Real Time RF Processing for Space-Based Analytics

EJ Kreinar
Senior Processing Engineer, Hawkeye 360

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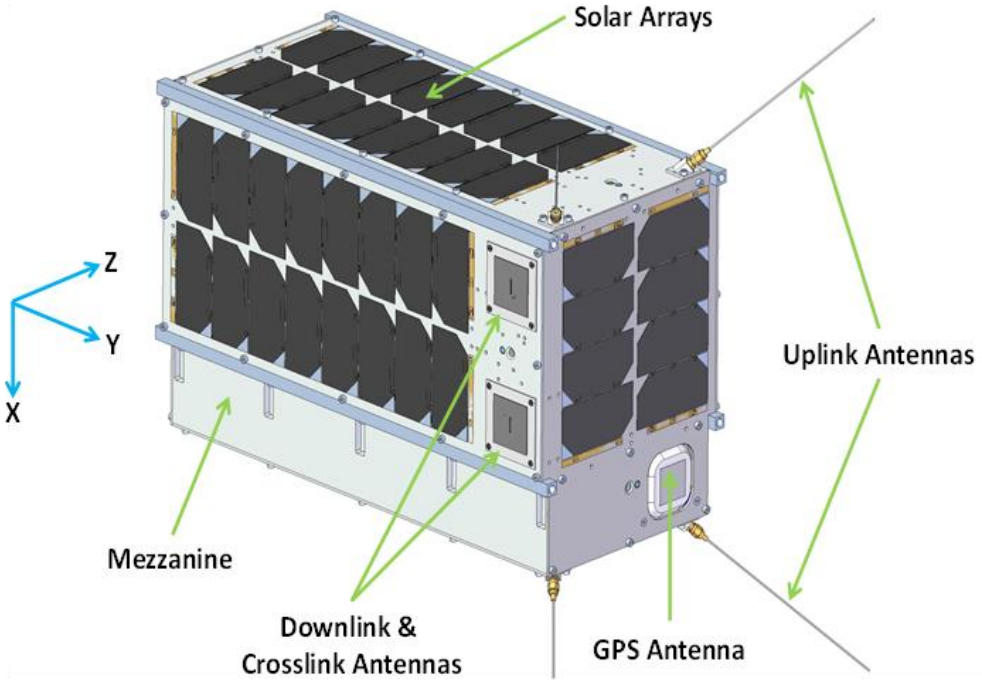
Hawkeye 360 Overview

- Venture-backed startup in Herndon, VA
- Technical Mission:
  - Launch a cluster of small satellites in Fall 2018
  - 3 satellites per cluster, flying in formation
  - Satellites in LEO (low earth orbit) in a polar orbit
  - Satellites share a common ground footprint and provide geometric diversity
  - Passively receive RF signals
  - Independently geolocate emitters from 100 MHz to 15 GHz ("DC to Daylight") using TDOA and FDOA measurements



Provide a new commercial data source for precise, global mapping of RF emissions

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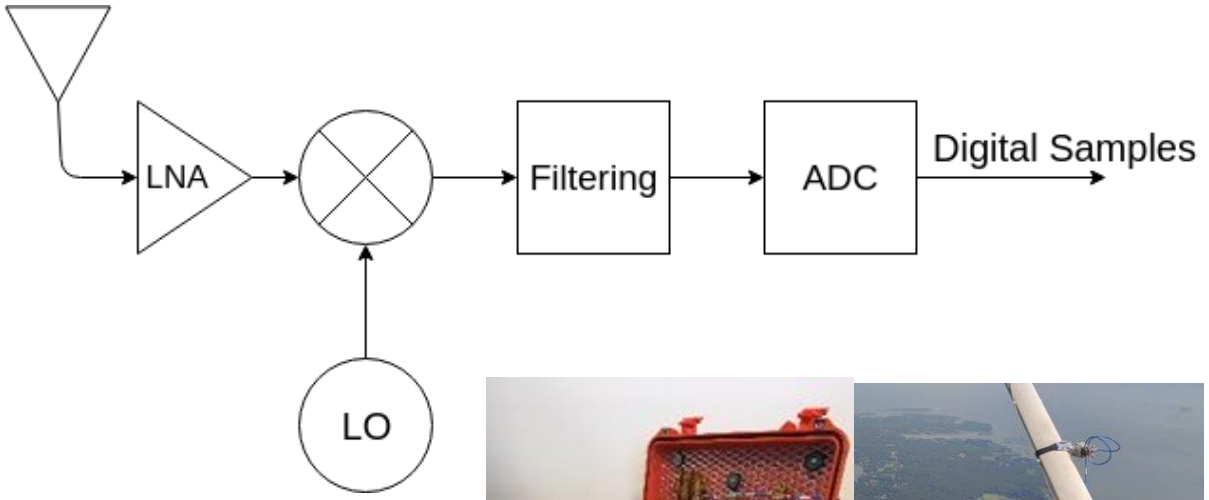
Software Defined Radio System

- Antenna(s) & frontend signal conditioning
- Analog to Digital Converter
- Baseband RF Processing: FPGA, Software
  - PC
  - Cloud
  - Spacecraft Payload!



Payload needs to 1) process onboard or
2) save/downlink data

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RF Processing Technical Challenges

Applications

- Communications systems
  - Transmit and receive data through an RF channel
- Measuring systems
  - GPS: Position/velocity/time estimation
  - Radar (pulsed, modulated)
- Signal detection and characterization
  - Modulation recognition

Limitations

- Hardware
  - Size, weight and power (SWAP)
  - Limited storage and downlink capability
- RF Tuning
  - When in time?
  - Where over the earth?
  - What frequency (100 MHz to 15 GHz)?

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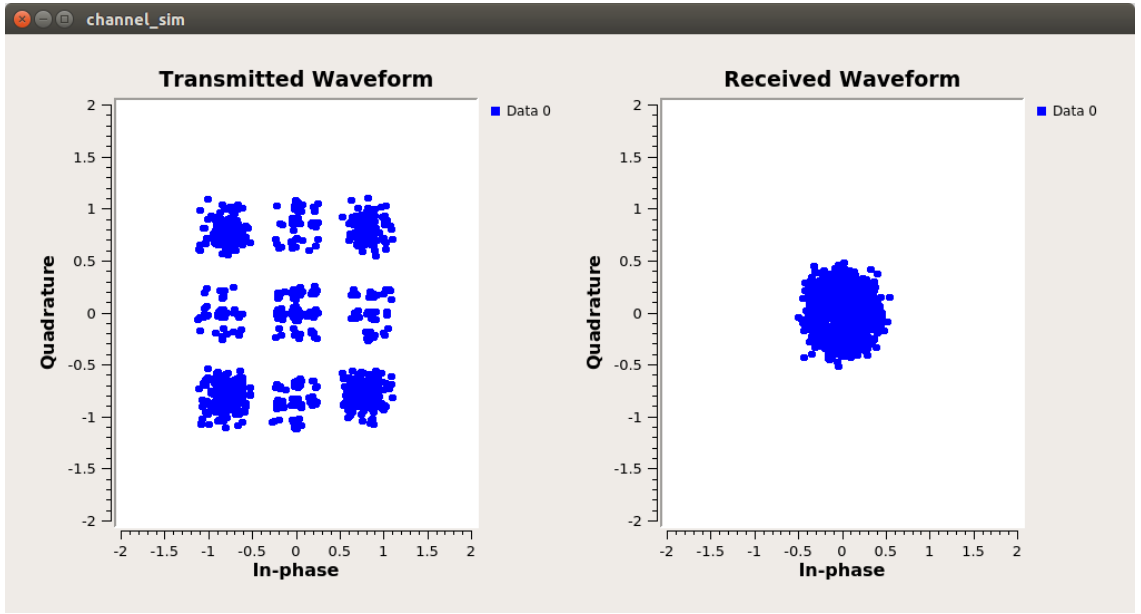
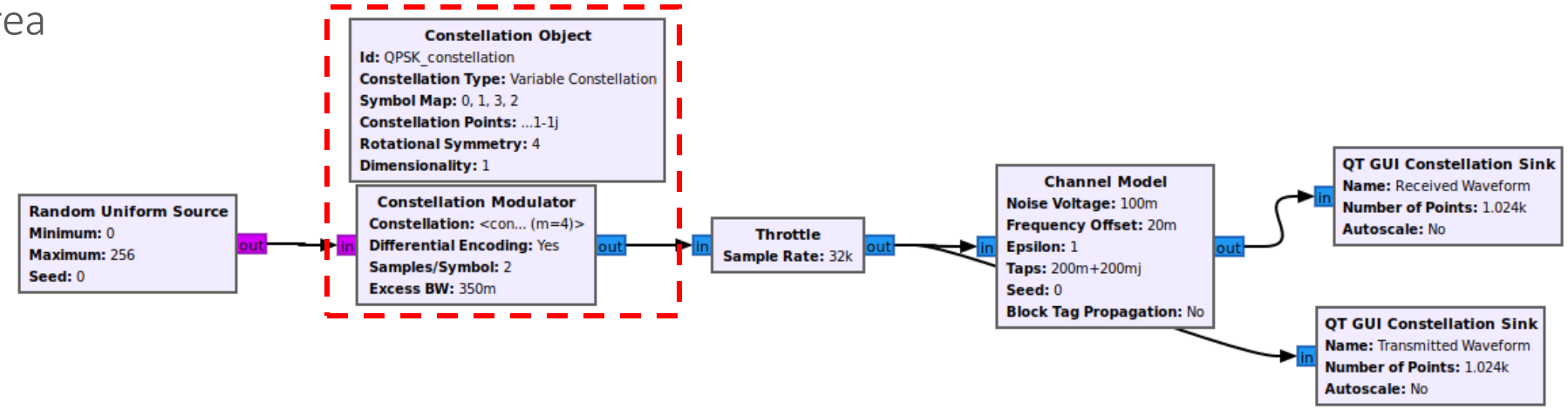
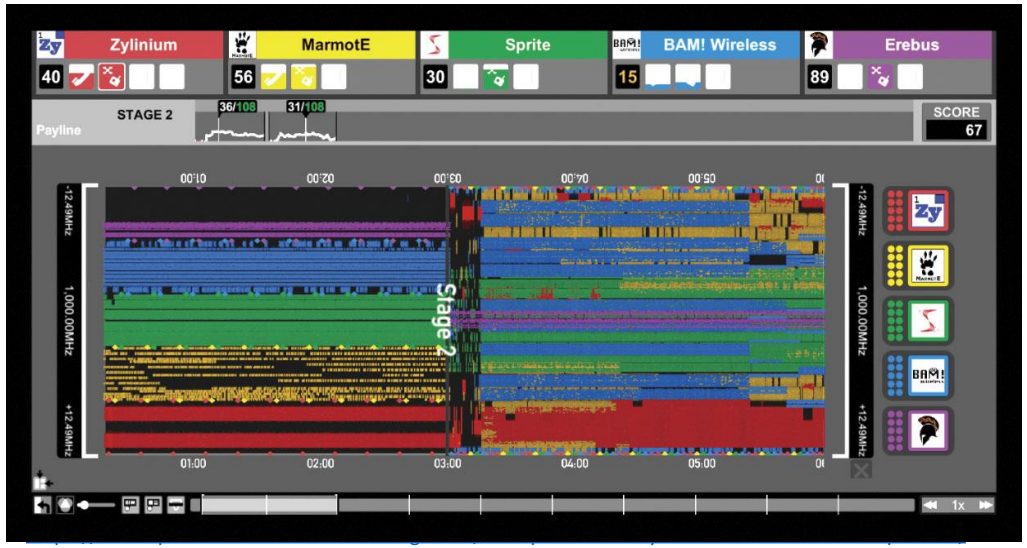
- **Goal**: Transmit and receive data through an RF channel
- Expert Solution:
  - Modulate onto the RF carrier
  - Remove channel effects
  - Perfectly reconstruct original dataset
- Learned Solutions:
  - Active research area



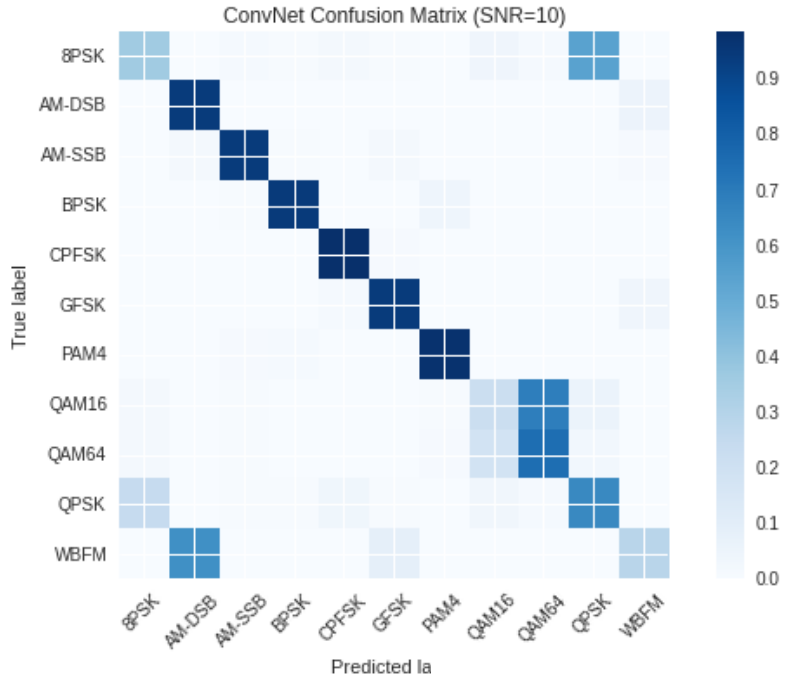


Modulation Recognition

- **Goal**: Detect and characterize received waveforms and modulation schemes
  - Amplitude Modulation, Frequency Modulation
  - Phase Shift Keying (PSK)
  - Orthogonal Frequency Division Multiplexing (OFDM)
  - LTE, or other standards



- Learned Solutions:
  - Classification problem
  - (Legacy) Use expert derived features
  - (More recently) Input raw data or spectrogram

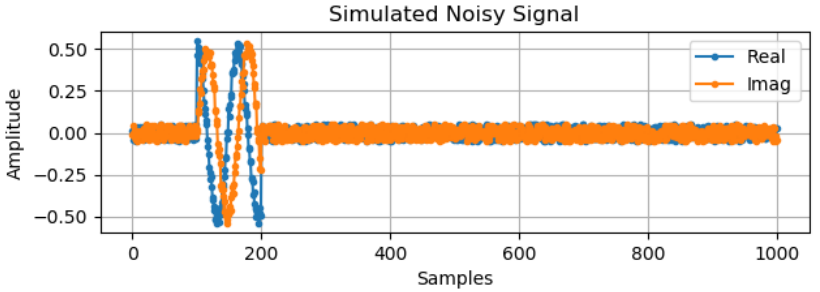


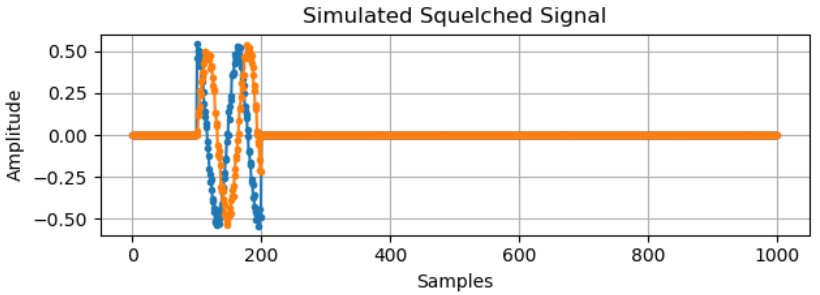
https://github.com/ejk43/examples/blob/master/modulation_recognition/RML2016.10a_VTCNN2_example.ipynb

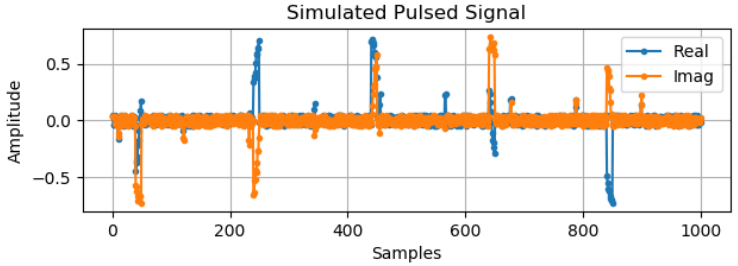
[1] O'Shea, Timothy J and Corgan, Johnathan and Clancy, T. Charles, "Convolutional Radio Modulation Recognition Networks", arXiv preprint arXiv:1602.04105, 2016
[2] O'Shea, Timothy J and West, Nathan, "Radio Machine Learning Dataset Generation with GNU Radio", Proceedings of the 6th GNU Radio Conference, 2016

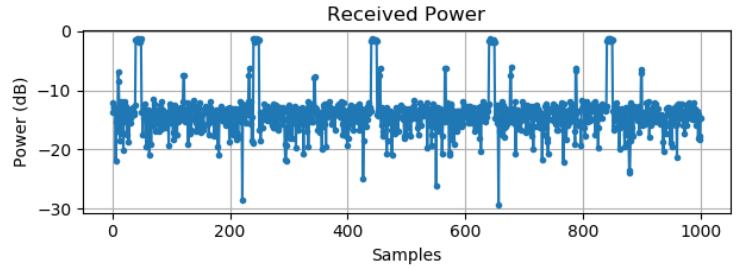
Energy / Pulse Detection

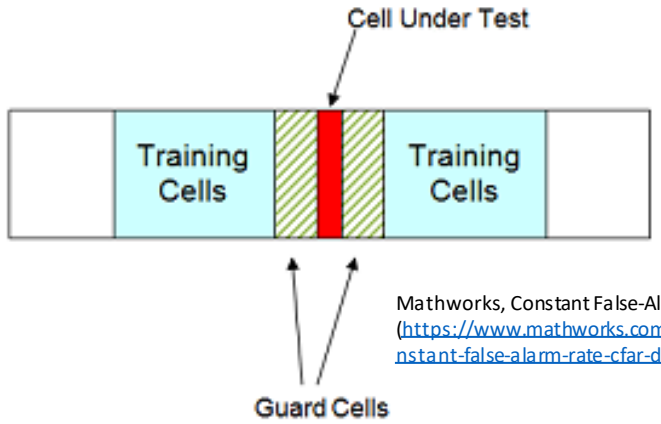
- **Goal:** Trigger and extract "relevant" RF data out of wideband digital captures
- Expert Solutions:
  - Squelch filters
  - Constant false alarm rate (CFAR) filters
- Learned Solutions:
  - Unknown! -- potentially a new area of research











Mathworks, Constant False-Alarm Rate Detectors (https://www.mathworks.com/help/phased/ug/constant-false-alarm-rate-cfar-detectors.html)

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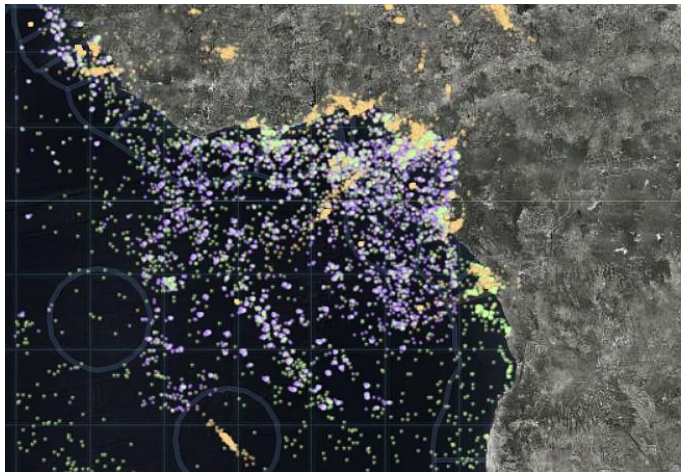
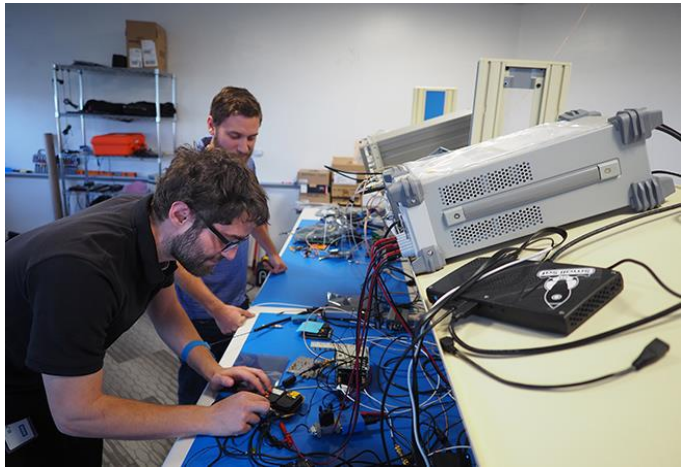
Summary

- Legacy, "expert" algorithms are commonly deployed onto FPGA fabric and embedded processors for real-time processing
- We see many potential improvements in both quality and efficiency by training and deploying machine learning solutions in future work





Happy to collaborate on solutions that can impact both problem-sets!

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Thank You!

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