“Aurora Touching Sunrise” from NASA archives
AERO VISTA Mission Introduction

- AERO & VISTA satellites will collect radio frequency (RF) data from the auroral regions
- Data will be used to accomplish science and tech goals
  - Study emissions such as Auroral Kilometric Radiation (AKR), Medium Frequency Burst (MFB), Auroral Roar, and Auroral Hiss
  - Validate usage of Vector Sensor Interferometry and RFI survey
Monopole, Horizontal Loop, and Rectangular Dipoles correspond to channels on spectrogram
Ground Station Radio Communications

T. Lucas Briggs
What is a Ground Station?

- Enables communication between spacecraft and mission operations
- Handles all radio operation, command scheduling, and data verification tasks

Source: https://www.gim-international.com/content/news/pasco-provides-rental-service-for-satellite-ground-station-facilities
For AERO/VISTA

- Multiple possible Ground Stations in different locations with a wide range of radio configurations

- Many different types of data with varying sizes of payload
  - **Commands**: small, carries data necessary for spacecraft to execute desired action.
  - **Acknowledgements**: very small, carries data necessary to say “command received”
  - **Telemetry**: large, carries as much information as possible about spacecraft state
  - **Science**: very large, carries a full time-series of spectrum data from auroral emissions
Digital Communications over Radio

**UPLINK**
- data I want to send
- "frame" for verification
- "modulate" for transmission
- "demodulate"
- "deframe" and verify

**Downlink**
- "frame" for verification
- "modulate" for transmission
- "demodulate"
- "deframe" and verify
- data I want to receive
Summary of Requirements

Need a software package that...

- Enables framing/deframing and mod./demod. on uplink/downlink.
- Allows for a wide range of data payload lengths.
- “Drops in”. Can be imported, started, and maintained anywhere.
- Provides a way to access data remotely and asynchronously.
- Is as configurable as possible
- Is as extendable as possible
Implementation - GNURadio Flowgraph
Implementation - Software (simplified)

- **Database** provides asynchronous remote access.
- **Ground Station** provides configuration, handles top-level operation.
- **Radio Interface** manages framing/deframing data, uplinking/downlinking frames.
- **Flowgraph** operates the Radio Transceiver.
Implementation - Software (simplified)

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MIT HAYSTACK OBSERVATORY
Live Demo - PNG File Transfer
Next Steps

- Interaction of the Ground Station with the Database needs to be expanded
  - Operation commands, logging, configuration, and satellite command scheduling, all remote-asynchronous
- GNURadio Flowgraph needs to be expanded
  - More/better signal processing for higher SNR (configurable)
- Develop a “mock satellite” version of the Ground Station
  - Responds to known commands with dummy data
  - Potentially applies a channel model to the signal to test non-ideal conditions
- Integrate with a real transceiver and satellite engineering model
backup
Implementation - Software (expanded)

- Radio Interface exists as 3 important blocks
- Each has a single responsibility, promotes extendability
- See report for more details
Modulation and Framing for A/V

- Modulation using Gaussian Frequency Shift Keying (GFSK)
  - Looks a bit like this:
  ![Waveform example]
- Flexible data framing with the following template:

![Data framing diagram]
Reliable Data Transfer: Framing

- **Preamble**: recognize symbols, “lock on” to binary data
- **Syncword**: find the start of the data packet
- **Length**: how many bytes to expect in the data
- **Address**: where should this data go

- **CRC (Cyclical Redundancy Check)**: Verify that the data has not changed
- **Whitening**: Deterministically randomize the data
Configuration Through YAML Files

Configurable parameters are categorized into “packet”, “radio”, and “redis” groupings
Digital Communications: Modulation

- Binary data representation on a “constant wave”, accomplished through **keying**
  - Amplitude-Shift Keying (ASK)
  - Frequency-Shift Keying (FSK)
  - Phase-Shift Keying (PSK)
  - ...many more

- Our solution: Gaussian FSK (GFSK)
  - FSK with no sudden jumps
Thank you to our mentors

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