The University of Texas at El Paso
NASA MIRO Center for Space Exploration & Technology Research

A CubeSat Mission Design & Communication System Development for GTO Mission

CubeSat Developers Workshop

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Orbital Factory 4

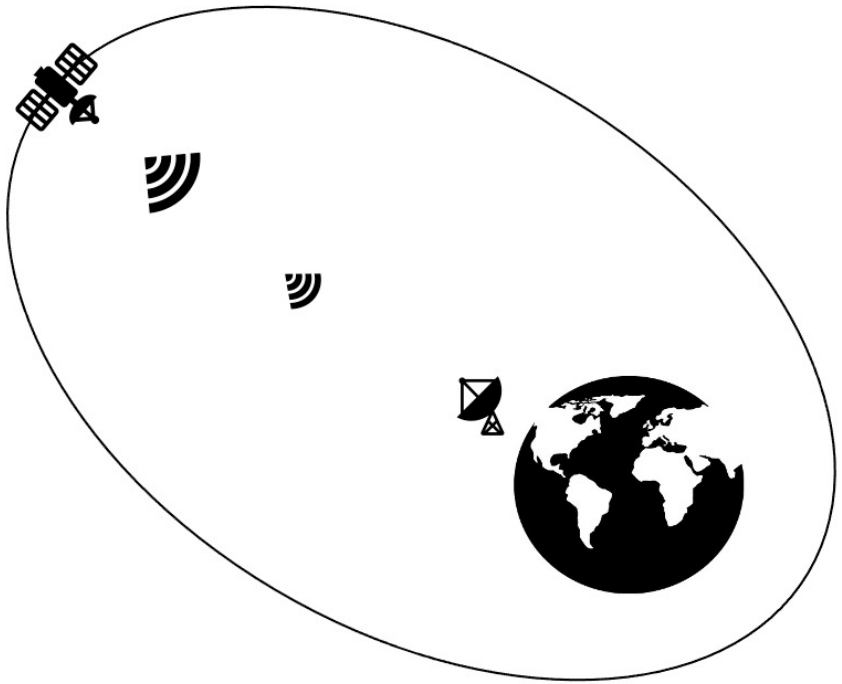
Goal

- **Demonstrate S-Band communication capability from apogee of GTO orbit**
- **Measure long-term radiation effects due to electrons & protons in GTO**
- **Develop and fly novel payloads**

Mission challenges

- Long distance communication during apogee passes
- Electrical and communication power limitations
- Increased communication losses
- Passage through the Van-Allen belts
- Probability of Single Event Effects

3U CubeSat planned to launch into GTO

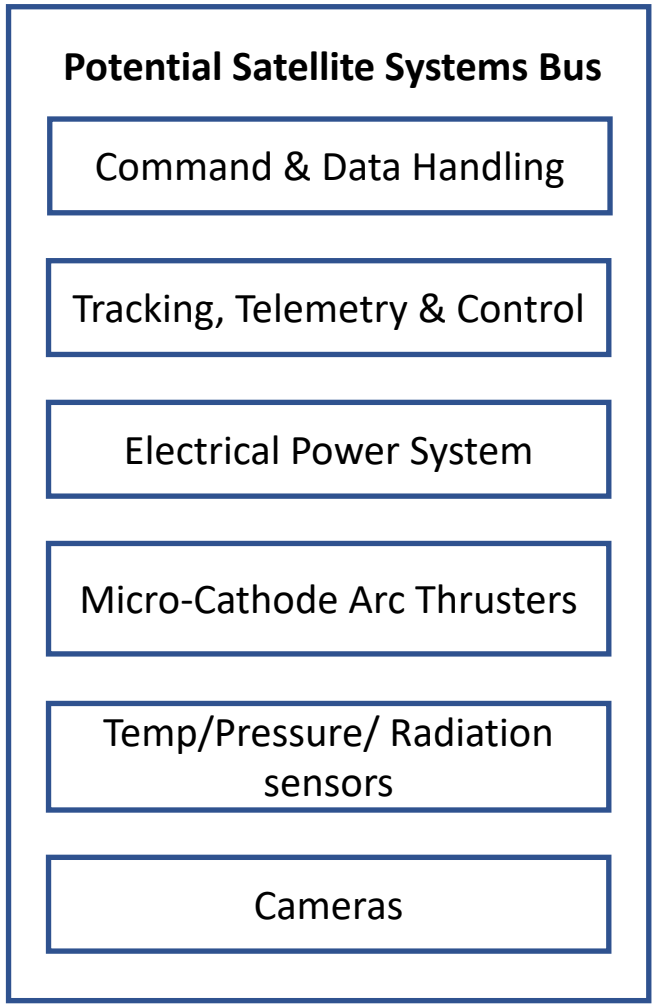


Estimated Orbital Parameters

- Mission not yet manifested
- Prior Atlas V GEO launches analyzed
- Orbital data from spent Centaur stages:
  - Apogee: 35,786 km
  - Perigee: 185 km
  - Inclination: 27 degrees
  - Period: 11 hours, 31 minutes

Satellite System Architecture

- 3U Structure
- PC/104 form factor & system bus
- Allows modules to easily be stacked and routed



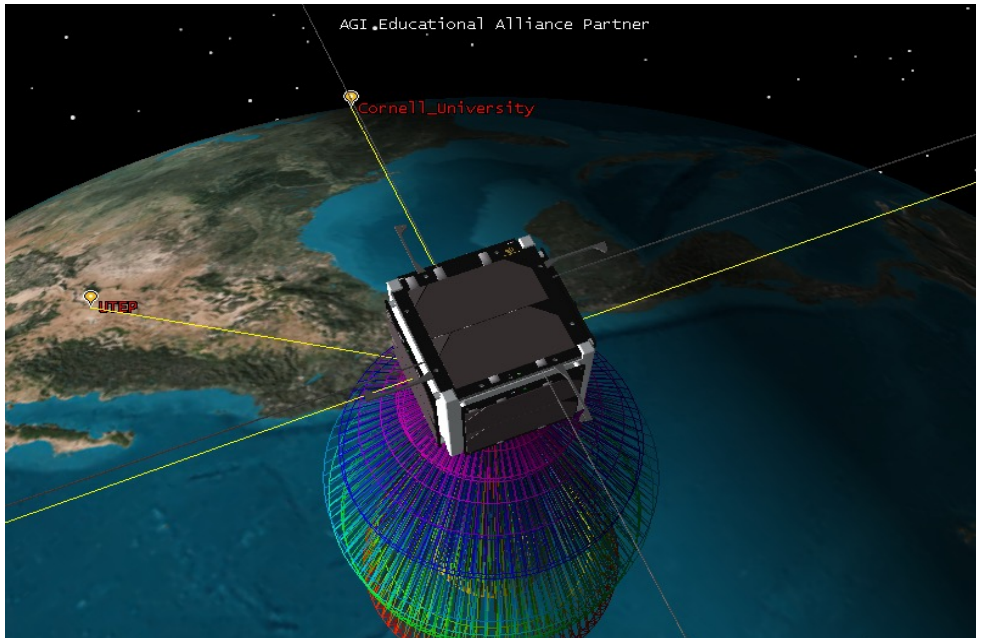
Link Analysis for S-Band Communication

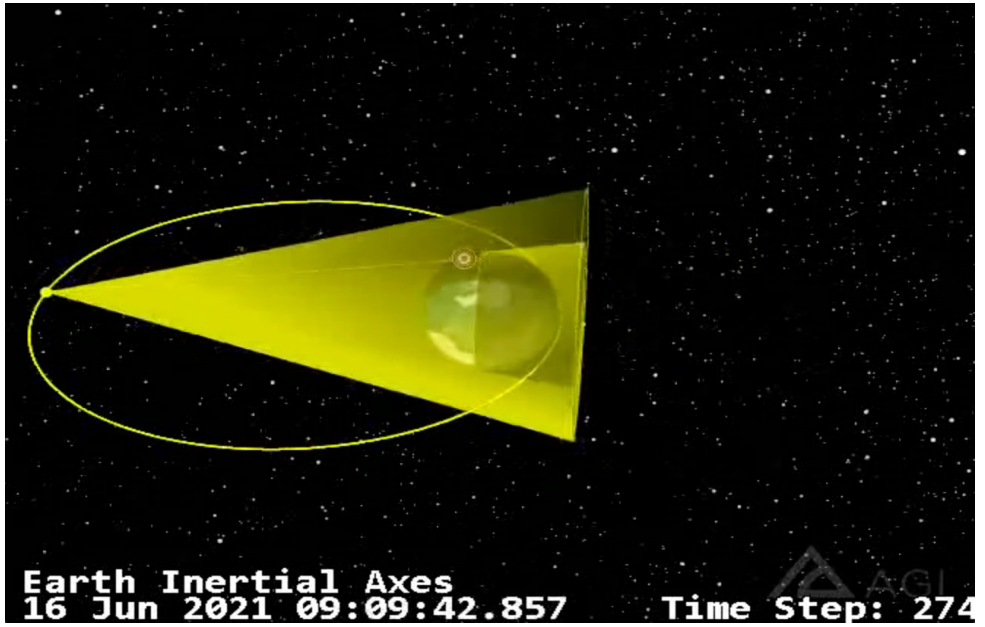
Link Analysis

- 6W transmitter with a 6dB directional antenna
- -125.6 dBm of received power at receiver end
- Signal to Noise Ratio of 10.78dB
- 2.425GHz frequency
- Maximum of 600bps from apogee
- Up to 1Mbps data rate for perigee communication

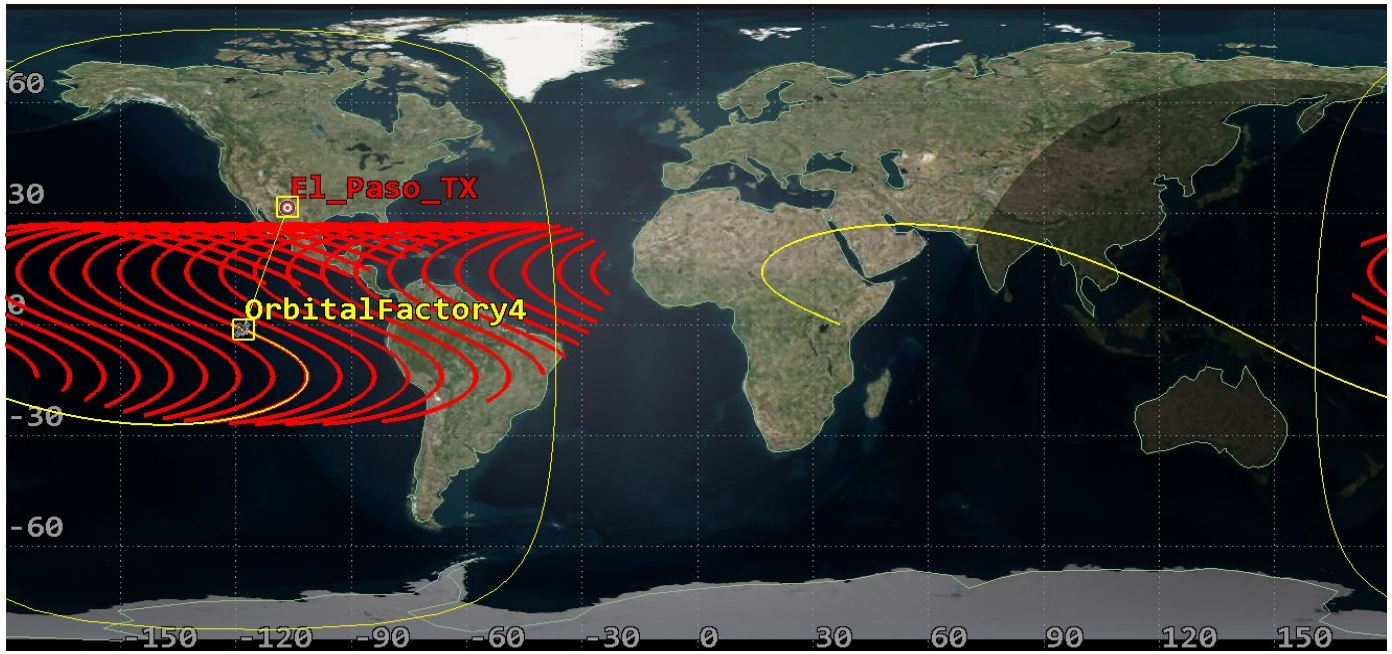
Antenna pointing

- Required Pointing accuracy ~5 degrees
- Attitude sensing system consists of sun and horizon sensor, star tracker
- Actuator system incorporates magnetorquer, momentum wheels and uCAT thruster

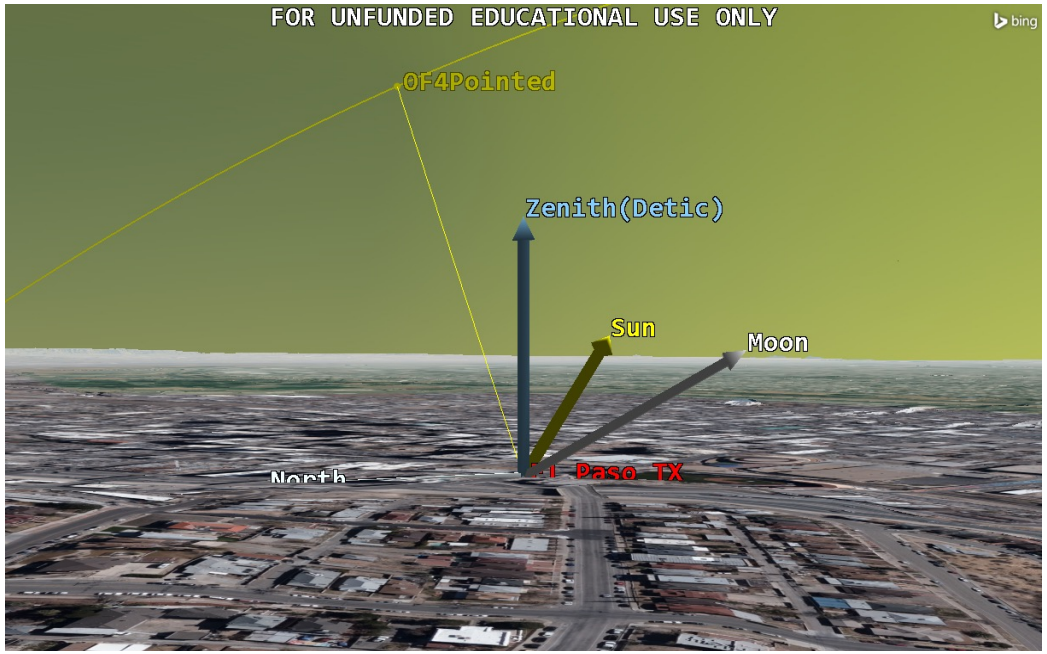




Communication window



Ground Track of Orbital Factory 4 GTO satellite from El Paso, TX



View of OF4 from the ground station at El Paso, TX. Sun, Moon and Zenith vectors are shown

OF-4 Communication Passes

- Simulated mission demonstrates passes occurring every other orbit per day approximately 11 hours apart
- 49 accesses within a 30-day period, with a min of 30 minutes and a max of 9.78 hours of high apogee passes observed

Radiation analysis for GTO

Potential mission challenges

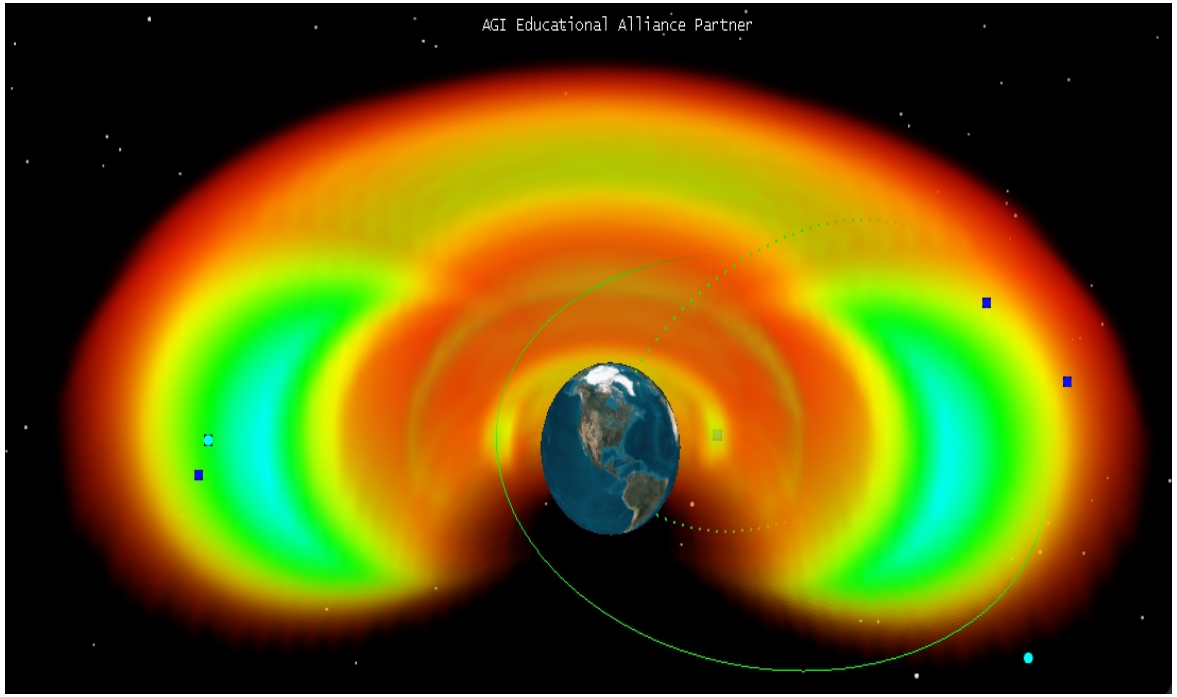
Van Allen Belt
Zone with positive and negative energetic charged particles consisting

1. Protons
2. Electrons
3. Alpha Particles

Inner Belt
Located between 1,000 to 6,000 kilometers and contains high concentrations of electrons and energetic protons

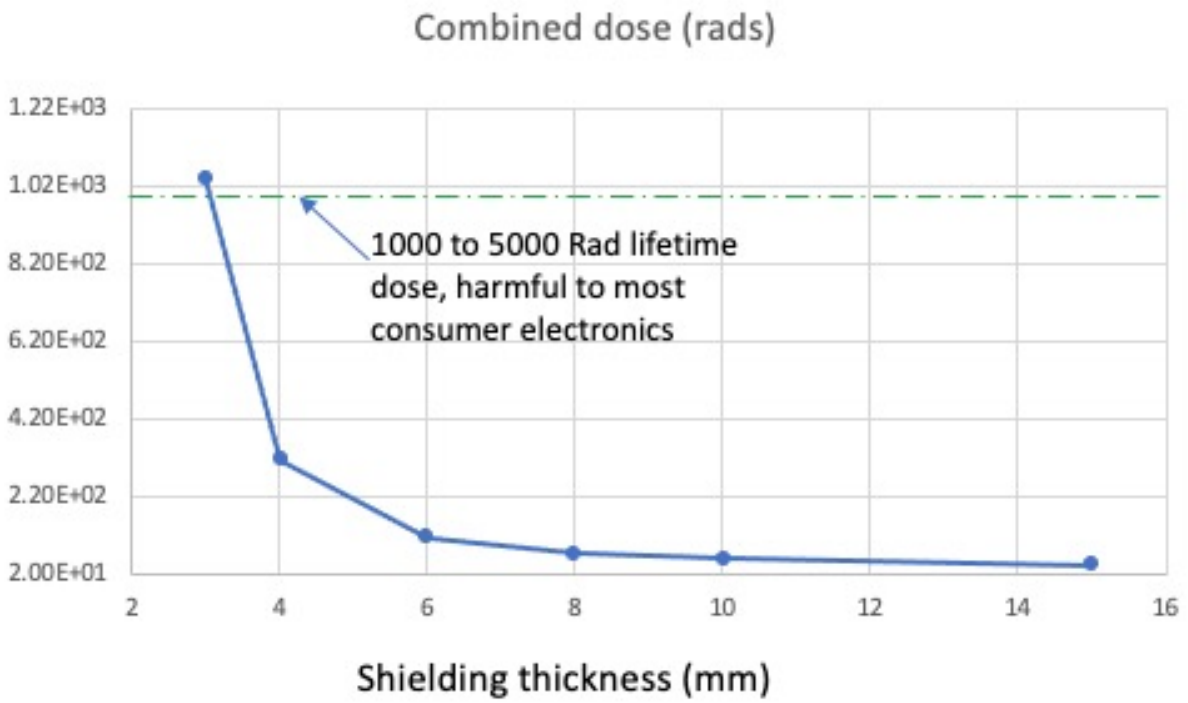
Outer Belt
Located between 13,000 to 60,000 kilometers with more solar activity and cosmic rays produced by inward radial diffusion

- Solar Wind (charged particles released from sun atmosphere)
- Cosmic Rays (high energy radiation originating outside the solar system)



Van Allen Belt Simulated in STK

Radiation analysis for GTO



Mitigation strategy

- 3mm of titanium shielding
- Use of GaAs circuits
- Use of components with linear energy transfer threshold (LETth) > 100 MeV·cm²/mg
- Reduced length and width of custom devices

Power budget estimation

Solar Cell Specifications

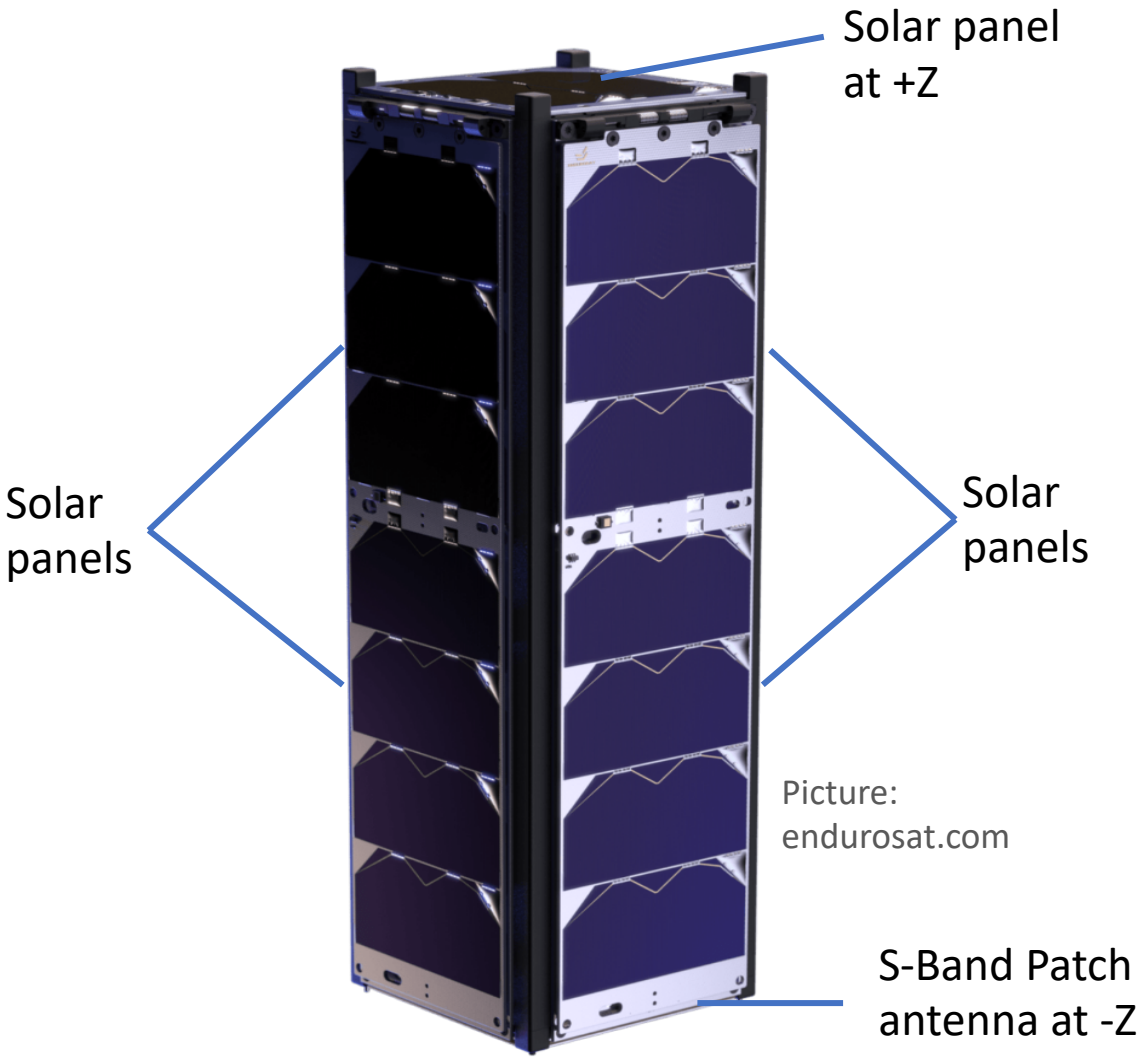
- Standard (GaAs) Solar Panels
- Efficiency: 29.5%
- Effective Cell Area: 30cm sq (per solar cell)
- Available in 5 positions
- Solar Panel +/- XY and +Z axis

Sunlight & eclipse time estimation

- Sunlight time: 86% of total orbital period
- Eclipse time: 14% of total orbital period

Power assumptions

- Recommended battery pack 84Whr
- Total power from solar panel 65Whr per orbit
- Total consumption 55.62Whr
- Regular activity can be performed on Solar power
- 35% battery discharge during eclipse
- Recharge time 4hours (approx.) after eclipse

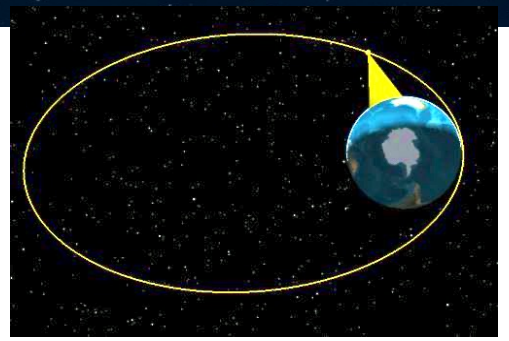


Demo 3U CubeSat showing Solar panels at 5sides and S-band patch antenna at the –Z axis of the satellite

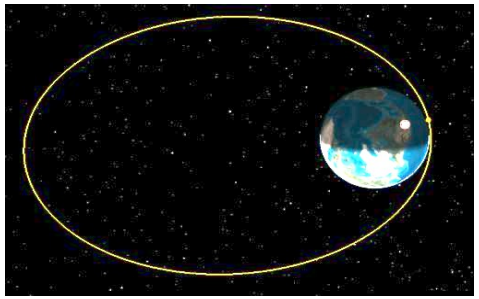
Attitude control

Default Attitude

- Antenna modeled to track the Earth throughout the orbit
- Orientation: Nadir alignment with ECI velocity constraint
- Targeted pointing method used in STK
- Nominal boresight direction of the antenna is along the Z axis



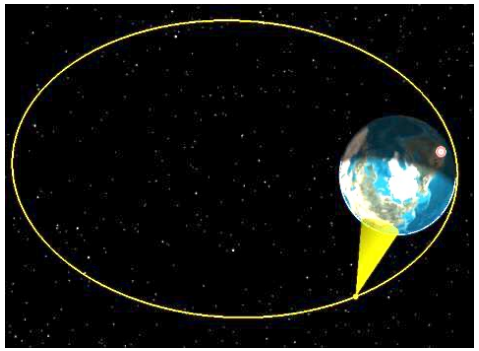
1. Approaching perigee after deployment



2. Detumbling performed at perigee

Procedure to obtain desired attitude

- Magnetorquer detumbling
- Satellite stabilization in 90 minutes in LEO region
- Require 2 perigee passes (24 hours approx.)
- Align satellite for earth viewing
- Attitude adjustments using Arc Thrusters
- Cancellation of disturbance torques



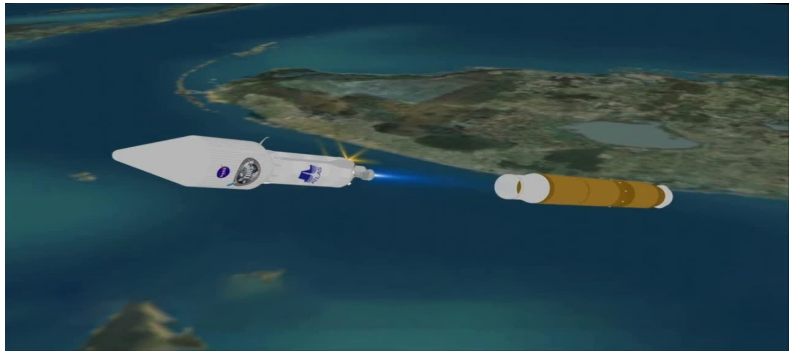
3. Earth viewing enabled after 2 perigee passes

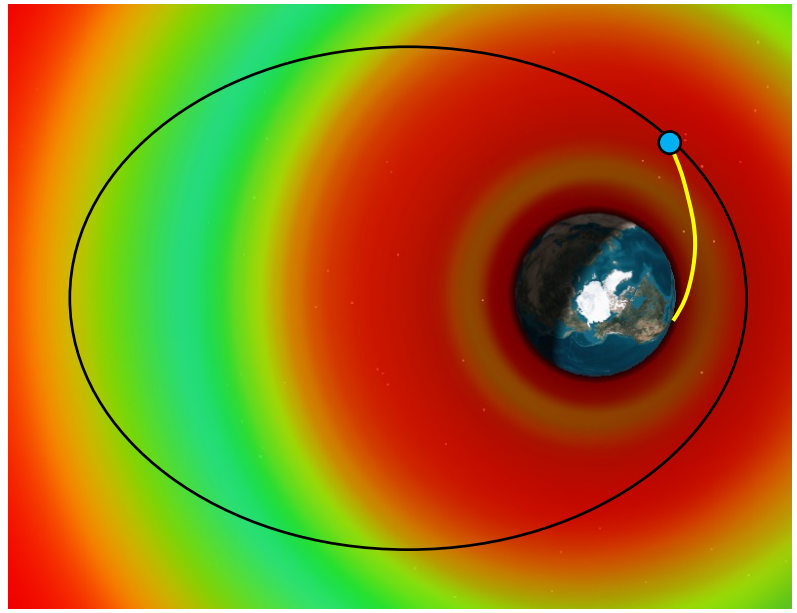
Tentative Mission Concept of operation

T + 24hrs	Phase 1	• Launch and deployment • EPS firmware checks status • OBC Boots up / UHF antenna deployment
T + 72hrs	Phase 2	• Transmission of beacon/housekeeping data reception (Analysis of gyroscope/accelerometer/GPS data) • Magnetorquer detumbling starts • Momentum wheel keeps satellite aligned with the Nadir axis for S-band pointing
T + 7days	Phase 3	• Selection of operating modes based on power status • Ensure full battery power / ensure satellite alignment • Transmit over S-band upon confirmation over UHF
T + 30 days	Phase 4	• Take pictures with camera after confirmation over UHF at any orbital location • Keep records of the Single Event Effects and Total Ionizing dosage • Transmit image data/radiation related data
T + 90 days	Phase 5	• Validation of the data received from satellite • Extended mission • Deorbiting procedure / Disposal

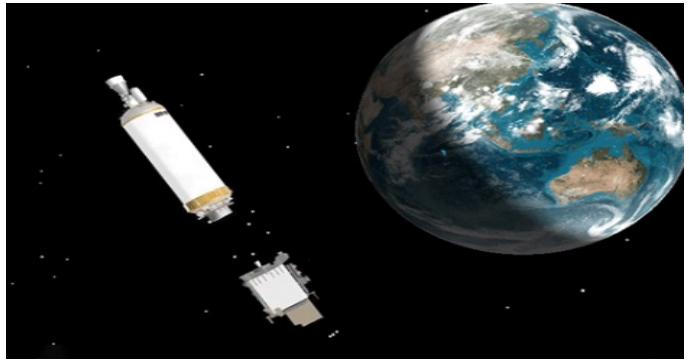
Launch and primary satellite separation

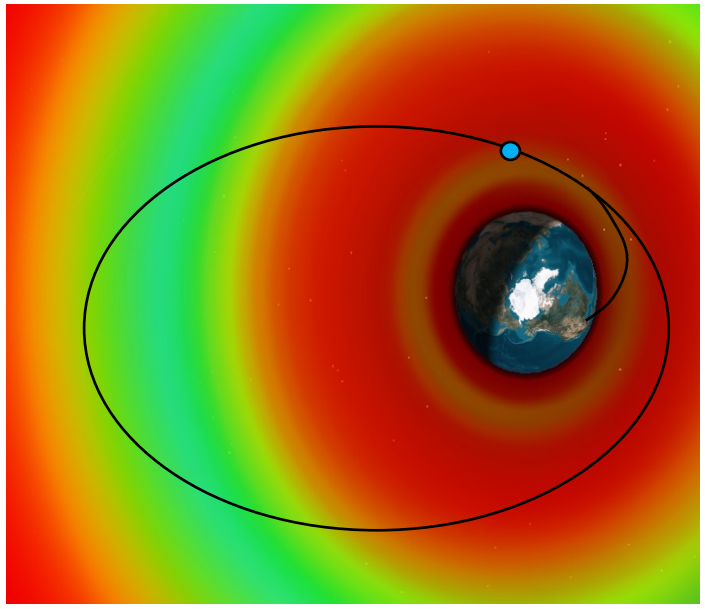
- Launch site: CCAFS (Probably)
- Launch date: TBD
- Vehicle: Vulcan/TBD
- OF-4 powered off during all launch phases



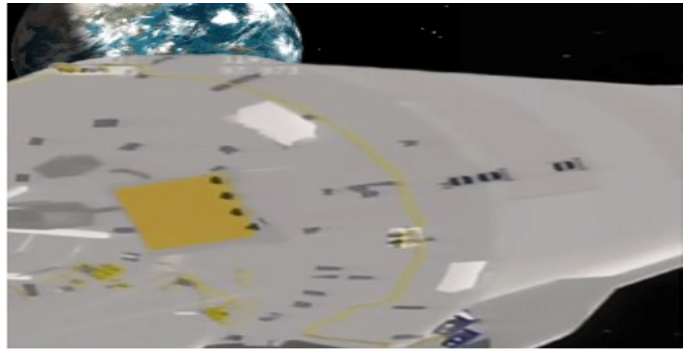


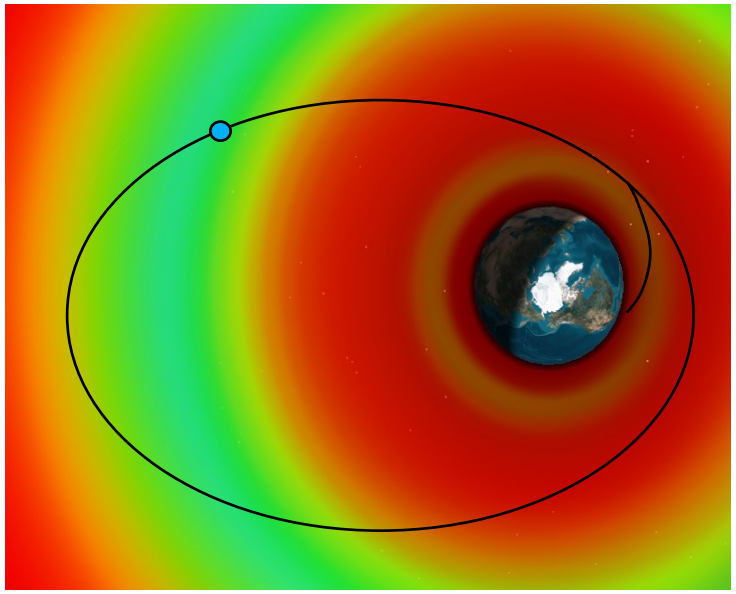
- Approx. T+ 105 minutes after liftoff
- Approx. 9000 km altitude
- OF-4 remains powered off





- Approx. T+ 210 minutes after liftoff
- Approx. Altitude: 29,000 km
- Deployment from ABC
- EPS turns on after 30 minutes
- OBC boot up

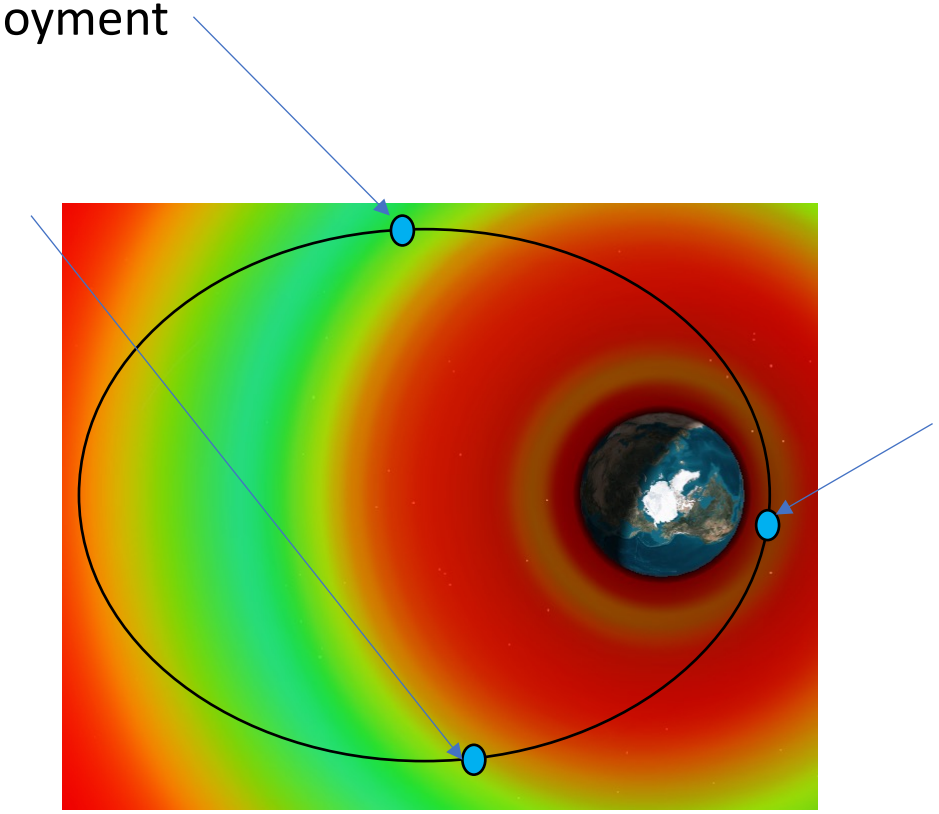


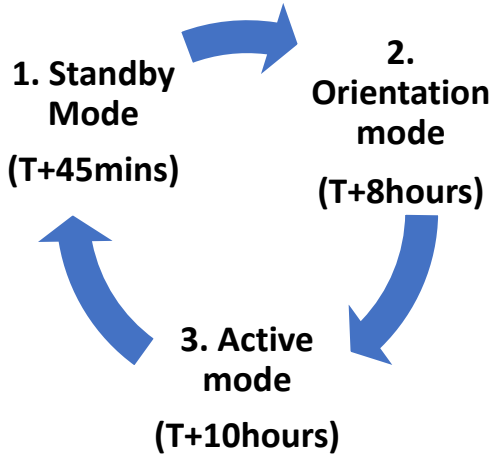


Operating modes

Stand by mode (T+ 7 hours)

- OBC in idle mode
- Nominal use of satellite components
- Initial system checkout
- Approx. T+ 7 hours from deployment
- Approx. Altitude: 14,000 km
- Exit outer Van Allen belt





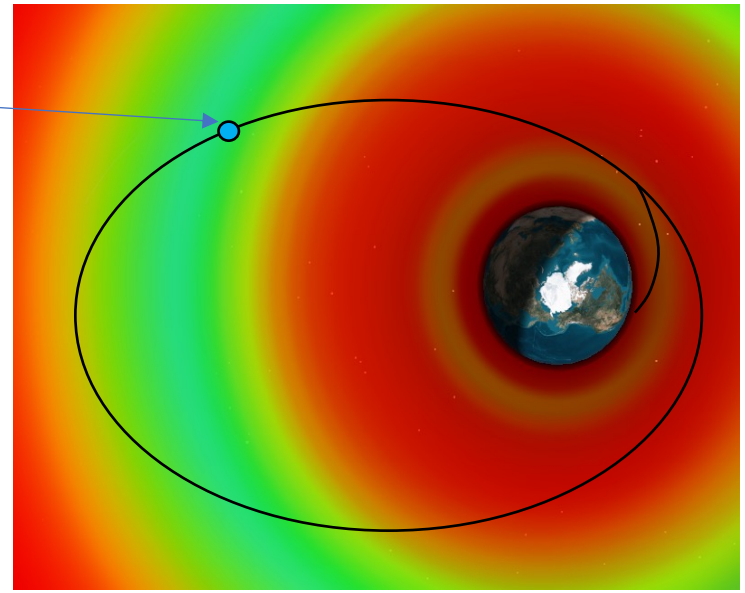
Orientation mode (T+8

- Basic attitude control
- Approx. T+ 8.5 hours from deployment
- Approx. Altitude: 250 km
- Enter orientation mode
- Ideal communication altitude
- Attempt UHF communication

Setting up communication in orbit

Active mode (Second orbit T+32hours)

- S-band TX(115min per orbit)
- Attitude control with CMG or momentum wheel (30min per orbit)
- Surface charge monitoring (60 min per orbit)
- Log data from SCM, gyro, accelerometer
- Camera usage (10min per orbit)
- UHF TX – 60min / RX – 11.5hr



Extended mission

- Check power, orientation, temperature and radiation status
- Take 1photo every 2hours
- 115 minutes of S-Band communication per orbit
- Transmit housekeeping data over UHF & S-band

Mission Success Criteria & Future Works

Mission Success Criteria

- Testing and validation of OF-4 payloads and systems pre-launch
- Successful reception of data and image from OF-4 at apogee
- Restore and validate data acquired from OF-4 by Ground Station located at El Paso, TX.
- Survive and continue extended mission in GTO for at least a month

Future works

- Stakeholders requirements Analysis
- Develop In-house design, fabrication, and testing methods
- Test & Validate Satellite Performance

Thank you!

Participating Live Q&A Panel on Thursday, April 29th at 11 AM Pacific Time