Globalstar

TAYLOR UNIVERSITY

NSL: NearSpace Launch Inc.

Technology. Service. Education

Globalstar Communication Link for CubeSats: TSAT, GEARRS1, and GEARRS2

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NearSpace Launch Inc., 8702 E. 825 S. Upland, IN 46989

Three Cubesats launched within 15 months 2014-2015 using the Globalstar constellation of satellites for communication

- EyeStar: *Anywhere-Anytime, 24 hr / 7 days/week coverage*
- *Agile 1-3 month Delivery* (F-Bus Series)
- *No Ground Station resources required*
- *Fully Operational G* and NSL ground segment for data and display*
- *Globalstar Capacity for TT&C for 1000's of satellites*

  (9 to 700 Bytes/sec but data is transferred continuously)
- *Critical Piece for Mission Success*

Acknowledgements

- **Air Force Research Labs (Small Satellite Portfolio):** Systems engineering support, Funding, and Analysis
- **DOD Space Test Program:** Launch opportunity
- **NRO Office of Space Launch:** Launch opportunity
- **NASA INSGC and ElaNa 5 Program:** Launch opportunity
- **Students: Data Analysis and ASEE Publications**
  Joel Kiers, Stephen Papierski, Blake Wheeler, Andy Krock, Aaron Voss
- **Globalstar Management, Engineering, Marketing, and Legal**
- **Taylor University and NSL general staff**
  Dr. Bill Chapman, Nate White, Matt Orvis and Others

NSL EyeStar Development

2014

TSAT 2U

EyeStar Simplex

Space X Launch
ElaNa 5 325 km
40 day life

2015

GEARRS1 3U

EyeStar 2 Simplex
EyeStar Duplex
SMS Commanding

Orbital Launch, ISS
410 km, Bat. Life
DOD STP
Deployment Delay
Partial Mission Success

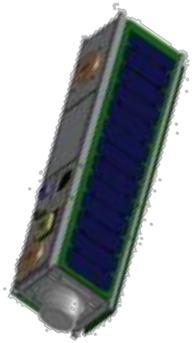
GEARRS2 3U 2015

EyeStar Simplex
EyeStar Duplex
SMS Commanding

Atlas Launch,
350X700 km, 1.5 yr.
DOD STP & NRO

2016

SHARC 5U



EyeStar Simplex
EyeStar Duplex
Commanding

3A Stable
ISS Launch, ~420 km
DOD STP

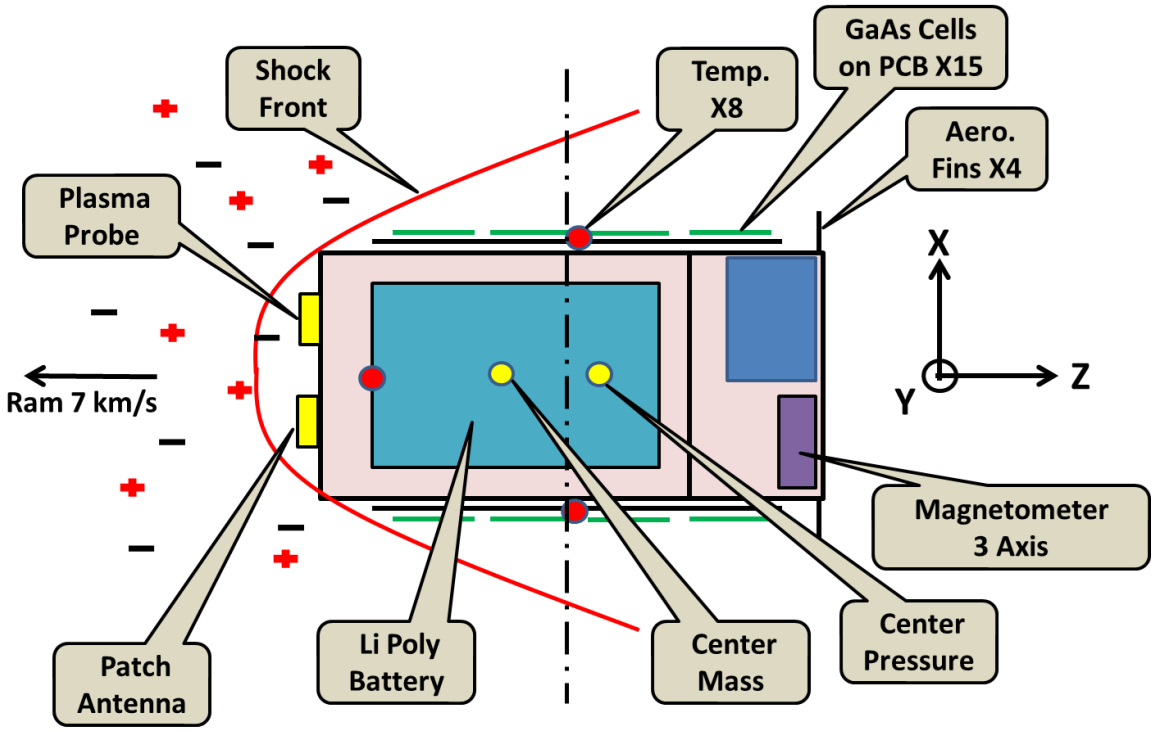
Other EyeStar Units Delivered, L2016+

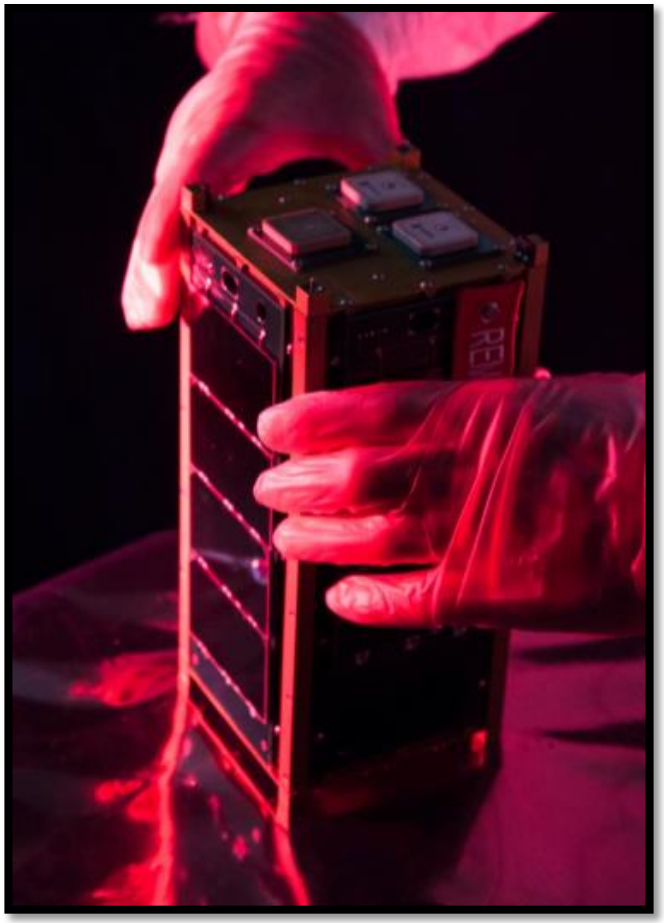
10+ Universities
NASA, AF, NSF,
Industry, Others,
25 units NSL Inventory

TSAT Results

TSAT Overview

TSAT Concept Diagram





TSAT details in Small Sat AIAA paper proceedings SSC14-WK-6, 2014, Also NSL at Booth - Hardware

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

- GlobalStar Constellation ($2B)
  - 32 plus LEO Satellites (1400 km)
  - Provides global data and voice services for
    - ~ 300,000 customers
- Used primarily for infrastructure/wildlife monitoring
  - Oil Rigs and Gas pipe-lines
  - Shipping Containers and Endangered animals

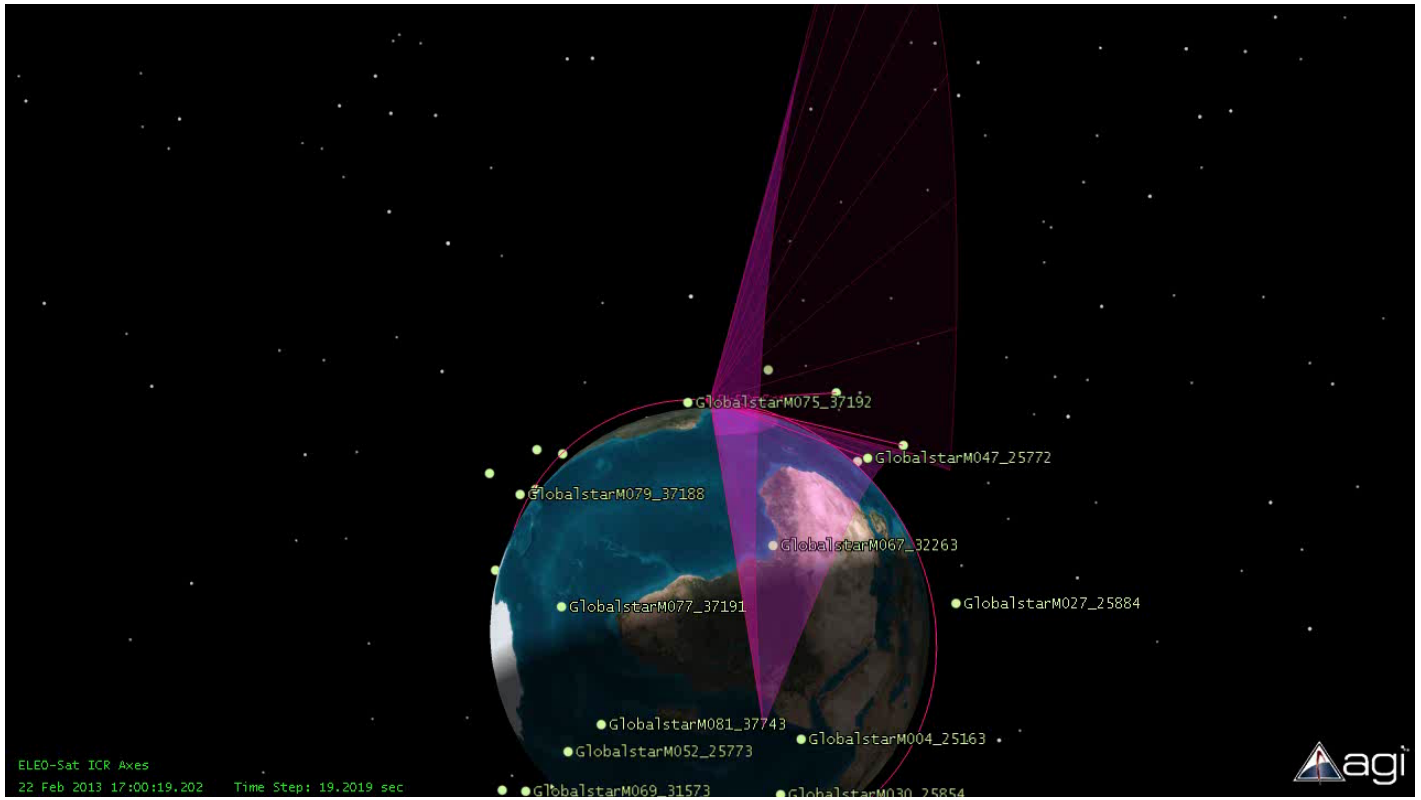
- **EyeStar** developed by NSL for satellites & **EyePod** for high-altitude ballooning
  - NSL developed relationship with GlobalStar and now Value Added Reseller (VAR) and
  - NSL has flown six EyeStar units (100%) & > 350 balloon launches with 99+% data/recovery
  - Data links via the GlobalStar and NSL network (Simplex and Duplex)
    - Code division multiple access (CDMA)
    - Payload commanding
    - Data downlinks
    - Recovery tracking (with GPS)

NSL EyeStar Simplex and Duplex now with flight Heritage

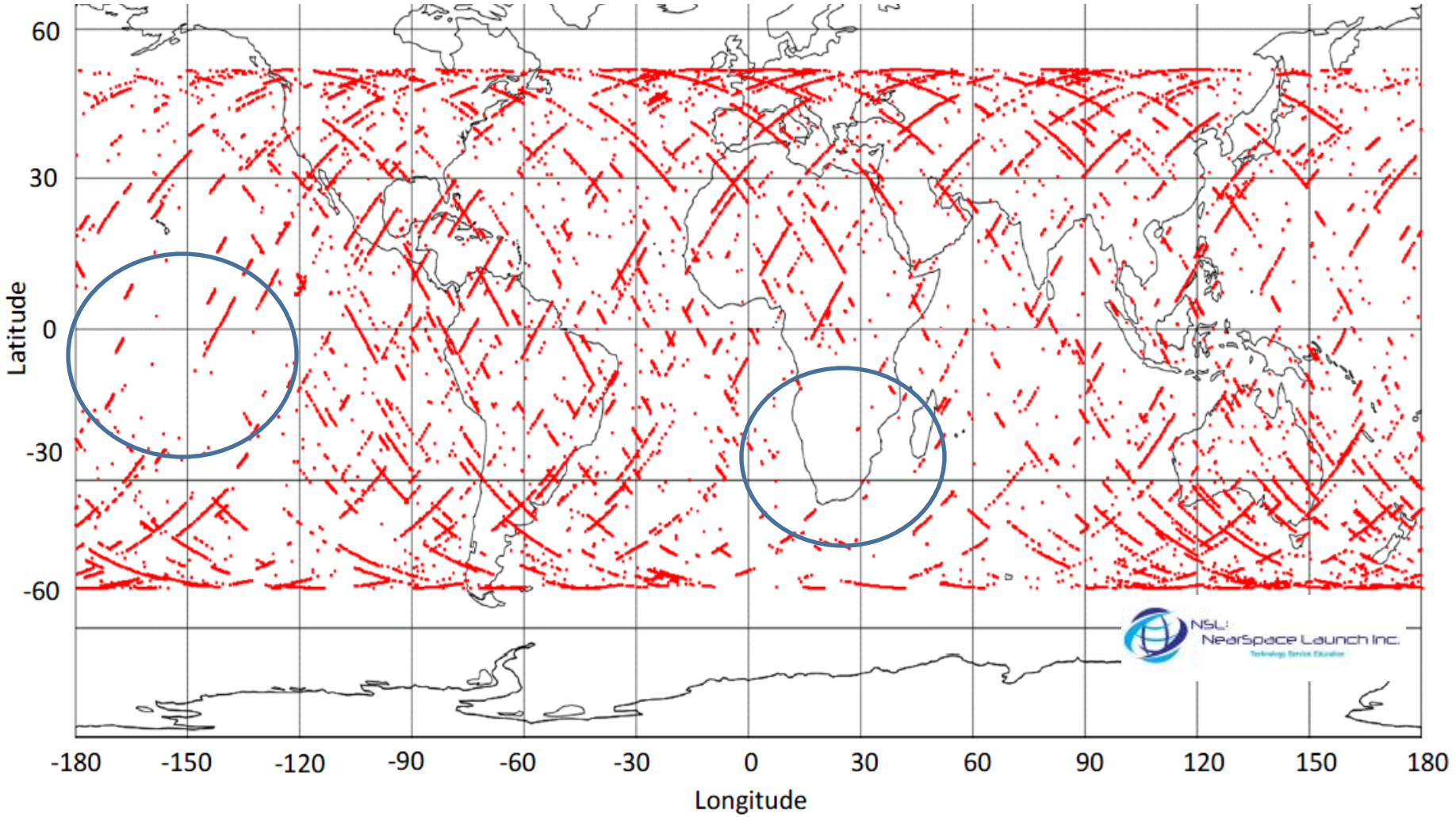
Globalstar with EyeStar Radio Simulations

("*Bent Pipe*" distributed data downlink)

- Commercial Research Grade link and FCC license, Not ITAR
- 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 conventional Ground Station cost &time required



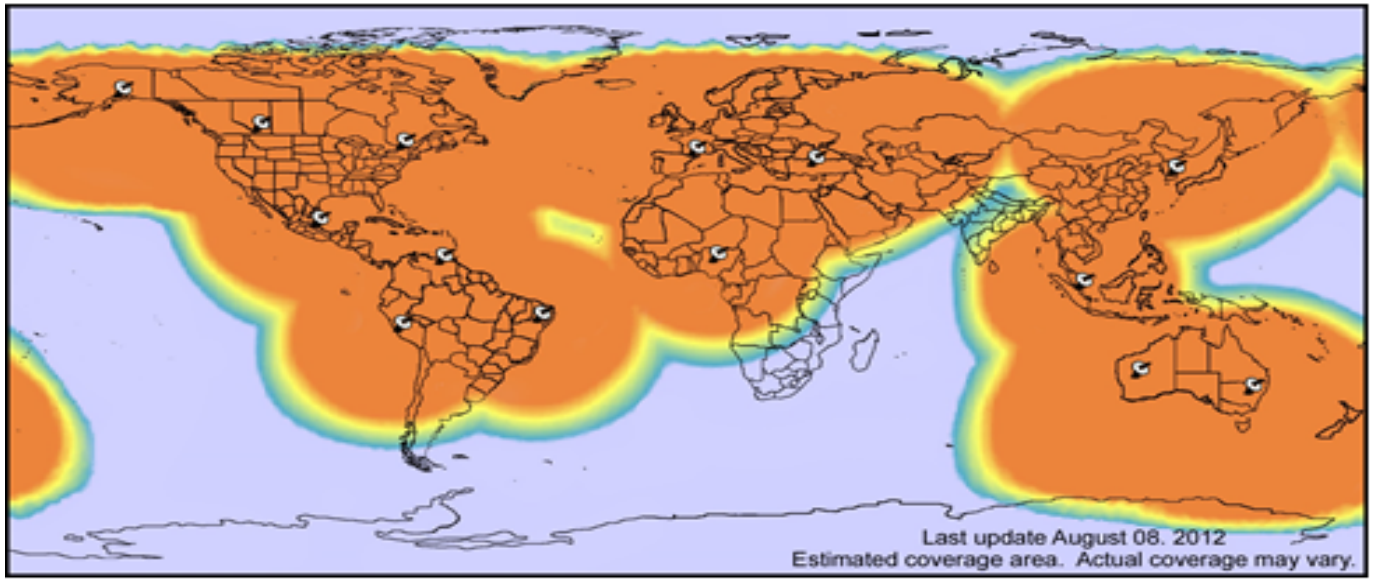
NSL EyeStar coverage with TSAT Globalstar Simplex Modem



May 2014, Beacon Cycle: 32 beacons (Five second interval), 15 minute off dwell

Contour Maps of Simplex Coverage

Terrestrial Simplex Map



TSAT Coverage

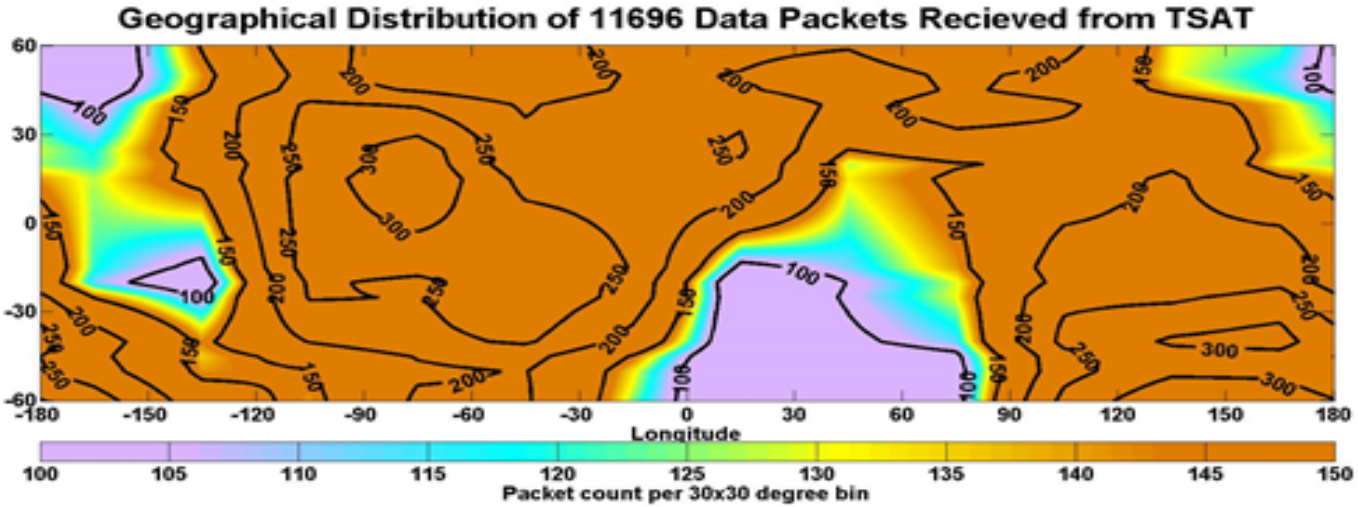
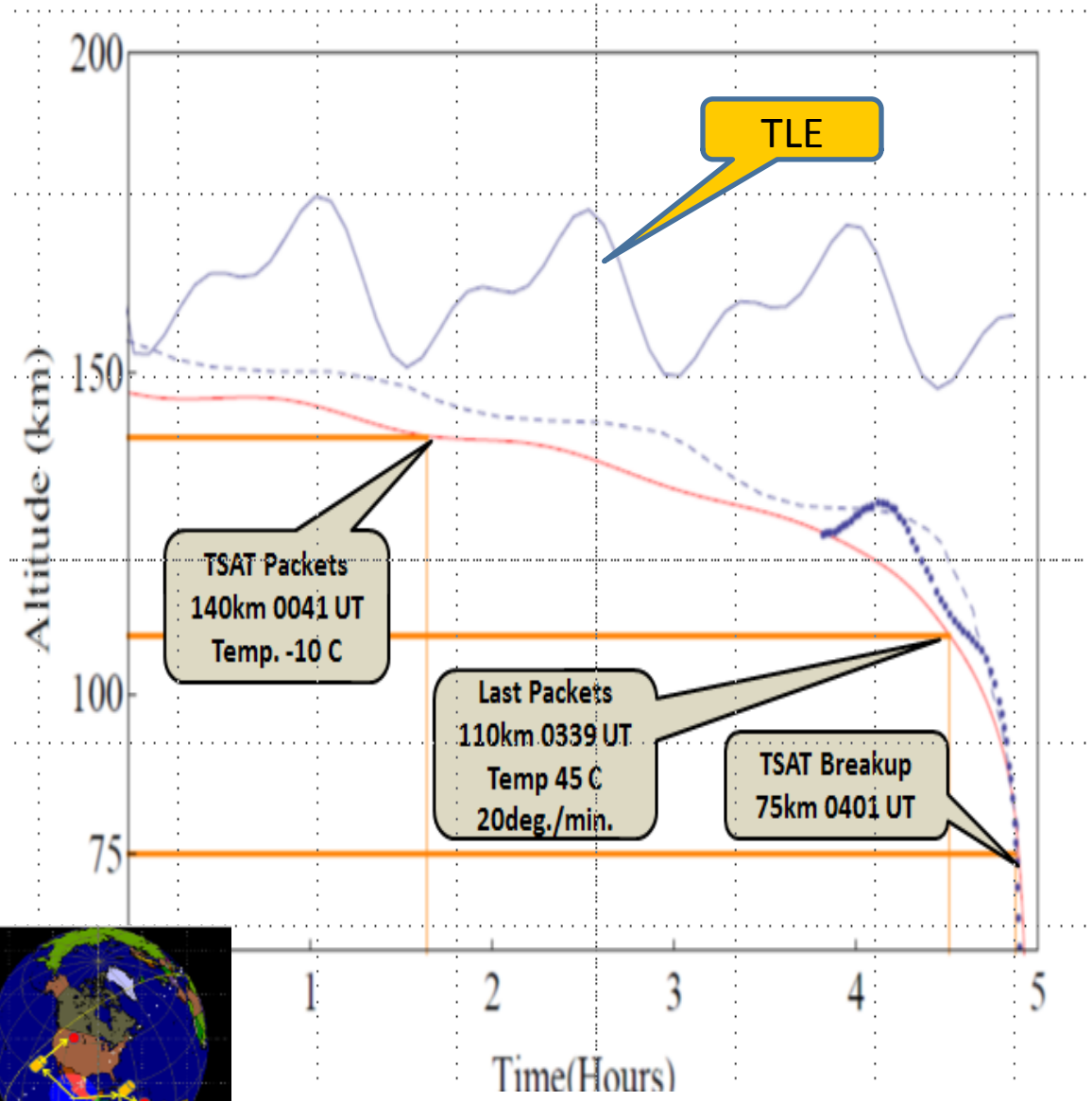


Figure 7: Comparison of Globalstar projected coverage and normalized TSAT results

TSAT, 2014
1M Byte data
~$4K for
40 day mission
Power limited

TSAT 110 km Reentry Data (T=20deg/min)



ELEO Electron Density

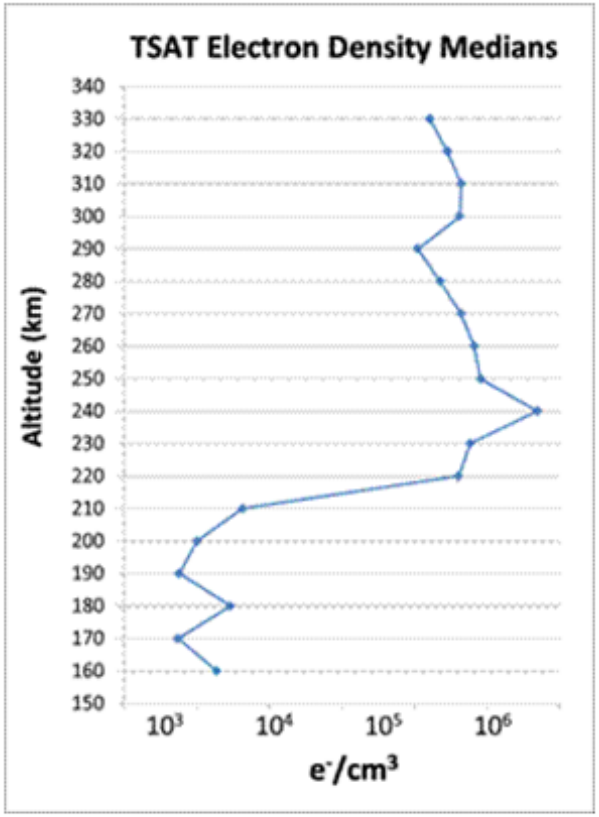
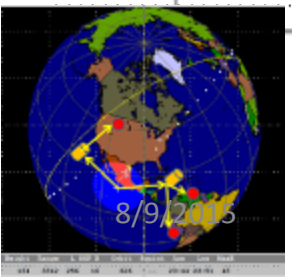


Figure 19: Mission medians of electron density for various orbit altitudes (10km bins). The higher density in the F-region transitions to the



Presentation Published Results

11th and 12th Annual CalPoly Spring Workshops and Utah Small Sat CubeSat Workshop, ***Aug. 2014***

SSC14-WK-6

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

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ABSTRACT

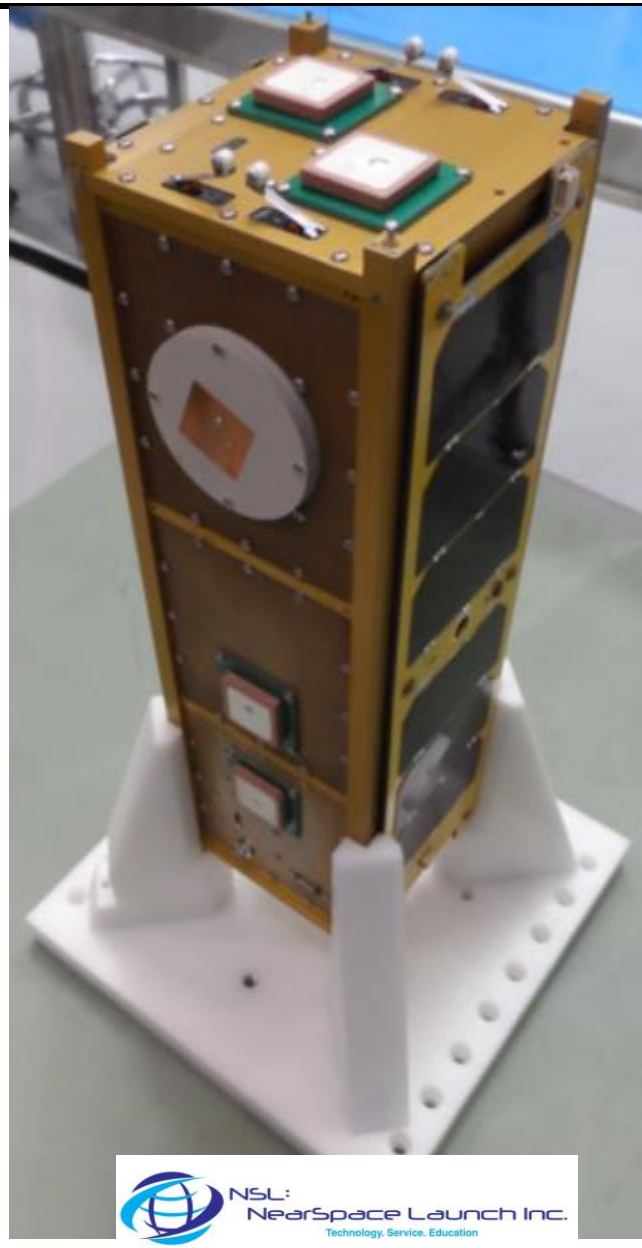
Global Star Experiment And Risk Reduction Satellite (GEARRS)

Globalstar Experiment and Risk Reduction Satellite (GEARRS)

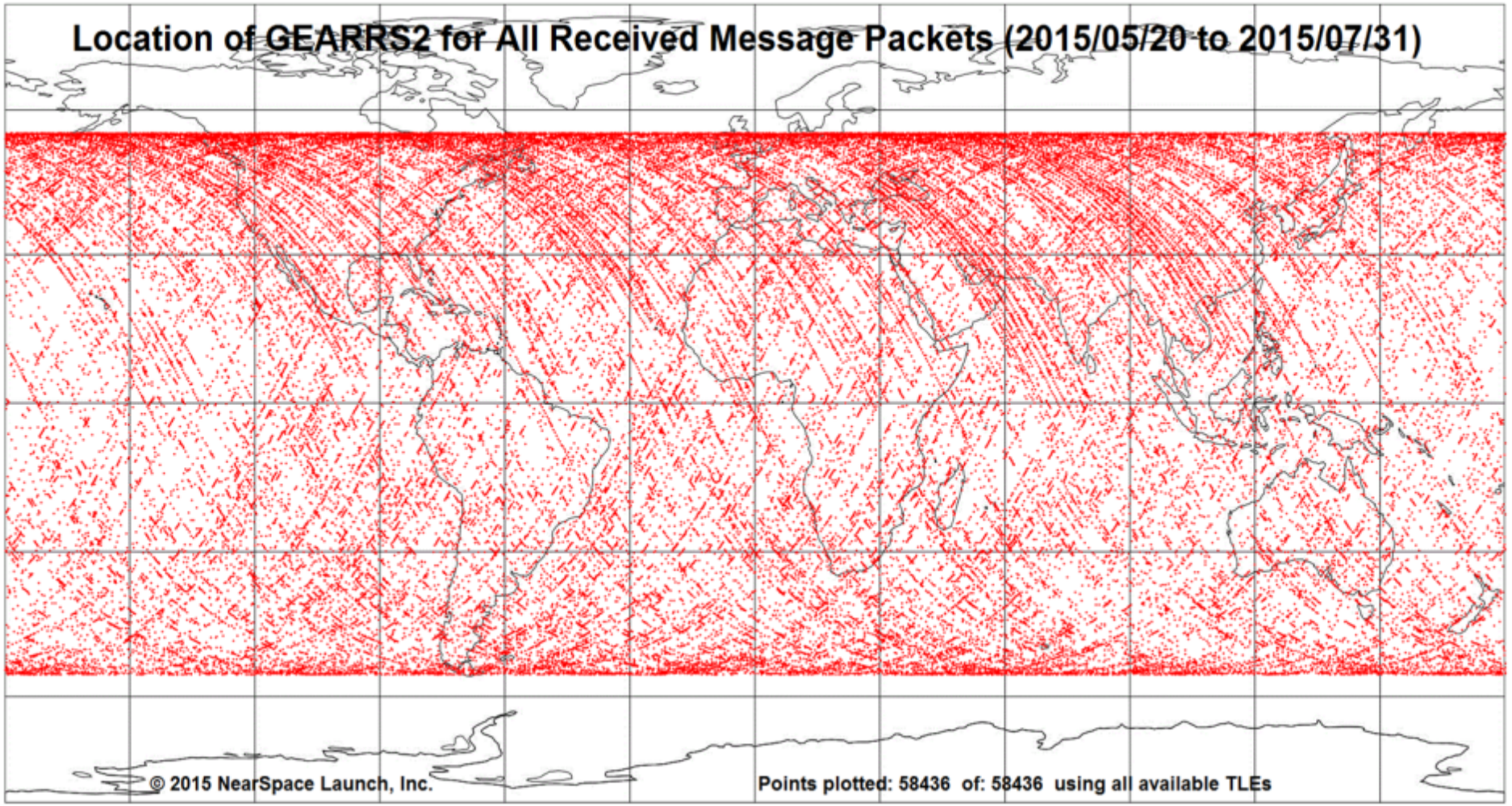
- **GEARRS 1:** launched from Nanoracks/ISS March, 2015:
  - First Duplex Tested with SMS Commanding, 2 Simplex units
  - Results presented at Ca Poly Workshop April, 2015
- **GEARRS 2:** Launched from P-POD Atlas Rocket May, 2015:
  - Elliptic orbit about 350 by 700 km
  - Currently in Operation for extended mission: Heritage, Flight Qualifications (Li-Poly Batteries, FP, EPS, Solar Arrays, Mag.), Rad testing, Particle data, Link testing, and De-spin effects

G* Experiment-GEARRS #2

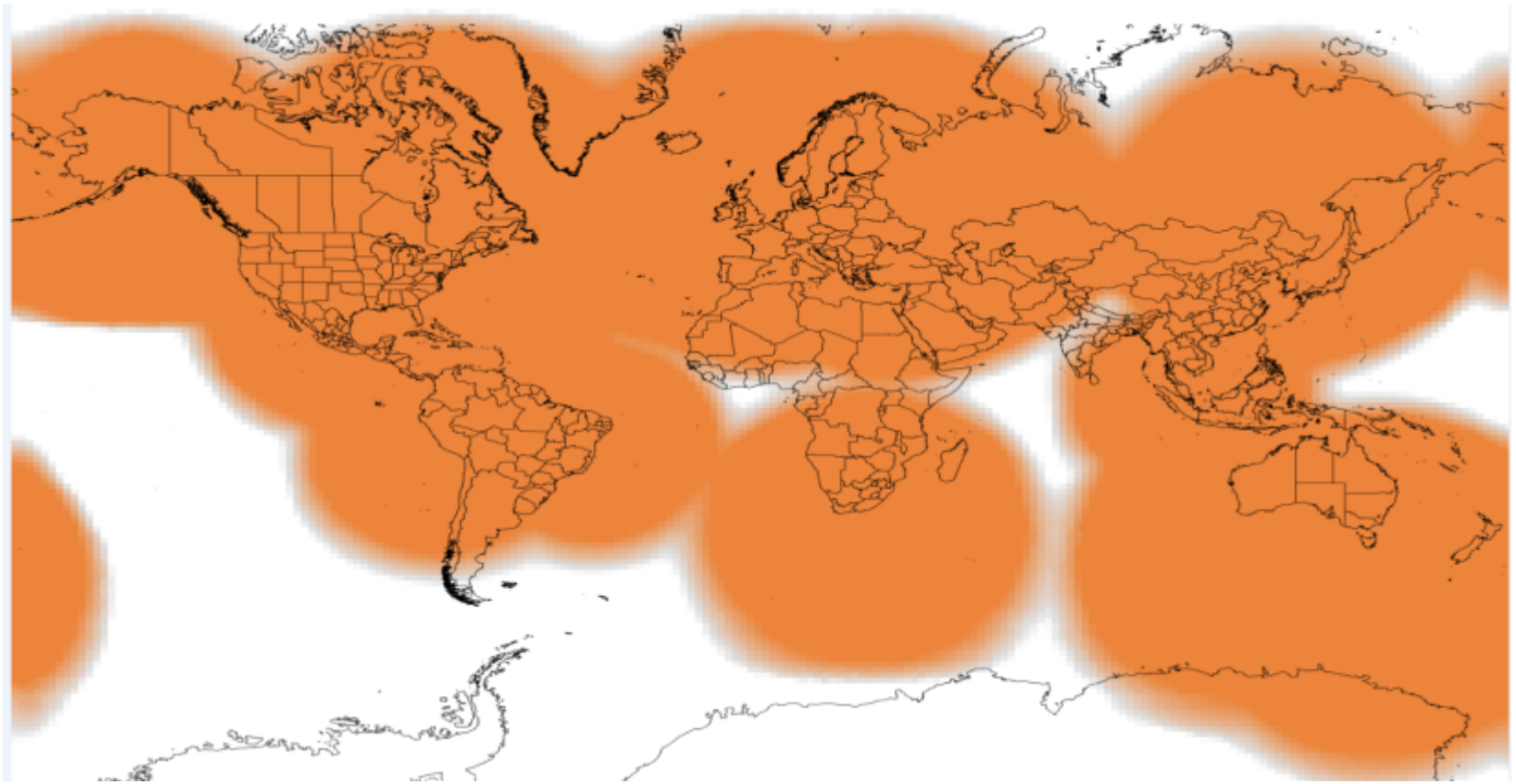
- 45 Day Turn-around by NSL
  - **FastBus**: (Structure, EPS, G* links, mag., solar, EMI enclosure, Thermal short, Asm. bench)
- GEARRS 2 photo showing Smplex and Duplex patch antennas and the plasma probe on the end cap.
- GEARRS #2 is currently operating and validating the end-to-end space and ground segment
- GEARRS #2 validating duplex coverage maps, costs, commanding rates/latency, file transfer rates and size, & much more.



GEARRS2 Globalstar Coverage



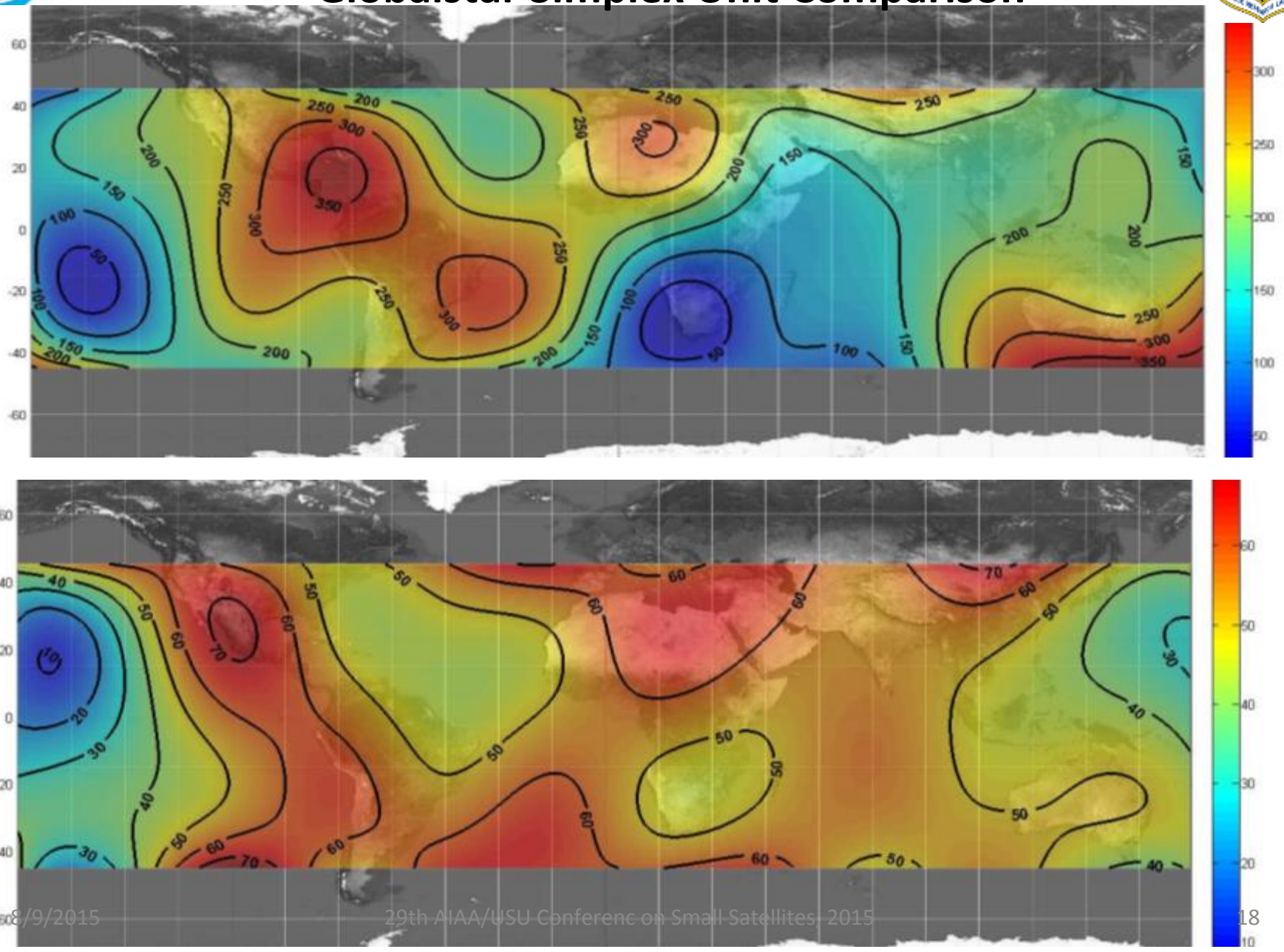
New G* Ground Station in Africa!
Spring 2015



TSAT and GEARRS2 (Preliminary) Globalstar Simplex Unit Comparison

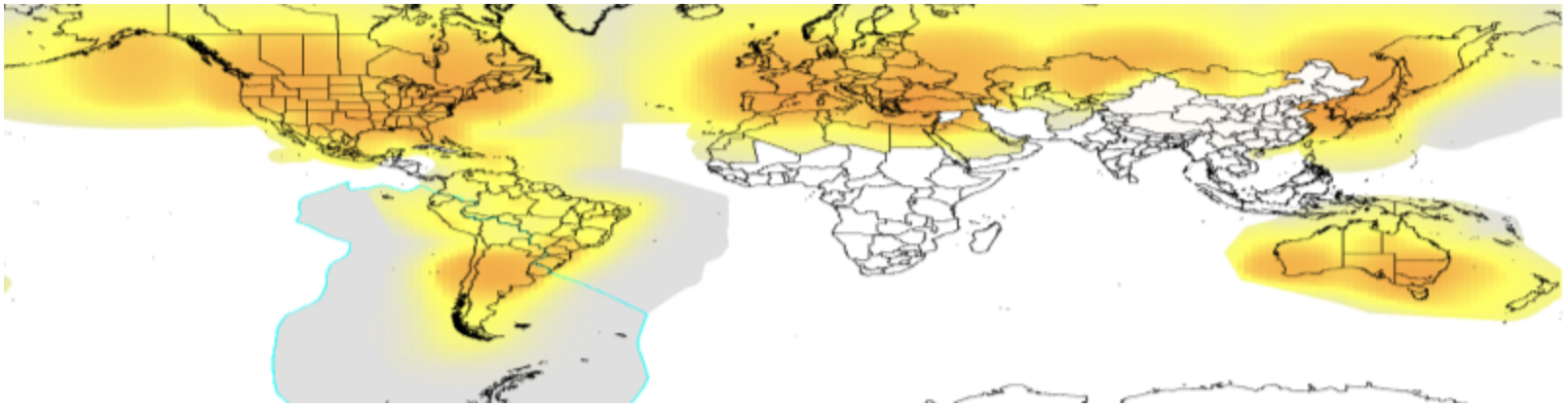
TSAT Coverage 2014

GEARRS2 Coverage 2015



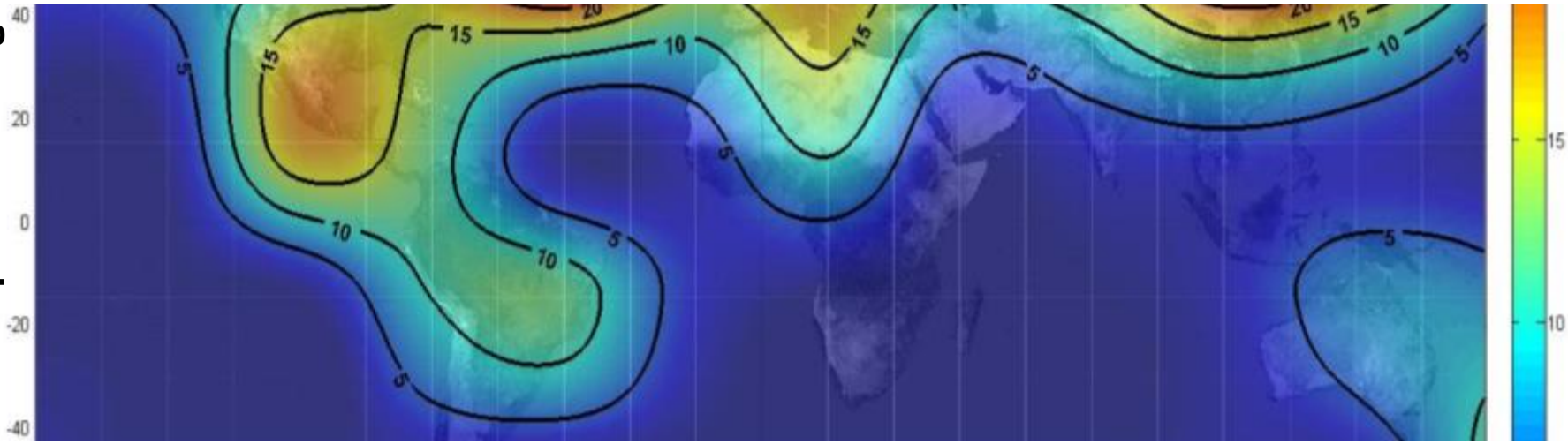
Duplex Connects and Signal Strength (RSSI)

G* Duplex Ground Map



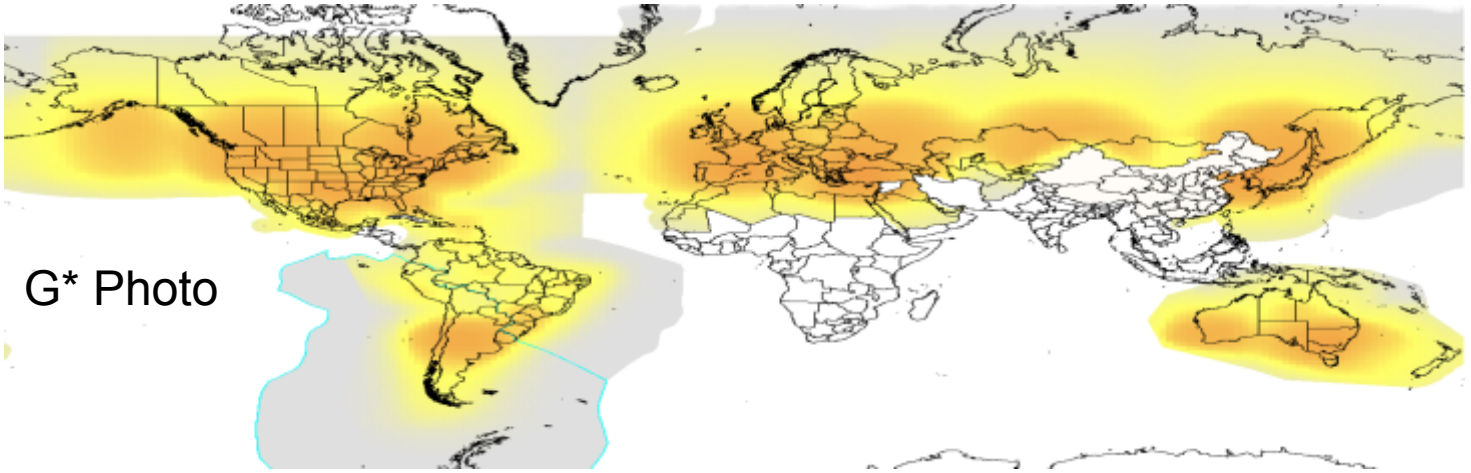
GEARRS Spinning at 2 PPM and 1 RPM Pitch

GEARRS Duplex Coverage



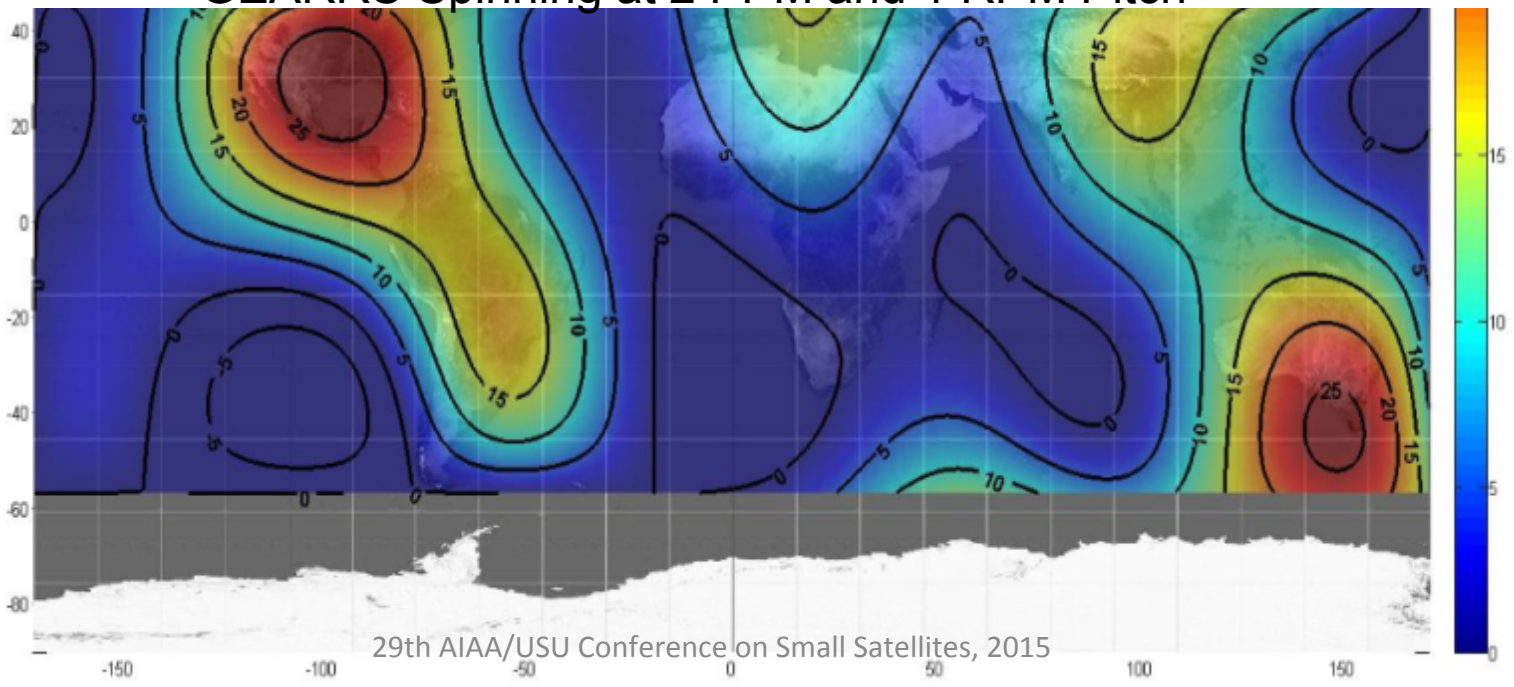
SMS Duplex Commanding (Preliminary) with Validation (~300 messages)

G* Duplex Ground Map



GEARRS Spinning at 2 PPM and 1 RPM Pitch

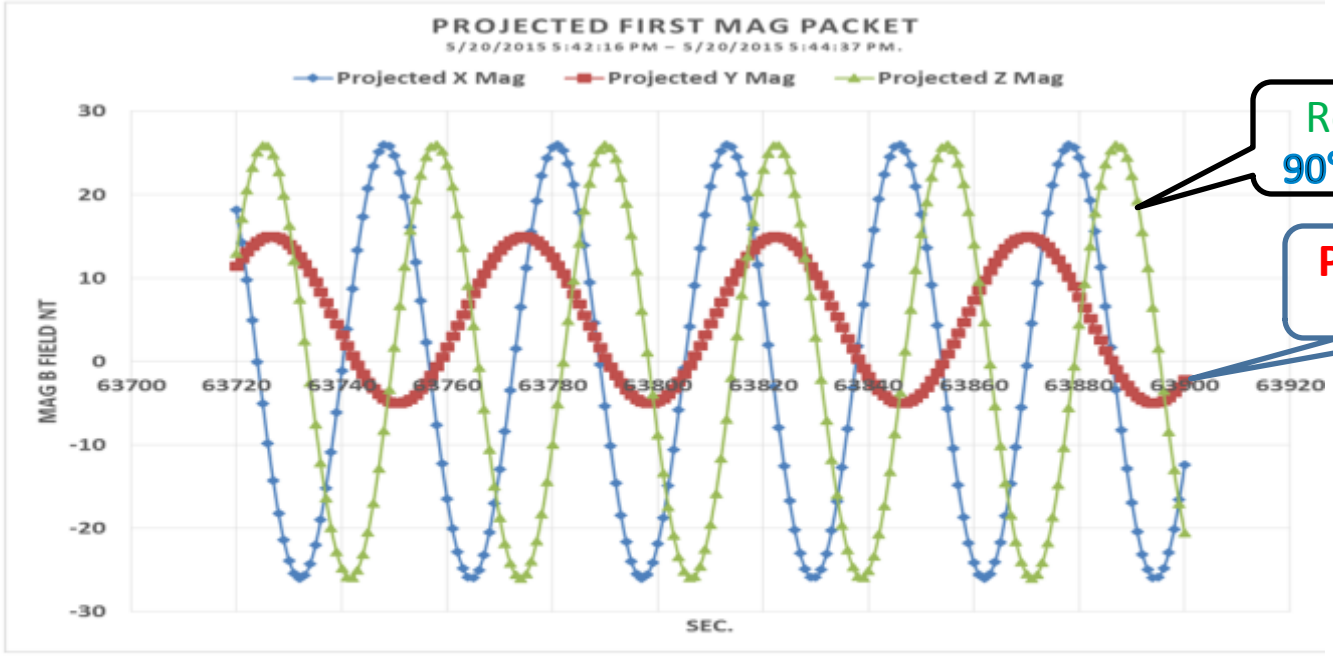
GEARRS SMA Coverage



Close Agreement to Terrestrial Map

GEARRS 2 Spin Motion at Release time

First packet Received -South Pacific- <10 sec after RF turn-on



Axis	Frequency_Hz	Rate_rpm	Period_sec	Phase Shift_degree
x	0.0308	1.848	32.46753247	-71.61972439
y	0.0209	1.254	47.84688995	-229.1831181
z	0.0309	1.854	32.36245955	48.70141259

GEARRS Permanent Magnetic Stabilization with Magnetic Damping GEARRS 1 Stabilized well from ISS but GEARRS 2 in its elliptic orbit, higher altitude, and higher initial spin will take some time to slow down.

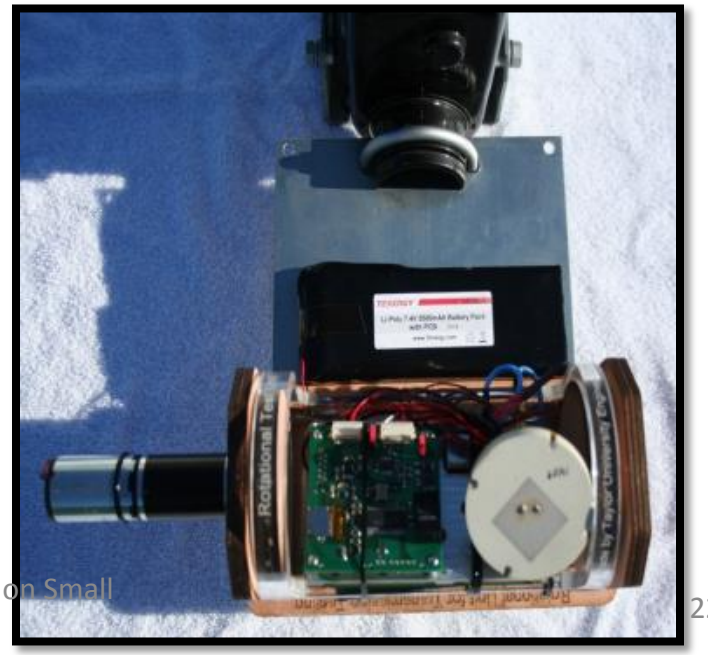
Ground Simulation

Data throughput is significantly reduced with GEARRS2 spin motion yet significant file connections are made for Gateway Connects, Duplex Connects, Signal Strength monitor (RSSI), and SMS Commanding.

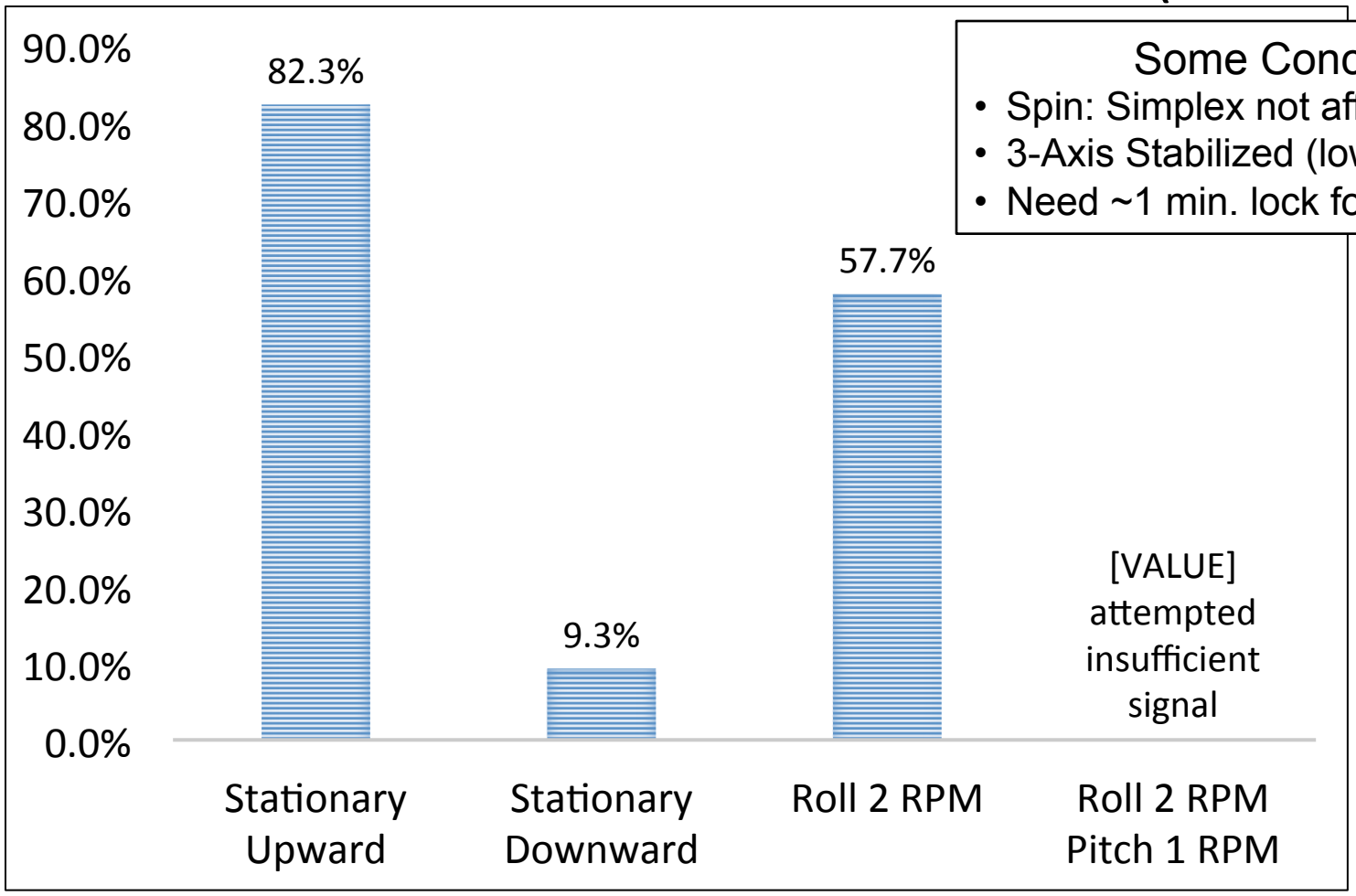
Because GEARRS 2 is spinning at 2 RPM roll and 1 RPM in pitch it does not have time to achieve long connections for large data file transfers.

To verify this effect, we rotated and pitched the GEARRS Engineering Model (EM) to test connectivity at various tumbling rates.

Duplex
1 and 2 axis
Rotation Testing
Device



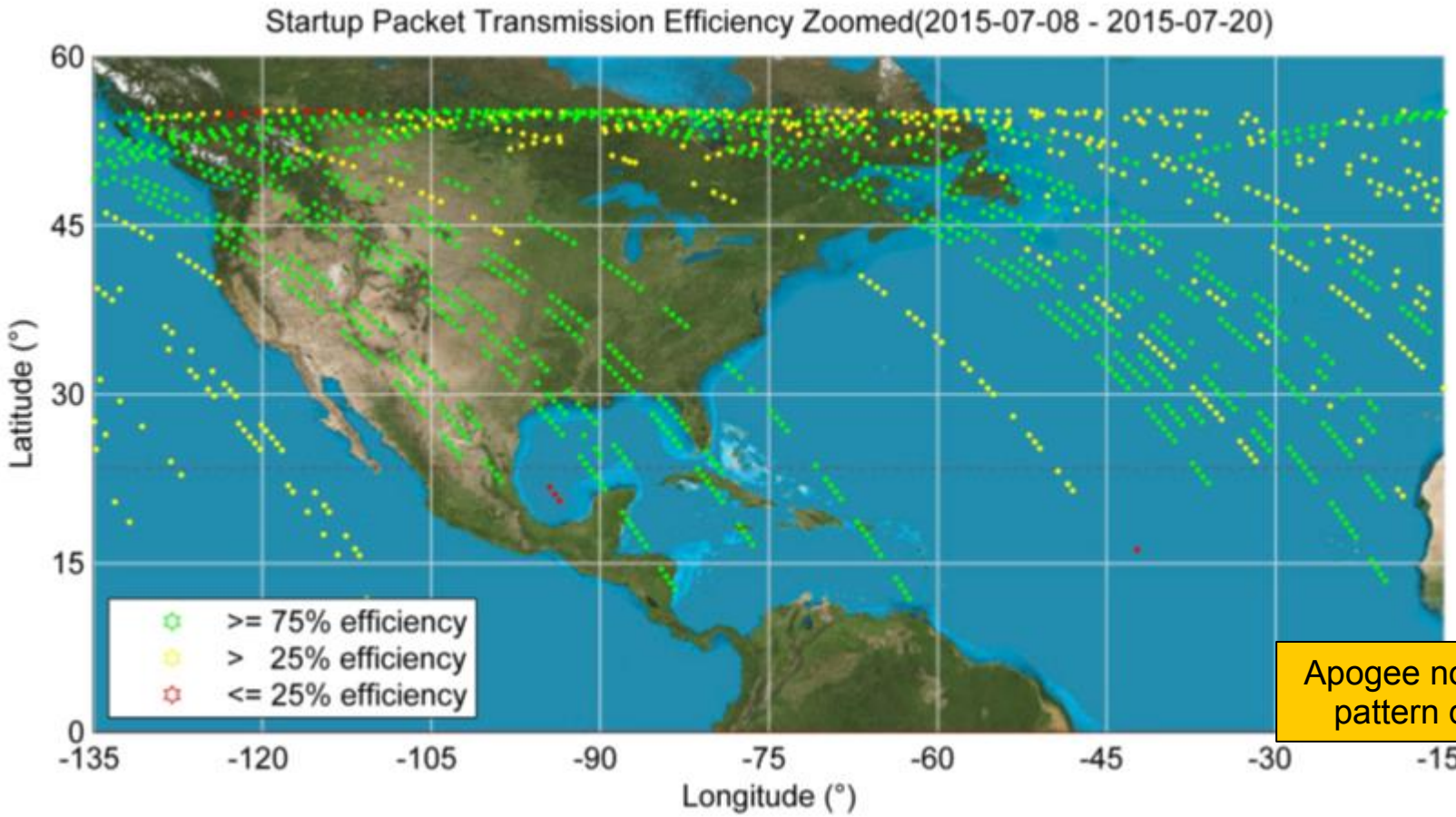
Duplex Modem % Successful Call Placement as a Function of Orientation and Motion (Preliminary)



Some Conclusions:

- Spin: Simplex not affected at 2 RPM
- 3-Axis Stabilized (low spin) for Duplex
- Need ~1 min. lock for File Transfer

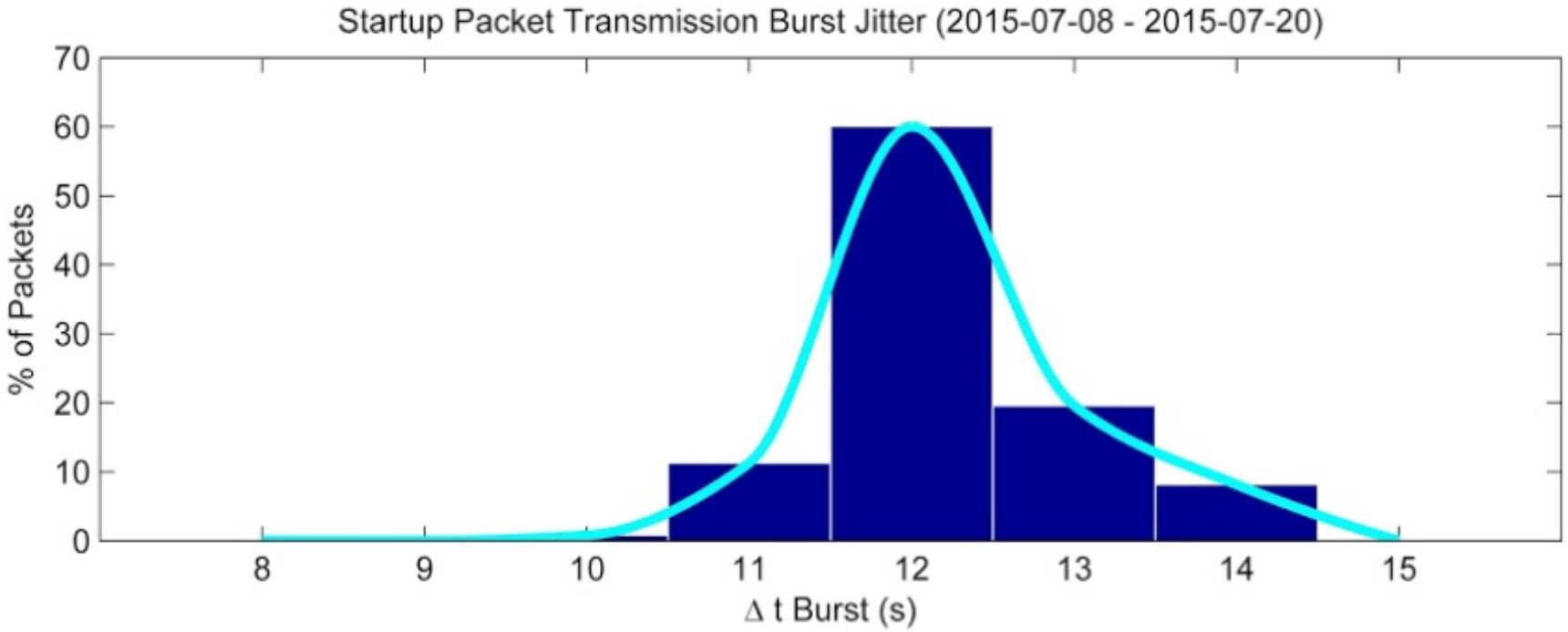
Simplex is not affected much by GEARRS2 tumbling. 85% efficiency for most cases, whether looking up or down



GEARRS 2 data in Sun sync lock with sequences of 75 packets

Near real time data:

Packet jitter about +/-1 sec. from CubeSat to Gateway UT Timestamp as recorded on NSL server



NSL:
NearSpace Launch Inc.
Technology. Service. Education

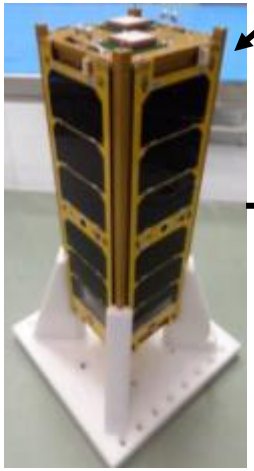
Commercial Products
See NSL Booth 104

1. EyeStar Radios: Globalstar Simplex and Duplex

1. 3 launches in 15 months (Space X-ELaNa 5, Orbital-ISS, Atlas) ,
2. Reliability: 5 for 5 simplex, 2 for 2 duplex all worked well
3. Delivery: 10 universities, NASA, NSF, AF, Industry

2. F-Bus Series (F1-F6): Fast, Fighter, Functional

1. 2-3 Month Delivery of Satellite Bus
2. Robust Structure, EPS, Solar, Li-Poly Battery, Comm., 3A-Mag, EMI shield, Isothermal, Optical bench plate
3. Nanoracks-ISS, P-POD launch, FCC, Safety, & Doc.
4. Flight Heritage: GEARRS 1, GEARRS2



3. Operational Data Ground Segment

1. Anywhere Anytime, 24/7 coverage, near real time
2. Fully functional with University, Government, and Industry Use
3. Graphics display software and command software
4. Multi-Sat. Standardized time-ordered Data base

4. Other Services:

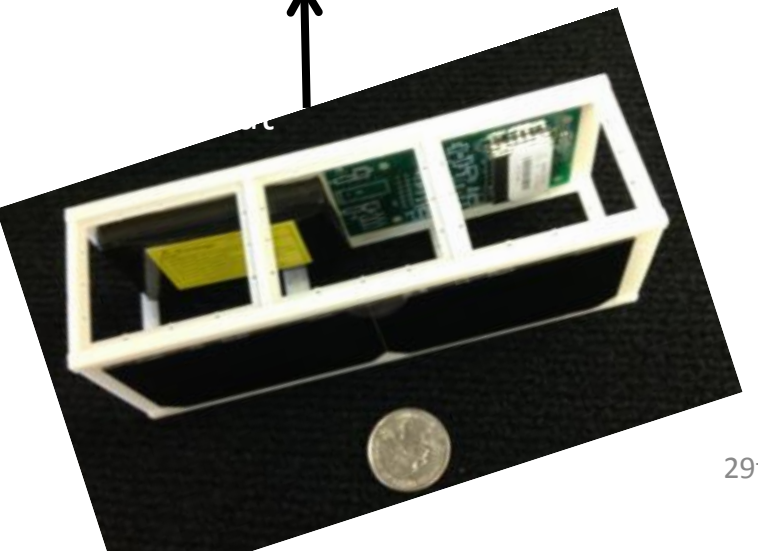
1. Sensors, High Altitude Balloons, EyePod Globlalstar Radios, (Over 370 Launches with 99% success)

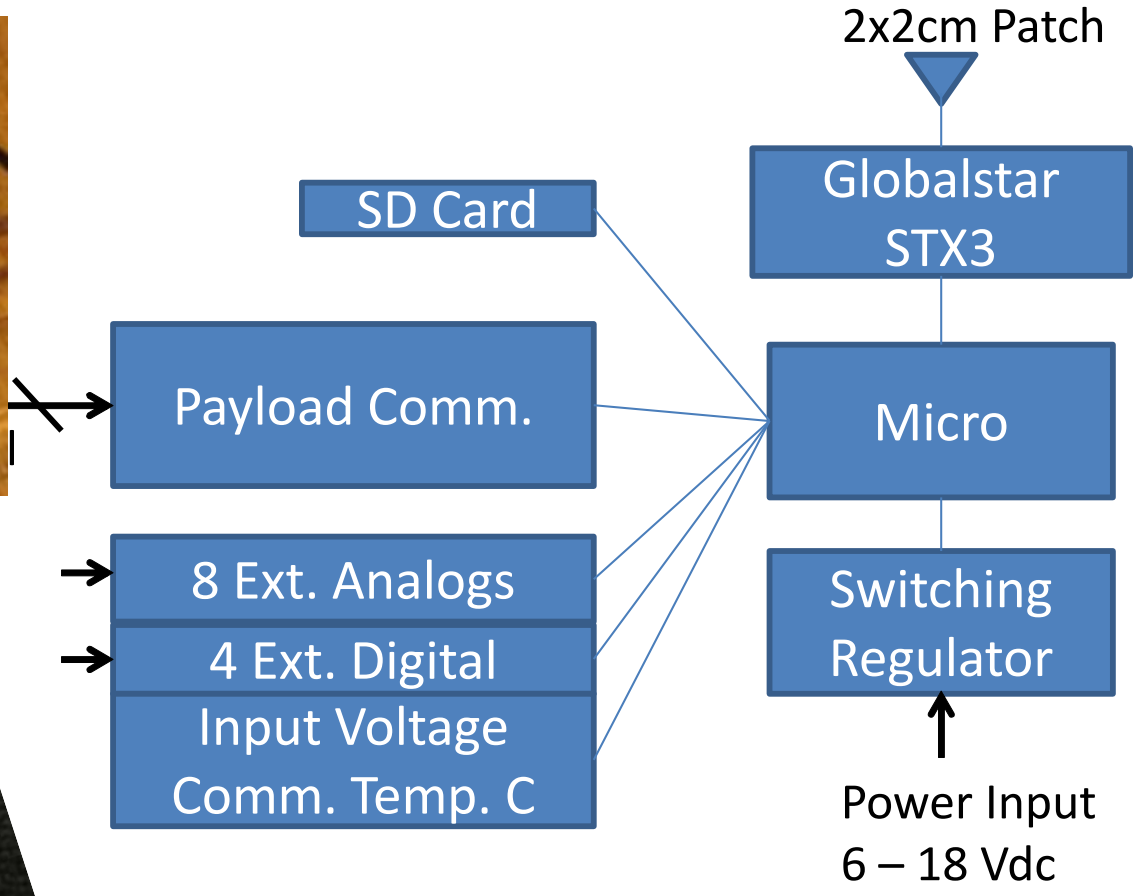
Globalstar Usage Plan

- Single Point Contact for Globalstar Simplex
  - NSL is POC as Value Added Reseller, VAR, product for Satellite and High-Altitude Balloons. Do not want to disrupt G* primary market.
  - Maintain Globalstar Interest with increased Satellite market usage while reducing G* overhead from interruptions, training calls, nonstandard protocols, problem solving, and putting out fires.
  - Cost $900 EM unit to $4,000 Flight FM Simplex unit and includes: **Beacon Flight Processor with IO, Flight Assembly, Antenna/Cable, FCC EMI Testing and Certification, Ground Segment Software, Optimization, FCC License, and Support.**
- Ensures satellite success using just beacon for basic health, summary sensor data, and GPS. Use S-band for Gbyte data.
- Ideal for MultiSatellites (1000s): Unified/Time-Ordered Cubesat Database (Selected collaborations)

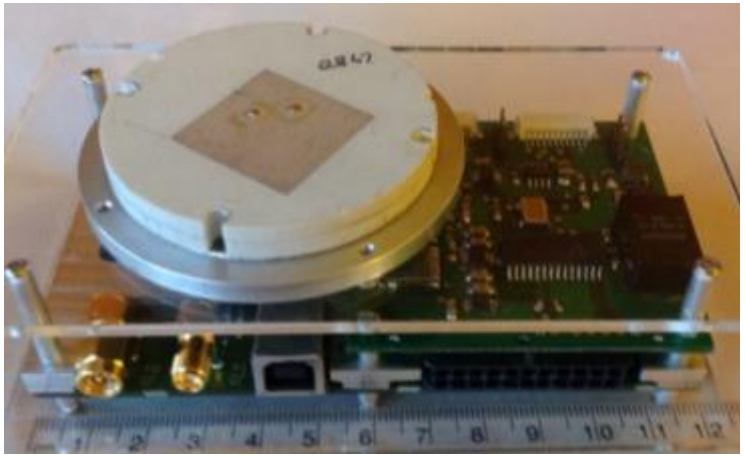
EyeStar Simplex Transmitter with Flight Beacon Processor, Plug and Play, ICD

STX-2, 8x3.5x0.6 cm (200mW ERP), and STX-3, 4x2.5 cm, 9 Bytes/s



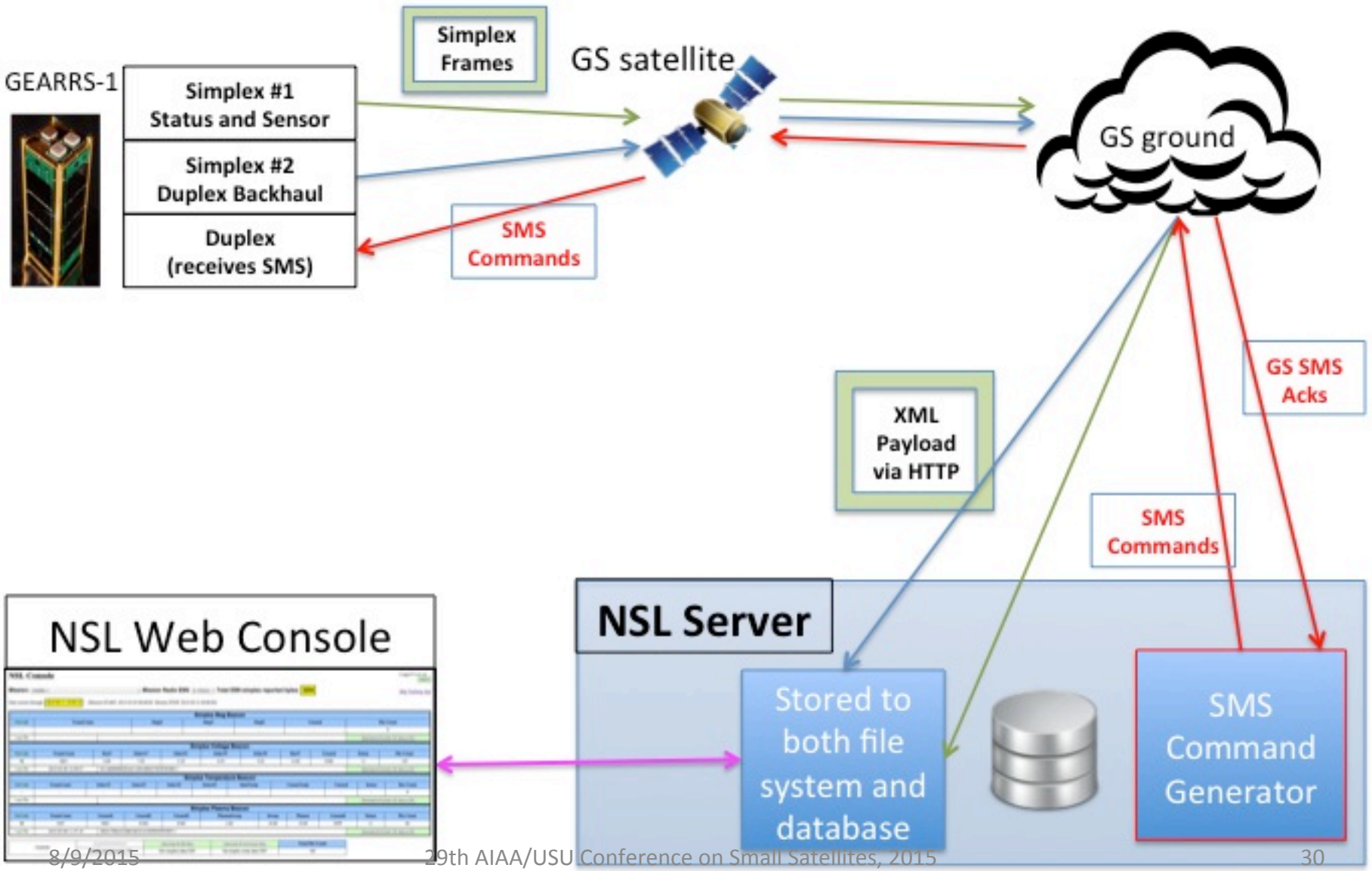


SAT Duplex Transceiver Product

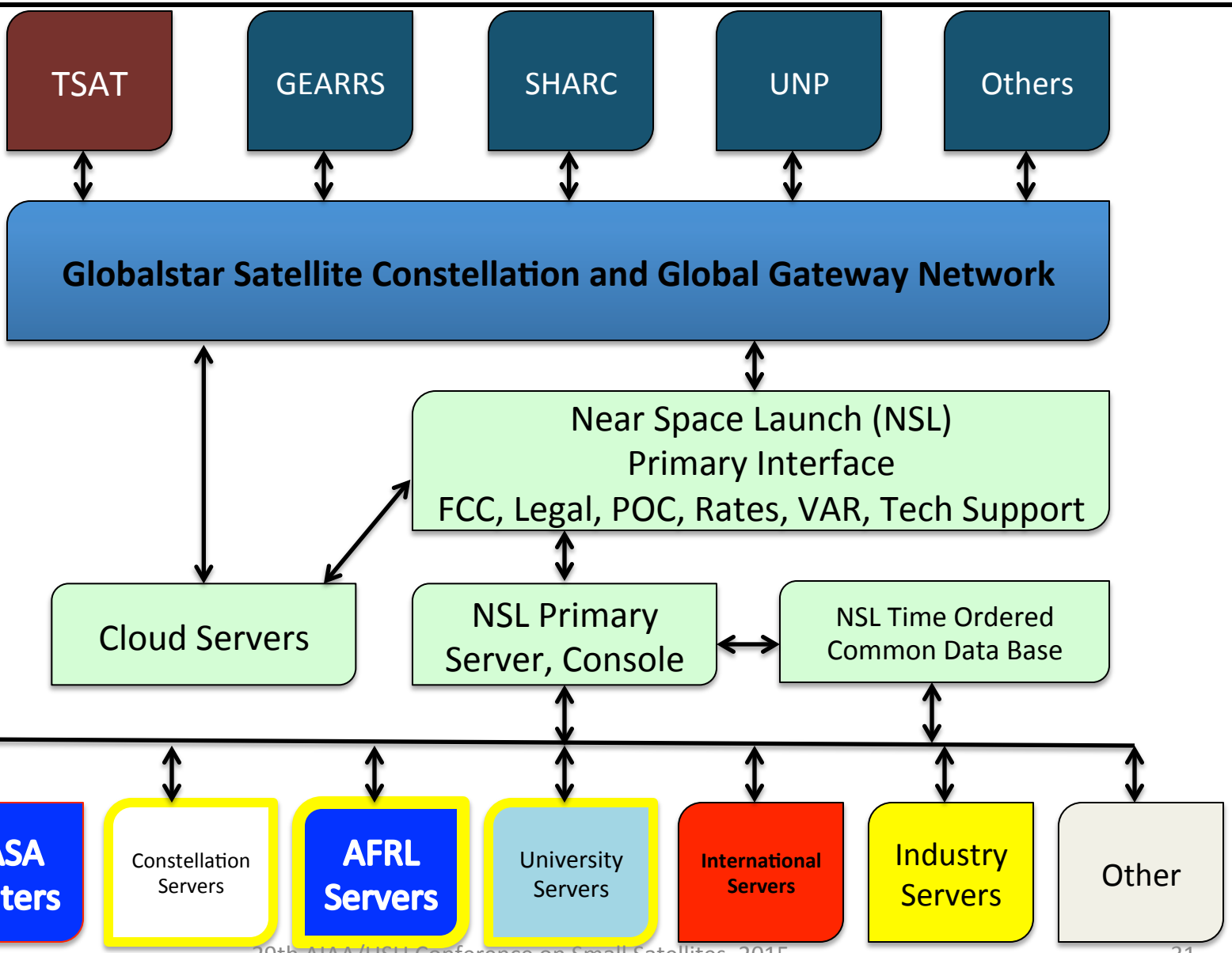


- Up to 7000 baud data rate
- Data and Command Control
- TCP-IP software with ARM processor
- Handshaking protocol
- Active patch antenna (6 cm)
- 1 Watt ERP
- 3.3 & 5 V, 5W input power
- Size 6.1 X 11.9 X 11.9 cm
- CAD, ICD, Support, FCC License

GEARRS-1 Data Link Model



Satellite-Globalstar-Server Data Network Operational



Questions

Meet us at Booth 104

Simplex Data Rates

Standardized Simplex Monthly Data Charges
January 29, 2015

Verified Data Bytes Received KBytes	Research & Retail Rate Cents/Byte	Academic Rate (less 15%) Cents/Byte
0- 360	1.00	0.85
361 -1,800	0.75	0.64
1,800-3,600	0.50	0.43
3,600-18,000	0.40	0.34
18,000-65,318	0.30	0.26

Note Savings in No Ground Station Operation and Hardware Costs.

NSL Space Flight Upgrades of Globalstar Modems

- FCC Cubesat-to-Satellite commercial license
- EMI PCB FCC certification of modem Product
- Firmware modem changes for spaceflight
- ARMProcessor board and Linux 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 clean interface with G*
- Network Tuning and optimization
- Certified for Spaceflight
- Ground Segment Data and Command Software
- Future plan for Open Source interface
- ICD, RF Spectrum EMI, Antenna/Cable placement, Much Documentation,…