Globalstar

NSL: NearSpace Launch Inc.
Technology. Service. Education

Globalstar Link:
From Reentry Altitude and Beyond

Dr. Hank D. Voss, President and Chief Scientist, 765.618.3813, hankvoss@nearspacelaunch.com
Mr. Jeff F. Dailey, Chief Engineer, 260.241.0409, jfdailey@nearspacelaunch.com,
Mr. Matthew B. Orvis, Project Engineer, 808.990.4488, mattorvis@nearspacelaunch.com
NearSpace Launch Inc., 8702 E. 825 S. Upland, IN 46989

Professors Dr. Art White and Dr. Stefan Brandle
Taylor University, Physics/Engineering & Computer Science , Upland, IN 46989

Technology, Service, Education

Acknowledgements

- **Globalstar Management, Engineering, Marketing, and Legal** (4 years Pioneering Implementation with NSL)
- **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
- **NSL Investment and Staff** (Concept to Implementation)
- **Taylor University Students (TSAT) & Many others**

Presentation Published Results

11th and 12th Annual CalPoly Spring Workshops and
Utah Small Sat CubeSat Workshop, ***Aug. 2014 and August 2015***

Paper 1: SSC14-WK-6 Small Sat, August 2014 (19 pages)

TSAT Globalstar ENaNa Extremely Low-Earth orbit (ELEO) Satellite

Authors from NSL, Taylor University, and Globalstar

Paper 2: SSC16-WK-11 Small Sat, August 2016 (19 pages)

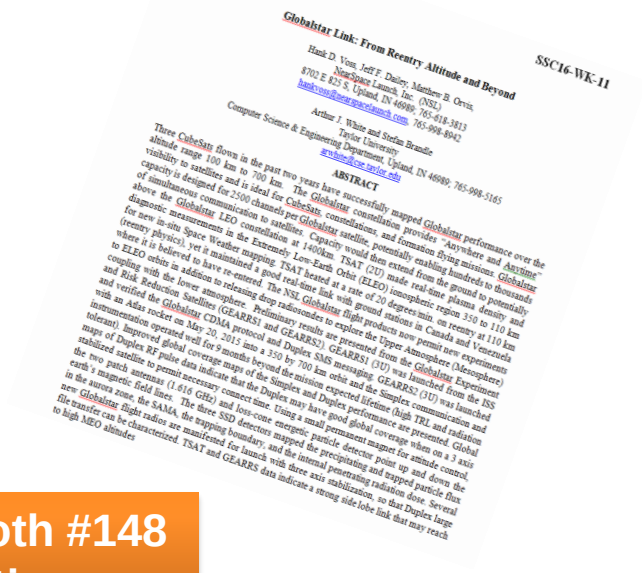
Globalstar Link: From Reentry Altitude and Beyond

Authors from NSL and Taylor University


SSC14-WK-6

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

ABSTRACT


Globalstar Link: From Reentry Altitude and Beyond

SSC16-WK-11

ABSTRACT

Visit NSL Exhibit Booth #148 for more information

Eyestar Simplex

Simplex: STX-3 (or STX-2): 200 Kbytes/day, 9 Bytes/sec

Low Power/cost/size , Turn-on data in seconds, 2KB/day, global Anywhere/Anytime data, Tumbling OK, processor validated
5 of 5 Validated in LEO Orbit!
3 week Available NSL Stock

Many Radios Sold to DOD, NASA, Industry, & Universities

Mission Success, No Ground station required

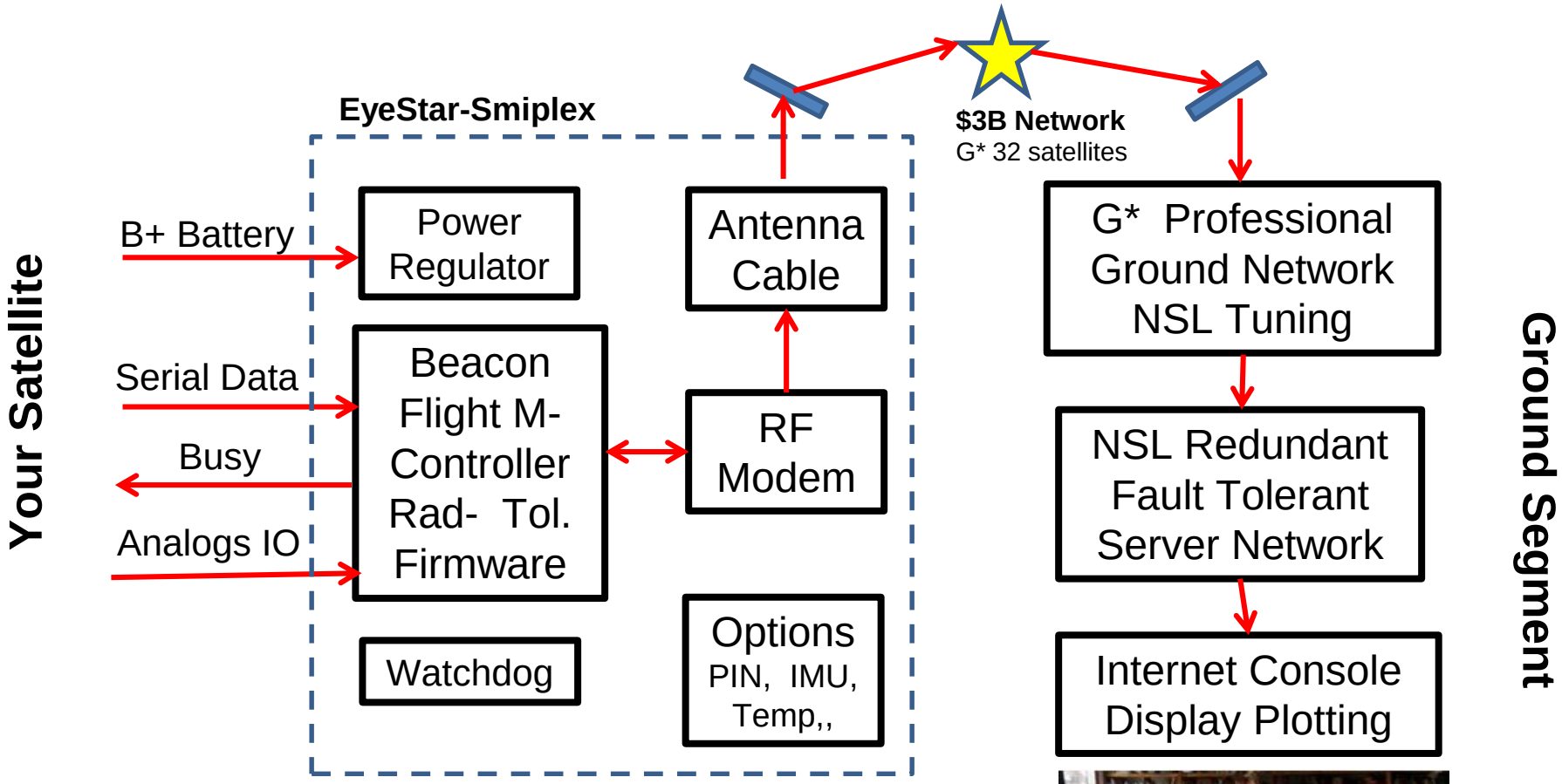
Eyestar Duplex

Duplex: 20 Mbytes/day, 700 Bytes/sec

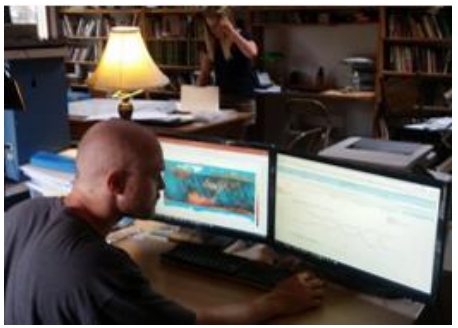
2 way- Commanding, 20 MB/day, 50% Anywhere/Anytime data, pointing, ARM processor, Geolocation, Handshaking,

2 of 2 Validated in LEO Orbit!
3 week available NSL Stock

NSl Simplex Products (STX-3 and STX-2) Research Grade, Commercial License, TRL=9

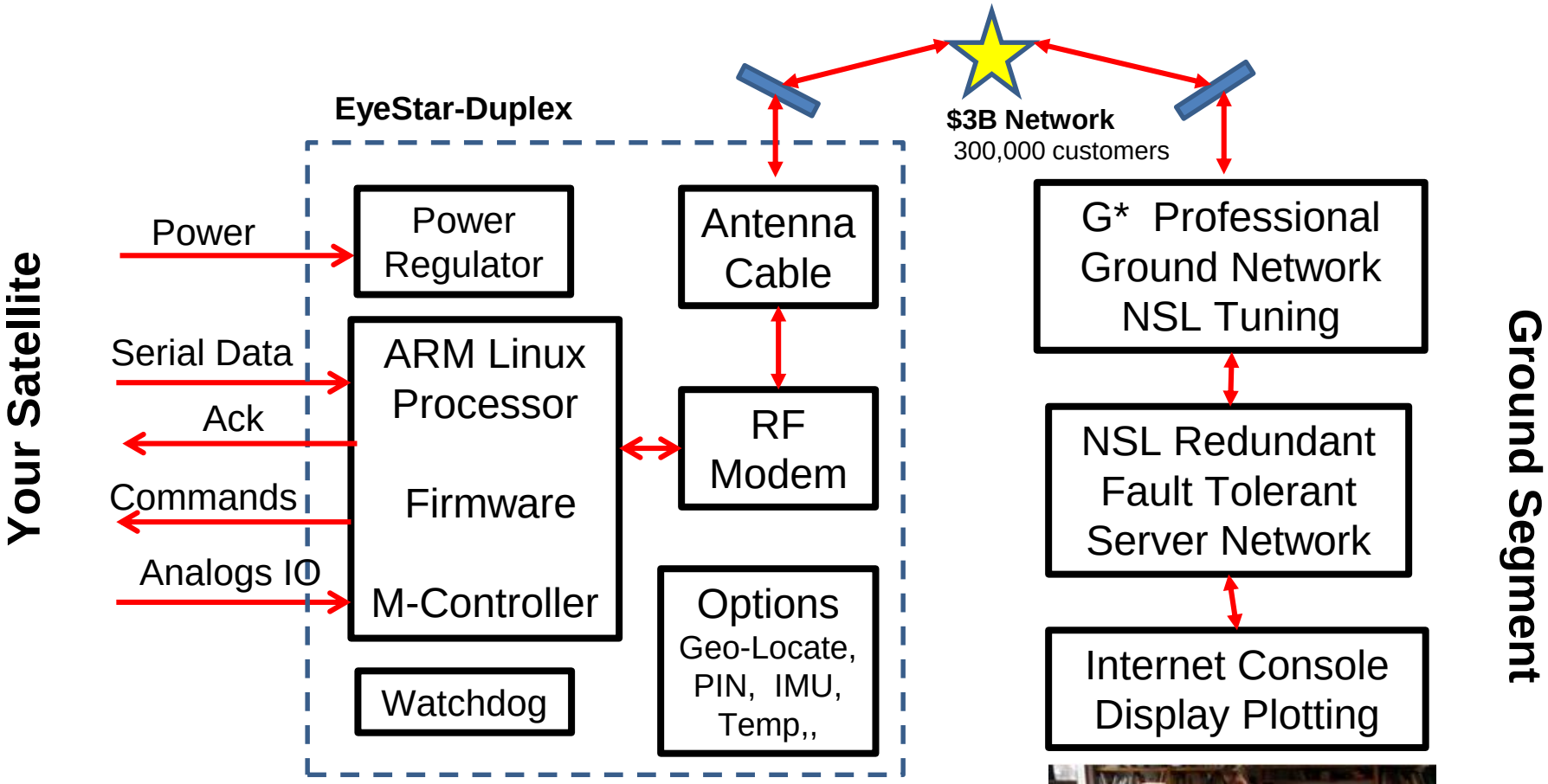


PCB, Shielding, Layout, EMI Test, Globalstar/NSL Value Added Reseller (VAR) Product, ICD, Engineering Model (EM), Firmware Options, Quality Assurance, Burn-in, Certification, Flight Model (FM), FCC License, NSL Support

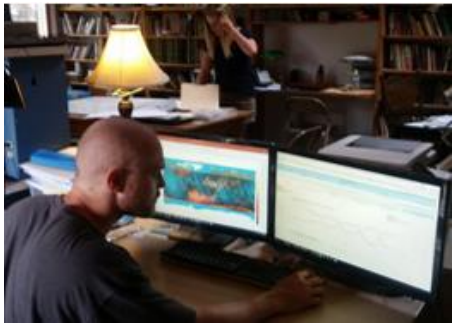


Much More than a Modem!

NSL Duplex Product
Research Grade, Commercial License, TRL=8-9



PCB, EMI Shielding, Layout, EMI Test certification, Globalstar requirements, Firmware flight, ICD, Engineering Model (EM), Quality Assurance, Burn-in, Certification, Rad shielding, Flight Model (FM), FCC License, Encryption, Compression, NSL Support



Much More than a Modem!

NSL EyeStar Development Flights

2014

TSAT 2U

EyeStar Simplex

Space X Launch
ElaNa 5 325 km
40 day life
NSL and Taylor U

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

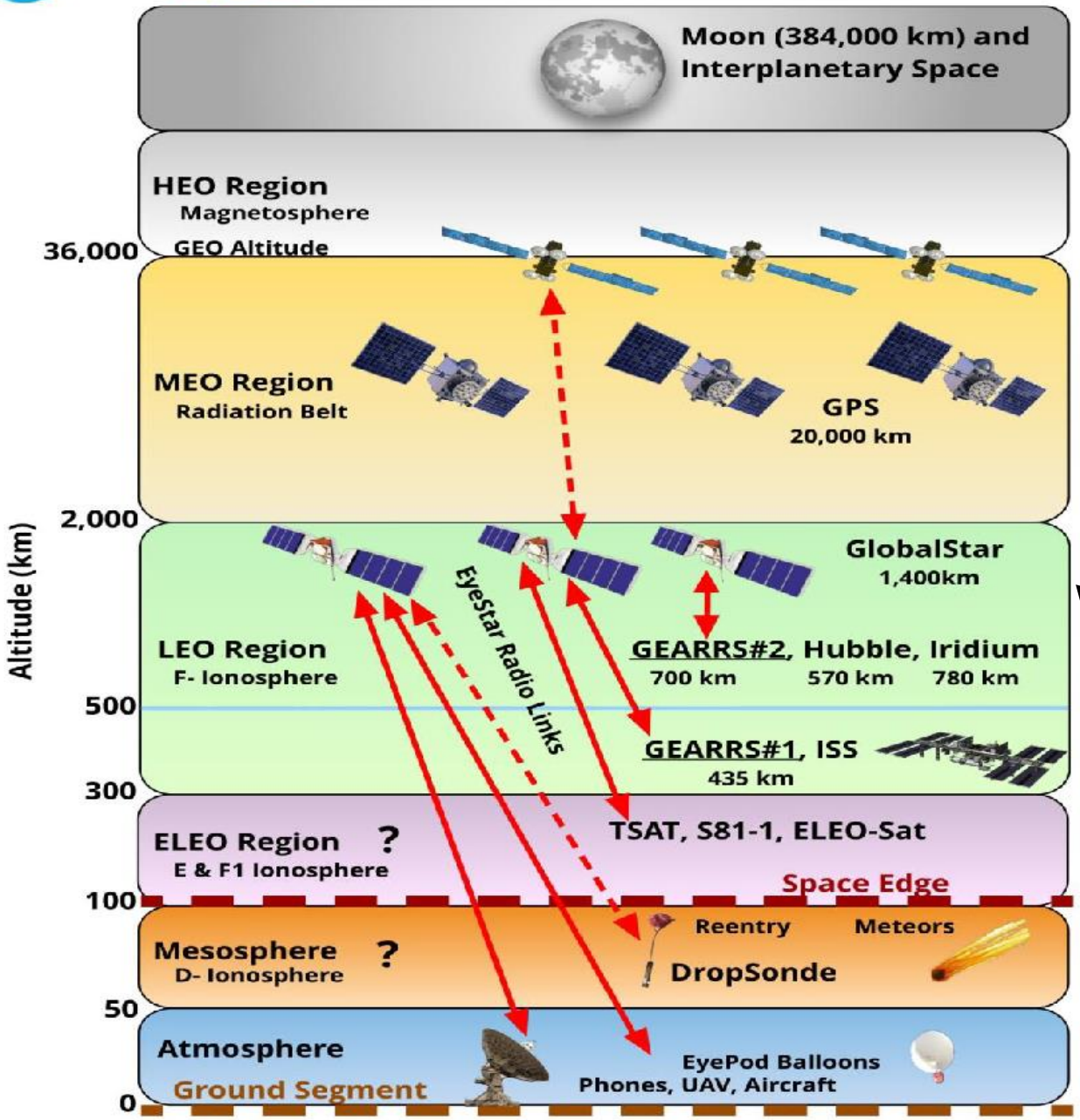
1U & 2U in Polar Orbit
SHARC 6U

EyeStar Simplex
EyeStar Duplex
Commanding

3A Stable
ISS Launch, ~420 km
DOD STP

Other EyeStar Units Manifasted, L2016+

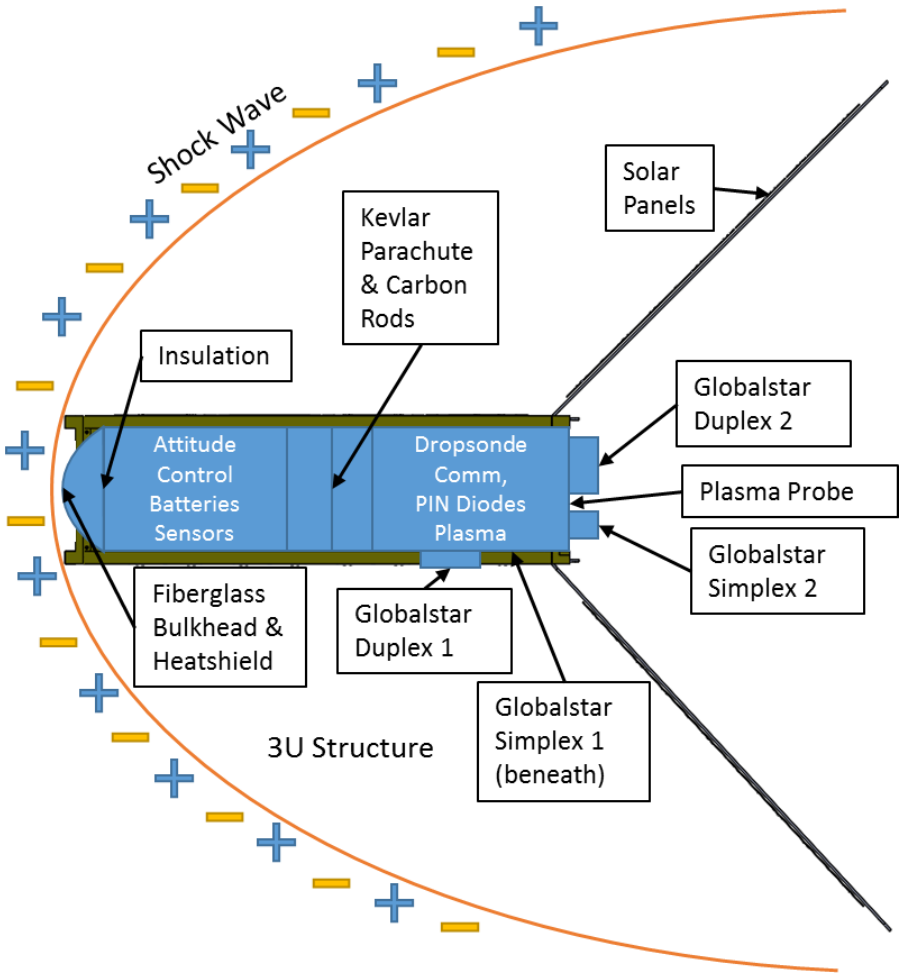
20+ Universities
NASA, AF, NSF,
Industry, Others,
25 units NSL Inventory

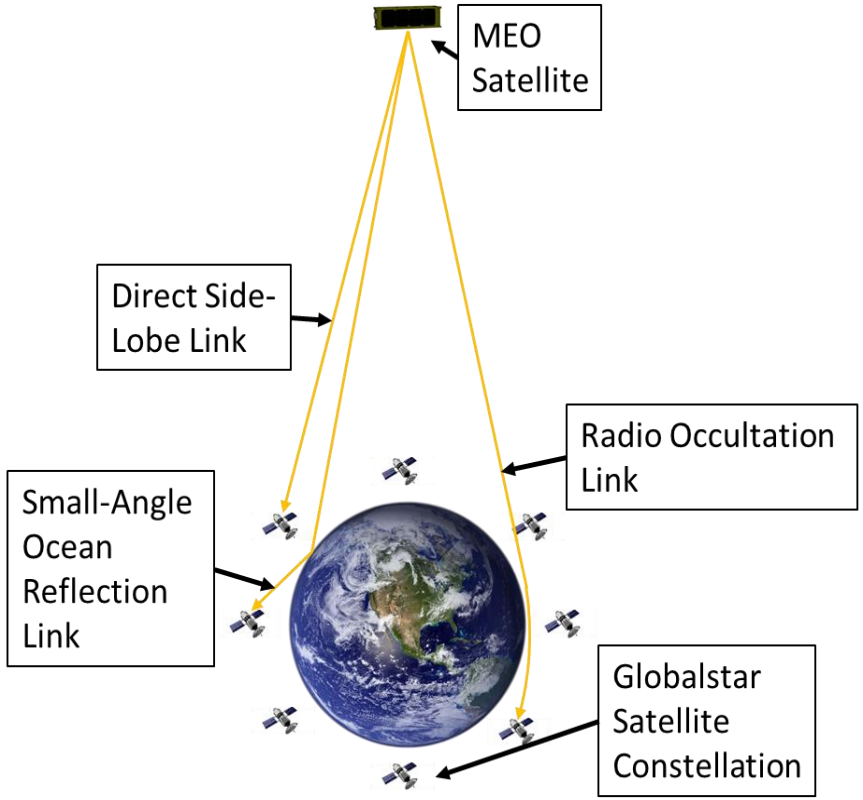


Globalstar Link: From Reentry Altitude and Beyond

Globalstar TSAT, GEARRS1 GEARRS2 ELEO Region Reentry Region Dropsondes MEO, GEO

Globalstar Link:
From Reentry Altitude and Beyond





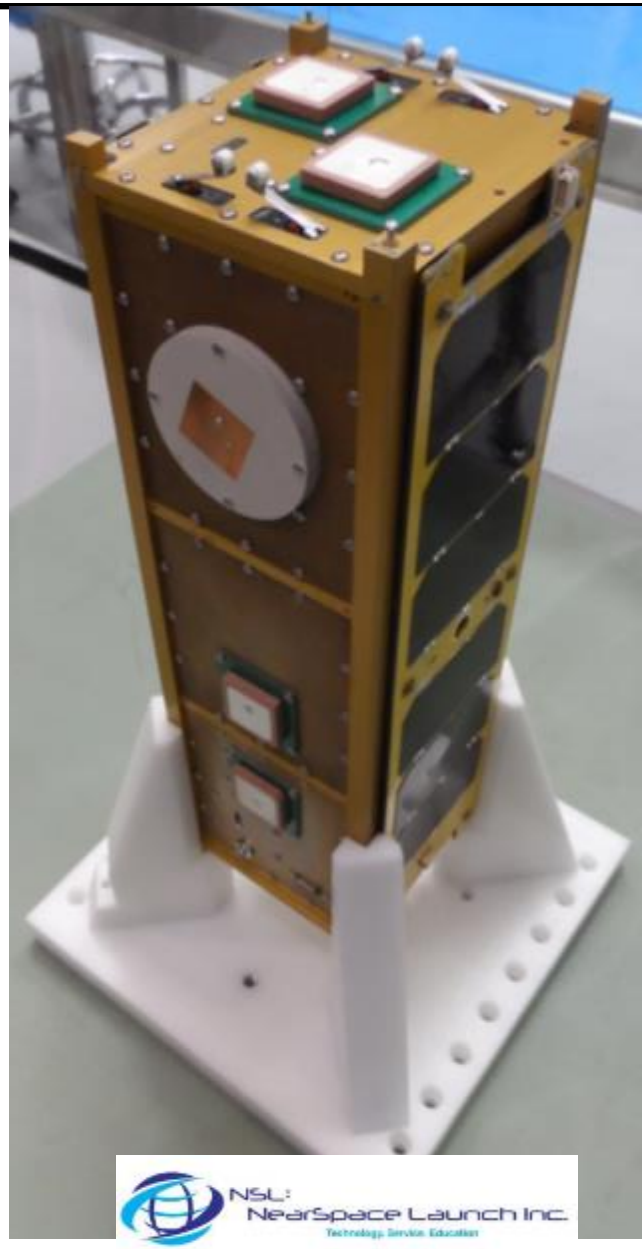
Reentry and Dropsonde
TSAT Temp. 20 deg./s, 110km

MEO and GEO Orbits

Please See SSC-11 Paper

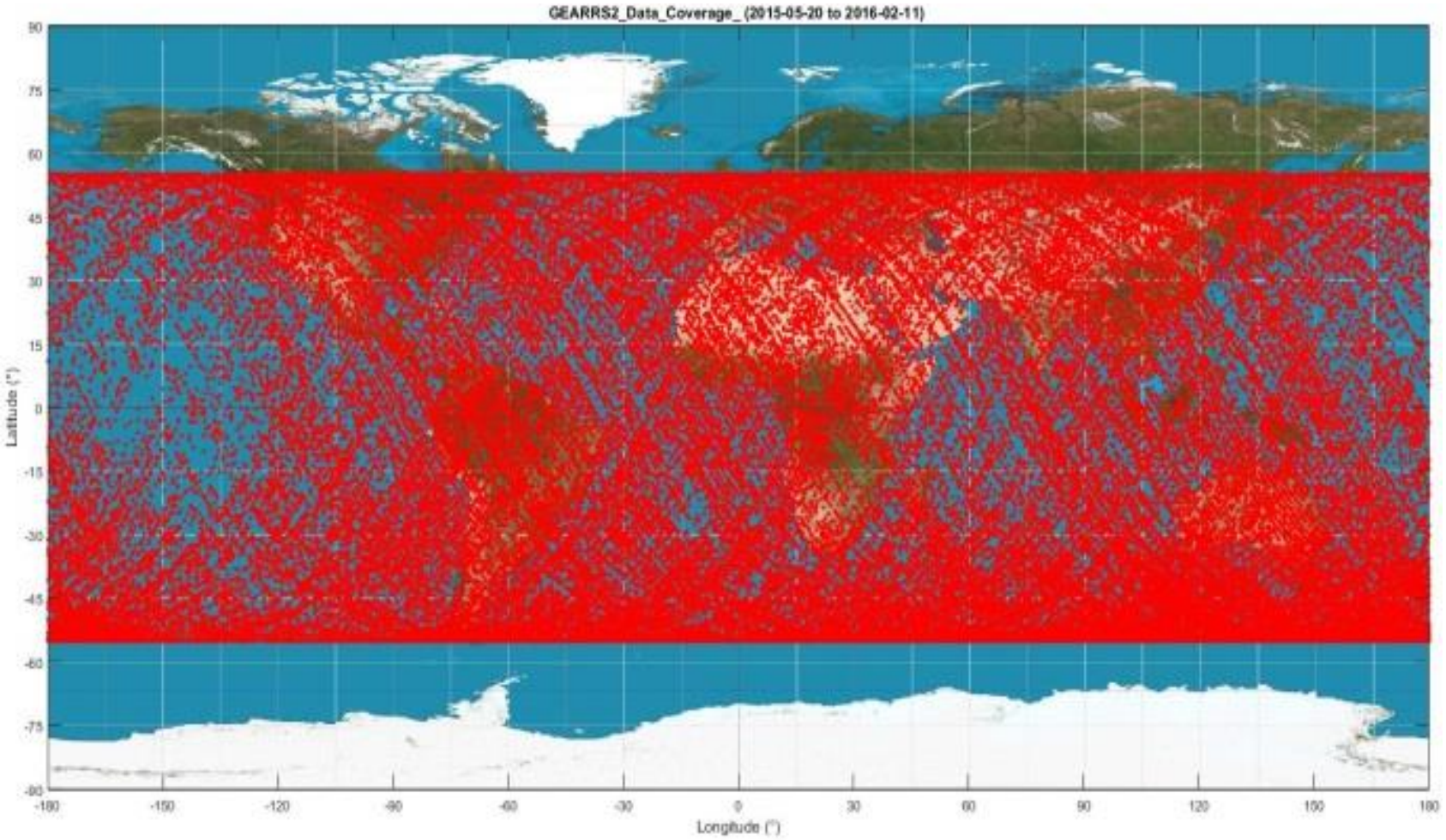
G* Experiment-GEARRS2

- 45 Day Turn-around by NSL
  - **FastBus Platform**: (Unit body Structure, PC104,EMI enclosure, Thermal short, Work Flow, Asm. Bench, ...G* links, mag., EPS, solar,..)
- GEARRS2 photo showing Simplex and Duplex patch antennas and the plasma probe and inhibits on the end cap.
- GEARRS2 operated for 9 months elliptical orbit. Mission requirement 1 month
- GEARRS2 validated FastBus, duplex coverage maps, costs, commanding rates/latency, file transfer rates and size, Globalstar network tuning & much more.



GEARRS2 Globalstar Coverage

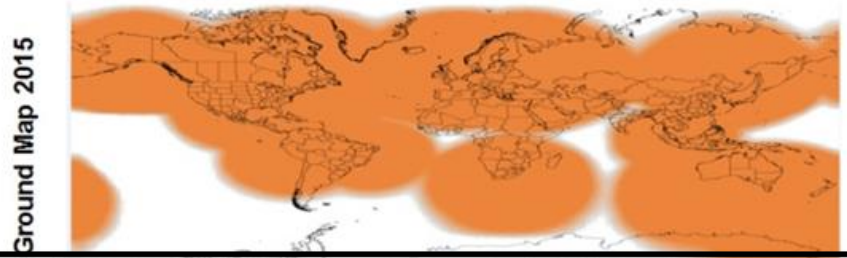
Some GEARRS2 Simplex raw data Raw Data Orbits before projection and sampling Normalization



Coverage Maps

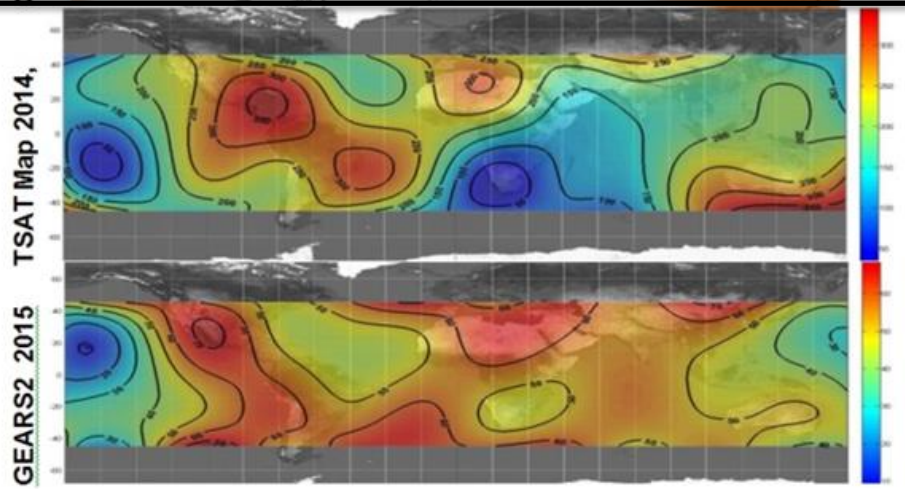
On-Orbit Results

Ground Map 2015

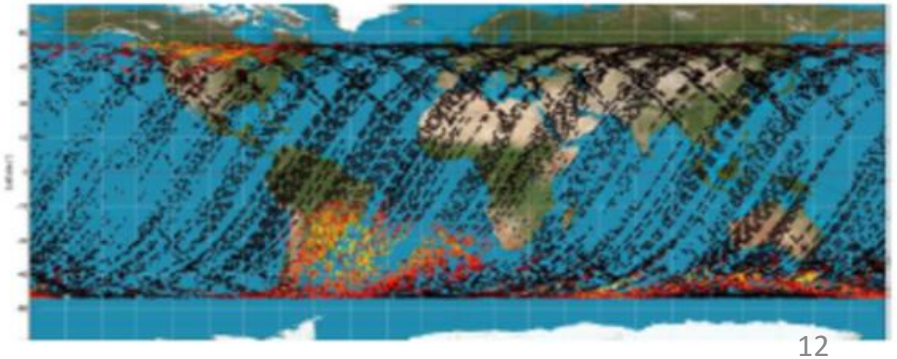


TSAT Simplex 2014

GEARRS 2 Simplex 2015

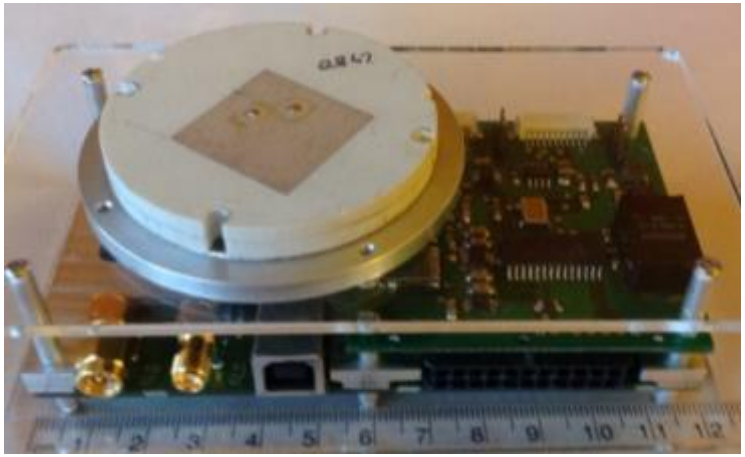


GEARRS 2 Particle Data Map



Latency and Jitter about 1-2 sec

EyeStar Duplex Transceiver Product



- Up to 7000 baud data rate
- Data and Command Control
- TCP-IP software with ARM Flight processor
- Handshaking Ack. protocol
- Active patch antenna (6 cm)
- 1 Watt ERP
- 3.3 & 5 V, 5W input power
- Size 27mm X 64mm X 119 mm
- CAD, ICD, Support, FCC License
- Encryption & Data Compression
- Quality Assurance and Rad shielding

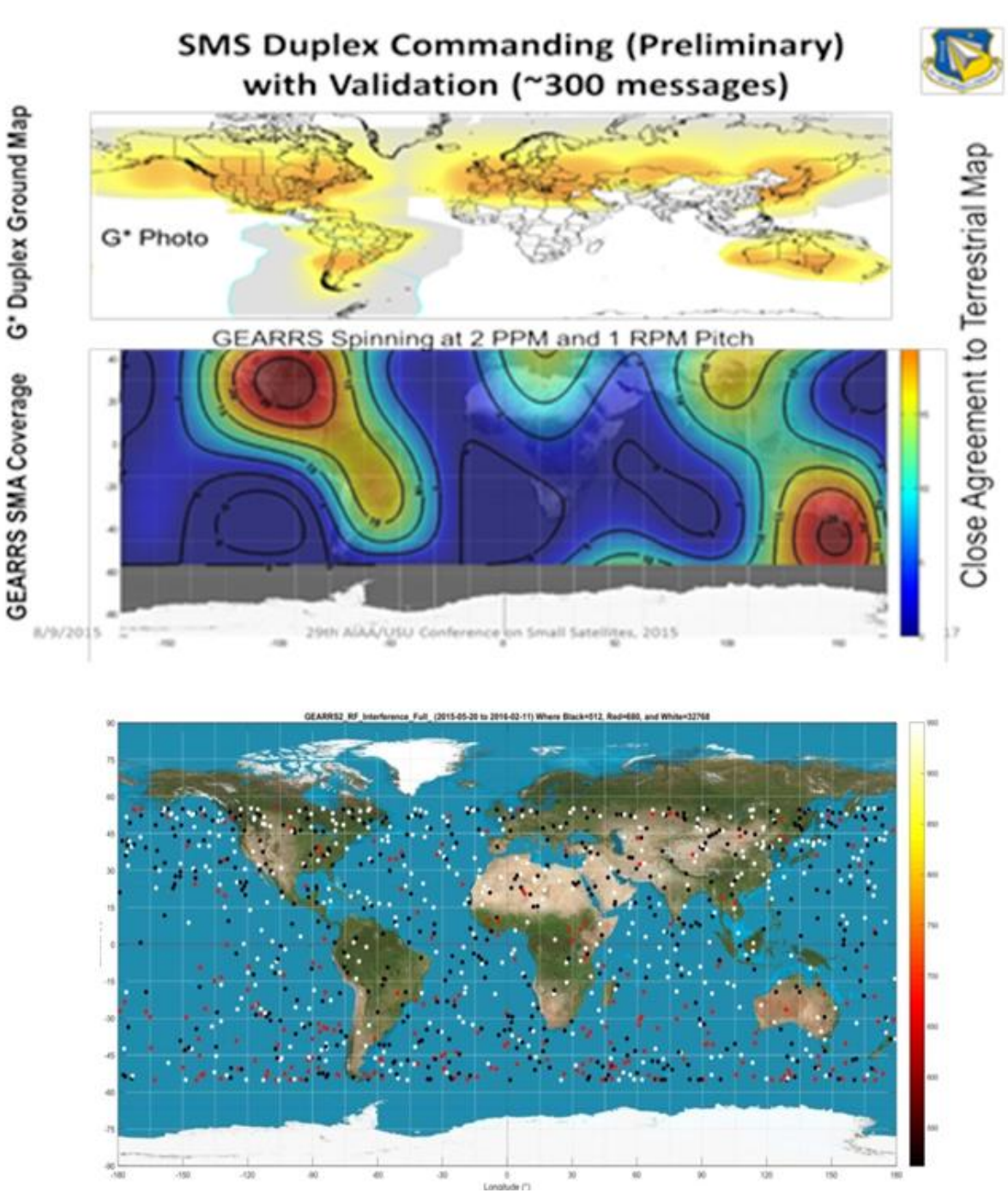


Figure 16-17: Top Panel first shows the Globalstar Duplex ground coverage and the Duplex connects/Signal strength connects for the Duplex unit when the satellite was spinning at 2 RPM and pitching at 1 RPM. (see paper)

The second panel shows the SMS Duplex Commanding.

The lower panel shows RF binary files (512-32,720 bytes) transmitted by the Duplex based on a 512 byte registration command received by the Duplex unit from the Globalstar satellite/Gateway. A uniform Duplex coverage map is expected for a non-spinning satellite (with all Ground stations open) .

Duplex Registration: RF Duplex Pulse Files of 512 bytes, 680 bytes, 32,720 bytes recorded on GEARRS2 Particle Detector

Duplex Gateway- Globalstar-Satellite -CubeSat for short (ms) 512 byte registration files.

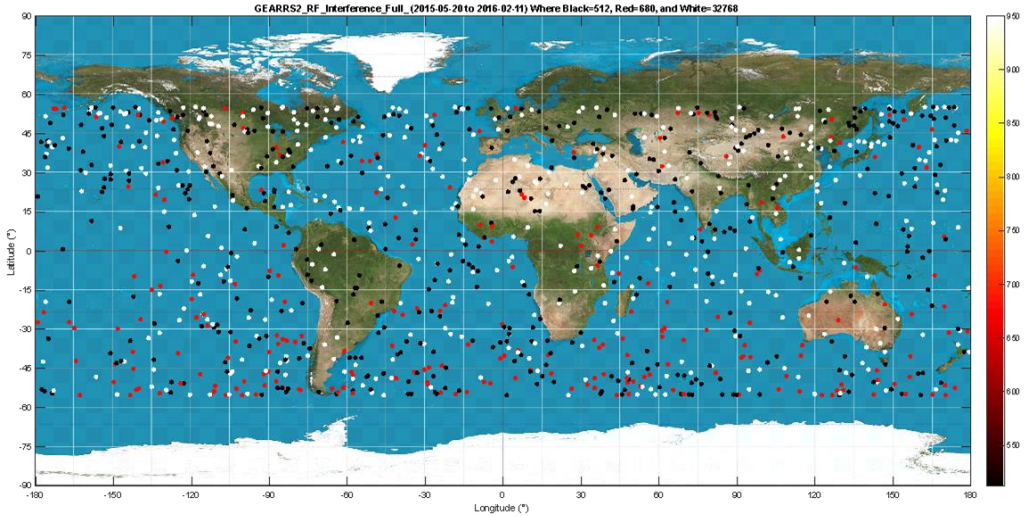
- Shows good duplex global connectivity,

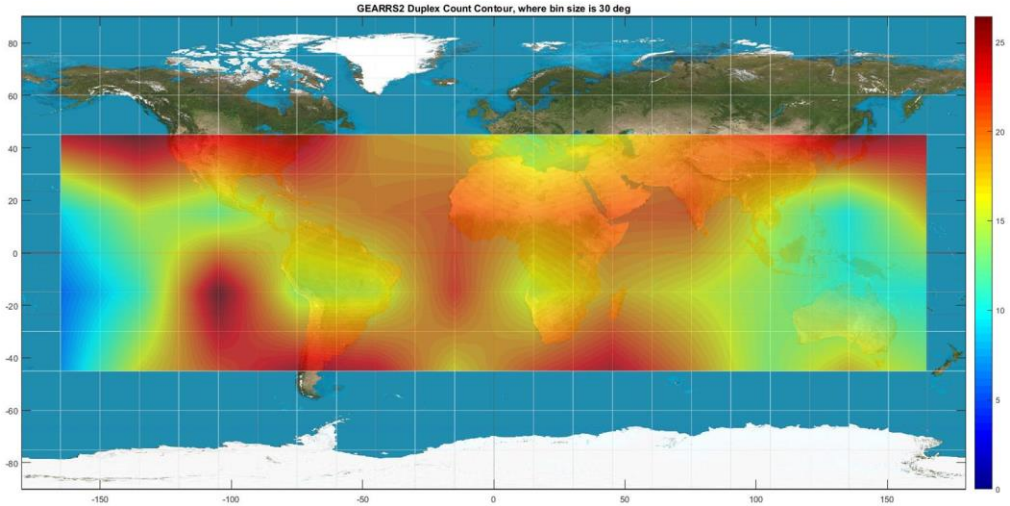
- Duplex CDMA Protocol timing and handshaking

- Estimate about 50% duplex coverage for existing ground station config.

- Working with Gstar on optimization

- New Sat stabilized flights soon





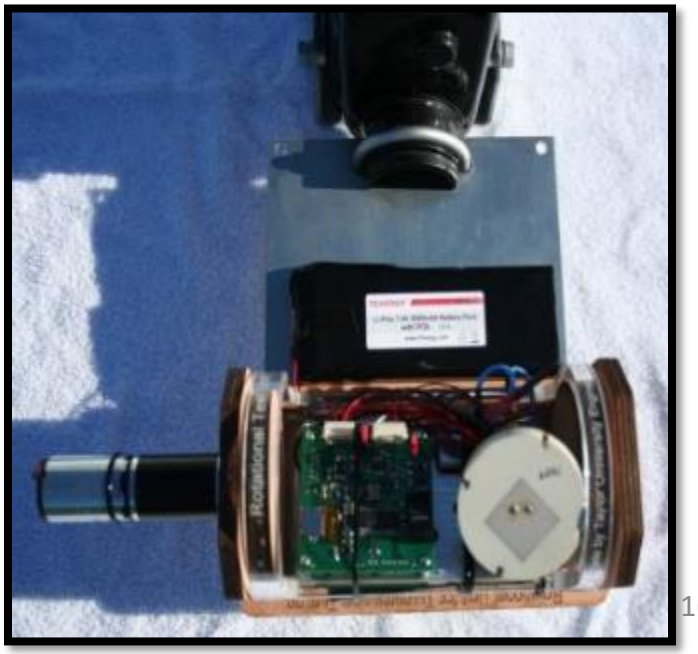
Ground Simulation

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

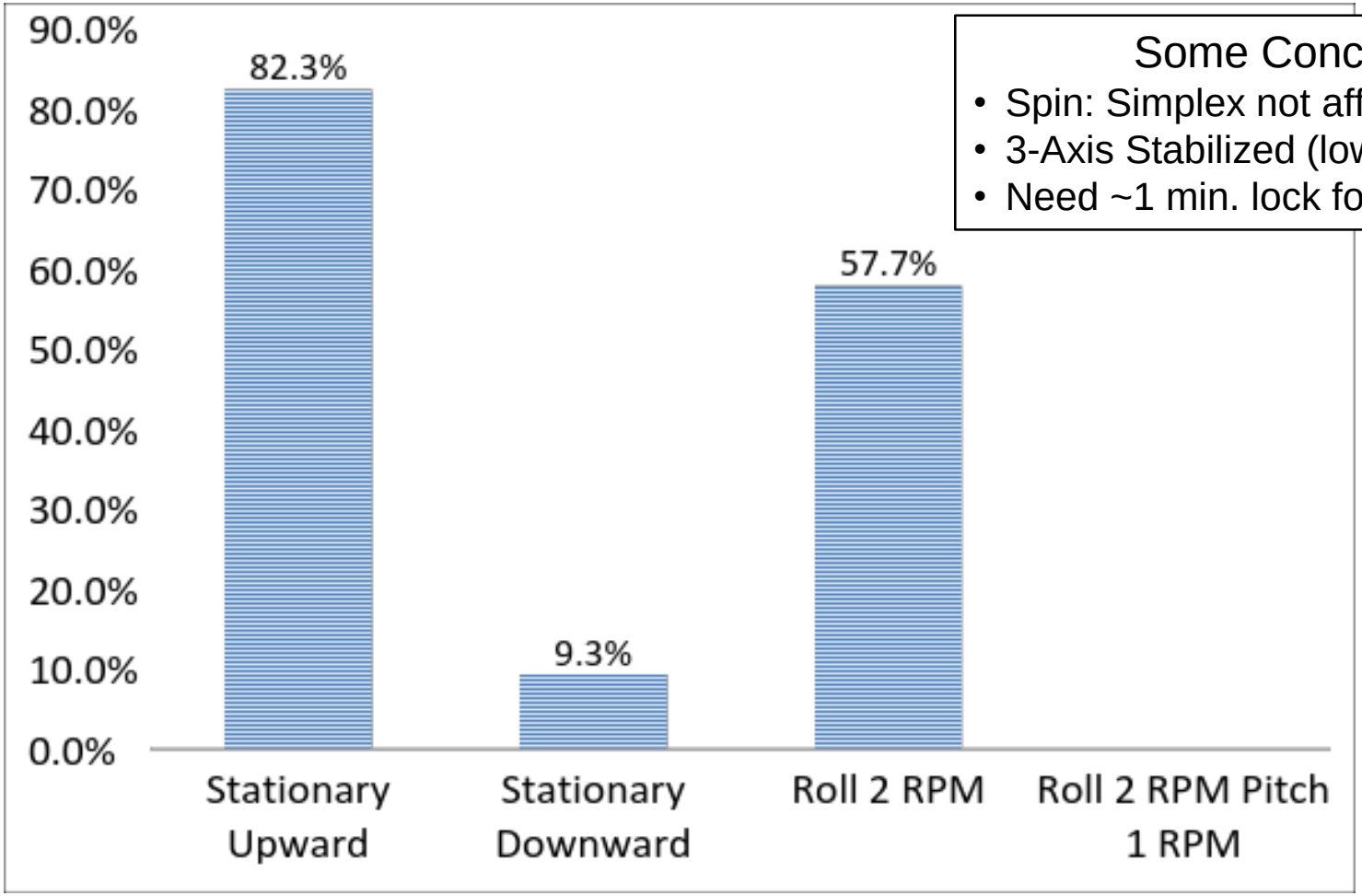
Because GEARRS2 is spinning at 2 RPM roll and 1 RPM in pitch it does not have time to achieve long connections for large data file transfers.

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 Ground Call Placement as a Function of Orientation and Motion (Preliminary)



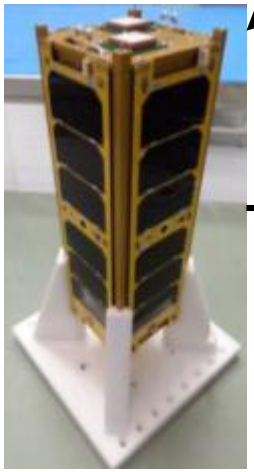
Some Conclusions:

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

NSL:
NearSpace Launch Inc.
Technology. Service. Education

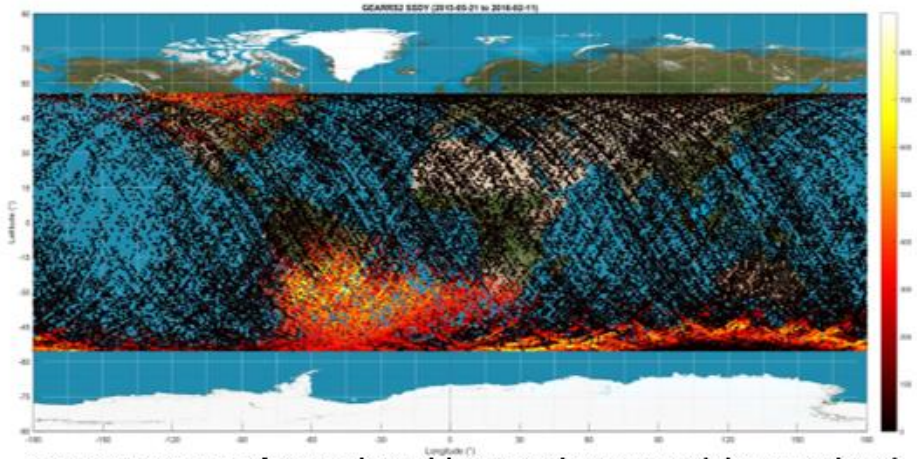
Commercial Products
See NSL Booth 148

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: 15 universities, NASA, NSF, AF, Industry
2. **FastBus Platform: Development 1U - 6U:**
   1. Low Cost and 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 Globalstar Radios, (Over 370 Launches with 99% success)



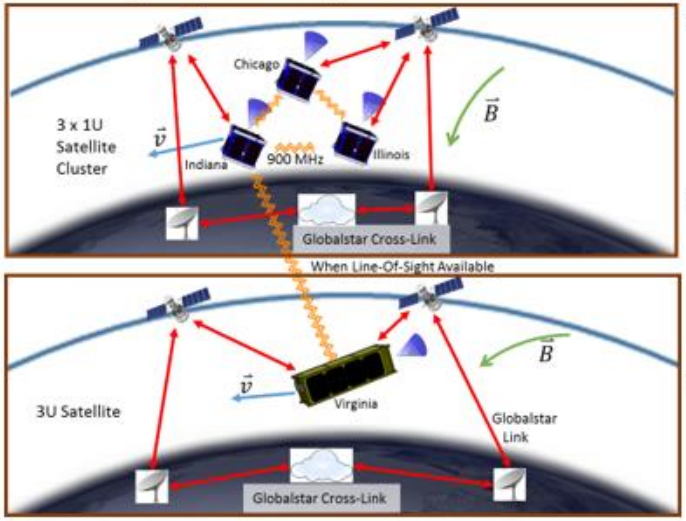
Multipoint Data, Swarms, Constellations & Common Data base

NSL-Globalstar Data Products



GEARRS2 Coverage of Energetic Particles. Note the SAMA and the Auroral Oval.

- Fully Operational Ground Station for thousands of Satellites, TRL=9
- Fault tolerant redundant cloud-based servers
- Full Ground Station Command & Data
- Custom data and console displays
- Online and mobile access
- Encryption Security



- Globalstar coverage for constellations of common data.
- Constellation communication option possible through 900 MHz link.
- Cross-link sends data through the cloud.

Suggestions

Don’t leave earth without a Simplex Processor!

-Very low S/C resources, Initial start-up phase and beacon (Heath, spin, GPS, summary data), 24/7, Mission Success!

Duplex Processor for intermediate data rates.

Commanding. Much lower data cost/month with no ground stations! Mission Success

Complements other Data Links

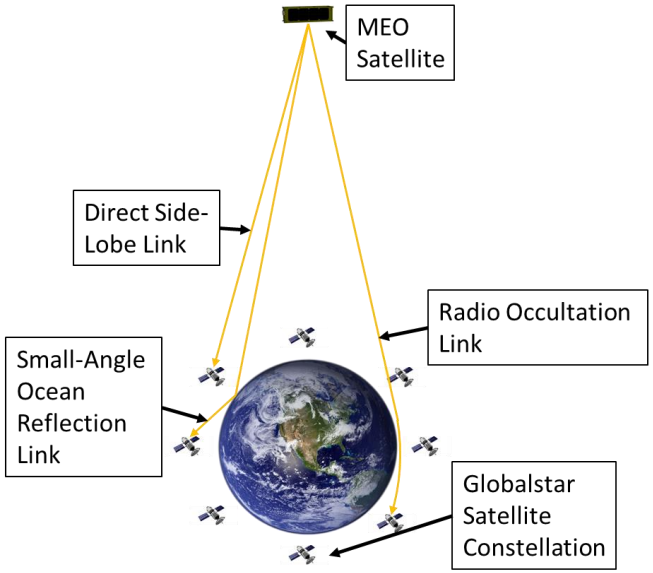
Questions

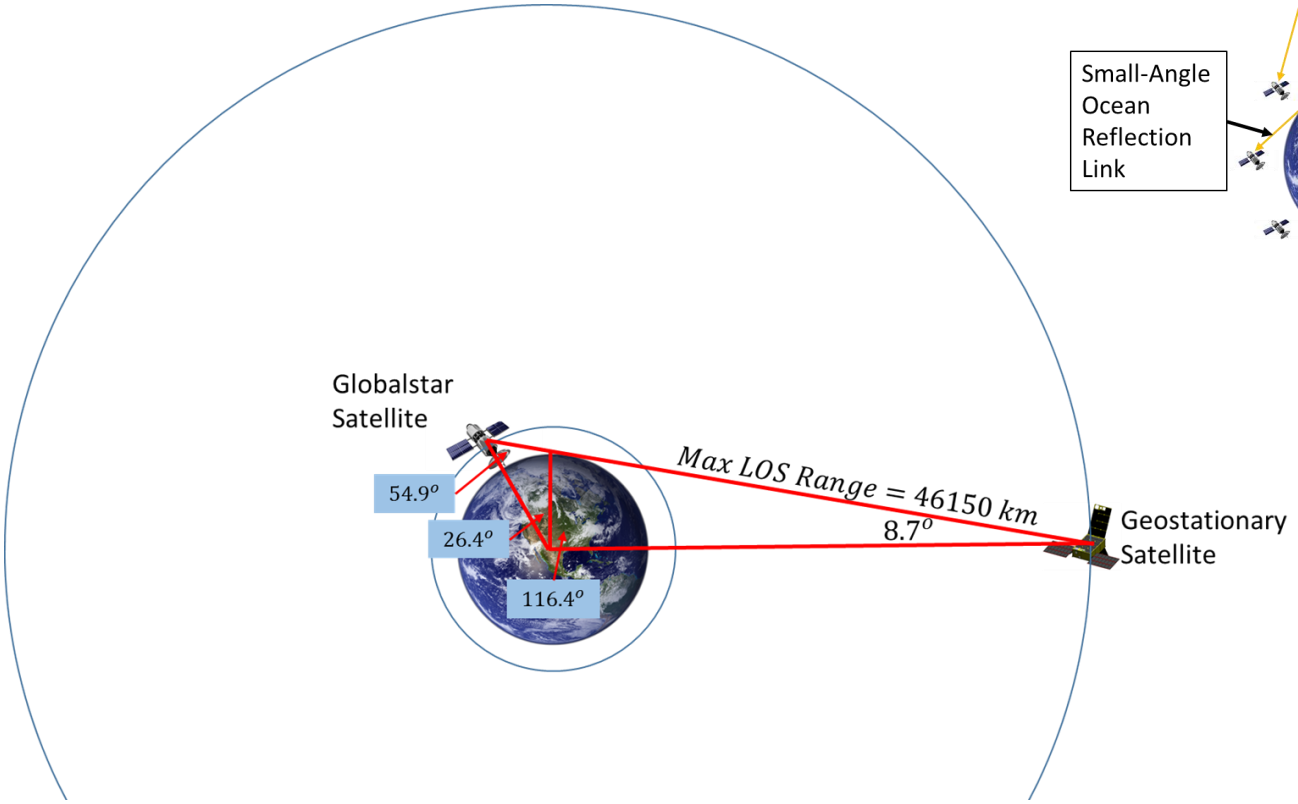
Please See SSC-11 Paper
Please Visit NSL Booth #148
downstairs by food

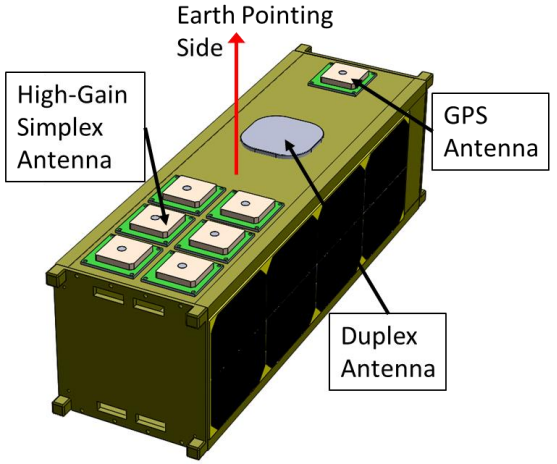
Experience: Three CubeSats launched within 15 months and many ready for launch using the Globalstar constellation of satellites for communication,

1. Low cost EyeStar Link: *Anywhere-Anytime, 24 hr./7days/week coverage*
2. *Critical Piece for Mission Success (9 to 700 Bytes/sec but practically 24/7)*
3. *No Ground Station required .. Ground Segment Included with Radio cost*
4. *Globalstar Capacity for TT&C for 1000's of satellites*
5. *Fully Operational NSL ground segment data and display (over 2 years)*
6. *Agile 1-3 month Delivery GEARRS2 and GEARRS1* (NSL precision unit body all-in-one FastBus Series)
7. Globalstar link below 200 km from reentry to many earth Radii!?

- Geostationary Sat







Simplex Data Rates

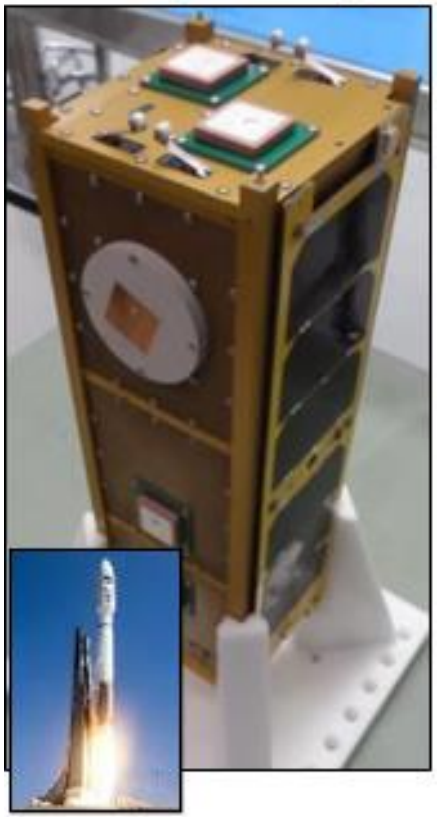
Standardized Simplex Monthly Data Charges

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

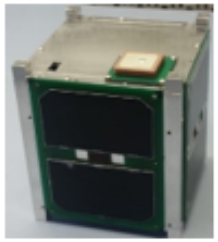
Note Savings: No Ground Station Operation, servers and and Hardware Costs.

42 Day Delivery



EyeStar S2 Simplex
EyeStar D2 Duplex
SMS Commanding
Atlas, 350x700 km,
DOD, STP, & NRO

- **All-In-One Complete Satellite Bus ready for flight!**
- **Technical Readiness Level: 8-9**
- **1U to 6U and 2x3U, Constellations**
- **100% on Orbit Success**
- **Structure: Precision Unit-body, EMI shielded, Thermal transfer, Rad shielded**
- **Includes: Globalstar radios, EPS, GaAs Solar Arrays, Battery, Inhibits, Processors, Harnesses and other Sub-Systems**
- **Pumpkin and PC104 Standard compatible**
- **3-6 Week Delivery**



1U FastBus CubeSat

2x3U FastBus CubeSat

GEARRS-1 Data Link Model

GEARRS-1

Simplex #1
Status and Sensor

Simplex #2
Duplex Backhaul

Duplex
(receives SMS)

Simplex
Frames

GS satellite

SMS
Commands

GS ground

GS SMS
Acks

XML
Payload
via HTTP

SMS
Commands

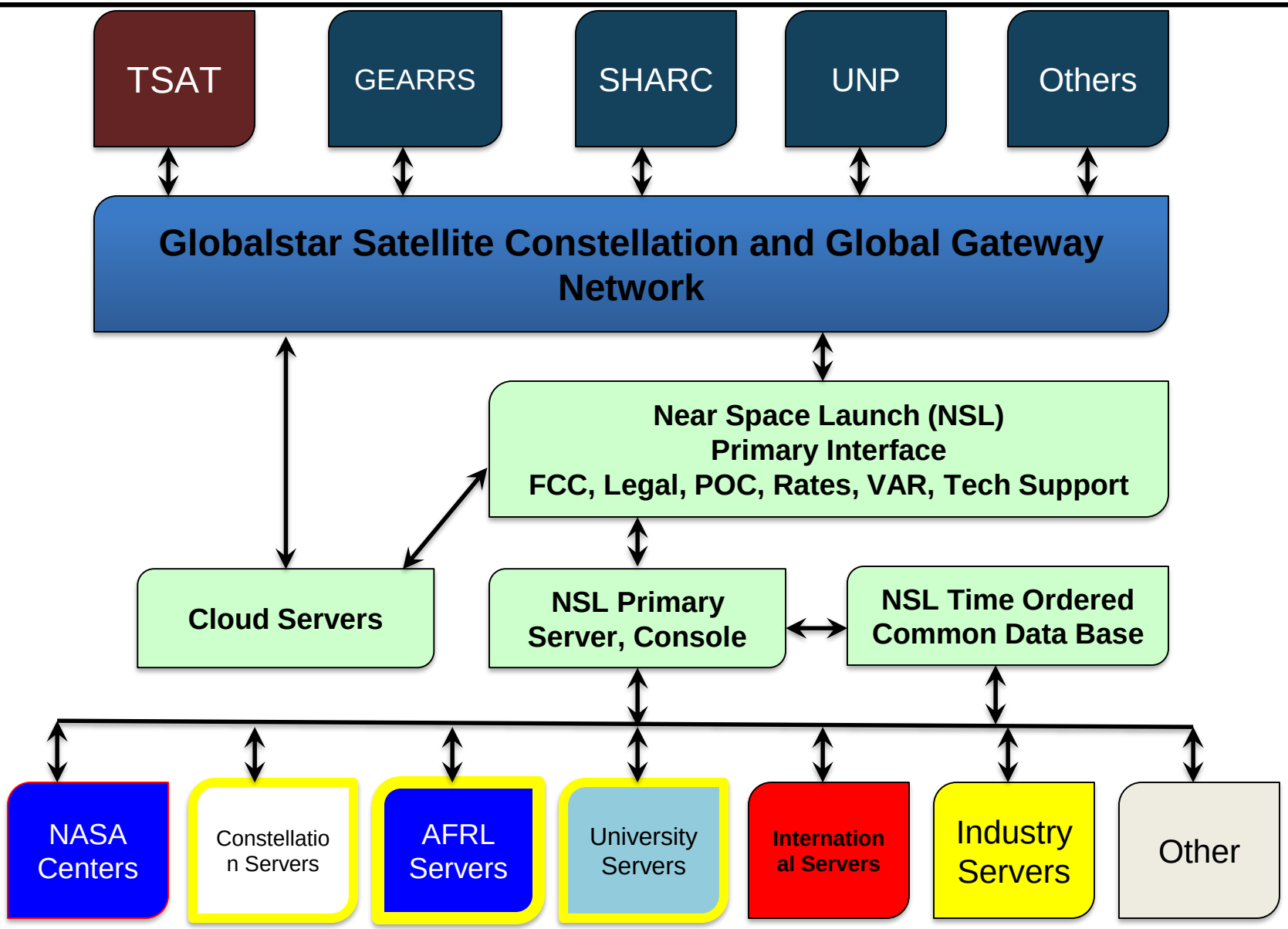
NSL Web Console

NSL Server

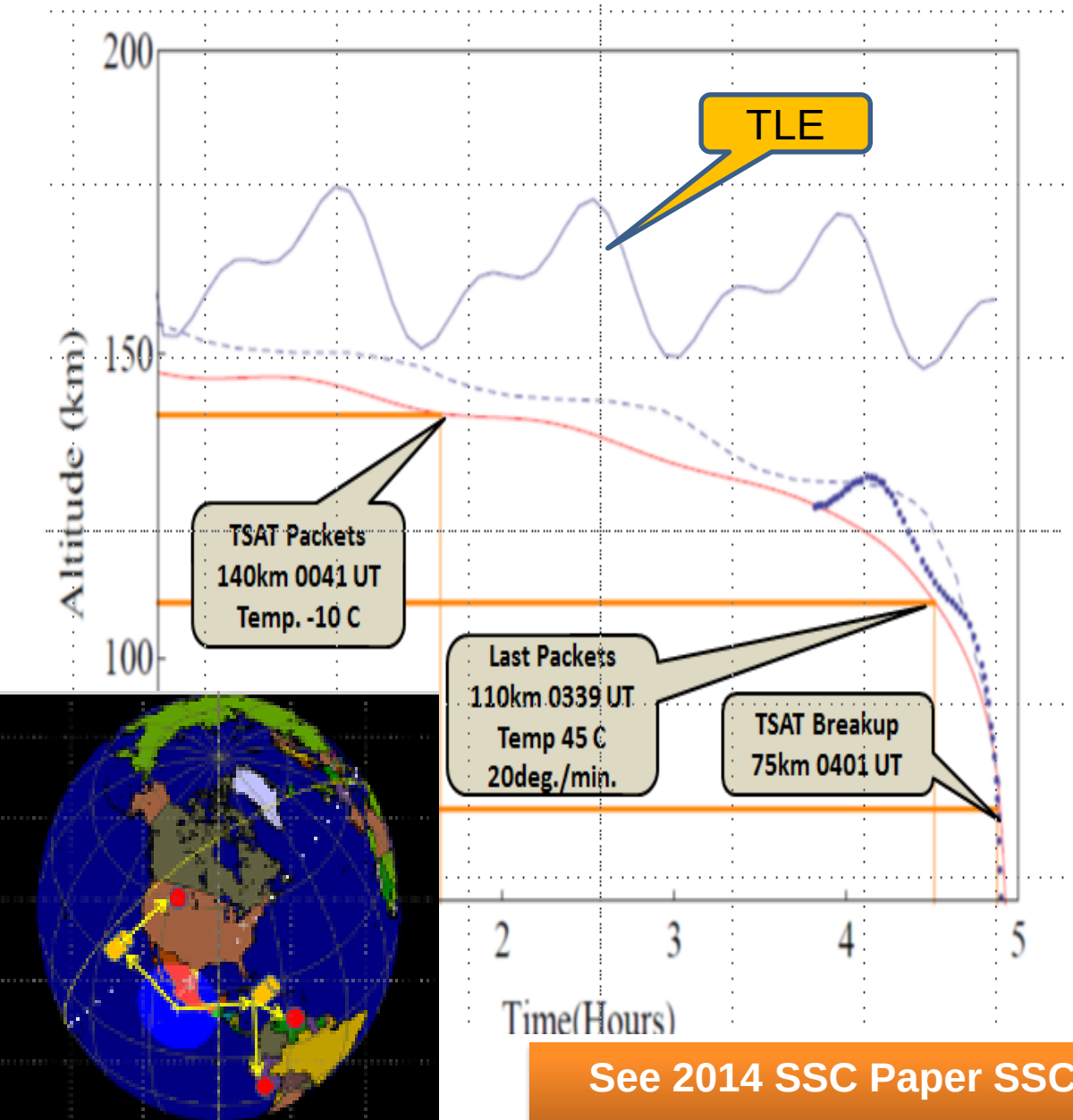
Stored to
both file
system and
database

SMS
Command
Generator

Satellite-Globalstar-Server Data Network Operational 2+ years



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



ELEO Electron Density

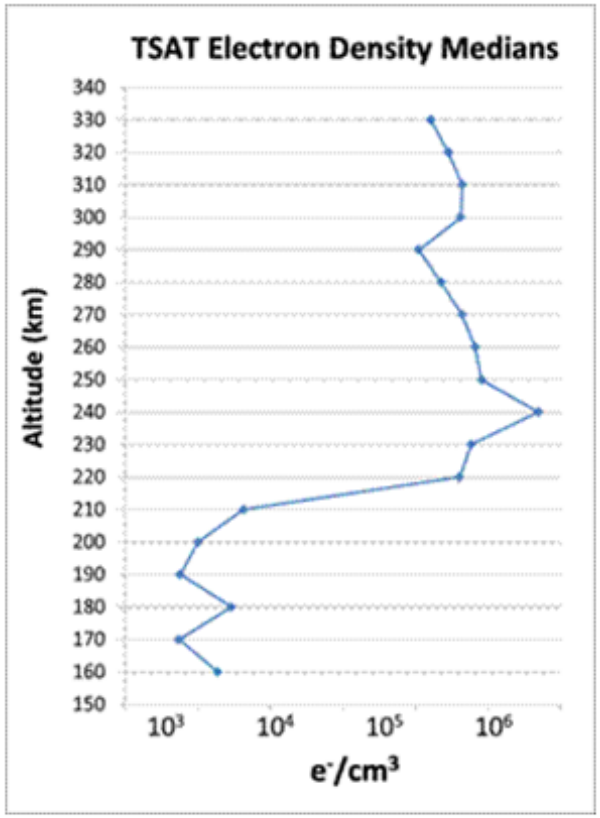


Figure 19: Mission medians of electron density for various orbit altitudes (10km bins). The higher density in the F-region transitions to the

See 2014 SSC Paper SSC14-WK-6

Globalstar Usage Plan

- Single Point Contact for Globalstar Simplex
  - NSL is POC as Value Added Reseller, VAR, product for Satellite and High-Altitude Balloons
  - 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 $1400 EM unit to $3,600 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 Multi-Satellites (1000s): Unified/Time-Ordered CubeSat Database