Variable Coding Modulation Testing On-Board NASA's SCaN Testbed

National Aeronautics and Space Administration

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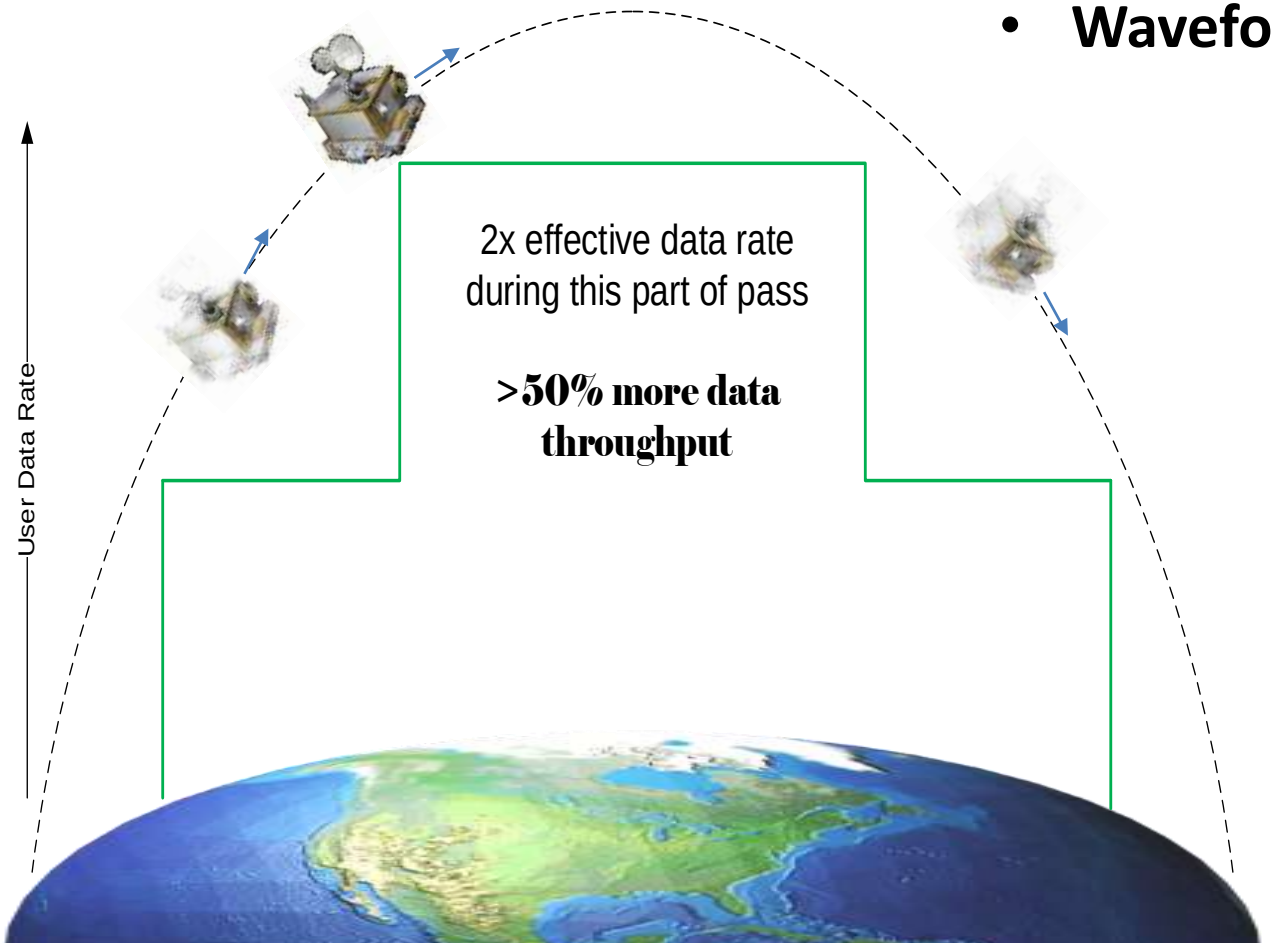
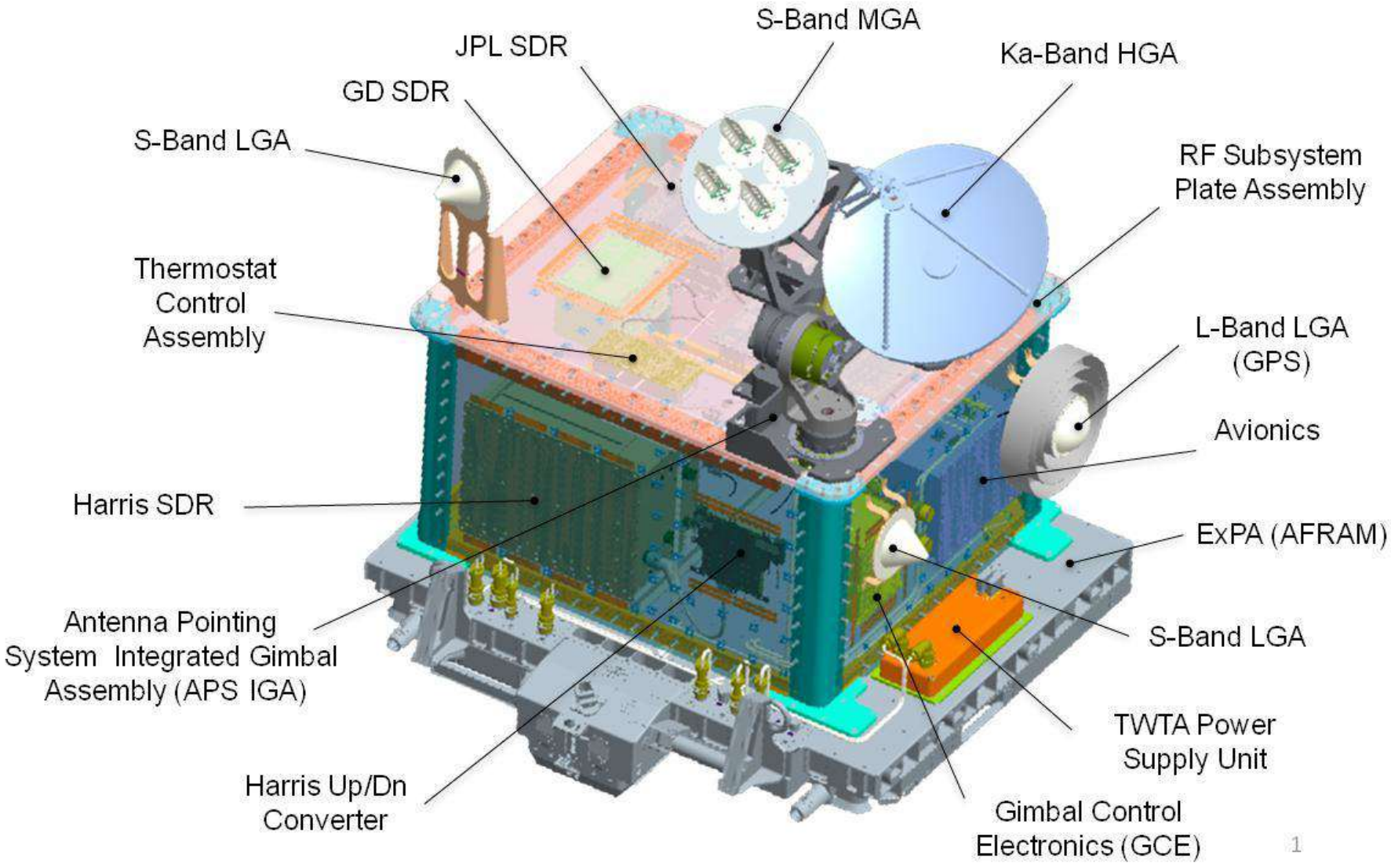
SPACE COMMUNICATIONS SCaN AND NAVIGATION

Presentation Outline

- SCaN Testbed Overview
- Waveform Configuration
- Experiment Implementation
- On-orbit Test Results
- Future work

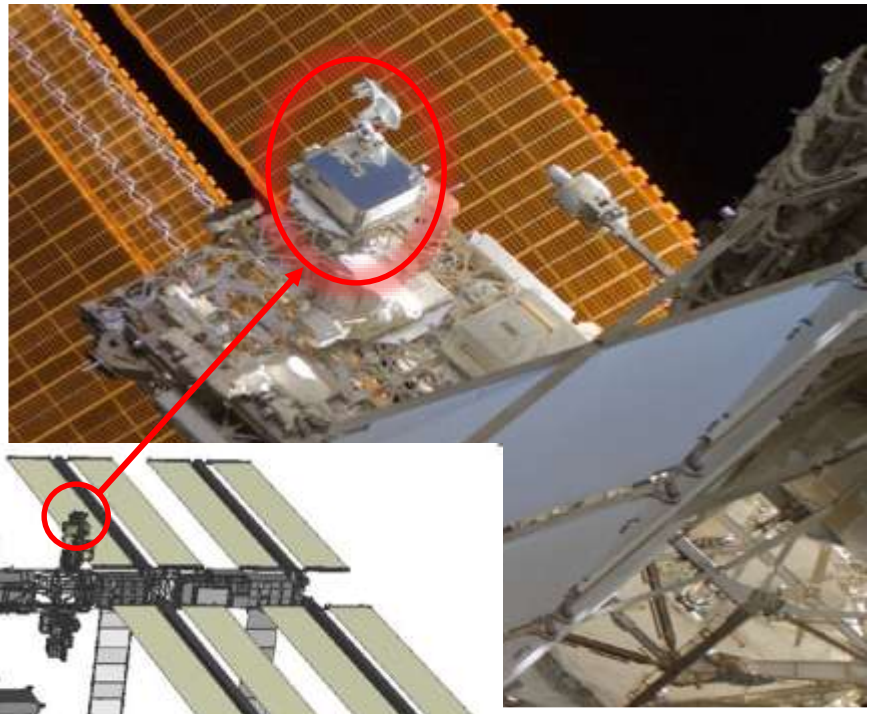


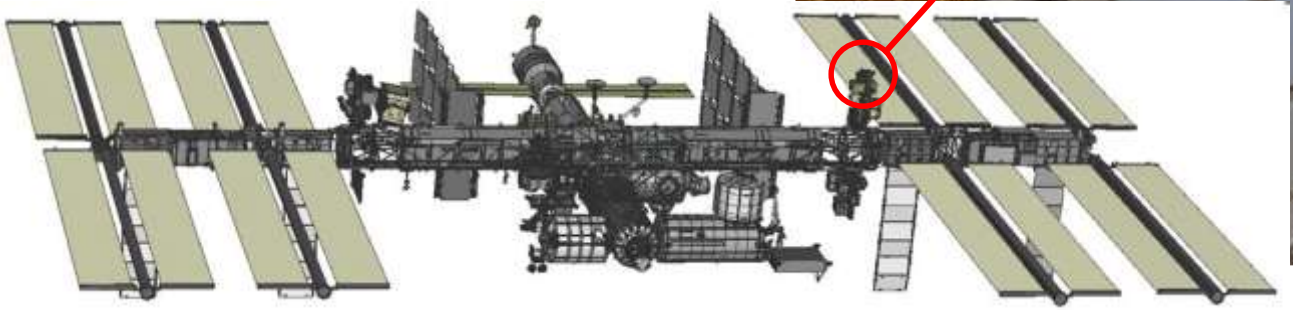
SCaN Testbed



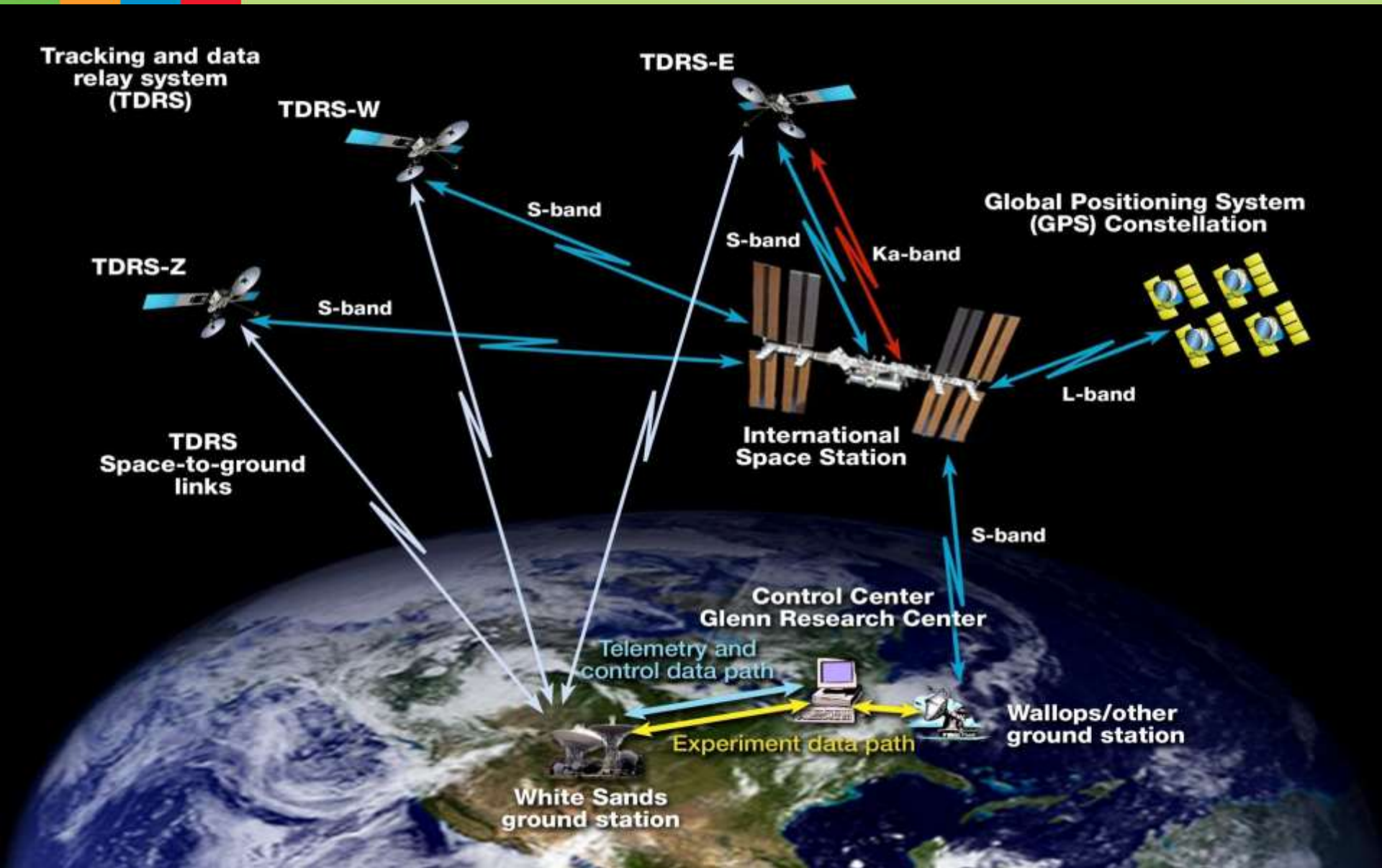
SCaN Testbed Mission

- **Mature Software Defined Radio (SDR) technologies and infrastructure for future SCaN architecture and NASA Missions**
  - –Ready for space use/verification/reconfiguration/operations/new software aspects
  - –Advance the understanding of SDR Standard, waveform repository, design references, tools, etc for NASA missions
- **Conduct Experiments Program**
  - –Portfolio of experiments across different technologies; communication, navigation, and networking
  - –Build/educate a group of waveform developers and assemble repository of waveforms
- **Validate Future Mission Capabilities**
  - –Representative capabilities; S-band, Ka-band, GNSS





SCaN Testbed System Architecture



Experiment Definition

Objective:

- Maximize data throughput by varying waveform application parameters for predicted link conditions. Improve over traditional mode selection based on predicted worse-case conditions.
- Lessons learned applied to new adaptive coding modulation (ACM) & Cognitive applications

Approach:

- Utilize existing BPSK waveform(WF)without code modifications
- ½ Rate FEC varied for predicted link conditions; variable coding modulation (VCM)
- CCSDS AOS Framing Trailer used to send change commands to receiver
- Idle frames sent during transition to prevent loss of user data

CCSDS AOS Framing Trailer

AOS Spec has Operational Control Field (OCF) which is part of the optional "Transfer Frame Trailer", in which maybe a "Type-2 Report" would be specified where the first bit being '0' indicates "the contents of the report are project-specific"

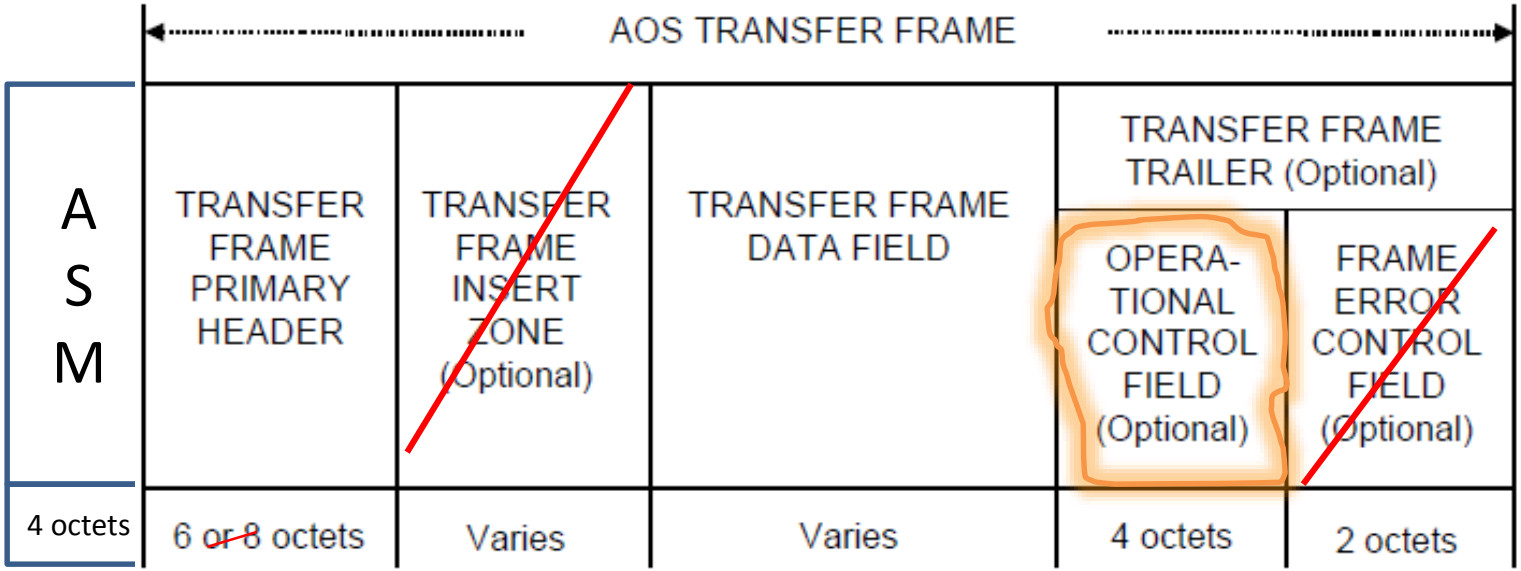
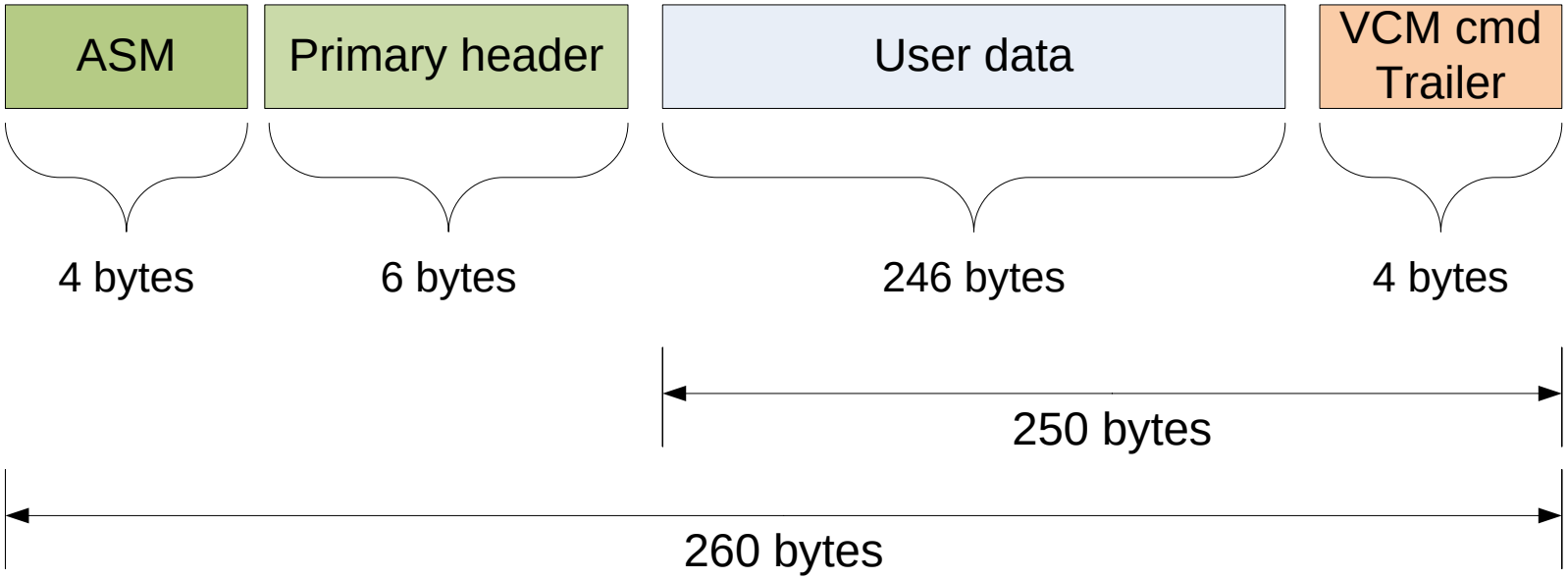


Figure 4-1: AOS Transfer Frame Structural Components

VCM Frame Format

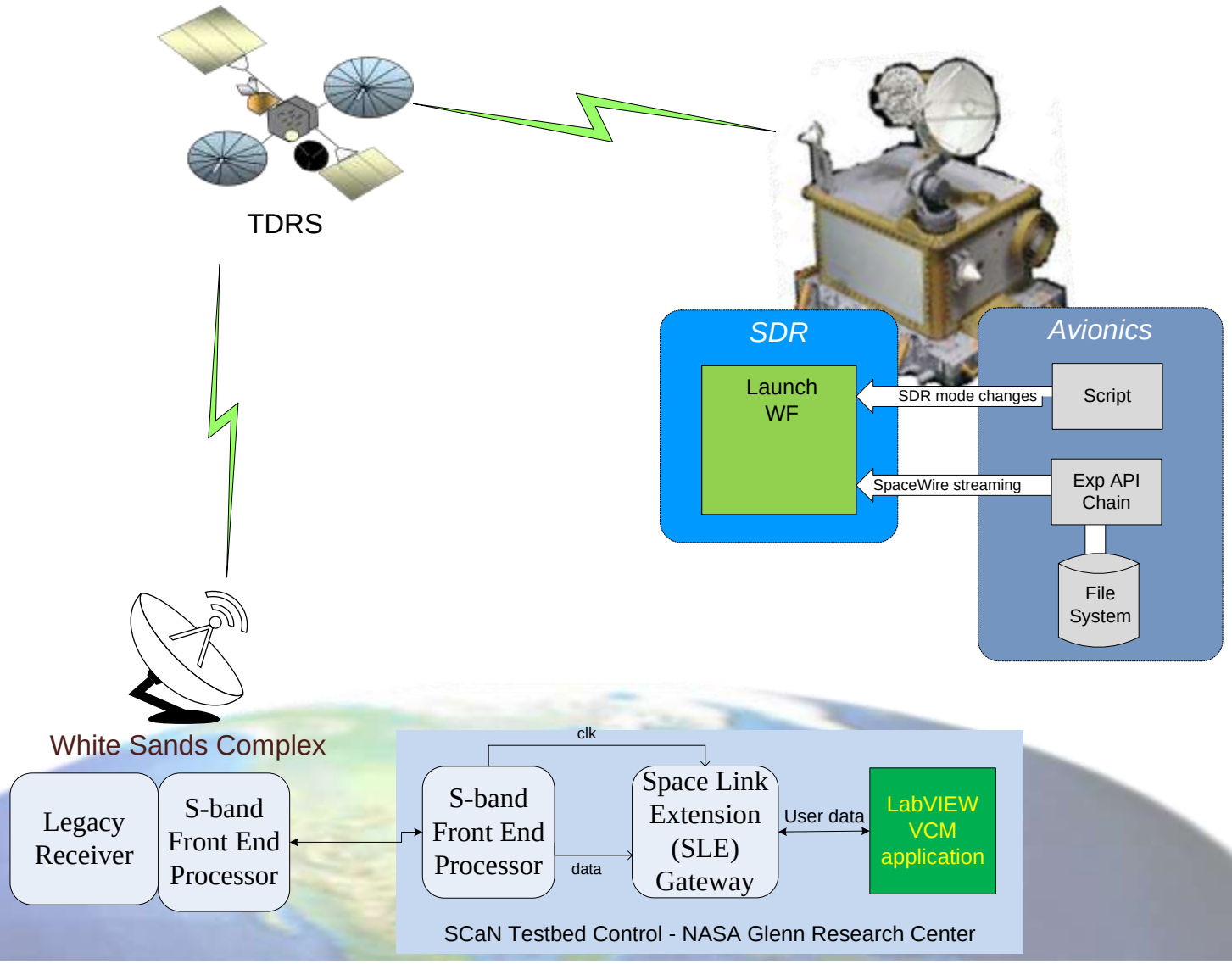
Keeping overall frame size to 260 bytes, but using four bytes of user data for trailer.



Experiment Implementation

- SDR
  - Runs BPSK ½ rate convolutional code waveform application
  - Coding can be switched on/off dynamically
- S-band antennas for Space Network (TDRSS):
  - +30 dBi medium gain antenna, w/mis-pointing options
  - +4 dBi low gain antenna
- Flight computer (avionics):
  - Experimenter API XML file (changes are relatively easy)
  - Avionics Scripting synchronization
    - Starts experiment
    - Sends commands to SDR to change mode

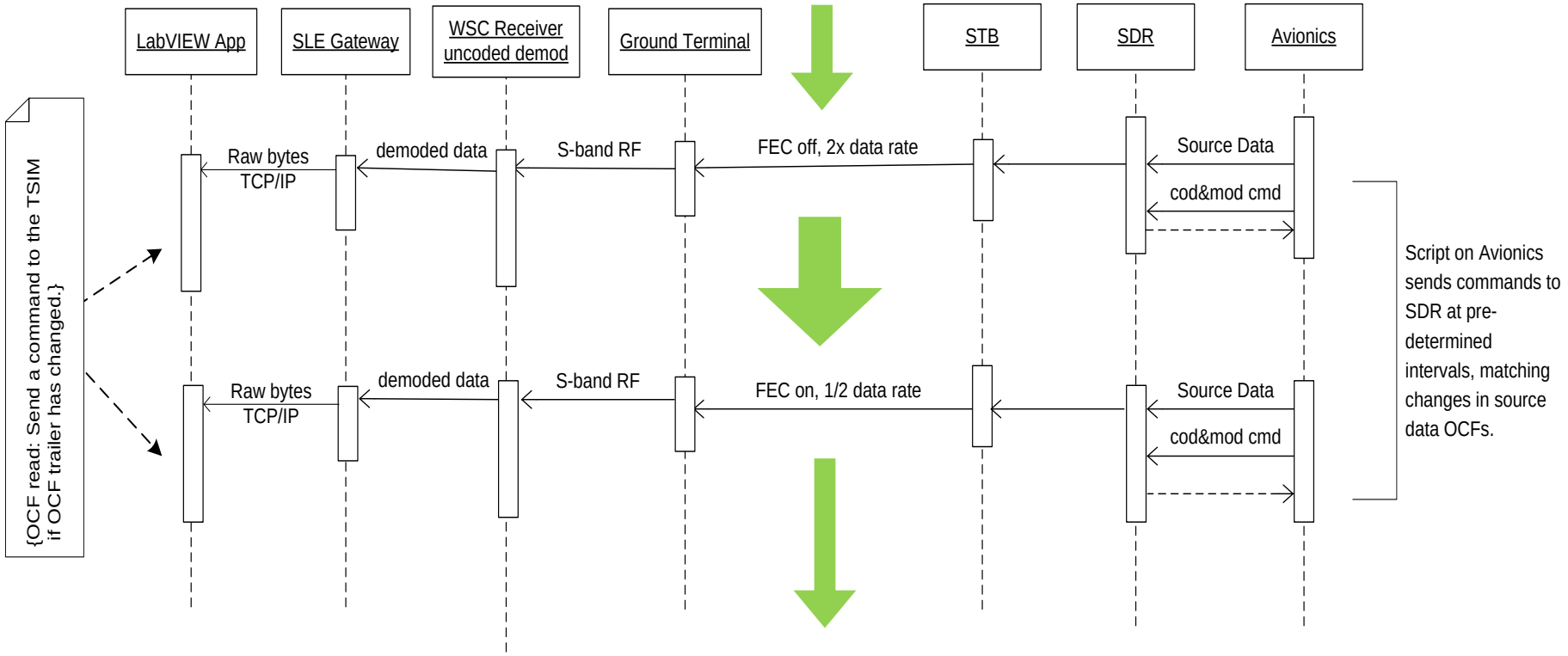
System Data Flow



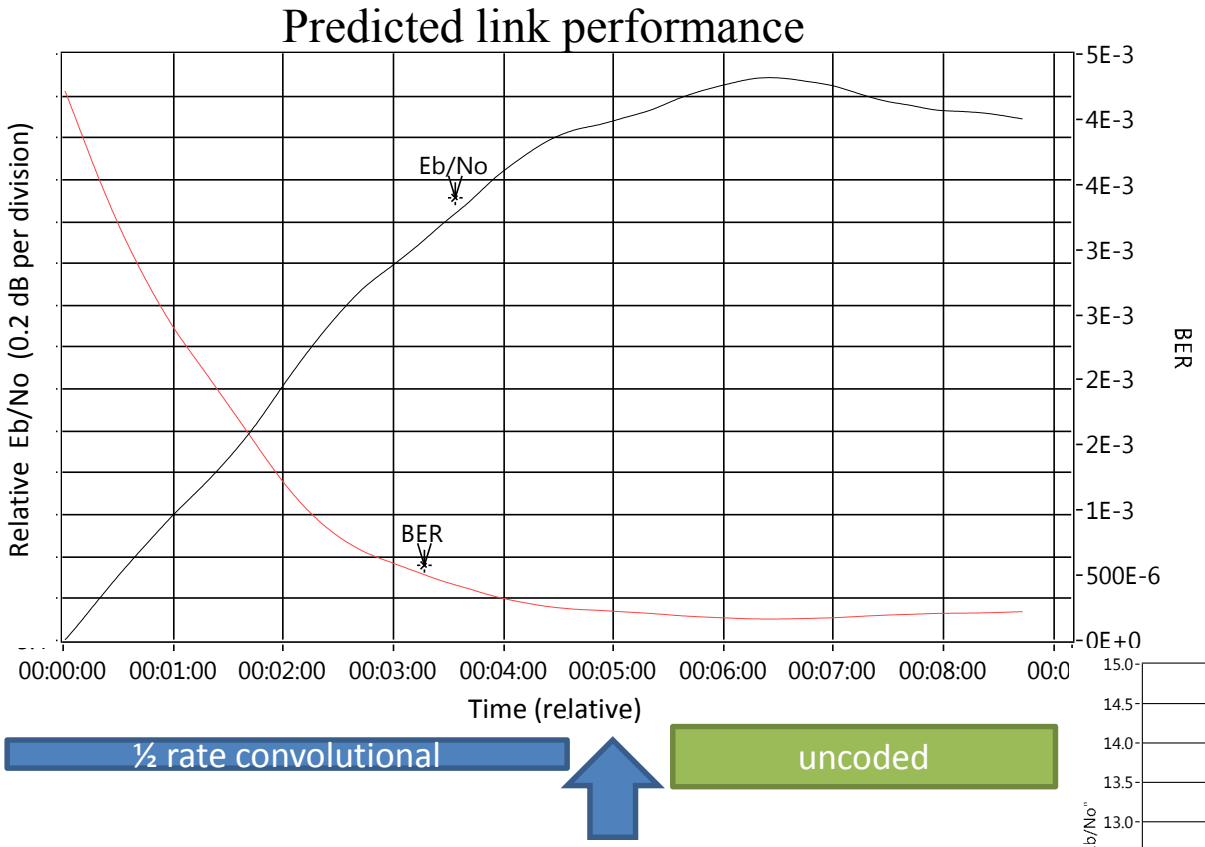
Command Flow Diagram

VCM – SN return link

VCM commands are transferred from SDR to ground recevier via OCF = Operational Control Field trailer of AOS Frame.

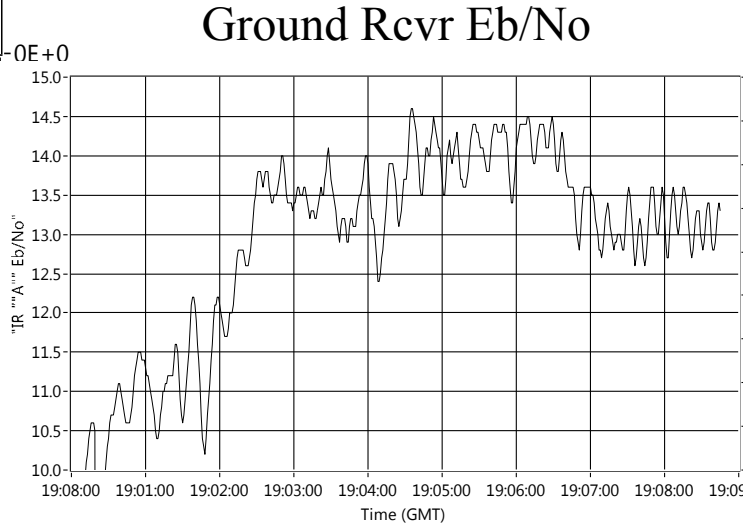


Test Results – fixed antenna



February 26, 2015 testing:

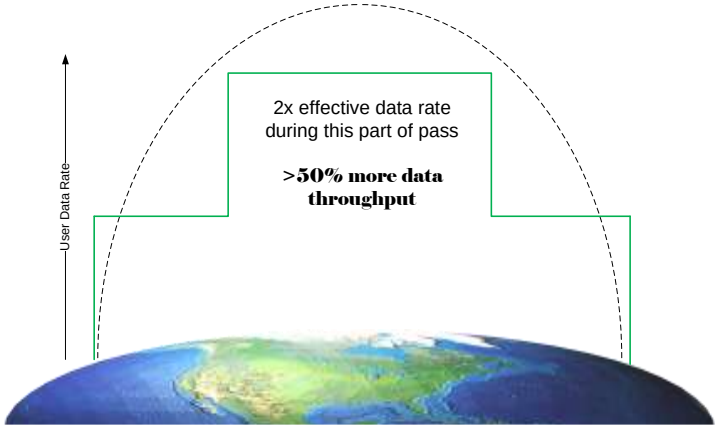
- *495 seconds in duration*
- *One transition from ½ rate coding to uncoded.*



Low-gain fixed antenna's typical link profile fits well with waveform's capabilities and performance.

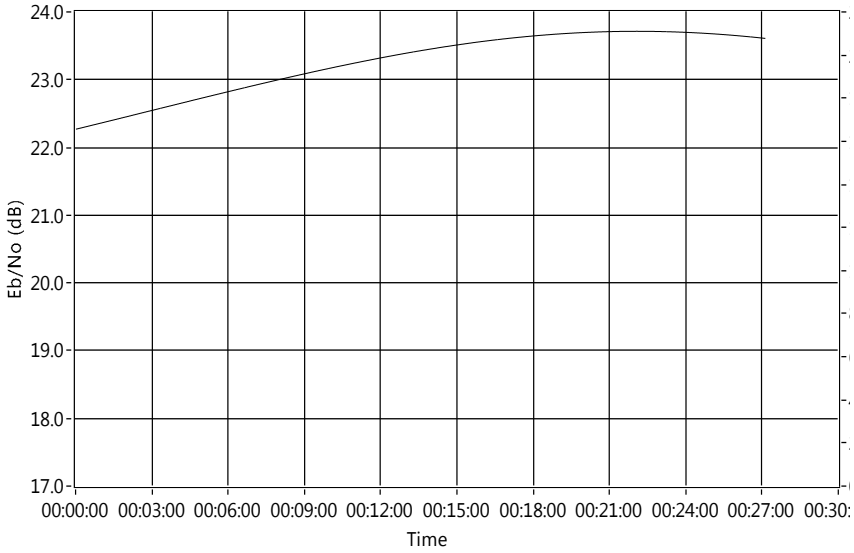
Test Results – Intentional Off-Pointing

Intentional antenna off-pointing results in desired profile at ground receiver; Jan 21, 2015, Event 3.

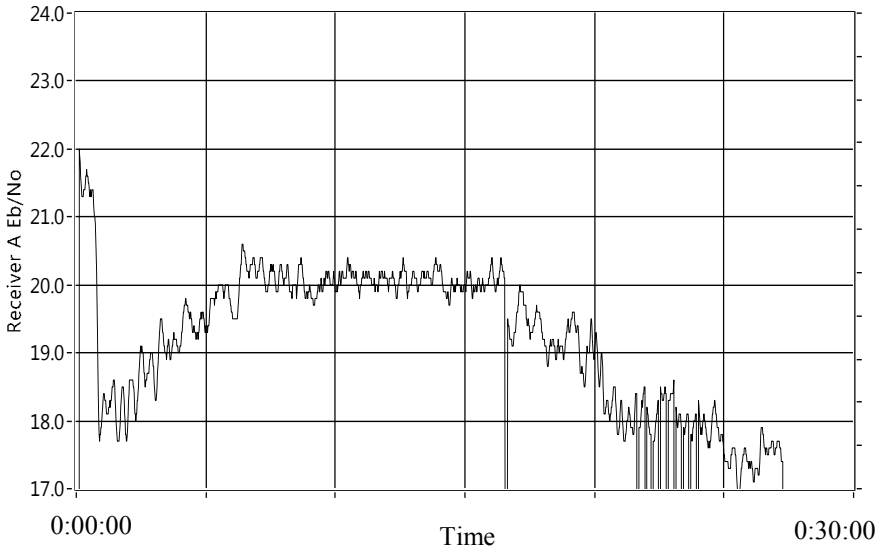


Eb/No versus Time

Nominal pointing (predicted)



With off-pointing (actual)



Data Throughput Increase

February 26, 2015 event with low-gain fixed antenna

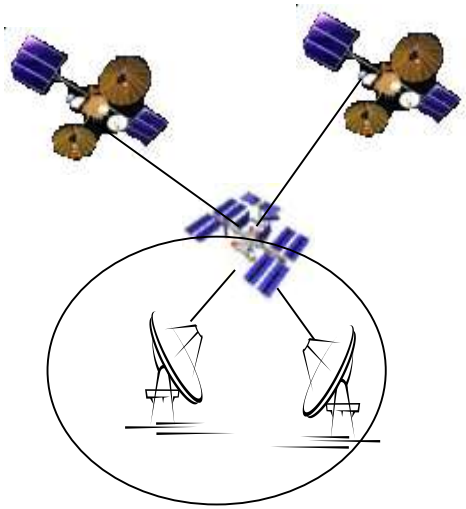
- 629 seconds in duration
- One transition from uncoded to ½ rate convolutional coding.

	Without VCM	With VCM	
Total data frames	3626	5870	
Idle transition frames	0	58	about 2% overhead
User data frames	3626	5812	60% increase

Flight Testing Summary

- 10 link tests January 21 – February 26, 2015

- Tests varied configurations:
  - 2 checkout & calibration
  - 6 with medium gain steerable antenna
    - intentional antenna off-pointing
  - 4 with low-gain fixed antenna

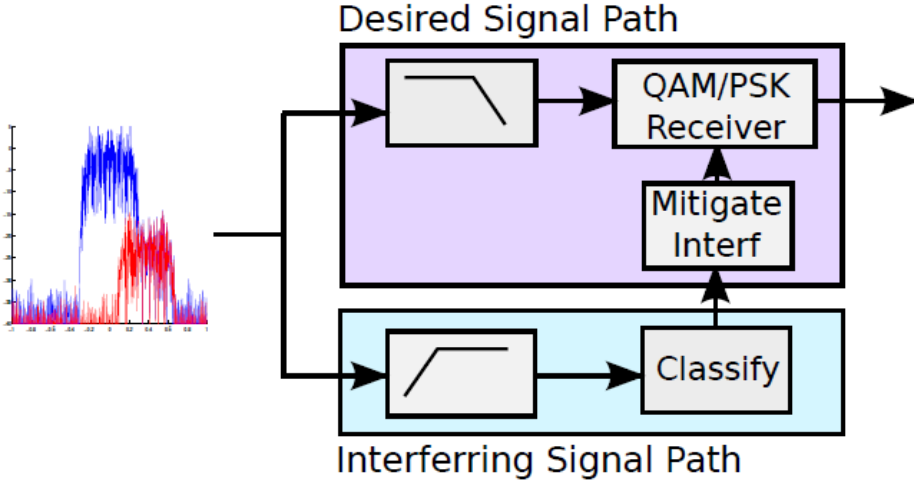


- 35-60% increased data throughput was demonstrated with low-gain fixed antenna

Ongoing and Future Work

- *More capable space-based VCM waveforms are in development:*
  - *DVB-S2 compatibility*
  - *Adaptive MAC protocol*
  - *Determine appropriate feedback path tailored for NASA's infrastructure*
  - *Leveraging and contributing to the STRS Waveform repository*
  - *Integrating with Cognitive Engines for autonomous operations*

- *Considering future cognitive mission scenario needs*
  - *Interferer mitigation*
  - *Power Efficiency*
  - *Spectrum Efficiency*
  - *Maximize Data Volume*



- *University partnerships: VT, WPI, FIT*

For more information

Visit SCaN Testbed on-line:

http://spaceflightsystems.grc.nasa.gov/SOPO/SCO/SCaNTestbed

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