Event-Driven Data Acquisition System (EDAS)

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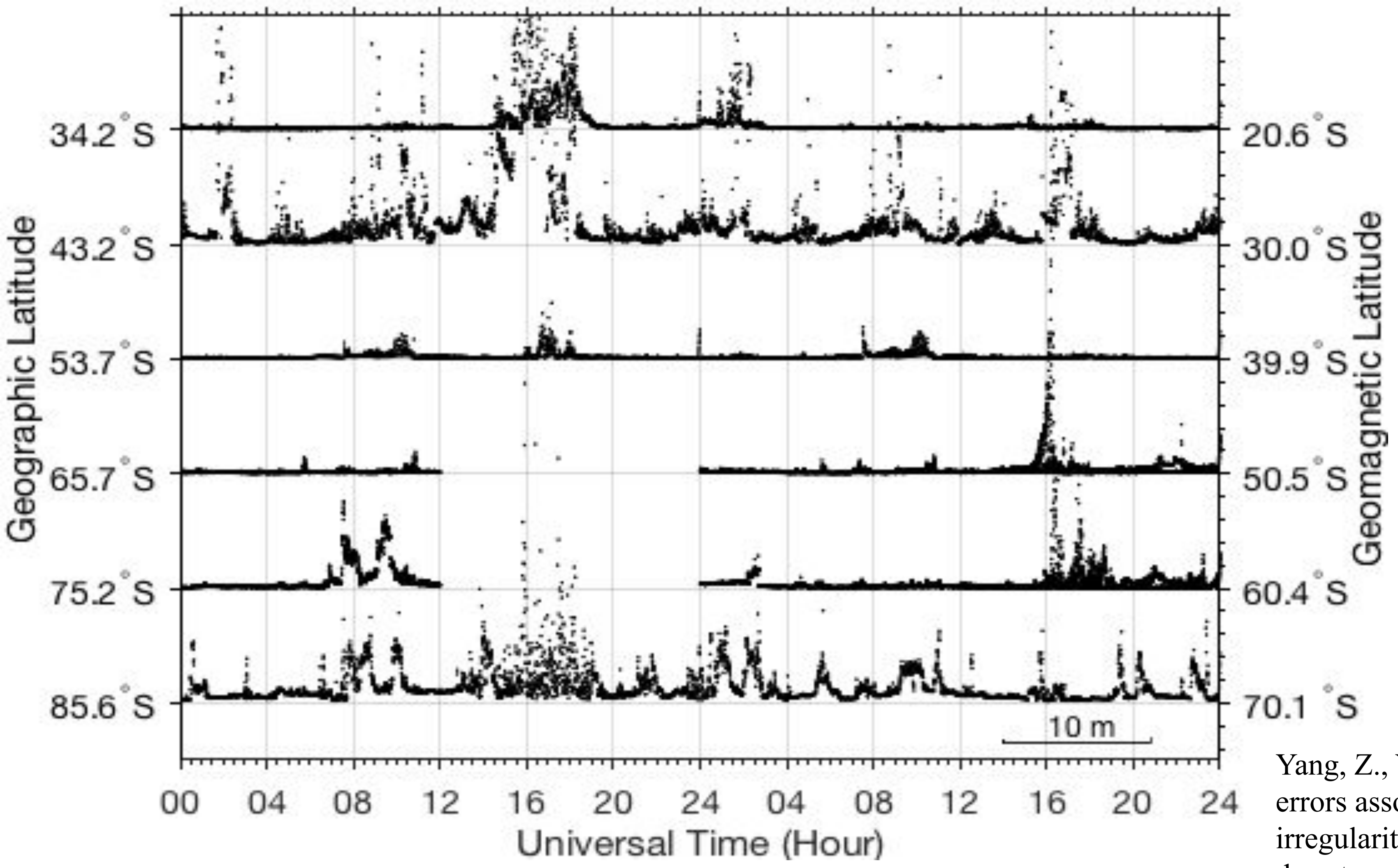
JRO 60th Anniversary Workshop

Steve Taylor and Harrison Bourne

Outline

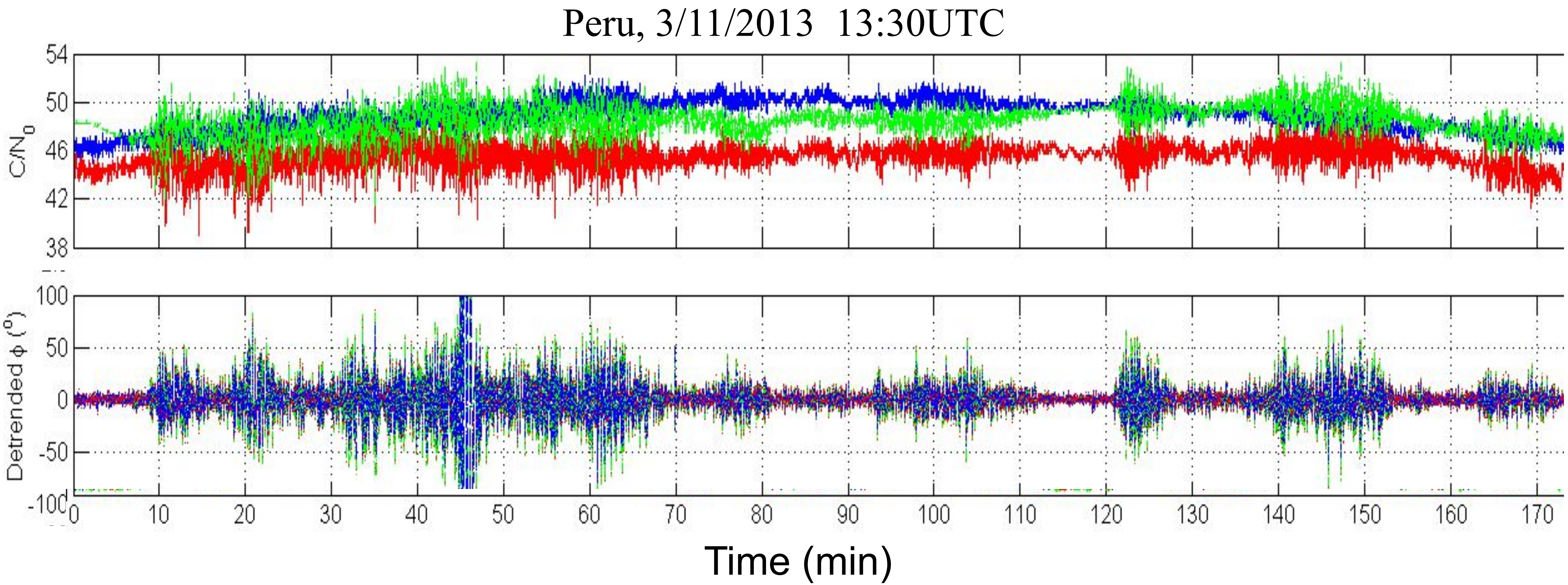
1. Background and Motivation
2. Hardware and Software
3. Application Highlights

Position Error: March 17-18, 2015 St. Patrick's Day storm



Yang, Z., Y. Morton, "Kinematic PPP errors associated with ionospheric plasma irregularities during the 2015 St. Patrick's day storm," *Proc. ION GNSS+*, 2019.

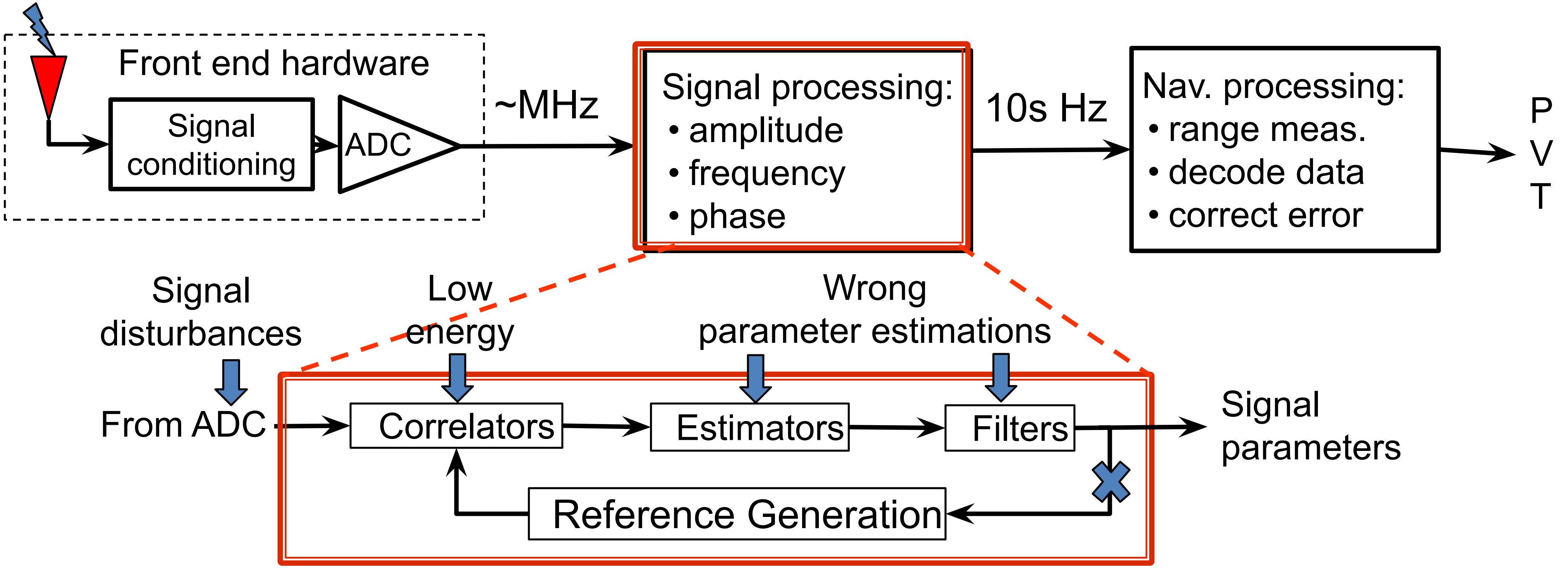
GNSS Signal Amplitude and Phase Disturbances



Commercial GNSS Scintillation Receiver Challenges

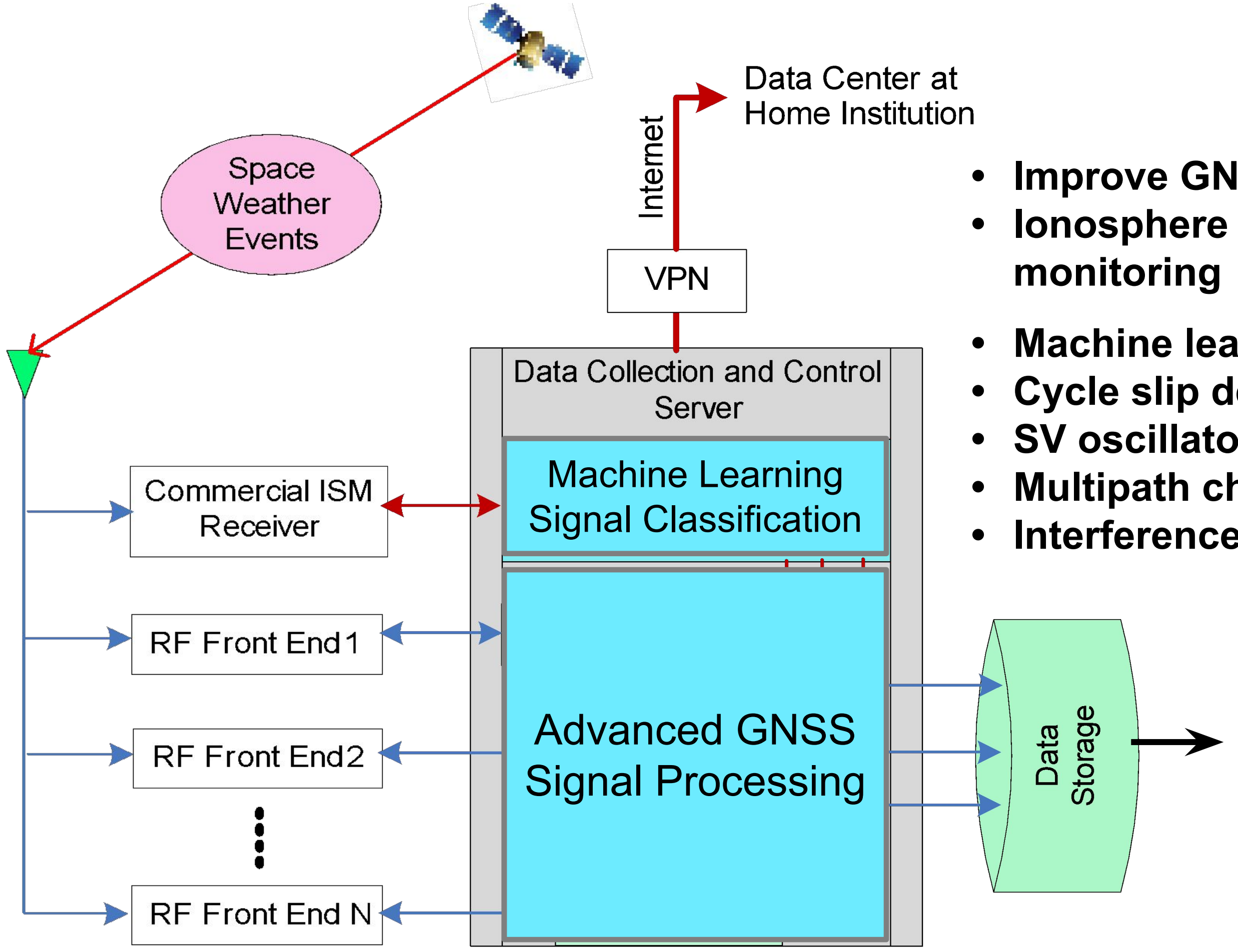
- **Availability**
  - During strong scintillation, receivers loss lock data is not available when needed
- **Accuracy**
  - Scintillation is a nuisance factor GNSS receivers are optimized to filter out ionospheric disturbance effects

A More Intuitive Way to Understand Why GNSS Receivers Lose Lock



Q: Where Do We Get the "Raw" Data?

Event-driven
Data
Acquisition
System



- **Improve GNSS Receivers**
- **Ionosphere and space weather monitoring**

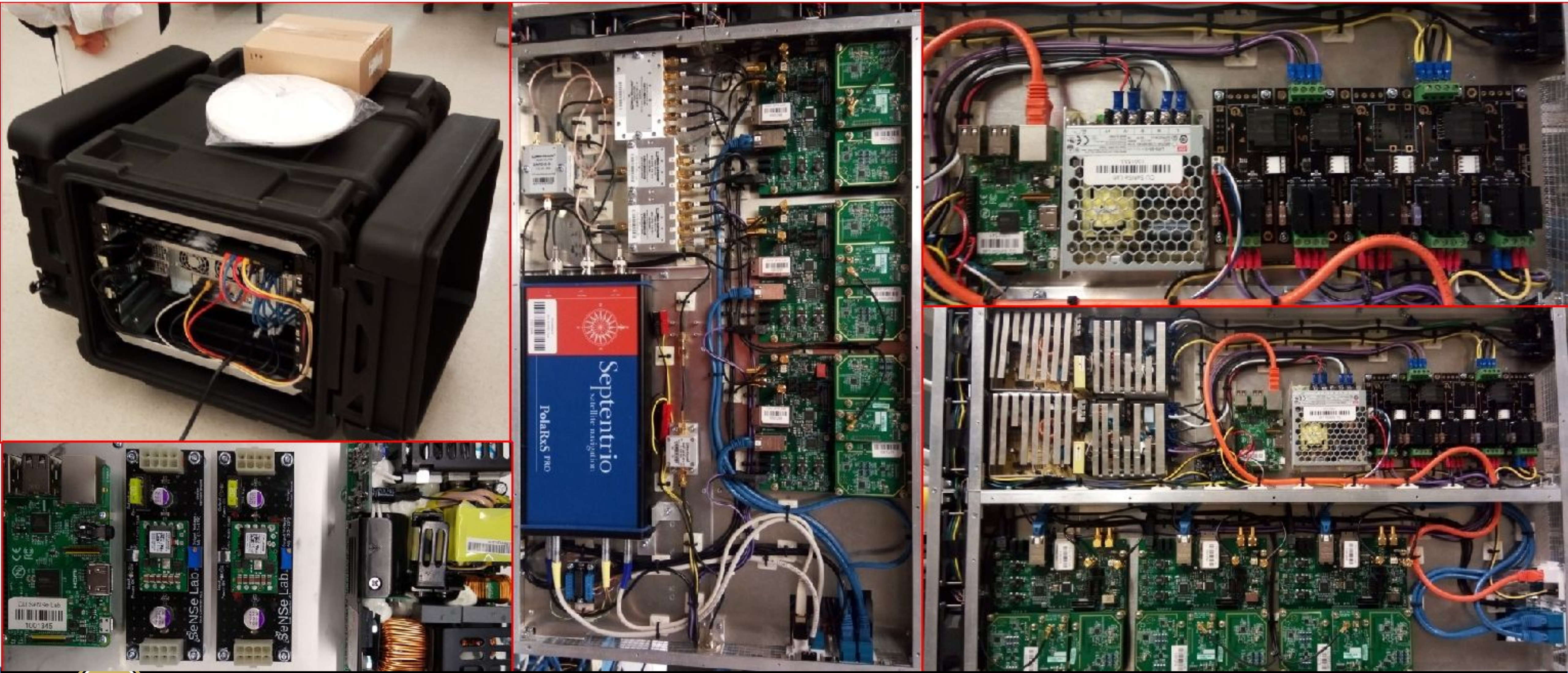
- **Machine learning**
- **Cycle slip detection/mitigation**
- **SV oscillator anomaly detection**
- **Multipath characterization**
- **Interference monitoring**

Receiver Signal Processing Algorithm Library

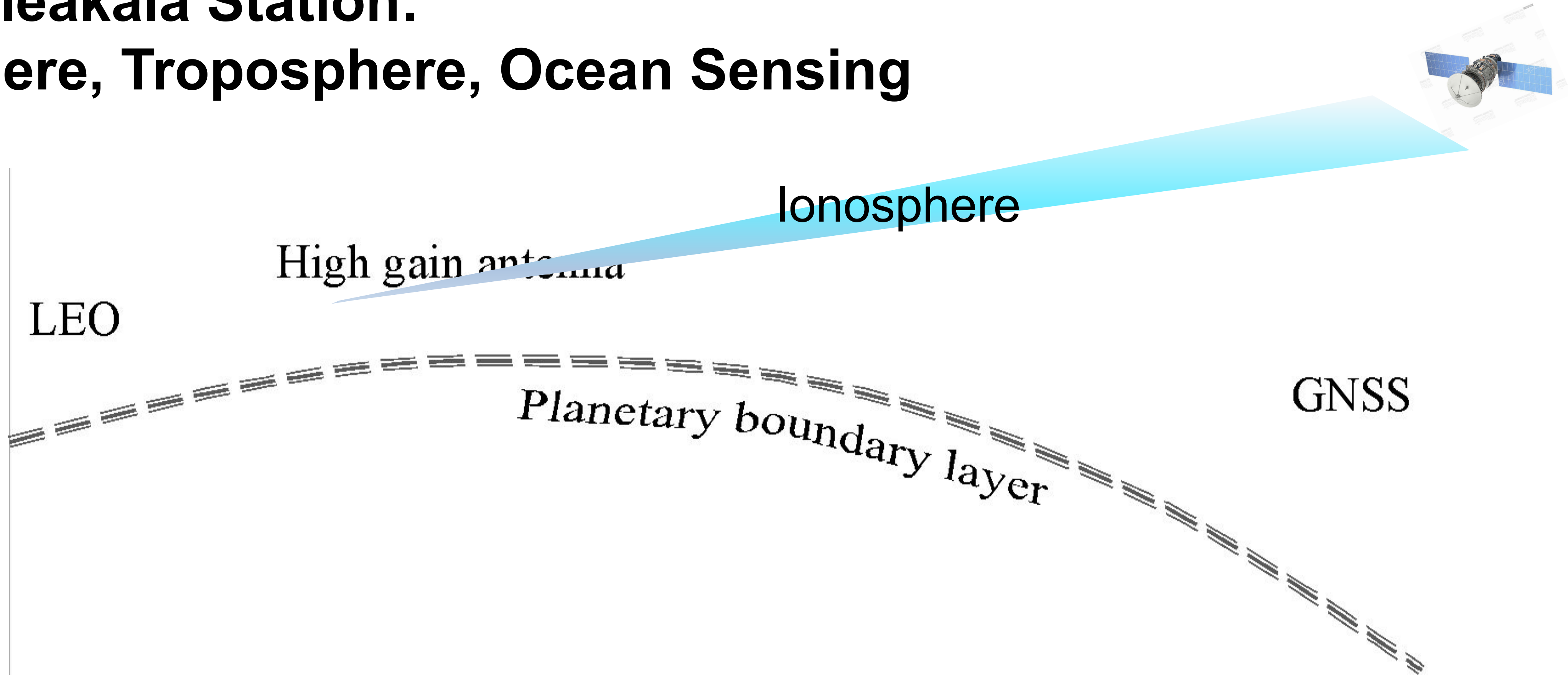
Early Data Acquisition System at JRO

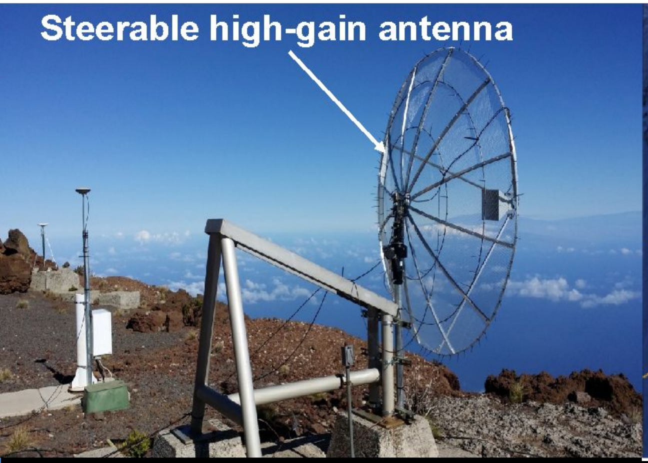
EDAS: Event-driven Data Acquisition System

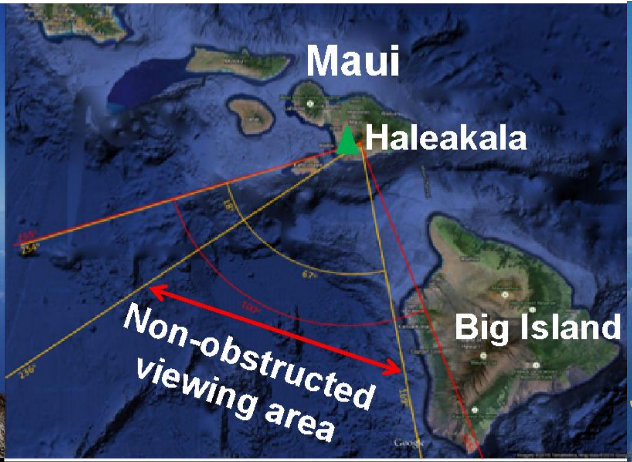
Event-Driven Data Acquisition System (EDAS)

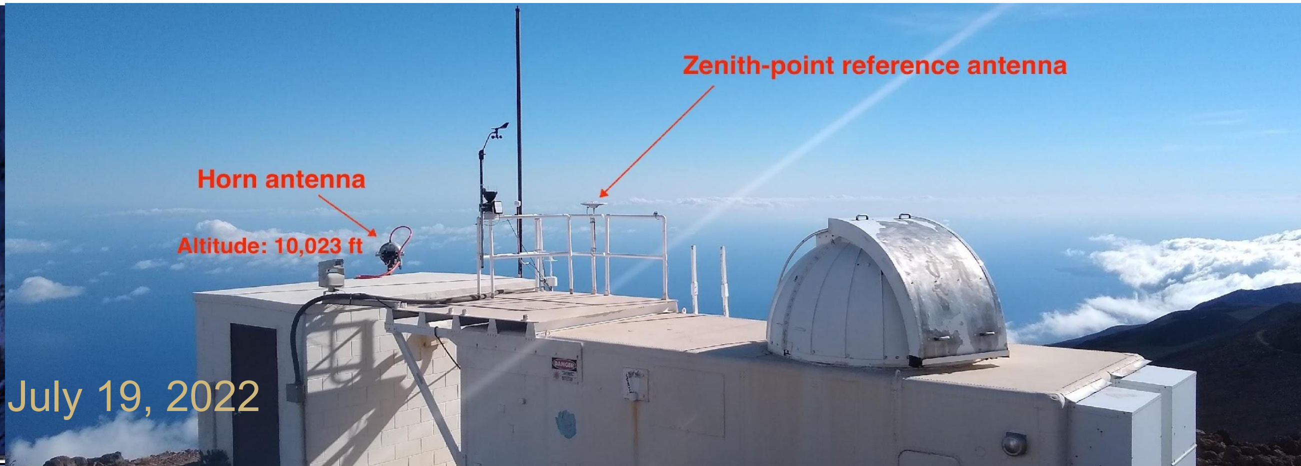


Maui Haleakala Station:
Ionosphere, Troposphere, Ocean Sensing

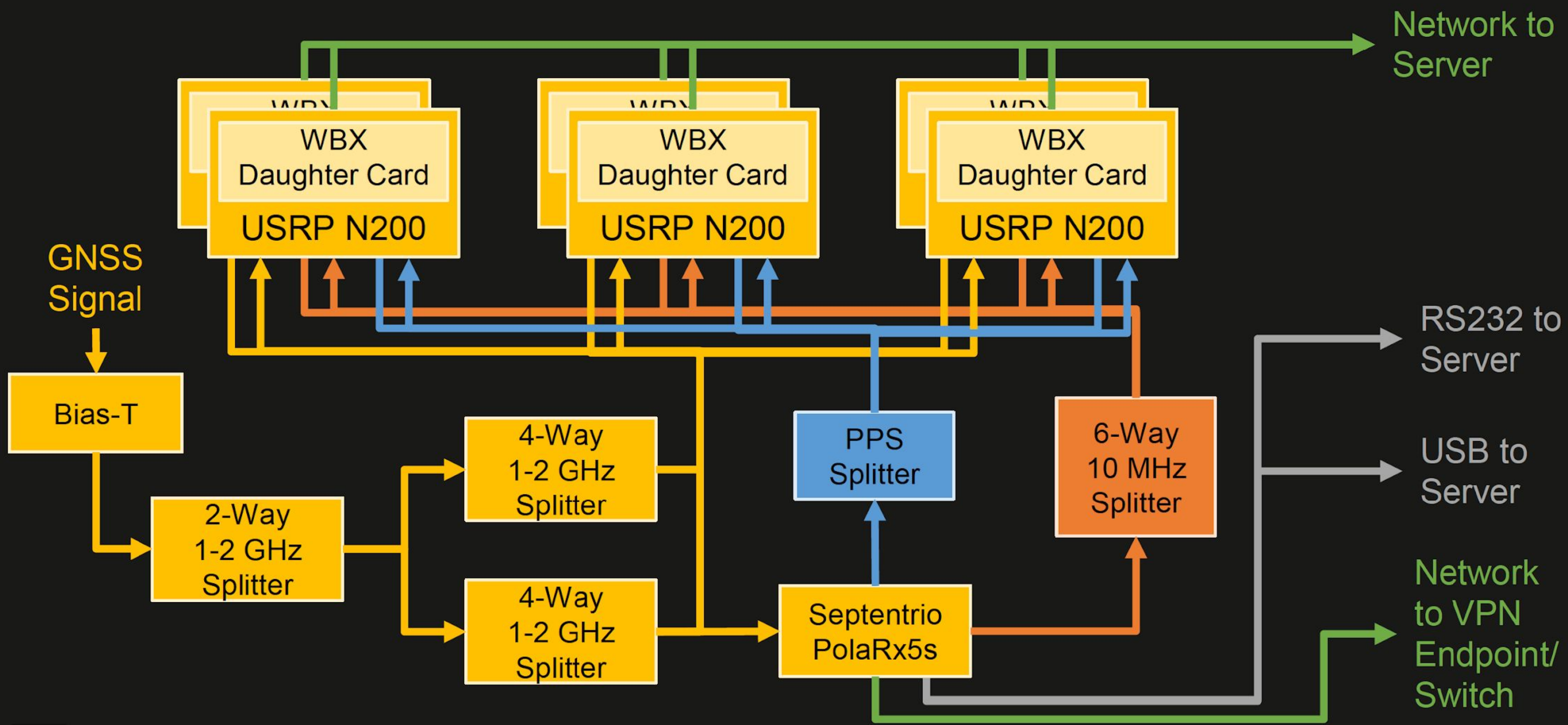




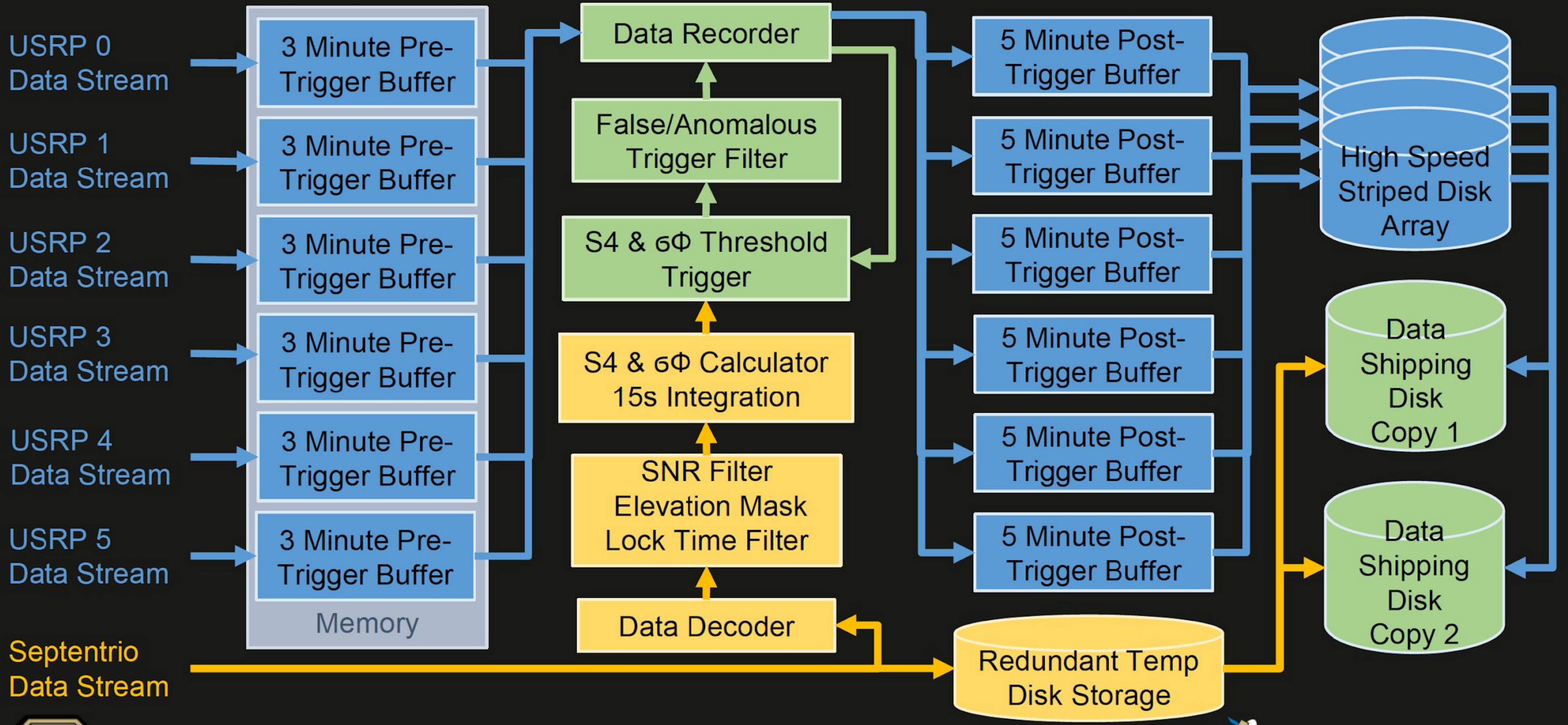




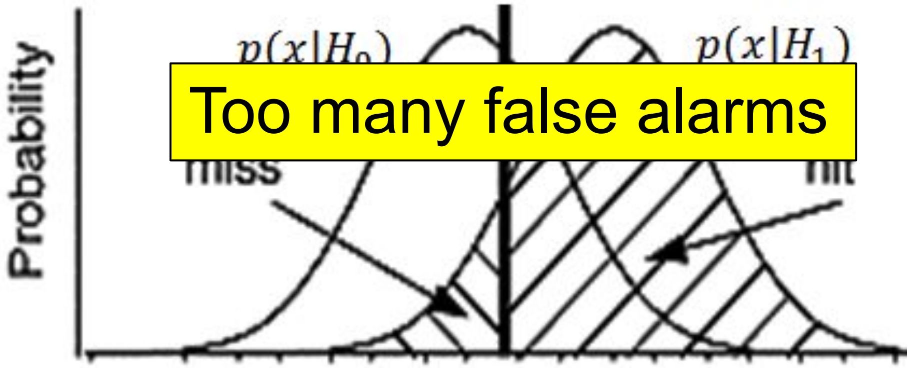
EDAS: RF Hardware Diagram



EDAS: Software Block Diagram



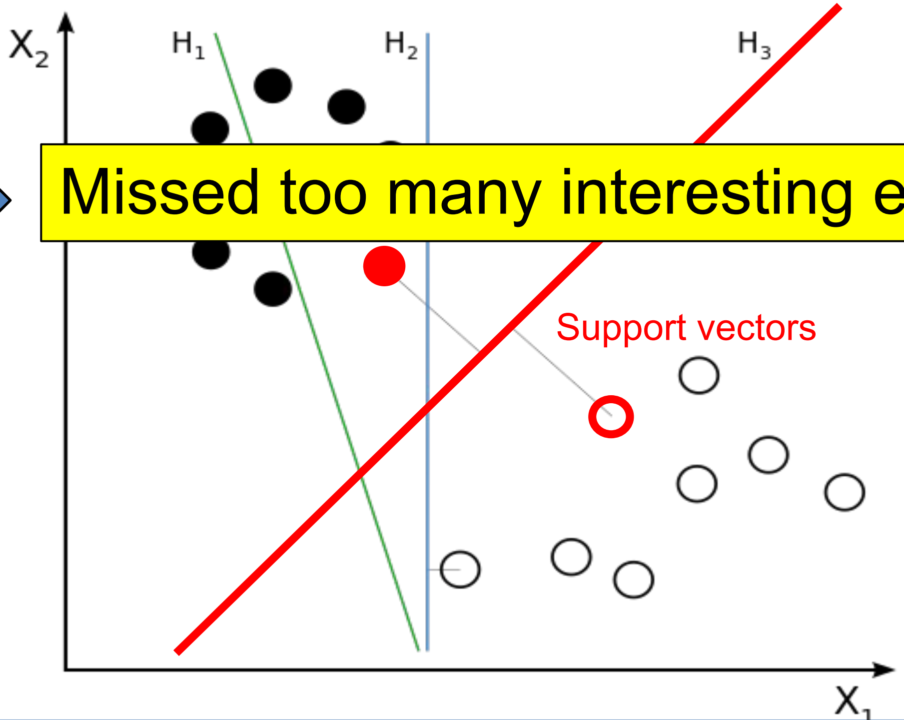
Evolution of Event Trigger Designs



Too many false alarms

Neyman-Pearson (NP)

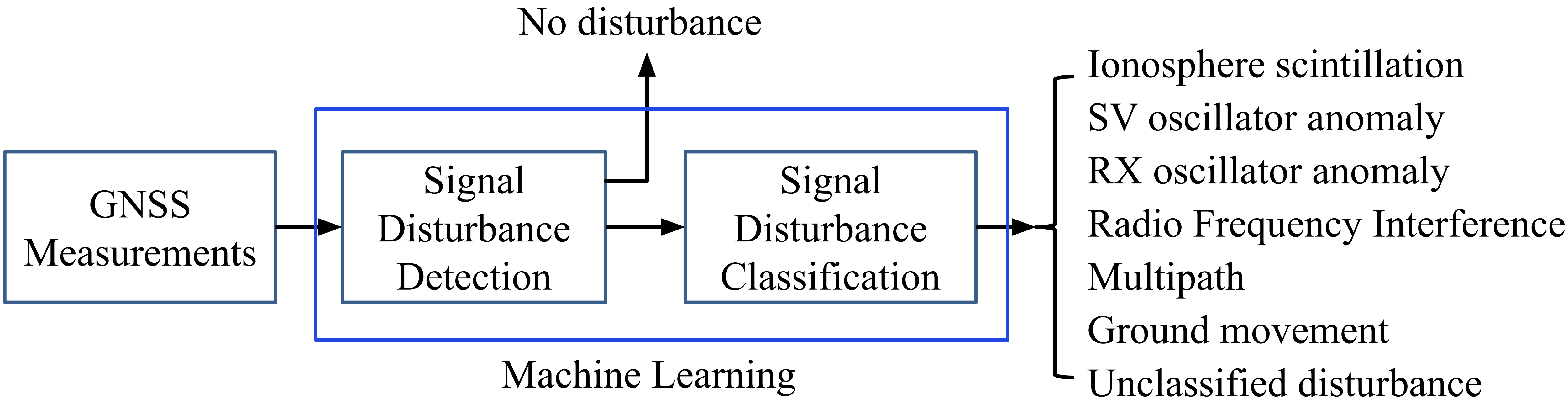
Support Vector Machine



Missed too many interesting events

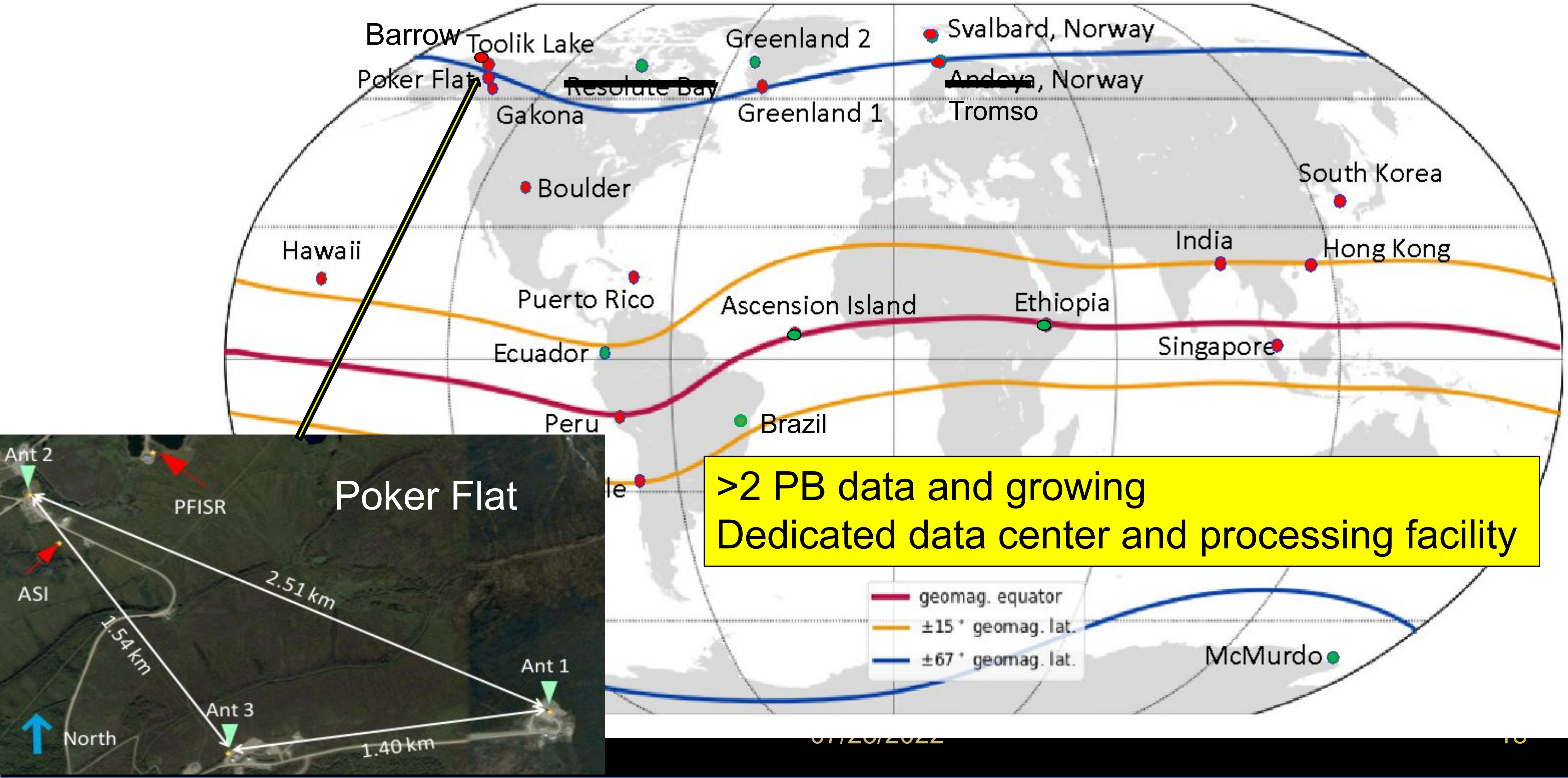
- Y. Jiao, J. Hall, Y. Morton, “Automatic equatorial GPS **amplitude scintillation** using machine learning”, *IEEE Trans. Aero. Elec. Sys.*, TAES-201600484, 2016
- Y. Jiao, J. Hall, Y. Morton, “Performance evaluation of an automatic GPS ionospheric **phase scintillation** detector using a machine learning algorithm,” *Navigation,* DOI:10.1002/navi.188, 2017.

ML for GNSS Signal Disturbance Classification



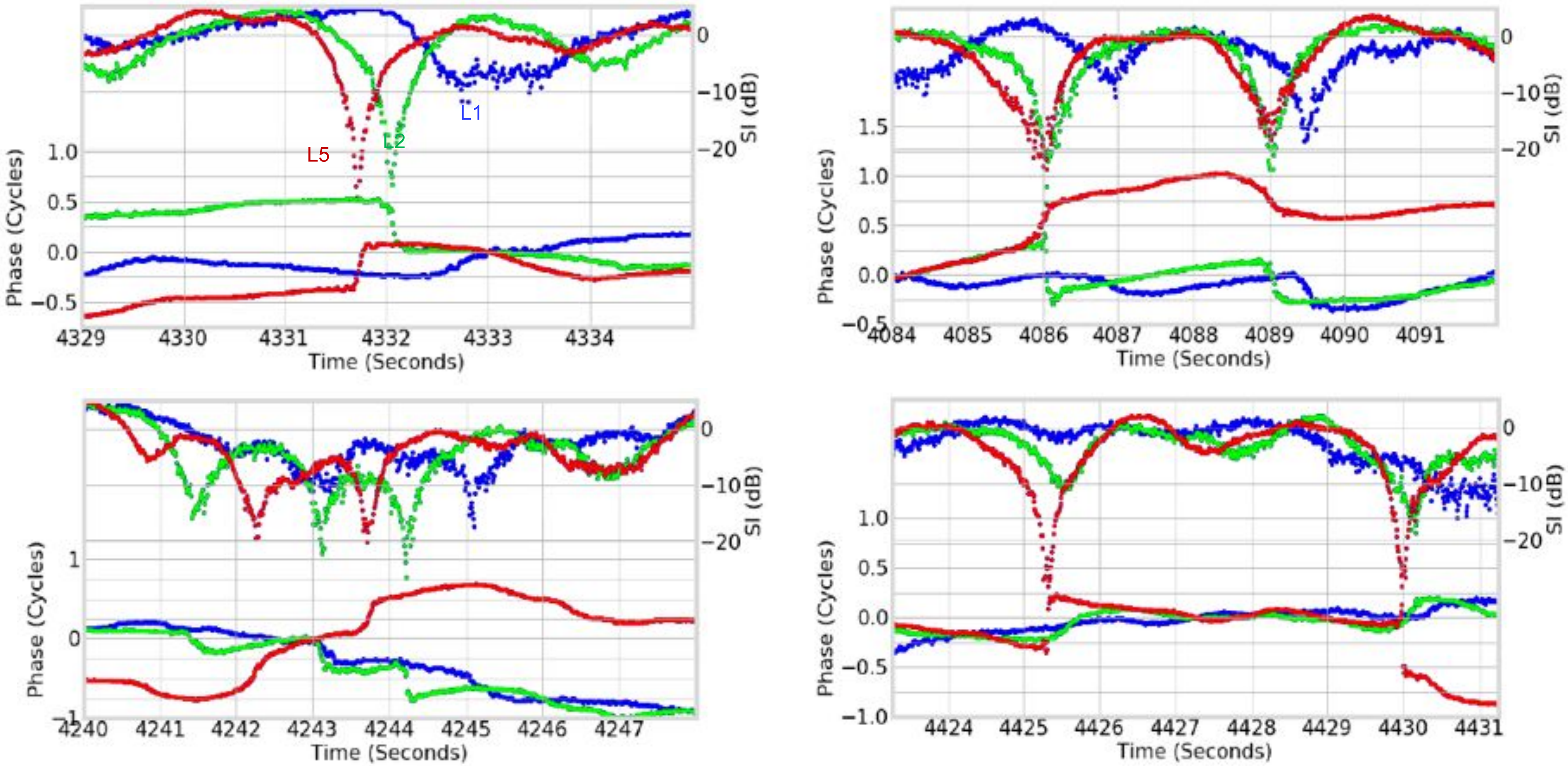
- ML architecture
- Feature engineering
- Feature importance
- Validation

Global SDR Data Collection Network

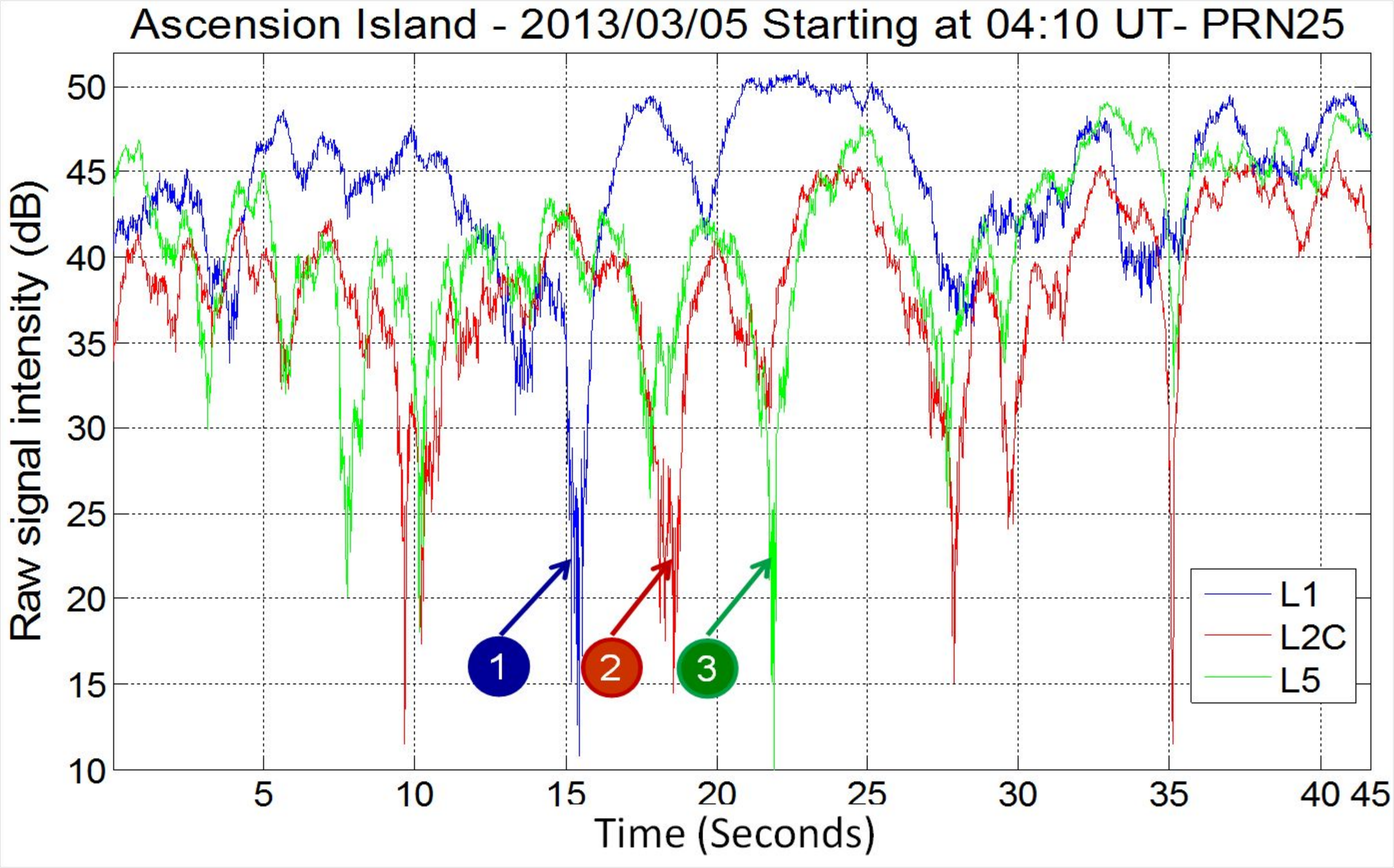


>2 PB data and growing
Dedicated data center and processing facility

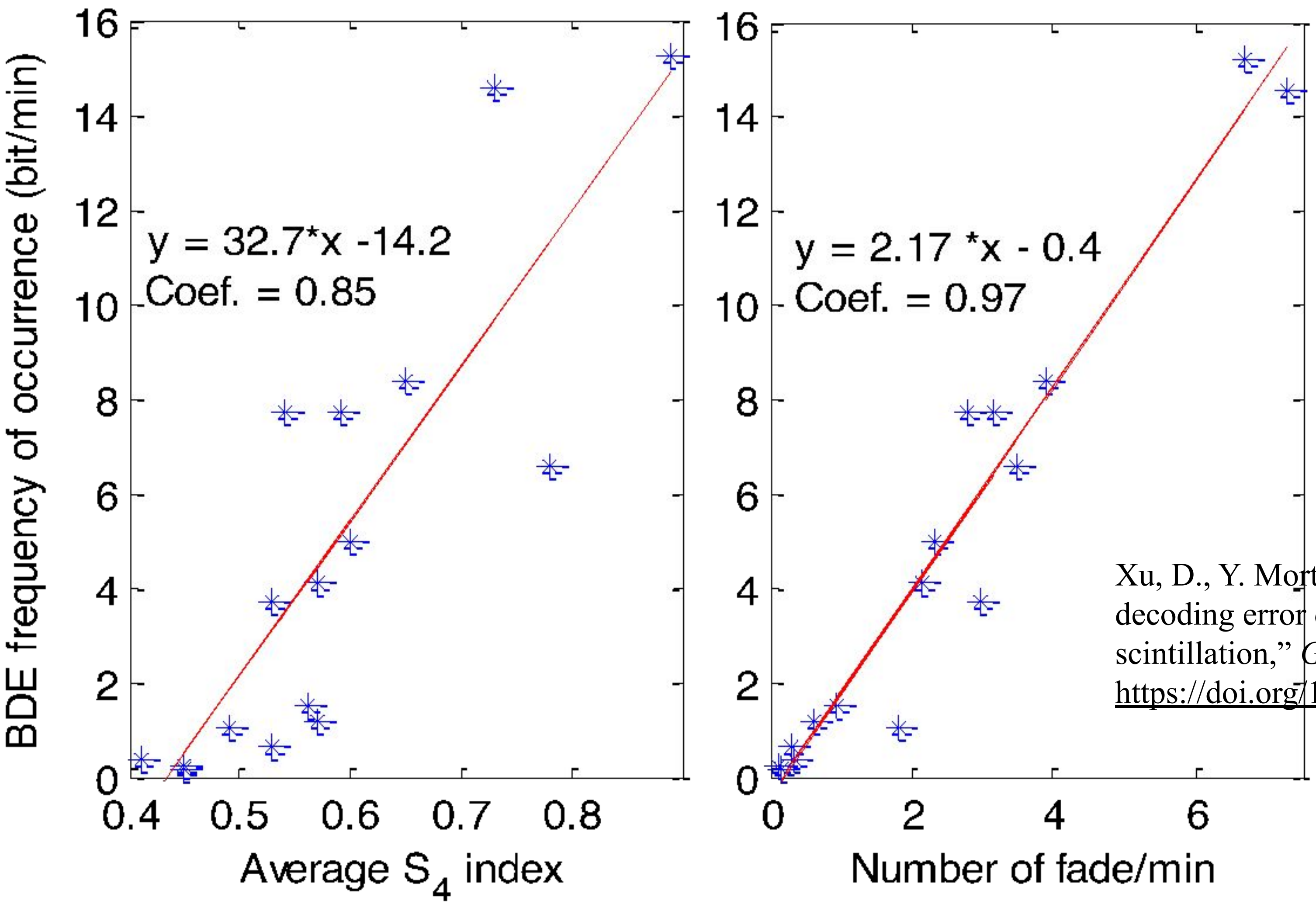
Simultaneous Amplitude Fading and Phase Jump



Frequency Diversity: Selective Fading



Navigation Data Bit Error Rate



Xu, D., Y. Morton, "GPS navigation data bit decoding error during strong equatorial scintillation," *GPS Solu.*, 22: 110, https://doi.org/10.1007/s10291-018-0775-1, 201

Multi-Domain GNSS Receiver Processing

- Adaptive tracking → Parameter optimization
- Multi-carrier tracking → Frequency diversity
- Vector processing → Signal spatial diversity
- Semi-open loop → Temporal diversity
- Open loop → Models
- Adaptive hybrid tracking → Models + parameter optimization

Conclusions

- EDAS: reconfigurable, baseband sampling across all GNSS signals
- Nearly 10 versions of EDAS developed/deployed in the past decade
- Lead to robust GNSS receiver algorithms development and massive amount of ionospheric scintillation data that were otherwise unavailable.
- Lead to next generation GNSS receivers for other applications such as GNSS reflectometry and navigation in urban environments.

Thank You

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DARPA grant # DI 9AC00009, AFOSR grant # FA9550-19-1-0226,

AFRL grant # FA8650-14-1735, and NSF grant # AGS-1428042

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Conclusions

- ML can be powerful tools for event detection, forecasting, and information retrieval from data
- Understanding the science is essential for designing good features
- Test, question, and validate ML outcome!