

The Next Step for High Data Rate Communications for Sounding Rockets and Balloons

Adam C. Escobar & Christine M. Escobar

Next-Generation Sub-orbital Researchers
Conference 2017





Presentation Overview

- **Current Communications Infrastructure**
- **IRIG-106 Telemetry Bands**
- **NASA Technology Roadmap**
- **NASA Sounding Rocket Programs Office Roadmap**
- **Science Experimenter Requirements**
- **Advanced Communication Techniques**
- **Simulated Communication Links Frequency Spectrum**
- **Over-The-Horizon Techniques**
- **Conclusions**

Current Communications Infrastructure

➤ Line-of-sight S-band

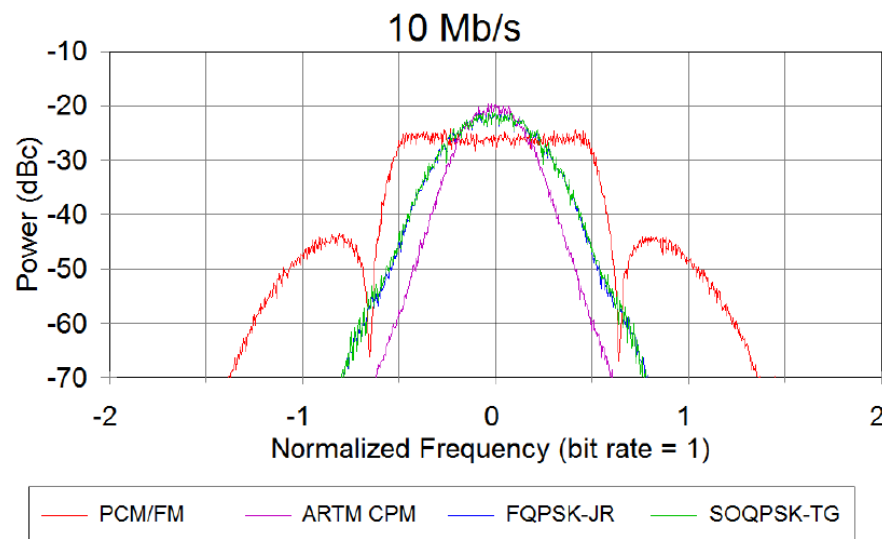
- Sounding Rockets:
 - PCM/FM @ 20 Mbps max
 - SOQPSK-TG @ 20 Mbps max
 - Working on up to 50 Mbps
- Balloons:
 - BPSK, PCM/FM @ 4 Mbps max

➤ Line-of-sight X-band

- Sounding Rockets: site dependent
 - Experimental only & not active
 - QPSK 125 Mbps and 1 Gbps
- Balloons: site dependent
 - QPSK 210 Mbps

➤ Over the Horizon Communications

- Tracking and Data Relay Satellite System @ 300 kbps / 258 Mbps max operational
- IRIDIUM @ 128k kbps max
- IRIDIUM NEXT @ 1.5 Mbps max
- INMARSAT BGAN @ 432 kbps max



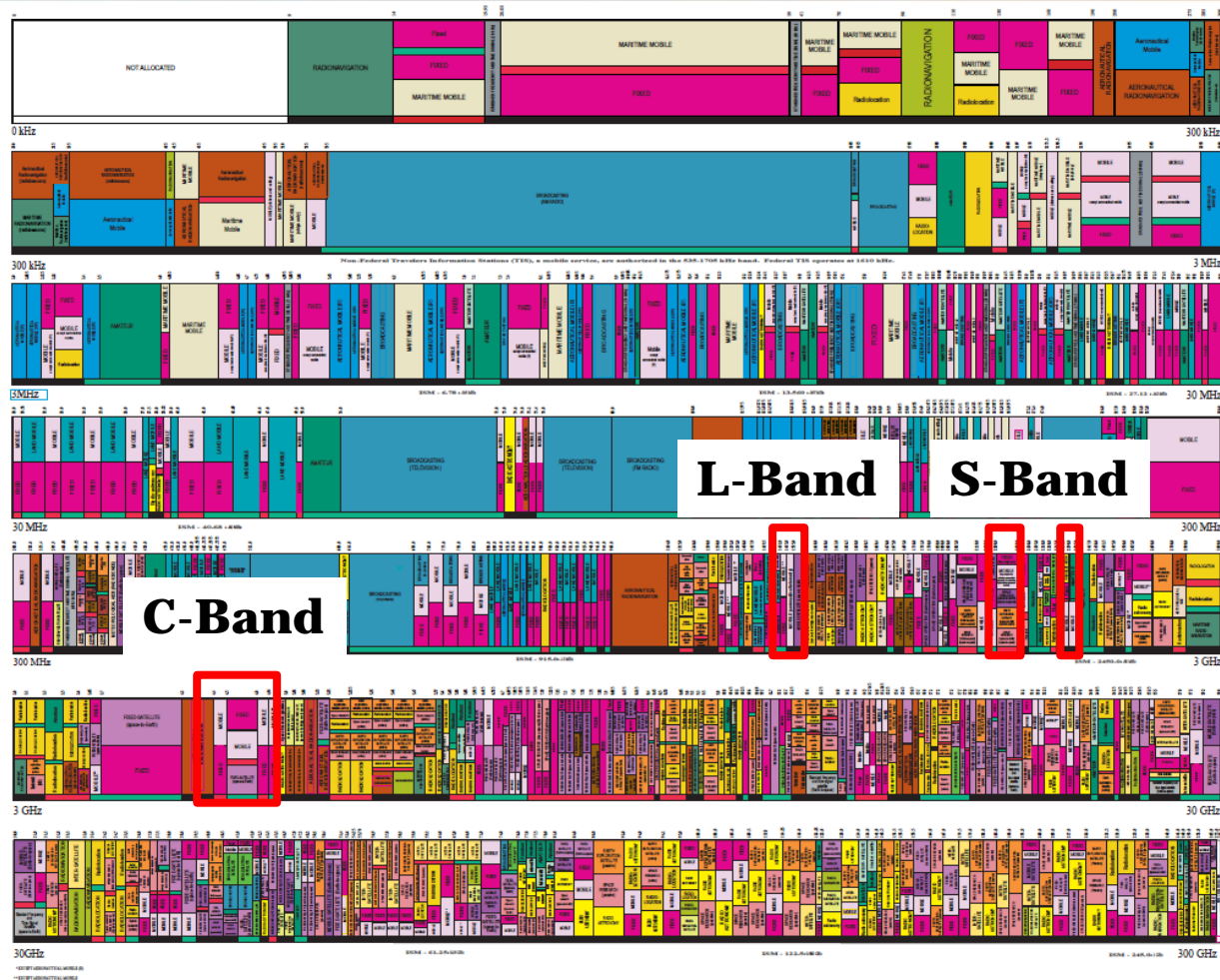
Derived from IRIG-106 Chapter 2
(formally Appendix A)



IRIG-106 Telemetry Bands

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM





IRIG-106 Telemetry Bands Continued



➤ **L-band**

- Lower L-band: 1435-1535 MHz
 - Phased out and no longer in primary use

➤ **S-band**

- Lower S-band: 2200-2290 MHz (90 MHz usable BW)
- Upper S-band: 2360-2395 MHz (35 MHz usable BW)

➤ **C-band**

- Lower C-band: 4400 to 4940 MHz (540 MHz usable BW)
 - Not in current use for sounding rockets and balloons

➤ **IRIG-106 provides the band-edge limitations of communication links**



NASA Technology Roadmap

➤ NASA's Technology Roadmap (July 2015)

- TA 5: Communications, Navigation, and Orbital Debris Tracking and Characterization Systems

“Increased data rates (e.g., 10 to 100 times) without increasing the mission burden in mass, volume, power, and/or spectrum;”

“With today's technology, downlink data rates can be more than 1 Gb/s.”

“Spectral bandwidth is a precious and legally-enforced commodity. In order to get as much use from the allocated bandwidth as possible, **innovative ways of fitting more bits into the same number of Hertz will need to be developed.**” ... “High-order modulation schemes (e.g., eight phase shift keying (PSK) and 16 quadrature amplitude modulation (QAM)), as well as careful pulse shaping (e.g., Gaussian Minimum Shift Keying) are examples of current technologies being developed in this area.”

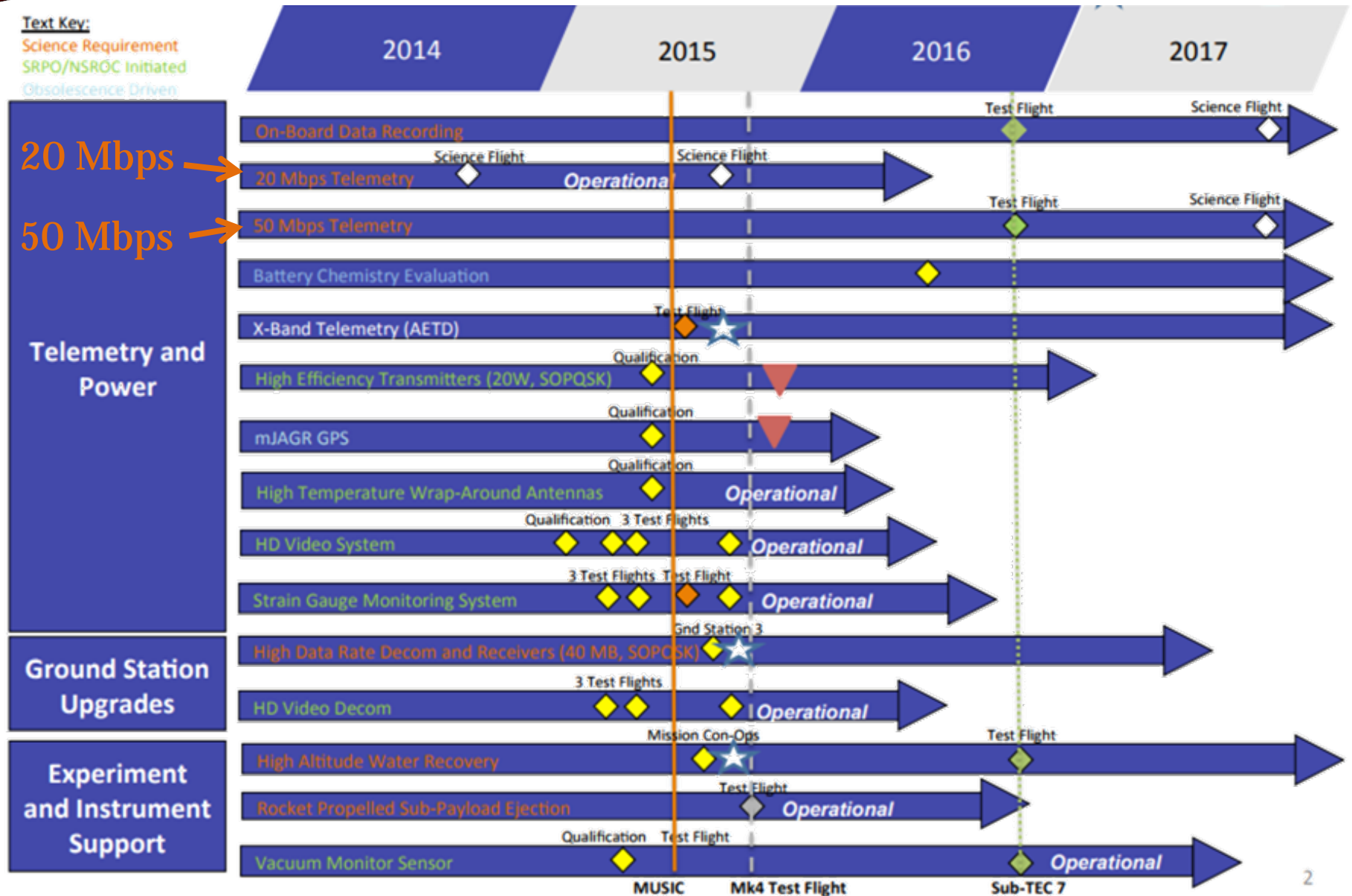
NASA Sounding Rocket Programs Office Roadmap

Text Key:

Science Requirement

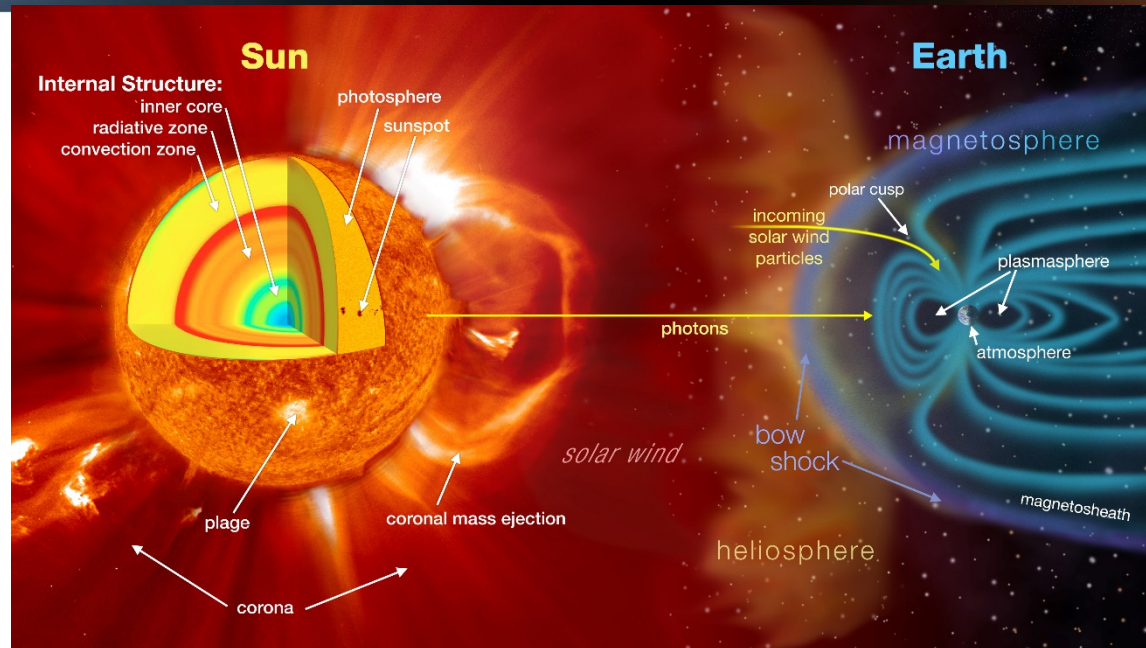
SRPO/NSROC Initiated

Obsolescence Driven



The content of this slide is subject to the propriety statement on the title slide.

Science Experimenter Requirements



Courtesy NASA

- **Sounding Rocket Working Group (SRWG)**
 - Astronomy, Earth Science, Geophysics, Space Physics, Planetary Science, Microgravity, and Re-entry Testing
- **> 60 Principal Investigators**
- **Minimum Data Rate: 100-200 Mbps (up to 1 Gbps)**

Advanced Communication Techniques

➤ Constellation Map

- 16-APSK, 32-APSK, 64-APSK, 128-APSK, 256-APSK

➤ Pre-Emphasis & Equalization

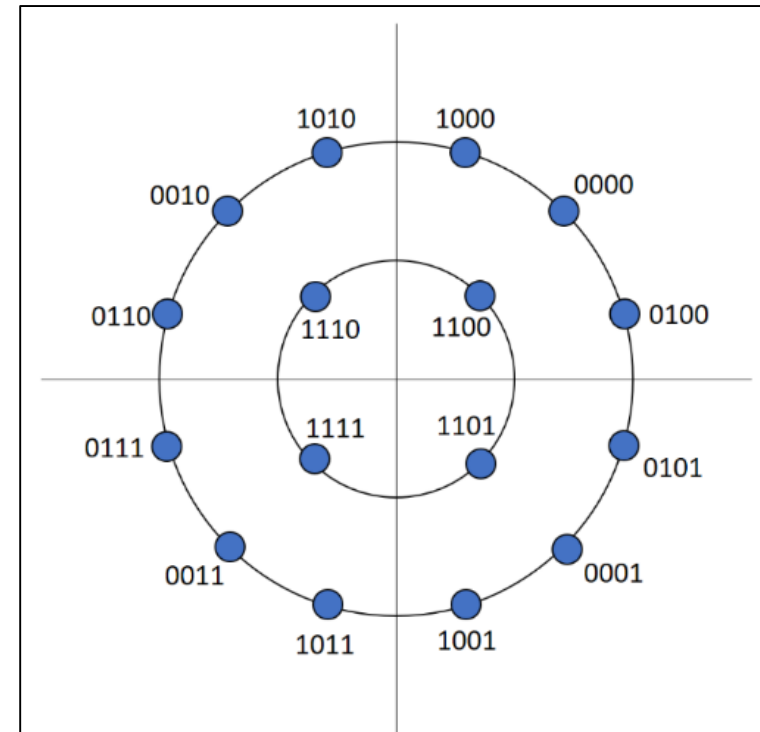
➤ Frequency Division Multiplexing

➤ Forward Error Correction

- Reed Solomon
- Bose–Chaudhuri–Hocquenghem (BCH)
- Low Density Parity Check (LDPC)

➤ Polarization Diversity

➤ Digital Filtering (Pulse Shaping)

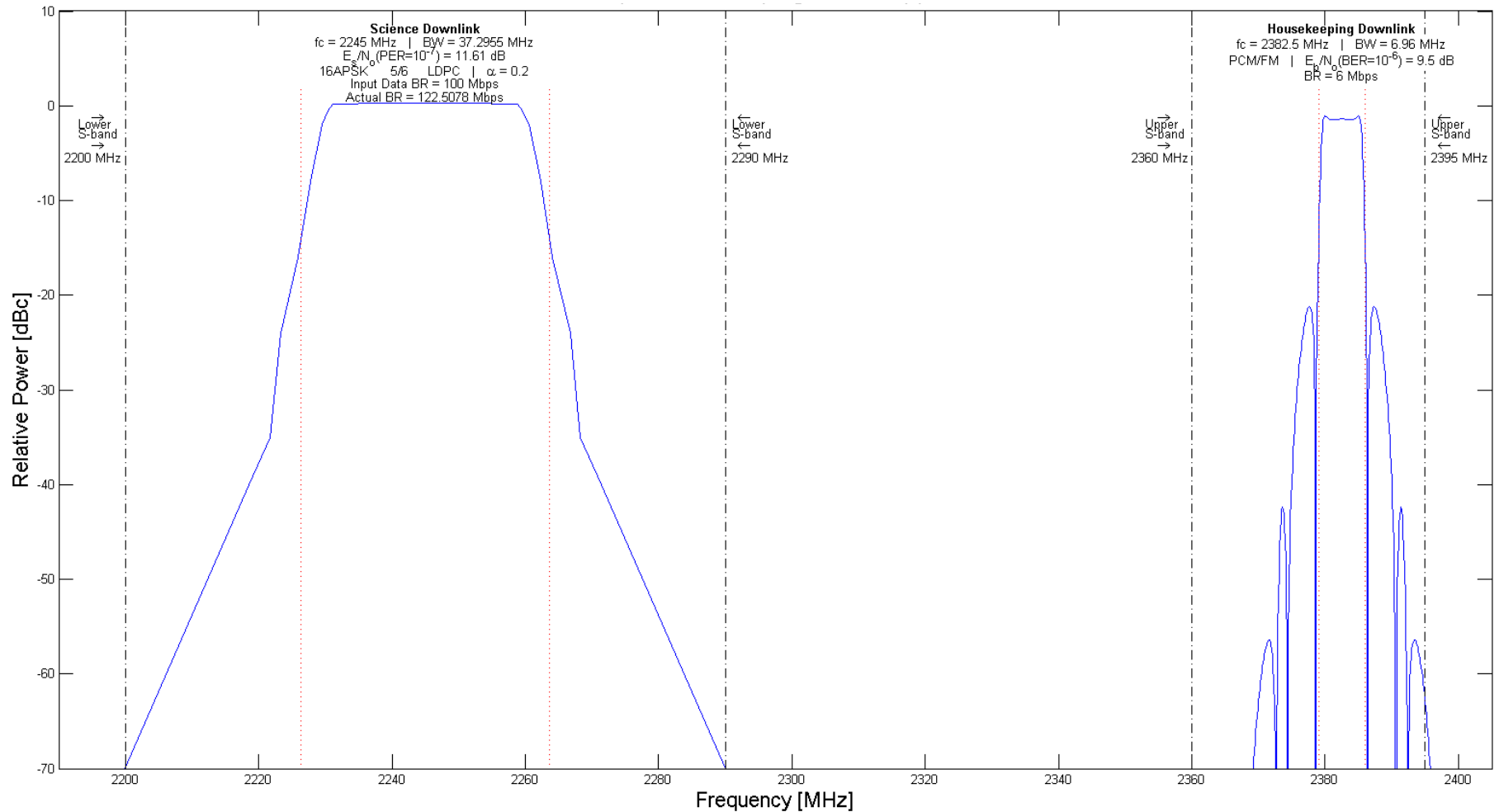


16-APSK Constellation



Simulated Communication Links

Frequency Spectrum Example



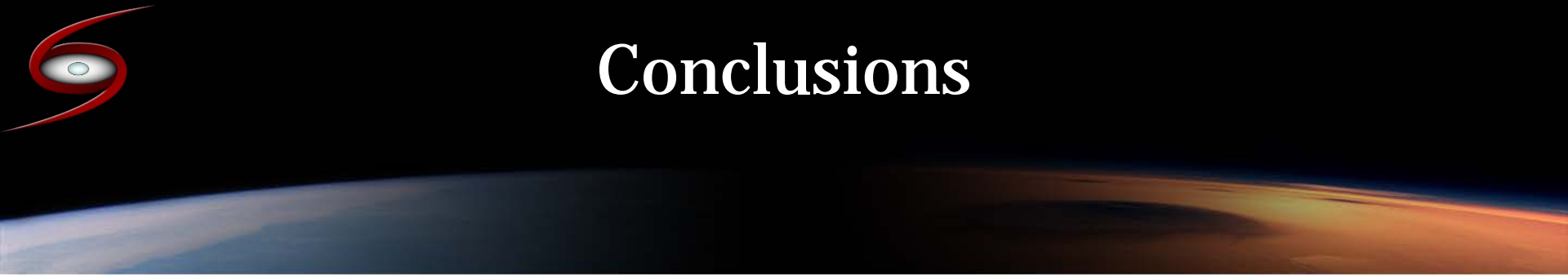
The content of this slide is subject to the propriety statement on the title slide.

Over-The-Horizon Techniques

- **Controllable Flight for Balloons (persist in one location)**
- **Ground/Balloon Based Communications Network**



McMurdo Station (Antarctica) Remote Monitoring Station



Conclusions

- **Reviewed Current Communication Technology**
 - Line-of-sight S-band
 - Line-of-sight X-band
 - Over-The-Horizon Communication Services
- **Technology Roadmaps and Experimenter Requirements**
 - NASA HQ vs NASA SRPO
 - Commercial sector needs to fulfill these technology gaps
 - Communications technology development needs to meet science experimenter needs
- **Advanced Communications Techniques and Example**
 - Follows the goals outlined in the NASA HQ Technology Roadmaps
- **Over-The-Horizon Communications**



References



- Chandler, F., Townes, S. A., and Israel, D. (Jul. 2015). TA 5: Communications, Navigation, and Orbital Debris Tracking and Characterization Systems. NASA Technology Roadmaps.
- Field, C. (May 2017). *Telemetry Options for LDB Payloads*. NASA Technical Reports Server. Scientific Ballooning Technologies Workshop. Minneapolis, MN. USA. GSFC-E-DAA-TN42609.
- Lefèvre, J. P. and Verdier, N. (2011). *Flight Telecommunication Systems under Balloons*. Proceedings of the 20th ESA Symposium on Rocket and Balloon Programs and Related Research. Hyère, France.
- Leading Edge Turbines Ltd t/as Leading Edge Power. (2016). *McMurdo Station uses LE-v50 for Off-grid Telemetry*. <https://www.leadingedgepower.com/mcmurdo-station-uses-le-v50-for-1227451.html>
- Mathis, D. (Dec. 2015). *Earth Sun System*. Defense Video Imagery Distribution System. <https://www.dvidshub.net/search/?filter%5Bunit%5D=NASA&filter%5Btype%5D=image&view=grid&sort=date>
- NASA Sounding Rocket Programs Office Technology Roadmap (2015). *Technology Roadmap: 3-year*. NASA Sounding Rocket Programs Office.
- Office of Spectrum Management. (Jan. 2016). *United States Frequency Allocations*. U.S. Department of Commerce. National Telecommunications and Information Administration. https://www.ntia.doc.gov/files/ntia/publications/january_2016_spectrum_wall_chart.pdf
- Telemetry Group (Jul. 2017). *Transmitter and Receiver Systems*. IRIG-106 Telemetry Standards. RCC Standard 106-17. Chapter 2.