Globalstar Link:  
From Reentry Altitude and Beyond

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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

Visit NSL Exhibit Booth #148 for more information
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

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

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
Much More than a Modem!
NSL Duplex Product
Research Grade, Commercial License, TRL=8-9

EyeStar-Duplex

- Power Regulator
- ARM Linux Processor
- Firmware
- M-Controller
- Watchdog
- Antenna Cable
- RF Modem
- Options Geo-Locate, PIN, IMU, Temp,

$3B Network
300,000 customers

Ground Segment

- G* Professional Ground Network
- NSL Tuning
- NSL Redundant Fault Tolerant Server Network
- Internet Console Display Plotting

Your Satellite

- Power
- Serial Data
- Ack
- Commands
- Analogs IO

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**
  - Manifested, 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

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

Ground Map 2015

TSAT Simplex 2014

GEARRS 2 Simplex 2015

GEARRS 2 Particle Data Map

On-Orbit Results

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

- 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

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

- 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*

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

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

- 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
Globalstar Satellite Constellation and Global Gateway Network

Near Space Launch (NSL) Primary Interface
FCC, Legal, POC, Rates, VAR, Tech Support

Cloud Servers

NSL Primary Server, Console
NSL Time Ordered Common Data Base

NASA Centers
Constellation Servers
AFRL Servers
University Servers
International Servers
Industry Servers
Others
Figure 19: Mission medians of electron density for various orbit altitudes (10 km bins). The higher density in the F-region transitions to the...
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.
  • 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