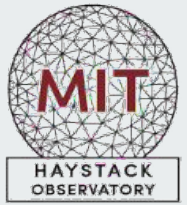
GNSS-SDR for Geodetic & Geospace Measurement

Incorporating GNSS Signals in VLBI Measurements

Anton Voronov, John Swoboda, Chet Ruszczyk, Dhiman Mondal, Pedro Elosegui

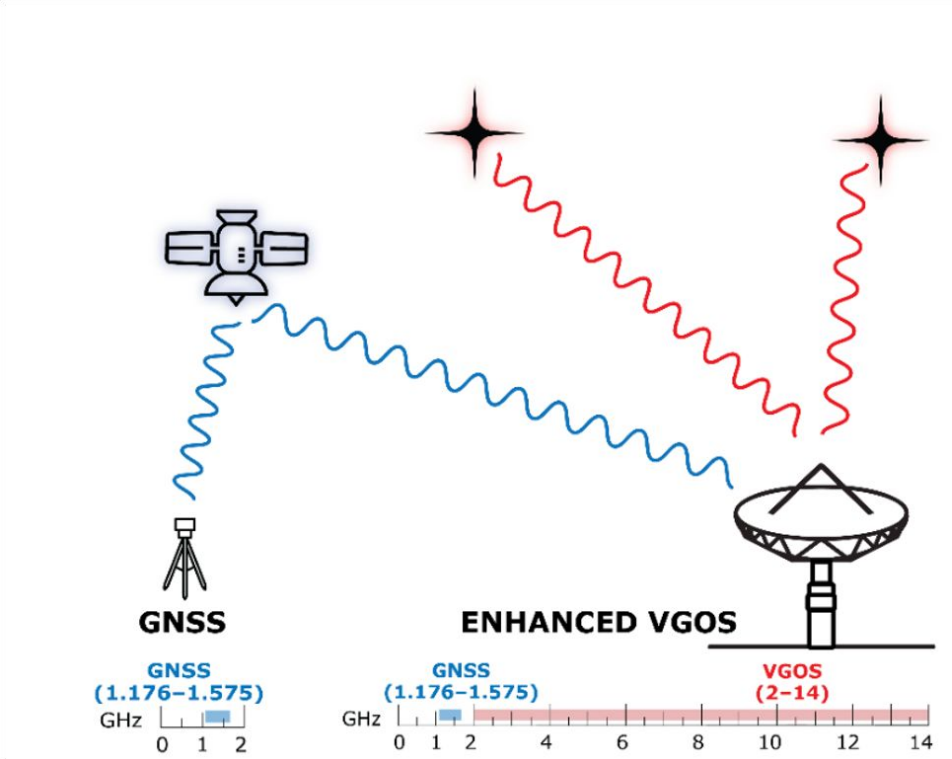


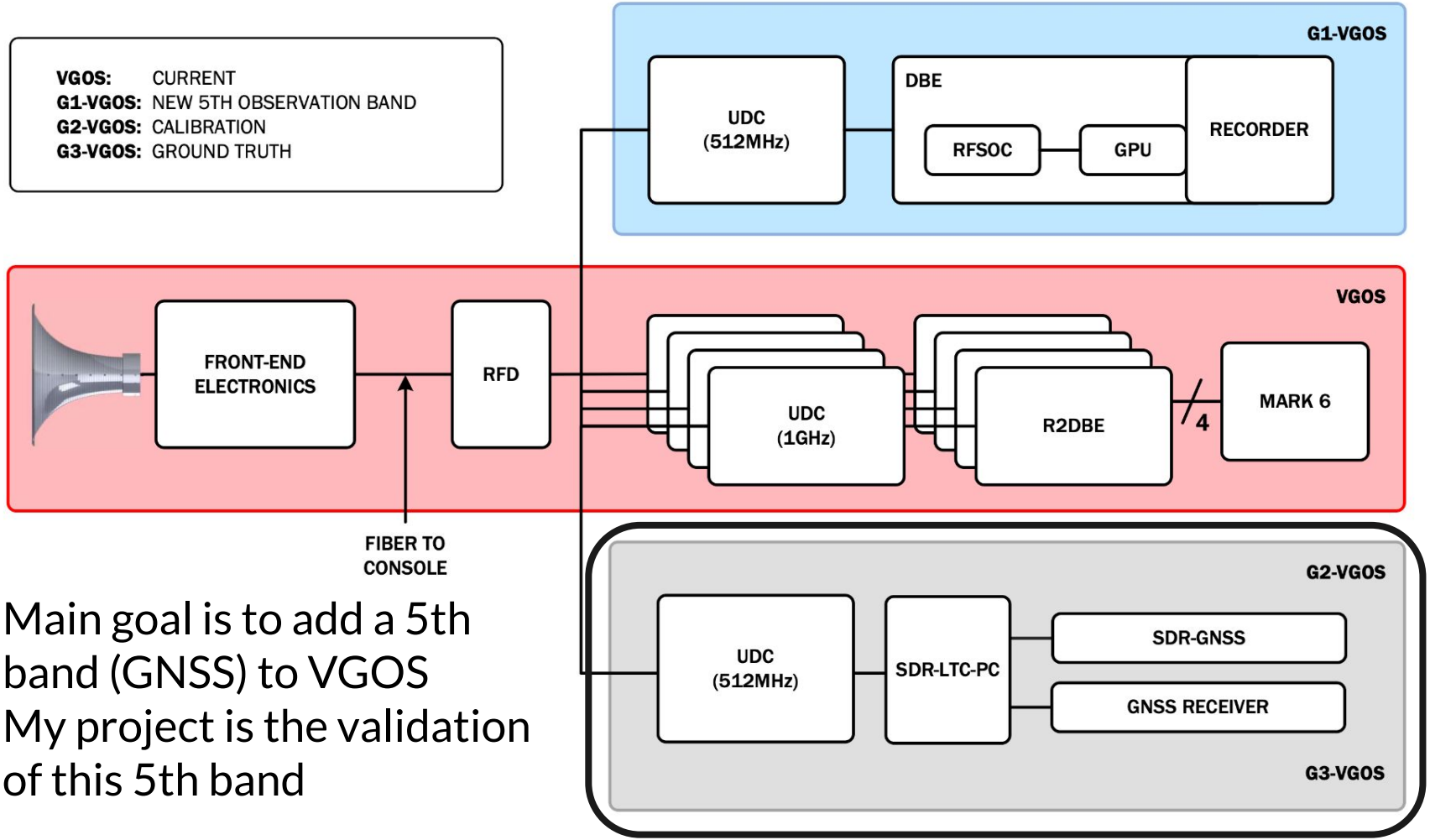
Background

- VLBI- **V**ery **L**ong **B**aseline **I**nterferometry
- Consists of many radio telescopes, spread out throughout the globe
- Enables many measurements: Astronomy, Geodesy, and more
- The Westford Radio Telescope is an example of a Geodetic VLBI Telescope

Background to Project

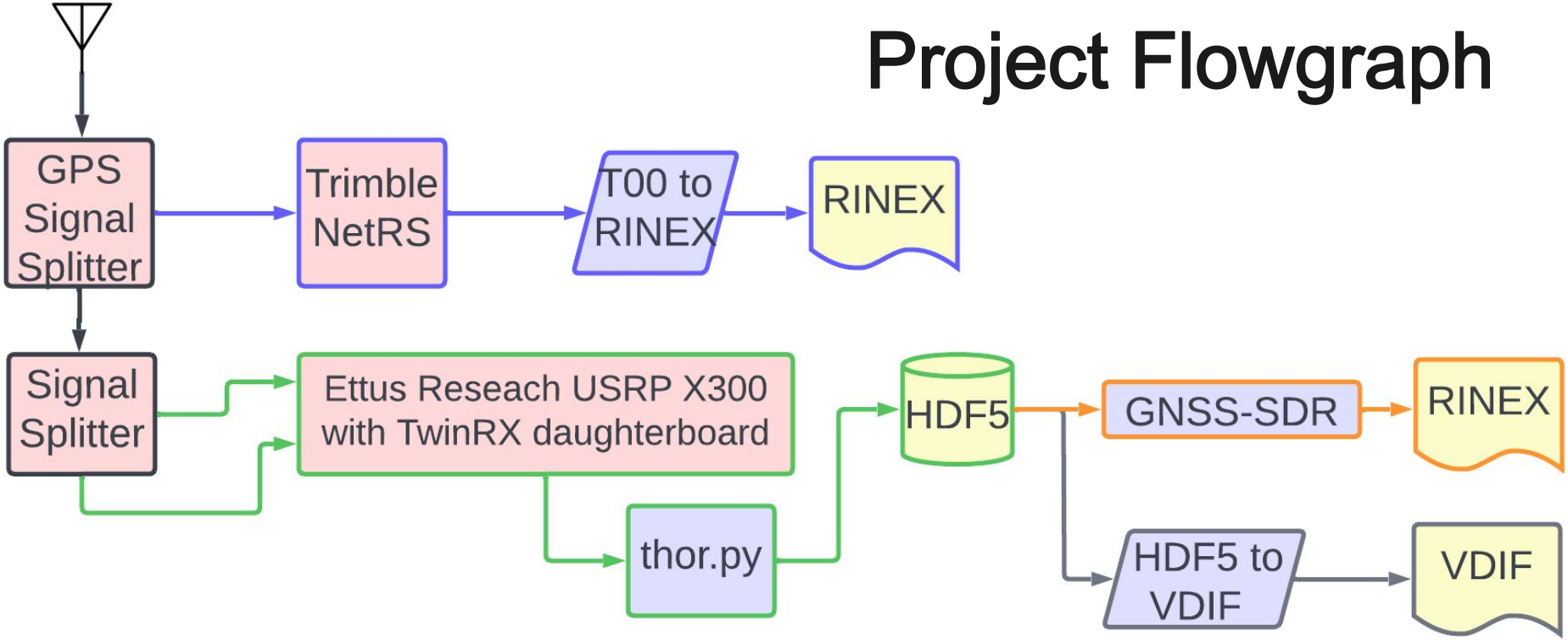
- **VGOS- V**LBI **G**lobal **O**bserving **S**ystem
- GNSS and VGOS are completely independent
- Idea is to add a GNSS band to VLBI
- Improves accuracy of terrestrial reference frame (TRF)
- Fuses VGOS and GNSS



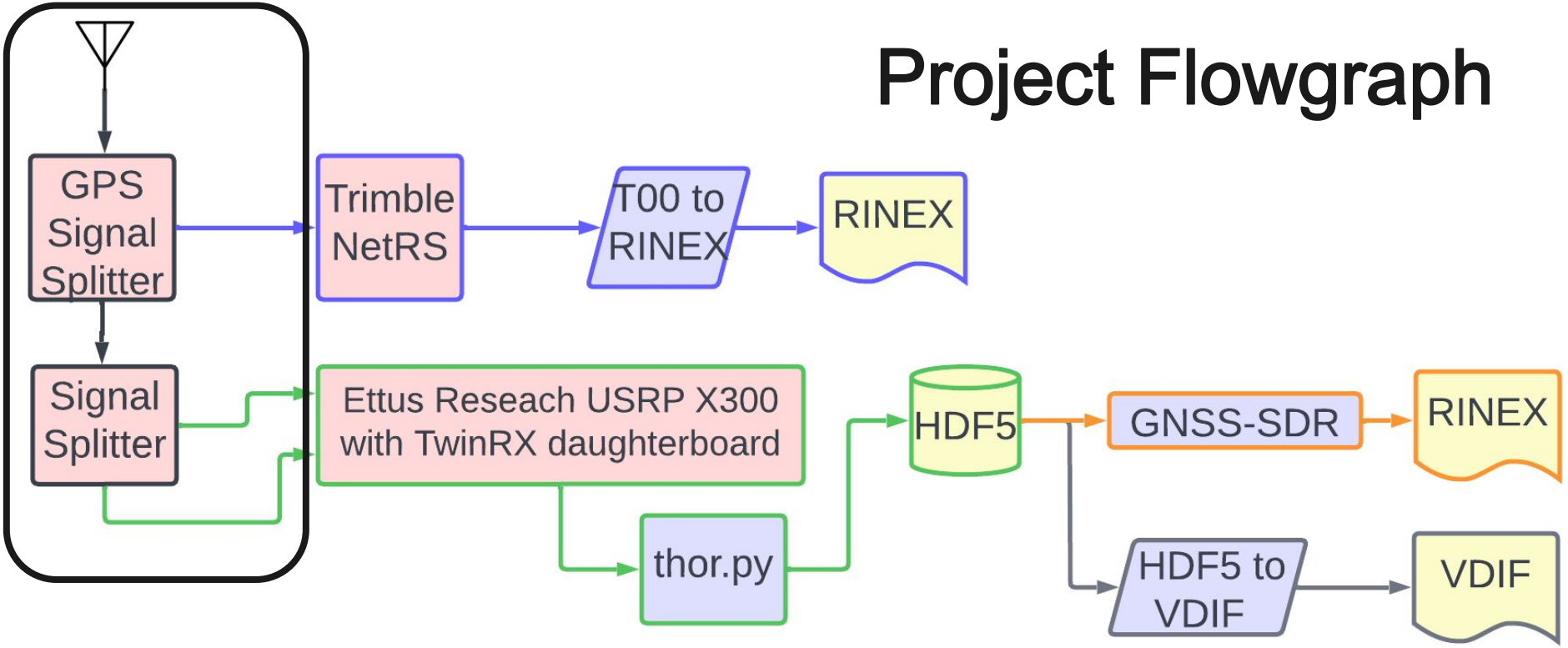


- Main goal is to add a 5th band (GNSS) to VGOS
- My project is the validation of this 5th band

Project Flowgraph

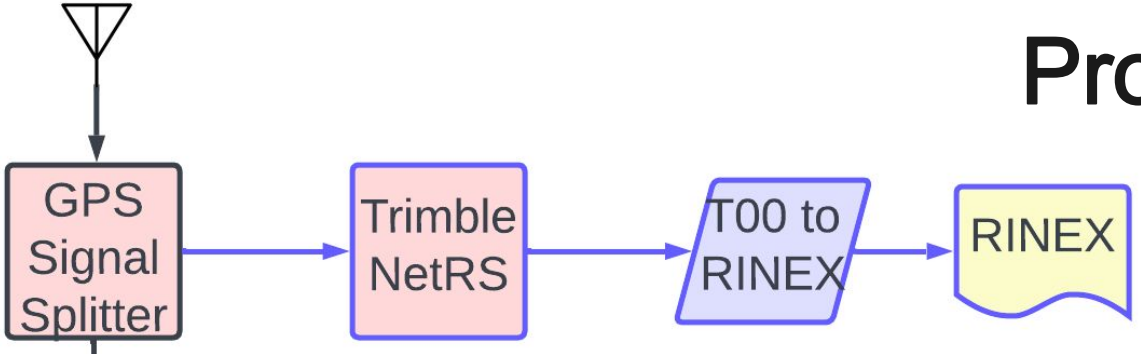


Project Flowgraph



- Geodetic antenna connected to two signal splitters
- Divides antenna into hardware and software defined radio paths
- Additional signal splitter for splitting the radio data into 2 channels

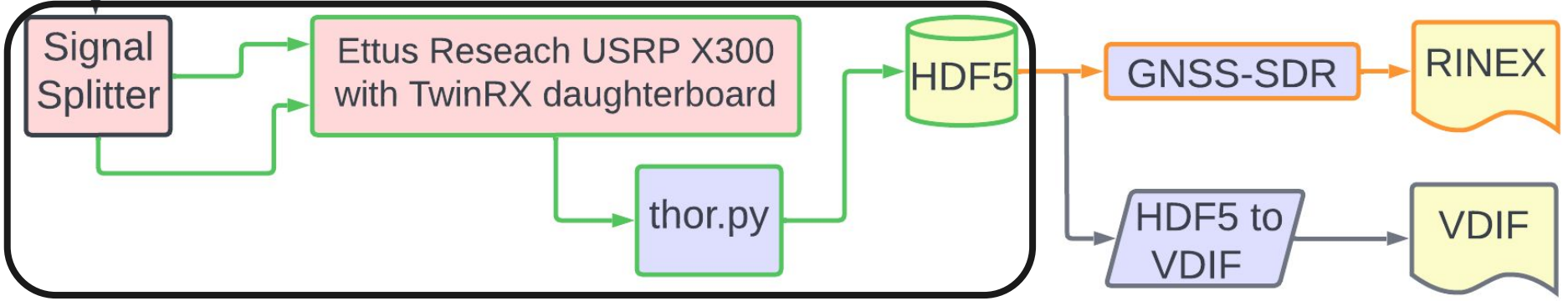
Project Flowgraph



- Hardware GNSS Receiver: Trimble NetRS
- Used for geodesy & datalogging, saves files in proprietary format
- This format is converted into RINEX

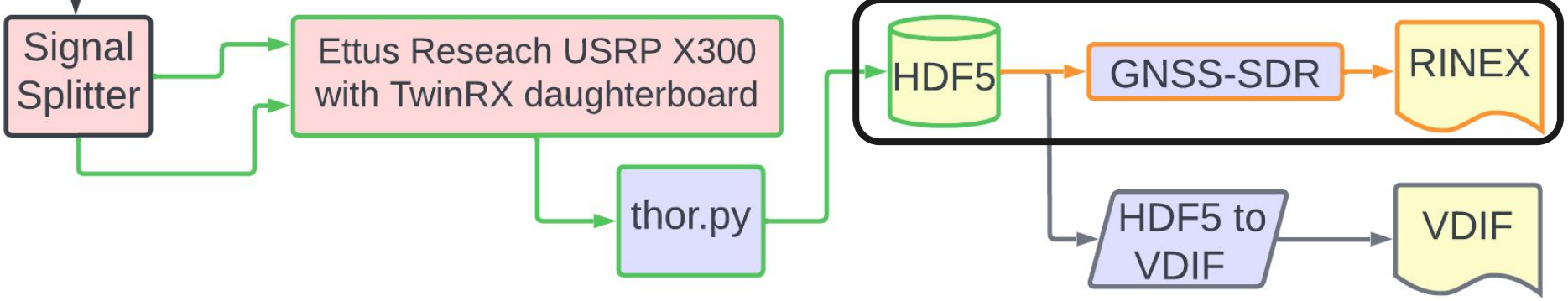
RINEX: **R**eceiver **IN**dependent **EX**change Format
Common exchange format for allowing any GNSS receiver to share observations. Frequently used by surveyors.

Why?
Validation for comparison against SDR GNSS receiver path



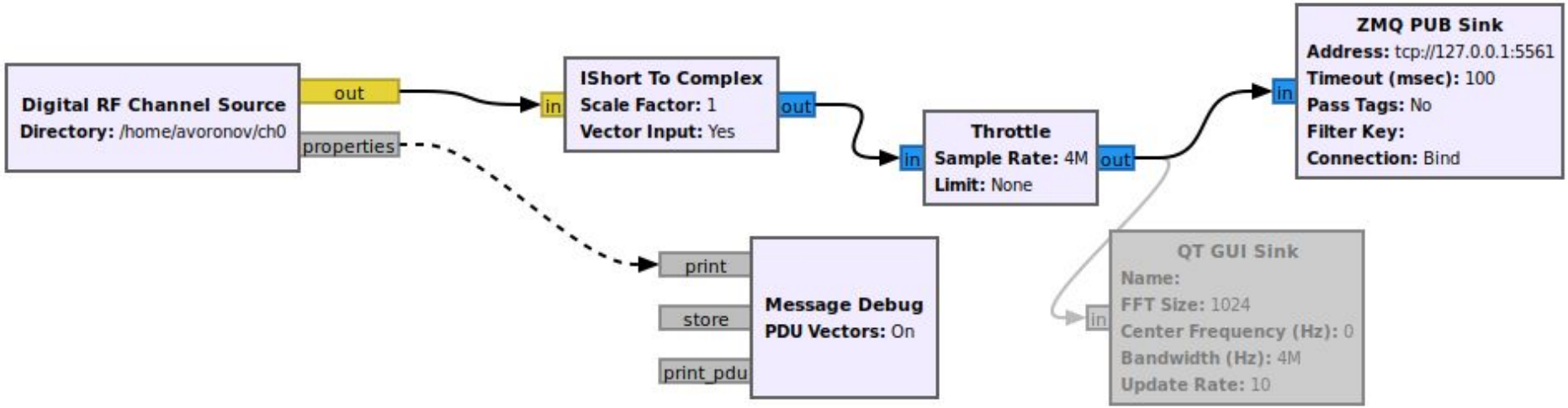
- Software defined GNSS receiver path
- Record 2 channel RF using thor.py, or **T**he **H**aystack **O**bservatory **R**ecorder

DigitalRF: a file format accompanied with software tools for R/W
Stores raw complex rf samples in HDF5 (binary) files
Very flexible format and excellent software suite



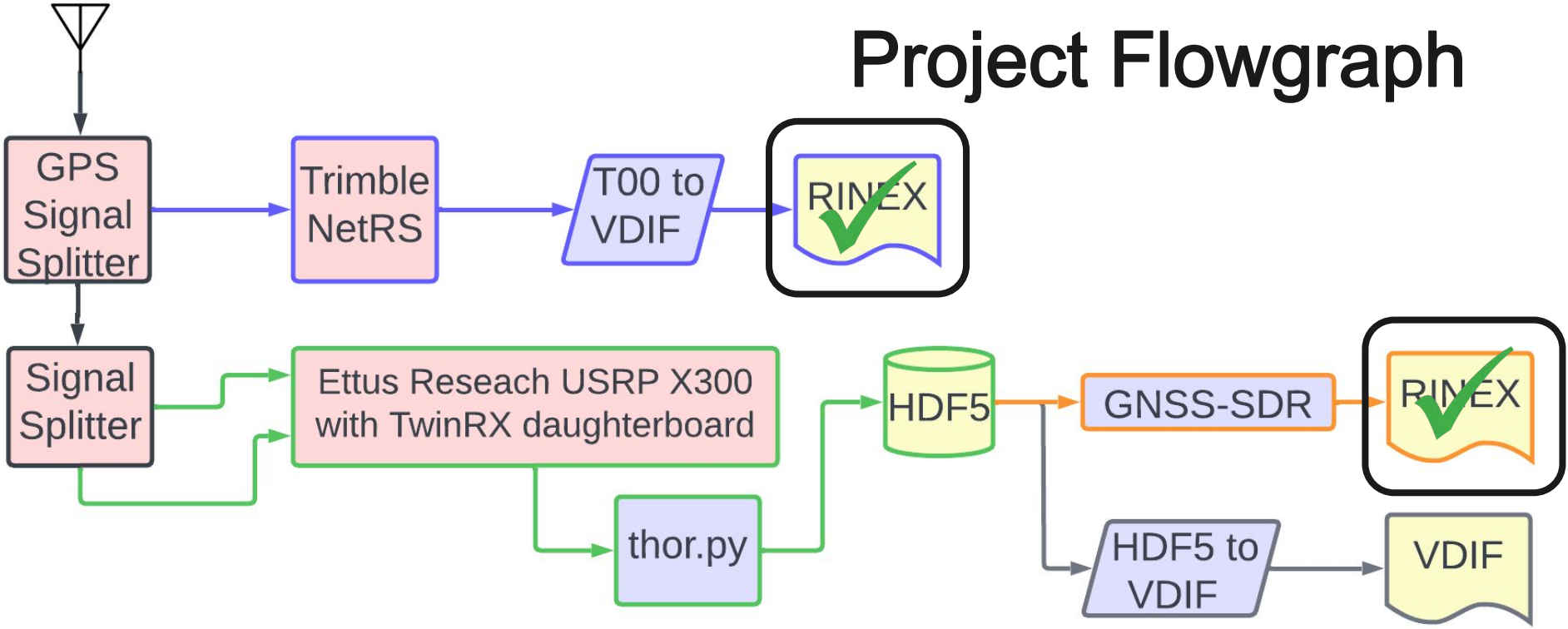
- GNSS-SDR: Open source software defined GNSS receiver
- Supports live data from SDR, or recorded data from file
- Uses “flowgraphs”, defined in config file, for signal processing and position triangulation
- Has many applications, we just need RINEX output
- Verify RINEX output by comparing it to hardware RINEX

- GNSS-SDR doesn’t support DigitalRF
- We need workaround to read RF data

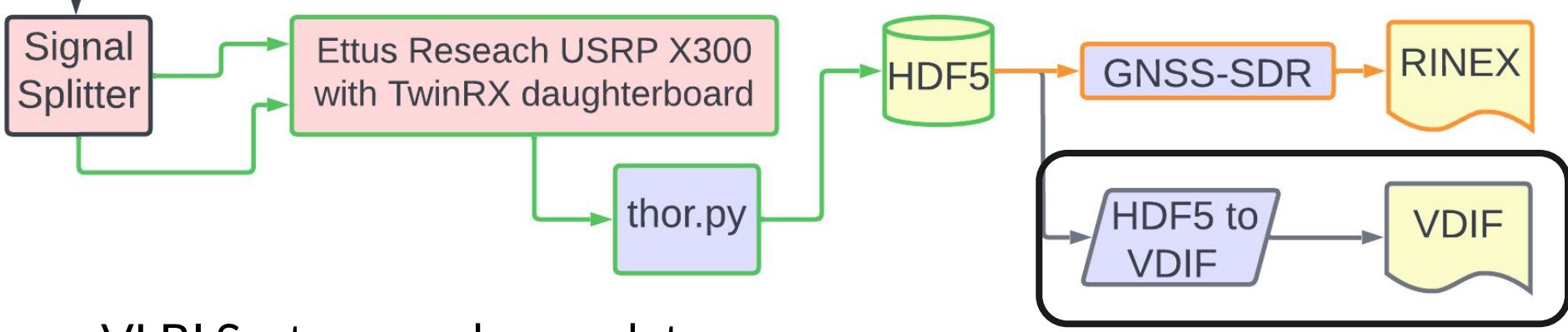


- Use GNU-Radio, software for RF data processing in “flowgraphs”
- Use DigitalRF library to read DRF data, convert datatypes, and pipe into GNSS-SDR
- Interprocess communication using ZeroMQ
- Has limitations compared to using other formats

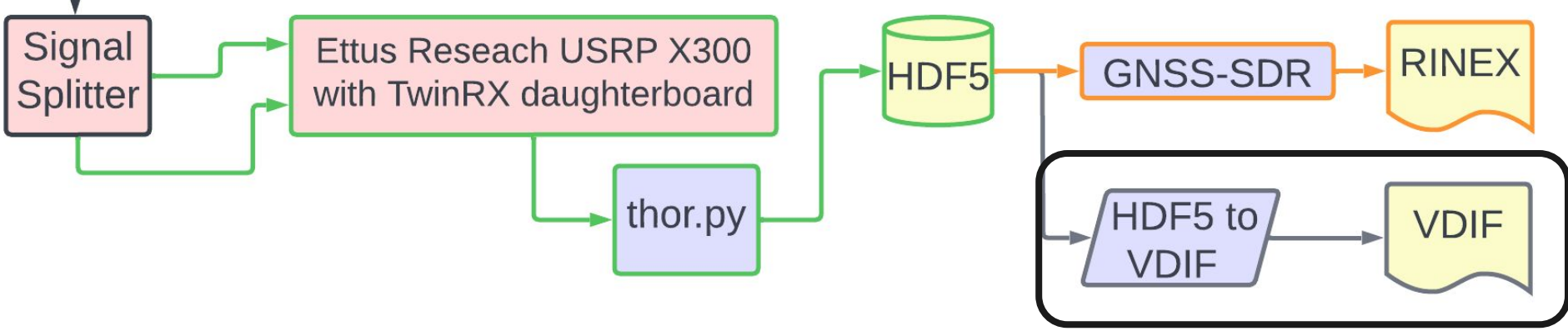
Project Flowgraph



- We have RINEX from hardware and software radio configs
- We will now convert recorded data into VDIF

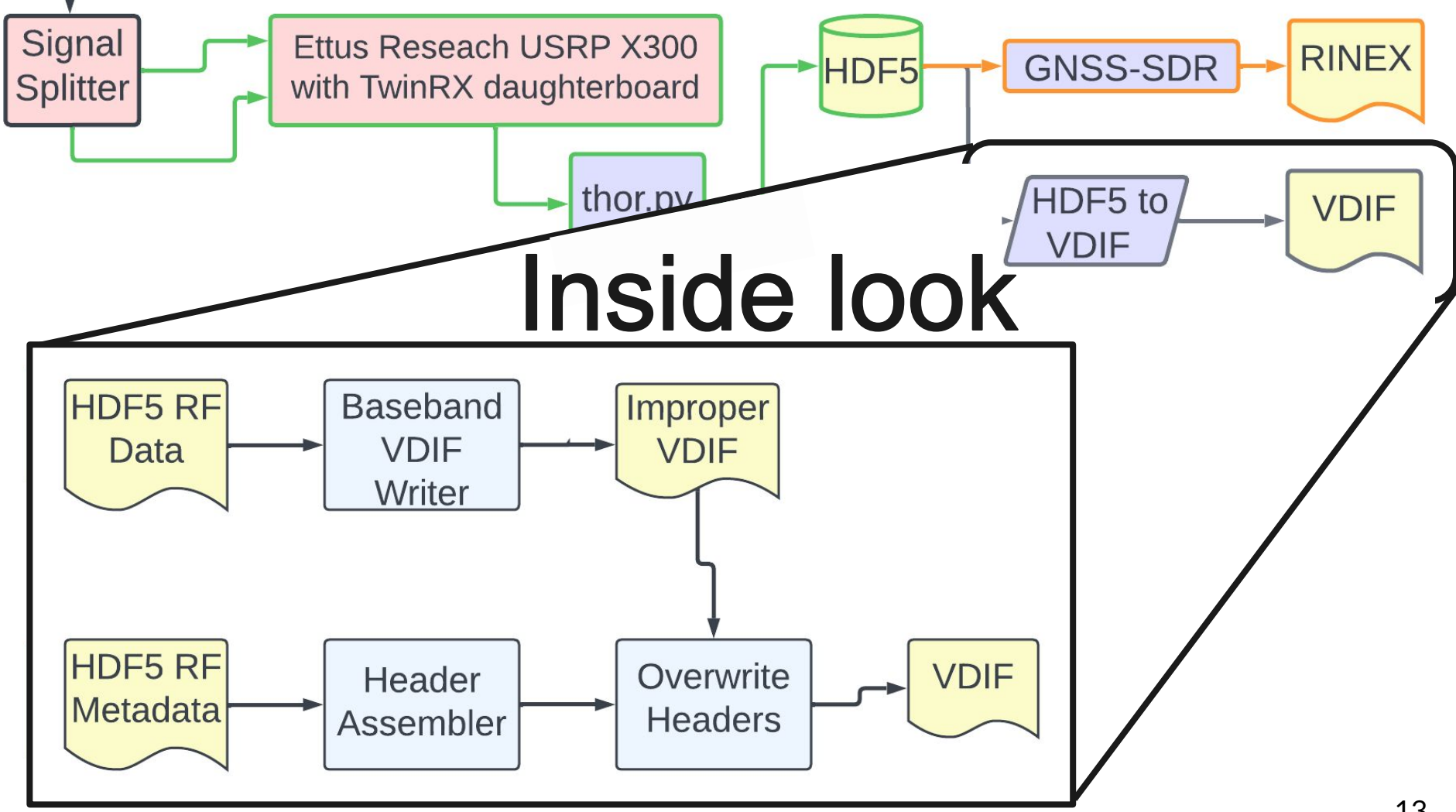


- VLBI Systems exchange data through packetized format
- VDIF: **V**LBI **D**ata **I**nterchange **F**ormat, has 32 byte headers and payload
- VDIF Headers have: Time of recording, data type, number of channels and threads, thread and station ID's

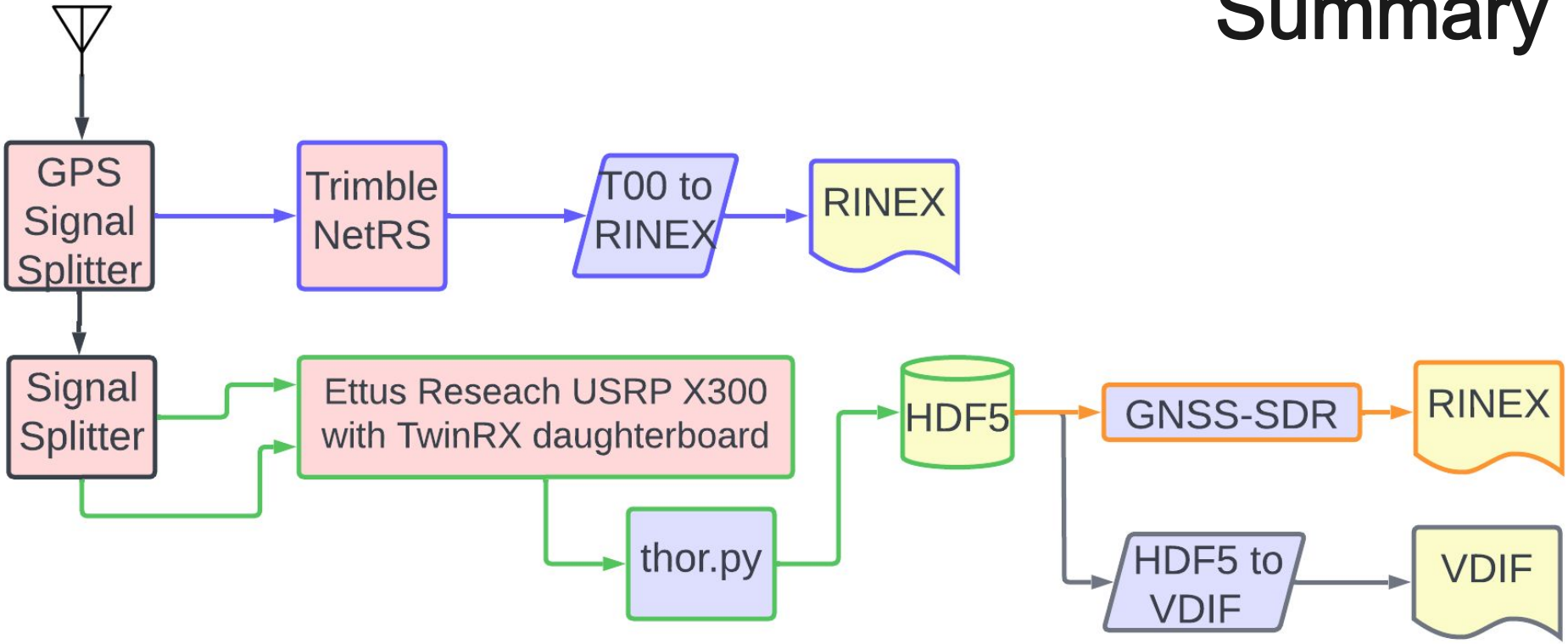


- Baseband Python library
  - Supports VDIF
  - Writes improper headers

- We want to include: Center frequency, sampling rate, bandwidth, etc, from metadata
- We will use Baseband to quantize RF data and do everything else ourselves.

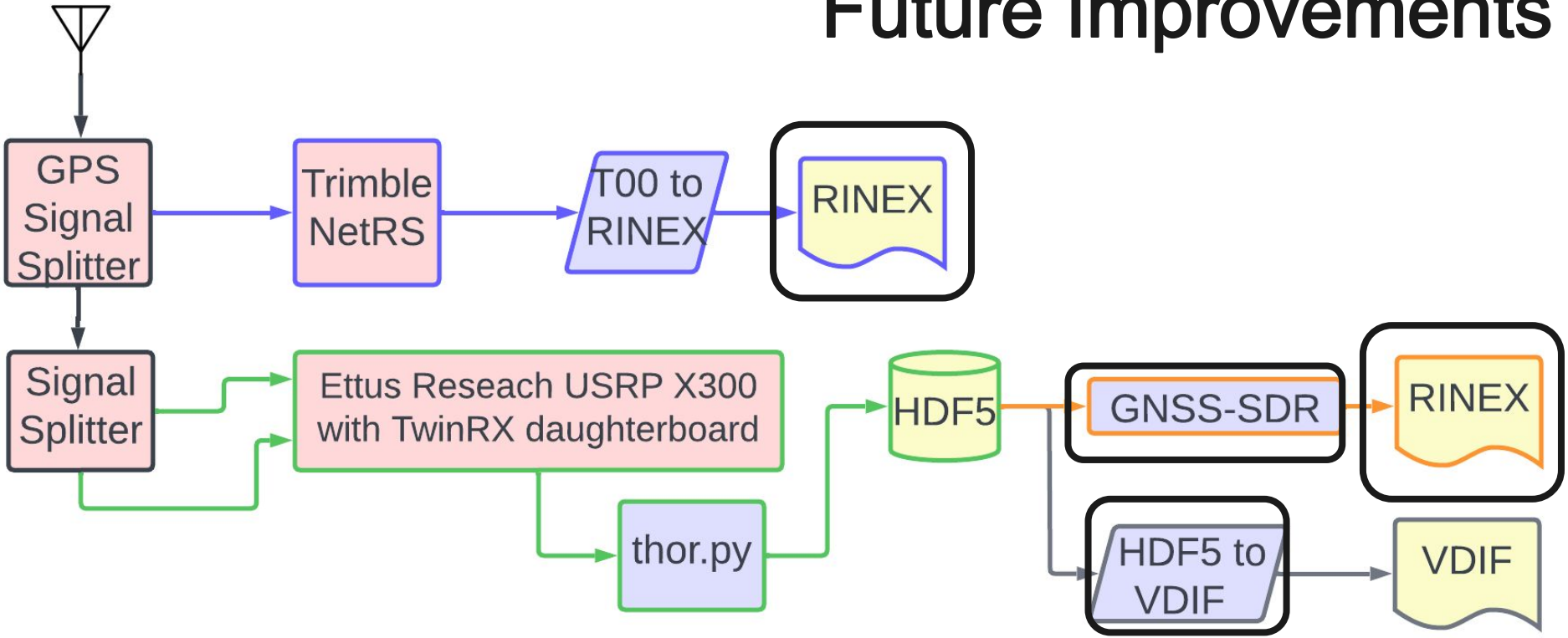

Signal Splitter
Ettus Reseach USRP X300 with TwinRX daughterboard
thor.py
HDF5
GNSS-SDR
RINEX
HDF5 to VDIF
VDIF
Inside look
HDF5 RF Data
Baseband VDIF Writer
Improper VDIF
HDF5 RF Metadata
Header Assembler
Overwrite Headers
VDIF

Summary



- Have hardware & software receiver stacks
- Recorded & processed GNSS data
- Verified & converted into VDIF format

Future Improvements



- More robust comparison for output RINEX files
- Working dual band GNSS-SDR configuration
- More robust VDIF converter program

Acknowledgments

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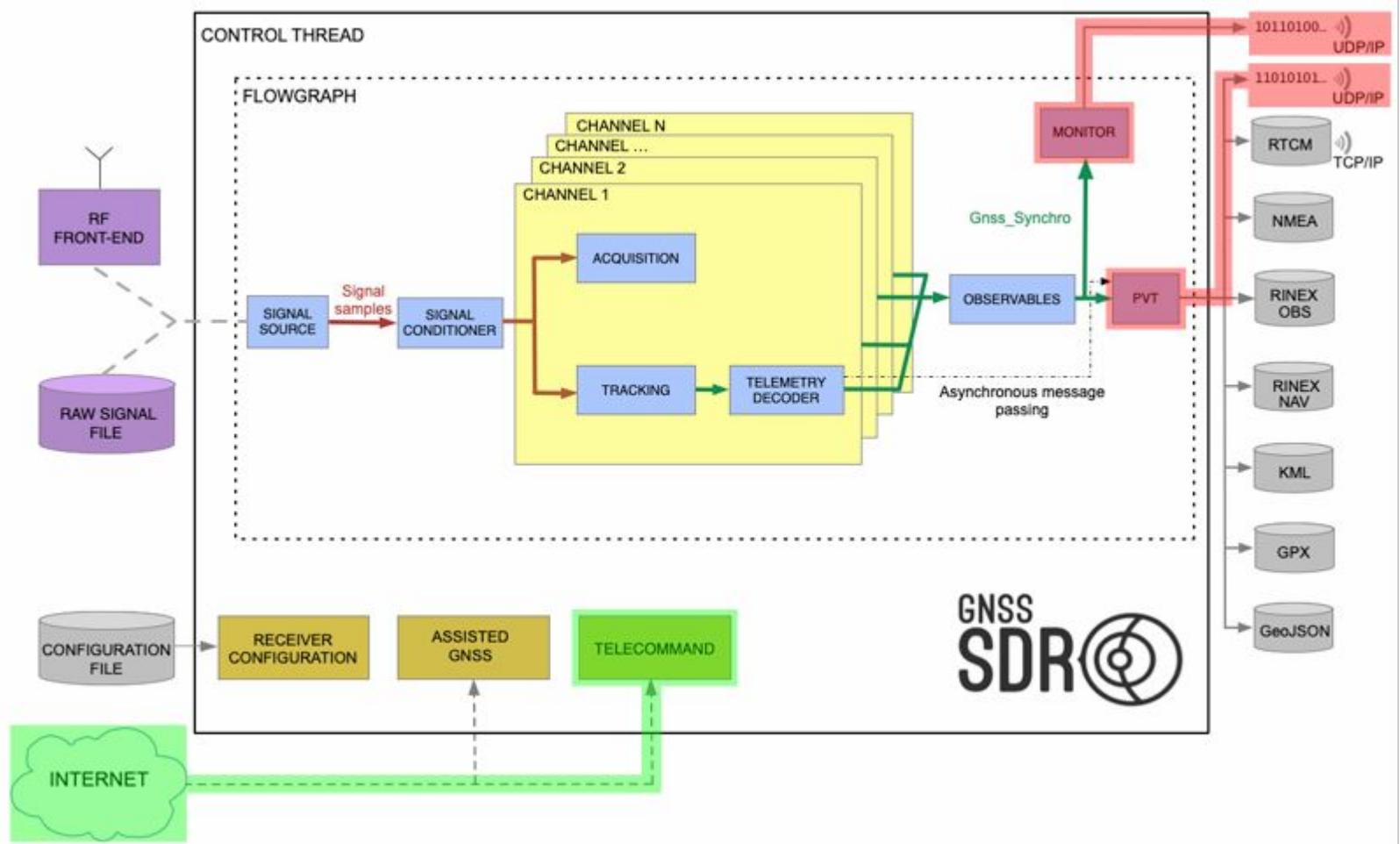
Questions?


CONTROL THREAD
FLOWGRAPH
CHANNEL N
CHANNEL ...
CHANNEL 2
CHANNEL 1
ACQUISITION
TRACKING
TELEMETRY DECODER
RF FRONT-END
RAW SIGNAL FILE
SIGNAL SOURCE
Signal samples
SIGNAL CONDITIONER
Gnss_Synchro
OBSERVABLES
PVT
MONITOR
Asynchronous message passing
10110100.. UDP/IP
11010101.. UDP/IP
RTCM TCP/IP
NMEA
RINEX OBS
RINEX NAV
KML
GPX
GeoJSON
CONFIGURATION FILE
RECEIVER CONFIGURATION
ASSISTED GNSS
TELECOMMAND
INTERNET
GNSS SDR

Challenges faced with GNSS-SDR

- It’s difficult to tell what exactly isn’t working when troubleshooting
  - Syntax error: Crash with limited details why
  - Configuration error: Shows no satellites or has poor performance
- GPS has a few radio bands, I wanted to record L1 and L2C:
  - L1: Most people use this band. It is the oldest.
  - L2C: Newer band with fewer users. In “preoperational” status
- Could not get GNSS-SDR to work with L2C band despite intensive troubleshooting. Unsure what the issue is.