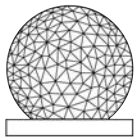
Haystack AeroVista REU

Hirani Sattenapalli, Aparna Rajesh, T. Lucas Briggs



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“Aurora Touching Sunrise” from NASA archives

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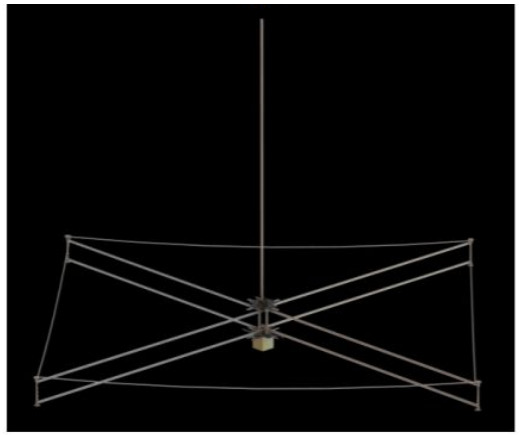
AERO VISTA Mission Introduction

AERO VISTA Payload ←



Antenna after Deployment →

- 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

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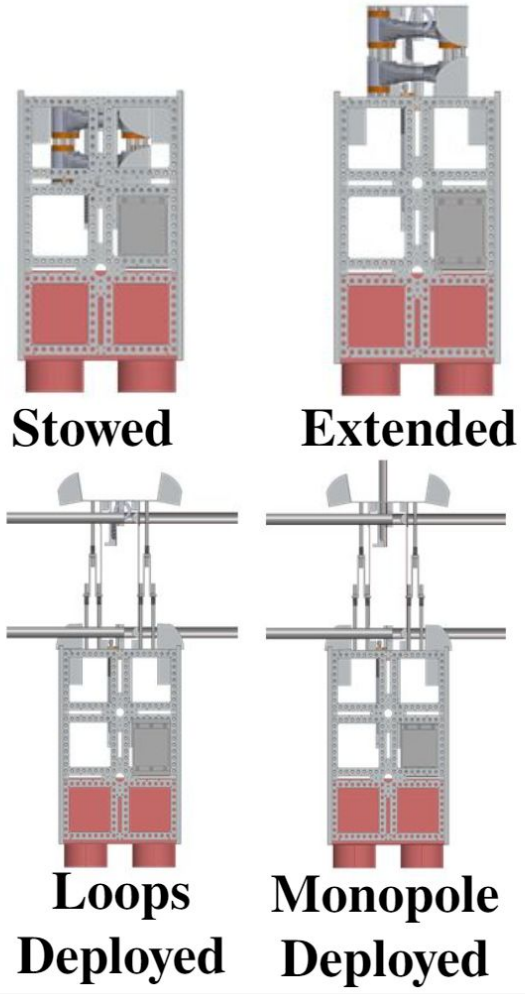
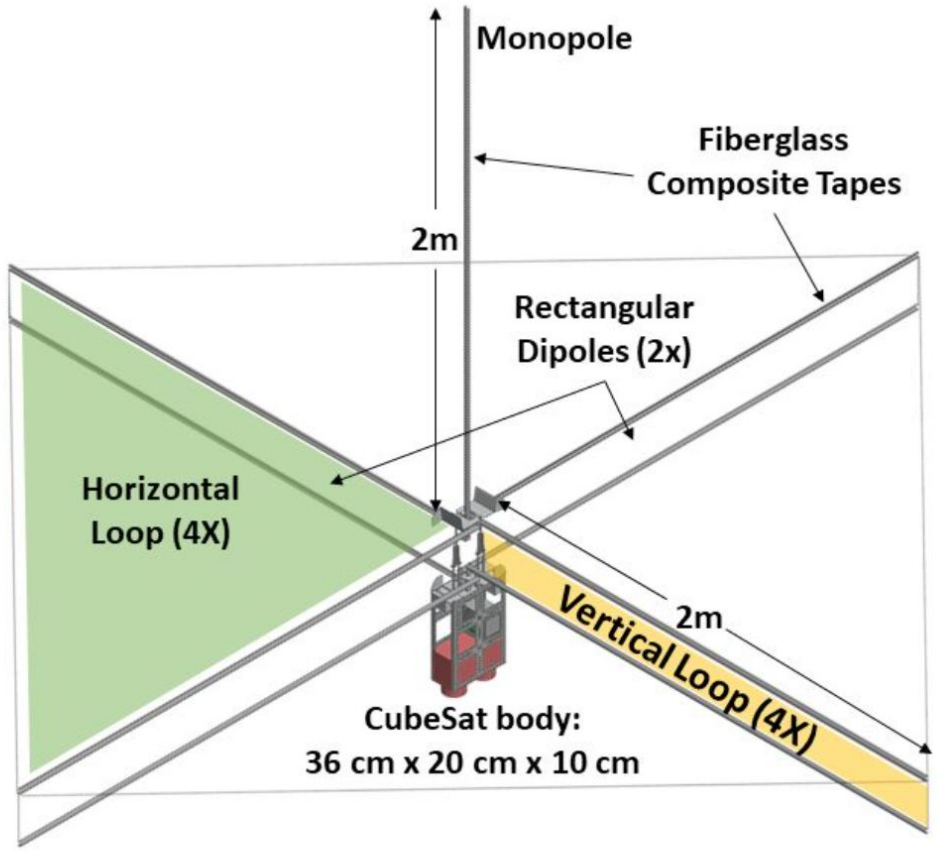
AERO
AURORAL EMISSIONS RADIO OBSERVER

AERO-VISTA RF Instrument

VISTA
VECTOR INTERFEROMETR SPACE TECHNOLOGY USING AERO

Dr. Philip J. Erickson, AERO Principal Investigator Dr. Frank Lind, VISTA Principal Investigator





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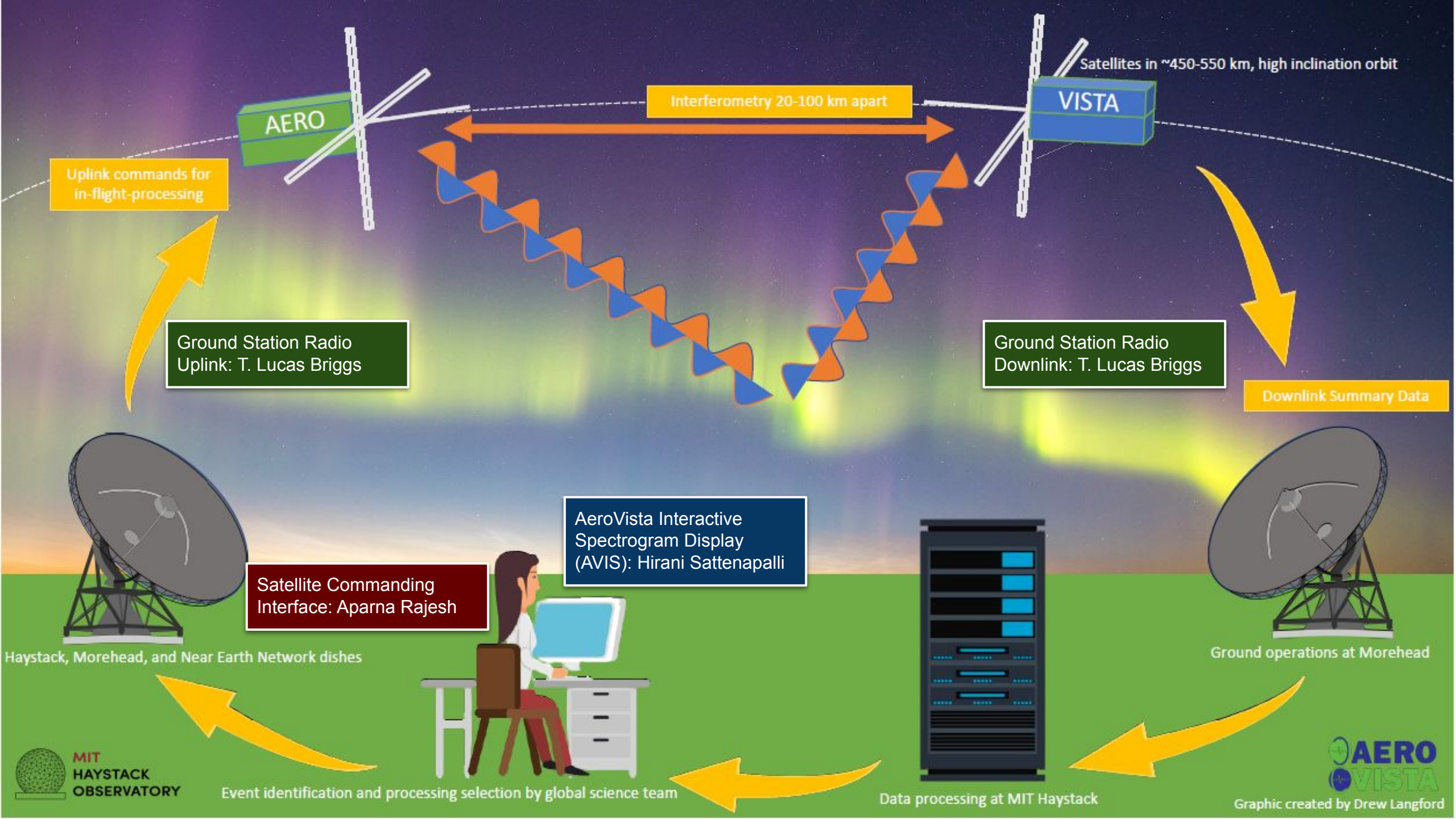
Monopole, Horizontal Loop, and Rectangular Dipoles correspond to channels on spectrogram

Slide from Mary Knapp
AERO-VISTA presentation 2021


AERO
VISTA
Satellites in ~450-550 km, high inclination orbit
Interferometry 20-100 km apart
Uplink commands for in-flight-processing
Ground Station Radio Uplink: T. Lucas Briggs
Ground Station Radio Downlink: T. Lucas Briggs
Downlink Summary Data
AeroVista Interactive Spectrogram Display (AVIS): Hirani Sattenapalli
Satellite Commanding Interface: Aparna Rajesh
Haystack, Morehead, and Near Earth Network dishes
Ground operations at Morehead
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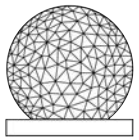
Event identification and processing selection by global science team
Data processing at MIT Haystack
AERO VISTA
Graphic created by Drew Langford

Ground Station Radio Communications

T. Lucas Briggs



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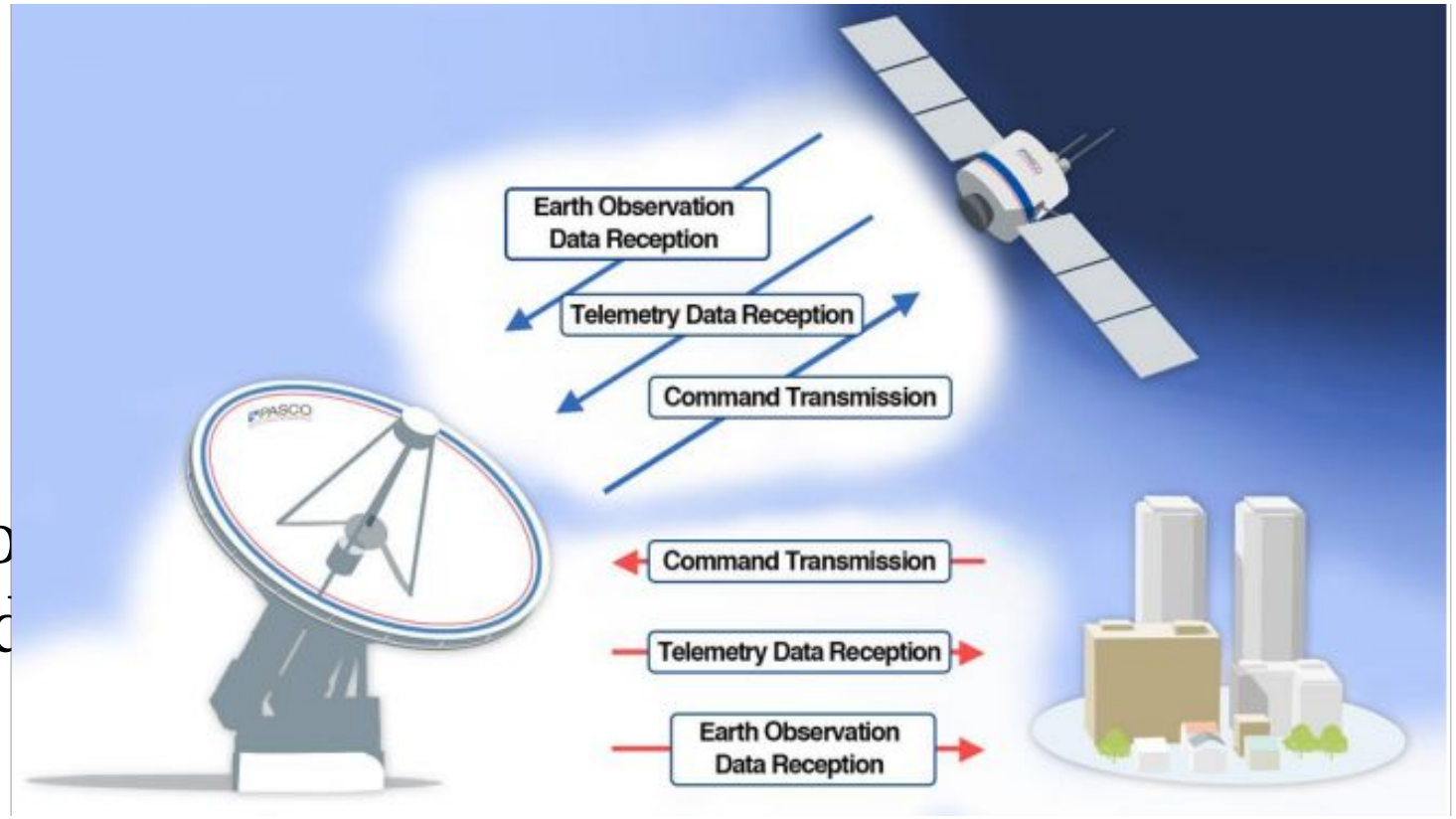
What is a Ground Station?

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



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

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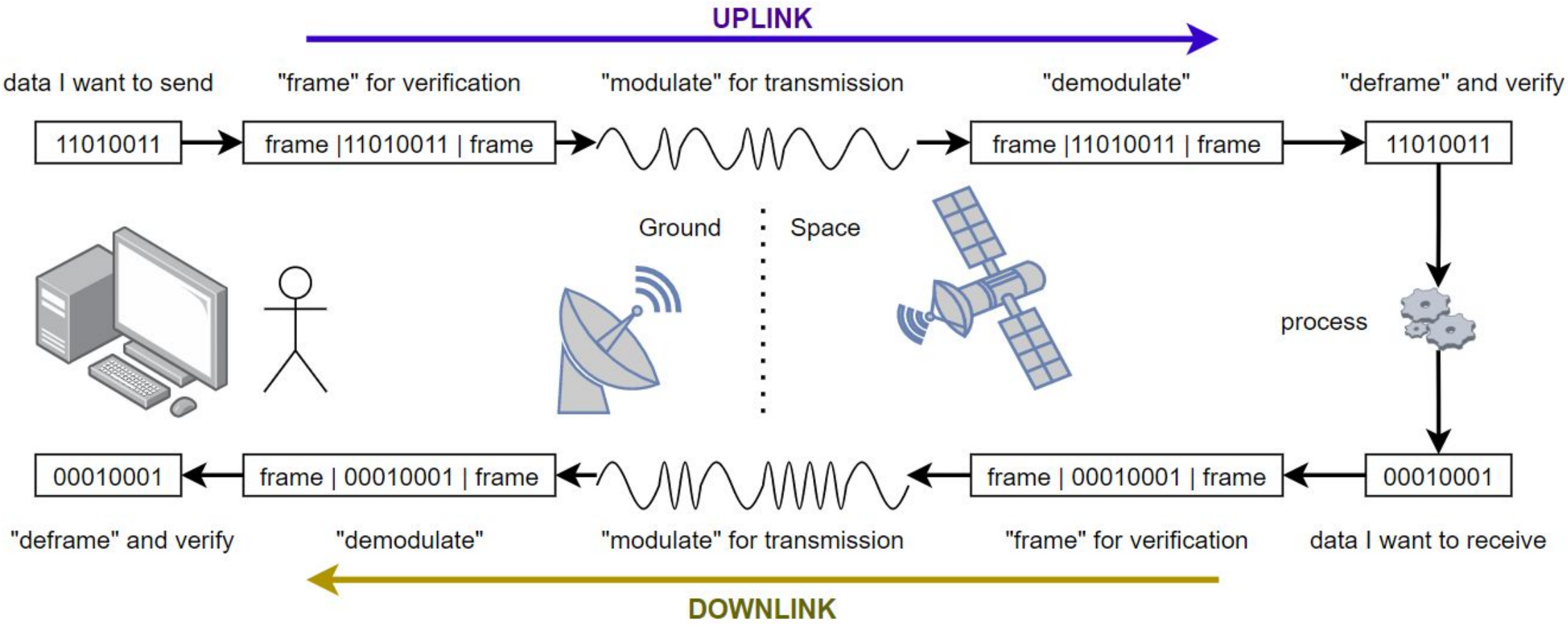
For AERO/VISTA

- 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



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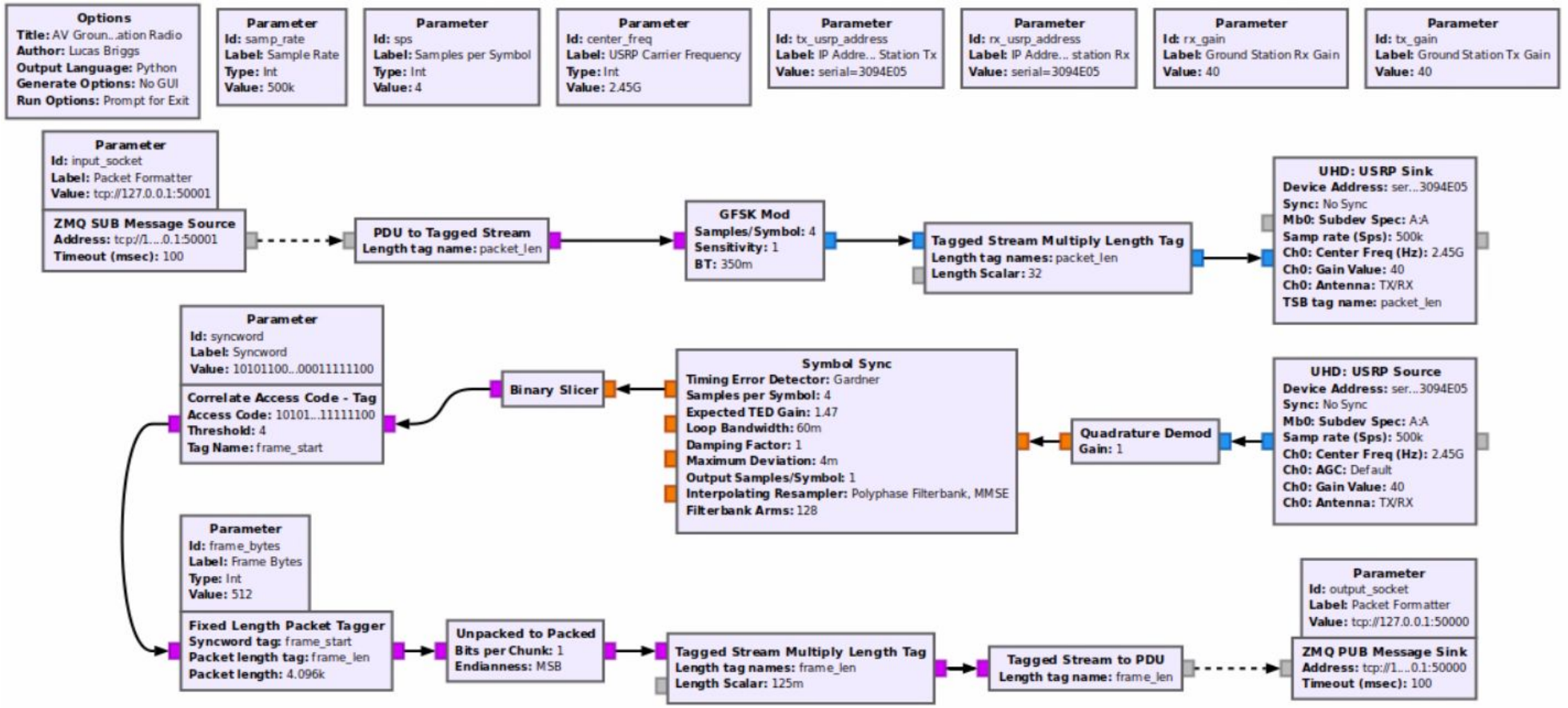
Summary of Requirements

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



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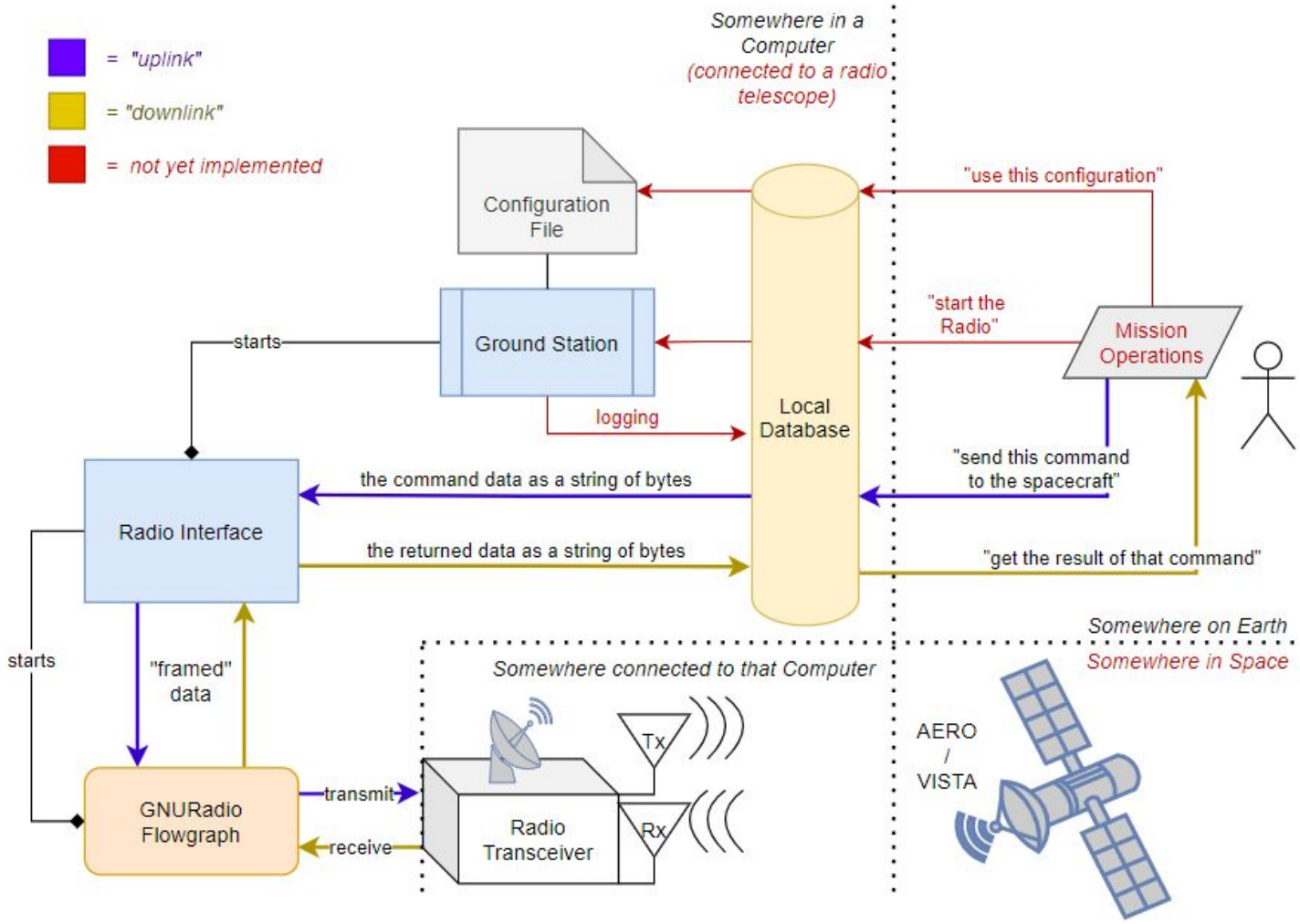
Implementation - Software (simplified)

- 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.



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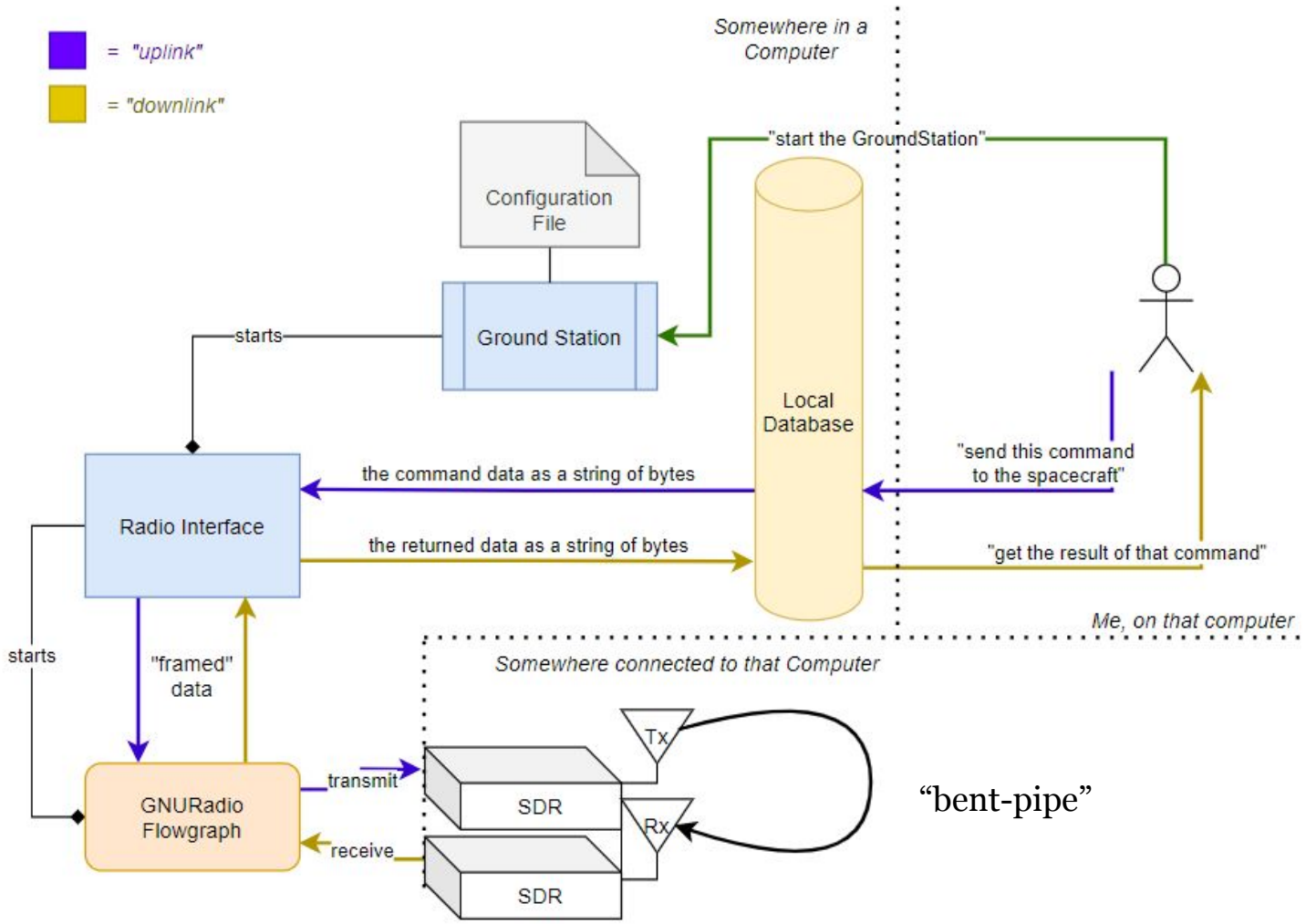

"bent-pipe"

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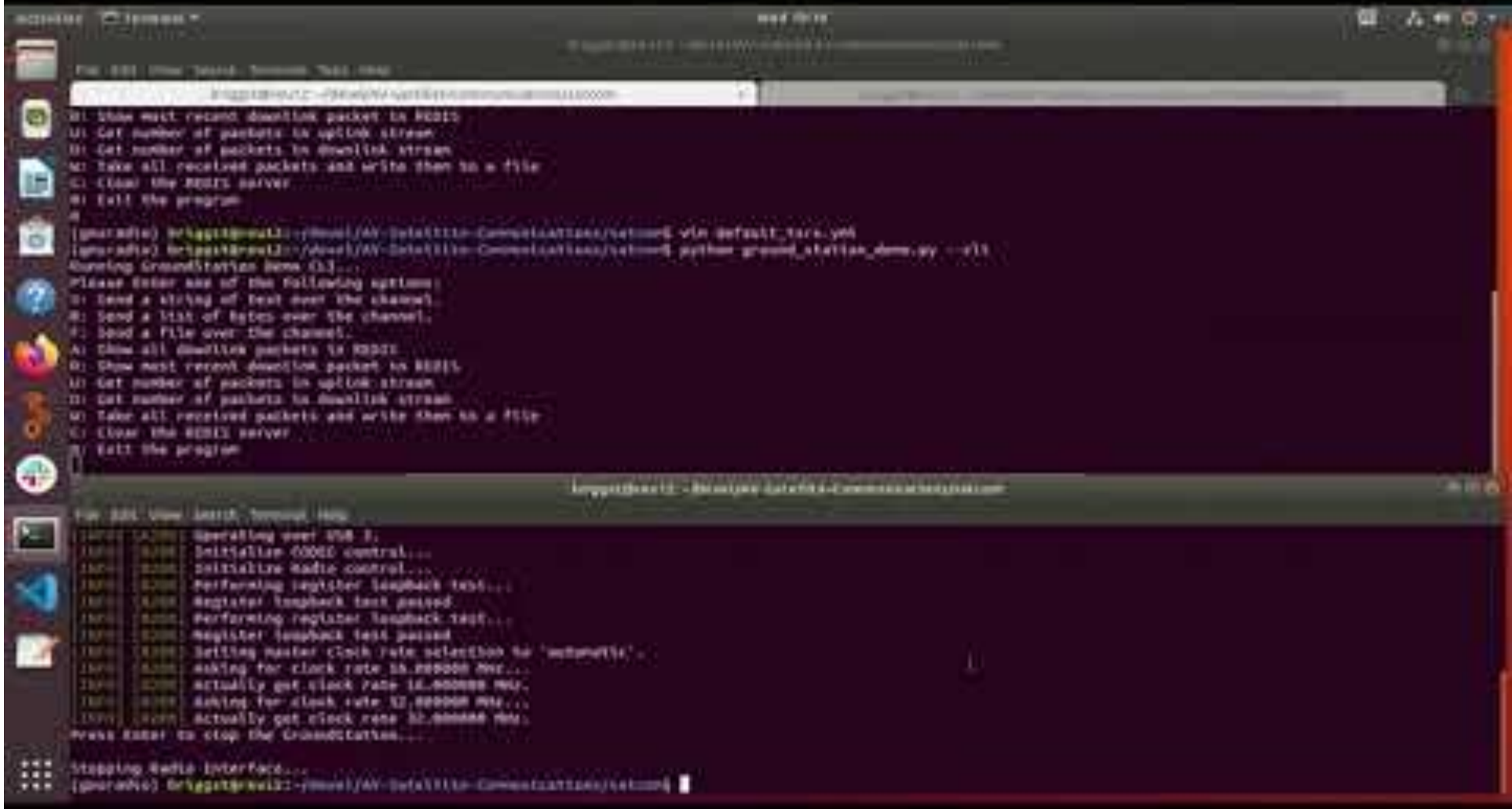
Live Demo - PNG File Transfer



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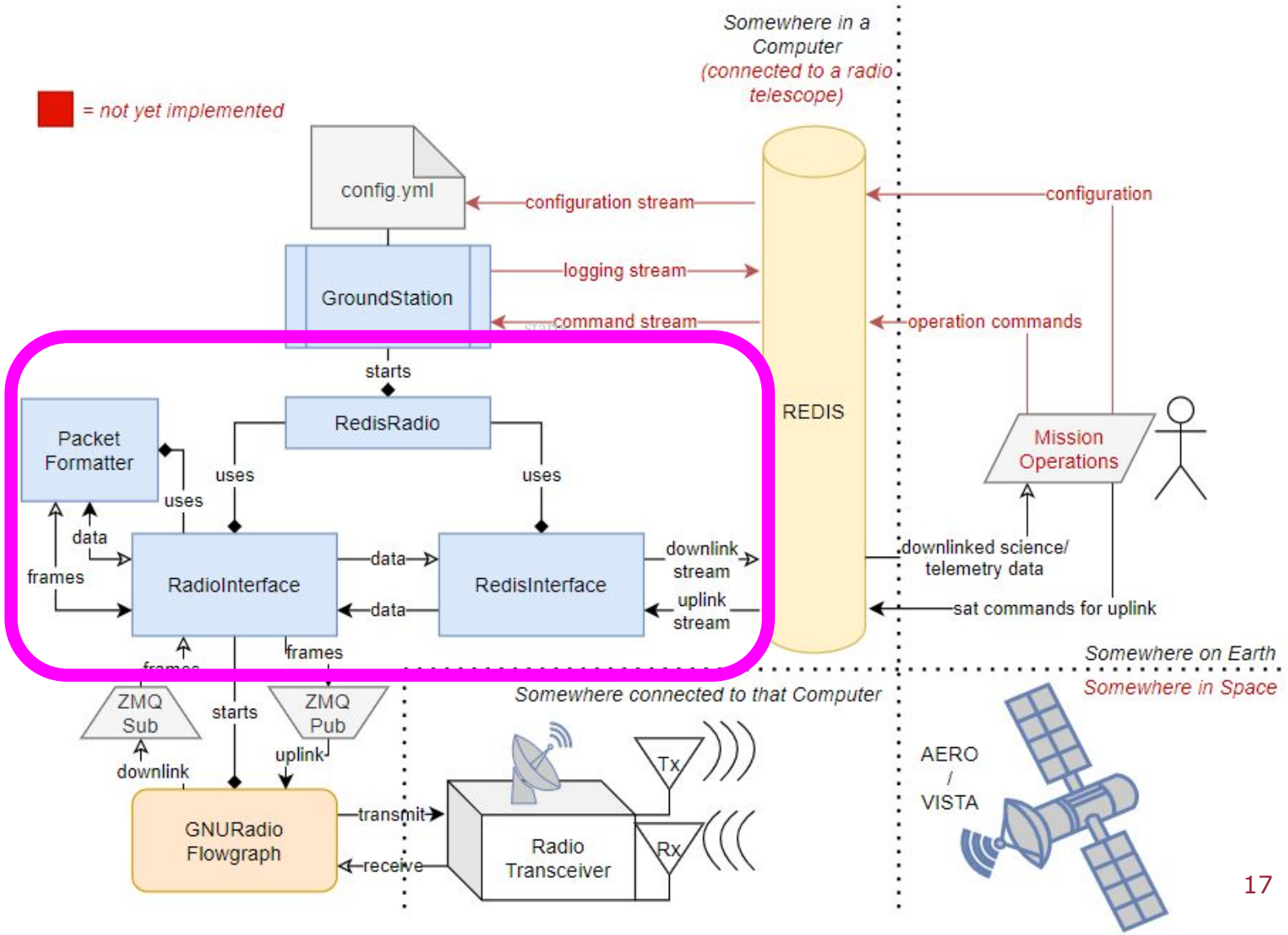
Next Steps

- 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



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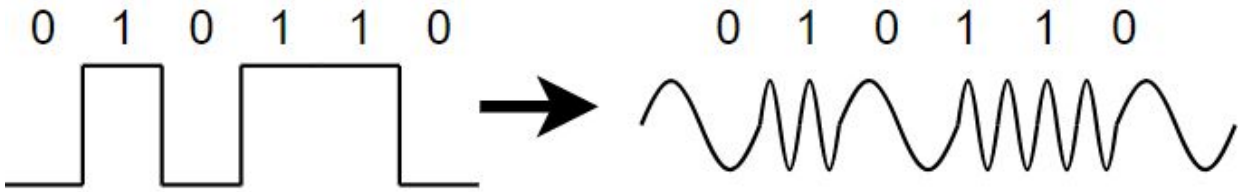
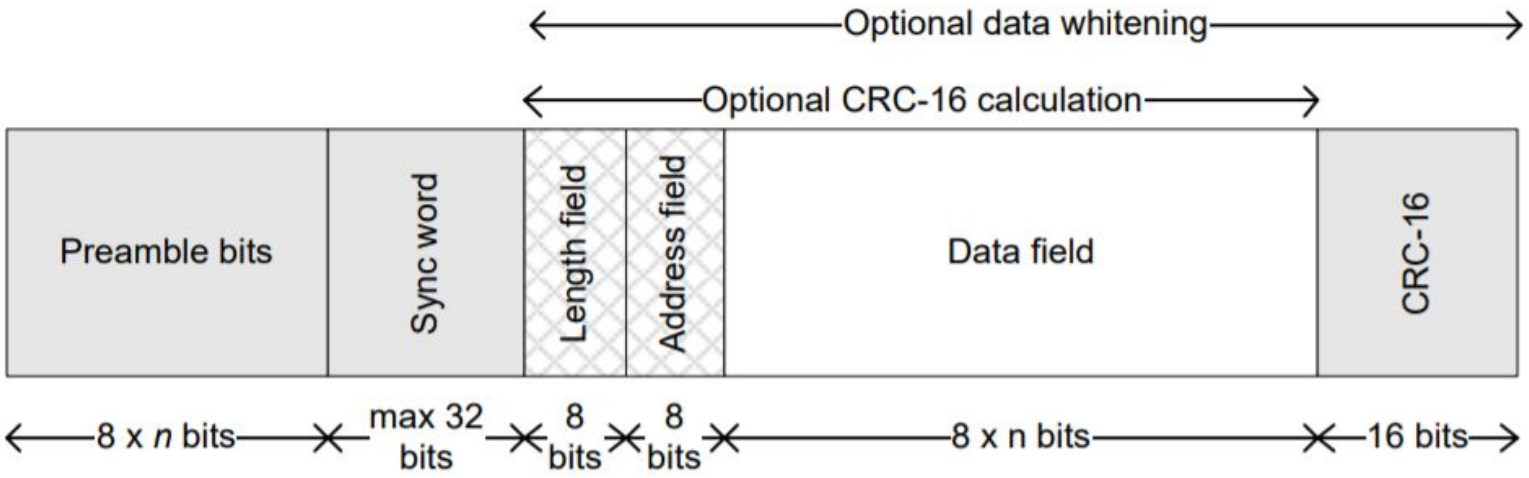
Modulation and Framing for A/V

- Modulation using Gaussian Frequency Shift Keying (GFSK)
  - Looks a bit like this:



- Flexible data framing with the following template:



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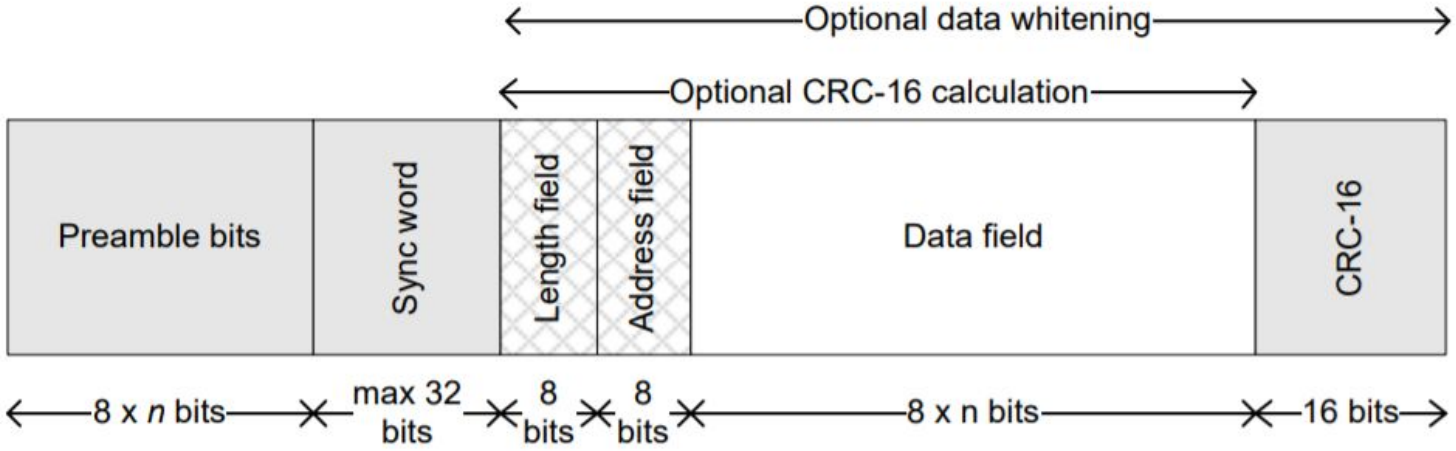
Reliable Data Transfer: Framing

- 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

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Configuration Through YAML Files

Configurable parameters are categorized into “packet”, “radio”, and “redis” groupings

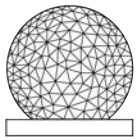
default_txrx.yml M

AV-Satellite-Communications > satcom > default_txrx.yml

```yaml
packet:
  formatter: "default"
  preamble: "1010010011110010" # ""
  syncword: "10101100110111011010010011100010111100101000110000100000011111100"
  whiten: True
  whitener_offset: 0
  crc: True

radio:
  center_frequency: 2450000000
  sample_rate: 500000
  samples_per_symbol: 4
  rx_gain: 40.0
  tx_gain: 40.0
  # These addresses can be the same (sat-in-the-loop test)
  rx_usrp_address: "serial=3094DF7"
  tx_usrp_address: "serial=3094E05"
  # These addresses must be different
  rx_socket_address: "tcp://127.0.0.1:50000"
  tx_socket_address: "tcp://127.0.0.1:50001"
  receive_waits_s: [0.1, 1, 3, 5]
  max_payload_bytes: 512

redis:
  host: "localhost"
  port: 6379
  db: 0
  pkt_uplink_stream_name: "pkt-uplink"
  pkt_downlink_stream_name: "pkt-downlink"
  clear_on_start: True
```



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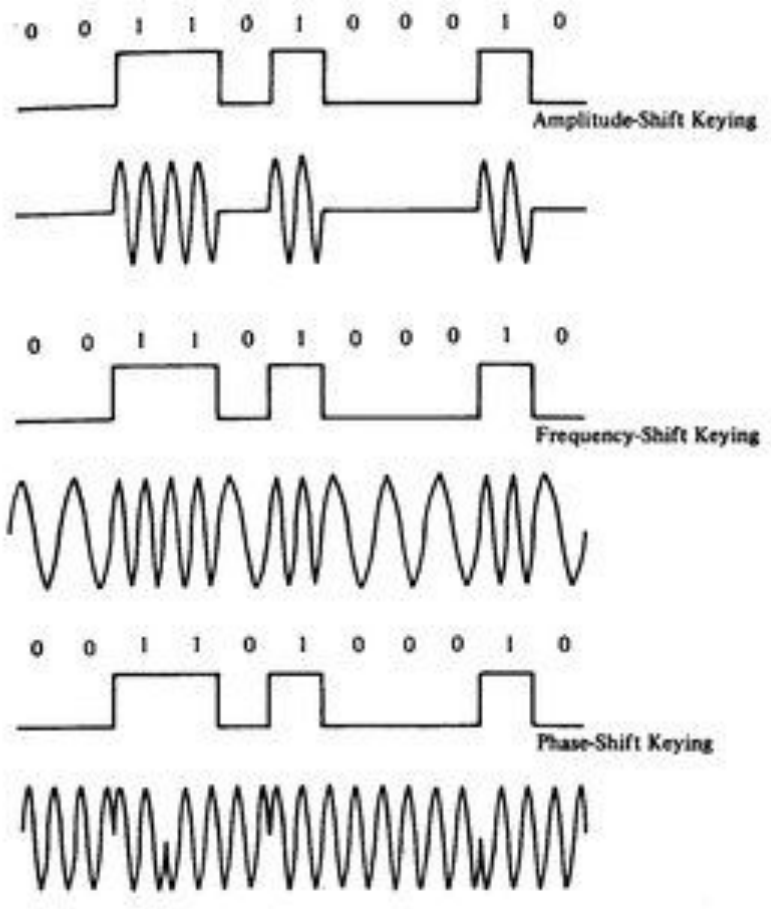
Digital Communications: Modulation

- 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



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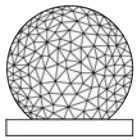
Thank you to our mentors

Mary Knapp, Ryan Volz, John Swoboda, Frank Lind, Phil Erickson, Toby Gedenk, and Geoff Crew



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