An Evaluation and Demonstration of a Network Based Aircraft Telemetry System

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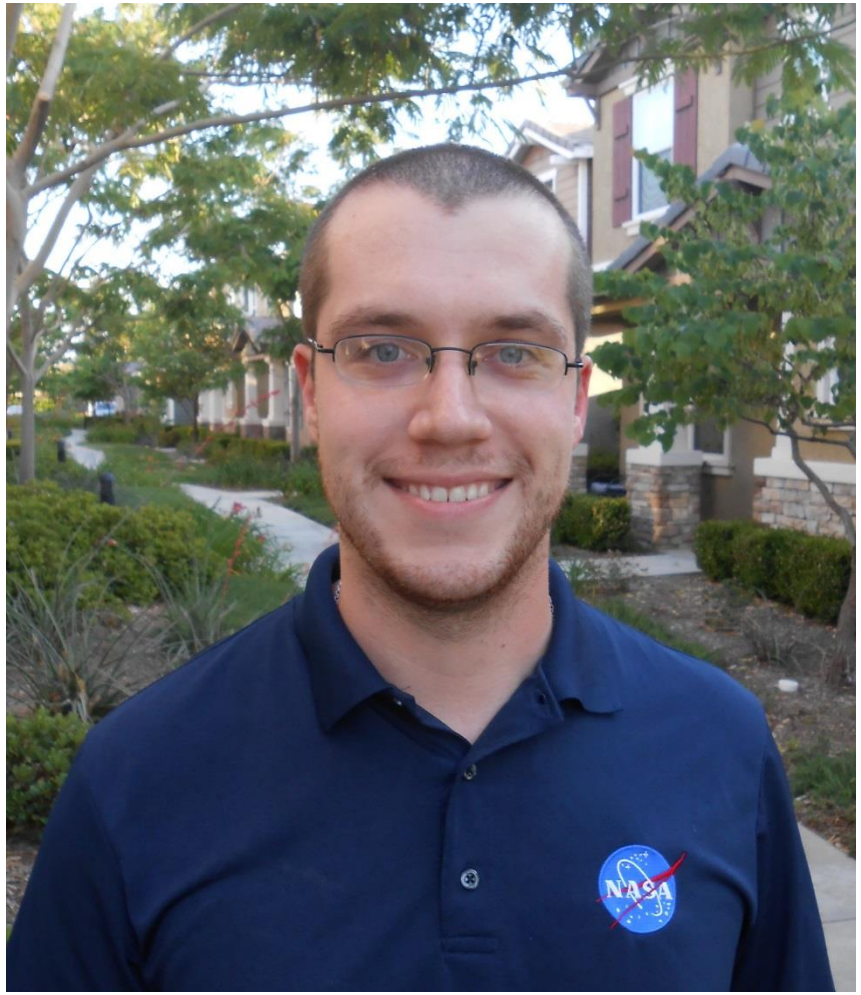
Presenter Introduction: Matt Waldersen

- Research and development engineer at the NASA Armstrong Flight Research Center
  - AST Avionics Systems
- Received a B.S. in Electrical Engineering from Purdue in 2013
- Worked at Orbital ATK – Propulsion Systems Division for 2.5 years
  - flight instrumentation, avionics, and electrical ground support systems for the Space Launch System solid rocket boosters and the Orion spacecraft launch abort system
- Electrical hardware and software design for Network Based Telemetry research project



Presenter Introduction: Otto Schnarr

- Research and development engineer at the NASA Armstrong Flight Research Center (AFRC)
- Attended Missouri University of Science & Technology
  - Computer Science B.S. (2008)
  - Applied Mathematics B.S. (2010)
- Experience throughout AFRC
  - Instrumentation Engineer
  - Range Engineer
- Principle investigator for Network Based Telemetry research project

Ethernet Via TeleMetry (EVTM)

- Flight tests utilized EVTM technology to integrate a telemetry link into an Ethernet network
- The benefits over a traditional telemetry system include:
  - Direct Ethernet network compatibility
  - Bi-directional communication
  - Real-time ground-based experiment control
  - Reconfigurable downlink data architecture
  - Frequency spectrum reallocation
    - Higher data rates
    - Or free up space for other applications
  - Future aircraft to aircraft data communication

Photo Credit: Quasonix

Research Objectives

- Characterize the EVTM in a real flight scenario
  - Measure Data Throughput and Connectivity
- Establish a proof-of-concept for next generation range capabilities that utilize higher-level networking protocols and features
  - High-definition video streaming
  - Video Chat
  - File-Transfer Protocol (FTP)
  - Text based communication
- Evaluate these features across two advanced modulation techniques
  - Shaped Offset Quadrature Phase Shift Keying (SOQPSK)
  - Multi-H Continuous Phase Modulation (Multi-H CPM)

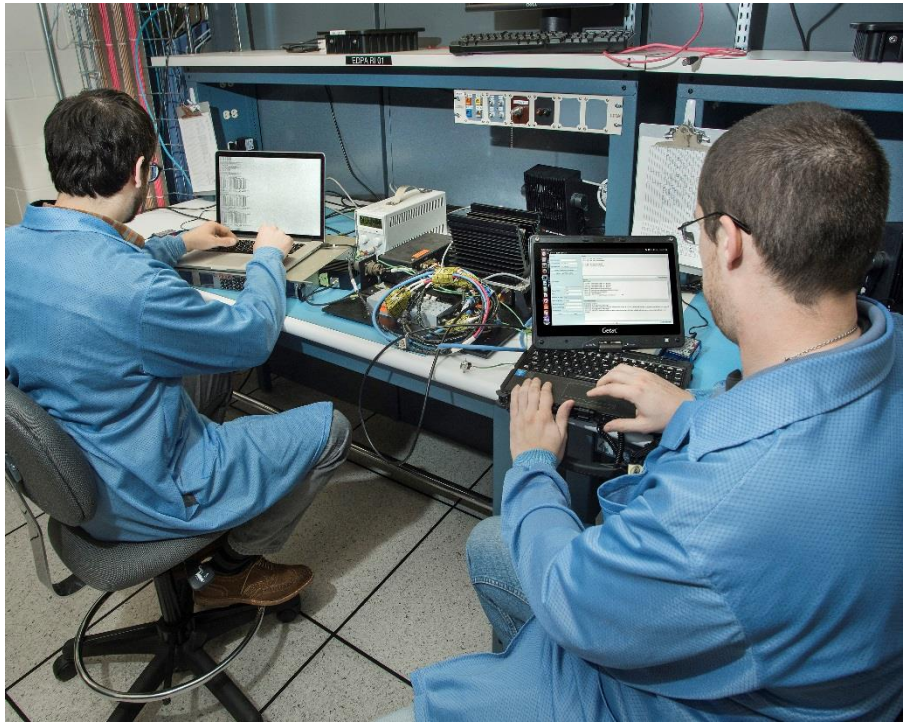


Photo Credit: NASA Photo / Ken Ulbrich

Flight Test Overview

- Three flights were conducted onboard the NASA 801 King Air Aircraft
  - Equipped with a single EVTM antenna
- Flight paths north of Edwards Air Force Base
  - Expanding on distance, bitrate, and modulation schemes
- Ground system was set up at the NASA Armstrong Aeronautical Tracking Facility
- Custom testing software automated the use of standard network tools

Photo Credit: NASA Photo / Lori Losey

Modulation Spectral Efficiency

- SOQPSK and Multi-H CPM utilize less frequency spectrum at equivalent bitrates compared to current telemetry systems
- PCM/FM
  - Bandwidth ~2x bitrate
- SOQPSK
  - Bandwidth ~1x bitrate
- Multi-H CPM
  - Bandwidth ~0.6x bitrate
- These numbers are -20dB down from modulated carrier, not scheduled numbers

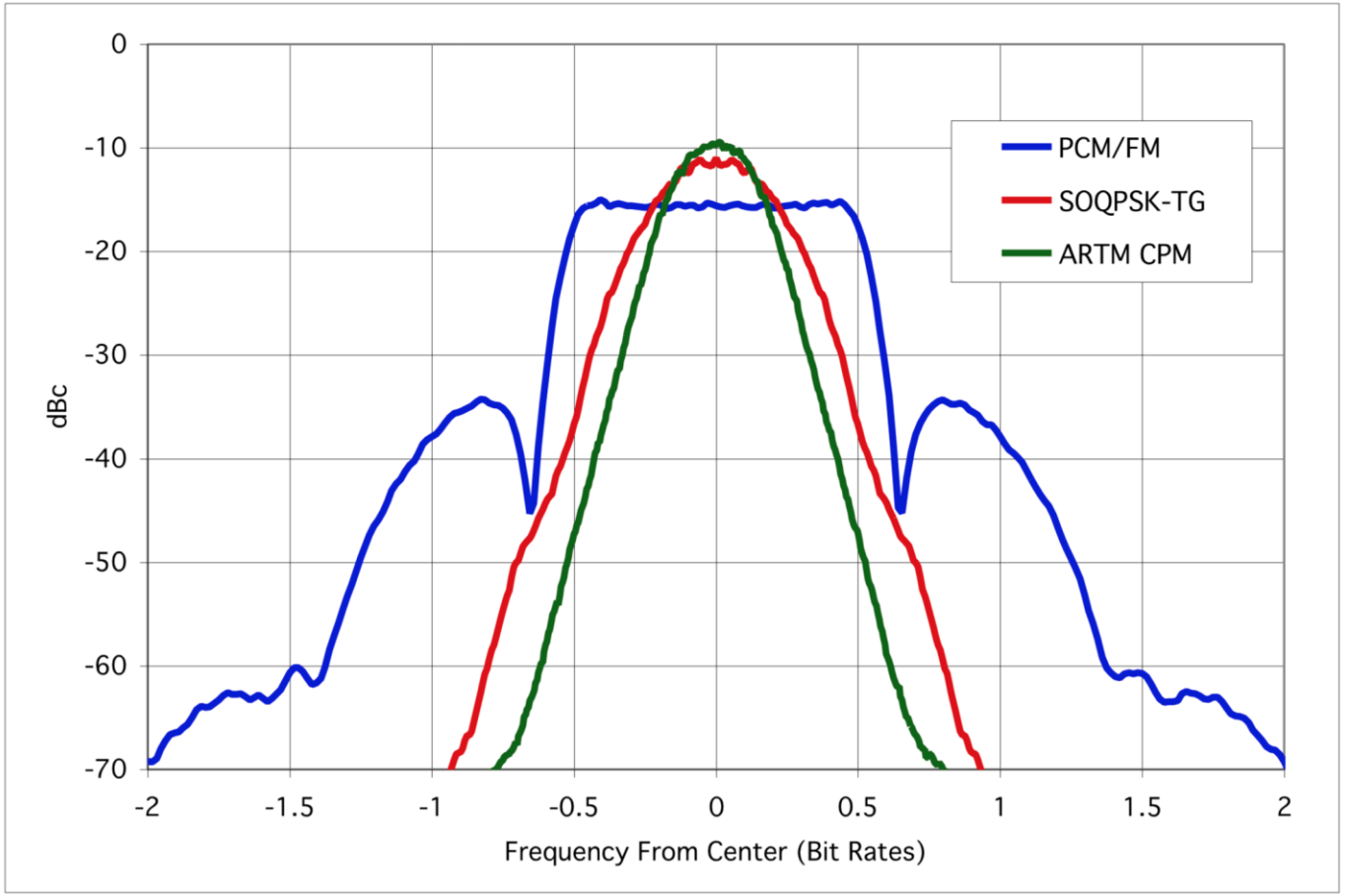
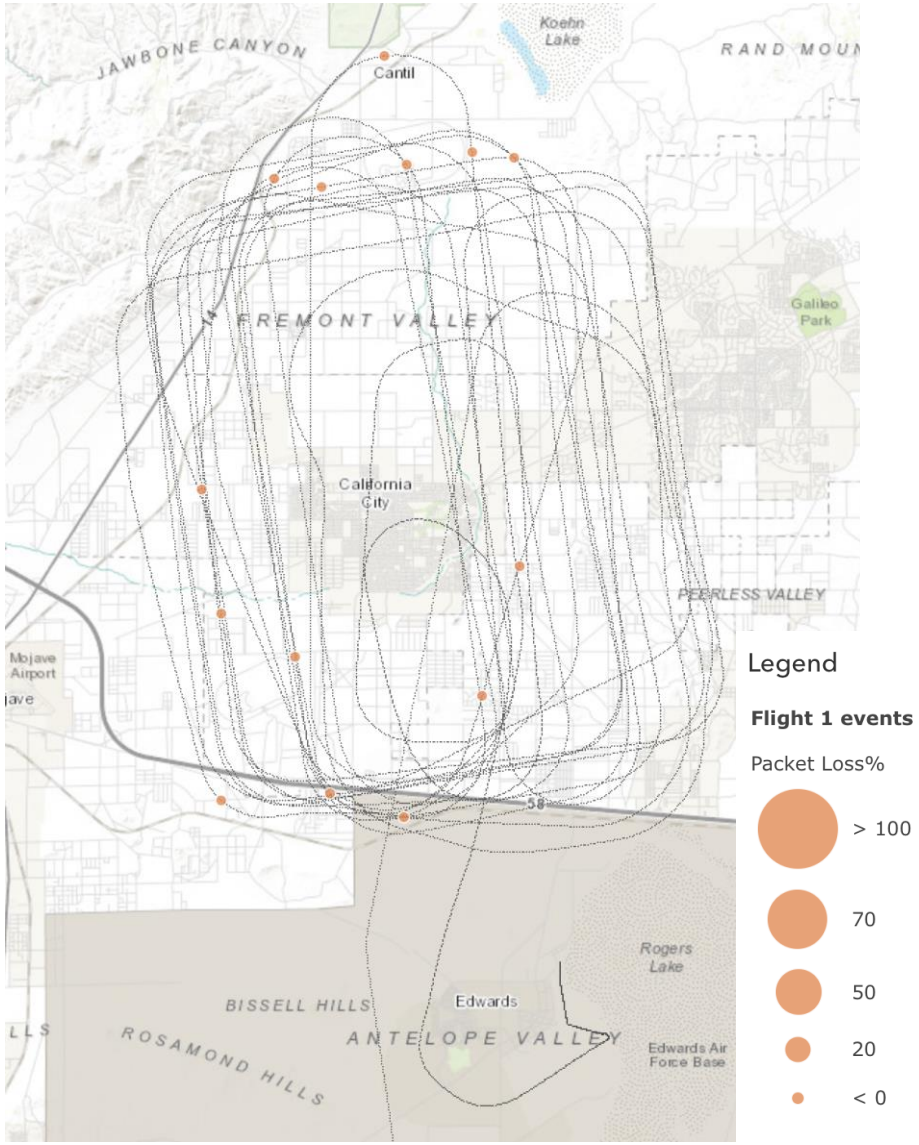


Photo Credit: 2011 ITC Advanced Modulation Course / Quasonix

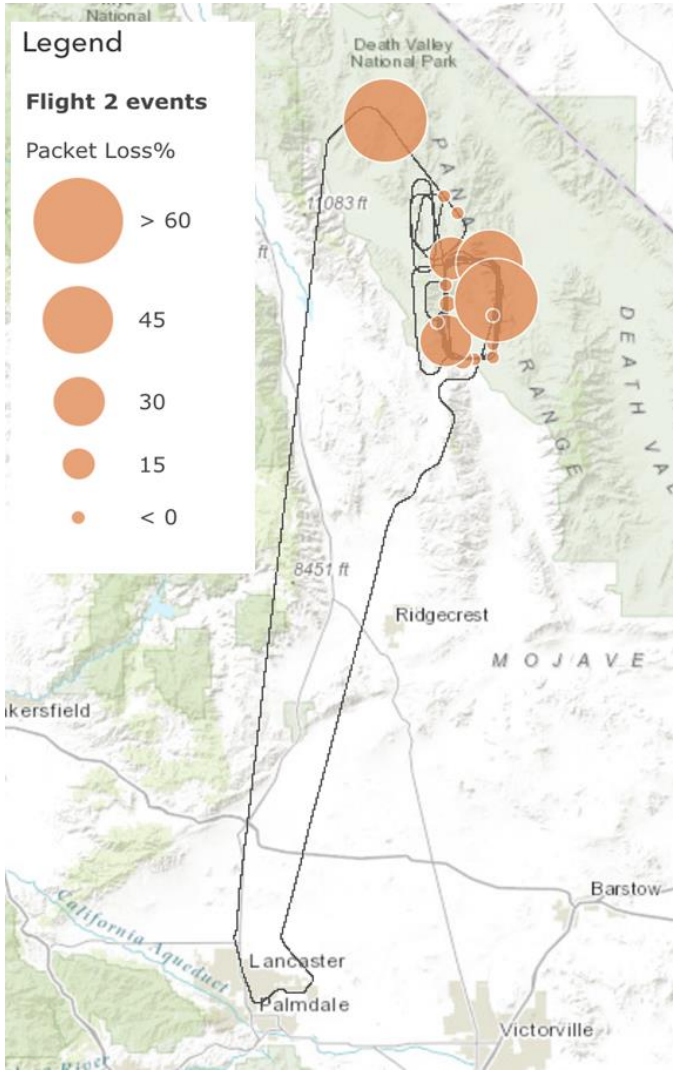
Connectivity Results – Flight 1

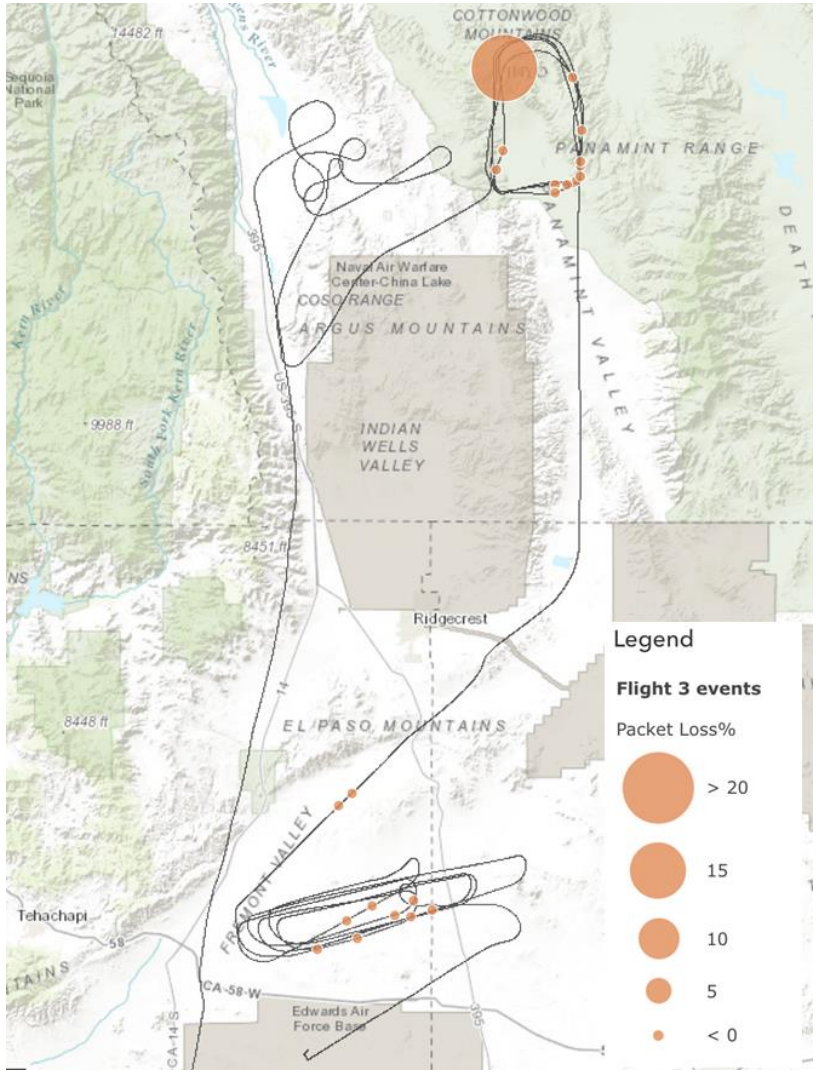


- Connectivity tests utilized ping (ICMP)
  - Also provides Round Trip Latency
- Flight 1 took place at relatively short distances north or Edwards Air Force Base
  - ~30 miles @ 25,000ft
- Data Round Trip Time
  - Min 1.93ms
  - Average 2.043ms
  - Max 2.16ms

Connectivity Results – Flight 2 & 3

- Flight 2 ~110nm @30,000ft
  - Min 1.907ms
  - Average 2.322ms
  - Max 3.17ms
- Flight 3
  - Min 1.202ms
  - Average 2.16ms
  - Max 3.204ms
- Drops correlate to antenna position



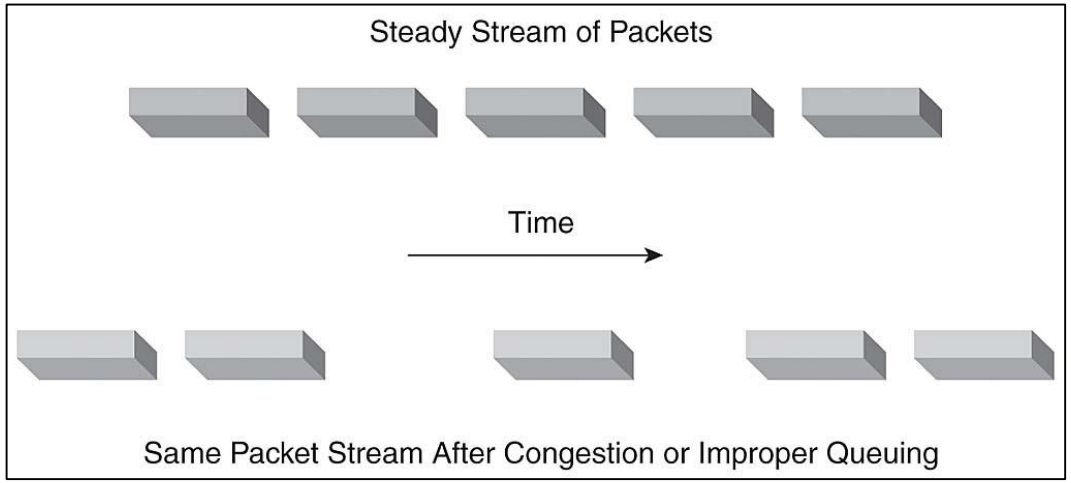


Bitrate-Jitter Test Overview

- Used commercial off-the-shelf network analysis tool called iperf3

- Measured the following parameters:
  - Bitrate Performance (speed data is transmitted vs speed data is received)
  - Network Jitter (variation in delay that data packets are received)

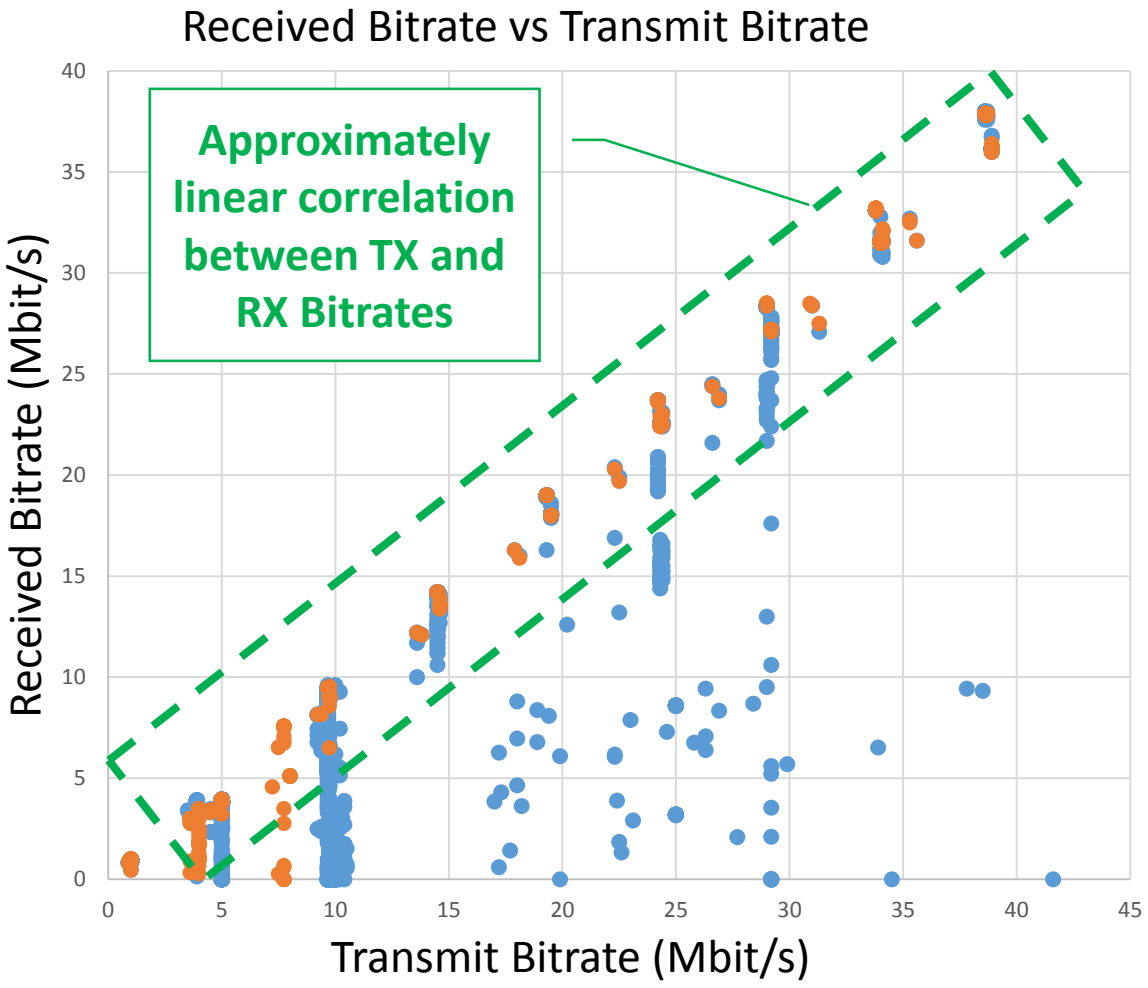
- All parameters were measured for both SOQPSK and Multi-h CPM modulation schemes

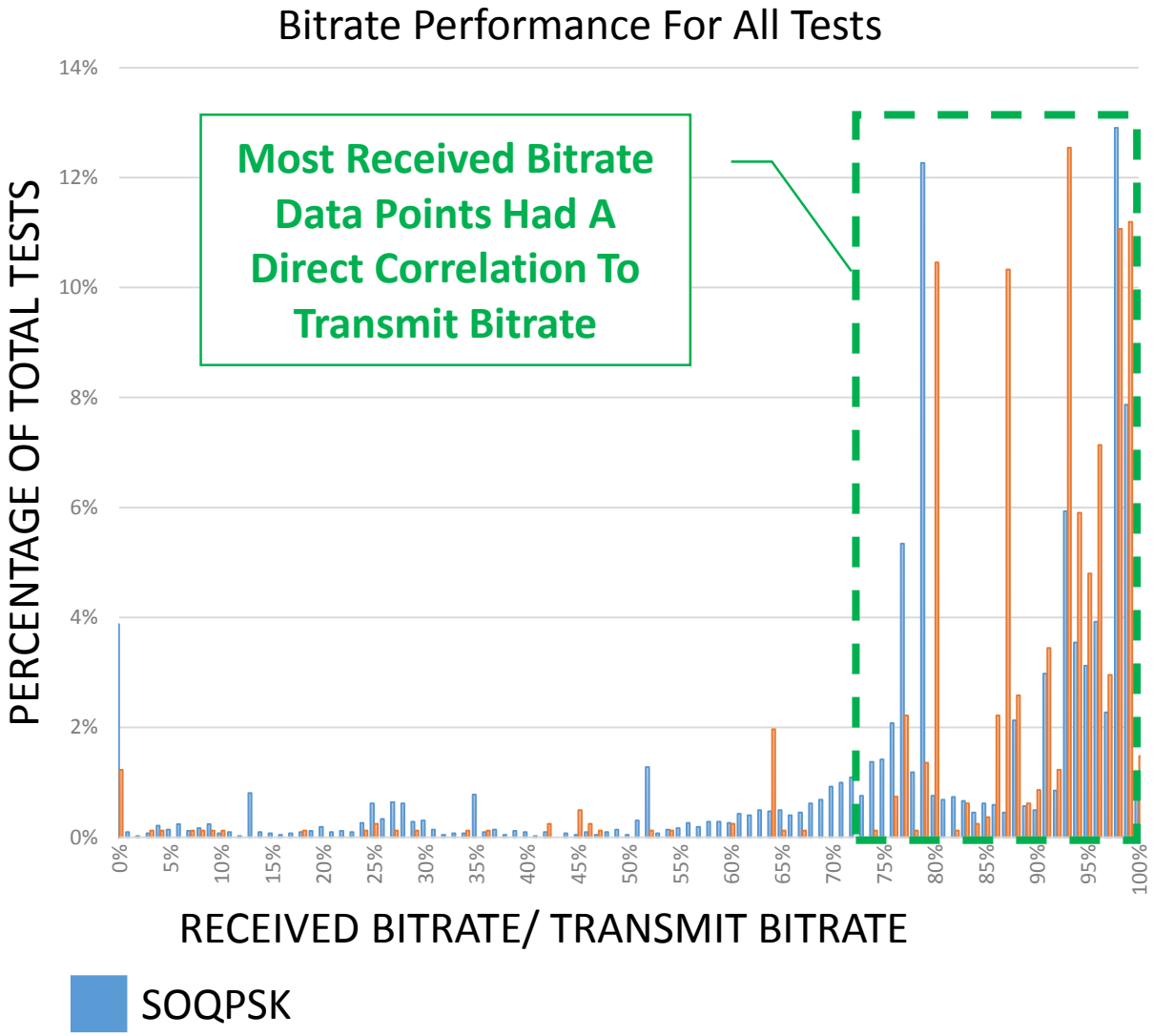


Network Jitter Visualization*

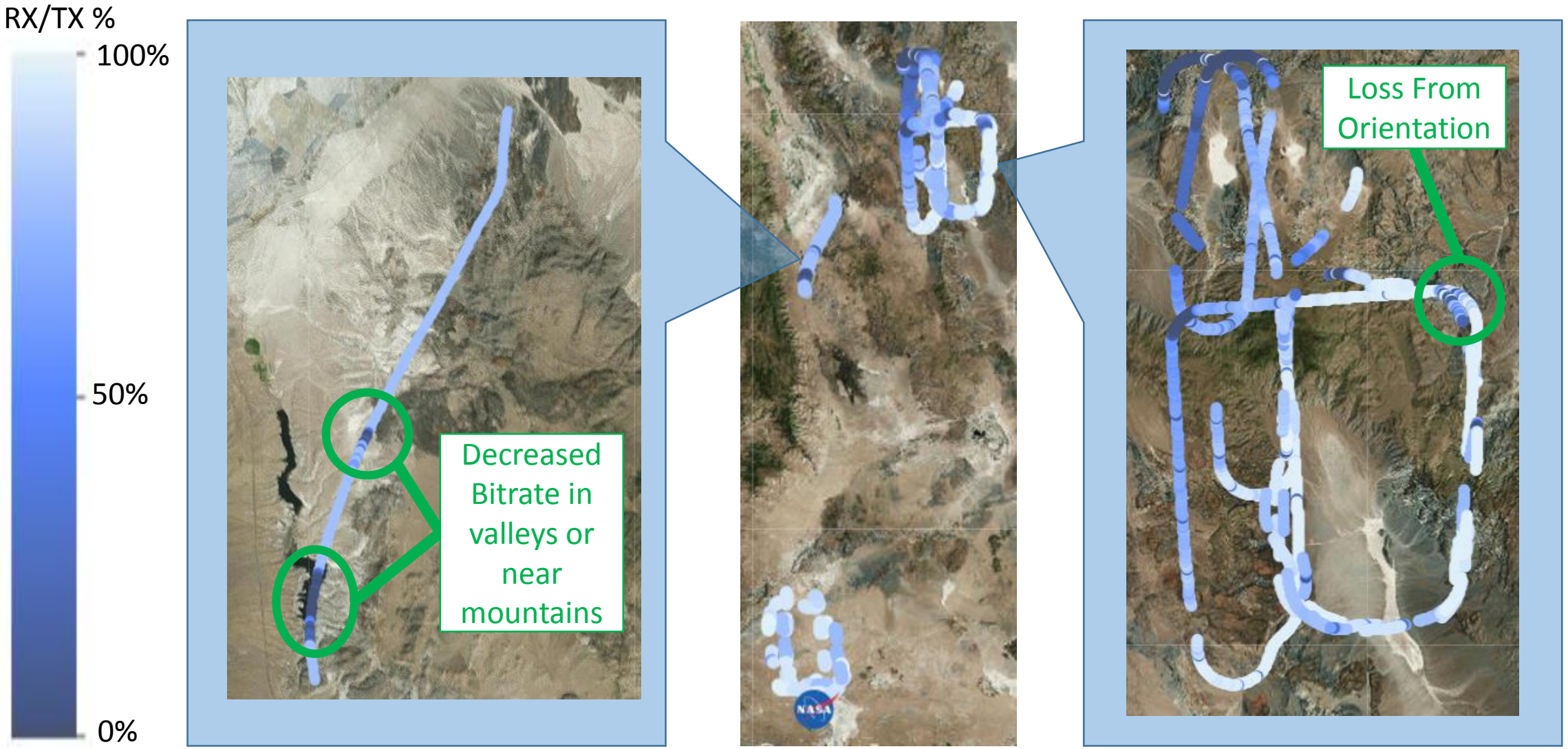
*K. Wallace, "Chapter 7: Improving and Maintaining Voice Quality," Network World, 17 March 2008.

Bitrate Performance





SOQPSK Bitrate Analysis At Various Locations



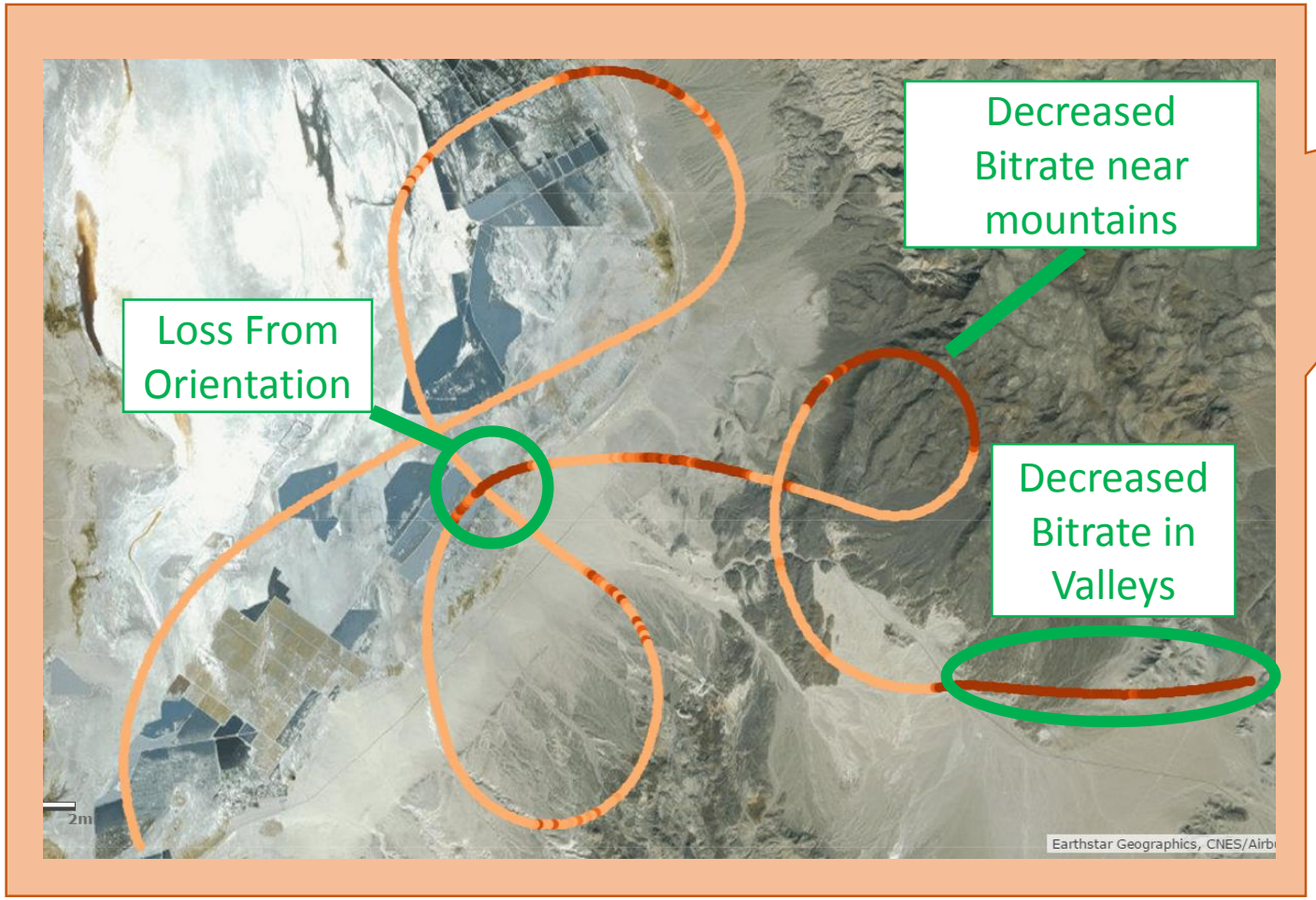
Multi-h CPM Bitrate Analysis At Various Locations

RX/TX %

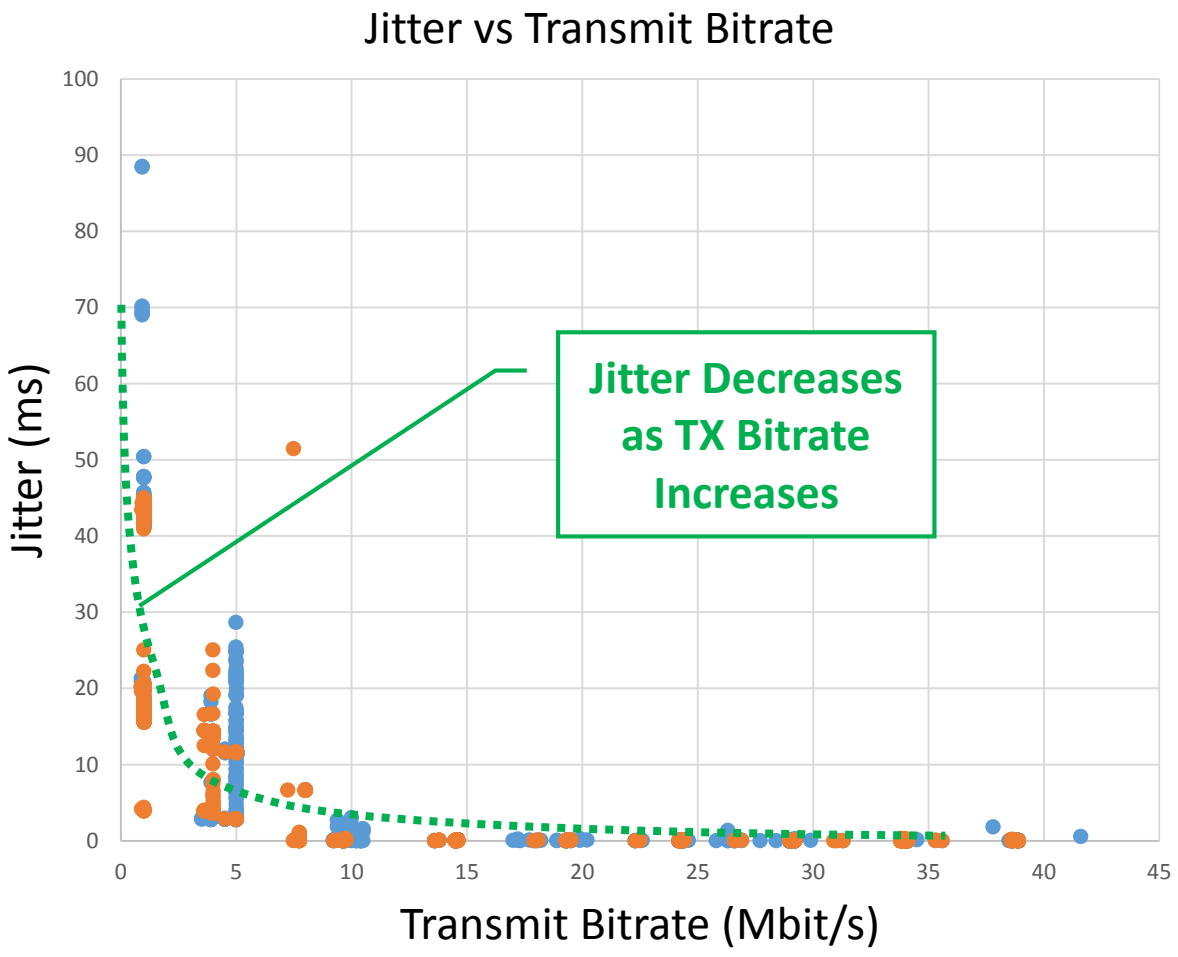
100%

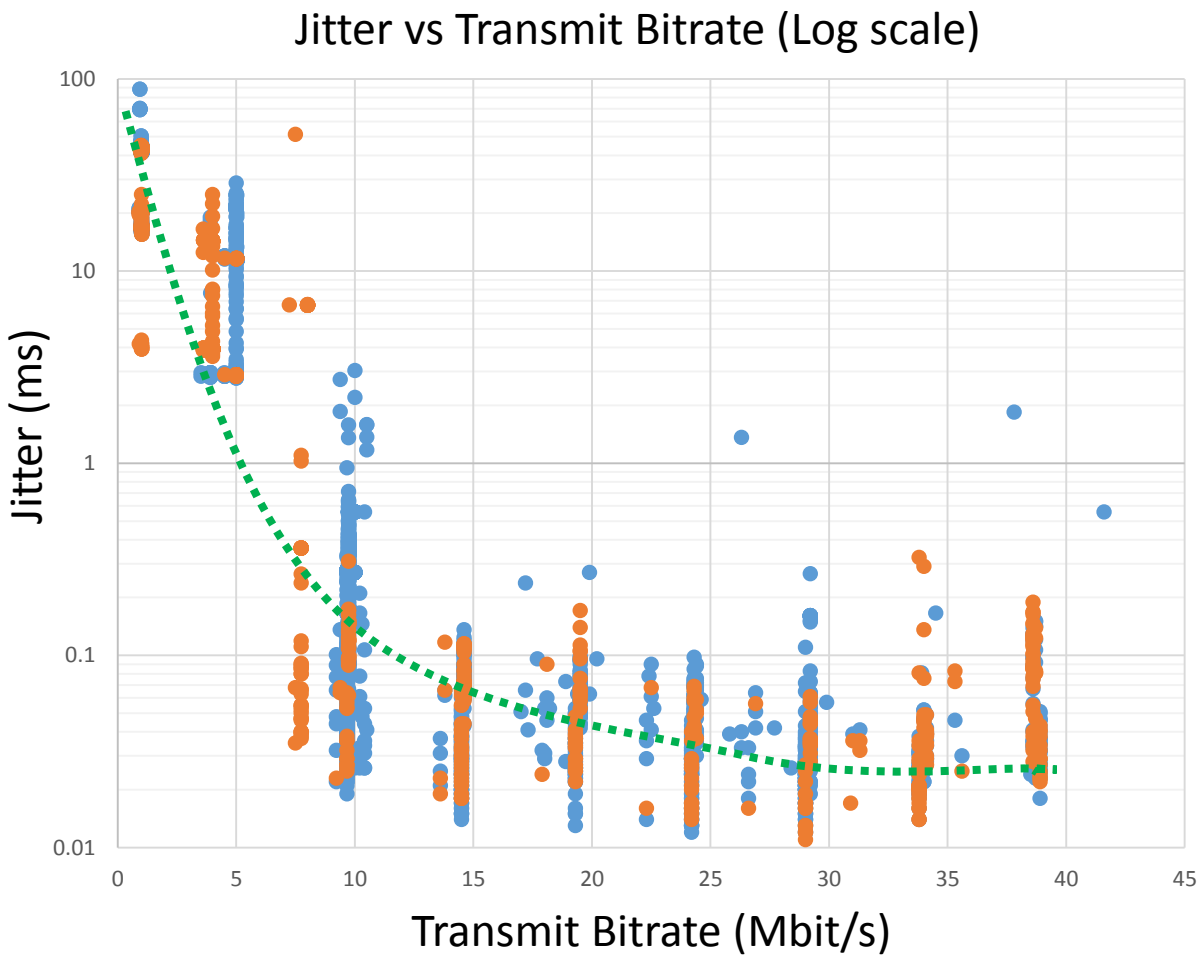
50%

0%



Jitter Analysis



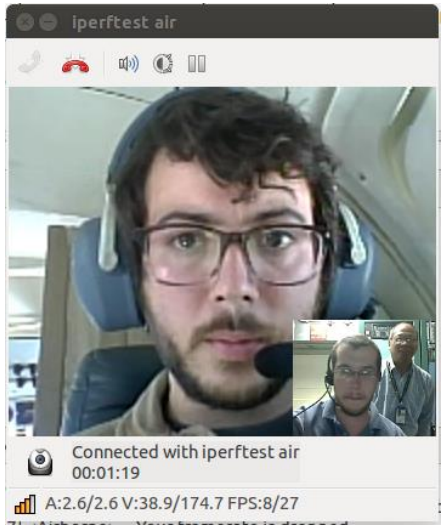


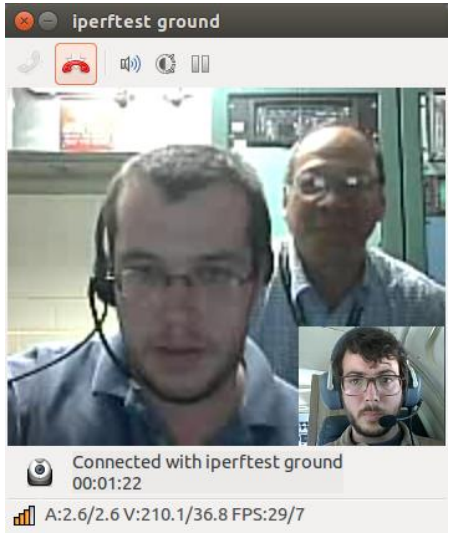
Multi-h CPM

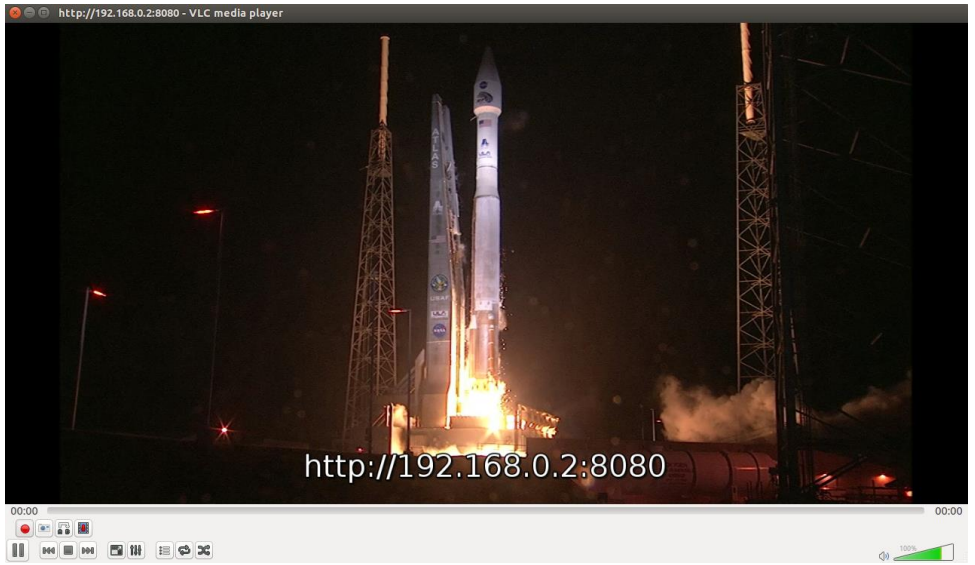
SOQPSK

Networking Tools and Features

- Communications
  - Ekiga Software provided Video/VOIP
    - RTP - Real-time Transport Protocol
    - 1% Packets lost during testing
- Video Streaming
  - 720p video stream over 10Mbit
- File Transfer Protocol
  - Onboard FTP client and server capability was demonstrated
  - File upload/download sizes ranged from 1Kbit to 10Megbit
- Instant Messenger
  - Helped test engineer communicate directly with ground support
  - Logged conversations to aid with post-flight analysis







Conclusion

- There wasn't substantial difference between the performance of Multi-h CPM and SOQPSK
  - Would recommend further investigation into Multi-h CPM for improved spectral efficiency
- Best practices for PCM/FM systems also apply to Multi-h CPM and SOQPSK modulation schemes
  - Best results were seen with direct line of site
  - Drop outs that resulted from poor aircraft orientation could be mitigated with multiple antennas
- Jitter is decreased as bitrate is increased
  - If Jitter is a concern, increase bitrate
- Approximately linear correlation between TX and RX bitrates
- Rapidly integrate and apply state-of-the-art networking tools and features for flight research applications

Questions?