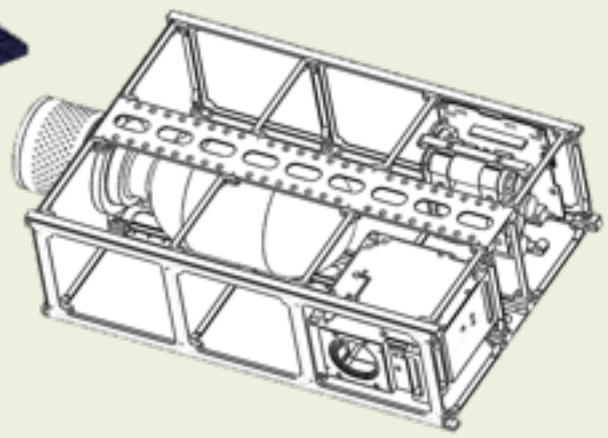
National Aeronautics and Space Administration

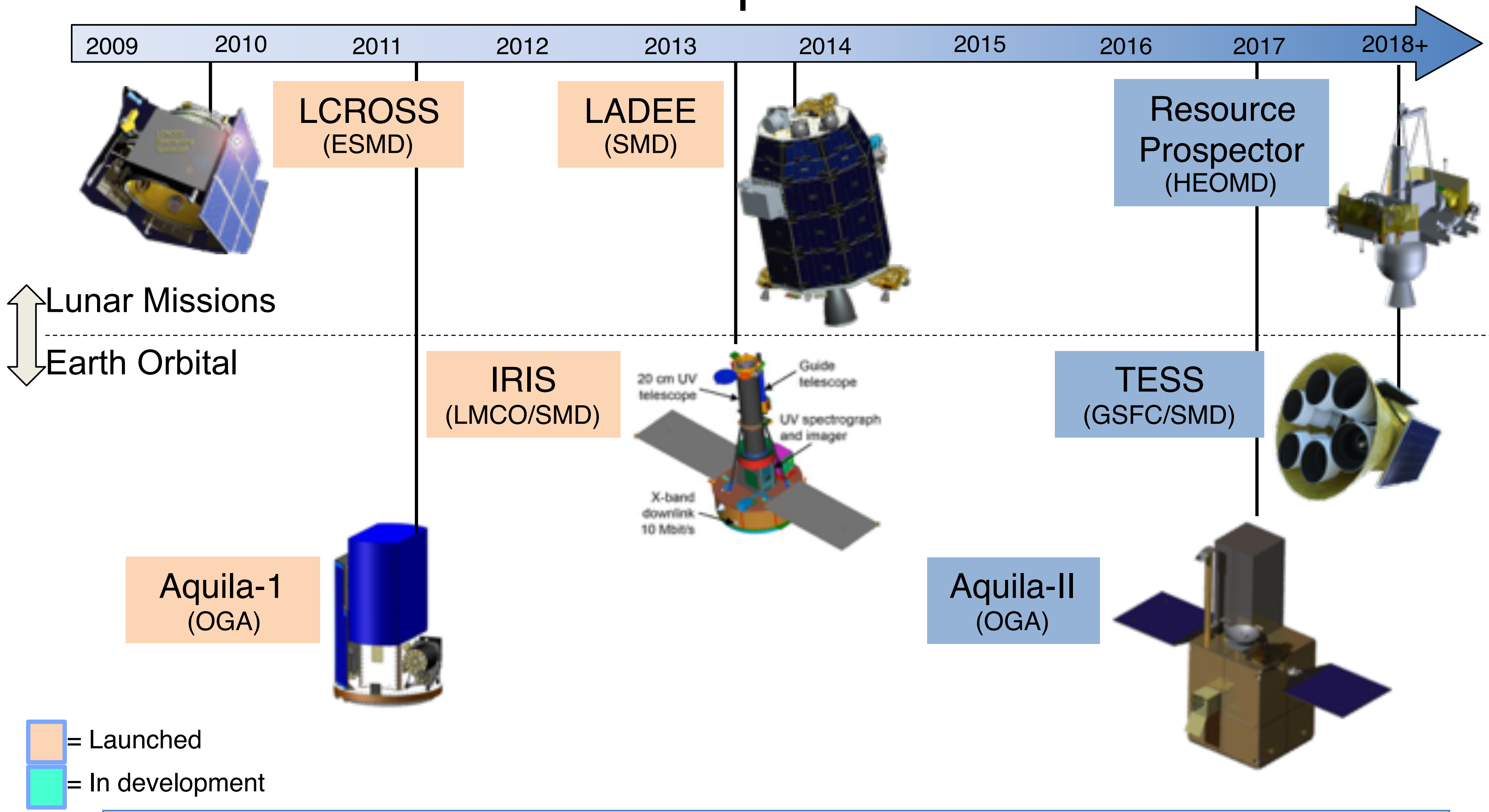
Pathfinder Technology Demonstrator

GlobalStar Testing and Results

Vanessa Kuroda
Communications Subsystem Lead
April 20-22, 2016
CalPoly CubeSat Workshop

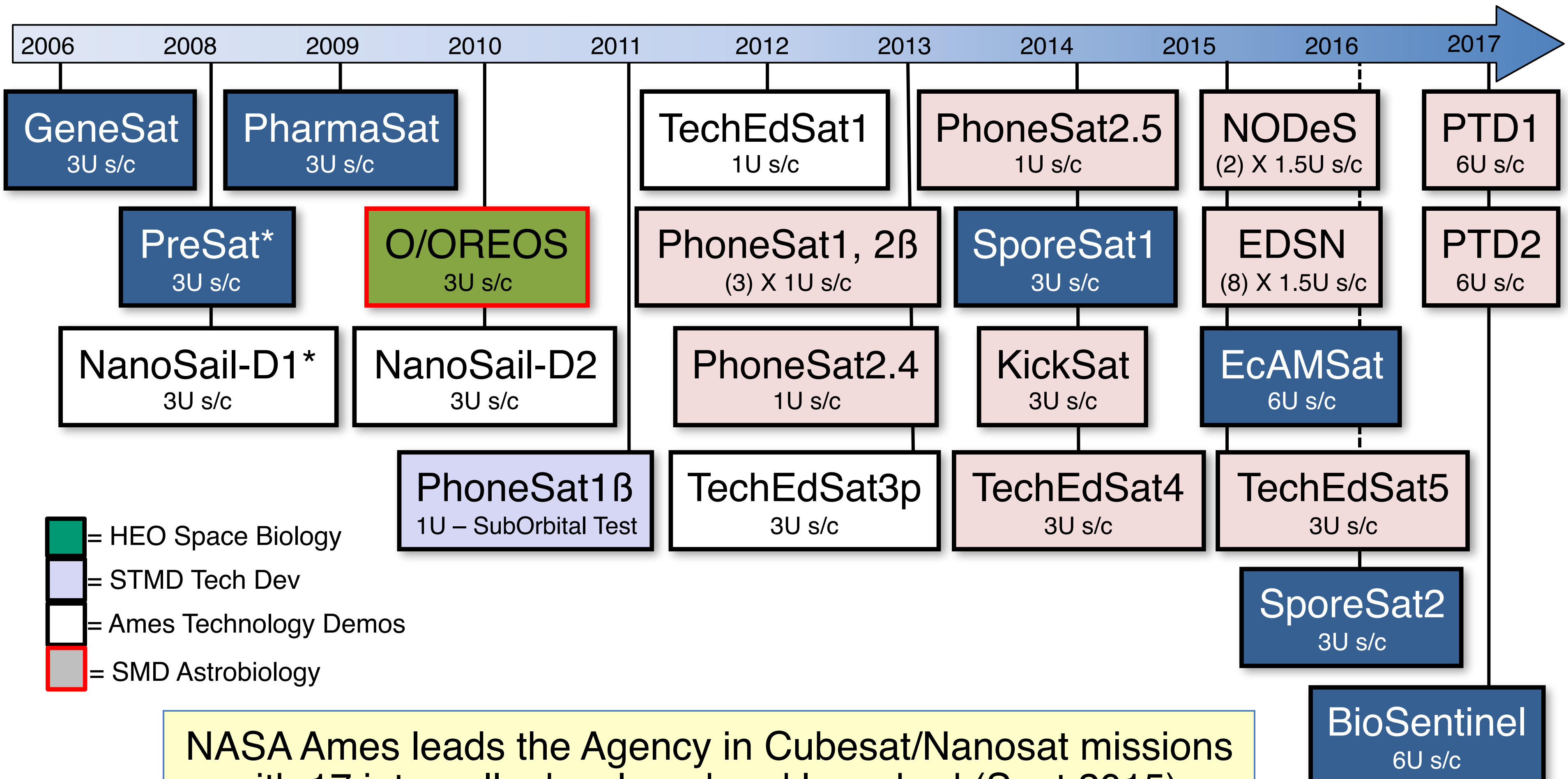


Ames’ Small Spacecraft Timeline



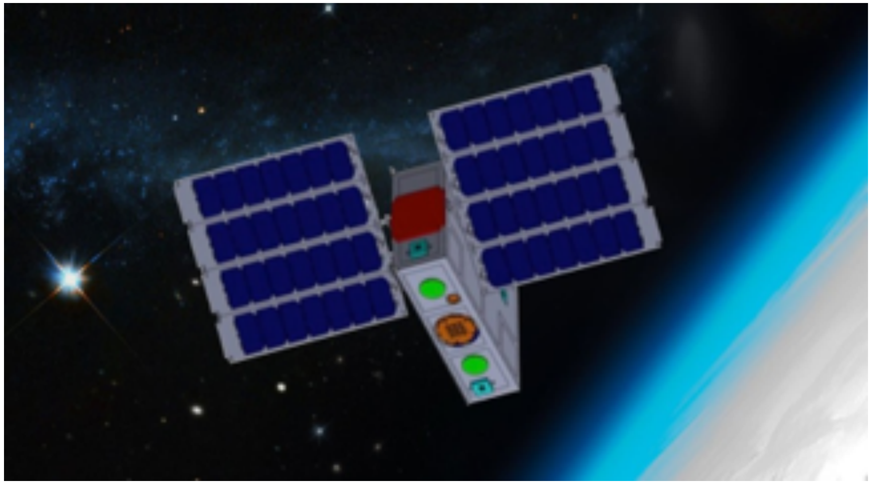
NASA Ames develops capable, cost efficient (< $250M) Small Satellites

NASA Ames' NanoSat Missions



NASA Ames leads the Agency in Cubesat/Nanosat missions with 17 internally developed and launched (Sept 2015). 16 more are in development and funded for flight

Pathfinder Technology Demonstration



Spacecraft Specifications

- Mass: 10-12 kg
- Quantity: One 6U CubeSat
- Orbit: 350-800 km, 51°, 98° incl.
- Size: 50 x 9.1 x 13.5 (*inches*)
- Communication: S-band

Mission Description

The Pathfinder Technology Demonstrator (PTD) project will demonstrate novel spacecraft technologies (hereafter referred to as the payload), in Low Earth Orbit. The cubesat will be operated by NASA, in partnership with the spacecraft and technology payload vendors using either a NASA or vendor ground data system.

Potential payloads:

- New Cubesat propulsion systems
- Novel attitude determination and control systems
- High bandwidth communications

Status

- Spacecraft RFP released on February 12, 2016
- RFP response window closed April, 2016
-
- Options for parallel Globalstar demo included in RFP
-
- 5 PTD Missions being considered

Rationale for Testing

Flexible and cost-efficient communications options enable many Cubesat missions

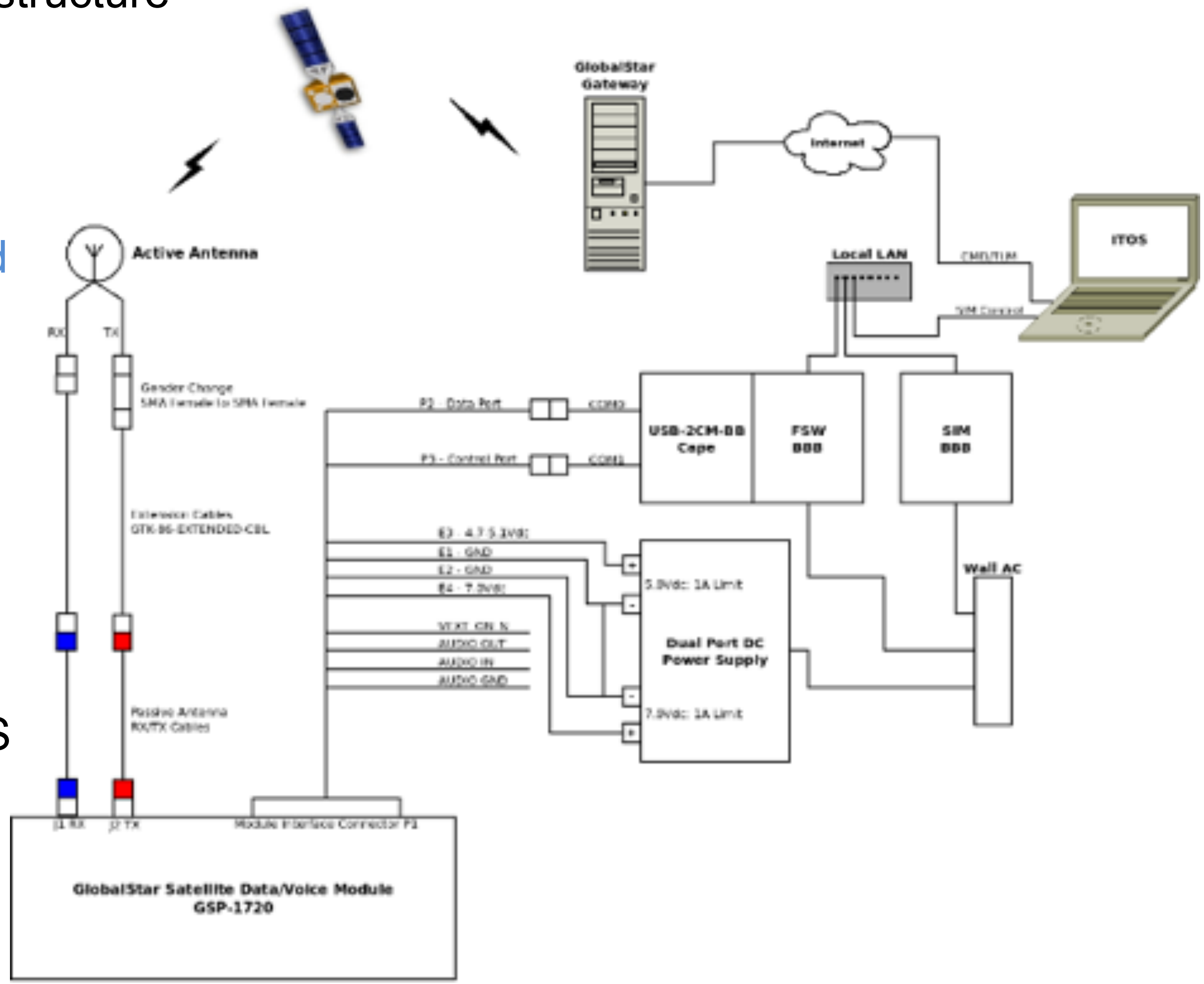
- Maintenance of infrastructure
- FCC licenses

The GlobalStar network is a constellation of satellites in LEO for satellite phones and low speed data communications

- Low cost, low SWaP
- Existing infrastructure

GSP-1720 unit tested for feasibility on PTD

- Possible tech demo
- Builds on TSAT, GEARSS & GEARSS2



Key Questions

1. Can it survive the space environment?
2. What is the quality of the communication service?
    1. What do we mean by quality of service?
        1. Data Rate/Throughput – what can we expect it to be?
        2. How often will the link be dropped?
        3. What does it take to re-establish the link? Does it come back on easily?
        4. How does it interact with normal spacecraft configuration?
            1. Interactions w/ BeagleBone Black and our FSW

GSP-1720 Test Approach

-Vibration testing

-TVAC testing

- -4 hot and cold cycles
- -1 hot survival turn on
- -1 cold survival turn on

-Performance Testing

- -Flatsat setup
  - -iPerf
  - -ftp
  - -ITOS

GSP-1720 Duplex Modem Board

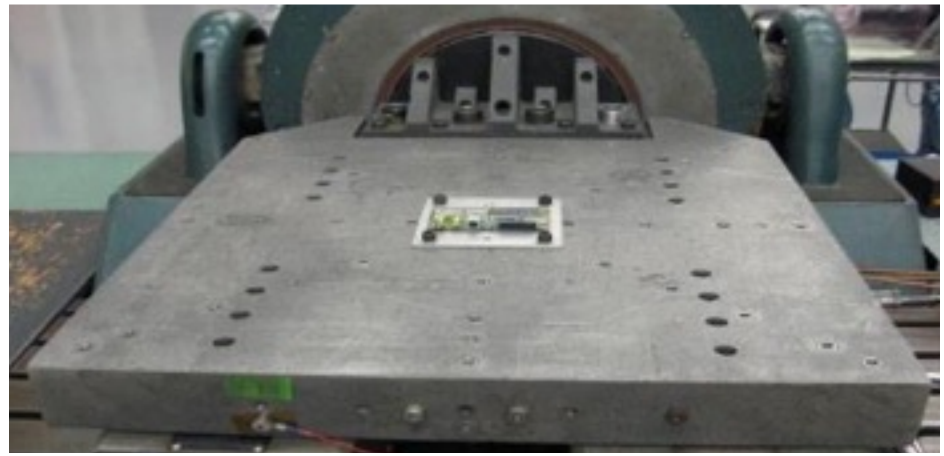
Vibration Testing

The Globalstar radio (GSP-1720) was subjected to random vibration equivalent to the GEVS qual test levels (14.2grms) using the vibration test facility in the Ames Engineering Evaluation Lab

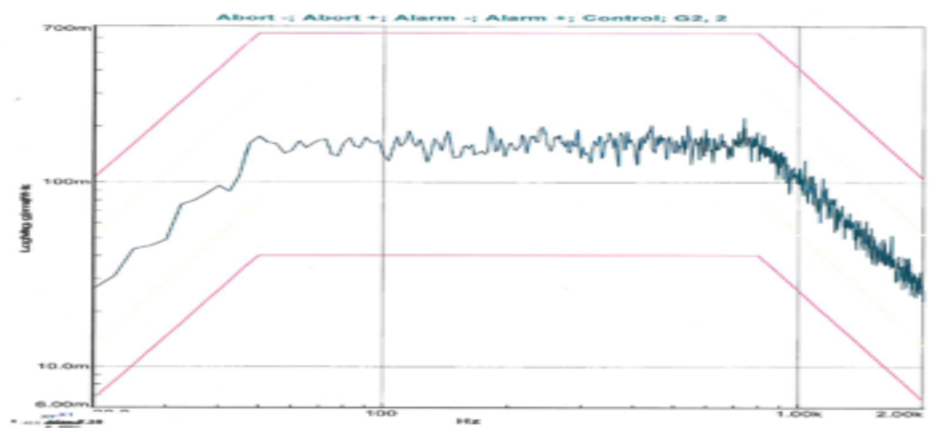
The test timeline consisted of the following major elements:

-Pre-vibe functional test
-Mounting of the GSP-1720 to the vibration facility
-Performance of the test
-Post-vibe functional test

-The GSP-1720 successfully turned on, communicated with the GlobalStar network, and transferred data after the vibration test



GSP-1720 on EEL Vibration Table



Vibe Profile

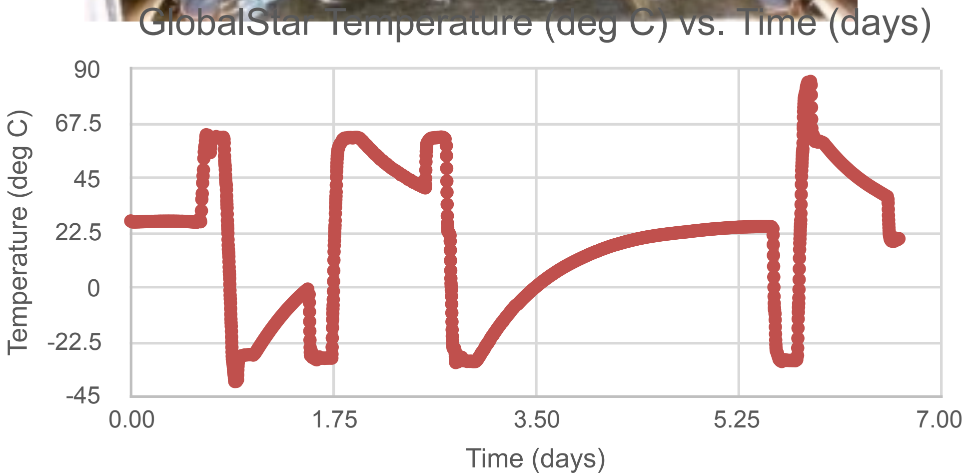
Thermal Vacuum Testing

The Globalstar radio (GSP-1720) was subjected to thermal vacuum testing using the small TVAC chamber in the Engineering Evaluation Lab (EEL) at Ames Research Center.

The test timeline consisted of the following major elements:
-4 thermal cycles
-8 proto-qualification plateaus for electrical performance testing of the component
-8 transitions
-One cold and one hot survival plateau for survival turn-on

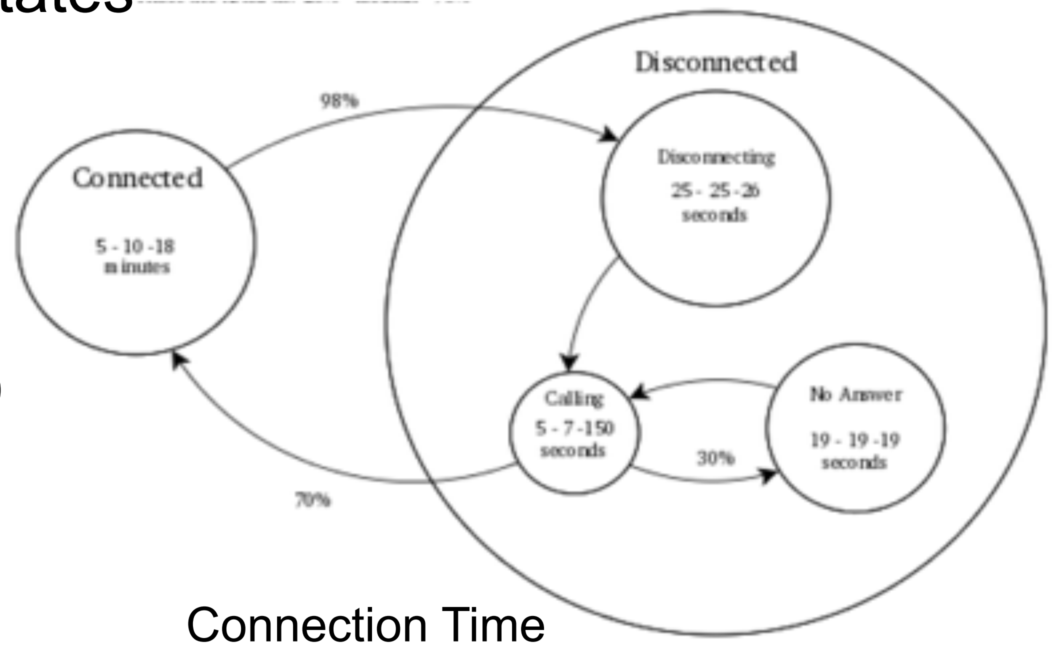
-The GSP-1720 successfully turned on, communicated with the GlobalStar network, and transferred data during each plateau and after the cycling was complete

GSP-1720 in EEL TVAC Chamber



Connection Time

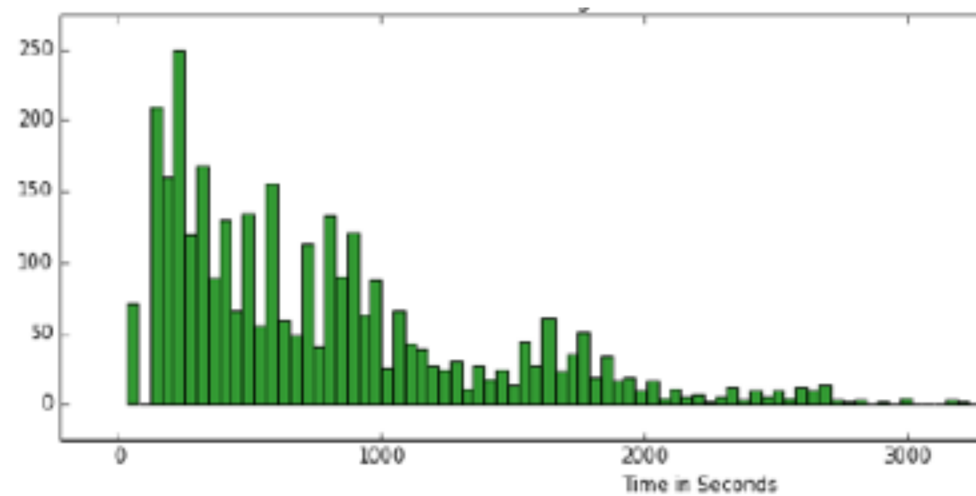
- System consists of four states
  - Connected
  - Disconnected
  - Calling
  - No Answer (Wait)



- Connected times ("pass") varied from 5-18 minutes (25%-75%)

- Reconnection took from 30 seconds to several minutes

Connection Time

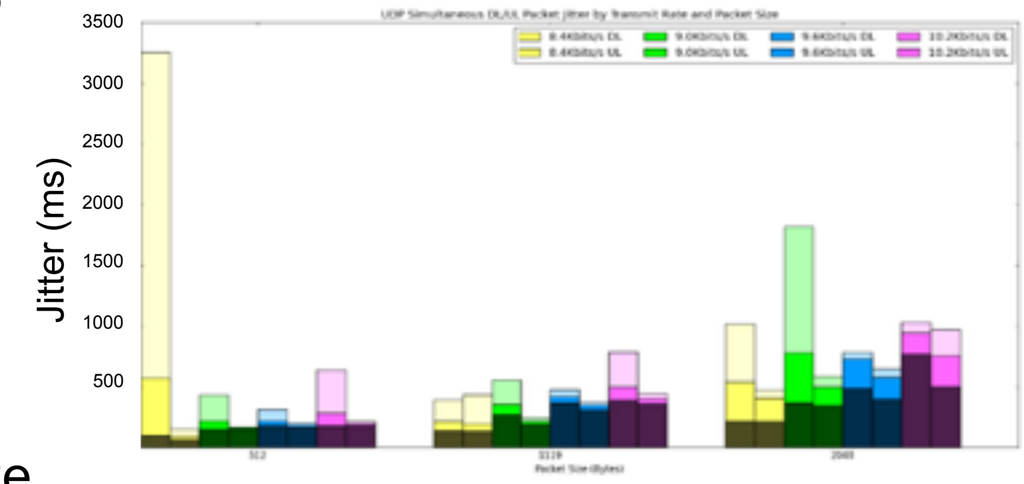


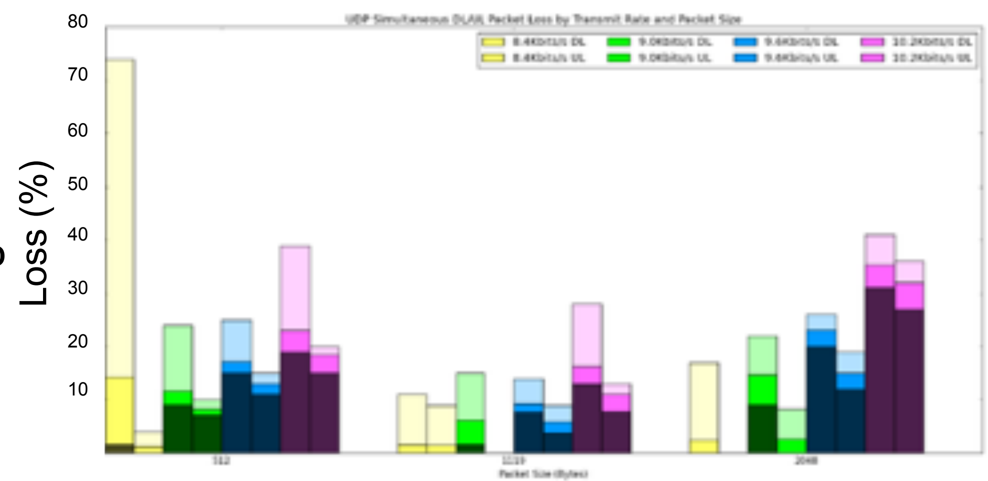
Characterization of System Jitter

- Test performed using UDP
  - Connected
  - Disconnected
  - Calling
  - No Answer (Wait)

- Jitter
  - Jitter increases w/packet size
  - Downlink worse than uplink
  - Jitter generally < 1 sec

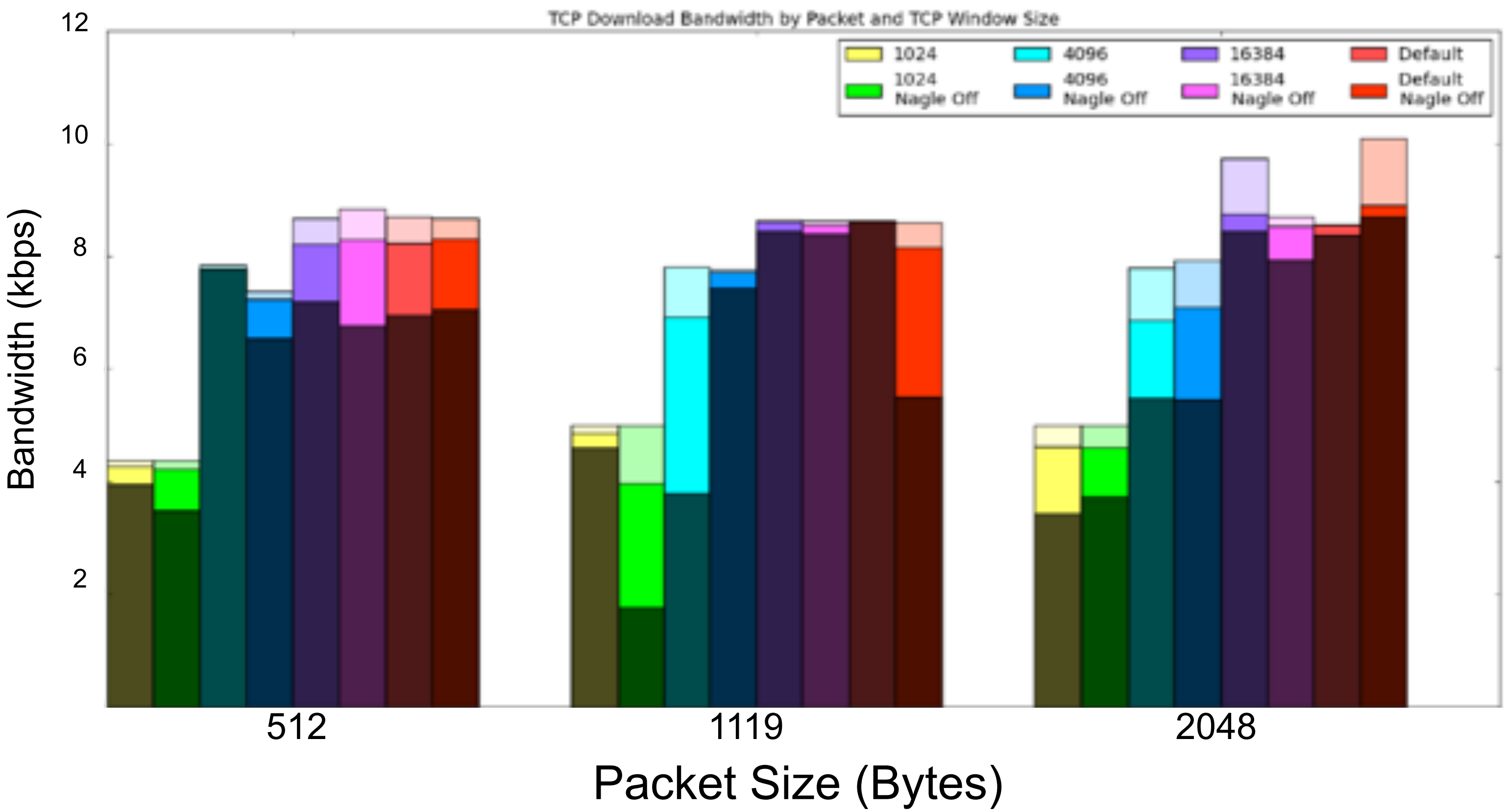
- Packet Loss
  - Individual packet loss 10-30% for UDP (no retransmission)
  - Downlink worse than uplink





Data Rates Using TCP/IP

- Uplink and downlink data rates between spacecraft and ground system characterized over several days
- Data rate reduced by 20% due to overhead (8 kbps vs. 9.6 kbps capability)
- Some reduction in performance for:
  - Smaller packet sizes
  - Arbitrarily constrained TCP window size
  - Disabling Nagle processing



Interactions Between Ground and Flight Software

- Ground/FSW interactions characterized using full system – spacecraft, GlobalStar & ground system running ITOS
- Telemetry latency bounds calculated using timestamped events in data stream
  - Command execution
  - Receipt of data
  - Resumption of operations after waiting for housekeeping
- Command links established 108 times over several days
- Latency measured at between two and eight seconds
- Six transfer failures logged by the system

Conclusions

- GlobalStar GSP-1720 modem passed vibration and TVAC tests to GEVS levels
- Modem successfully integrated with existing NASA flight software and ground system
  - LADEE flight software running on BeagleBone Black with cFS/cFE stack
  - ITOS ground software suite running on LINUX box
- Performance of overall system characterized
  - Successfully ran UDP, PPP, FTP and TCP/IP protocols
  - Jitter and throughput reasonably close to expected capability of system
  - Larger packet size transfers were more efficient
  - Loss of signal was handled autonomously, although the time for reconnection varied
  - Simultaneous uplink and downlink did not affect overall performance
- Demonstrated CFDP – CCSDS File Delivery Protocol
- Further characterization required on-orbit
  - Ground tests did not include GlobalStar spacecraft or Ground Station hand offs
  - Re-acquisition time will depend on relative positions of spacecraft and GlobalStar constellation

Questions?

National Aeronautics and Space Administration

Acknowledgements:

- Pathfinder Technology Demonstrator Project, funded by NASA STMD/ SSTP (Space Technology Mission Directorate/Small Spacecraft Technology Program)
- PTD Team
    - John Hanson
    - John Marmie
    - Greg Limes
    - Shi Lei Han
    - Scott Christa
    - Pat Castle
    - Andy Goforth
- GlobalStar – Joe Crowley