

Development Status of NASA's TriG GNSS Science Instrument

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Topics

- Heritage, Architecture, Some Req.
- Development Progress
- Basic SWAP Features
- More on the power numbers
- Using the Science Processor

Heritage with IGOR / BlackJack



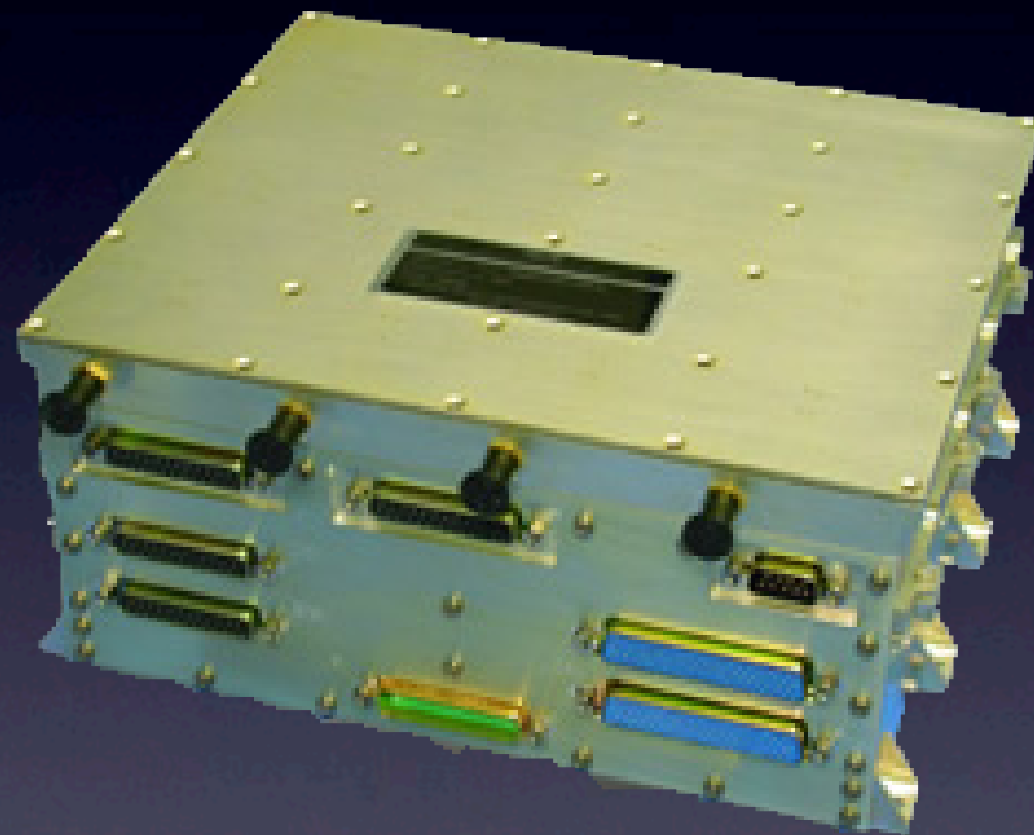
22x20x11 cm

~20W...

15 kRad?

4 antennas L1 & L2

~4kg + Ants



TriG GNSS Receiver

Next Generation GNSS Science Instrument

Precise Orbit Determination (POD)

GNSS Radio Occultation (GNSS-RO)

Neutral Atmosphere, Ionosphere, and Scintillation

GNSS Reflections (GNSS-R)

Developed in collaboration with Broad Reach Engineering (BRE)

Upcoming missions:

COSMIC-2, DESDynI, ICESat-2, Jason-CS, SWOT, DSAC, GRACE-FO, and other NASA/NOAA missions

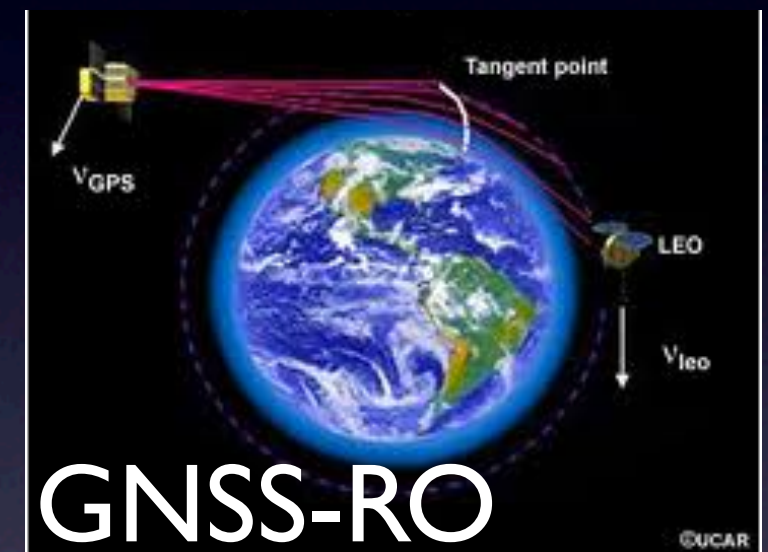
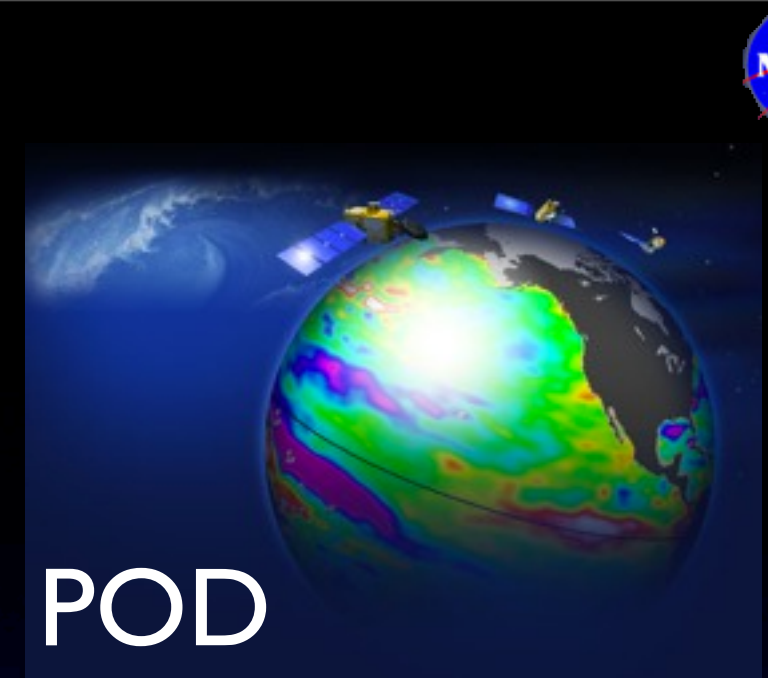
Key mission needs:

Track many more GNSS signals...

Higher SNR (particularly for RO and reflection)

Higher reliability to meet mission critical reqs

Greater flexibility to accommodate future requirements



Requirements Sampling

Table 5-1: Neutral Atmosphere Product Requirements

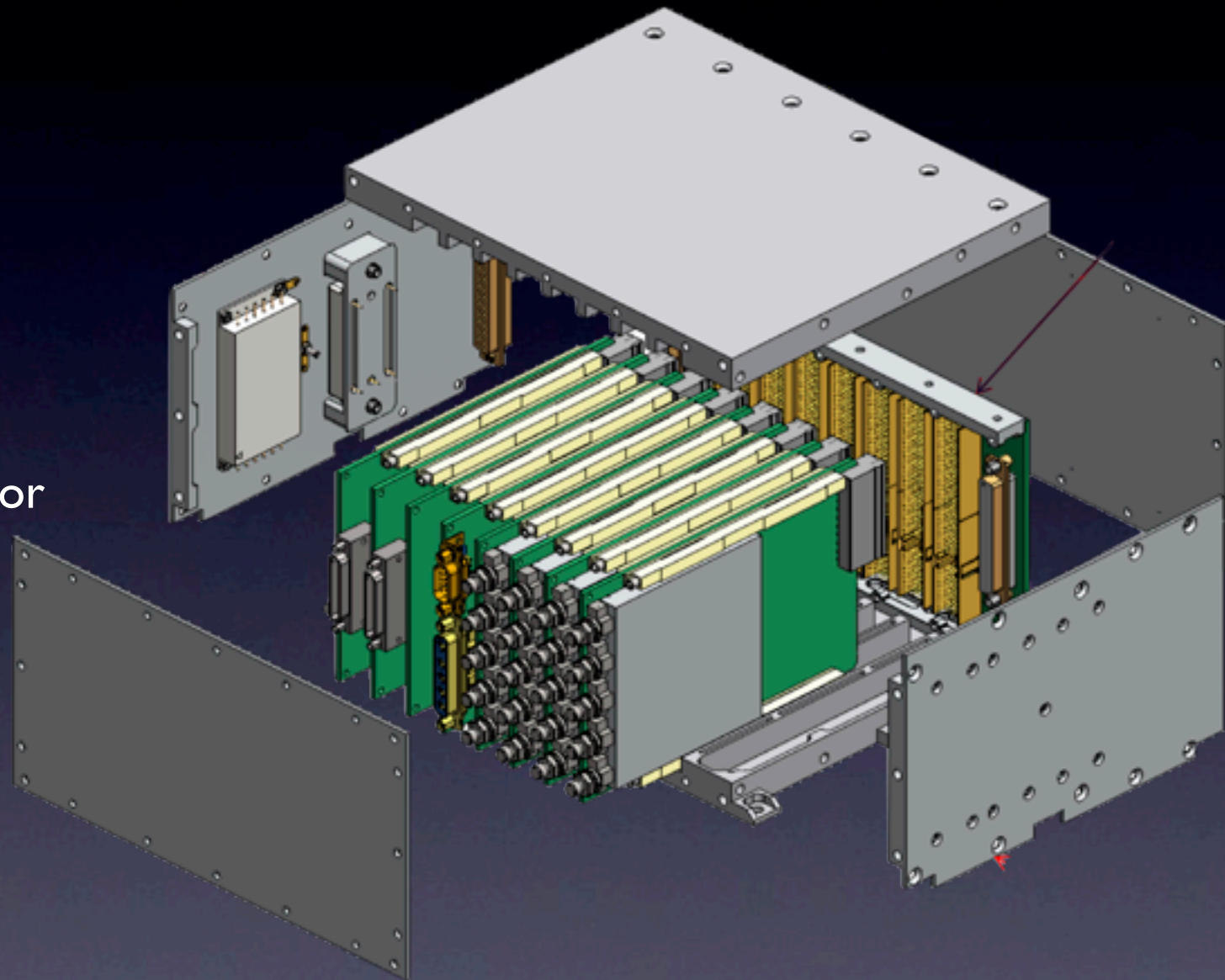
Data Type	Threshold	Objective
Common Requirements for all Neutral Atmosphere Product Types		
5-1.1. a. Number of Profiles per day**	8,000	10,000
b. Corresponding avg. number/location/day	4	5
5-1.2. Vertical Data Resolution [km]		
a. Altitude Range 0 – 25 km MSL	0.1	0.1
b. Altitude Range 25 – 60 km MSL	1.0	1.0
5-1.3. Average Latency [minutes] Hi/Lo Incln 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

Requirements & Design Trades



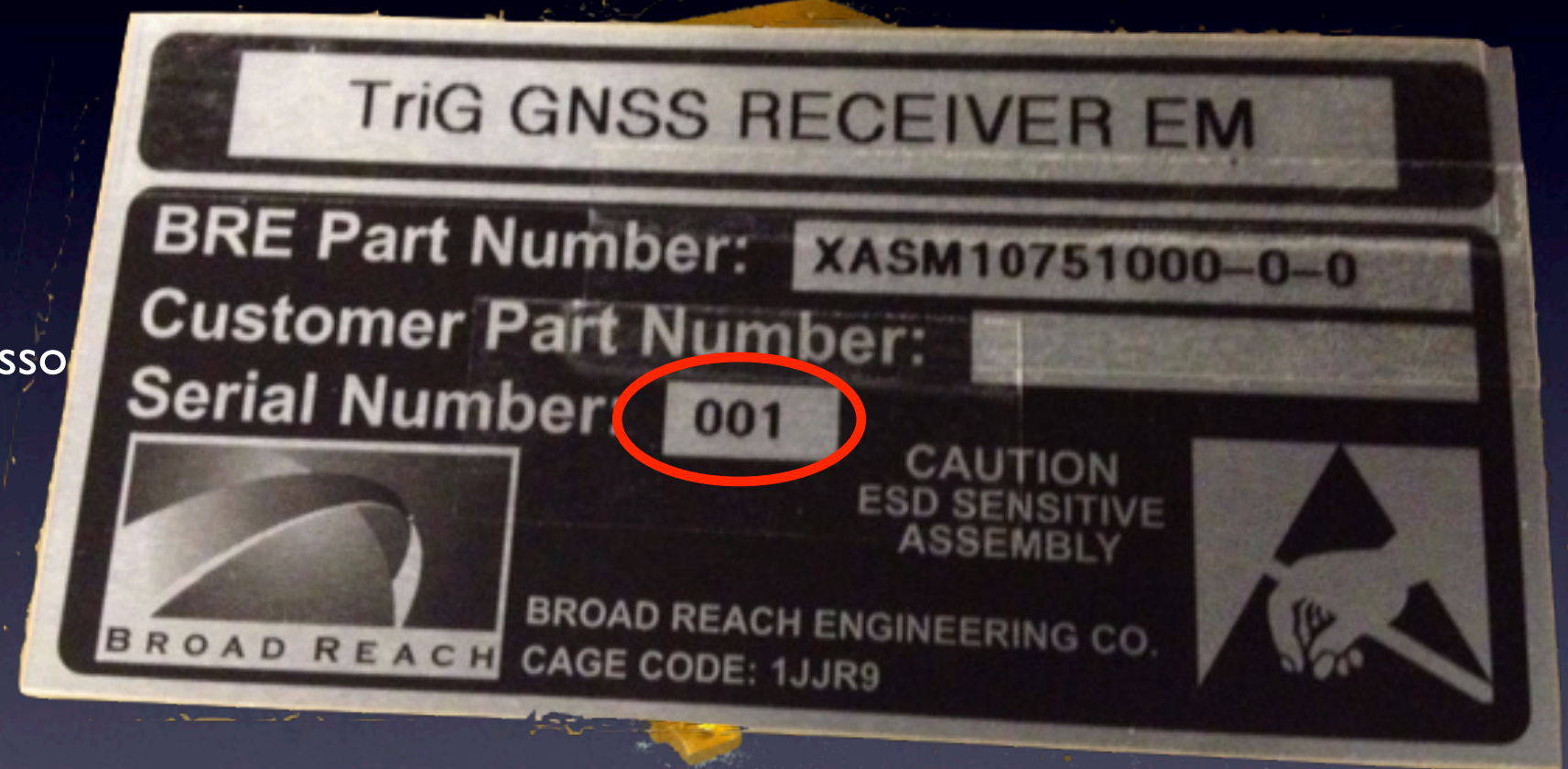
3U cPCI Design

- Up to 16 Antennas
- Nav-POD Processor
- Science CPU (Linux)
- Science Digital Signal Processor
- Oscillator



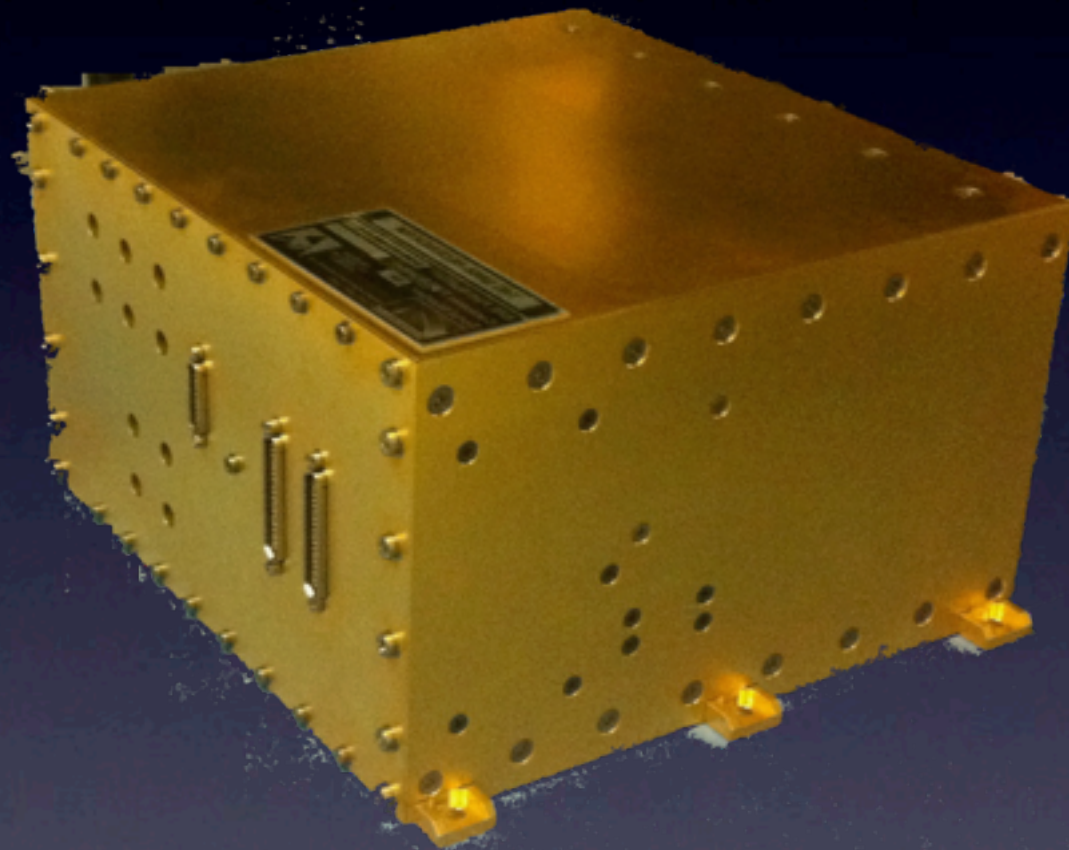
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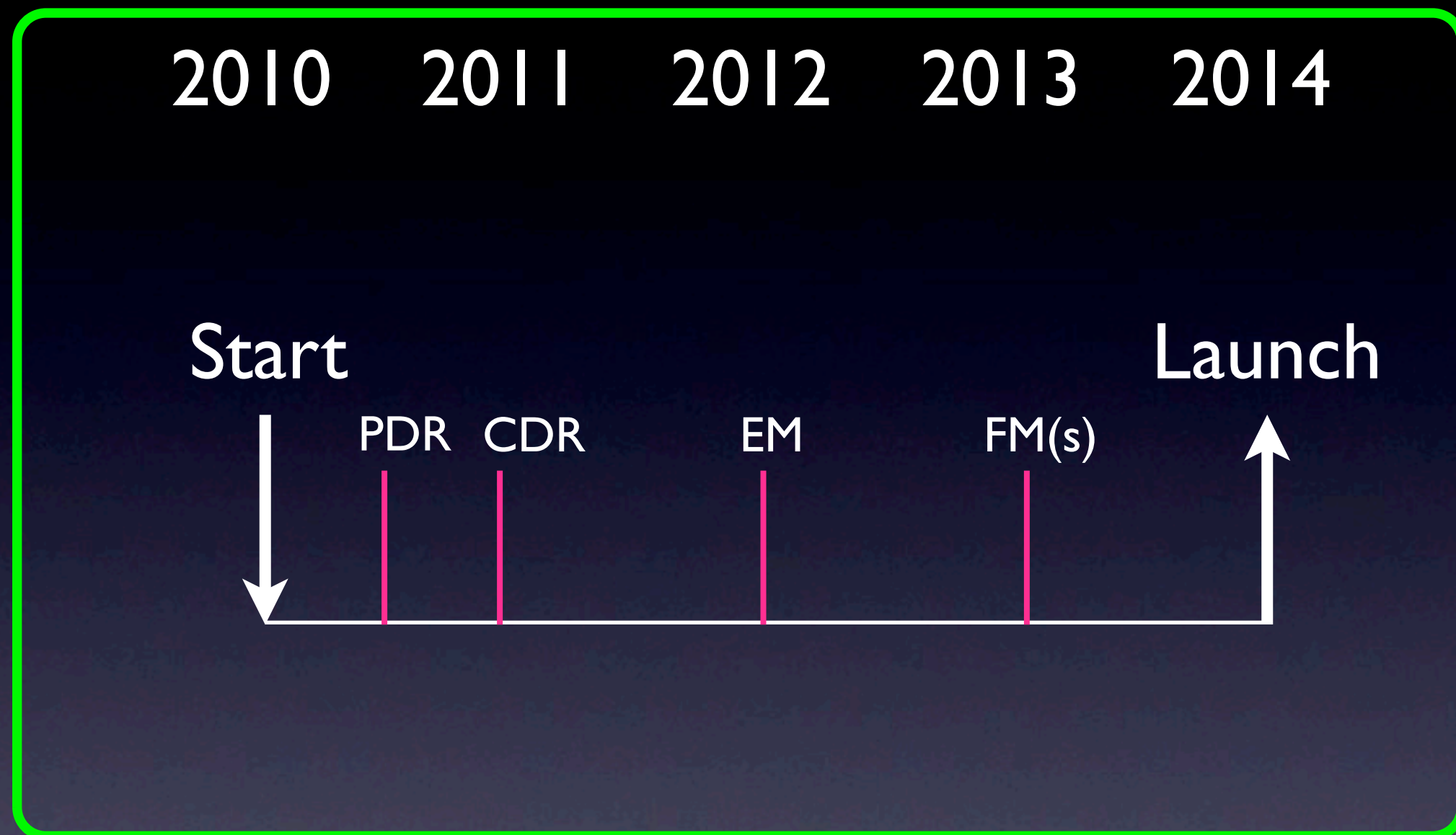


3U cPCI Design

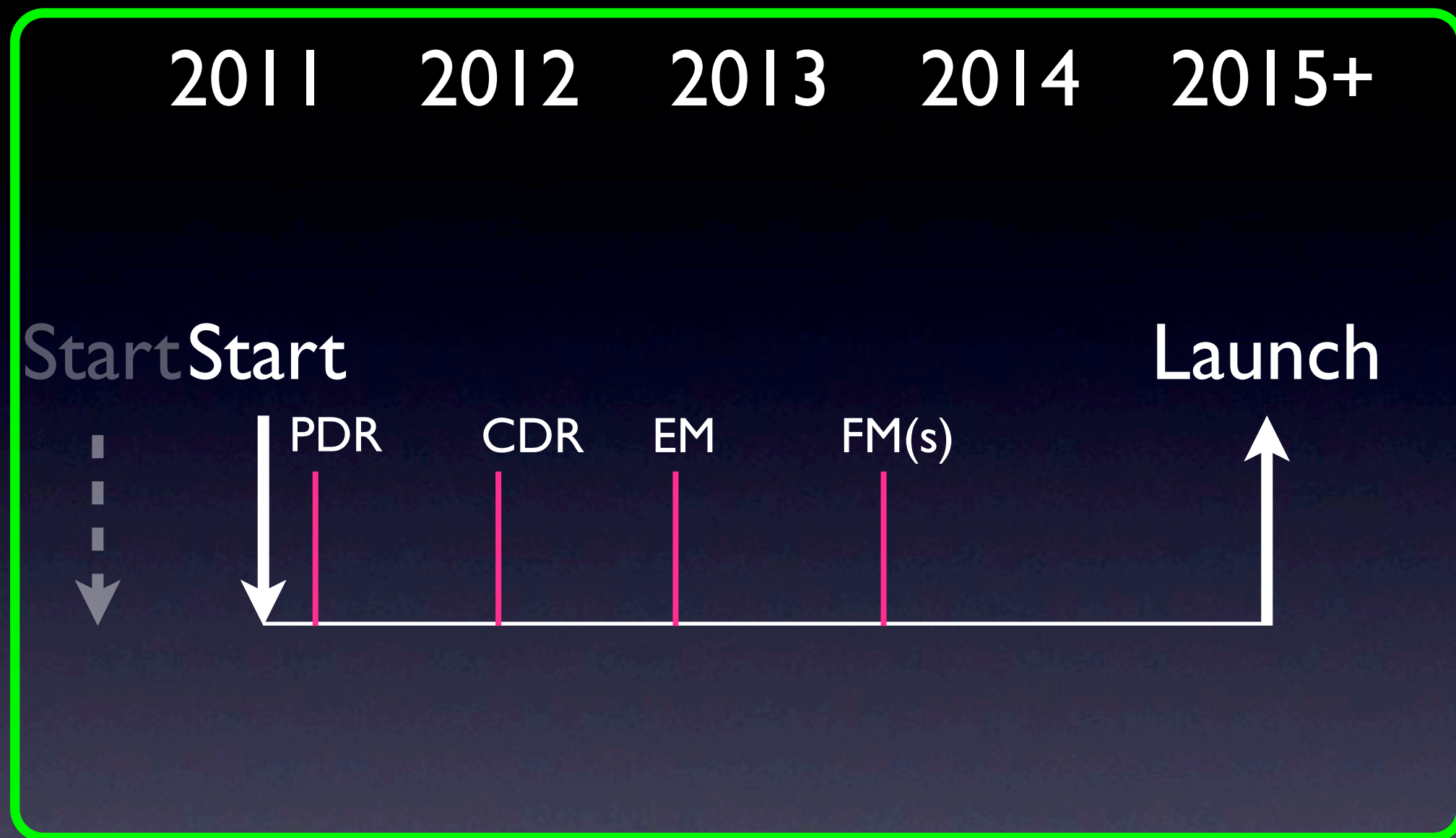
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Task Schedule (IROWG-1)

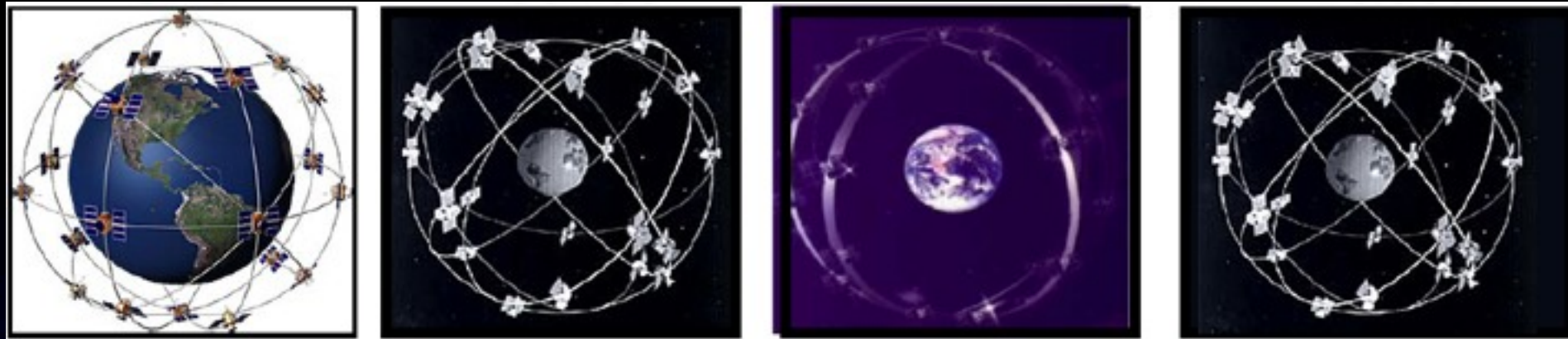


Task Schedule (IROWG-2)



Design Requirements Trades

Receive All GNSS Signals



Wide bandwidth RF Downconverter capable of receiving all GNSS signals:

GPS, Galileo, GLONASS, Compass

Other navigation signals (QZSS, DORIS, etc)

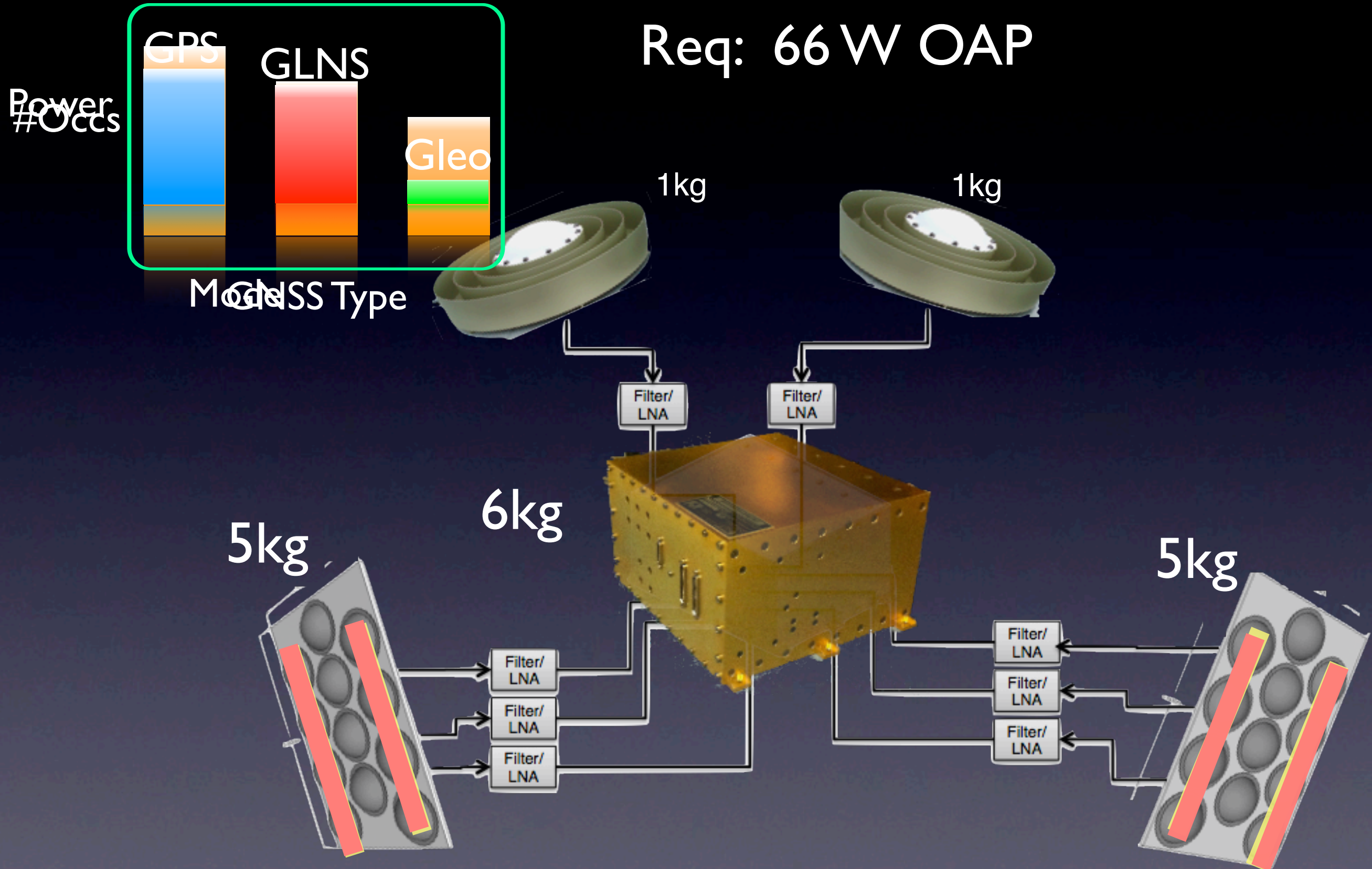
TriG will track both legacy and new GPS signals:

Uninterrupted multi-frequency GPS tracking service through 2020 retirement of semi-codeless

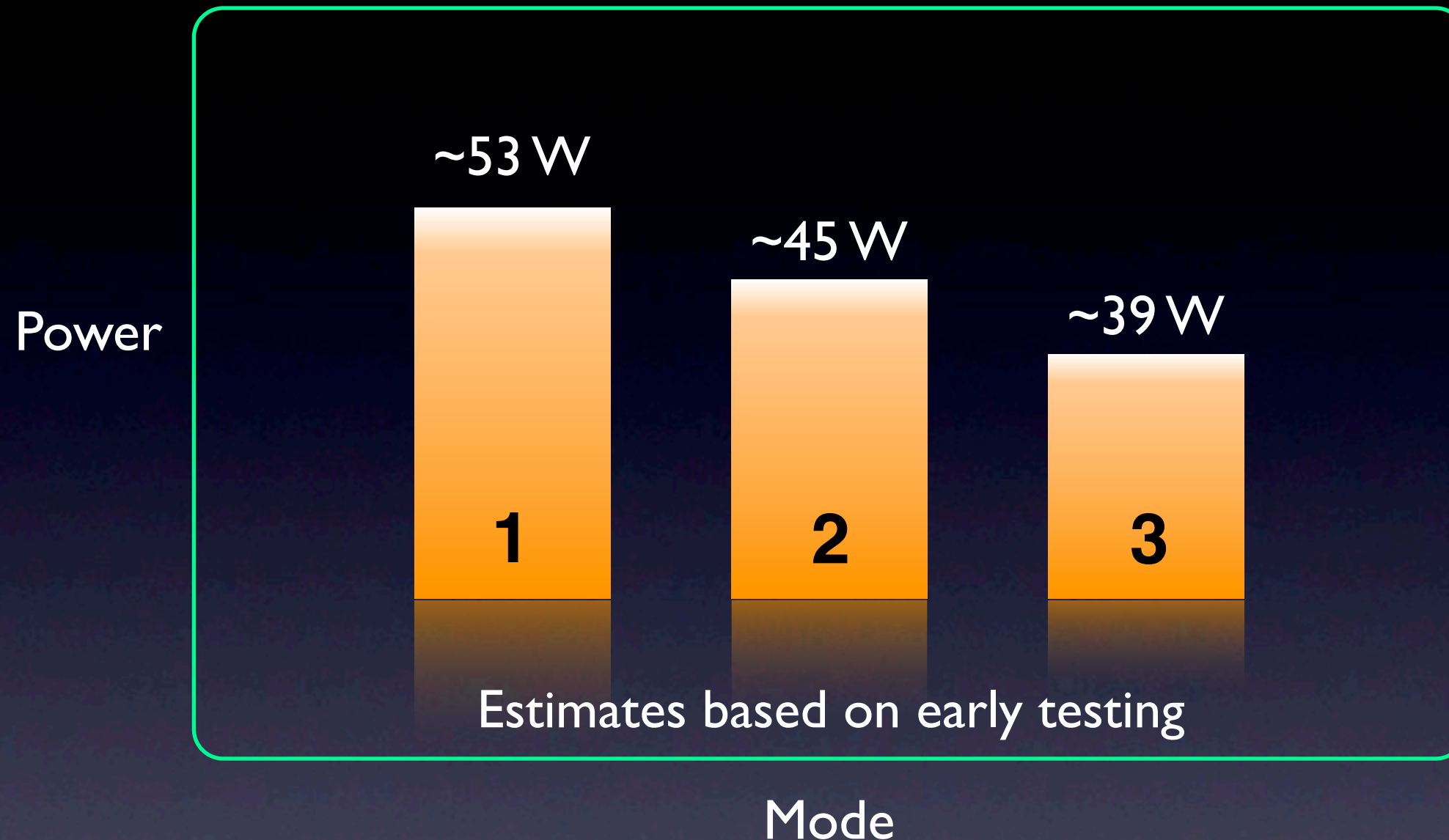
Tracking more GNSS signals will improve both POD and the quality and quantity of the measurements from RO and surface reflection observations.

Mass, Power, Dimensions

Req: 66 W OAP



Power Flexibility



- Mode 1: Full-time beam-forming; GPS+GLONASS; Full RO DSP
- Mode 2: Limit beamforming to LI; Reduced RO DSP
- Mode 3: No beamforming; GPS + Galileo only

Better Signal Processing



- *Multi-Lag Processing:*
 - Allows use of a spread of range and Doppler models so that rising signals can be reliably captured for atmospheric occultation

- *Time Delayed Processing:*
 - Large buffer memory for sample data storage allows occultation data to be processed after receiving more accurate models of SC geometry and oscillator behavior from the Navigation processor.

- *Open Loop Tracking*
 - Generate data from signals below the threshold for closing tracking loops

Better Signal Processing

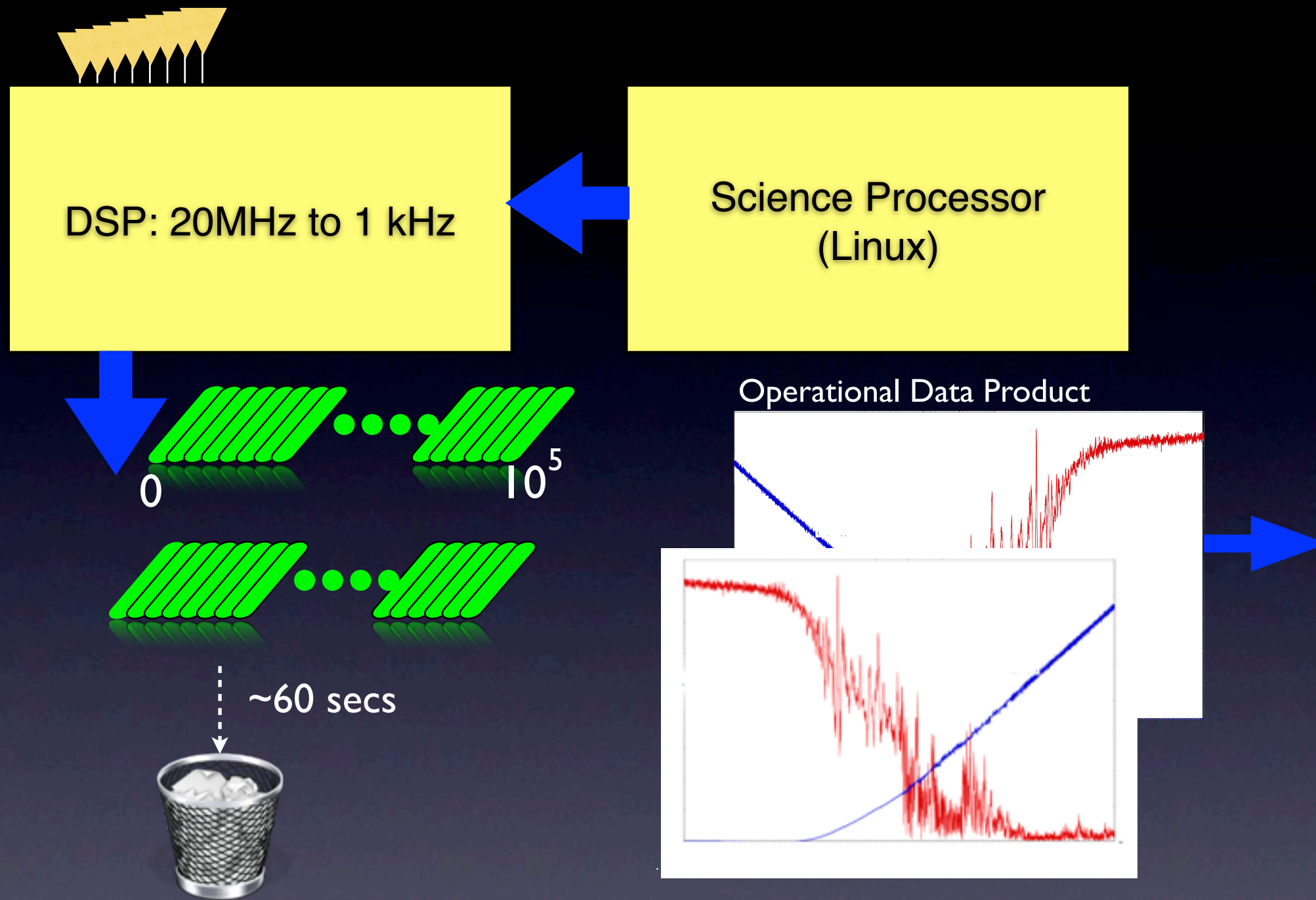


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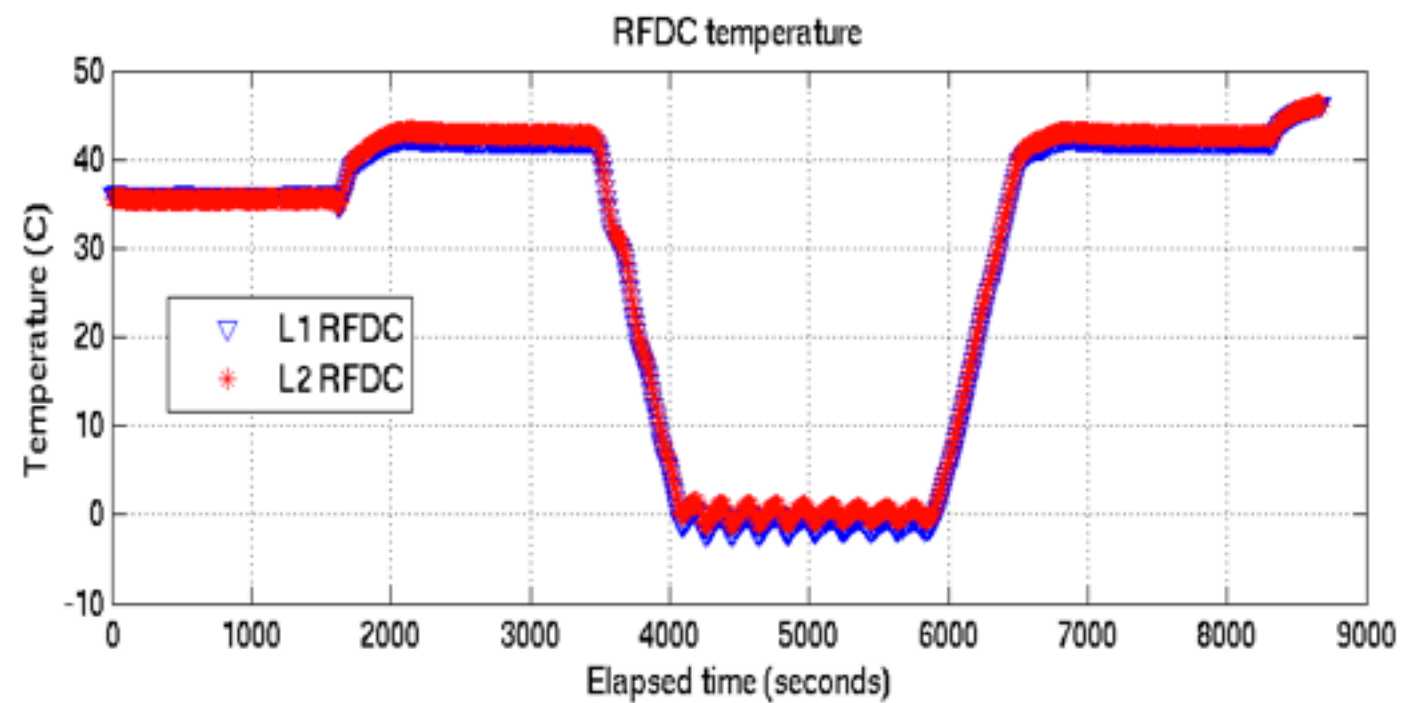
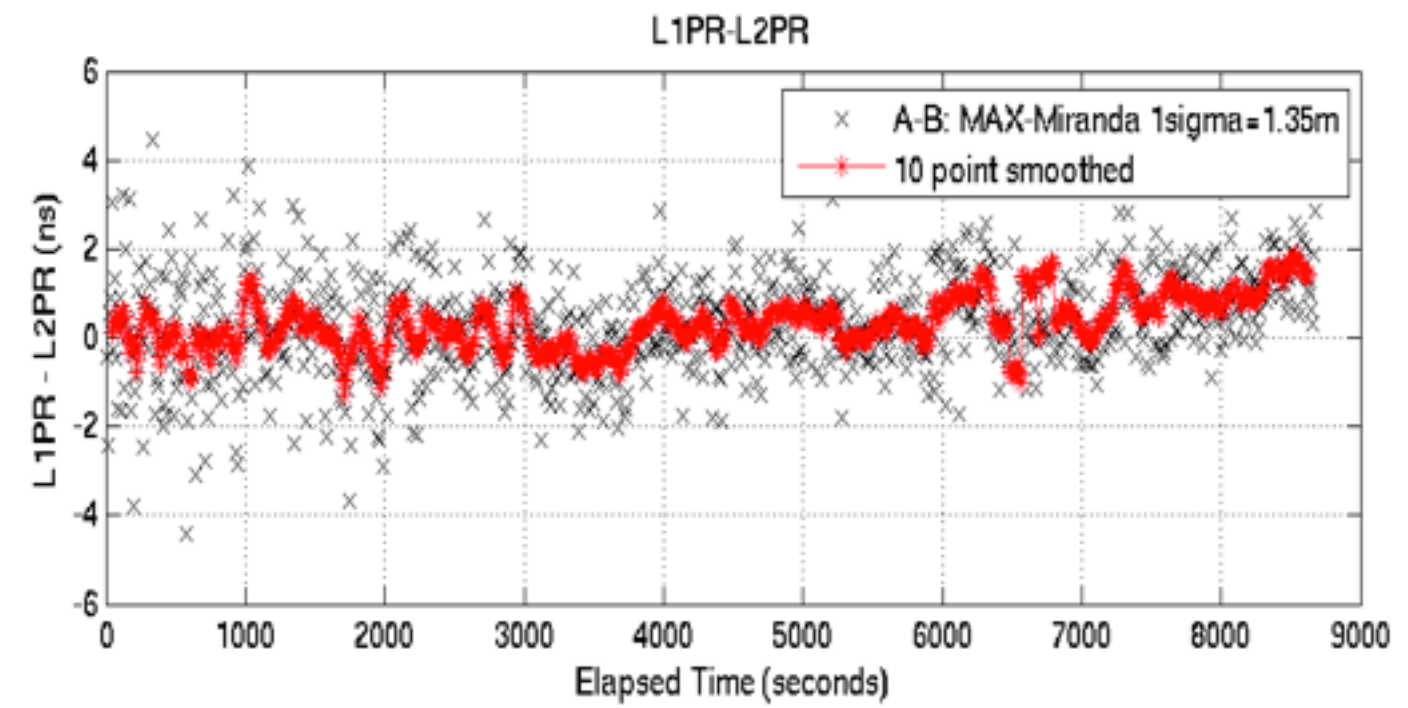
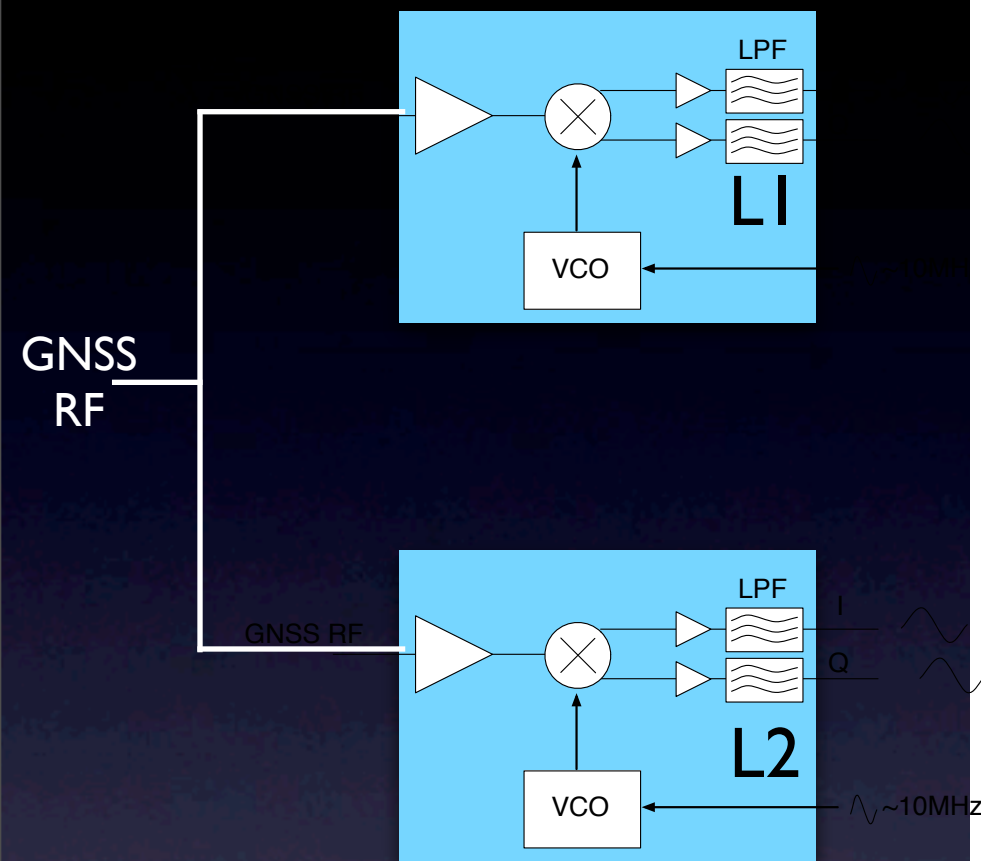
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Better Signal Processing



Other Initial Testing

Stability for Absolute & delta-TEC



Frequency Reference

- Internal Ovenized Crystal Oscillator (OCXO)
 - $< 3\text{E-}12$ (1 sec) for 1 sec clock differencing
 - $< 6\text{E-}11$ (0.01 sec) for 100 Hz clock differencing
- Allow external USO inputs for
 - Zero difference allows for traceability to International Standard of Unit (SI) for Climate Benchmark.
 - High precision inter-satellite ranging missions (e.g. GRACE-FO)

Mass, Power, Dimensions Electronics Unit

Configuration	Power (W)	Mass (kg)	Dimensions LxWxH (cm)
4 Ant/ NavProc	18-25	4	21x16x12
4 Ant / Nav+SciP	30-50	6	21x19x12
8 Ant / Nav+SciP	40-60	6	21x19x12

- TriG GNSS receiver is scalable and the mass, power, and dimensions varies with configuration.
- Antenna assembly is not included in the mass and dimensions estimates.



Summary

- TriG is the next generation of NASA scalable space GNSS Science Receiver
- Will track all GNSS and additional radiometric signals (GPS, GLONASS, Galileo, Compass, and DORIS)
- Scalable 3U architecture and fully software and firmware reconfigurable, enabling optimization to meet specific mission requirements.
- TriG GNSS EM is currently undergoing testing and expected to complete full performance testing later this year.

