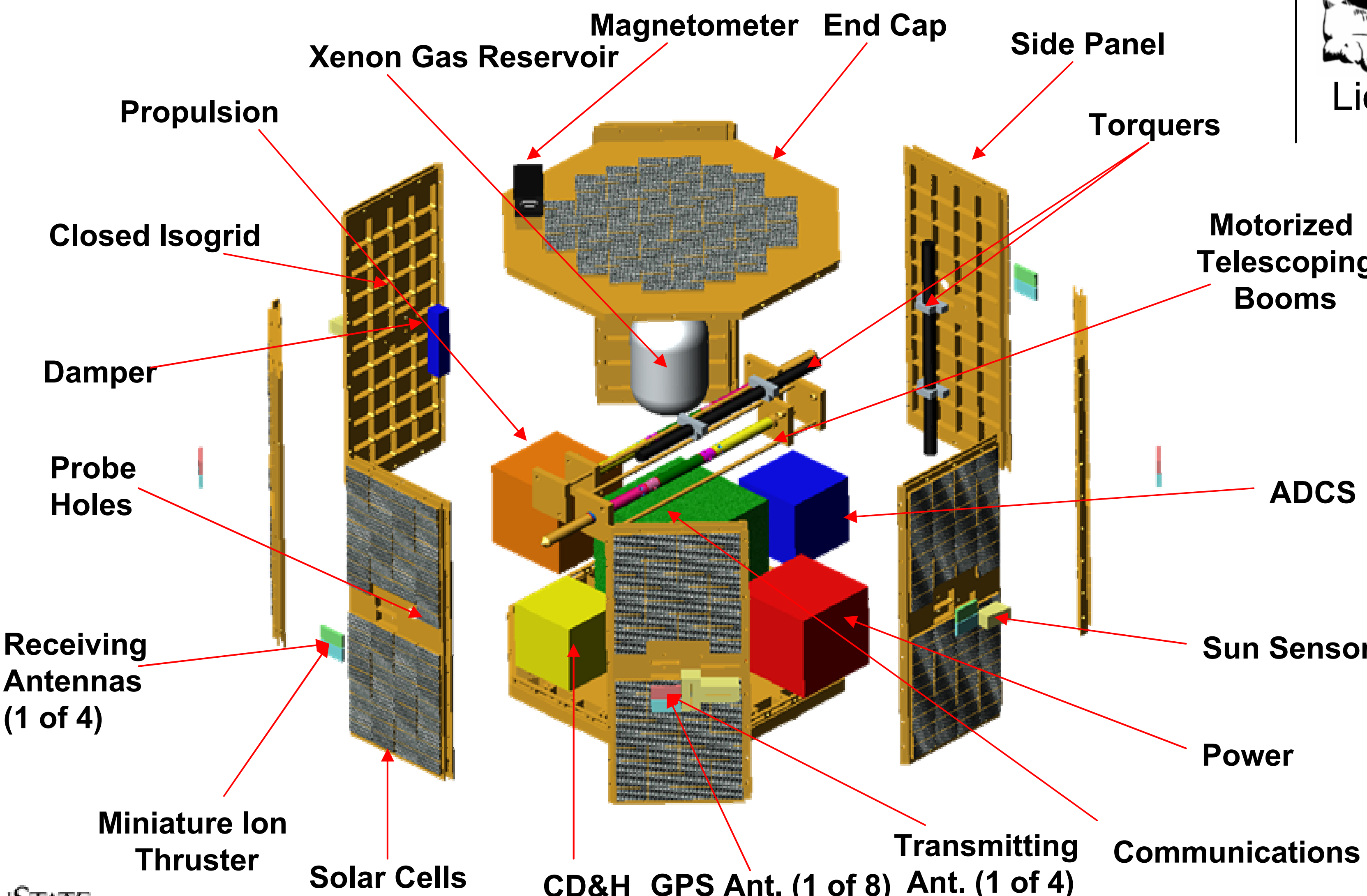

Hybrid Plasma Probe

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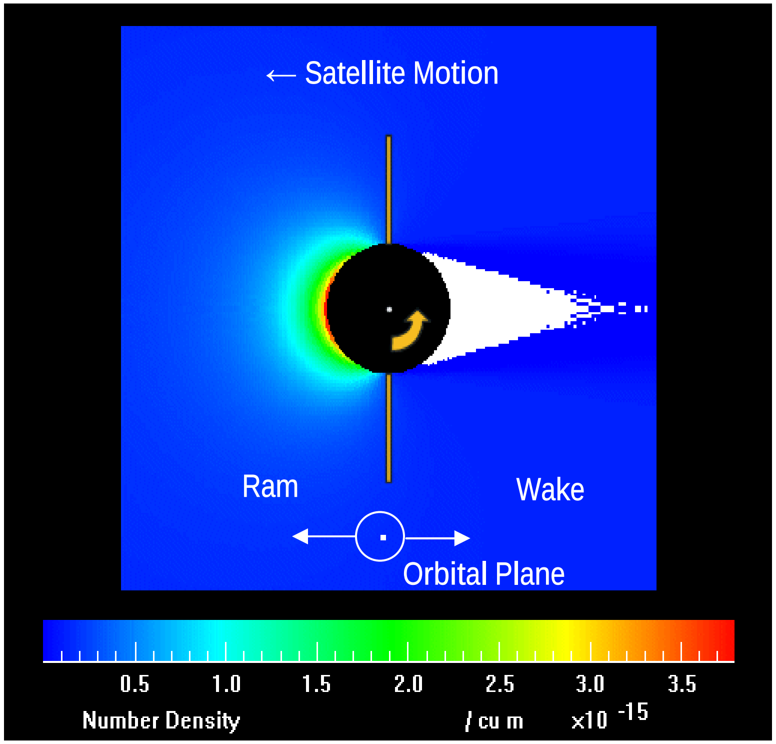
- Purpose
  - To collect data on ionospheric plasma in perturbed and unperturbed regions within geophysically interesting areas of low earth orbit
  - To demonstrate that combination of several plasma diagnostics is feasible, efficient, and powerful
- Modes of operation
  - Swept Bias Langmuir Probe (SBLP) mode yields electron and ion density, electron temperature, and spacecraft potential
  - Fixed Bias Langmuir Probe (FBLP) mode yields fast relative electron or ion density
  - Plasma Frequency Probe (PFP) mode provides fast absolute electron density measurements
  - Fast Temperature Probe (FTP) mode yields fast, relative electron temperature measurement



Discrete Monte Carlo Simulation of neutral gas density surrounding satellite. Orbital plane coincides with image plane. Booms rotate through ram and wake

Miniature RF Ion Thruster (MRIT)

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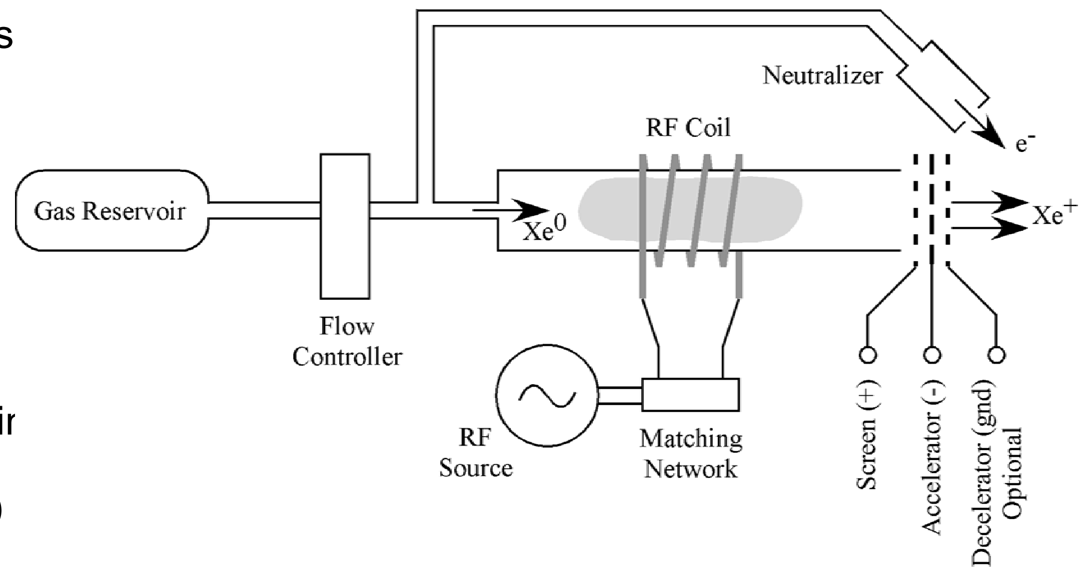
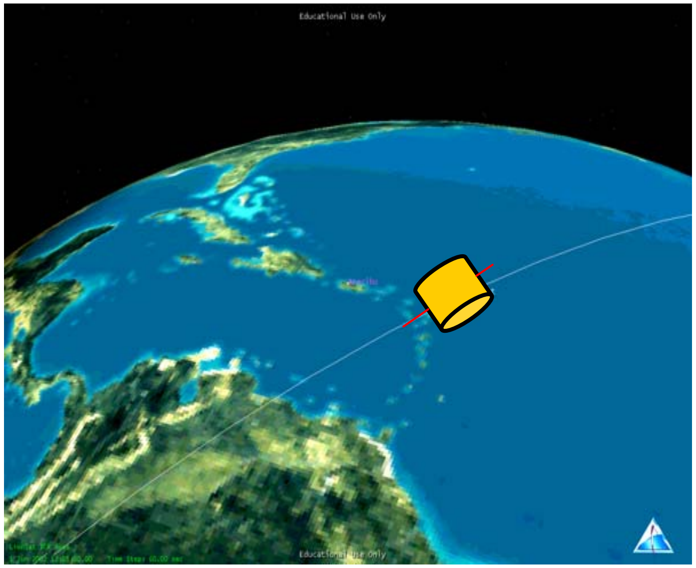
- Purpose:
  - MRIT will be tested by increasing s spin rate
- Functional characteristics:
  - Thrust: 0.6 mN (calculated)
  - Specific impulse: 3800 s
  - Exhaust velocity: ~38 km/s
- Physical characteristics:
  - Total input power: 15 W
  - Excitation frequency: 13.56 MHz (ir unregulated frequency)
  - Mass: ~1.1 kg (total system mass)
  - Acceleration (grid) voltage: ~1 kV
- Propellant
  - Xenon gas (total stored Xe mass TBD)
  - Propellant contained in sealed container with pressure <100 psia (per requirements)



System diagram of the low-power, miniature RF ion thruster system

Guidance, Navigation, and Control

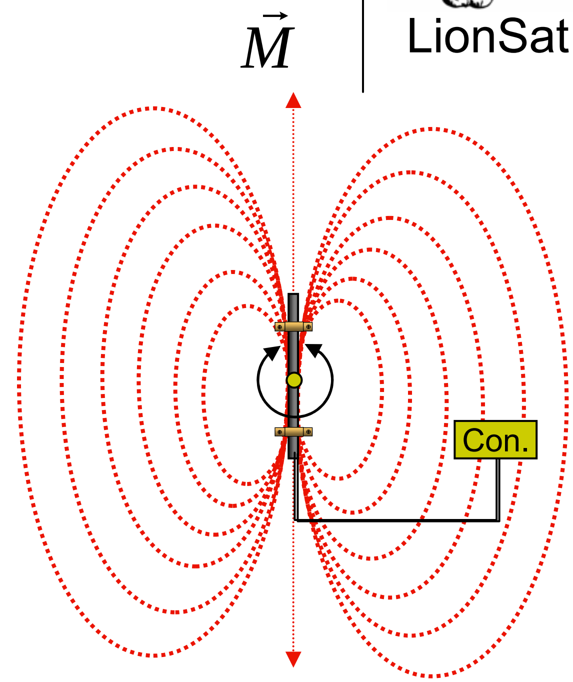
LionSat



Notional LionSat overpass of Arecibo for correlation of plasma density measurement

- Type of control
  - Spin stabilization using geomagnetic field and magnetometer only for attitude determination
  - Passive nutation damping

- Magnetic torque rods
  - Mass depends on size of rods
  - For 10–15 A•m², magnetic moment rods ~0.5 kg
  - Controller decides polarity of rod to change $\mathbf{T}_{mg}$
  - Two magnetic torque rods will be used to maintain desired attitude
- Power consumption
  - 1 W/axis
- Torque
  - 5×10^{-5} N•m (400 km)
- Operational modes
  - Orientation control
  - Spin-rate control
  - Stand-by (idle)



Disturbance	Torques (mN-m)
Gravity Gradient	0.0072
Magnetic Field	53.4569
Solar Radiation	1.7871
Aerodynamic Drag	0.0156

Command and Data Handling

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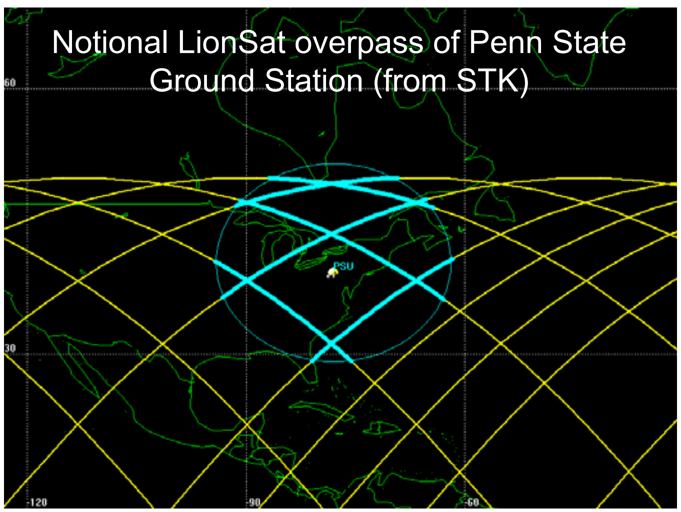
- Main components
  - CPU - Intel SA1110 @ 206 MHz (baseline)
- SA1110 Memory
  - Up to 768 MB memory such as SRAM, FLASH
  - Up to 512 MB dynamic memory
- SA1110 subsystems interfaces
  - 28 GPIO lines
  - Multiple serial systems (SPI, UART, USB)
- Ground interface through TCP/IP

- Roll rate of ~10 rpm →14,400 rolls/day
- 12 samples per roll × 4 sensor heads →691,200 samples/day



Notional LionSat overpass of Penn State Ground Station (from STK)

FO	SBFP	SBLP	PFP	FTP	FBLP	Portion of day	MB/ day
1	5%	10%	40%	10%	35%	15%	11.0
2	100	0	0	0	0	1.5	10.6
3	0	20	40	10	30	15	11.0
4	0	2.5	0	0	97.5	100	10.2

Communications

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- Lionsat will use IP communications for return of science data
  - After mission criteria met, can be used as testbed for testing/verifying relative performance of various protocols
- Why IP?
  - Many popular applications use TCP/IP
  - Allows use of MDP (Multicast Dissemination Protocol), which only requires one-way link
  - Allows secure communications via applications like SSH (Secure Shell) and protocols like IPSec
  - Allows ease of uploading new applications
- CPU: Intel SA1110 (baseline)
- Requirements
  - Downlink frequency = 2.365 GHz
  - Downlink data rate = 200 ksymbol/sec
  - Uplink data rate = 9.6 ksymbol/sec

Conclusions/Summary

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- LionSat design at PDR stage
  - Mission concept defined
  - Flow down of requirements performed
  - Preliminary designs for all subsystems (sizings, power, vendors, interfaces, etc.)
  - Significant progress in thermal design, structure, power, etc.
- Educational impacts
  - Involved in several exhibitions (Penn State Engineering Open House, Space Day, engineering camps, etc.)
  - Development of subsystems for fall semester
- Remaining challenges: Ion thruster to be developed, plasma probe, budget, etc.
- Next major review: Subsystem design review in January 2004

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Acknowledgments

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www.psu.edu/dept/aerospace/lionsat/