

TSAT Globalstar ELaNa-5 Extremely Low-Earth Orbit (ELEO) Satellite

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Globalstar, Inc.



also students Joel Kiers, Josh Kiers, and Kayla Cross

See Reference section for student publications

TSAT Review Objectives

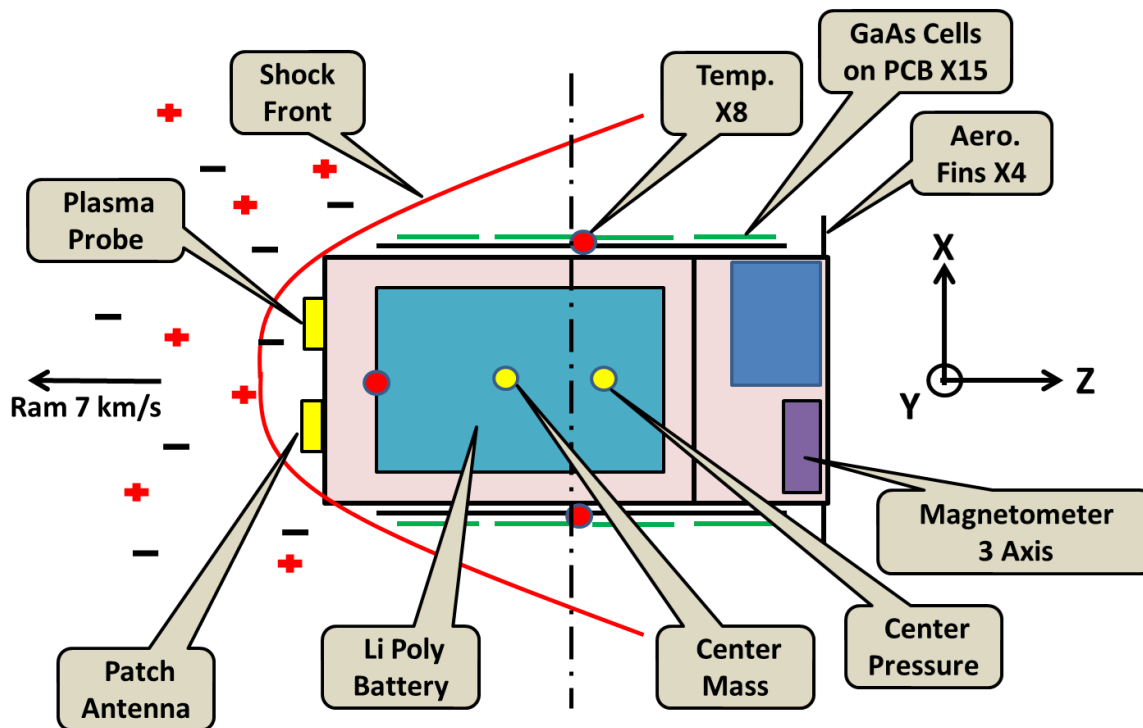
- Test Globalstar network for Small Sats
- Education
- Explore Extremely Low Earth Orbit (ELEO)
Ionosphere 325 km to 110 km
- Plasma Density ELEO data

Talk Outline

Hank Voss on TSAT Preliminary Results

Jeff Dailey on Globalstar Communication Network Details

TSAT Concept Diagram



TSAT details in Small Sat AIAA paper proceedings SSC14-WK-6, Also NSL at Booth 117 - Hardware

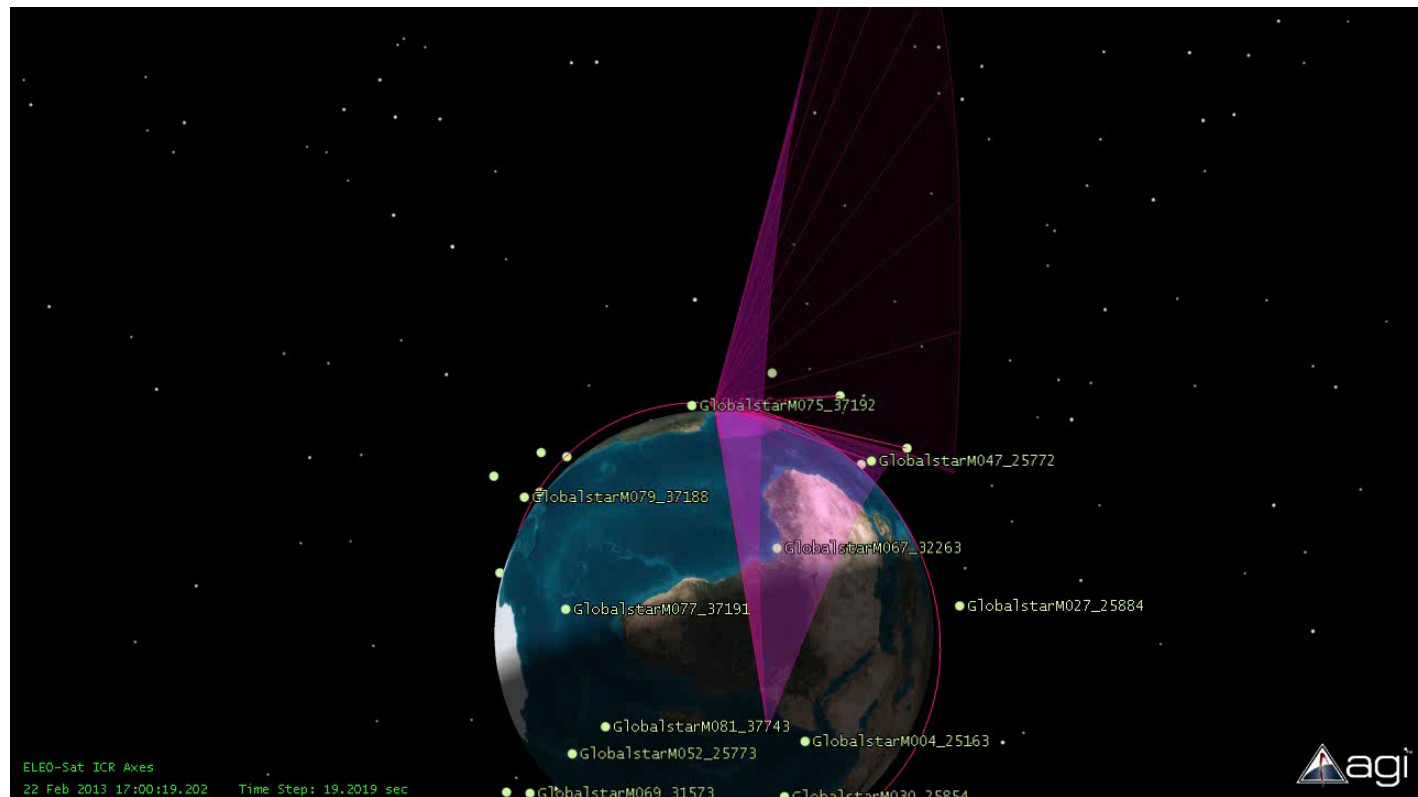


TSAT is a 2U Cubesat launched April 18 on Space X to 325 km orbit

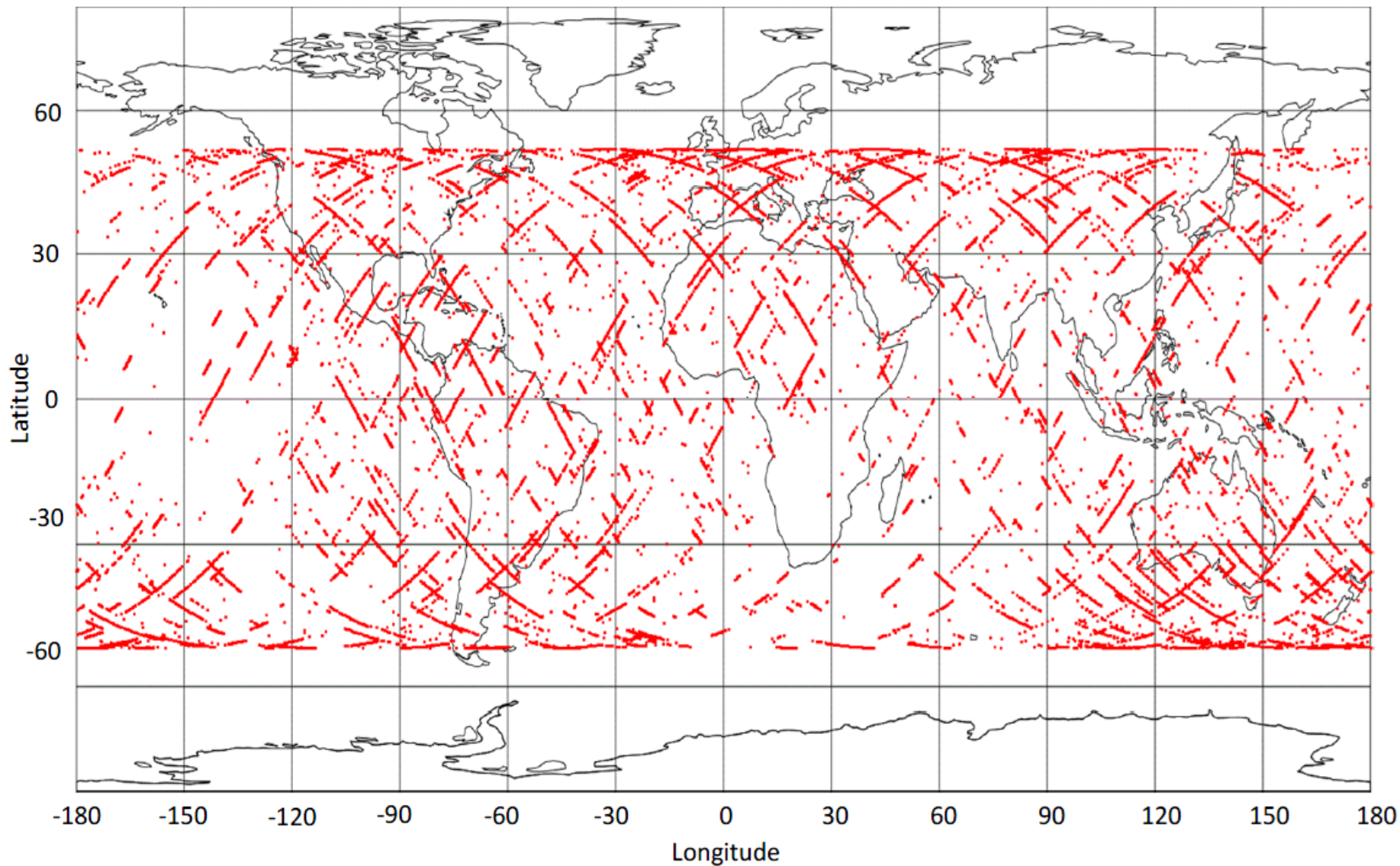
Globalstar with EyeStar Radio Simulations

(“*Bent Pipe*” distributed data downlink)

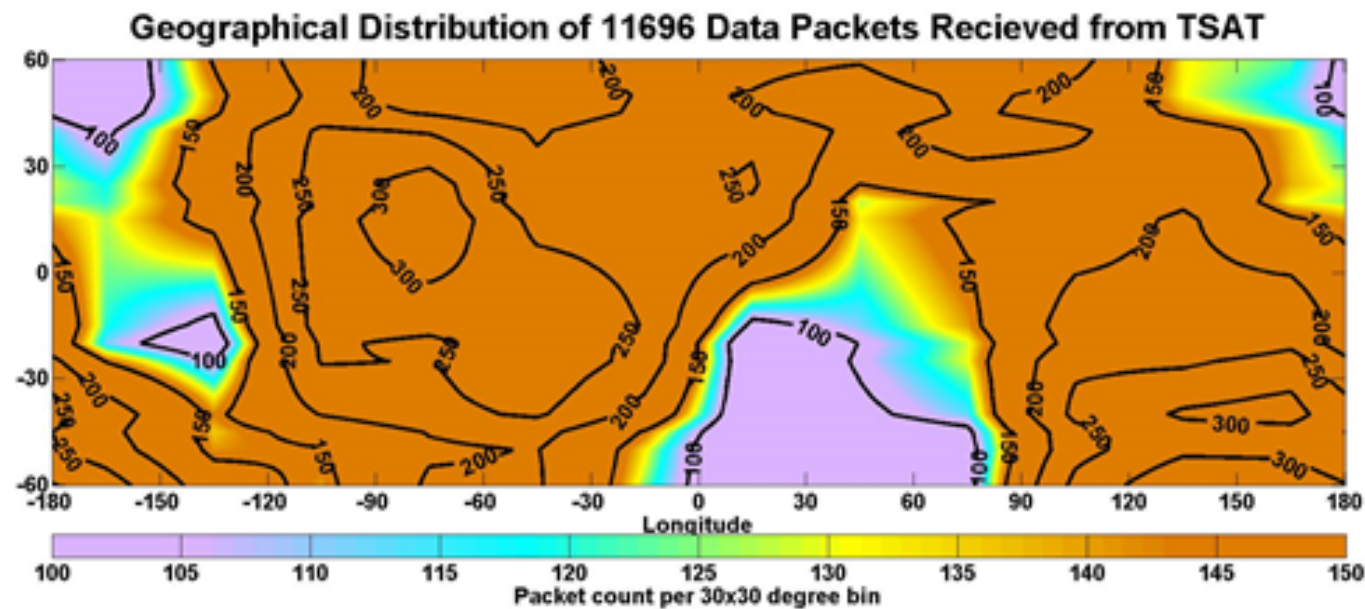
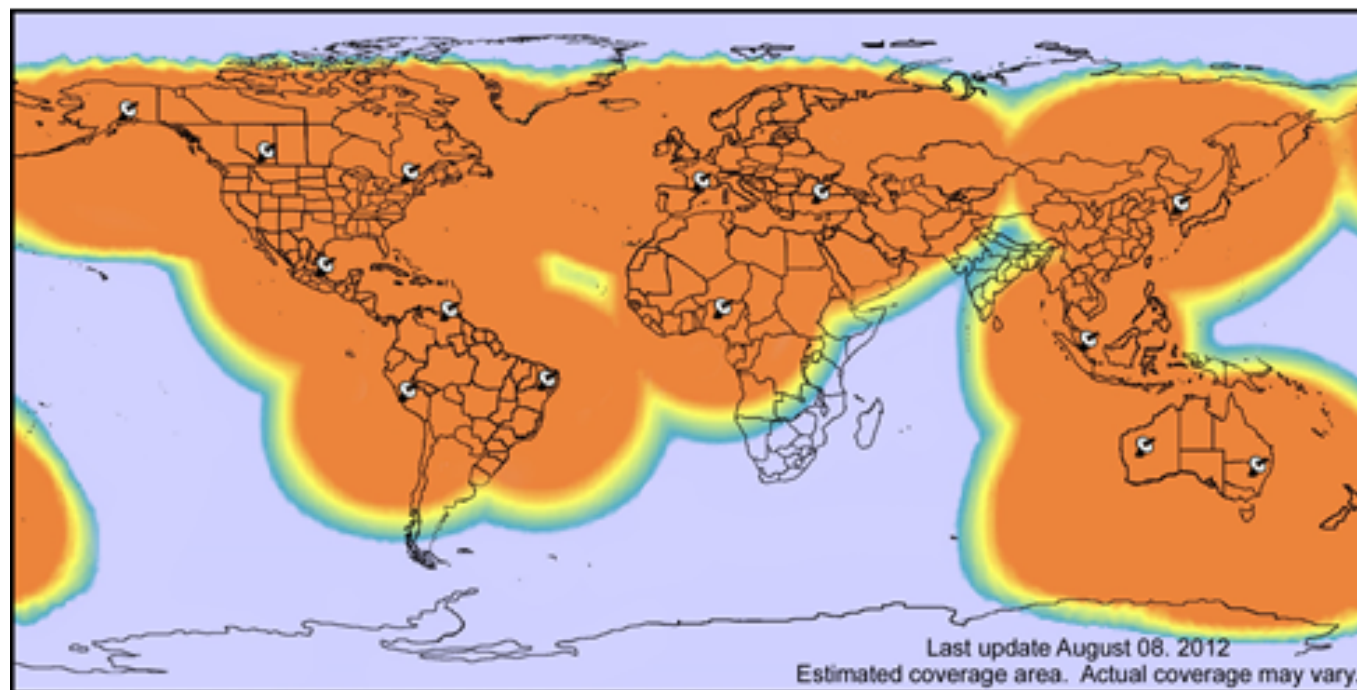
- \$2B satellite constellation at 1414km (terrestrial use)
- Commercial Research Grade link and FCC license
- Low latency near real time global data and command
- 1.61625 GHz Simplex TSAT transmitter/patch (170 deg.FOV)
- 1.6 GHz & 2.4 GHz band Duplex CDMA transmit/receive patch
- No need for conventional client Ground Station cost &time



TSAT Data Packet Distribution for 11696 Received Data Packets



Beacon Cycle: 32 beacons (Five second interval), 15 minute off dwell



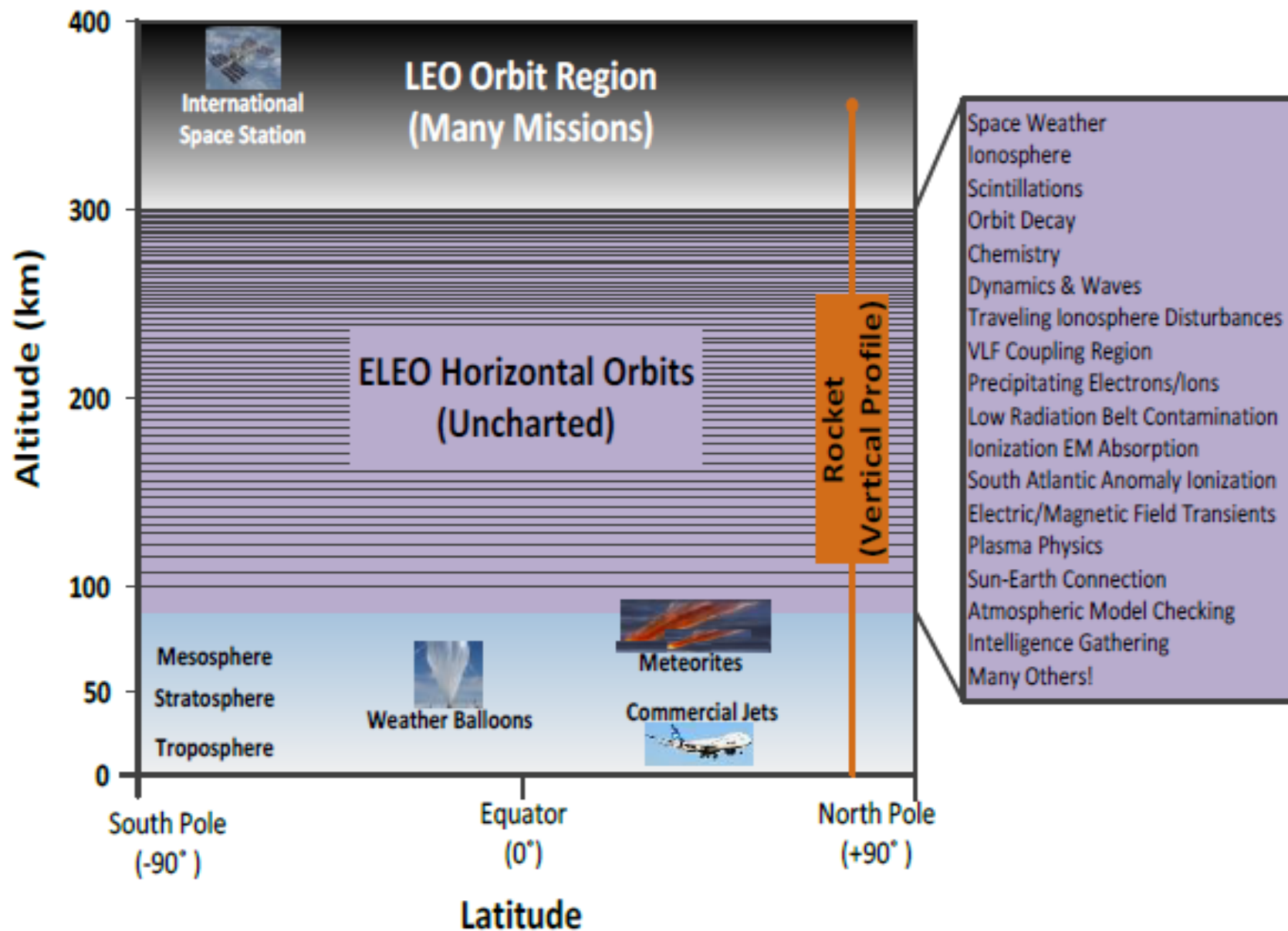
TSAT
1M Byte data
Power limited

Figure 7: Comparison of Globalstar projected coverage and normalized TSAT results

Globalstar Link Features

- Cubesat-to-Globalstar link demonstrated by TSAT, 2014
- Downlink cubesat data anywhere at any time
- TSAT first data IP 11s after turn-on over South Pacific
- Command Cubesat anywhere at anytime
- Frequency selection to avoid Radio Astronomy EMI
- Unified Cubesat Constellation Database
- NSL Single Point of Contact for Globalstar (NSL is Value Added Reseller, VAR, for Spaceflight and High Altitude Balloons, cost \$1000 EU to \$10,000 Flight)
- All satellite success with beacon/GPS on G* beacon

ELEO Exploration



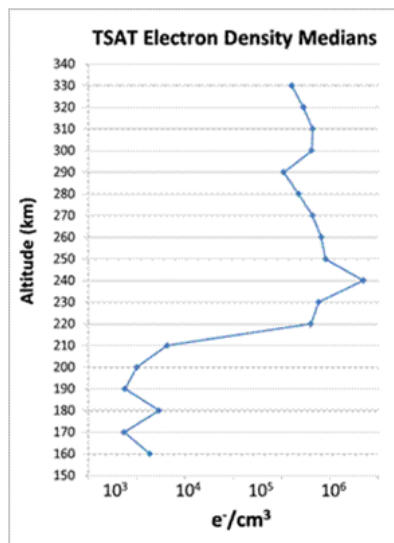
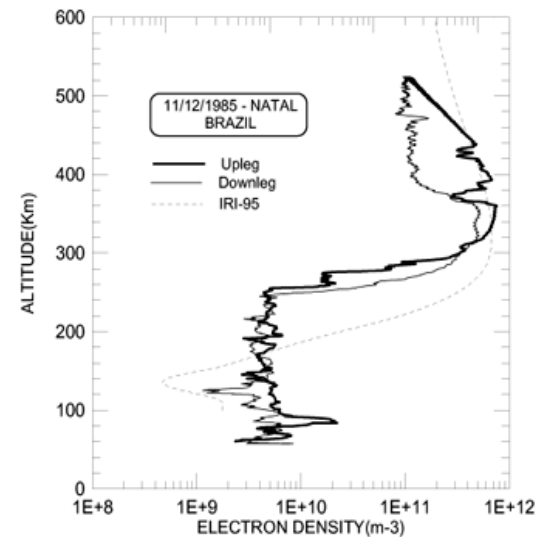
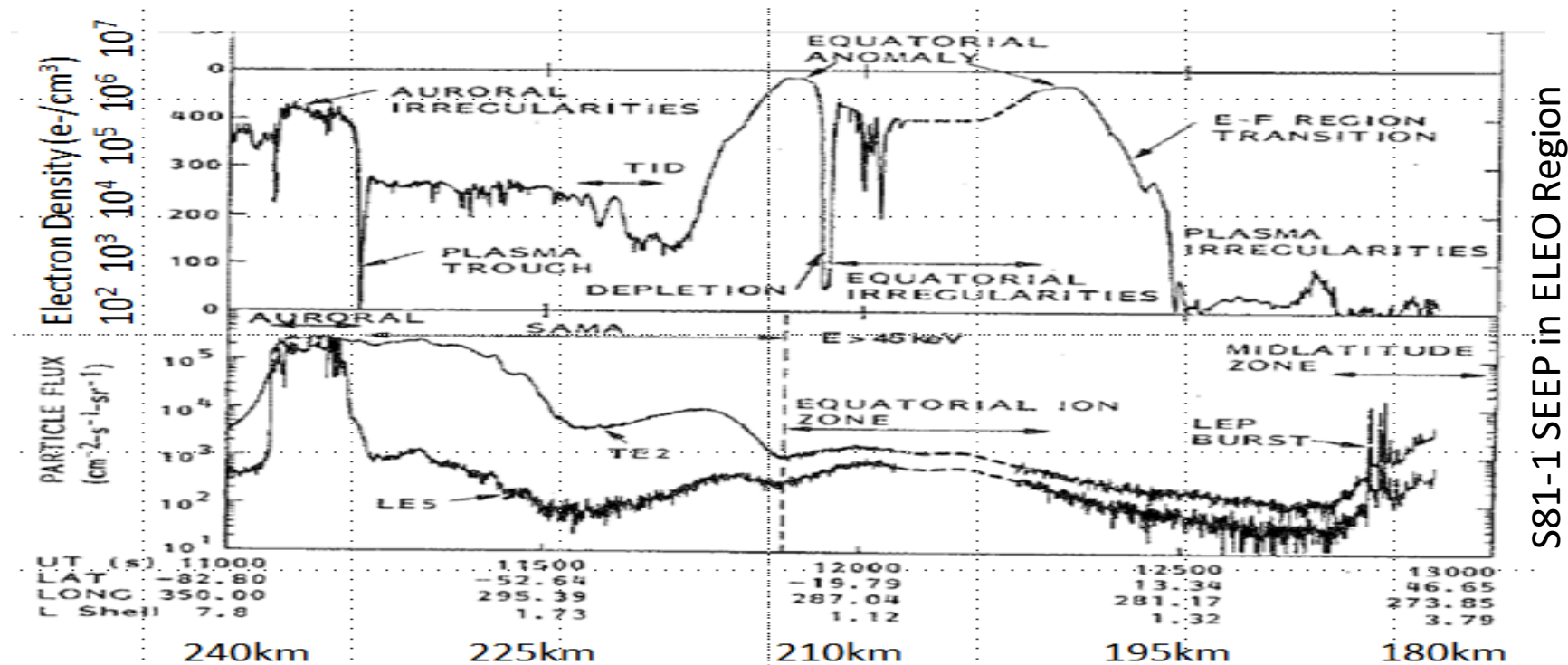


Figure19: Mission medians of electron density for various orbit altitudes (10km bins). The

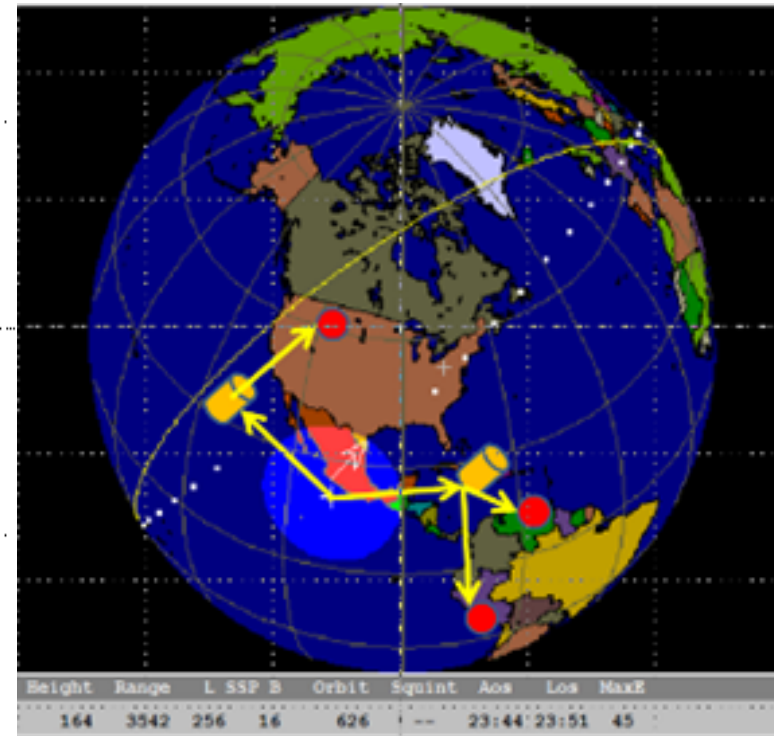
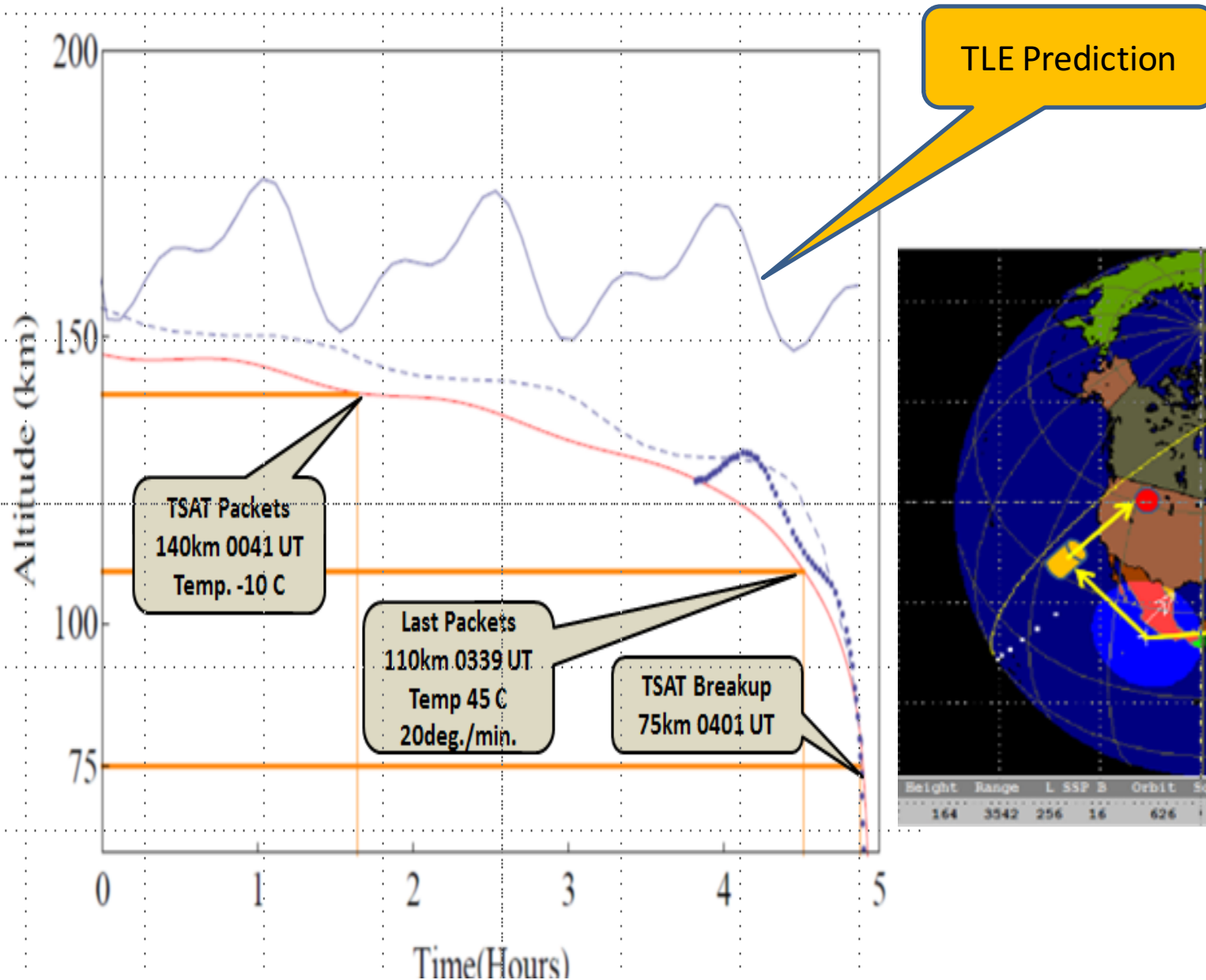


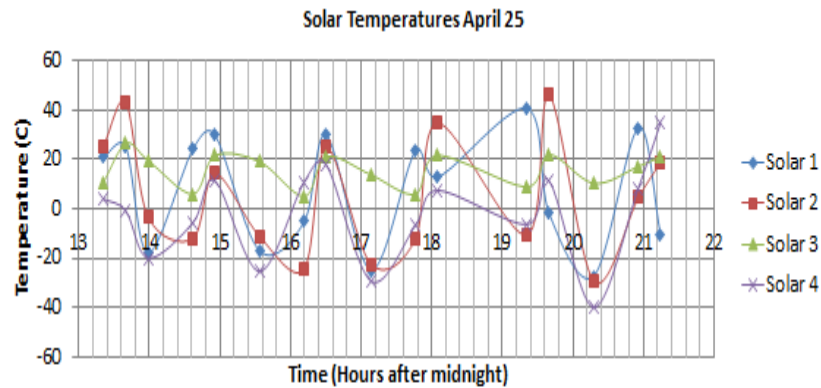
Rocket: Muralikrishna and Abdu, Adv. Space Sci. 2006



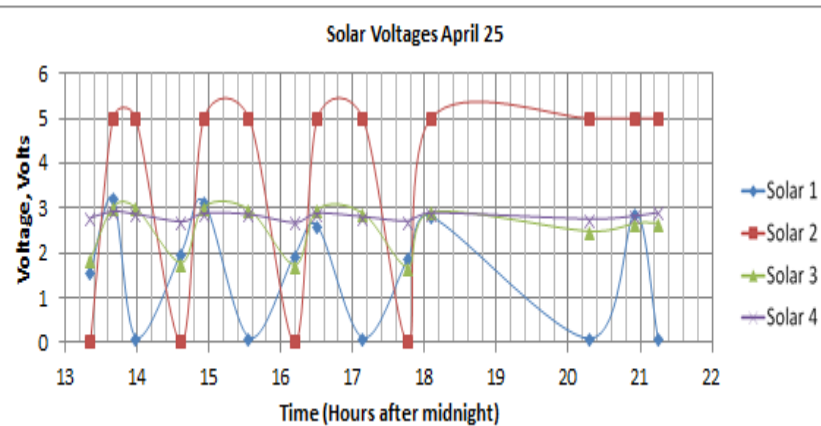
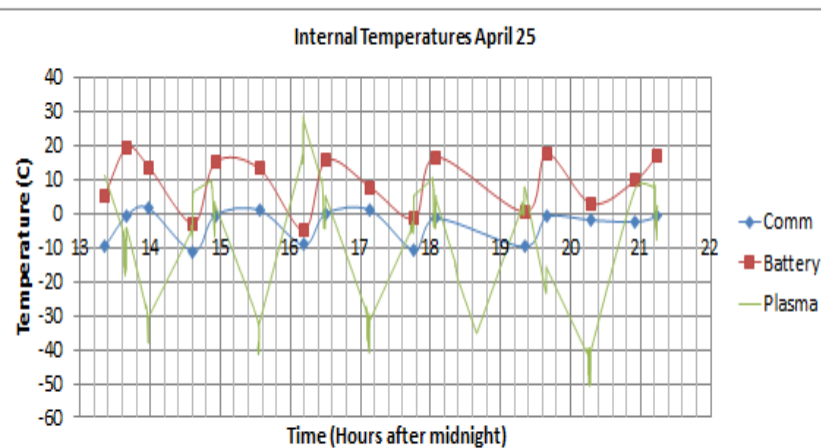
S81-1 SEEP in ELEO Region

TSAT Reentry and Predictions





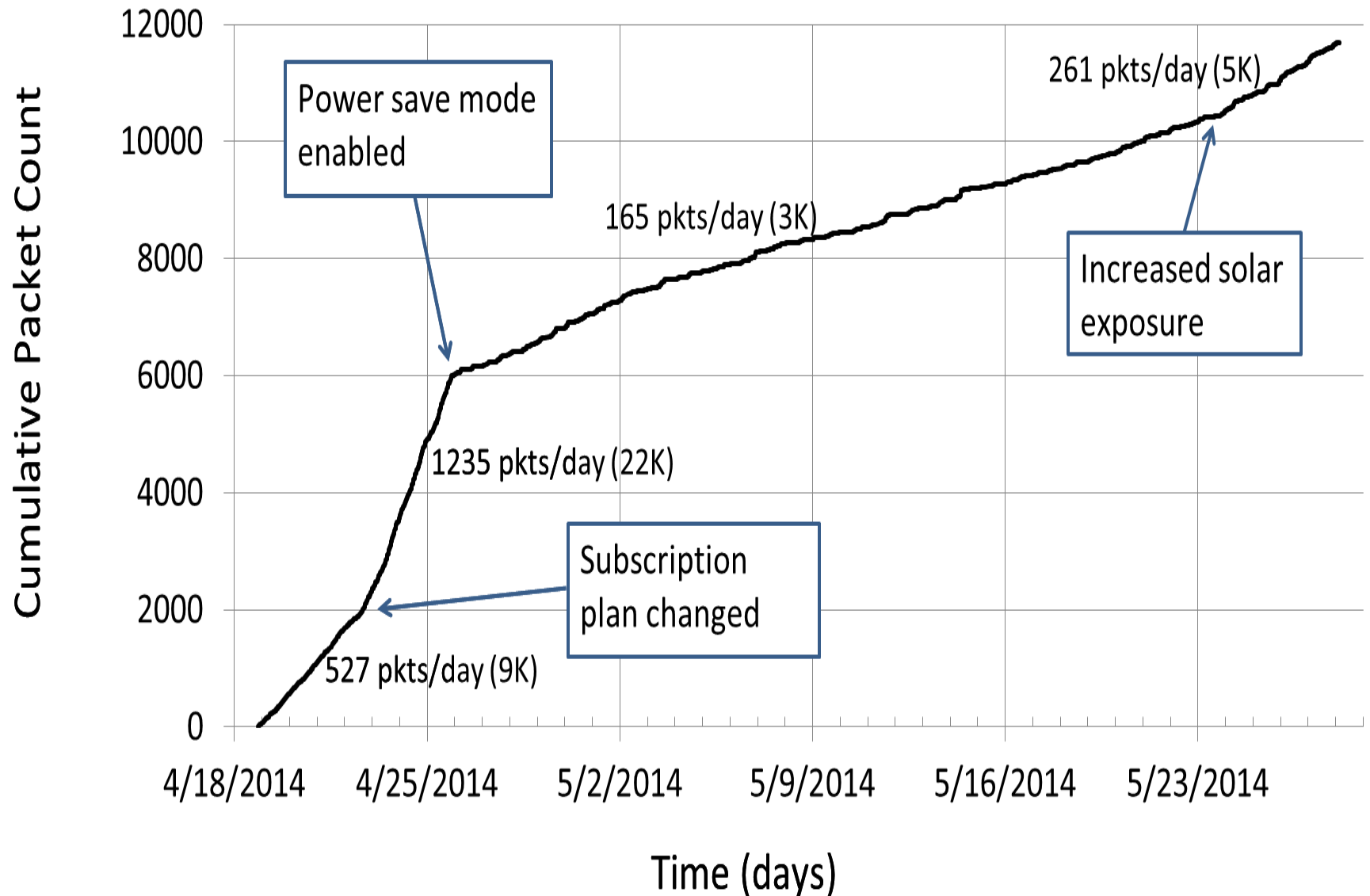
- Satellite Solar Illumination,
- Internal and External Temperatures,
- 3-axis Magnetometer



No Dead Zones
No Lost Data

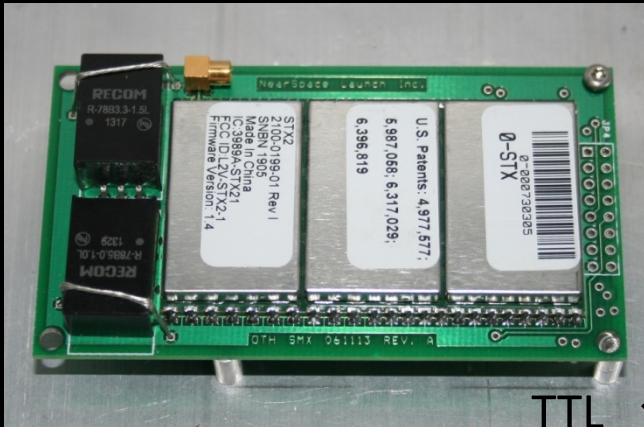
TSAT Data Packet Rate

Data Cost: \$3000
for 40 Days

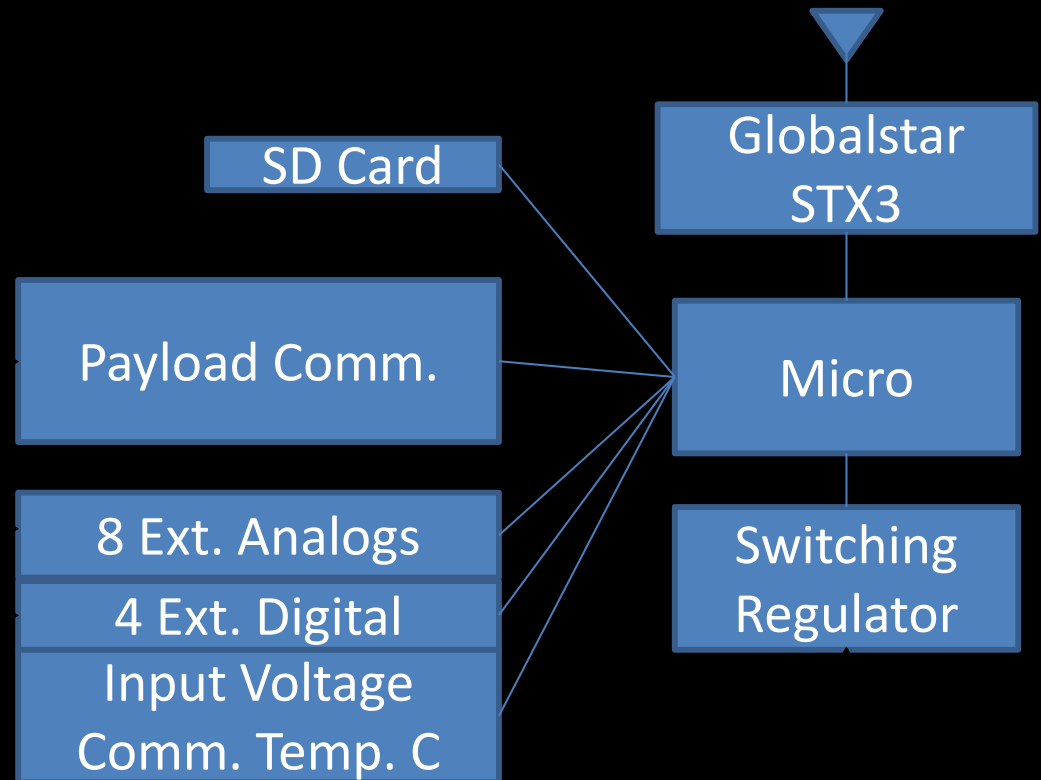
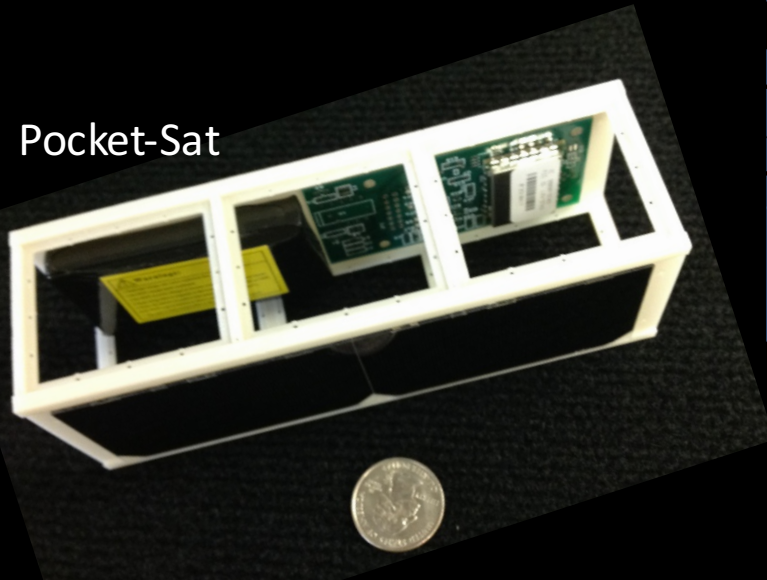


EyeStar Simplex Transmitter Product

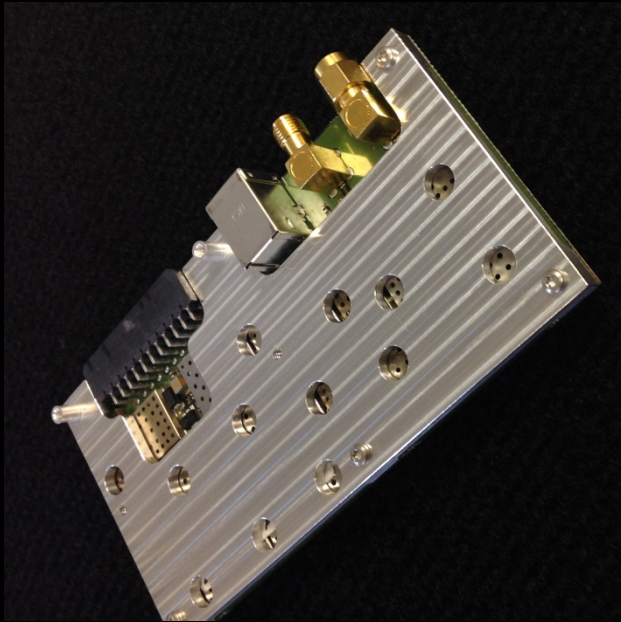
8x2x0.6 cm, 200mW ERP, 38 Byte/s



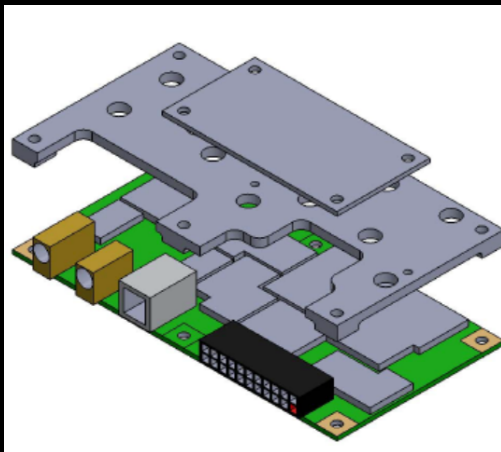
Pocket-Sat



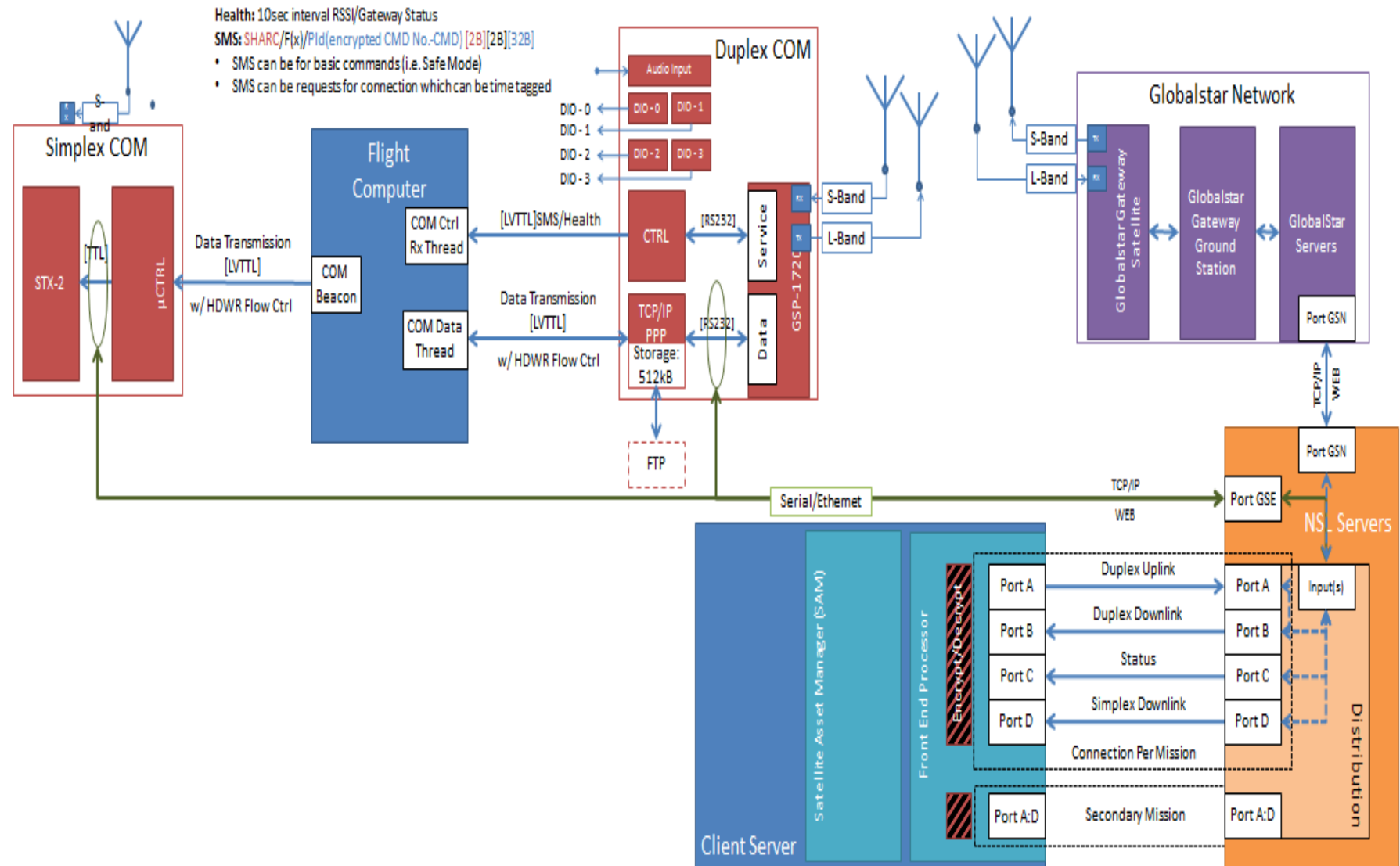
SAT Duplex Transceiver Product



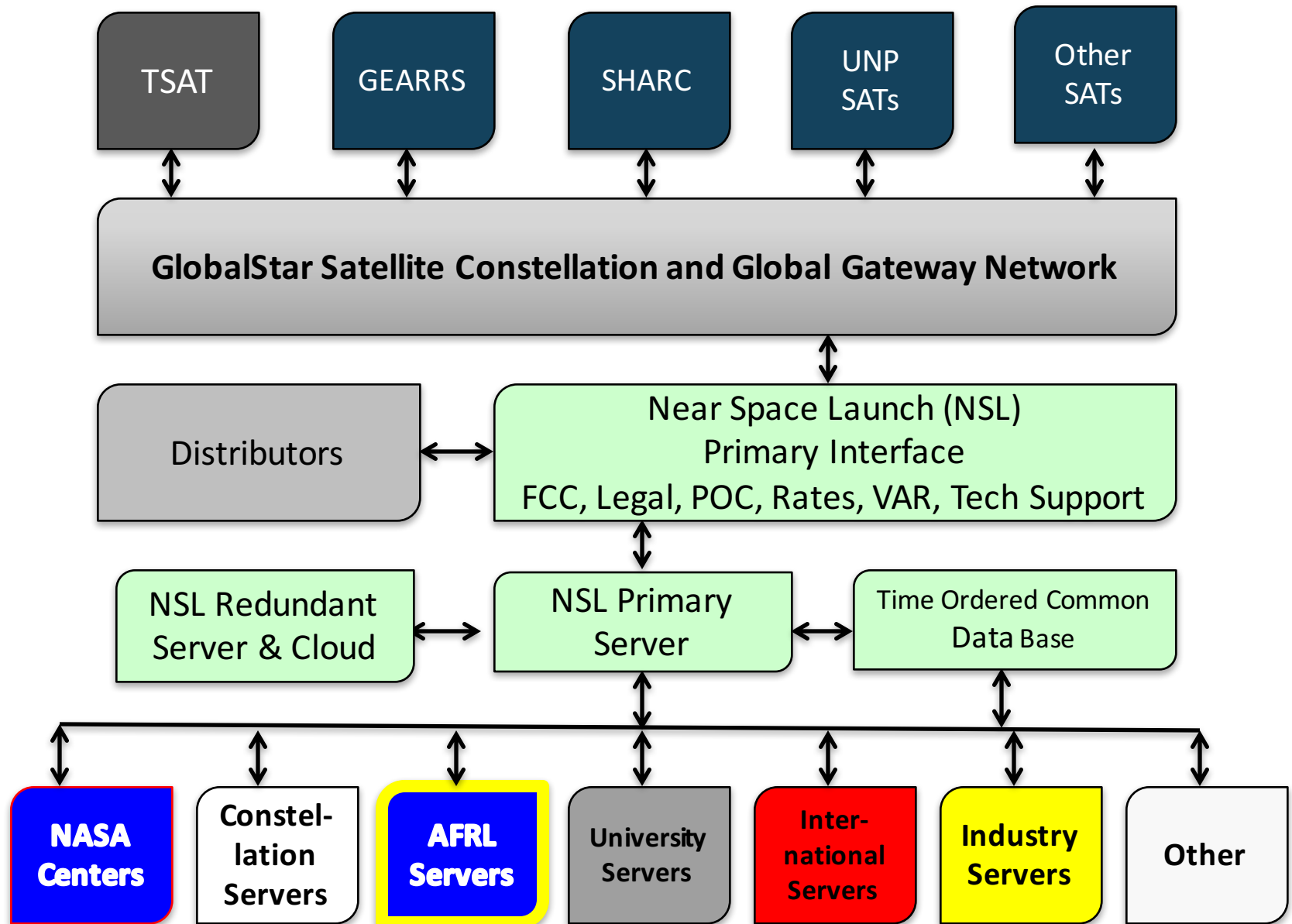
- Up to 7000 baud data rate
- Data and Command Control
- TCP-IP software
- Handshaking protocol
- Active patch antenna (6 cm)
- ARM Processor
- 1 Watt ERP
- 3.3 & 5 V, 5W input power
- Size 6.1 X 11.9 X 11.9 cm
- CAD, ICD, Support, License



SAT-NSL-Globalstar-NSL-Client Data Flow



Satellite-Globalstar-Server Data Network



Spacecraft

ELEO-Sat

Starboard
Zenith
Ram

Solid State Detectors

Deployable Solar Tail

NSL EPS

Aerodynamic Channel

EPSILON Drive

Langmuir Probes

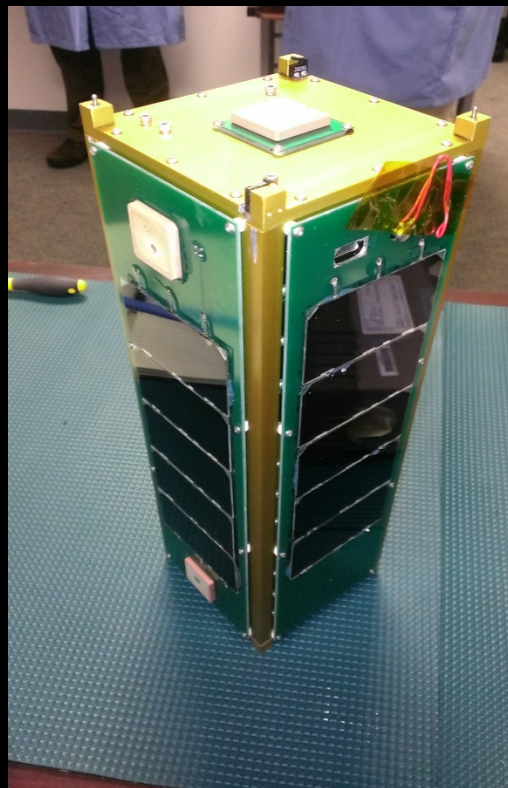
VLF and E-field Probes

COTS Magnetometer

Externally Stowed Booms

Global Star
Communication Modules

300 – 450 km
55° - 90° Inclination

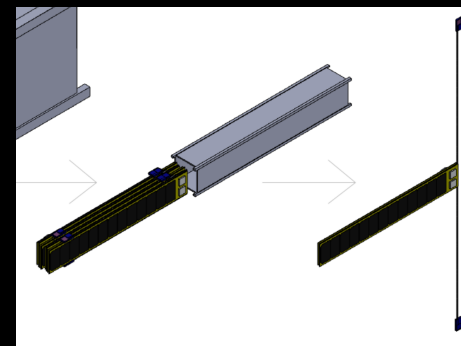


3U AF GEARR SAT, 2014
Globalstar, Plasma, Other



2U TSAT-EIaNa-5, 2014
Globalstar, Plasma, Reentry

3-6 U Aerodynamic THIN SATs,
Globalstar, Plasma, Particles,
Waves, 2 booms, Other



6U AF ELEO SAT, UNP-8
Globalstar, Plasma, Particles,
Waves, 4 booms, Other

NSL Space Flight Upgrades of Globalstar Modems

- FCC Cubesat-to-Satellite commercial license
- Firmware modem changes for spaceflight
- Processor board and software for data interface
- TCP-IP processor software to modem
- Thermal, vacuum, and EMI modem shield
- Radio astronomy frequency avoidance
- GSE bypass of Globalstar network for testing
- Burn-in and Testing, Conformal Coating
- Globalstar VAR POC for modifications
- Certified for Spaceflight

Student Published Papers on TSAT:

- McClure, Dan, Seth Foote, and Hank D. Voss, ***TSAT Solid State Detector and Plasma Probe Particle Detectors***, 2013 Illinois/Indiana-ASEE Section Conference Proceedings, Trine University, Angola, IN. <http://ilin.asee.org/2013/>, April 6, 2013
- Orvis, Matt, Kevin Seifert, Jeff Dailey, ***TSAT VLF and Electric Field Sensor on Boom System***, 2013 Illinois/Indiana-ASEE Section Conference Proceedings, Trine University, Angola, IN., <http://ilin.asee.org/2013/>, April 6, 2013
- Lew, David J., Jacob L. Baranowski, Richard Min, ***TSAT Student Flight Processor and Ground Support Equipment***, 2013 Illinois/Indiana-ASEE Section Conference Proceedings, Trine University, Angola, IN. <http://ilin.asee.org/2013/>, April 6, 2013
- Kilmer, Adam and David Boyajian, ***Thermal and Ultraviolet Modeling, Balancing, and Sensing***, 2013 Illinois/Indiana-ASEE Section Conference Proceedings, Trine University, Angola, IN., <http://ilin.asee.org/2013/>, April 6, 2013
- Emison, J., Yoshino, K., Straits, S., and Voss, H. ***Satellite Design for Undergraduate Senior Capstone.***, Paper Presented at ASEE National Conference proceedings. Indianapolis, IN., June 2014

Other Acknowledgements:

Thanks to the students, faculty, staff, and Administration who worked many volunteer hours to make TSAT successful. Many thanks to the Globalstar team for their patience and creativity in the work they did to implement the satellite to satellite links as a VAR product. Scott Higginbotham and Ryan Nugent for their efforts on the NASA ELaNa 5 program and launch. NASA INSGC Space Grant, the University Nanosatellite Program (UNP) for their funding of UNP-3 and UNP-8. AFOSR KAFB support for developing GEARRS to test the duplex and simplex radios on a very short three month time line.

Questions

- NSL Booth: #117 with Hardware, ICDs, CAD
- See TSAT Paper SSC14-WK-6 Proceedings
- Contact: Hank Voss or Jeff Dailey
 - NSL: Nearspace Launch Inc.
www.nearspacelaunch.com