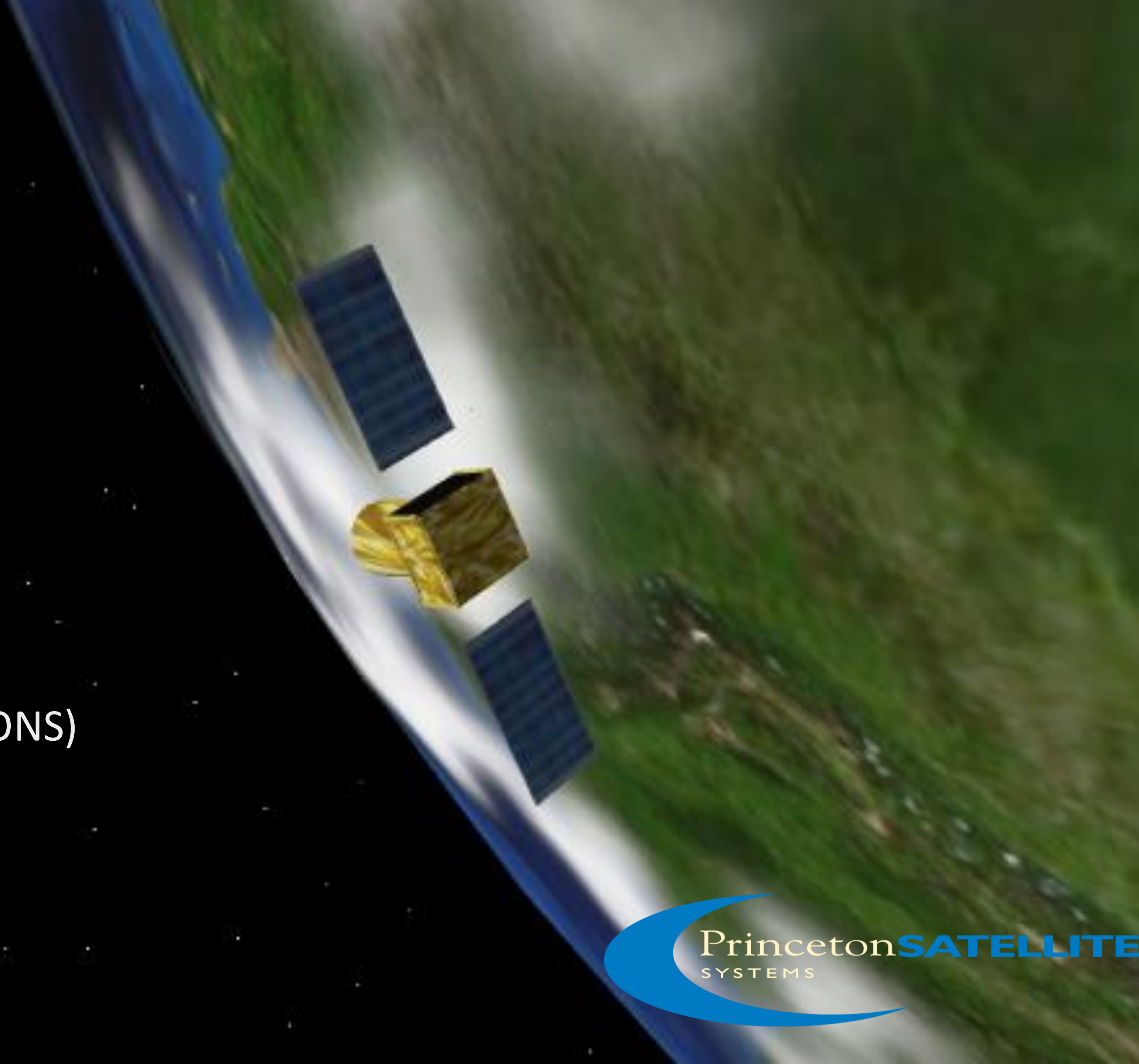
Princeton Satellite Systems

Optical Navigation System (ONS)



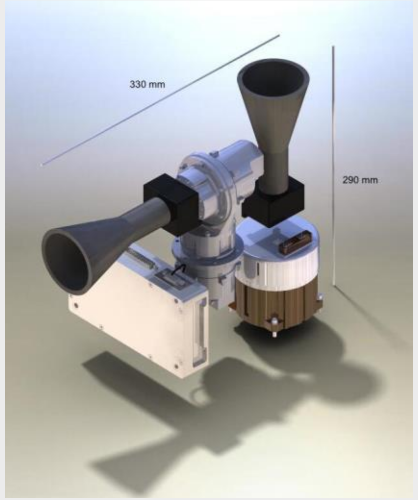
PrincetonSATELLITE SYSTEMS

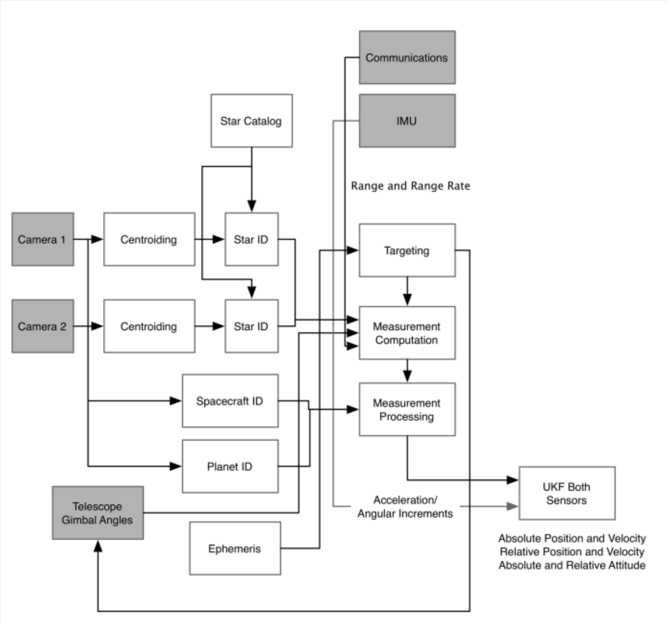
Summary

- Optical Navigation System SBIR (NASA)
- Precision Attitude Control System SBIR (Army)
- New developments
  - ONS simulations for Cis-Lunar operations
  - New sun sensor for deep space operations
  - ONS simulations for a Pluto Orbiter mission
- Proposed test mission
  - Support Army PACS
  - Demonstrate ONS
  - Host Earth-resources sensors

Optical Navigation System SBIR

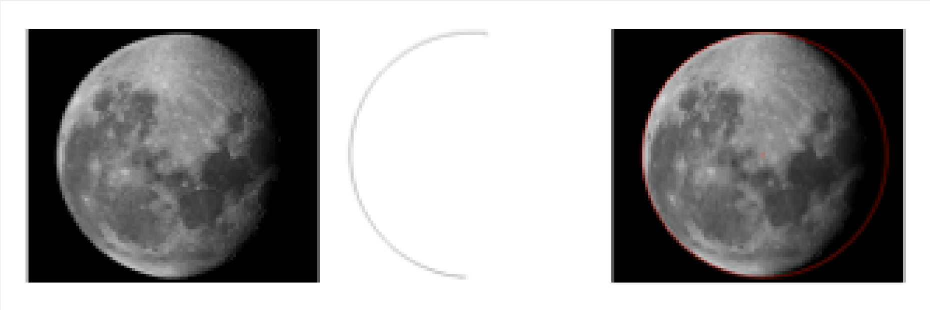
- Optical navigation
- Unscented Kalman Filters
  - Employs nonlinear dynamics and measurement models
  - Not necessary to compute derivatives of the dynamics or sensor models
- Two telescopes
  - One articulated to image planets
  - One fixed to measure the star field
  - Simultaneous position and attitude estimation
  - Moog double gimbal
  - Fiber optic IMU



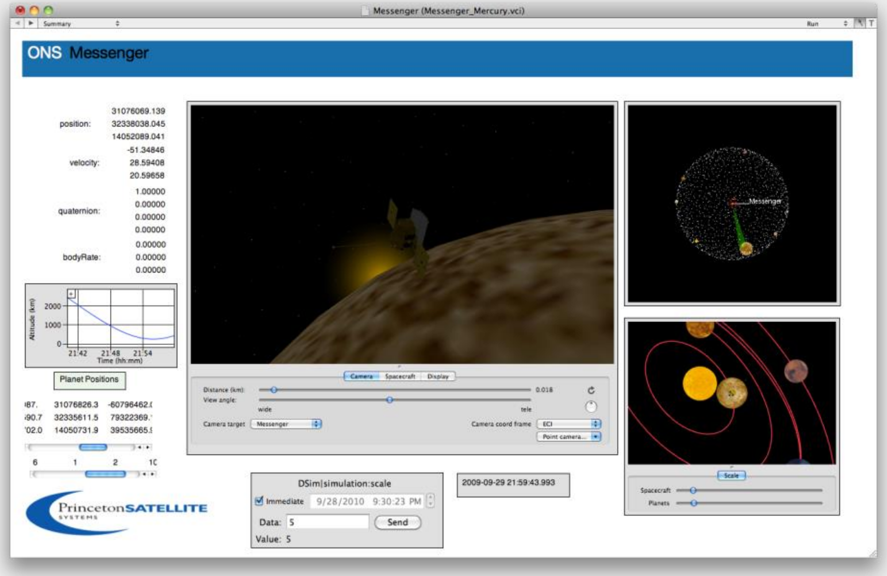


Deep Space Operations

- Focus of Phase II was deep space
  - Replace Deep Space Network
- Simulated Pluto and Mercury missions
  - Major difficulty is using planetary targets
  - Geometry is often poor
  - Ephemeris knowledge is only good for the inner solar system
- Need a new sun sensor
  - Measure distance from the sun accurately
  - Still need planetary sensor for target approaches



Shape detection for chords
Red arc shows fit



Precision Attitude Control System

PrincetonSATELLITE SYSTEMS

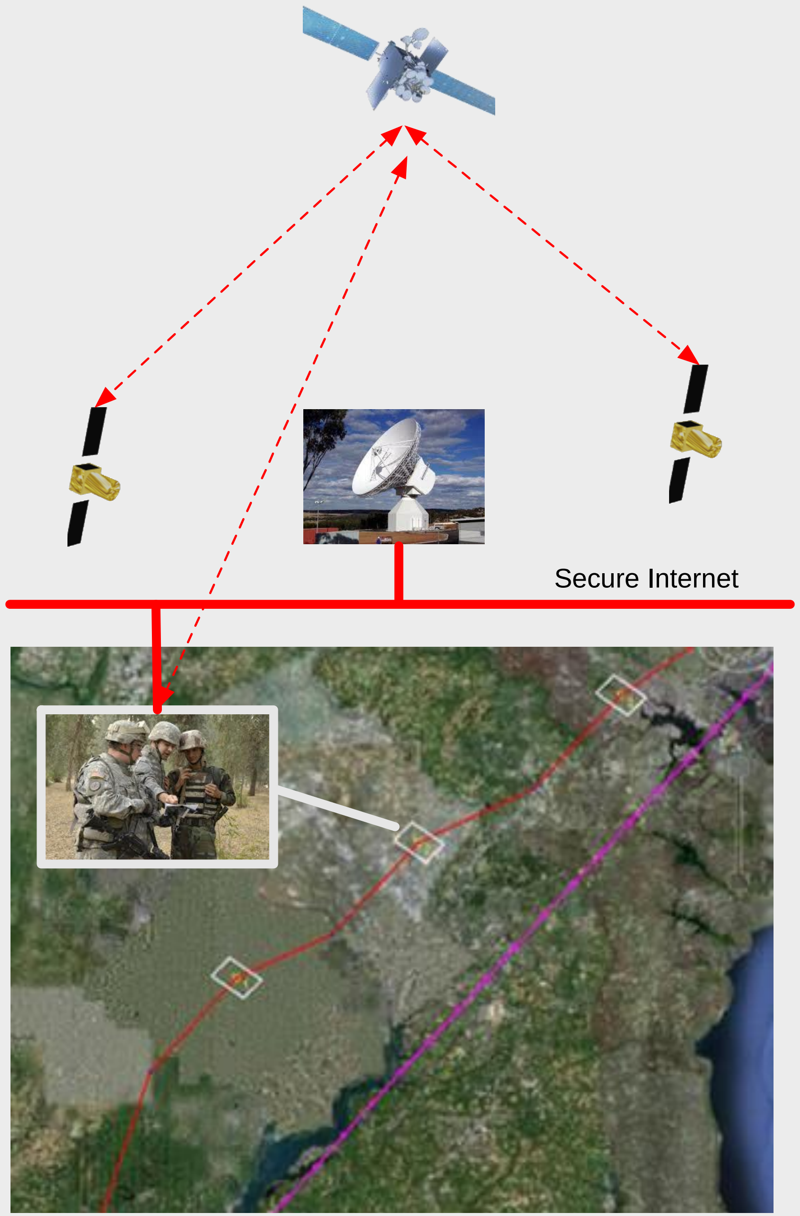
- Army Phase II SBIR
- Precision satellite pointing for small satellites
- Track a target on the ground more accurately than any other system -- at the same price point as conventional systems
- Better performance
- Applicable to wide range of military and commercial space applications
- Based on over 35 years spacecraft experience
  - MIT: Electrothermal Hydrazine Thruster research, Hall Thruster research
  - CSDL: Space Shuttle Orbiter On-Orbit Digital Autopilot
  - GE Astro-Space: GPS IIR ADS, Inmarsat-3 ACS, GGS Polar ACS, satellite launch teams
  - PSS: GPS IIR, Indostar-I/BSat 1, 2, TDRS H,I,J, Prisma Rendezvous Robots

PACS CONOPS

Army Kestrel Eye Concept

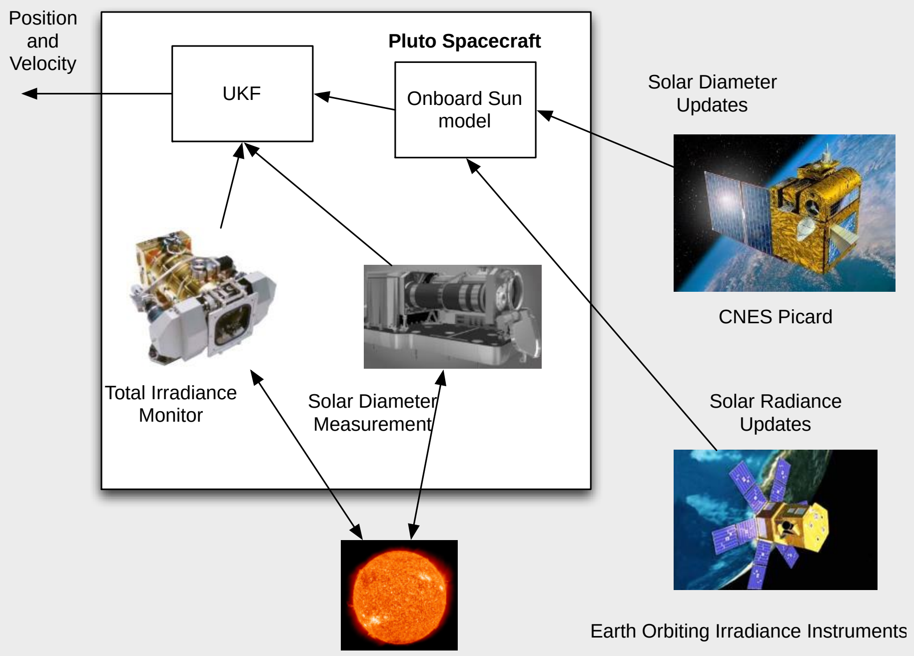
- Microsatellite-class imagery satellite for tasking by the tactical ground component Warfighter
- Requires very high ground location accuracy in a small package
  - Precision pointing and orbit knowledge
- Affordable, persistent presence
- On demand satellite data
- User makes requests through any Internet capable device

"A Kestrel Eye satellite constellation provides dramatically lower unit cost than typical space-based assets. With this low cost, large numbers of satellites can be procured enabling the system to be dedicated to the tactical Warfighter."
-- **USASMDC/ARSTRAT**



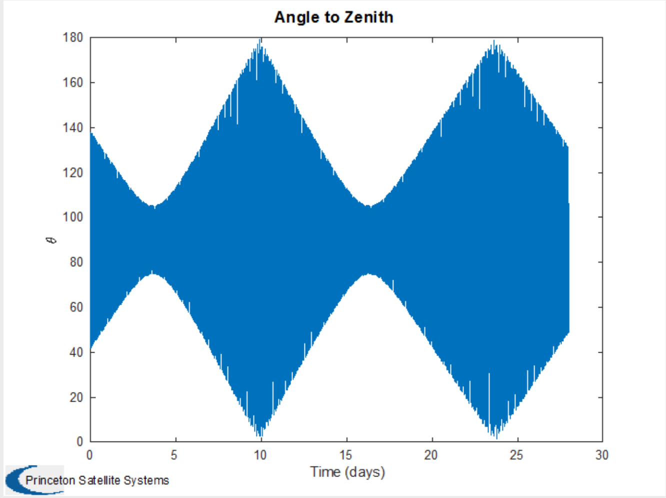
Recent Developments for ONS

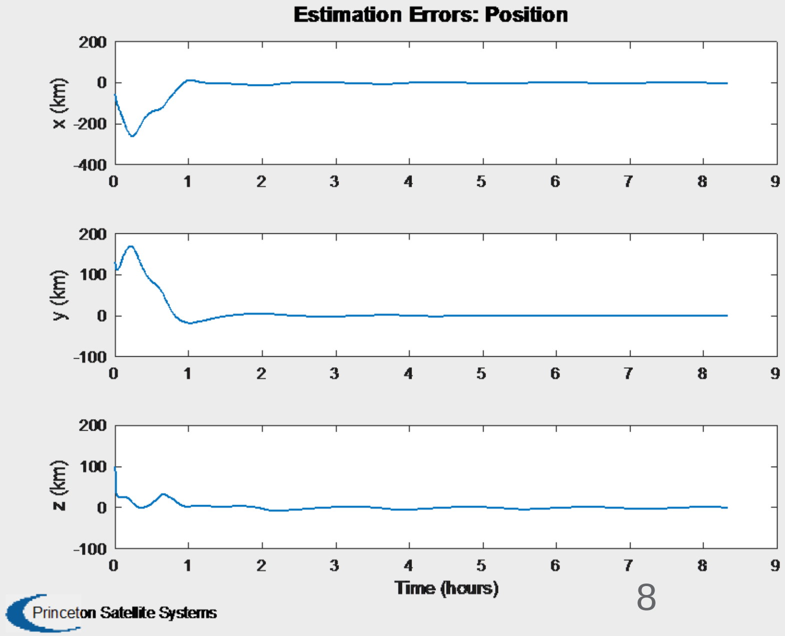
- Conceptual design of new sun sensor
  - Bolometer for radiance and CMOS for solar disk
  - Combine as separate measurements in UKF
- Work in India
  - Customer using our MATLAB ONS algorithms for cis-lunar and Earth orbit missions
- Cis-lunar missions
  - Sun synchronous
  - Geo transfer
  - Lunar orbit
- Pluto Orbiter
  - Sun distance sensor
  - Planet measurement sensor



Cis-Lunar

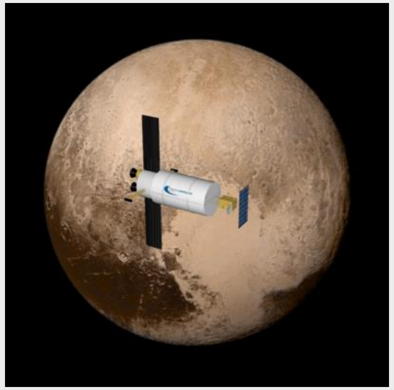
- Simulation in sun-synchronous orbit
  - 600 km altitude, e = 0
- Tracking moon and stars that are near the moon
  - CMOS sensor can see 4th magnitude stars and the moon
- Update measurements when the moon is visible
  - Angle of moon with respect to the boresight shown to the right

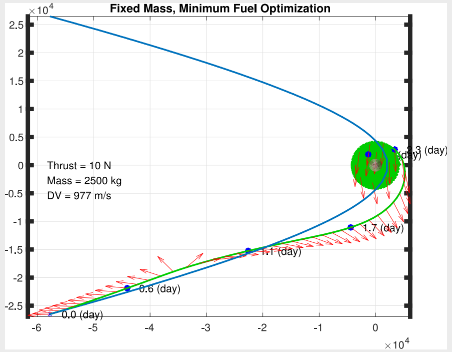


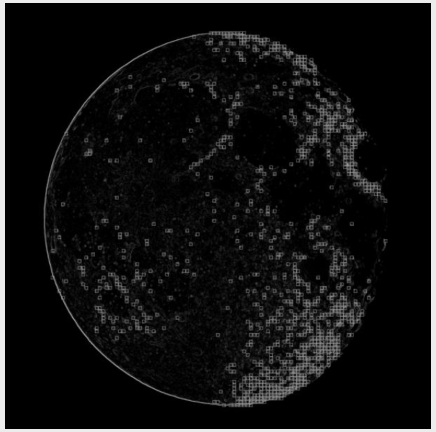


Pluto Orbiter

- Nuclear fusion rocket research
  - Supported by two NASA STTRs and a NIAC Phase II
  - Teaming with PPPL and MIT
  - Compact fusion reactor from 1 to 10 MW
  - Provides power and propulsion
- Spacecraft reaches Pluto in 4 years
- Use new sun sensor for interplanetary navigation
- Second camera for Pluto approach
  - Orbit insertion shown on right
  - Landmark tracking for Pluto orbit navigation
    - Landmark corner detection shown on right

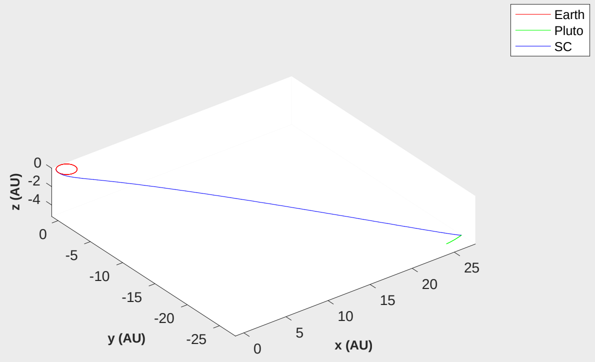


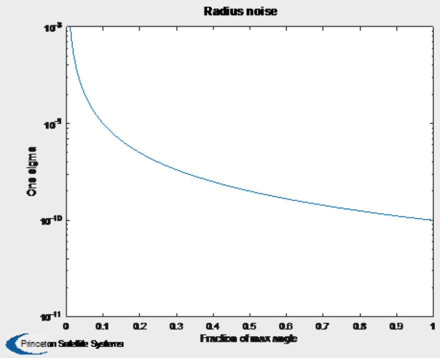




Pluto Orbiter Navigation

- Trajectory found by optimally varying acceleration
- Spacecraft reaches Pluto in 4 years
- Centroiding algorithm noise varies with distance from the target
  - Image spread over fewer pixels
- Sun sensor alone reduces the mean position error by 43%
  - Combines radiance and sun radius measurements
  - 800 km error at Pluto in the heliocentric frame





PACS/ONS Test Mission

This mission will provide on demand multi-spectral imaging from two satellites.

Precision Pointing Agile Satellites

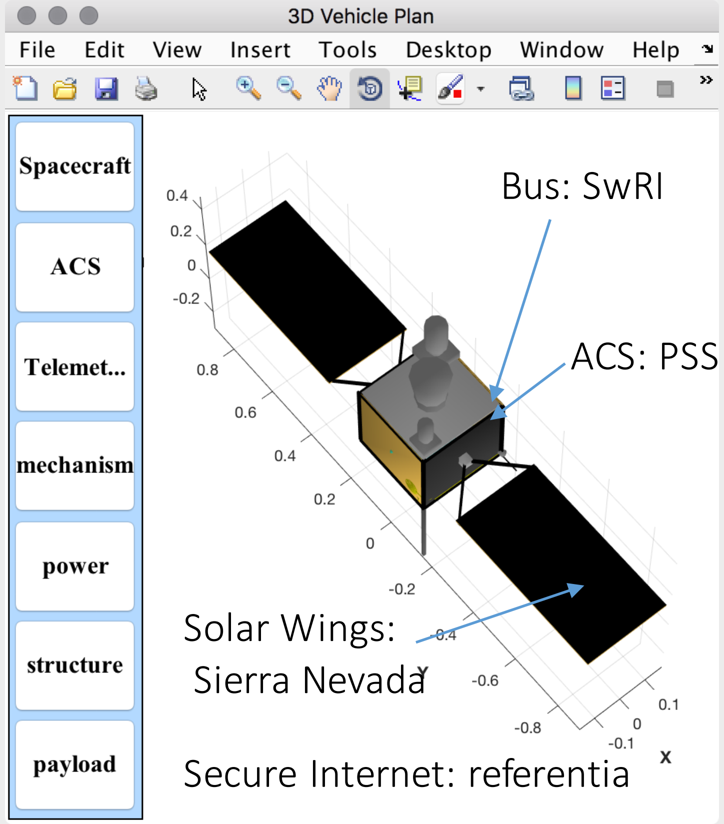
- Take multiple images per orbit based on ground user demand
- Any Internet connected user can request and receive images
- Visual, near and far infrared images

Two satellites in Sun-Synchronous Orbit

- Launch in 2020 on a SpaceX Falcon 9 mission
- Communications over Ka-band network
- High data rates for rapid image download
- 500-600 km altitude
- Can coordinate imaging from both satellites
- Secure communications
- Optical navigation test (NASA)

Applications

- Ground water measurements
- Fire detection (FireSat)
- Multi-spectral imaging



Princeton SATELLITE SYSTEMS

POC information

- Dr. Gary Pajer
- 6 Market Street, Suite 926
- 609 275-9606
- gpajer@psatellite.com
- www.psatellite.com