Using NASA's TriG Instrument for Space Weather, Weather and Climate

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA USA

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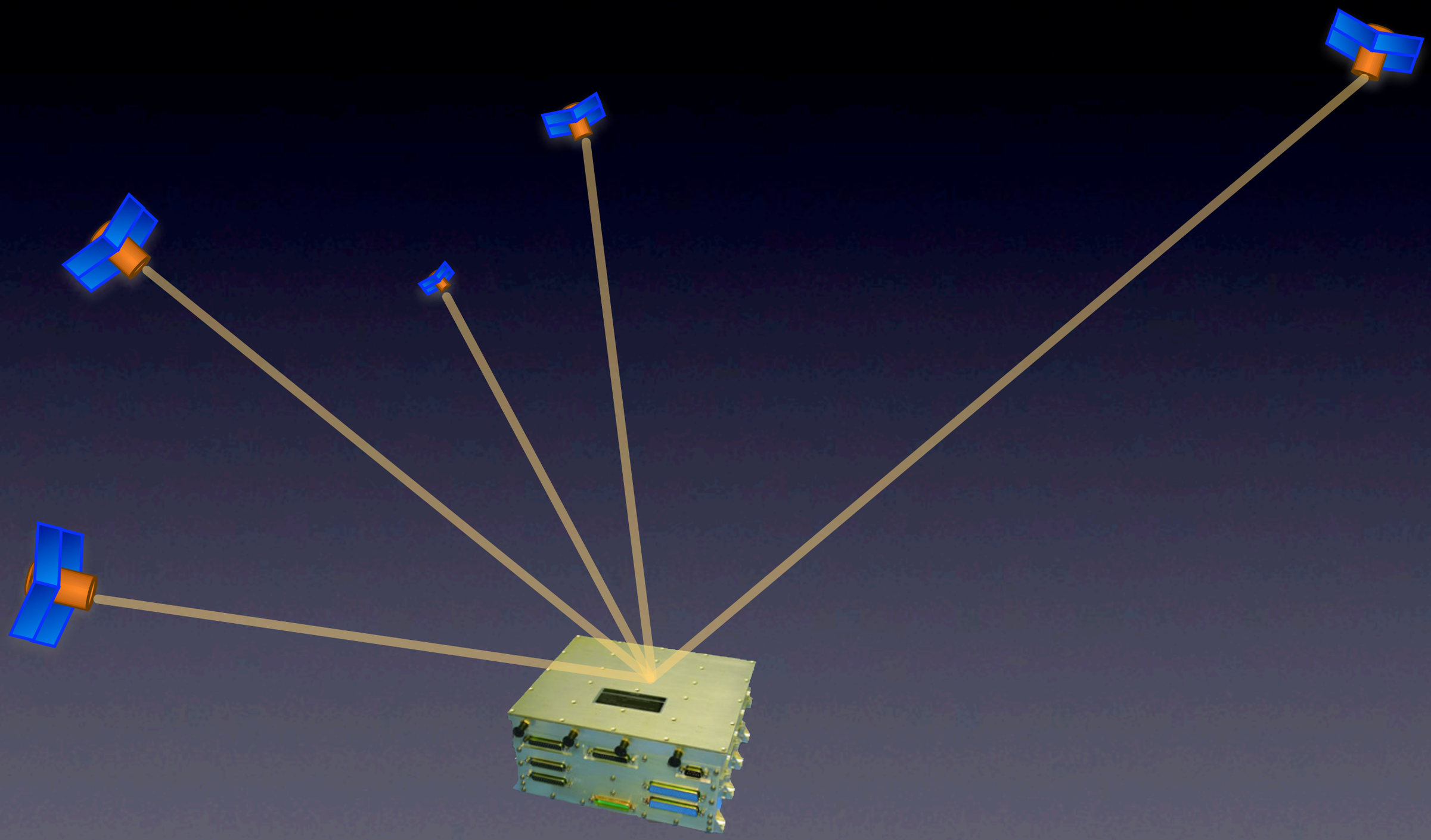
Topics

- A Brief Review of RO Tech
- The Thing We Build
- Requirements / Design Tradeoffs
- Three Sample Req's; Impact on TriG Design
- Additional Signal Processing

A Brief Review



Jet Propulsion Laboratory
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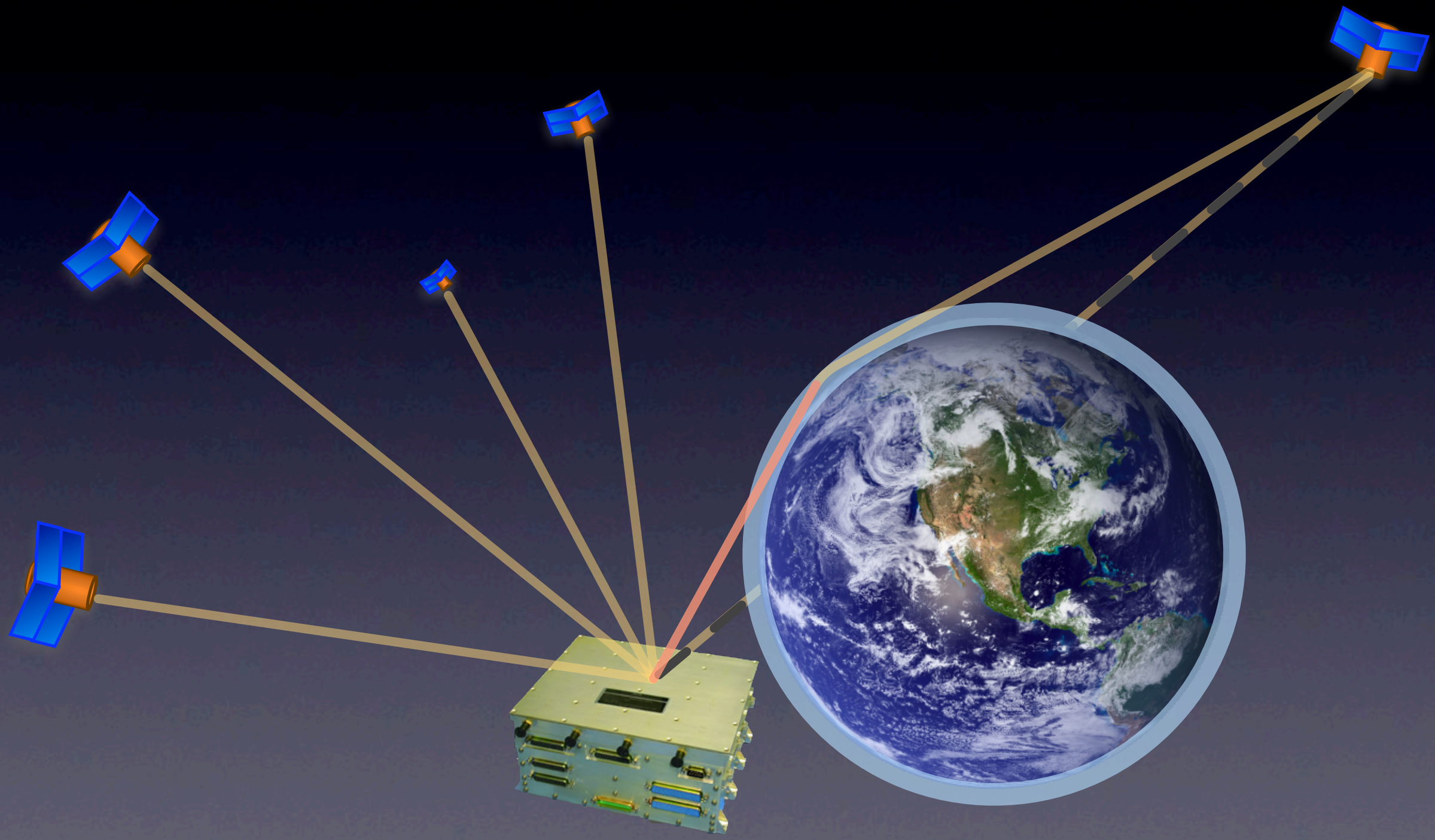
A Brief Review



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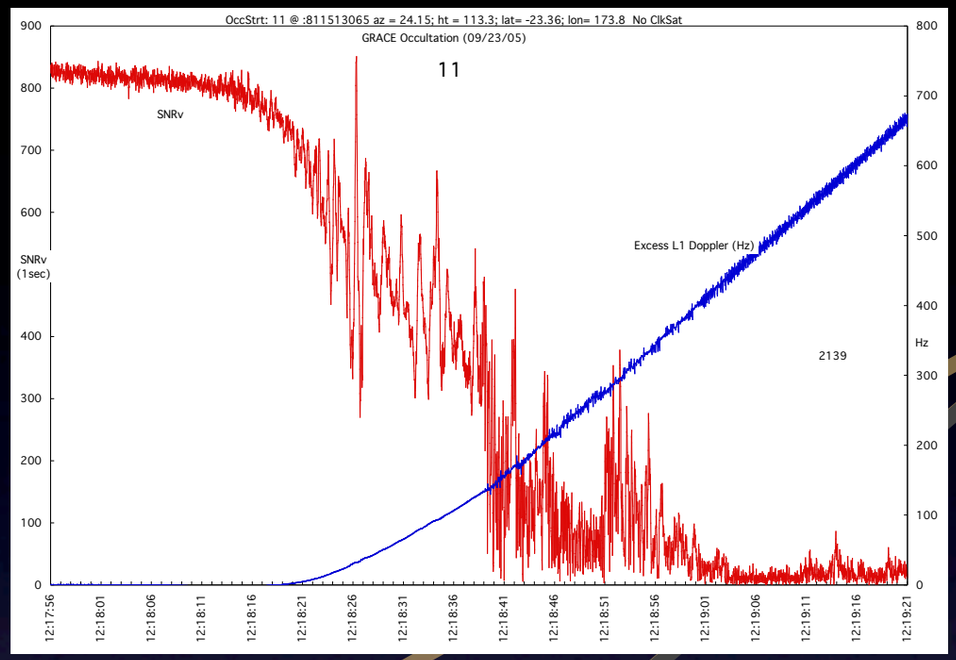
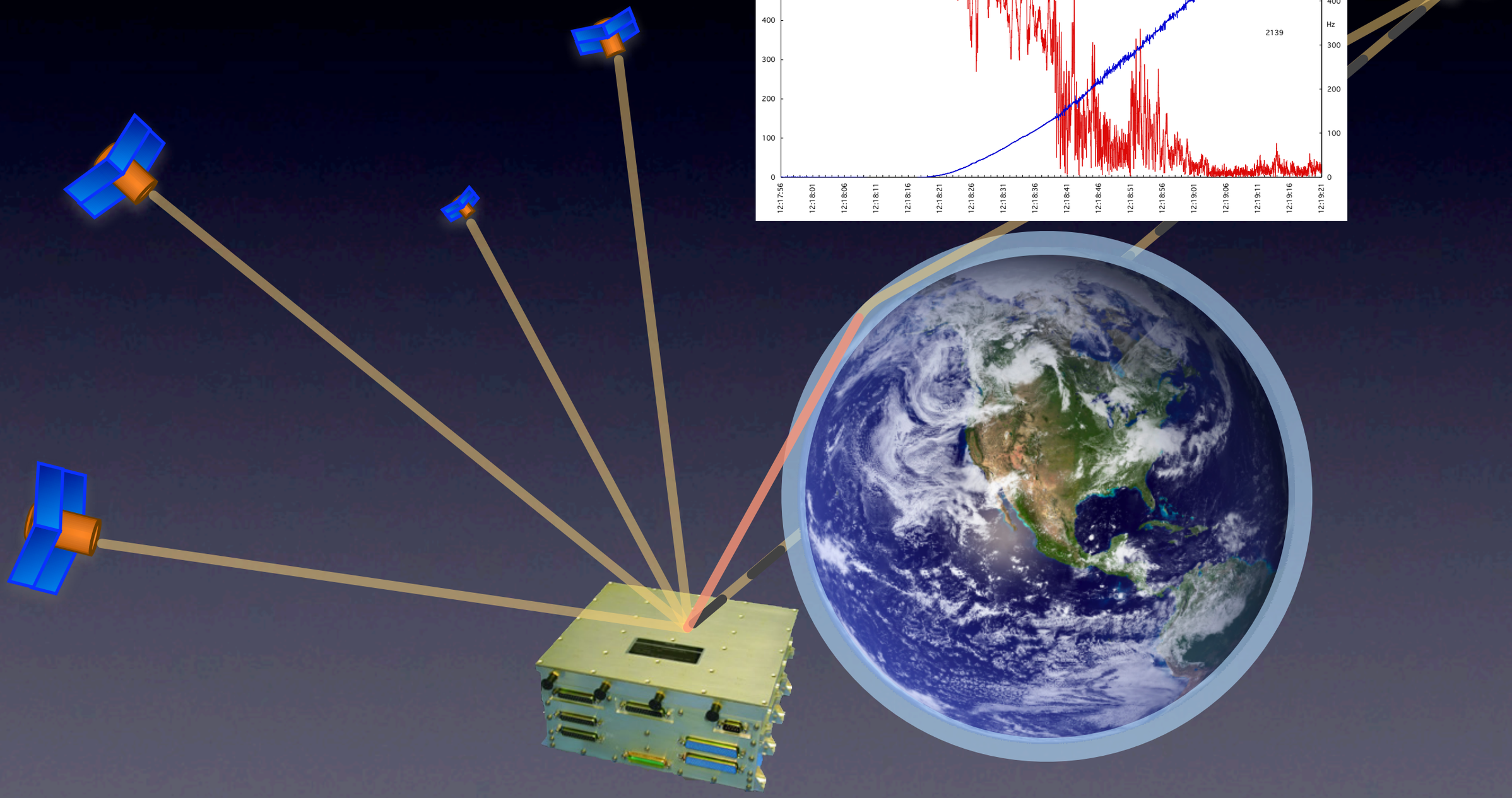
A Brief Review





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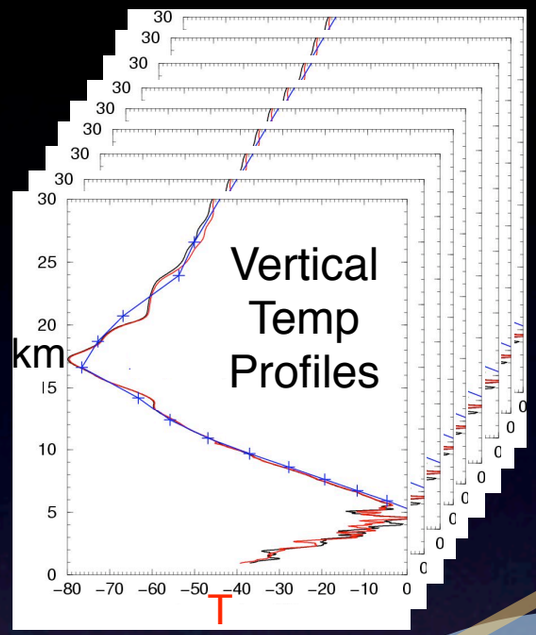
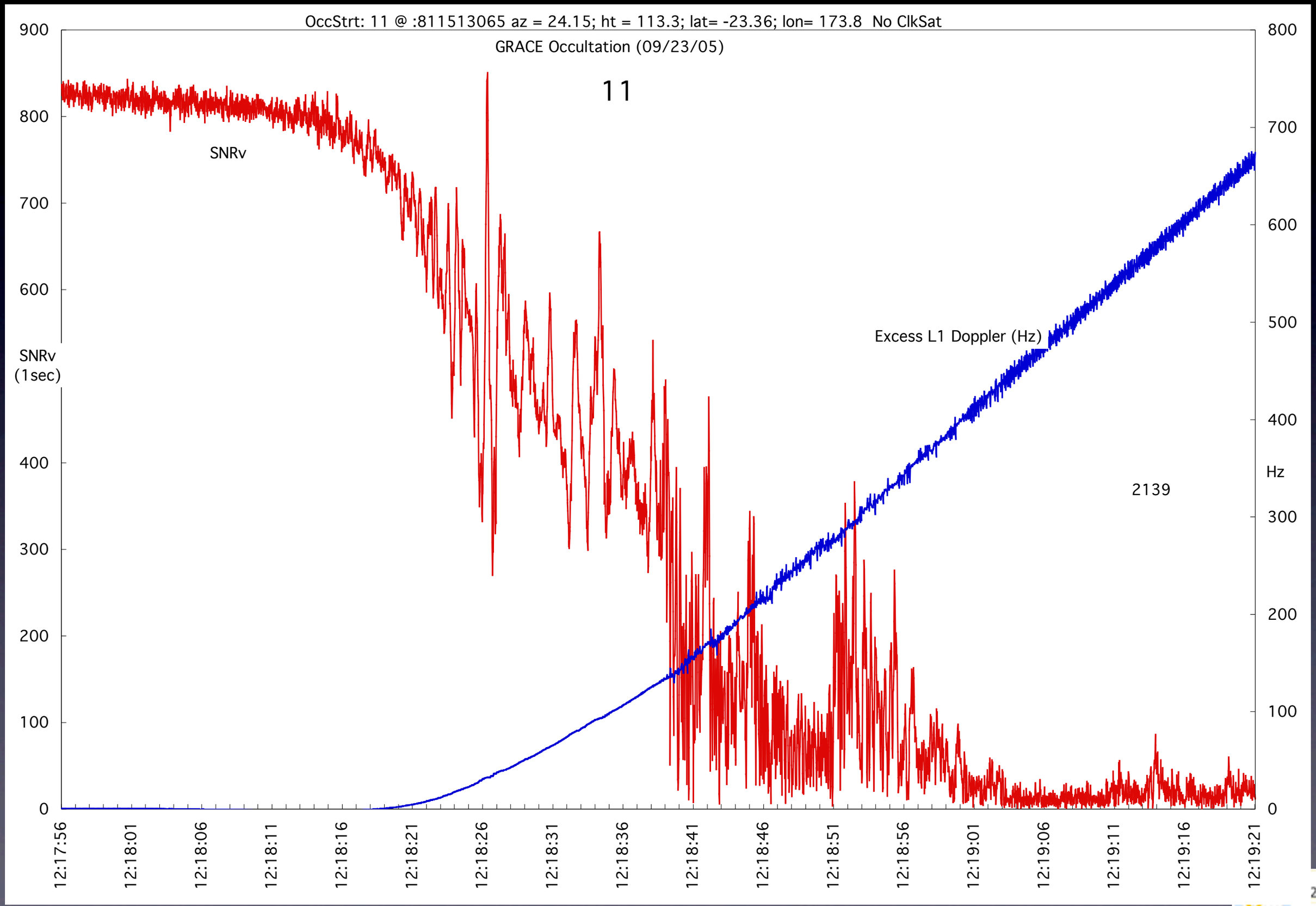


~1000/day

A Brief Review



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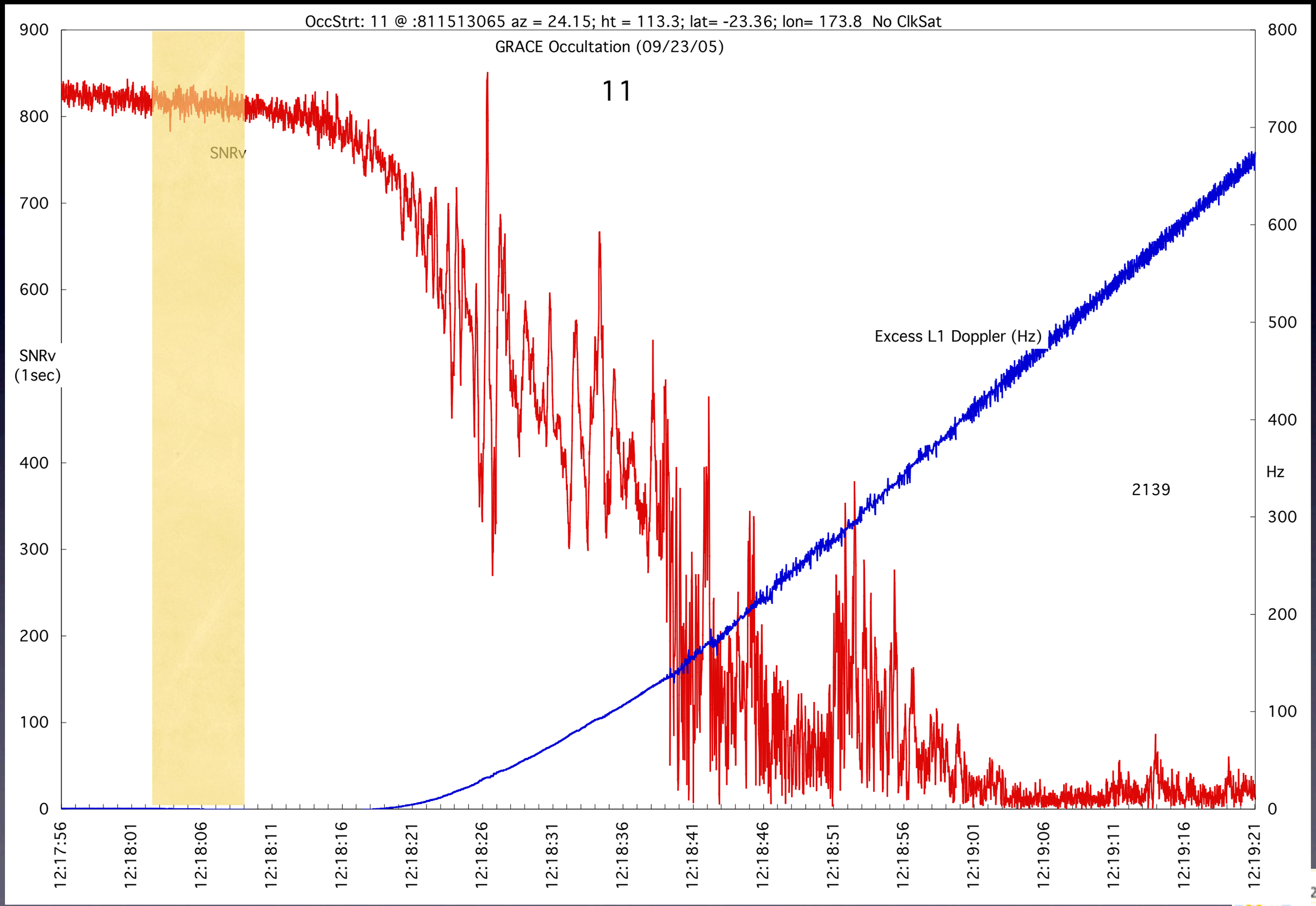

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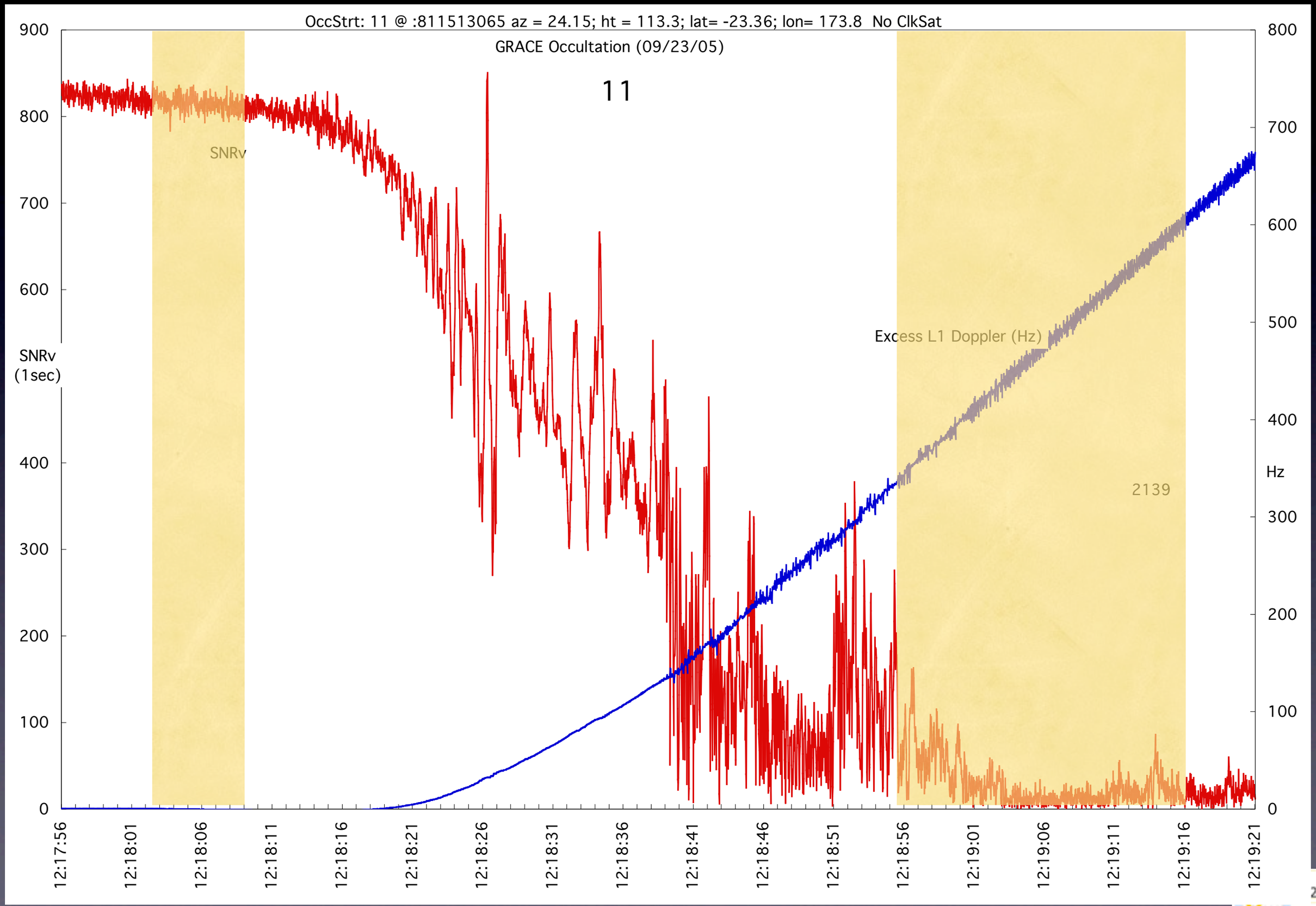
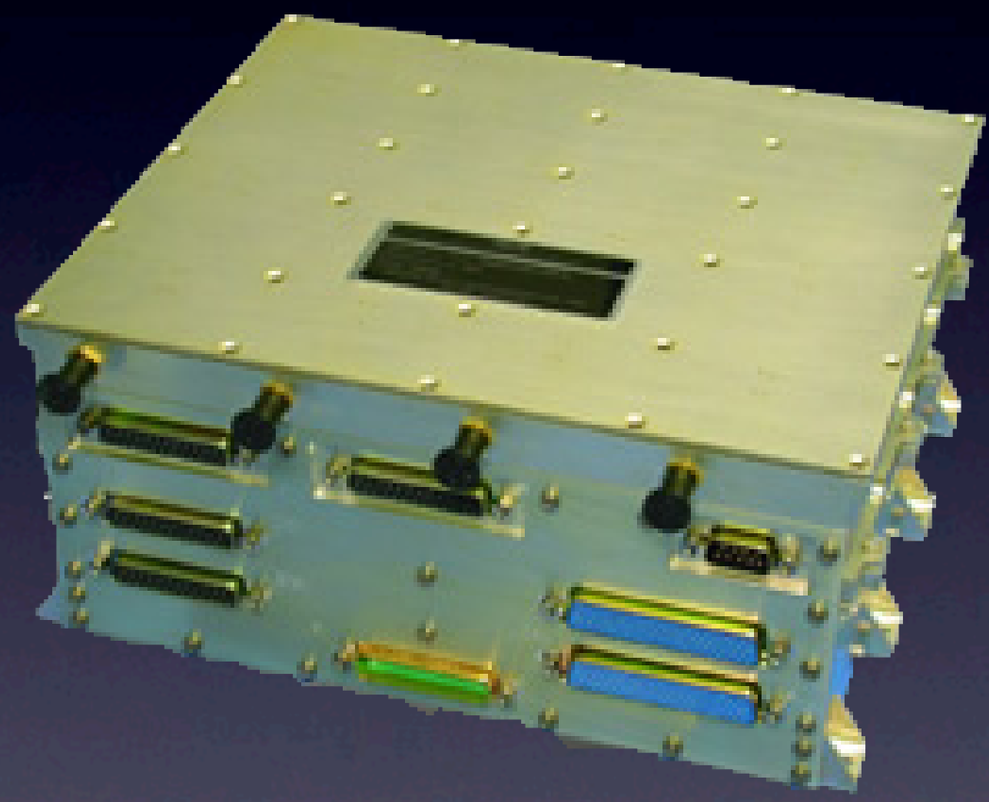
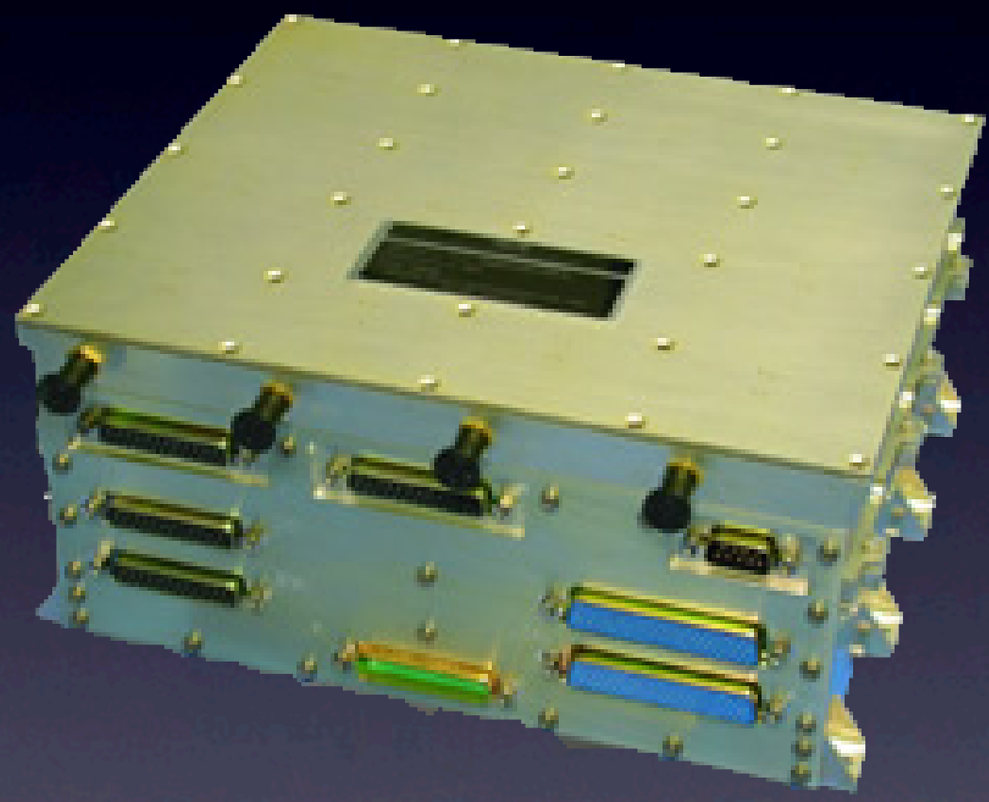


The Thing We Build



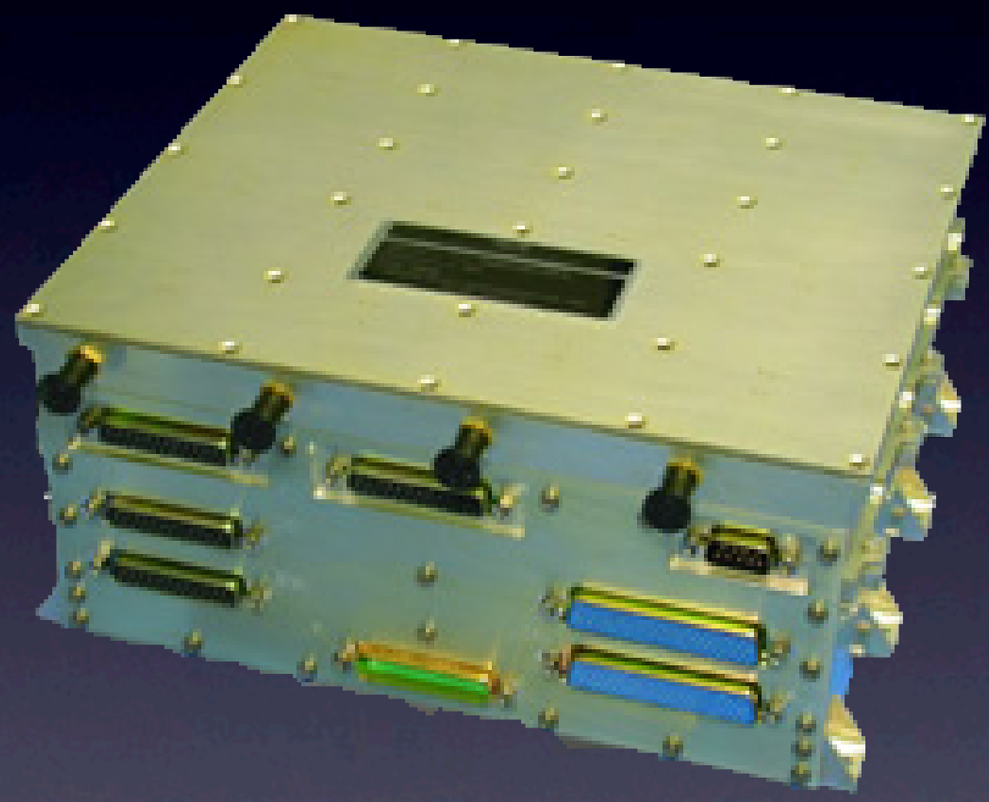
The Thing We Build

30x20x20 cm
~35W...
50kRad
~6kg + Ants



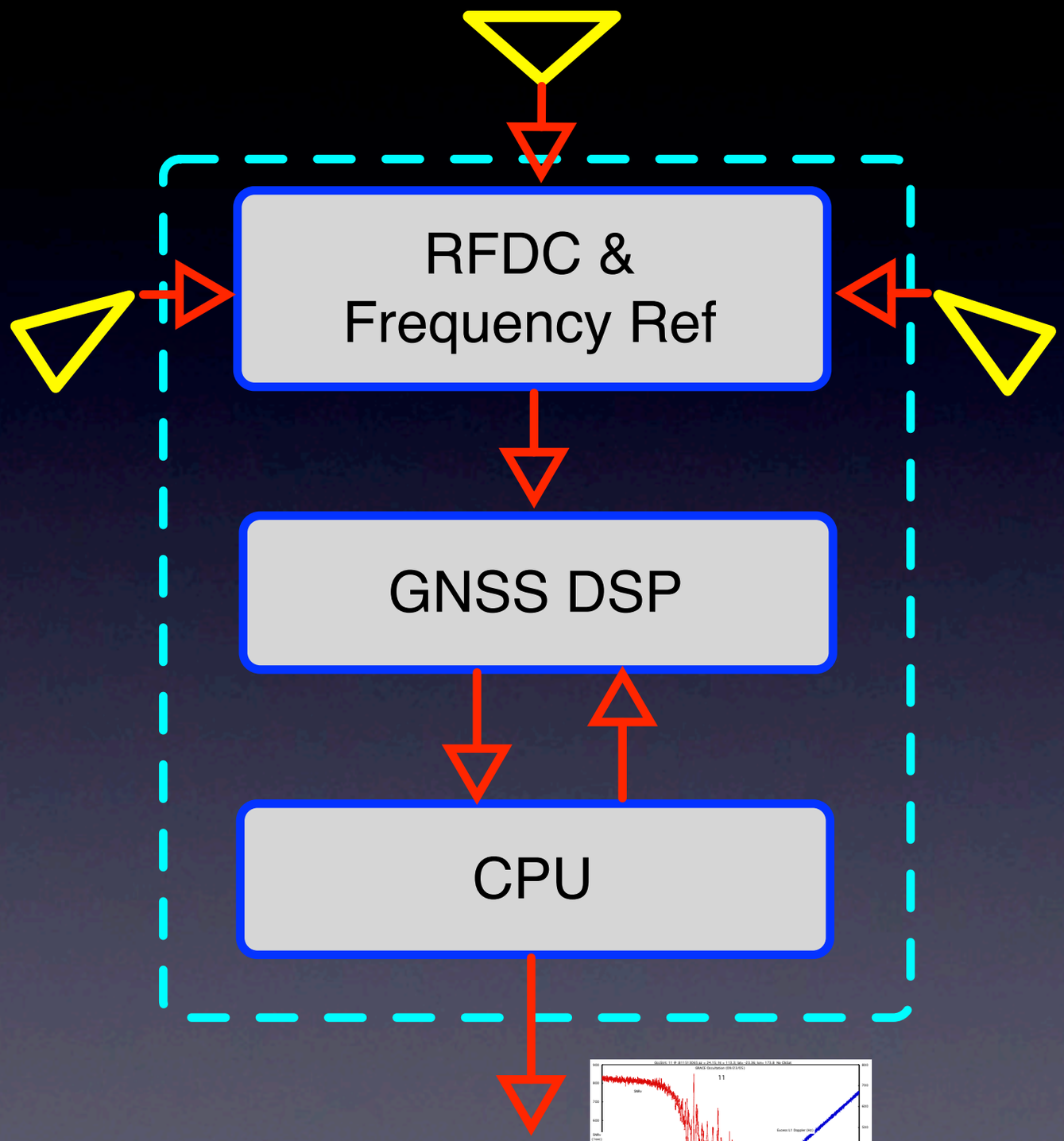
The Thing We Build

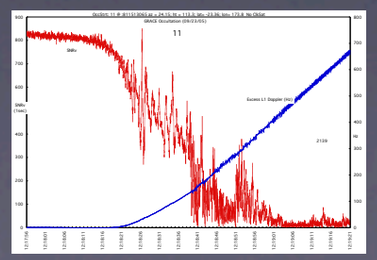
30x20x20 cm
~35W... < 50W
50kRad
~6kg + Ants



The Thing We Build

Generic RO Receiver





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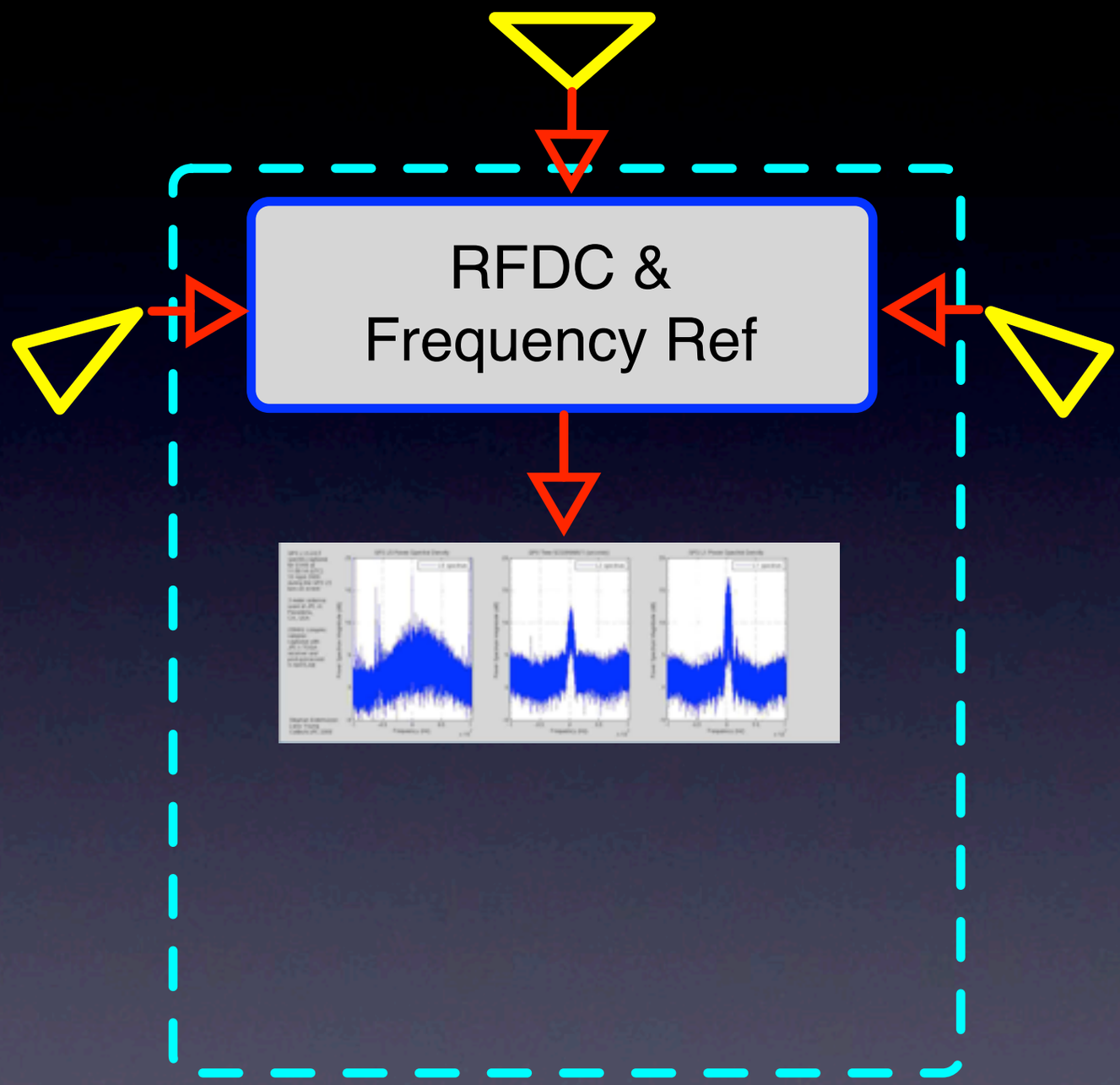
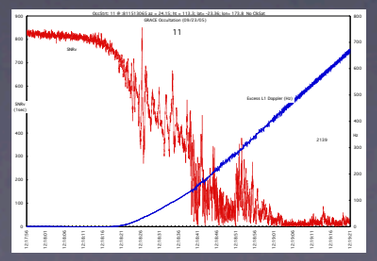
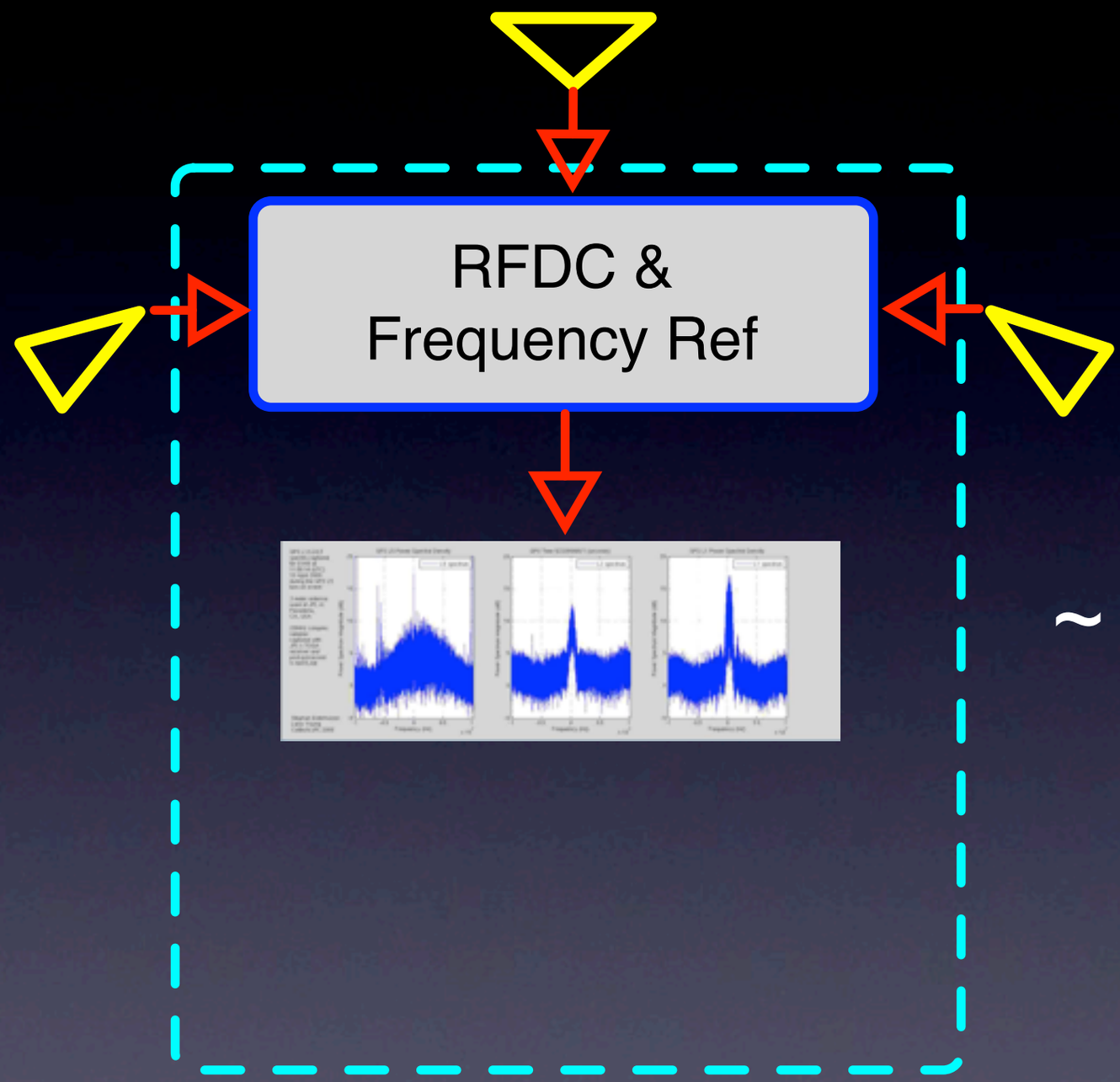


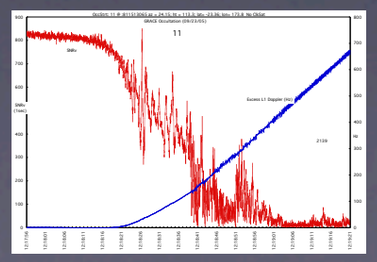


The Thing We Build

Generic RO Receiver



~1.8 TB/Day



Design/Requirements Trades

Global Navigation Satellite System (GNSS) Radio Occultation Follow-on Operational Capability

Level 1 Requirements Document - Preliminary

Version: 2.0 Final

May 27, 2010

U.S. Department of Commerce (DOC)
National Oceanic and Atmospheric Administration (NOAA)
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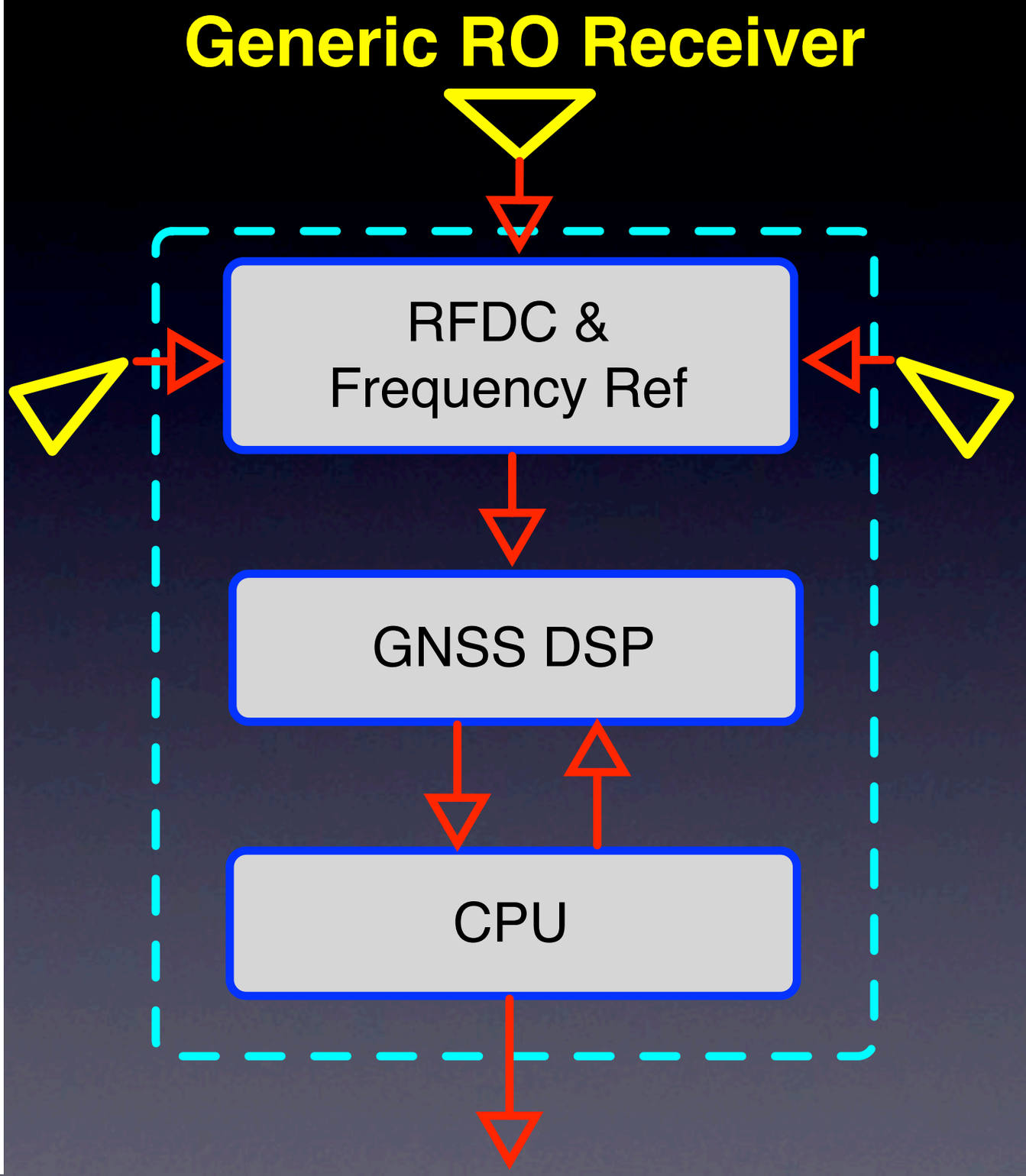
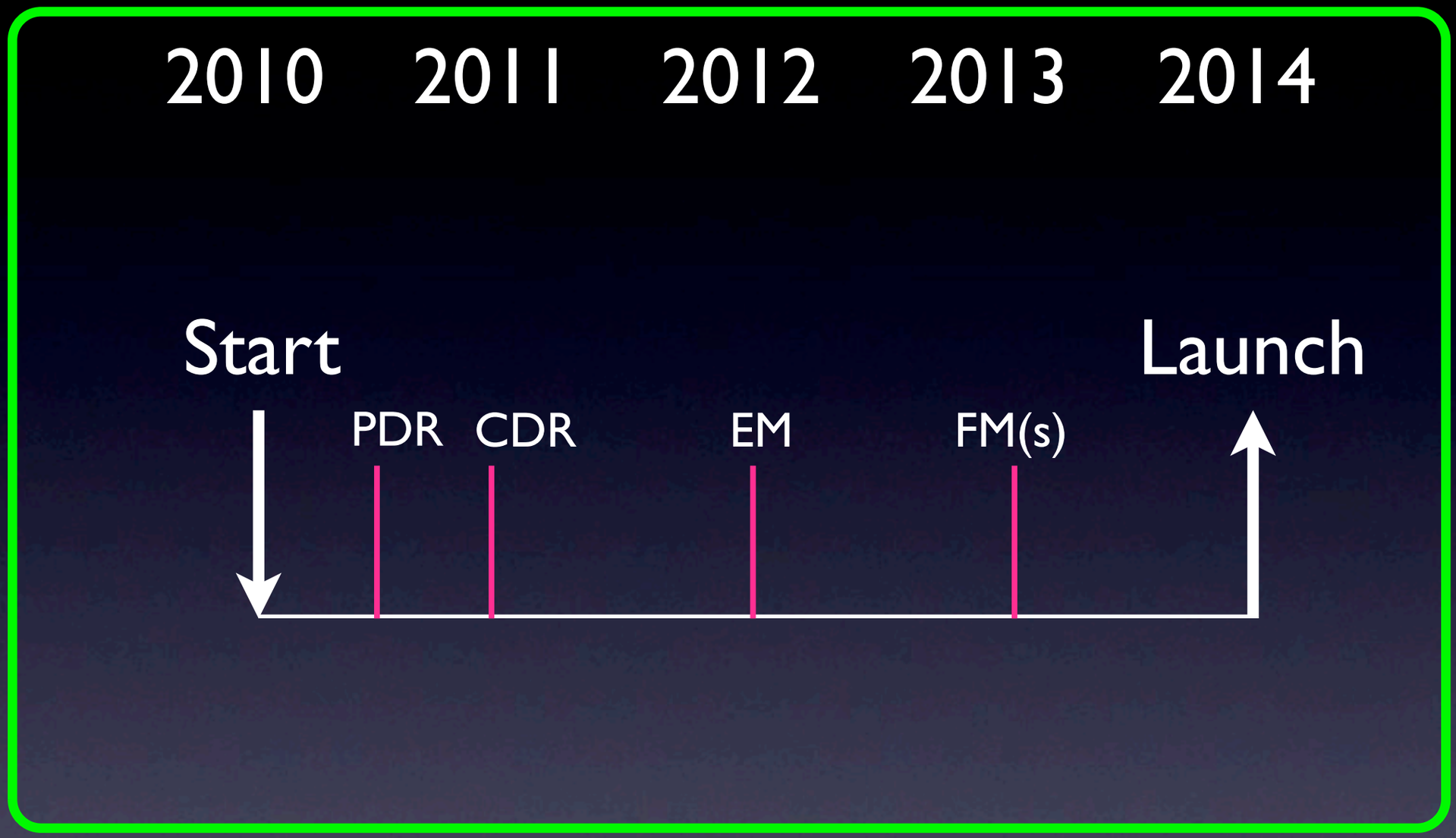


Requirements vs Design Trades

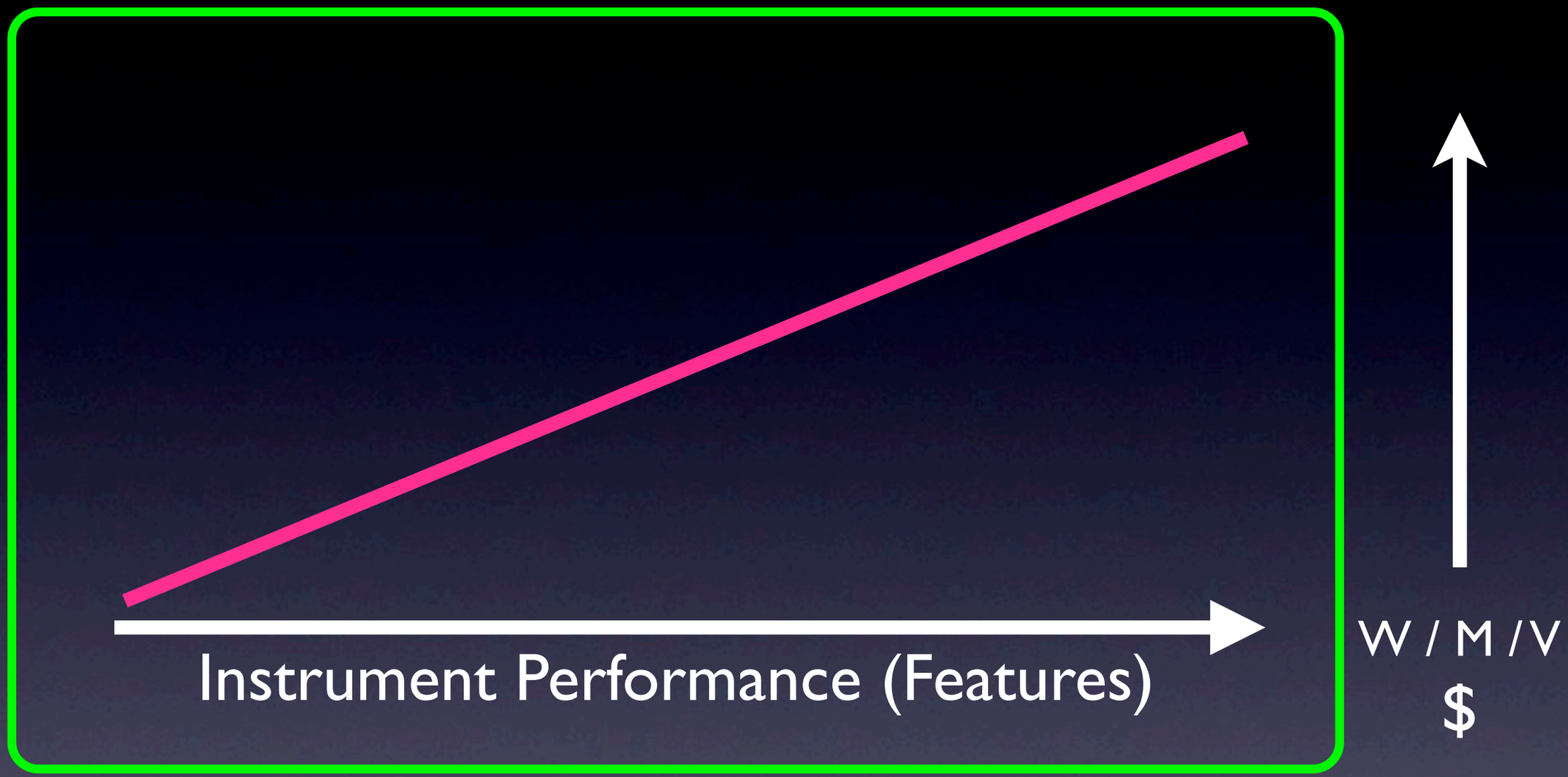
Requirements vs Design Trades

Requirements vs Design Trades

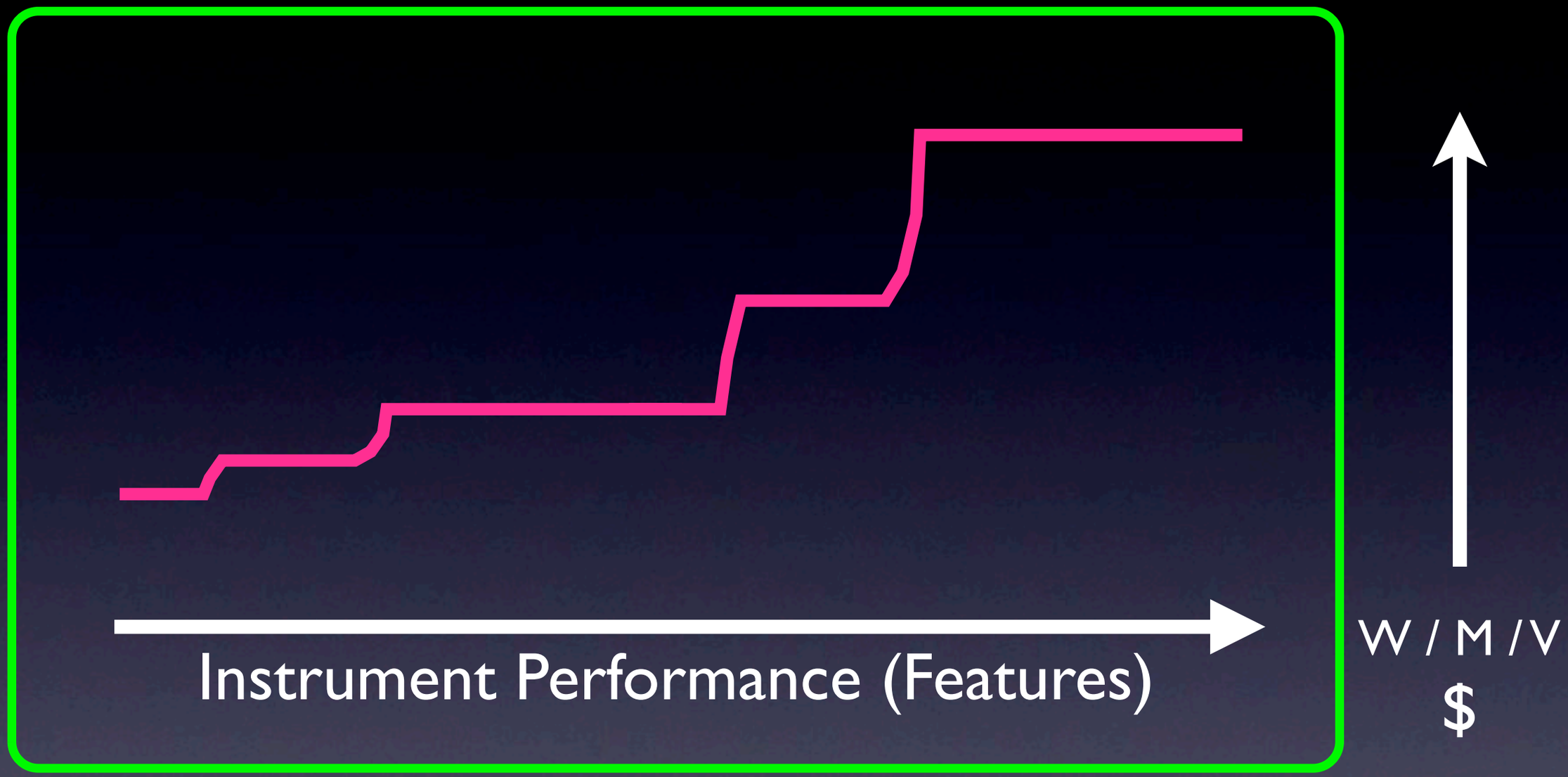
Task Schedule



Design Trades



Design Trades



Requirements Sampling

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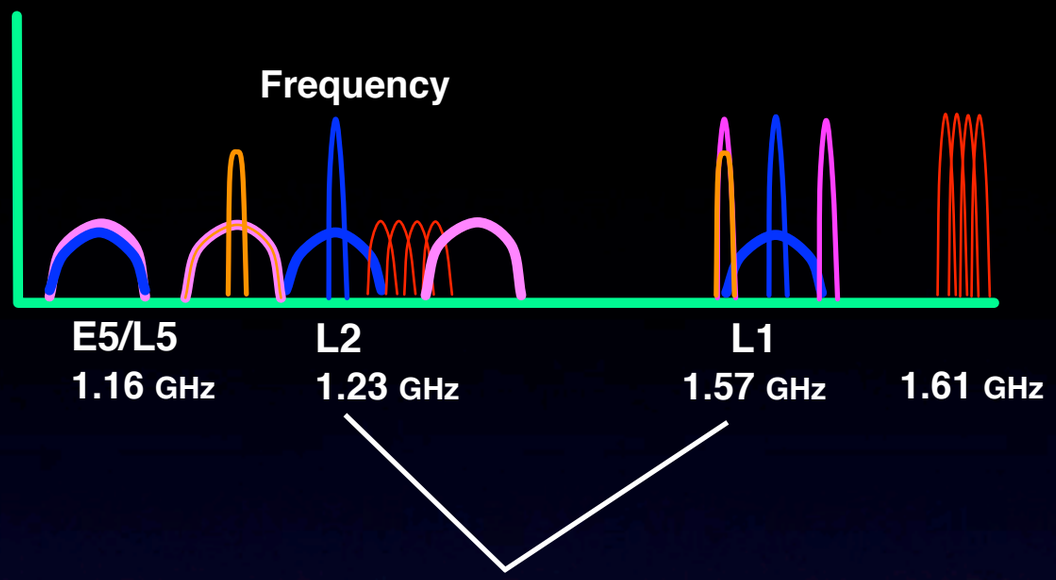
Requirements Sampling

Table 5-1: Neutral Atmosphere Product Requirements

Data Type	Threshold	Objective
Common Requirements for all Neutral Atmosphere Product Types		
5-1.1. a. Number of Profiles per day**	8,000	10,000
b. Corresponding avg. number/location/day	4	5
5-1.2. Vertical Data Resolution [km]		
a. Altitude Range 0 – 25 km MSL	0.1	0.1
b. Altitude Range 25 – 60 km MSL	1.0	1.0
5-1.3. Average Latency [minutes] Hi/Lo Inclin Orbits	45 / [TBD]	15 / [TBD]
5-1.4. Average Revisit Time*** [hours]	6	4.8
5-1.5. Refresh Time [hours]	TBD	TBD
Product-Specific Requirements		
Bending Angle Profiles*		
5-1.6. Measurement Range [Microradians-μrad]	0-1,000	0-1,000
5-1.7. Measurement Uncertainty [RMS] [μrad]	1.5	1
5-1.8. Height uncertainty [m] [sfc-100 km]	20	15
Refractivity Profiles		
5-1.9. Measurement Range [Refractivity-N units]	0-500	0-500
5-1.10. Measurement Uncertainty**** RMS [%Nunits]	1	0.7
5-1.11. Height uncertainty [m] [sfc-100 km]	20	15
Temperature Profiles		
5-1.12. Measurement Range [Temperature-deg K]	150-330	150-330
5-1.13. Measurement Uncertainty**** [RMS] [K]	0.6	0.4
5-1.14. Decadal Temperature Stability*****		
a. Height Range of Interest [km]	8-30	8-30
b. Measurement Range [K per decade]	0 - 1	0 - 1
c. Measurement Uncertainty [K per decade]	0.05	0.04
5-1.15. Height uncertainty [m] [sfc-100 km]	20	15
Water Vapor Profiles		
5-1.16. Measurement Range [HPa partial pressure]	0 - 50	0 - 50

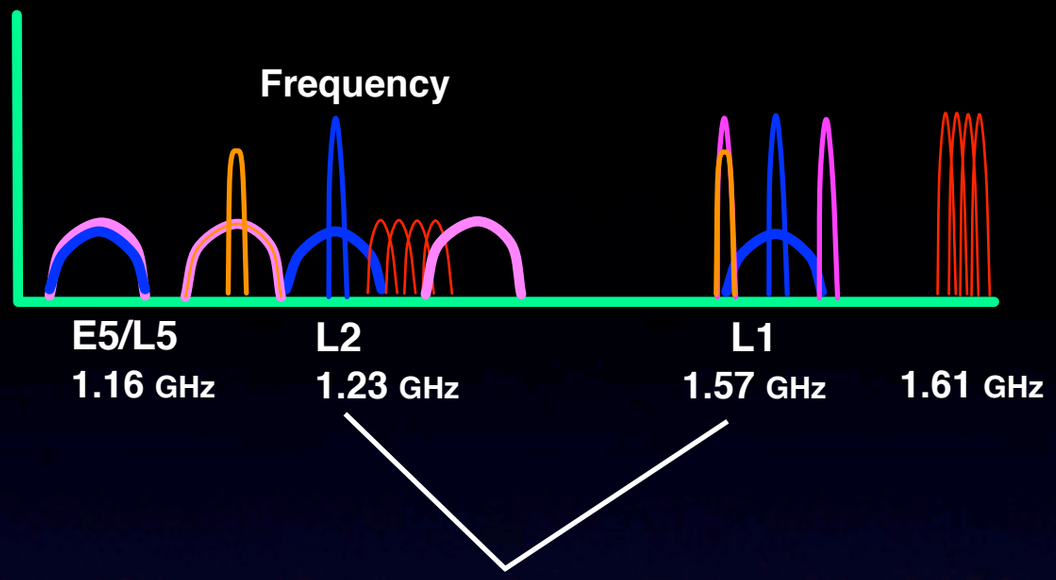
RF Processing

RF Processing



Current NASA tech processes these

RF Processing



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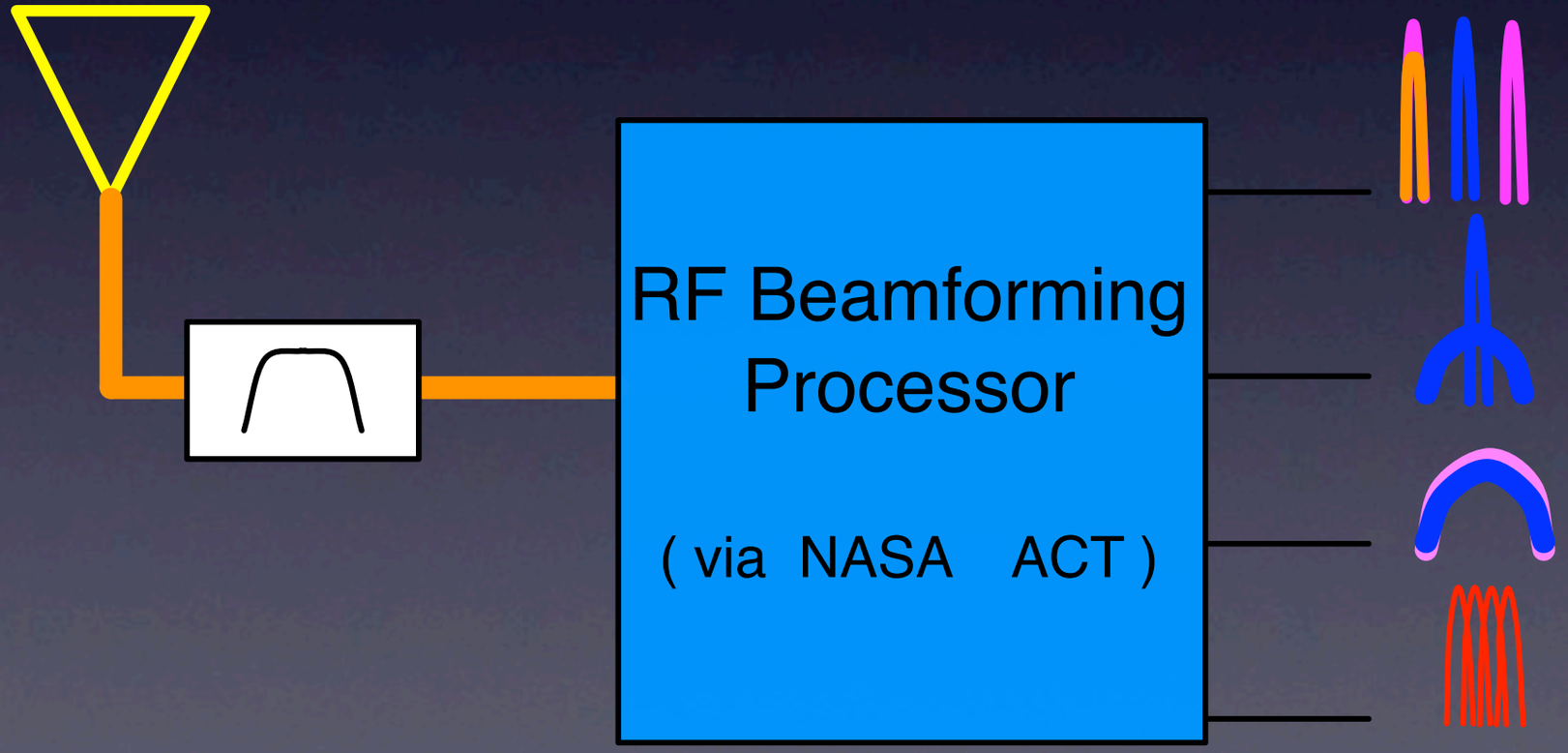

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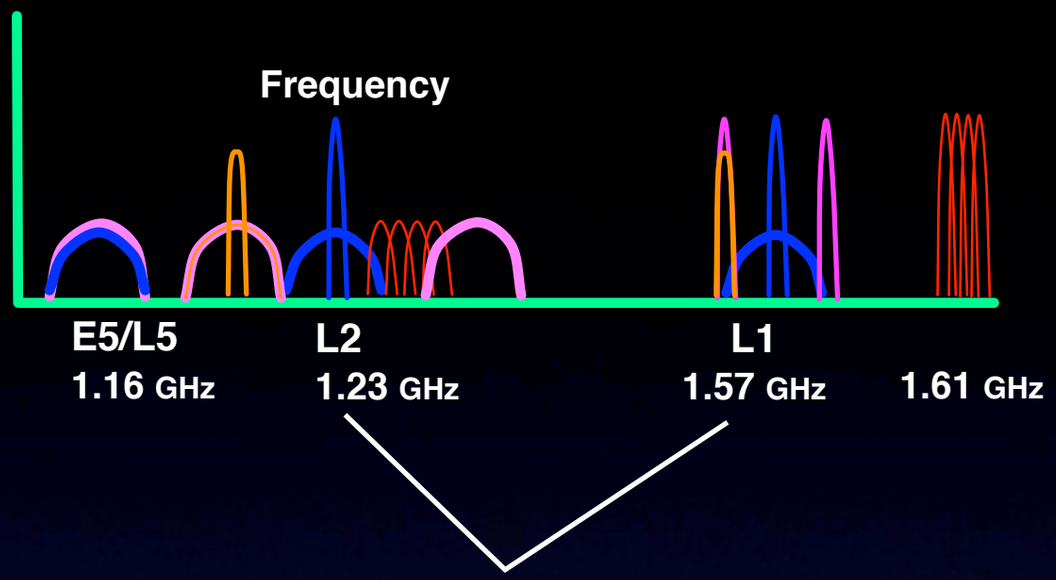

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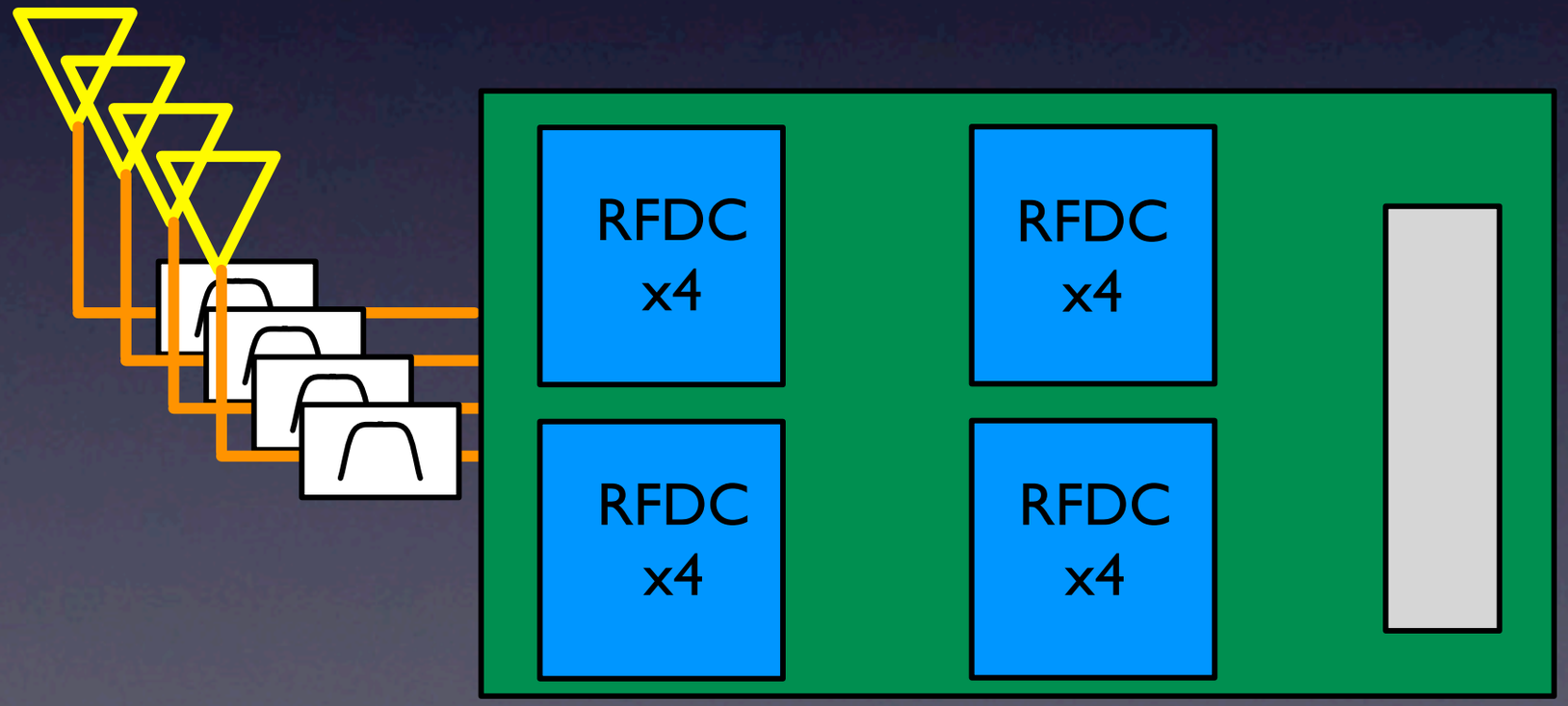

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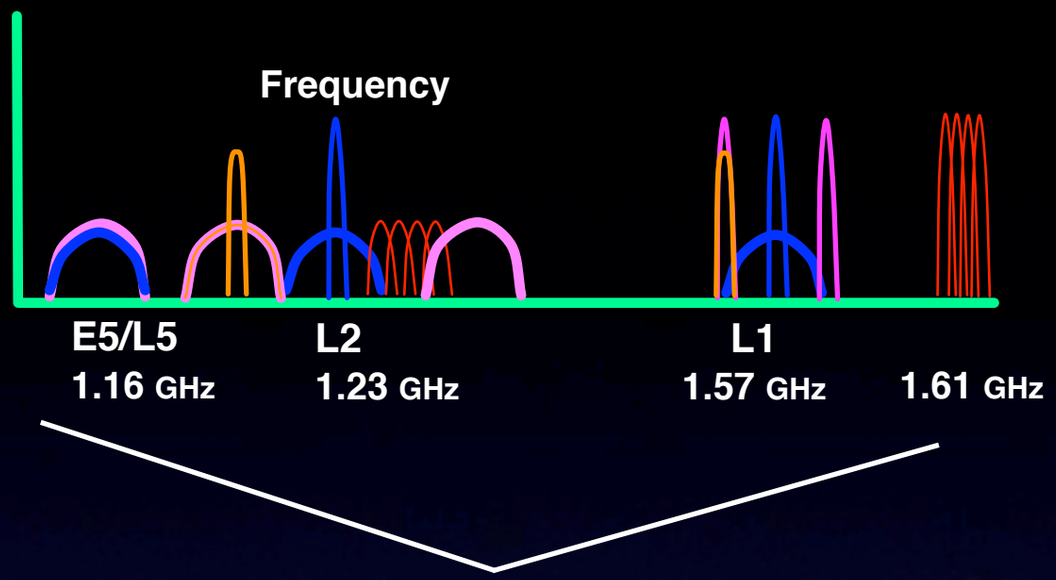
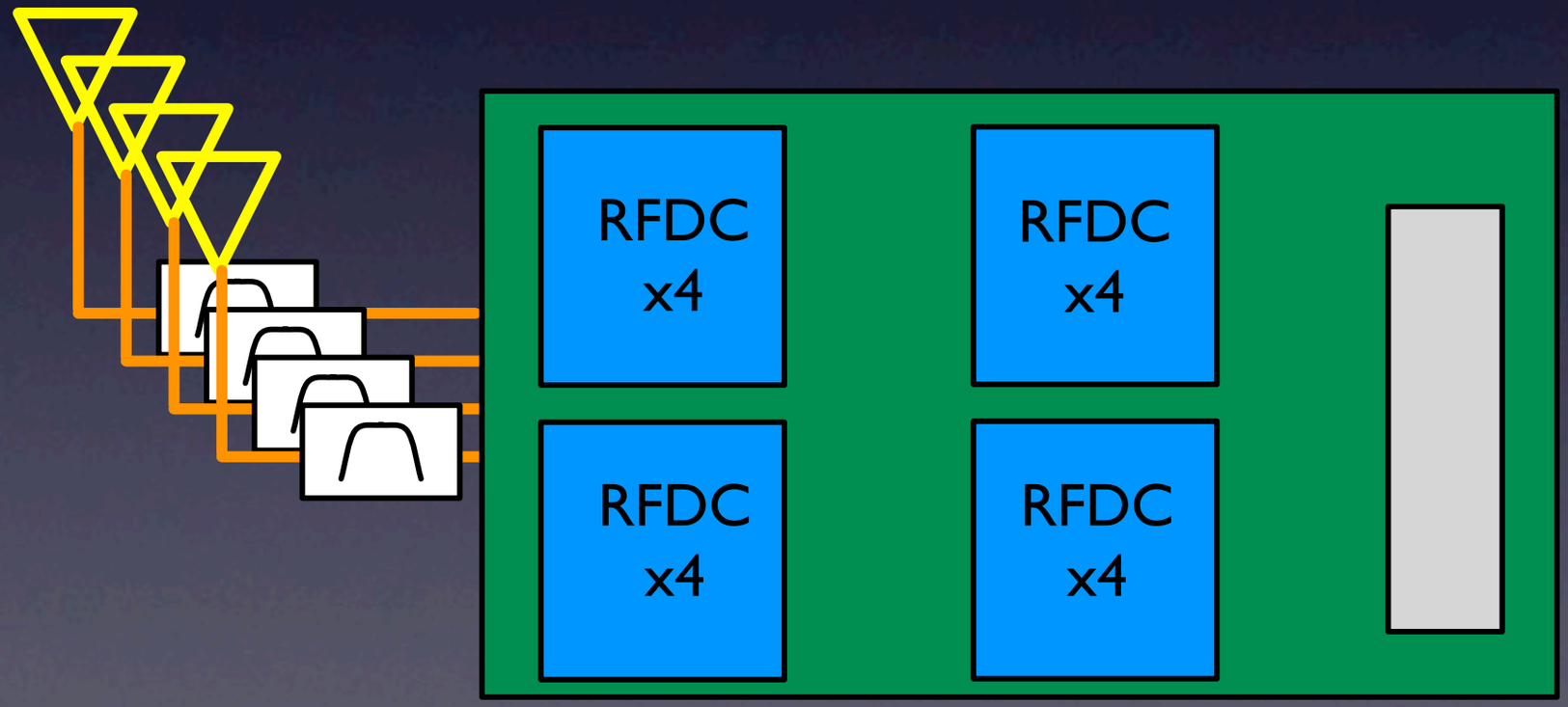


Newer NASA tech (TriG) processes these



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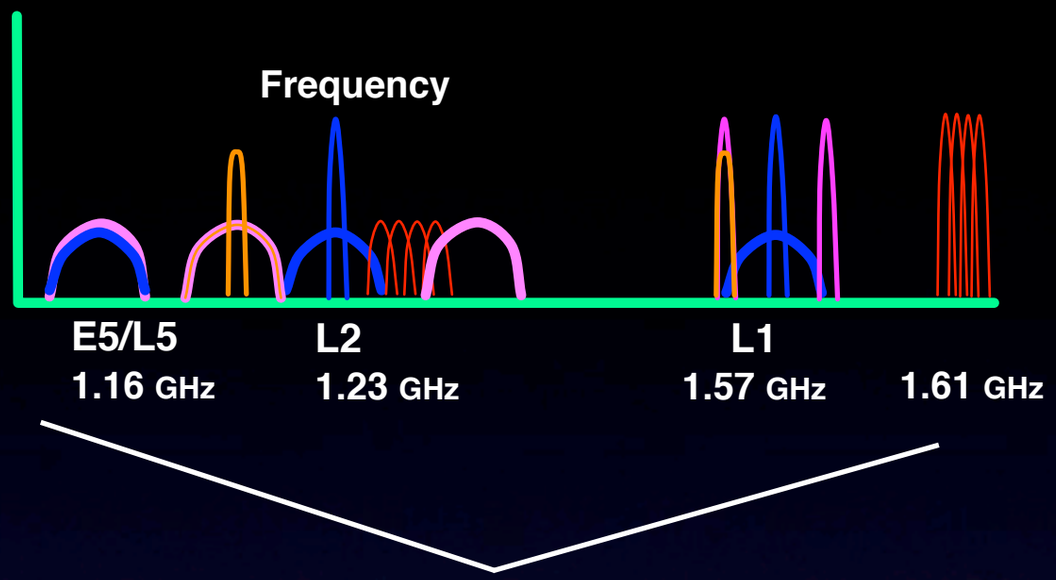

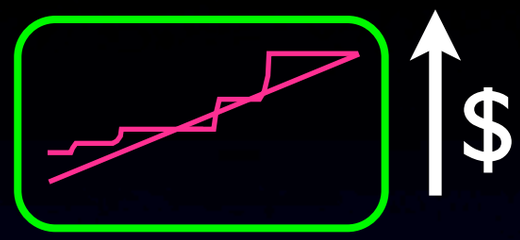

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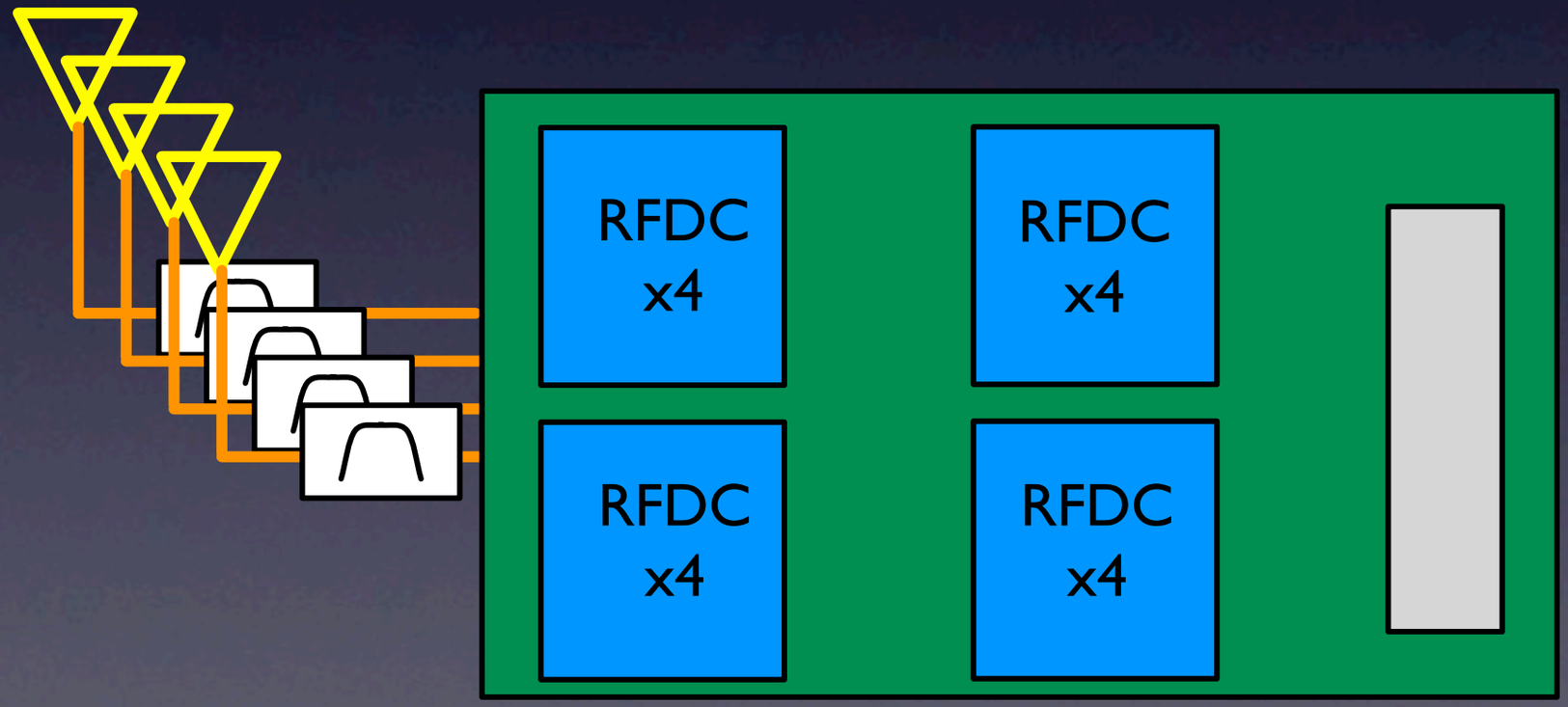
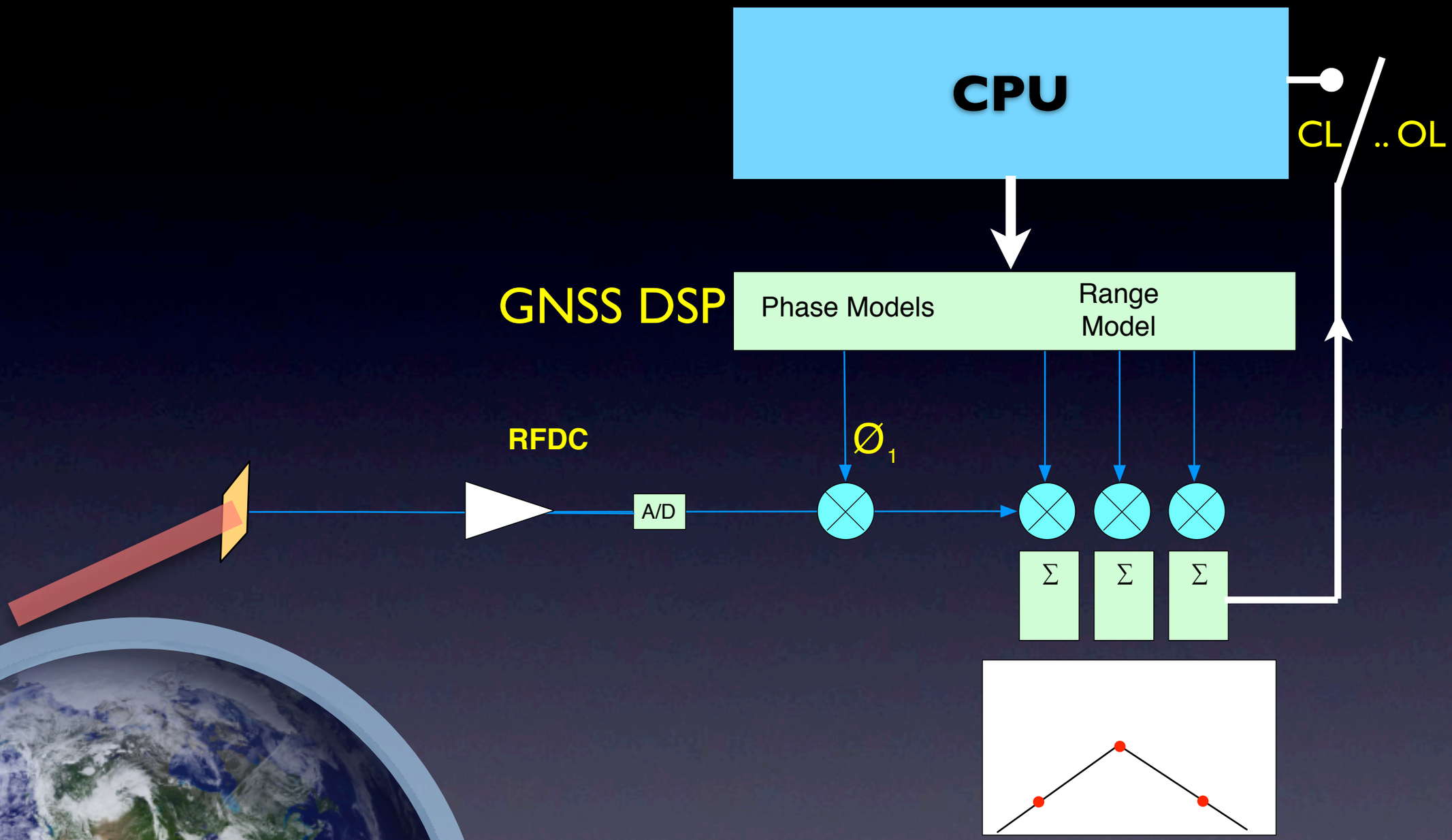
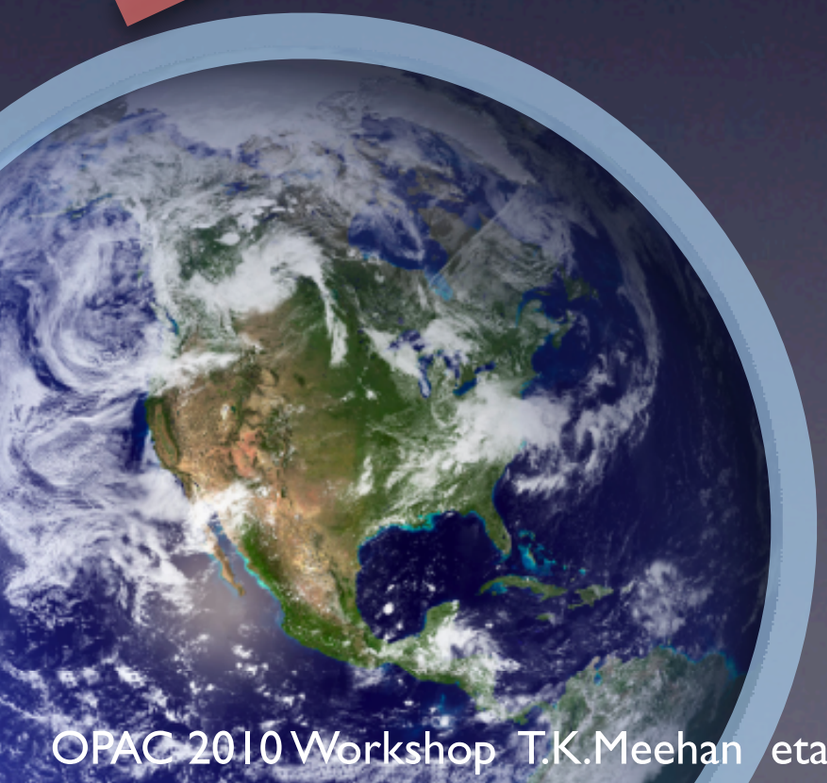


Processing for a Single Occultation





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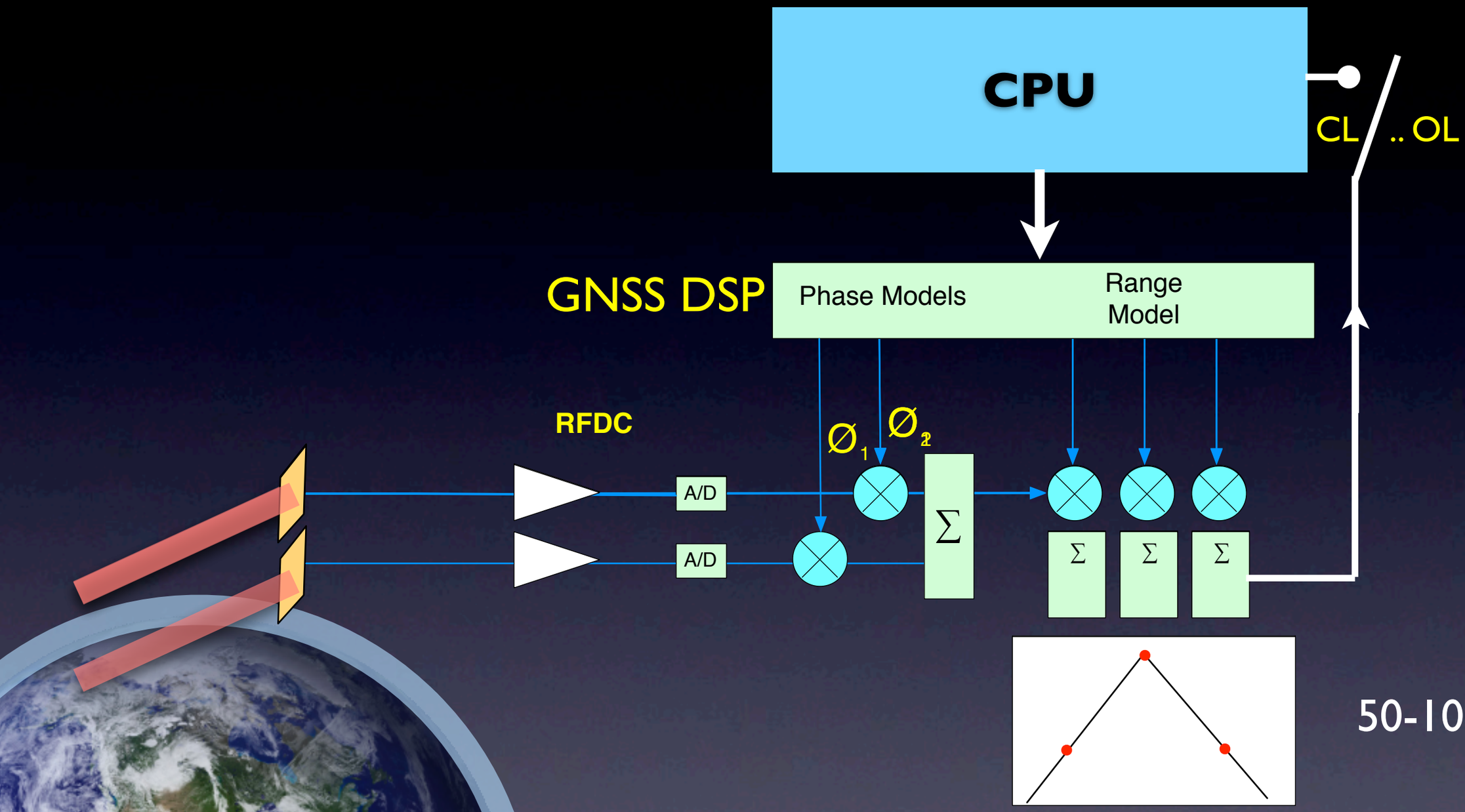
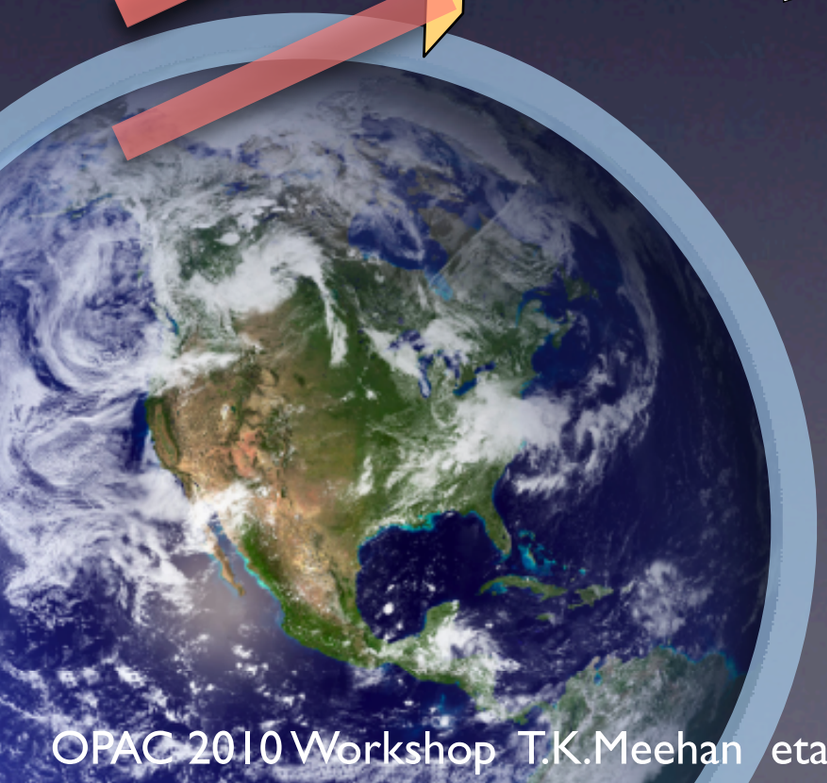
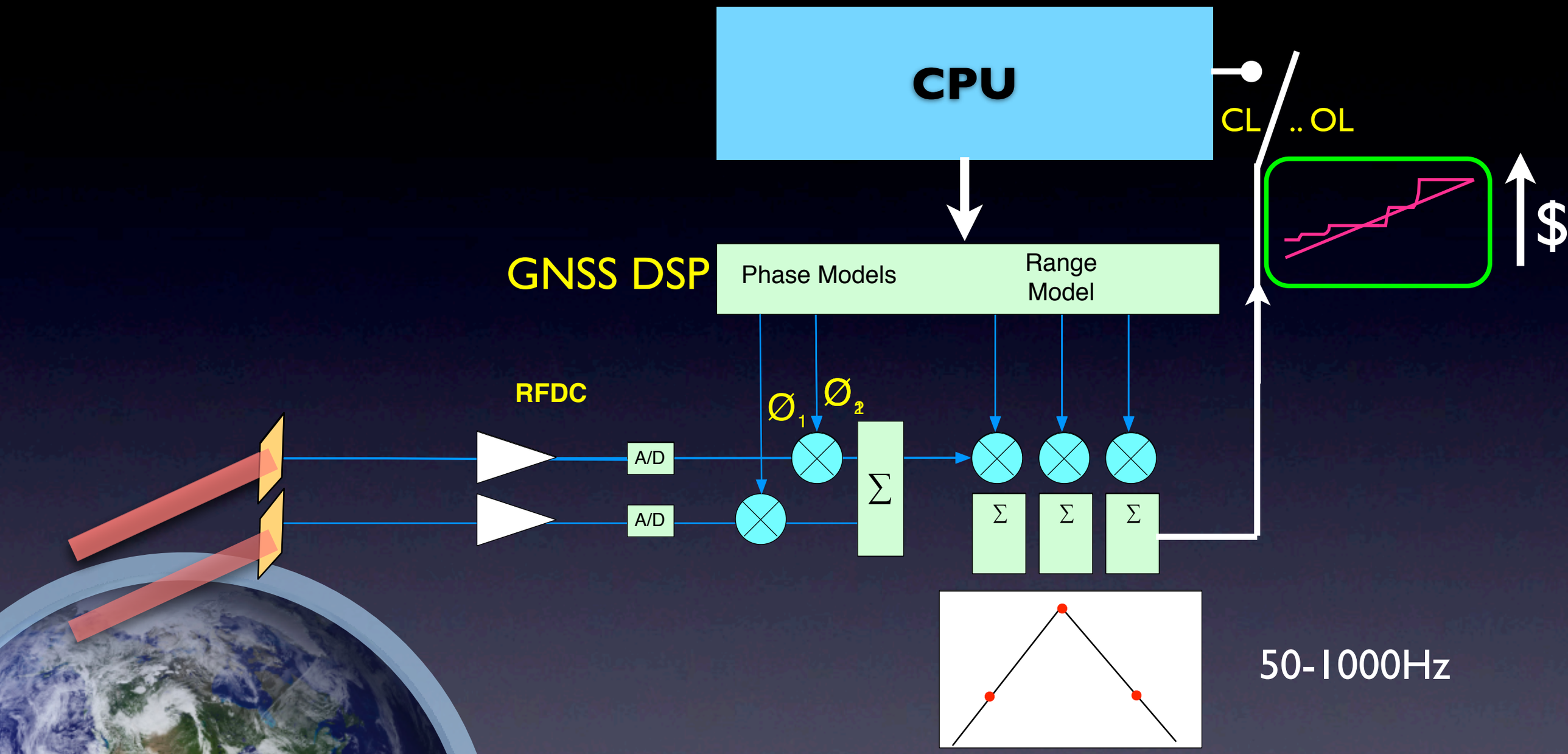




50-1000Hz

Processing for a Single Occultation



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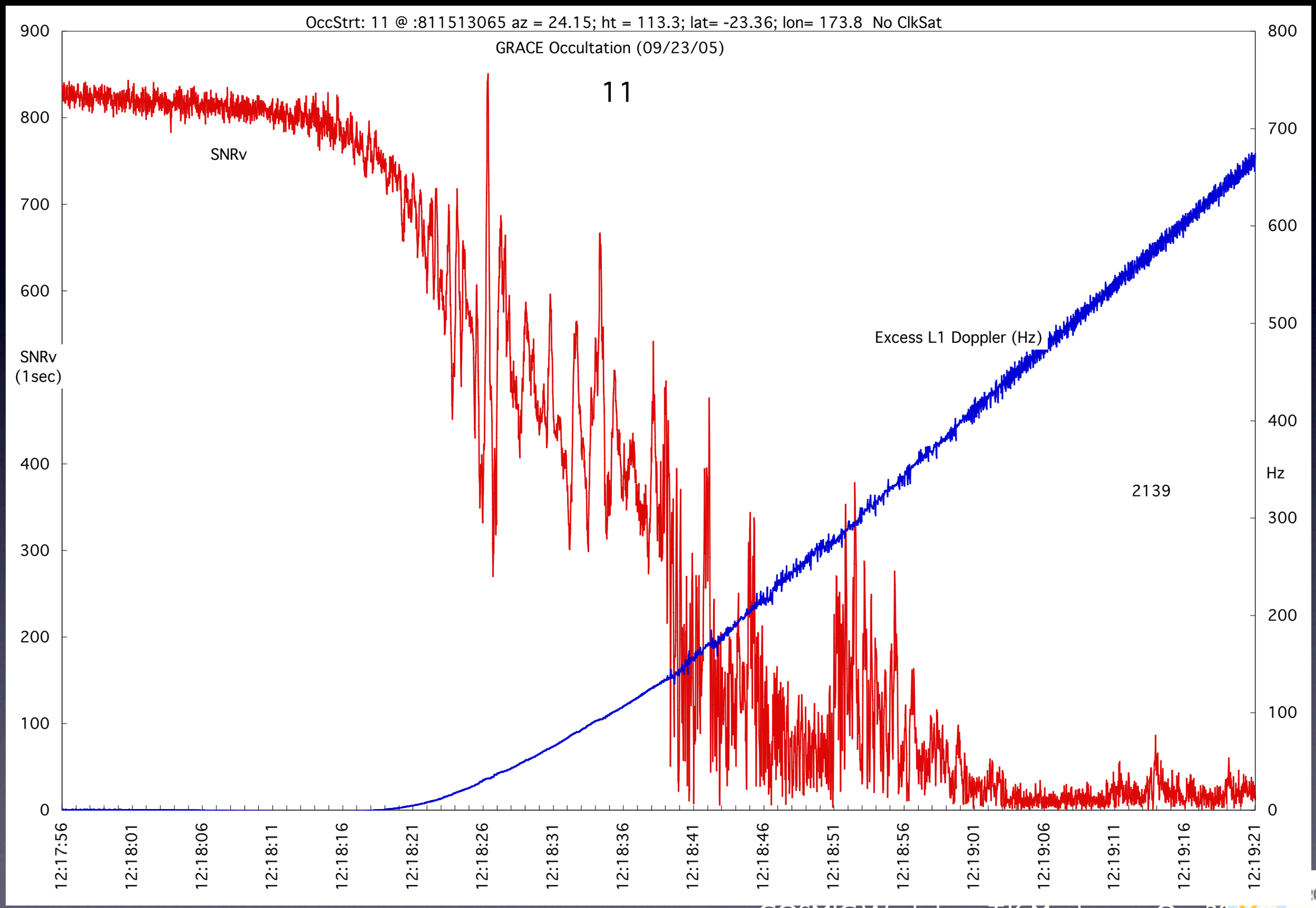
5-1.16. Measurement Range [HPa partial pressure]	0 - 50	0 - 50
5-1.17. Measurement Uncertainty [RMS] [% in	15	10

Requirements Sampling

Requirements Sampling



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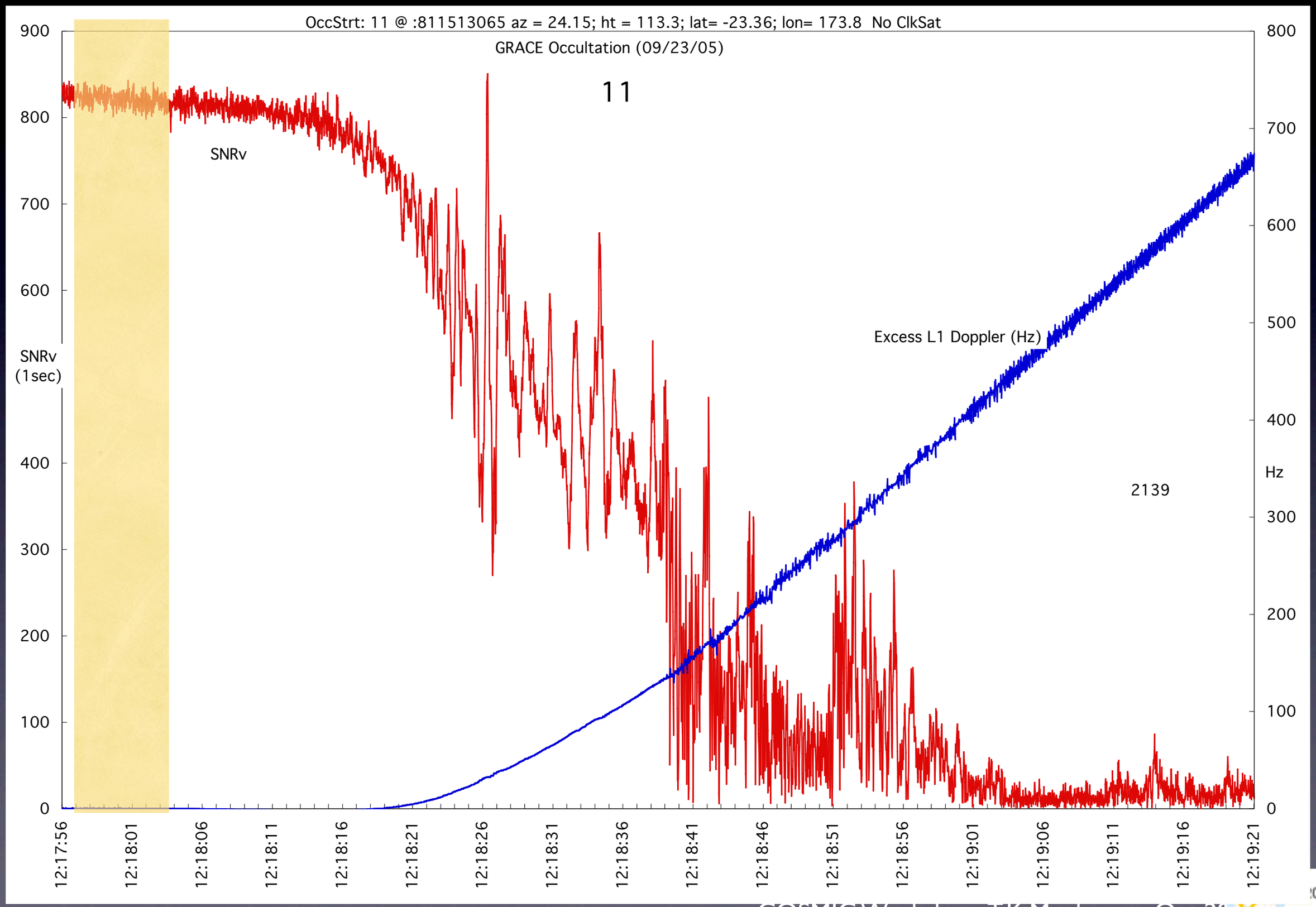
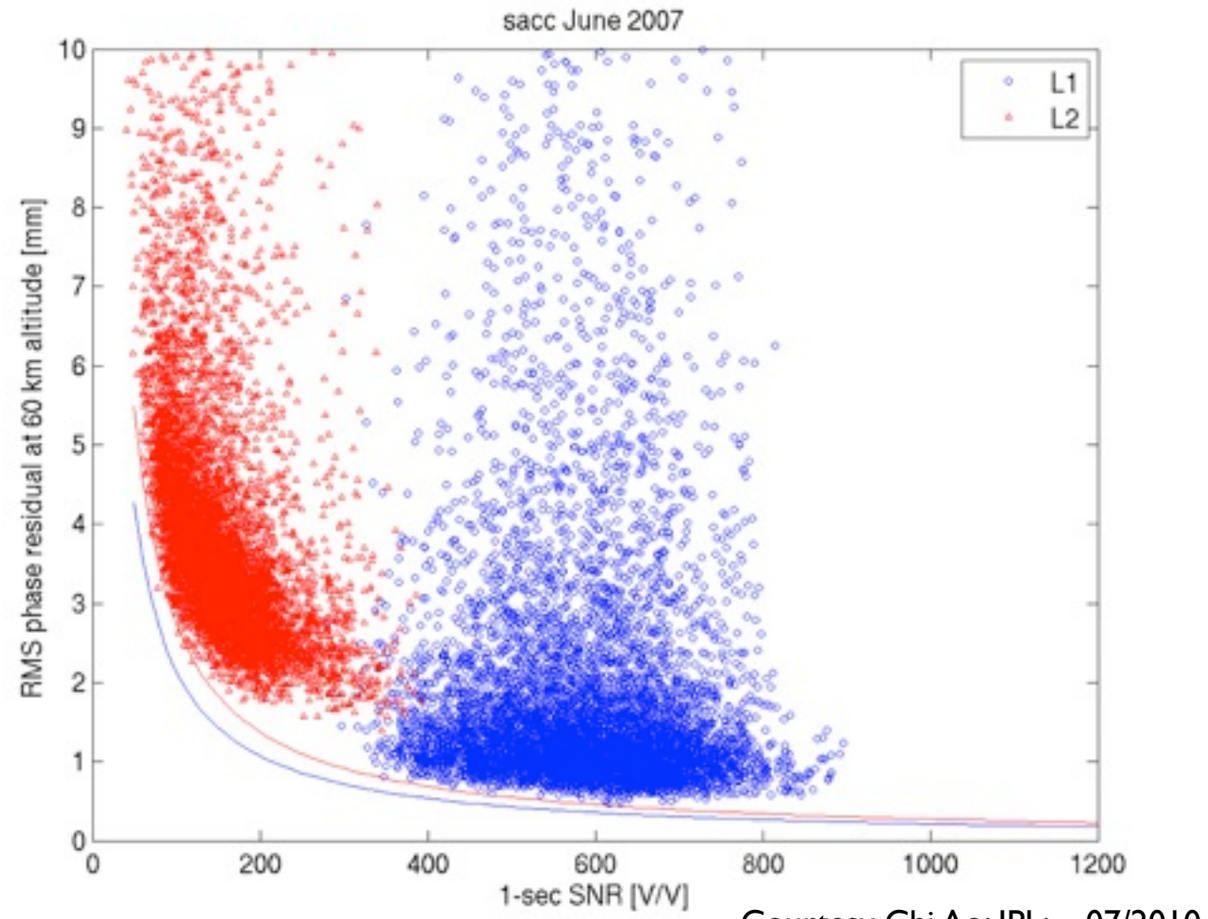
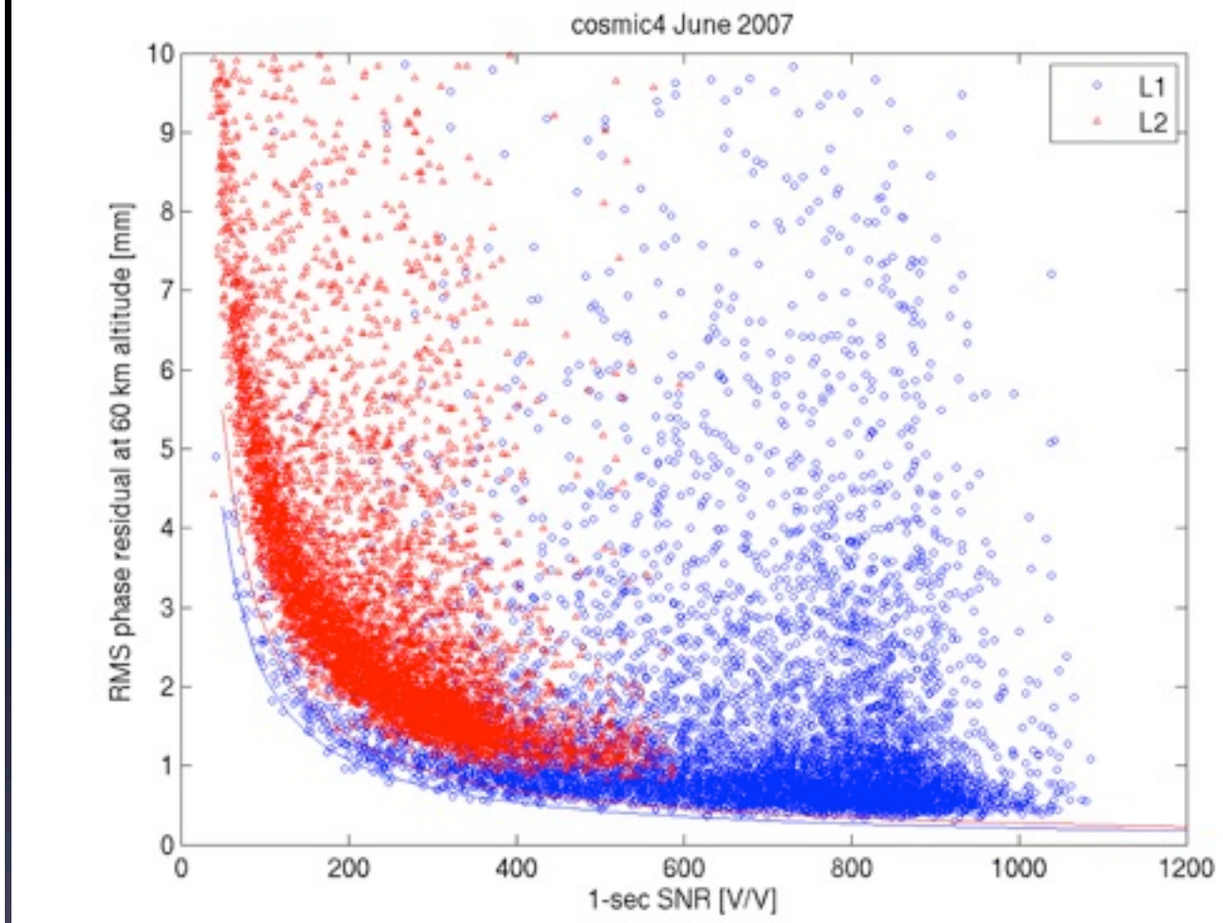


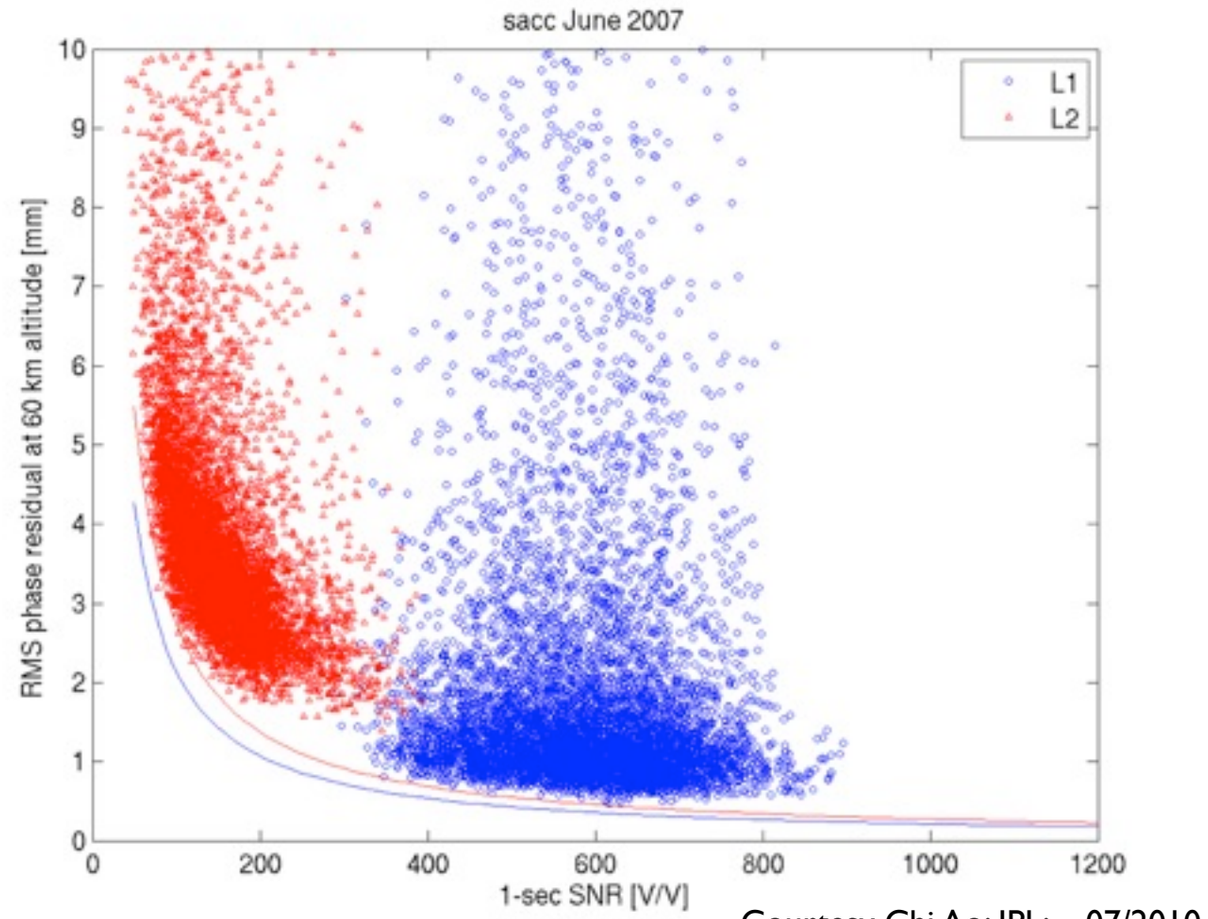
Same Instrument, Different Antennas





Courtesy Chi Ao: JPL; 07/2010

Same Instrument, Different Antennas



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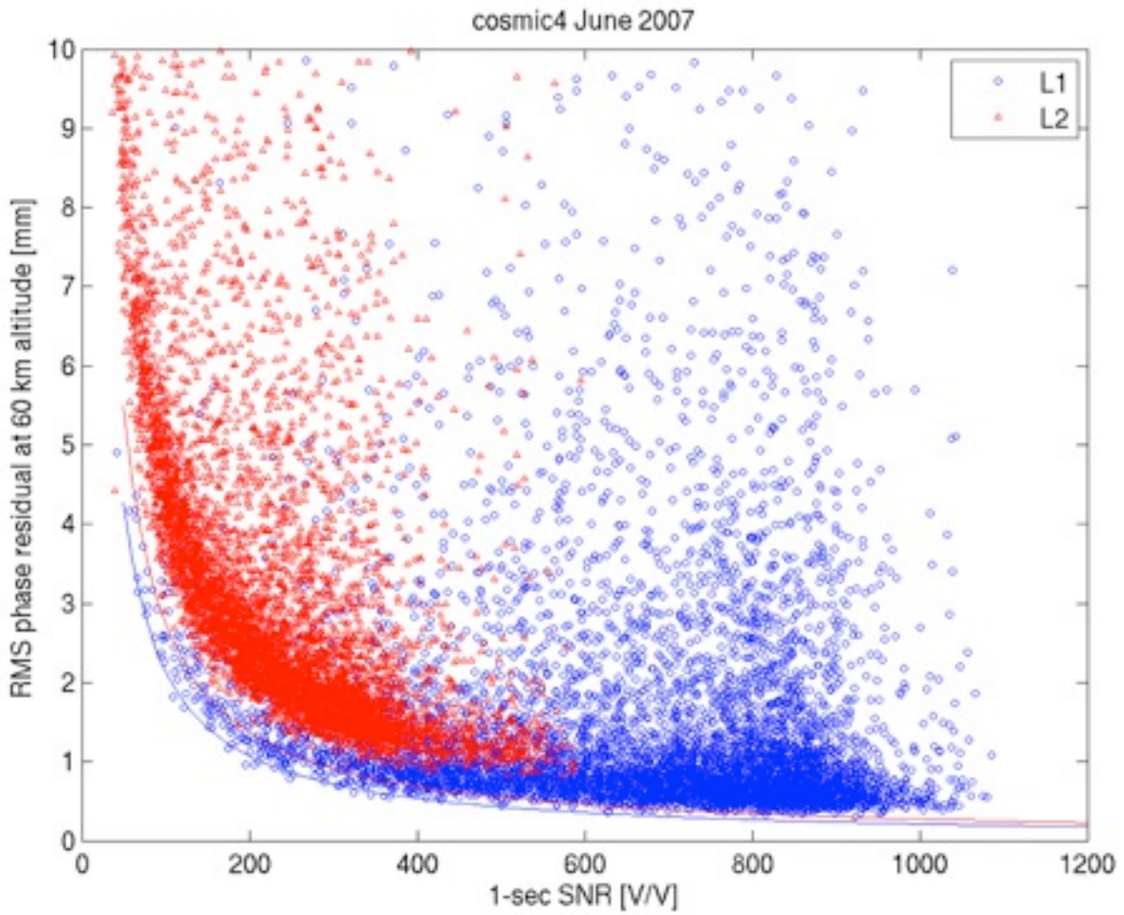

delta_alpha [rad] ~ delta_doppler [km/s] / v [km/s]

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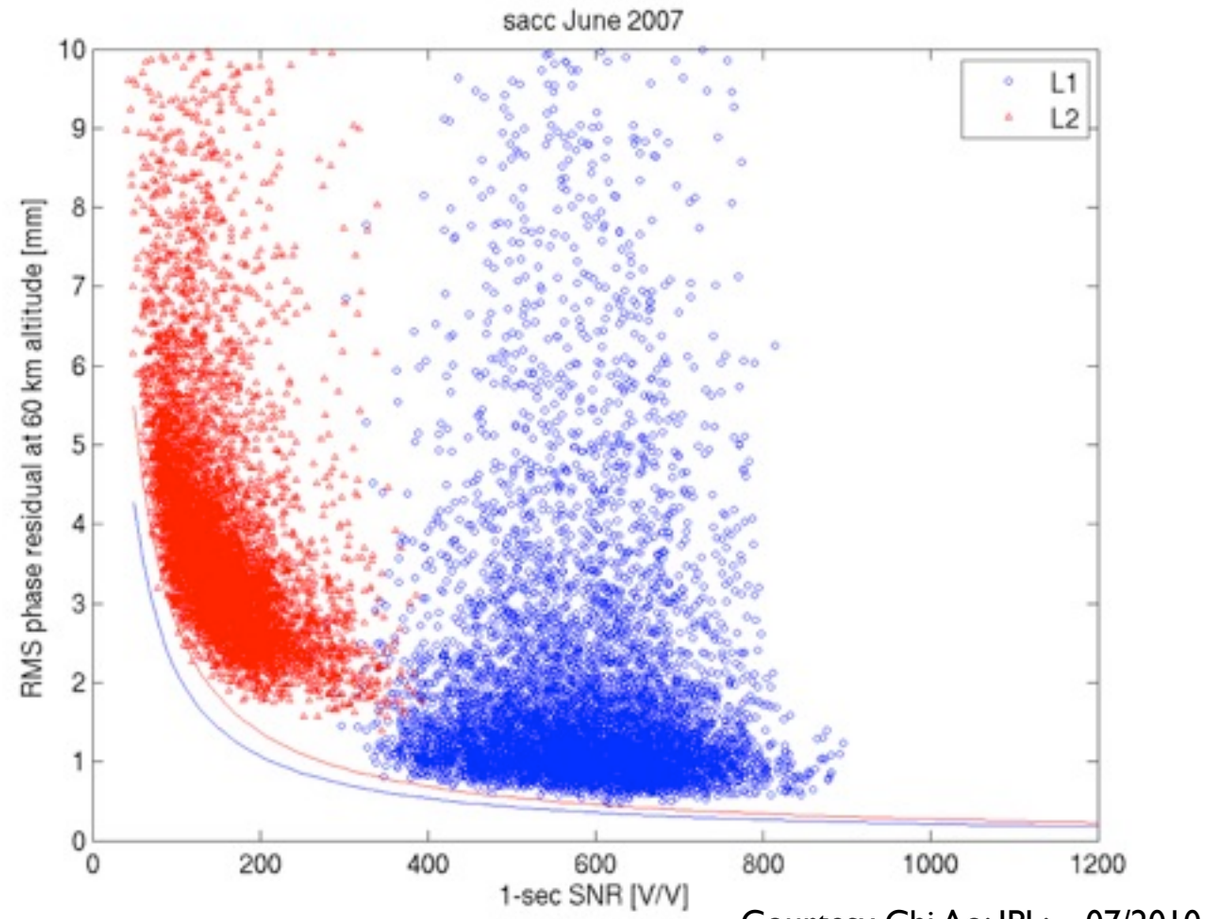
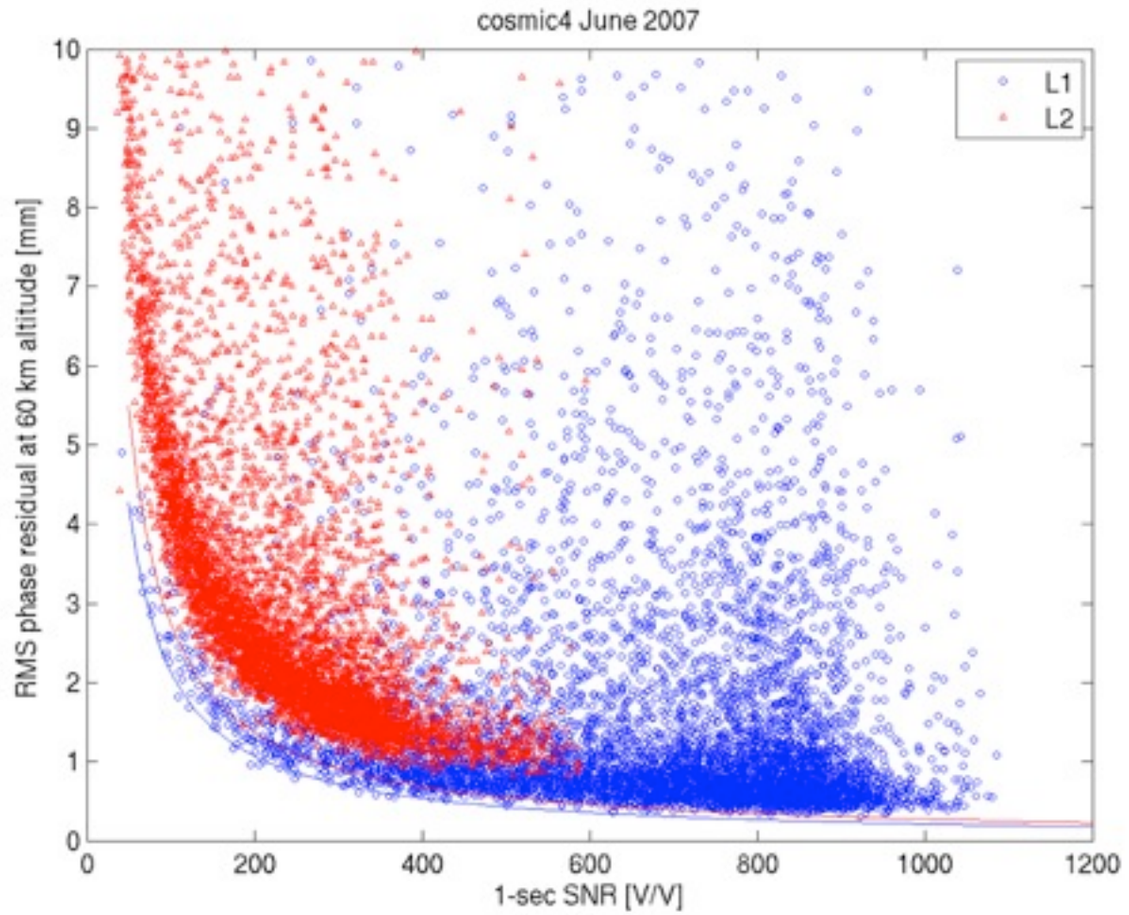
California Institute of Technology

Same Instrument, Different Antennas



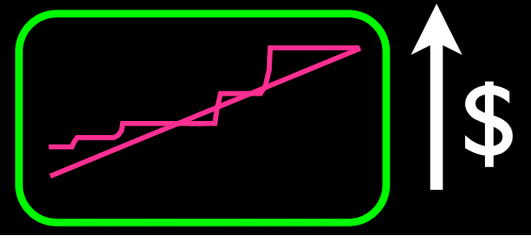


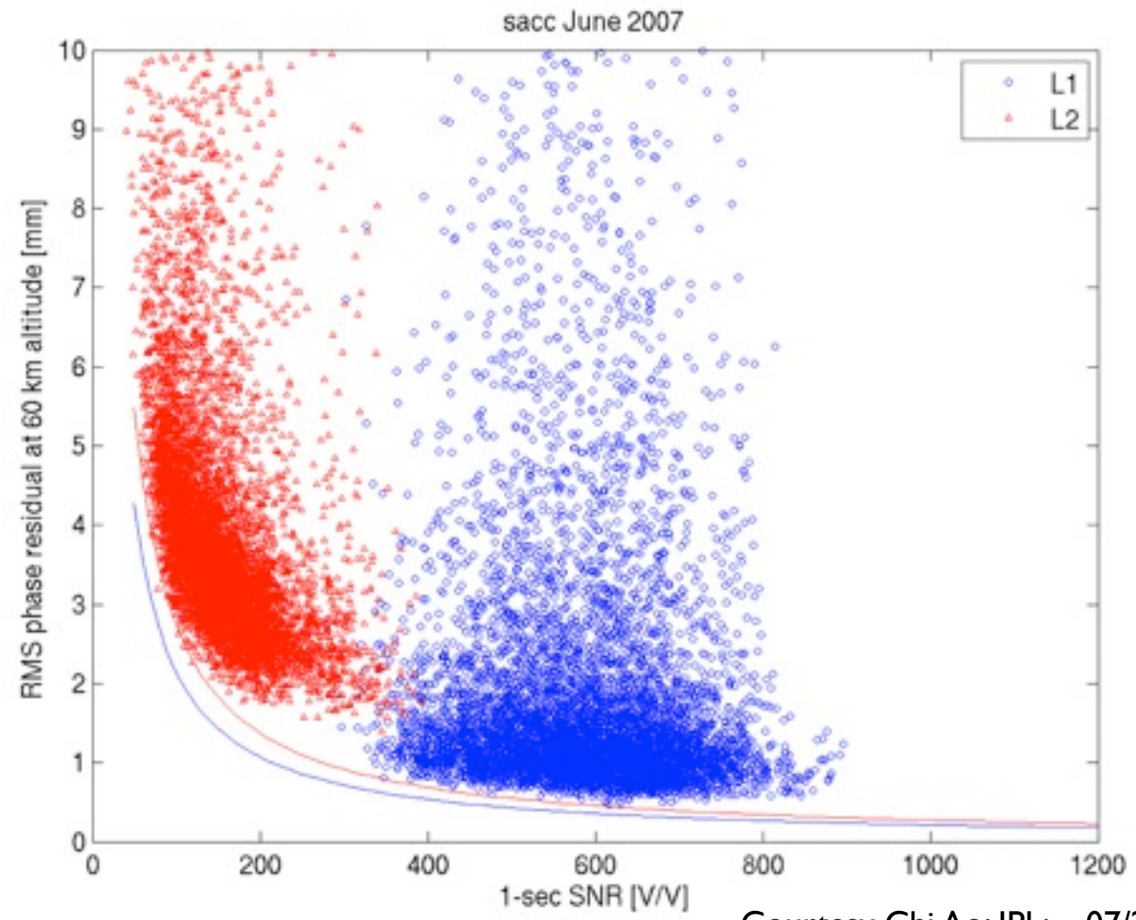
Courtesy Chi Ao: JPL; 07/2010

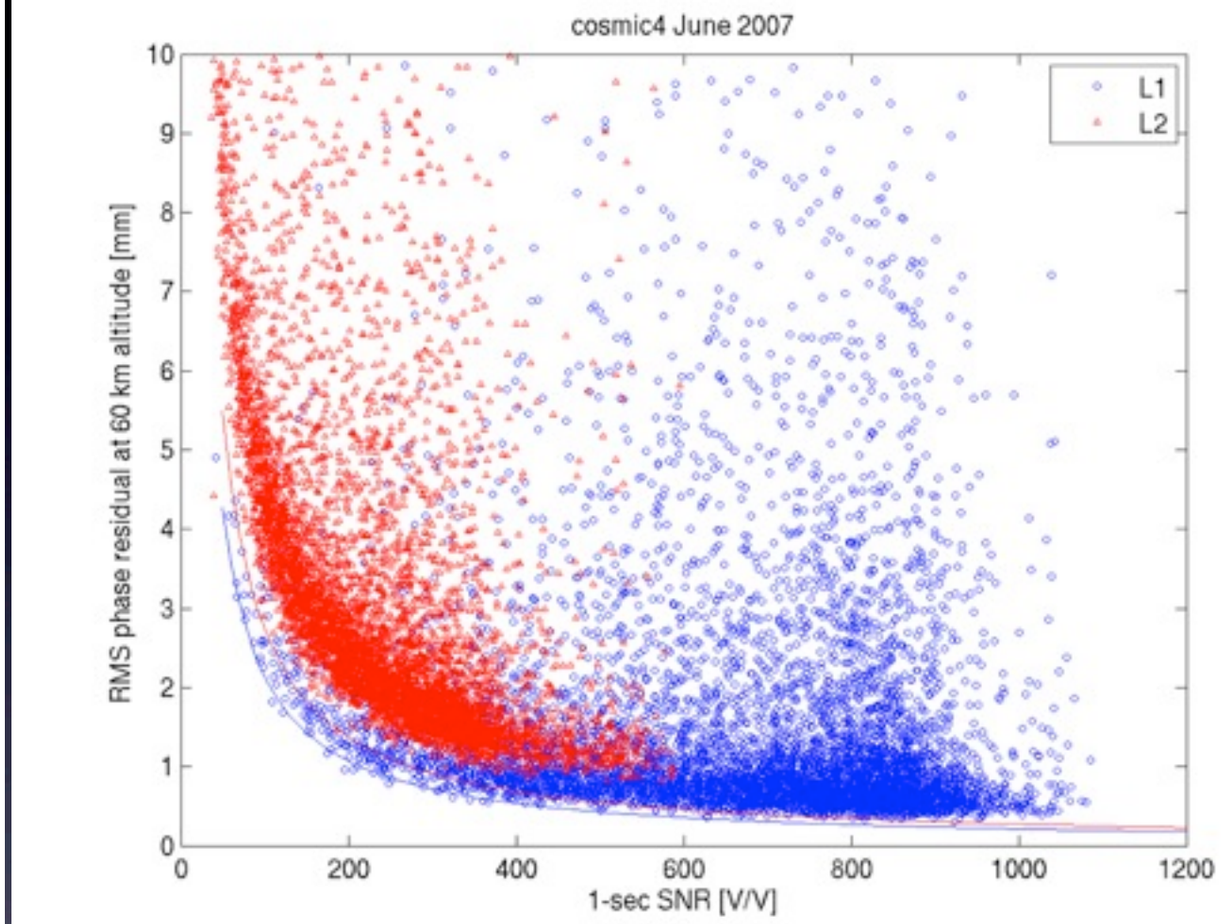
$$LC = 2.54L1 - 1.54L2$$

delta_alpha [rad] ~ delta_doppler [km/s] / v [km/s]

Same Instrument, Different Antennas







Courtesy Chi Ao: JPL; 07/2010

$$LC = 2.54L1 - 1.54L2$$

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Global Navigation Satellite System (GNSS) Radio Occultation Follow-on Operational Capability

Level 1 Requirements Document - Preliminary

Version: 2.0 Final

May 27, 2010

U.S. Department of Commerce (DOC)
National Oceanic and Atmospheric Administration (NOAA)
NOAA Satellite and Information Service (NESDIS)

5.4.1 Data Processing

5.4.1.1 The GNSSRO Follow-on Capability shall receive raw satellite data from the ground stations and transform it into geophysical parameters and derived data products as defined in 5.1 through the mission duration.

5.4.1.2 The GNSSRO Follow-on Capability shall provide quality control processed data and products that meet or exceed the defined data quality requirements in 5.1 and data sampling requirements in 5.2.

5.4.1.3 The GNSSRO Follow-on Capability shall format the data products into image and data file formats.

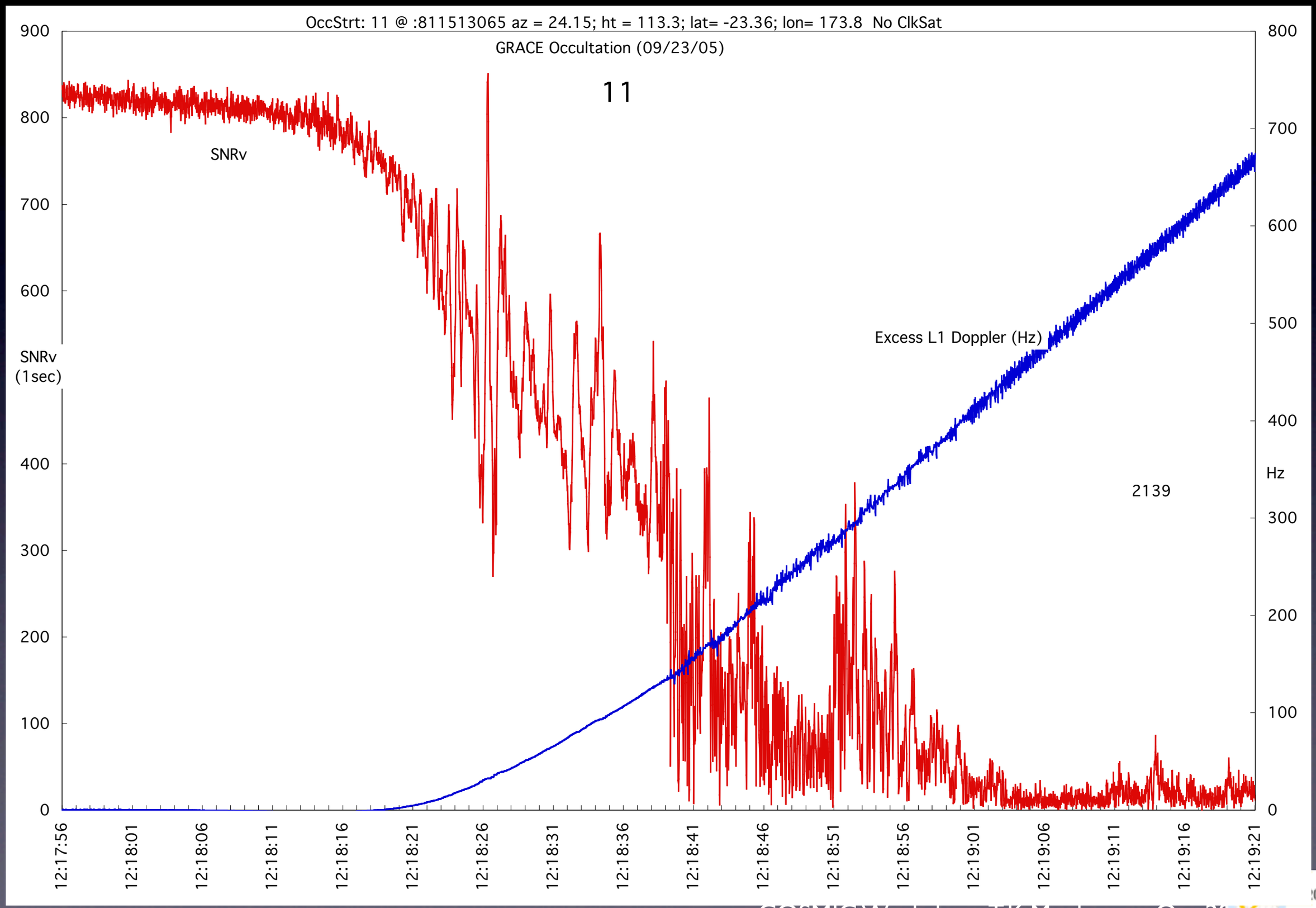
5.4.1.4 The GNSSRO Follow-on Capability shall provide at least 70% (threshold) or 90% (objective) of the collected raw neutral atmosphere data as processed quality-controlled data products. For ionosphere EDP data, the corresponding values are 75% (threshold) and 90% (objective).

5.4.1.5 The GNSSRO Follow-on Capability shall provide at least 85/65% (in regions outside/within 30 deg N or S latitude) (threshold) or 90/70% (objective) of the raw refractivity and bending angle data profiles as quality controlled profiles down to within 1 km of the Earth's surface. At that altitude the profiles shall achieve 2.5/4.0% standard deviation relative to state-of-the-art numerical weather prediction models (NOAA Global Forecast System and European Center for Medium-range Weather Forecasts)

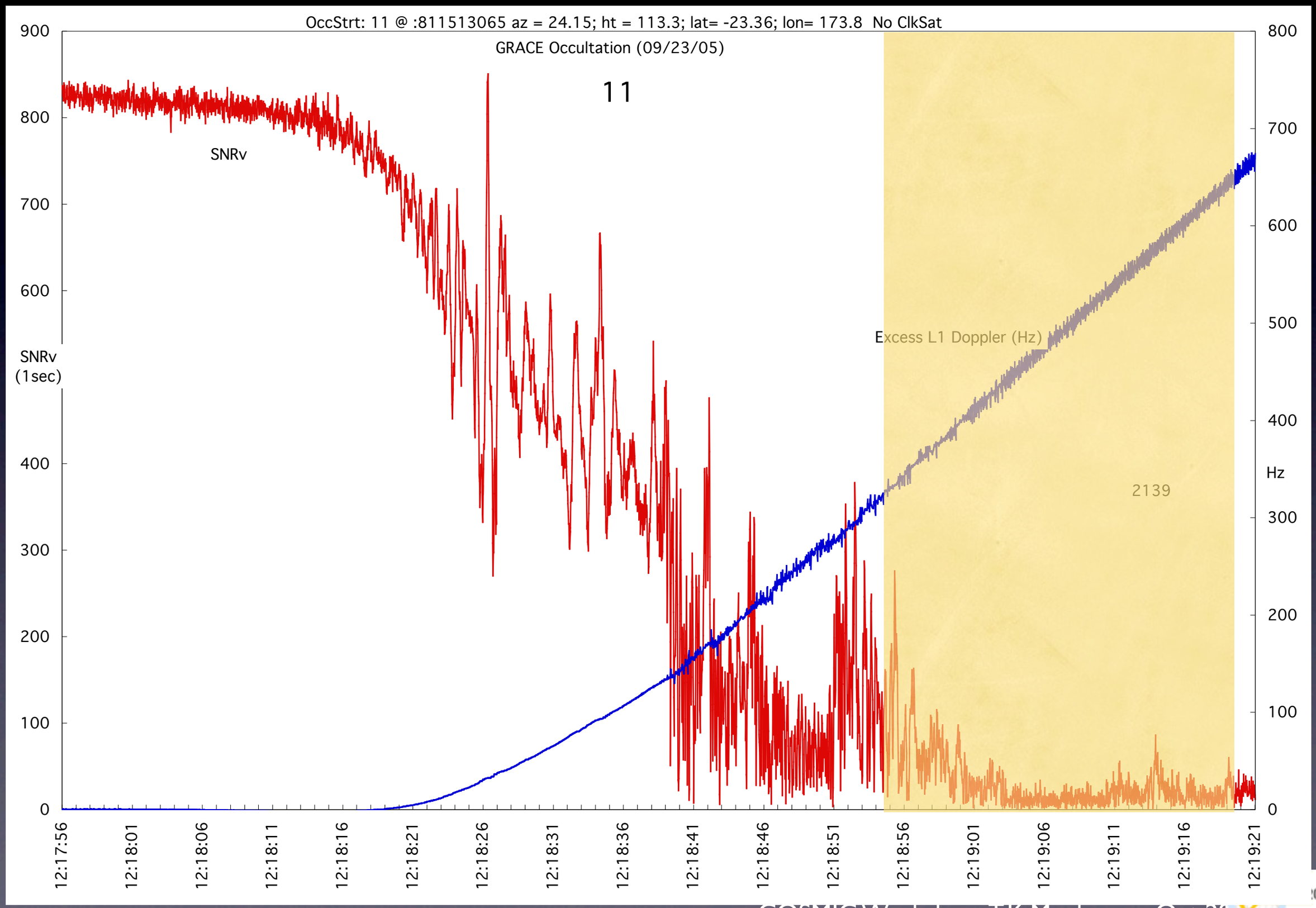
5.4.1.6 The GNSSRO Follow-on Capability shall provide for compatibility with all the current COSMIC ground processing capabilities – Taiwan Mission Control Center, NOAA ground stations, COSMIC Data Analysis and Archival Center,

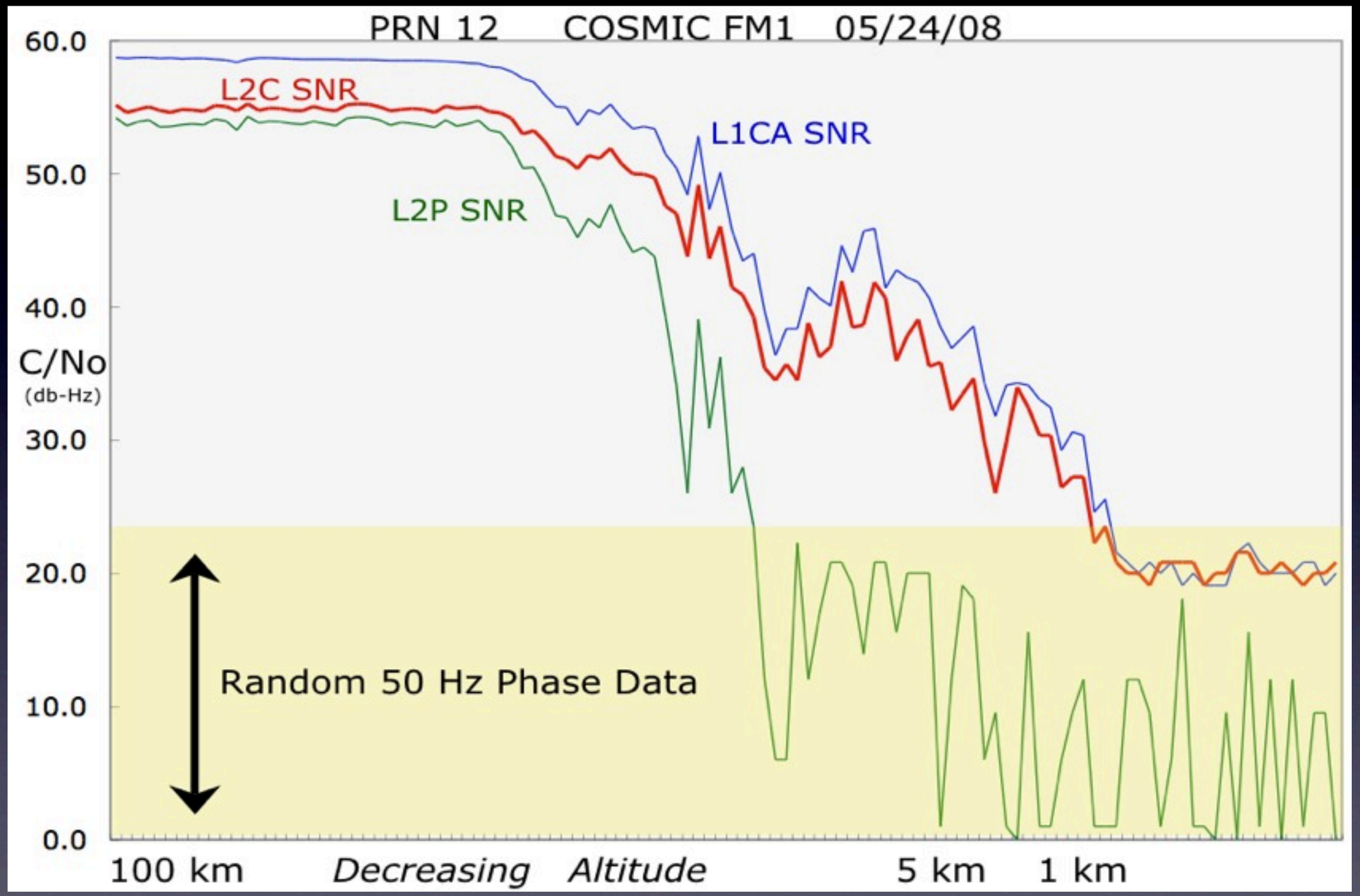
Requirements Sampling

Requirements Sampling



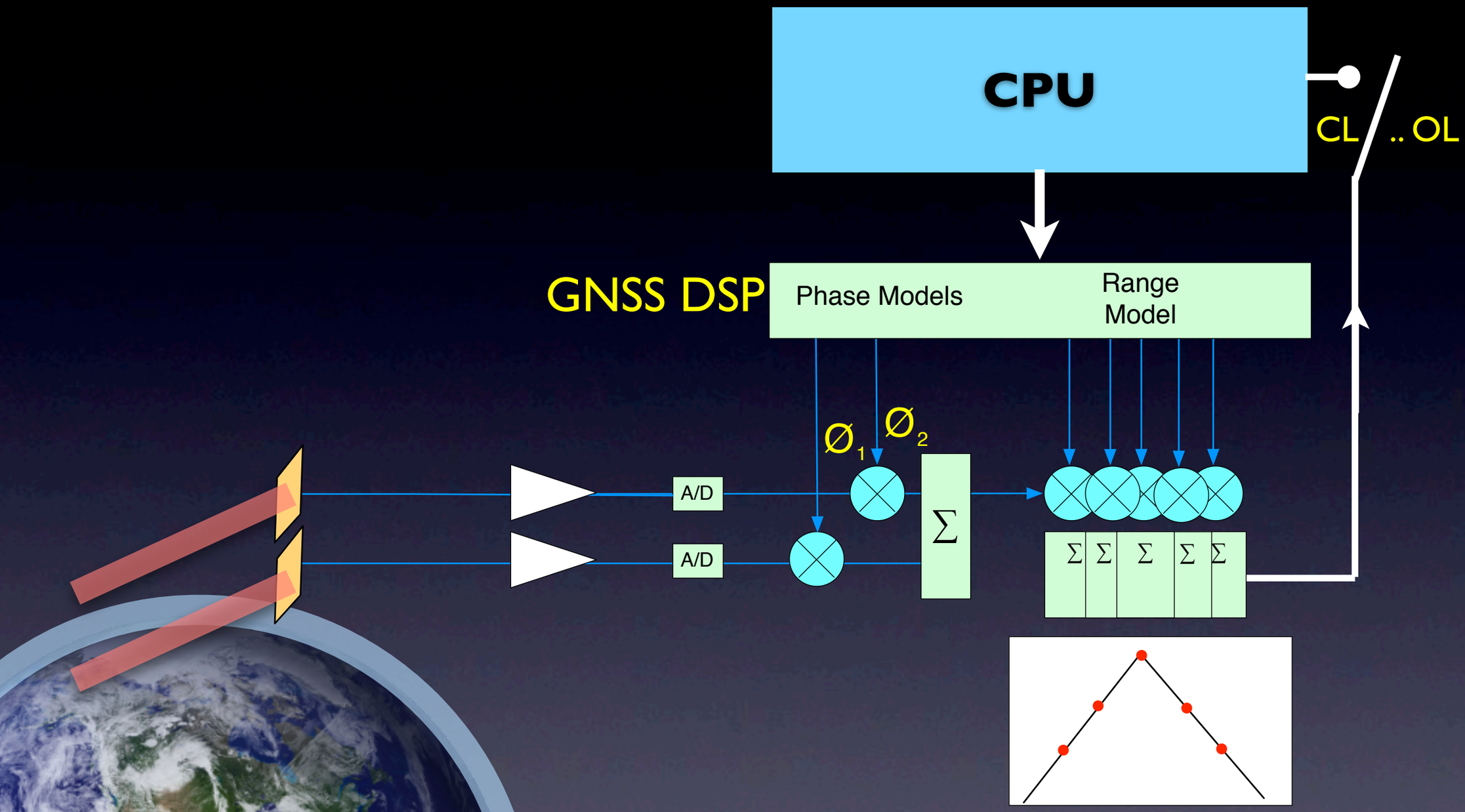
Requirements Sampling



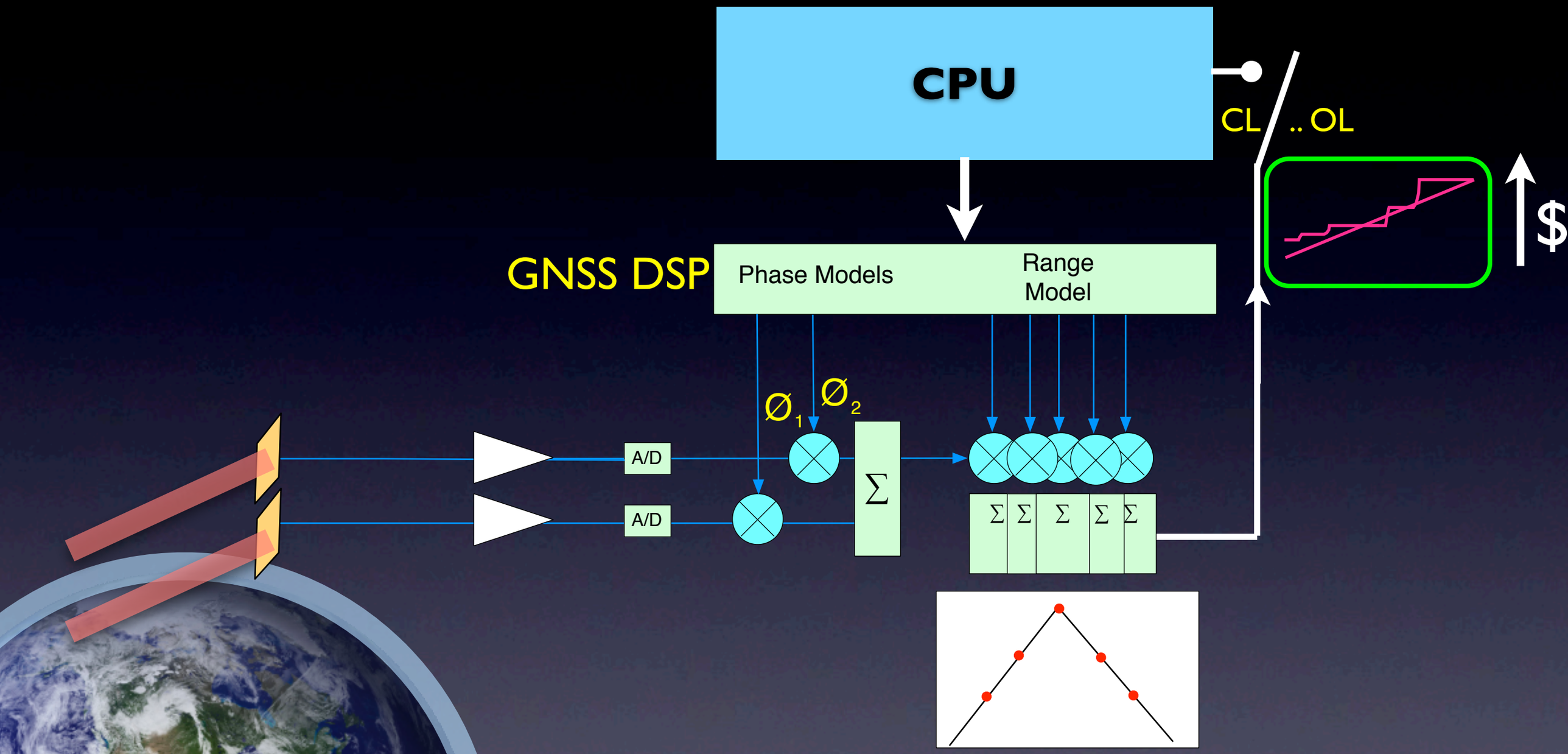


Meehan etal; Institute of Navigation Proceedings Sept 2008

Processing for a Single Occultation



Processing for a Single Occultation

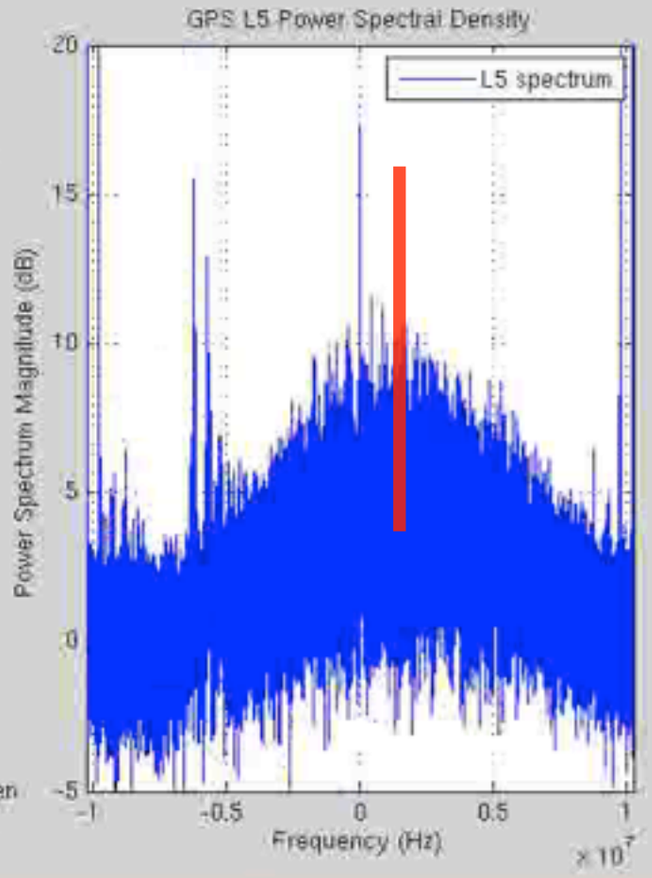


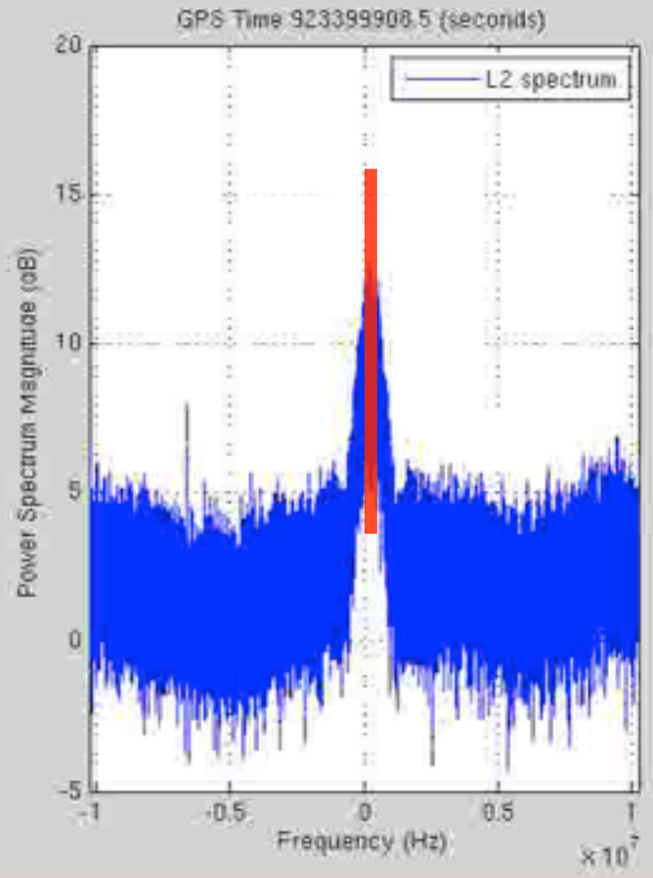
GPS L1/L2/L5 spectra captured for SV49 at 11:58:14 (UTC) 10 April 2009 during the GPS L5 turn-on event

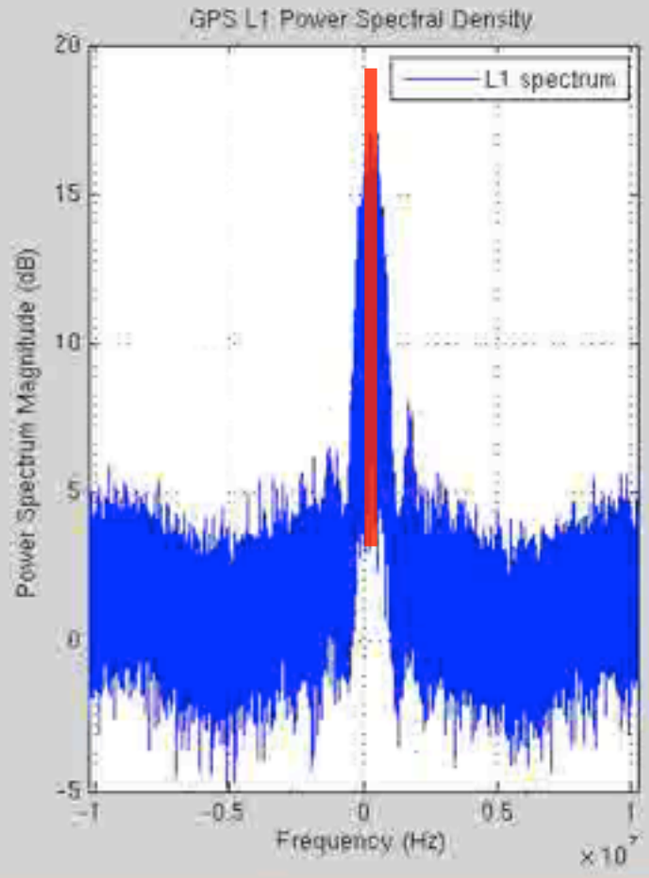
3 meter antenna used at JPL in Pasadena, CA, USA

20MHz complex samples captured with JPL's TOGA receiver and post-processed in MATLAB

Stephan Esterhuizen
Larry Young
Caltech/JPL 2009







Summary

- TriG .. |trig| (~~Triple G~~ ; ~~Tri-G~~)
  Development In Early Stages; EM in 2 yrs
- Requirements Generation for Neutral Atmosphere (Weather & Climate) and Space Weather Underway
- Modernized GPS & Galileo Baselined; GLONASS FDMA Feasible to Add
- Specialized Signal Processing for Lower Troposphere
- USO under consideration