Jet Propulsion Laboratory
California Institute of Technology

Evolving the TriG RO Instrument to Life in a Cubesat Ecosystem

September 21, 2017

Tom Meehan,
Garth Franklin, Stephan Esterhuizen

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA USA

Government sponsorship acknowledged.

To Summarize

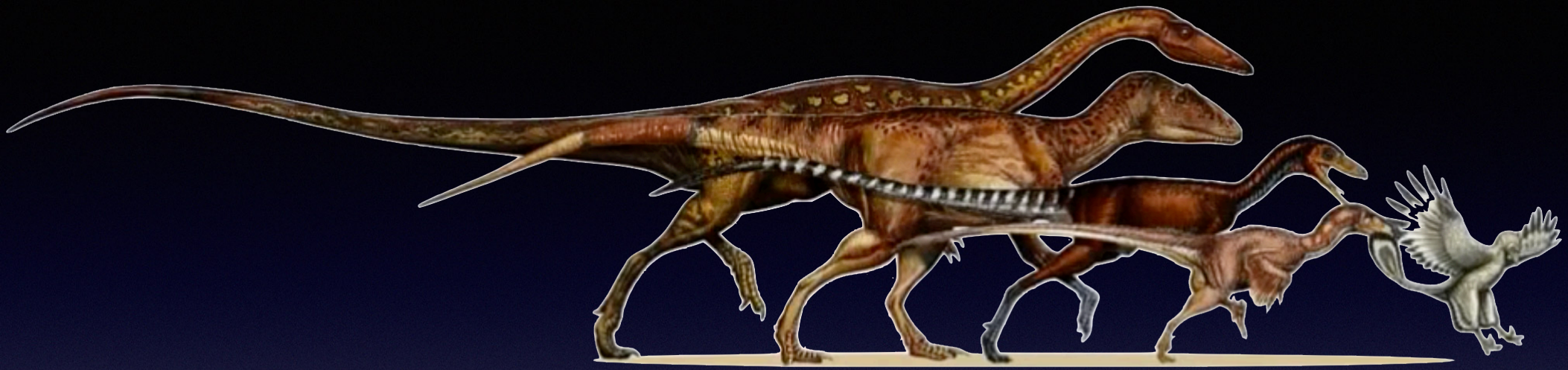
We have about 20 years of RO instrument development behind us

The environment for larger, more expensive and more capable instruments is static or declining

Smaller, less expensive but also less capable RO instruments are ascendant

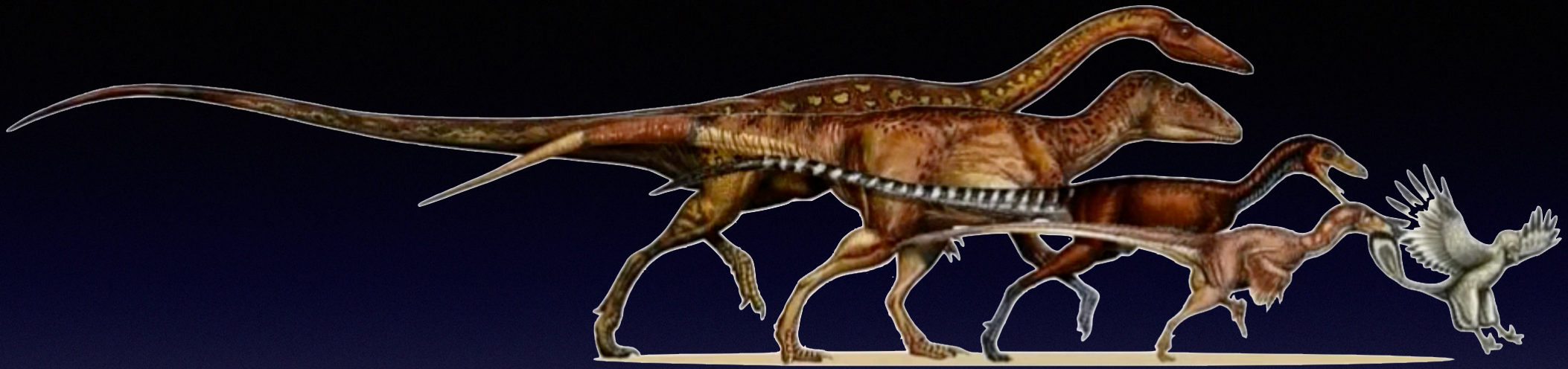
JPL is still active with tech development for high performance in a cube-sat ecosystem

A modest tech proposal



M.S.Y. Lee et al, Science(Aug 2014)

Jet Propulsion Laboratory
California Institute of Technology



M.S.Y. Lee et al, Science(Aug 2014)

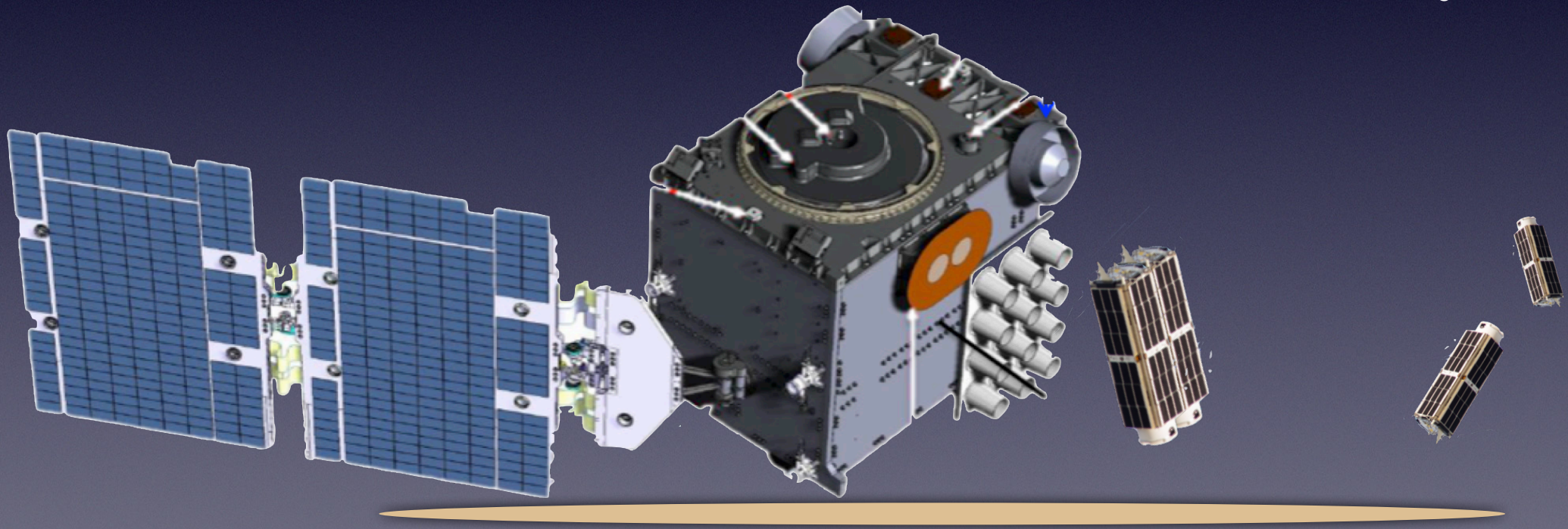


image: AMSAT-UK

Points

Having a few dinosaurs around can be helpful

Points

There's benefits but also side-effects to limiting the RO tech to one venue.

Points

From an instrument development POV, there's a healthy tension between the RO commercial data-buy sector and the legacy approach. But the environment has definitely put stress on that approach.

Where were we? i.e.; notes from the fossil record

Where are we? i.e.; TriG and C2 status

Where to? i.e.; JPL GNSS instrument future

Where were we?

TriG is an evolution from GPS/Met, a ground-dwelling instrument forced into the space environment

Conditions at the time (mid-90's) were for low-power, low cost with proof of concept specs.

GPS/Met-1995 (TurboRogue): ~3kg, 15 W
Limited to constellation test periods w/o encrypted L2
CHAMP-2000 (BlackJack): ~5kg, 12W
4 antennas; tracks semi-codeless L2; 200 occs/day
COSMIC-2006 (IGOR) ~4kg, 18W
4 antennas; Up to 500 occs/day

Where were we?

Tech was driven less by cost/power consumption and more by data quality and quantity.

There were small, low power tech initiatives but couldn't be justified for the development cost.

Where are we?

The TriG V4.2 software for C-2 is under validation for spacecraft upload in December.

TriG with V4.2 SW:

General: ~10 kg; 60 W; 30-sats L1,L2; high-rel.

Atmo-occs: >1100/day*, 130km to -400km, 100 Hz

Iono-occs : > 1015/day; S4 on all POD links

Scintillation: 100Hz SNR and phase, S4 triggered

SNRs 2-3x higher than COSMIC-1

*More if software upgraded to process Galileo, Beidou.

Where To?

TriG will continue after C2a, flying on:

Sentinel-6 A,B

SWOT

NISAR

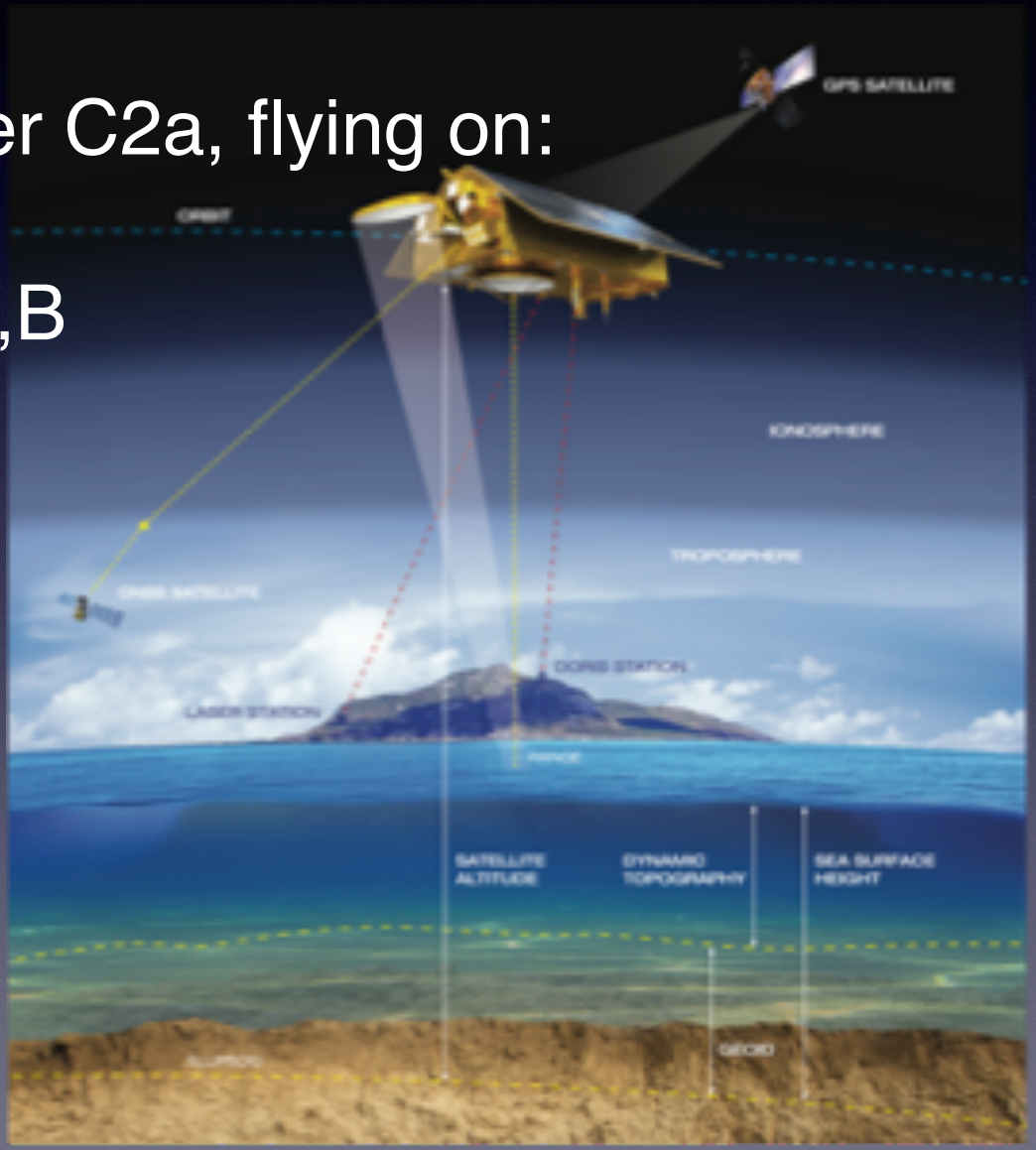
Where To?

TriG will continue after C2a, flying on:

Sentinel-6 A,B

SWOT

NISAR



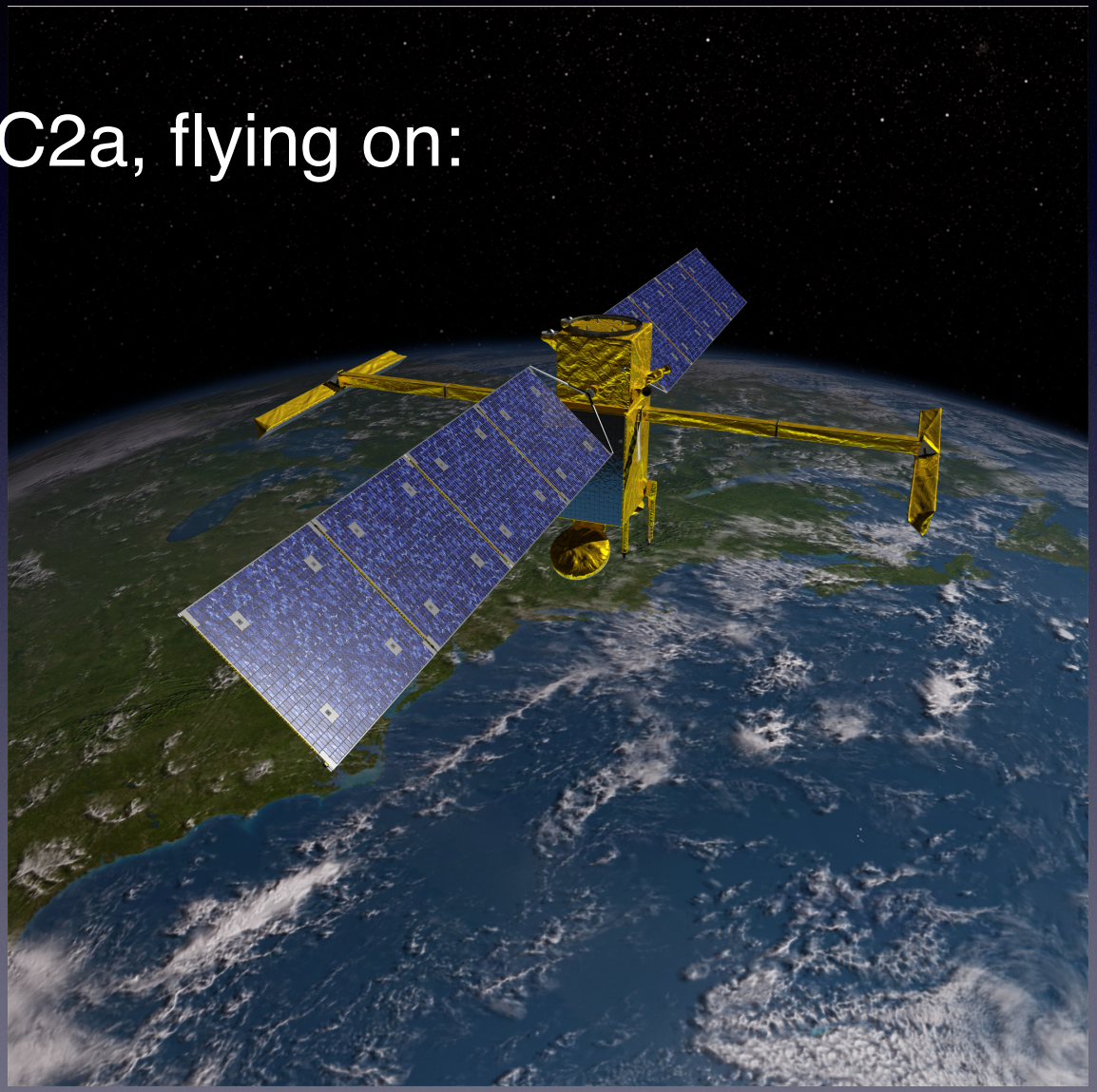
Where To?

TriG will continue after C2a, flying on:

Sentinel-6 A,B

SWOT

NISAR



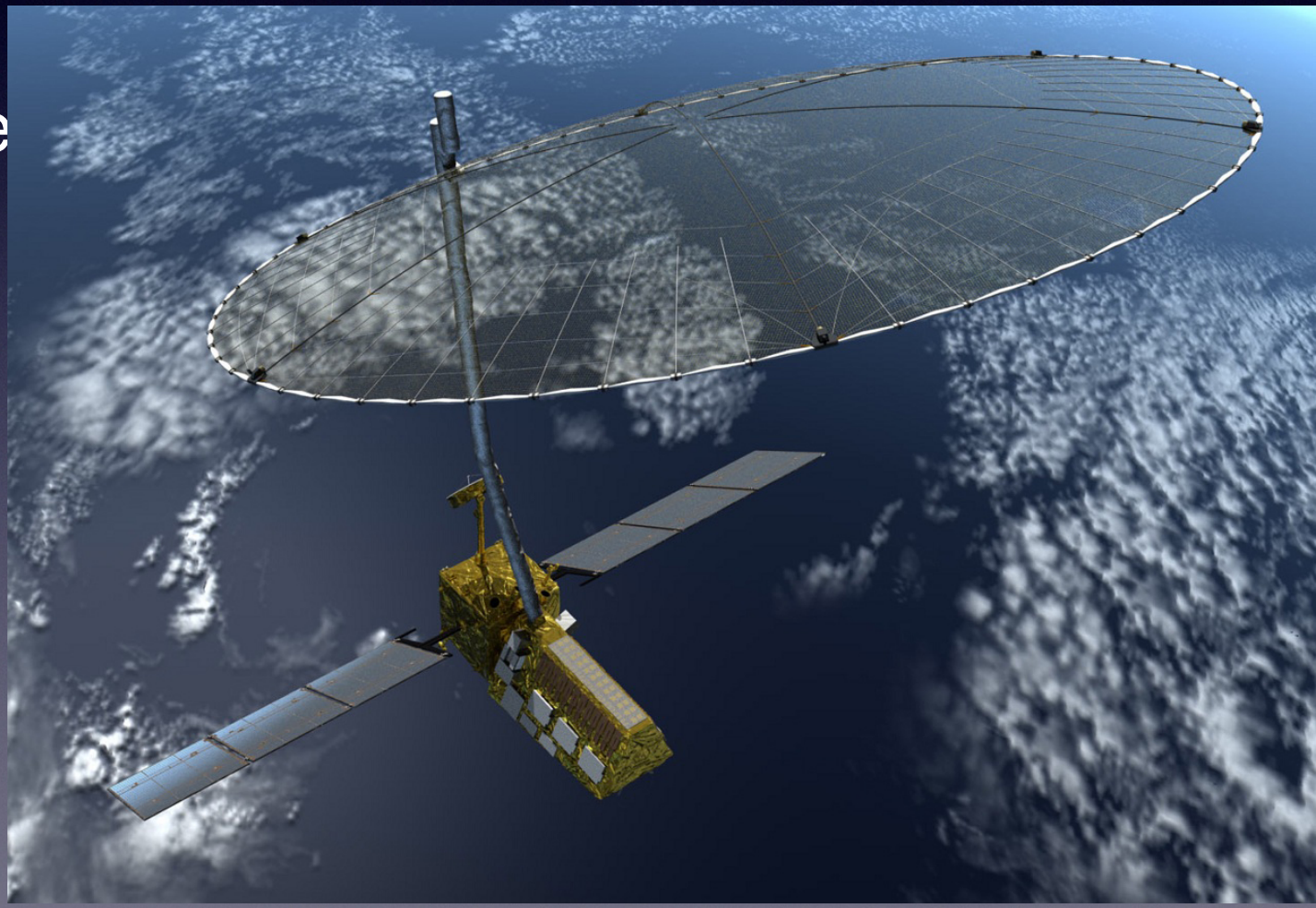
Where To?

TriG will continue after C2a, flying on:

Sentine

SWOT

NISAR

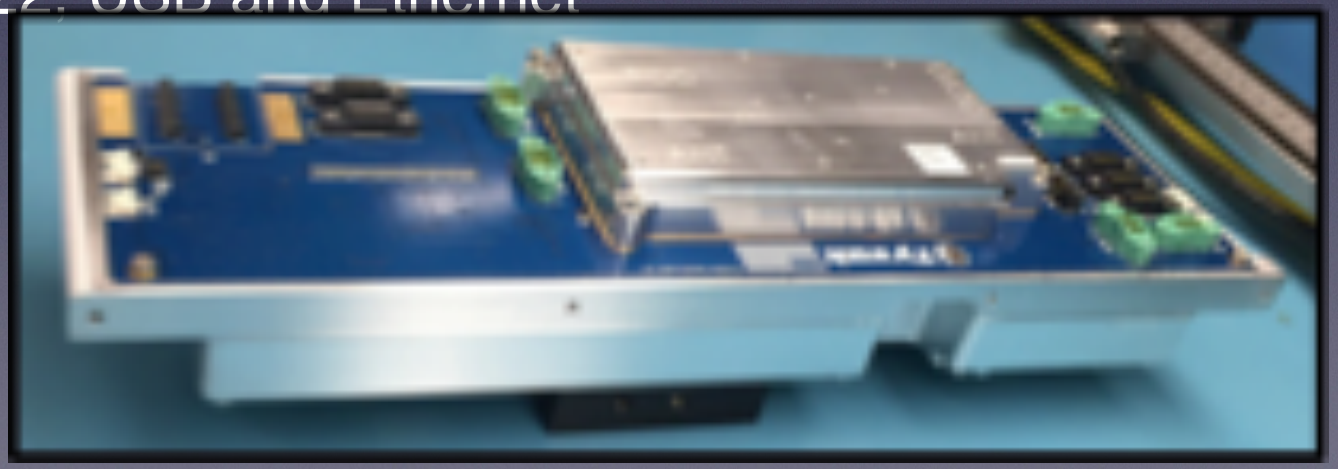


Where To?

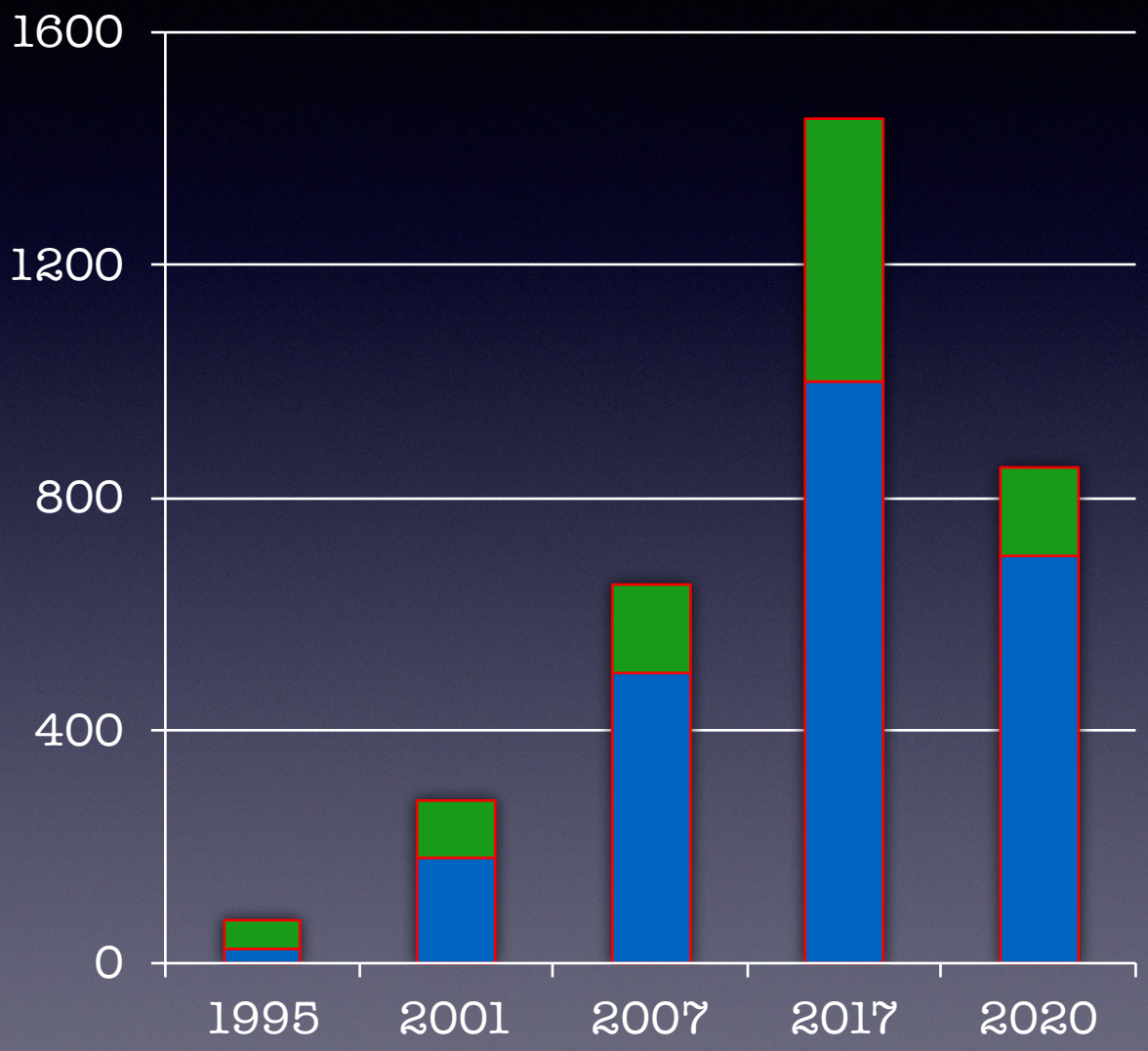
TriG open-loop algorithms and DSP logic ported to a low-power ARM-core DSP and TriG RFDCs. Dubbed “Cion”. Built by Tyvak

Cion Features:

- 3 antenna inputs each with 4 RFDCs
- Dual Core Arm processor - Linux OS
- DSP: Programmable FPGA
- 7 RO channels, dual frequency
- Volume: 3U cubesat size: 30cm X 10cm X 6cm
- Mass: ~1 kg Power: < 8 watts at 12 VDC
- Comm: RS 422, USB and Ethernet



RO Tech Quality Metric



Where To?

Beam steering important for both RO and GNSS-R.

TriG RF design is fairly power hungry with RF portion consuming about 40%.

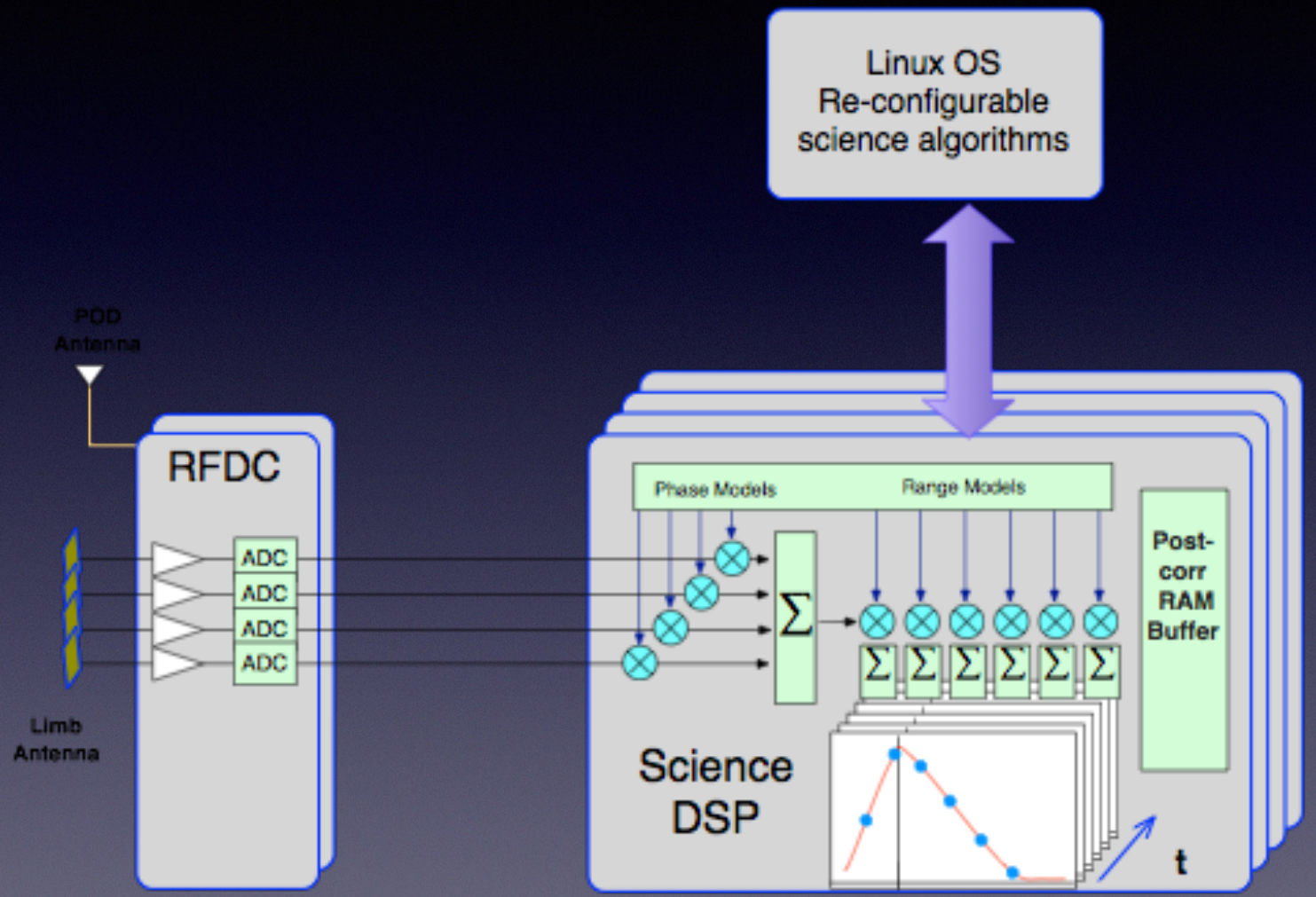
New RF ASIC development began 30 months ago with NASA Advanced Component Technology program. GigOptix PI and JPL Co-Is. Received first parts in July.

Where To?

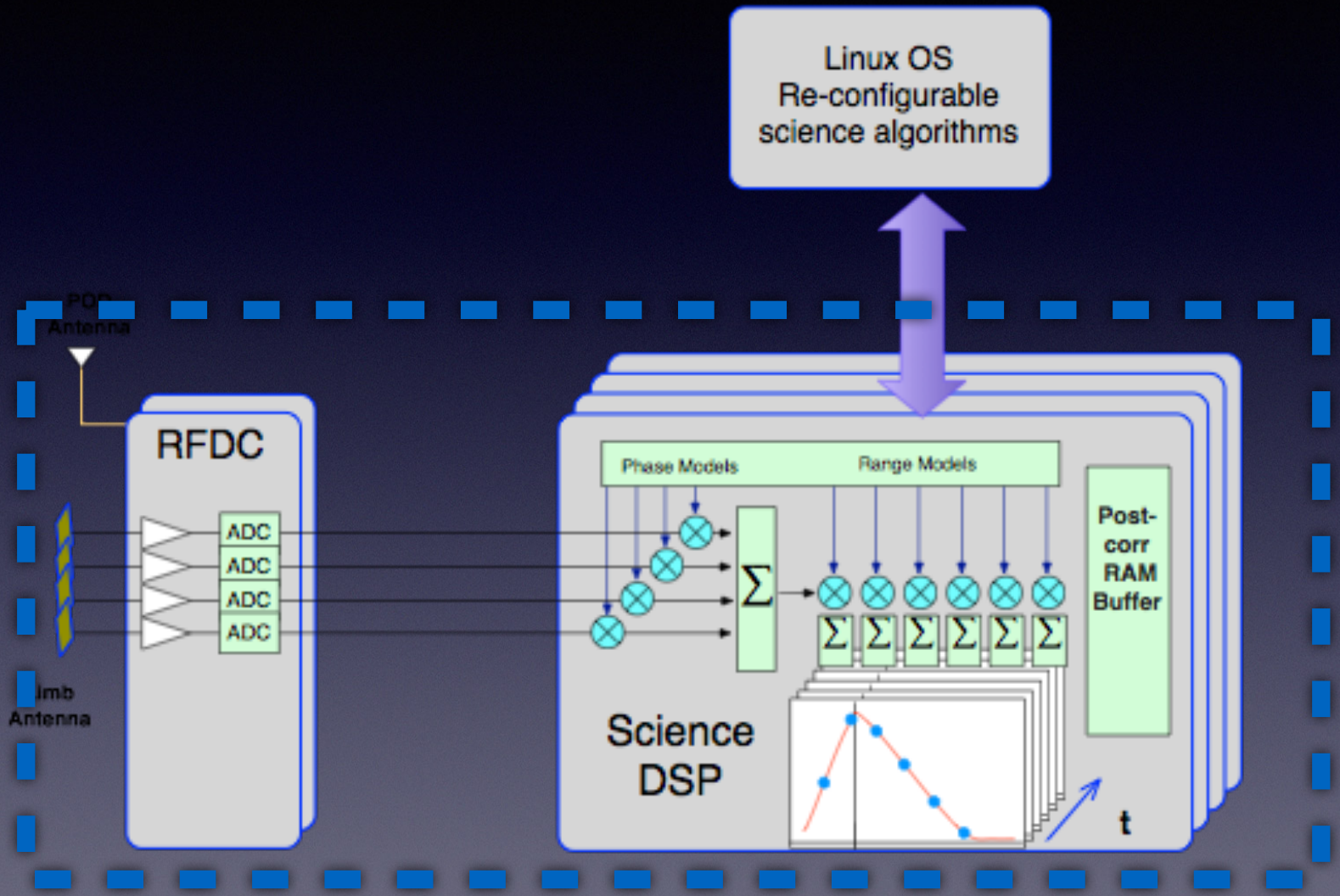
Built on SiGe process that is radiation hardened by design.
Entire GNSS spectrum for 3 antennas is processed.
Uses 1/5 the power for a TriG implementation

RO configuration

A Modest Proposal



Cut the Cord


Linux OS
Re-configurable
science algorithms
POL Antenna
RFDC
ADC
ADC
ADC
ADC
Imb Antenna
Phase Models
Range Models
Post-corr RAM Buffer
Science DSP
t

Cut the Cord

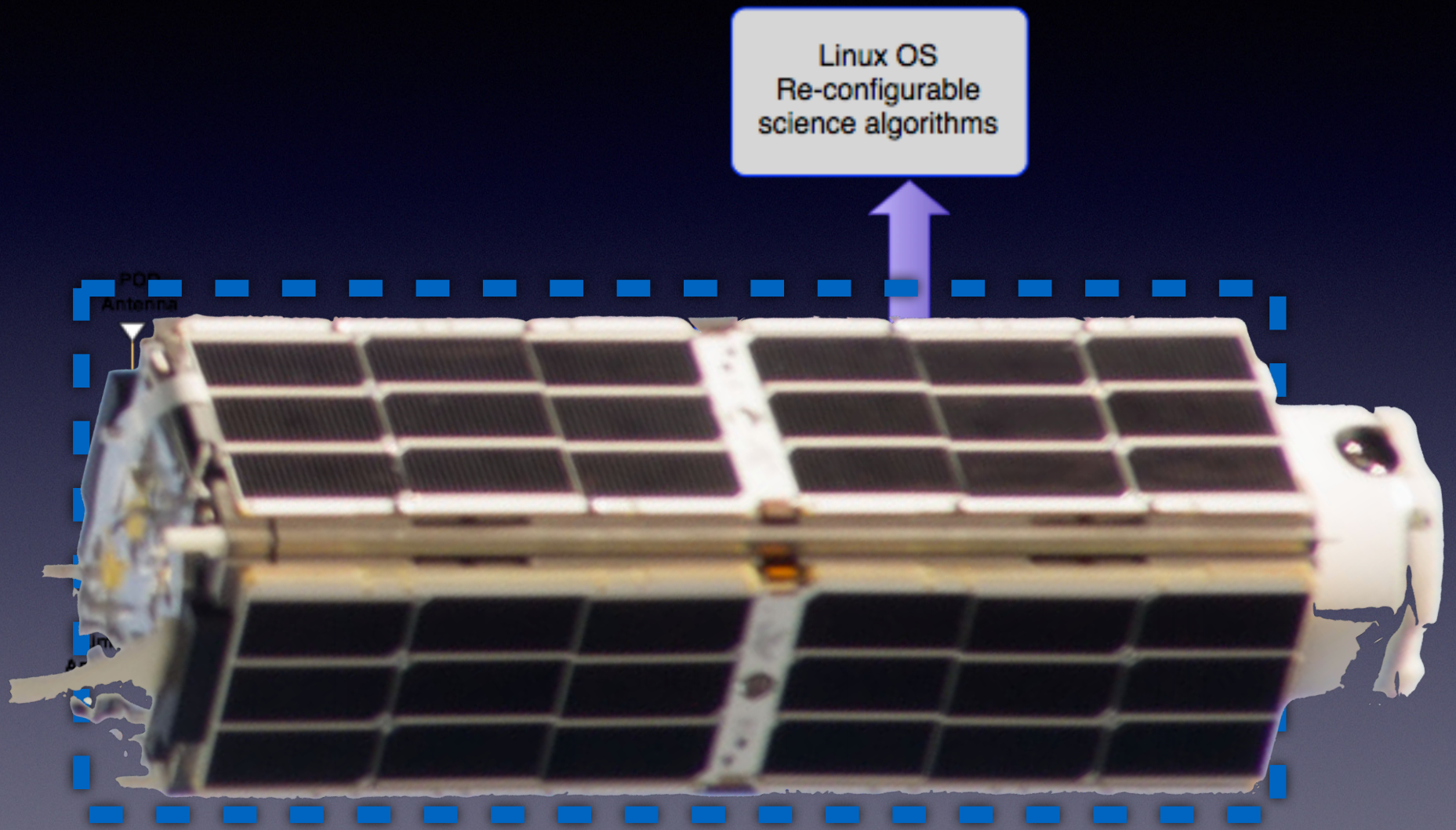
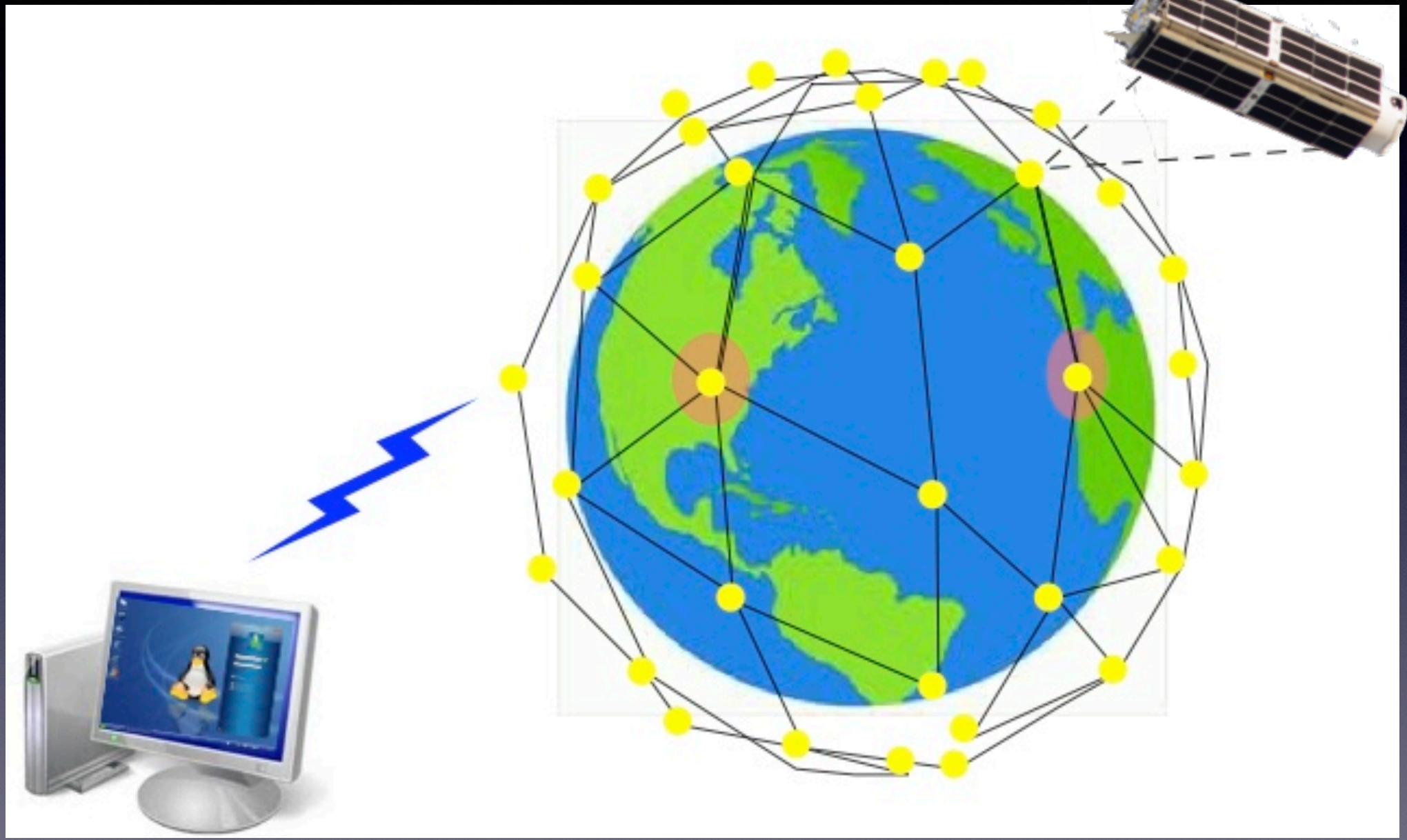
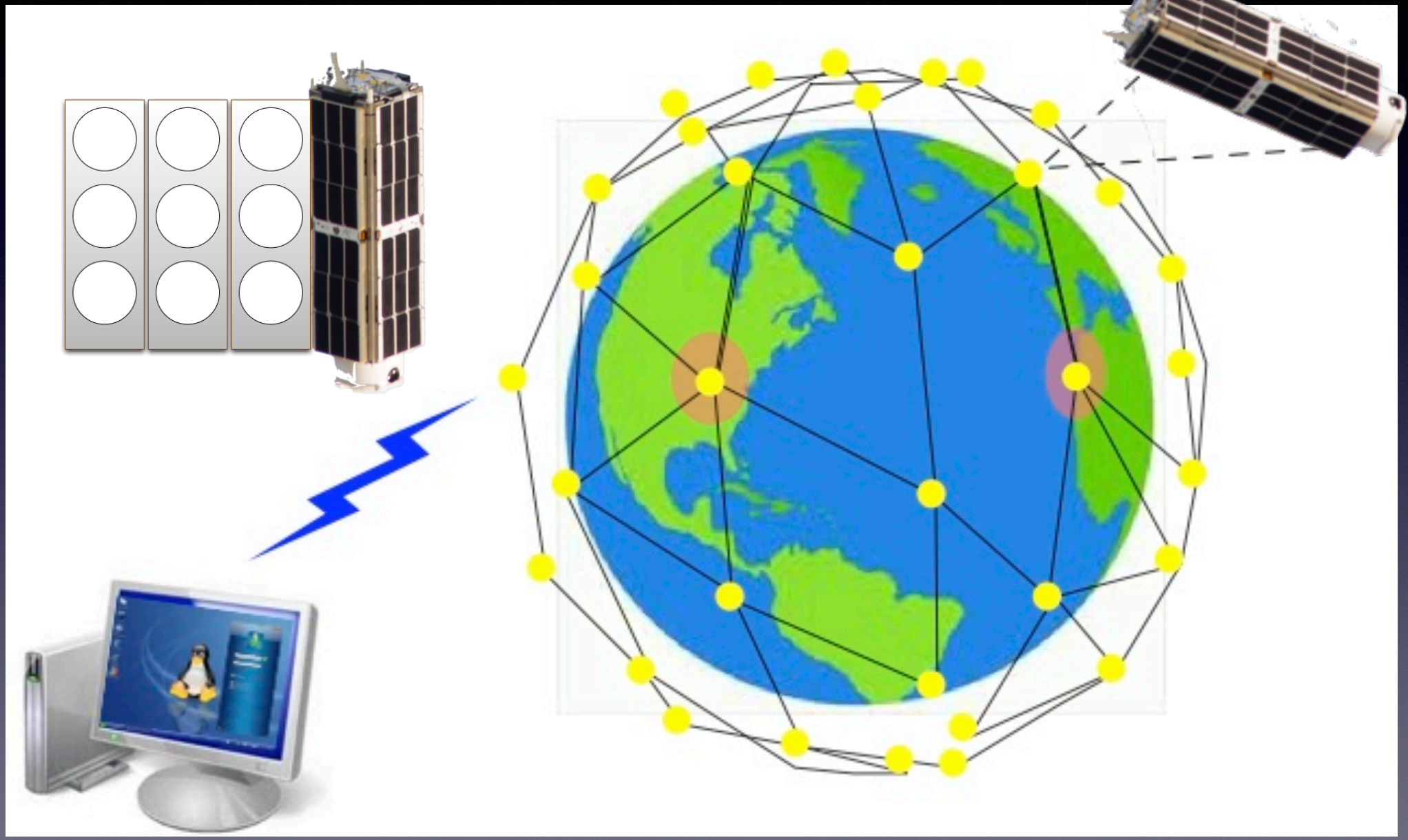


image: AMSAT-UK

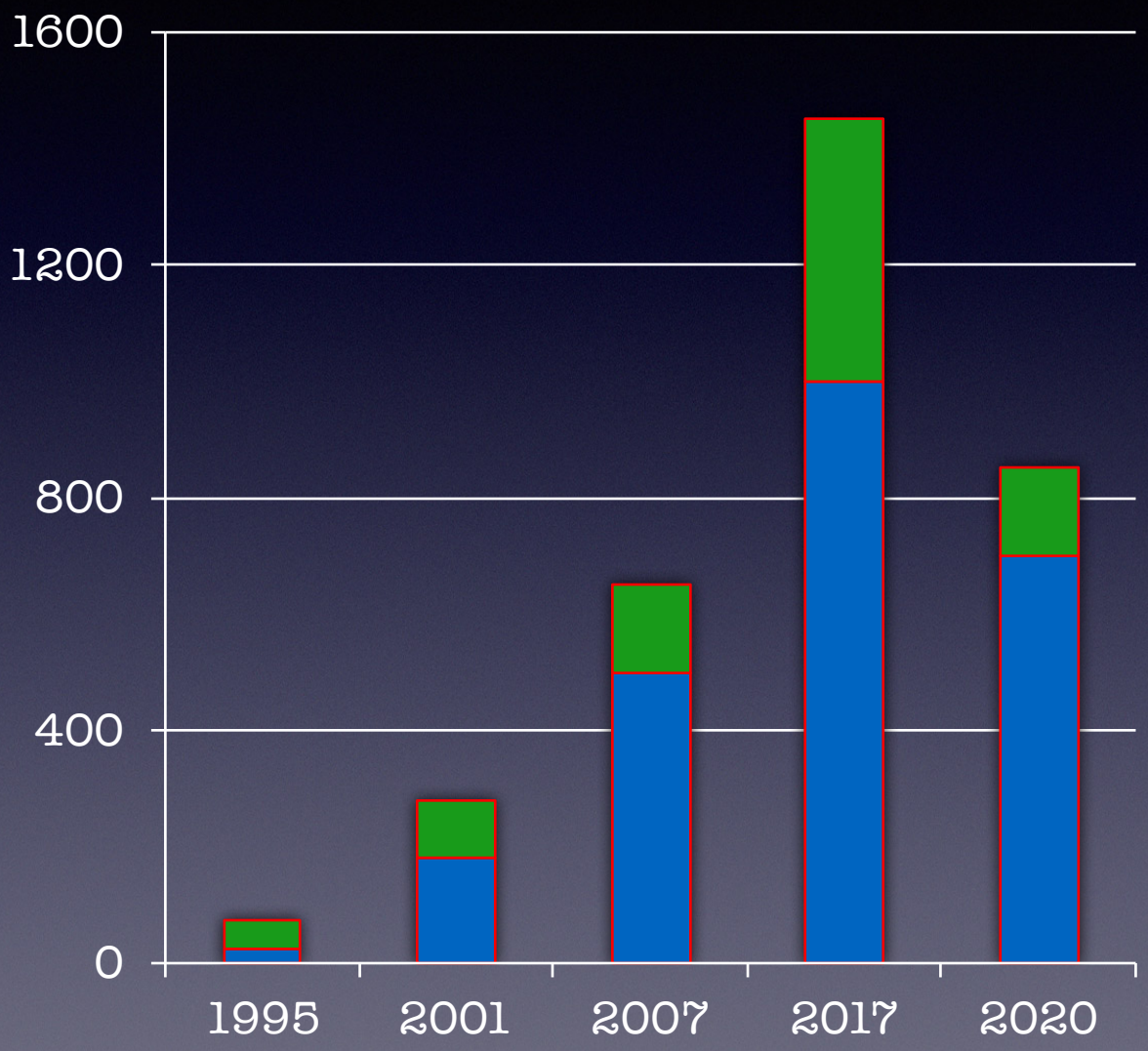
Networked Constellation One Instrument



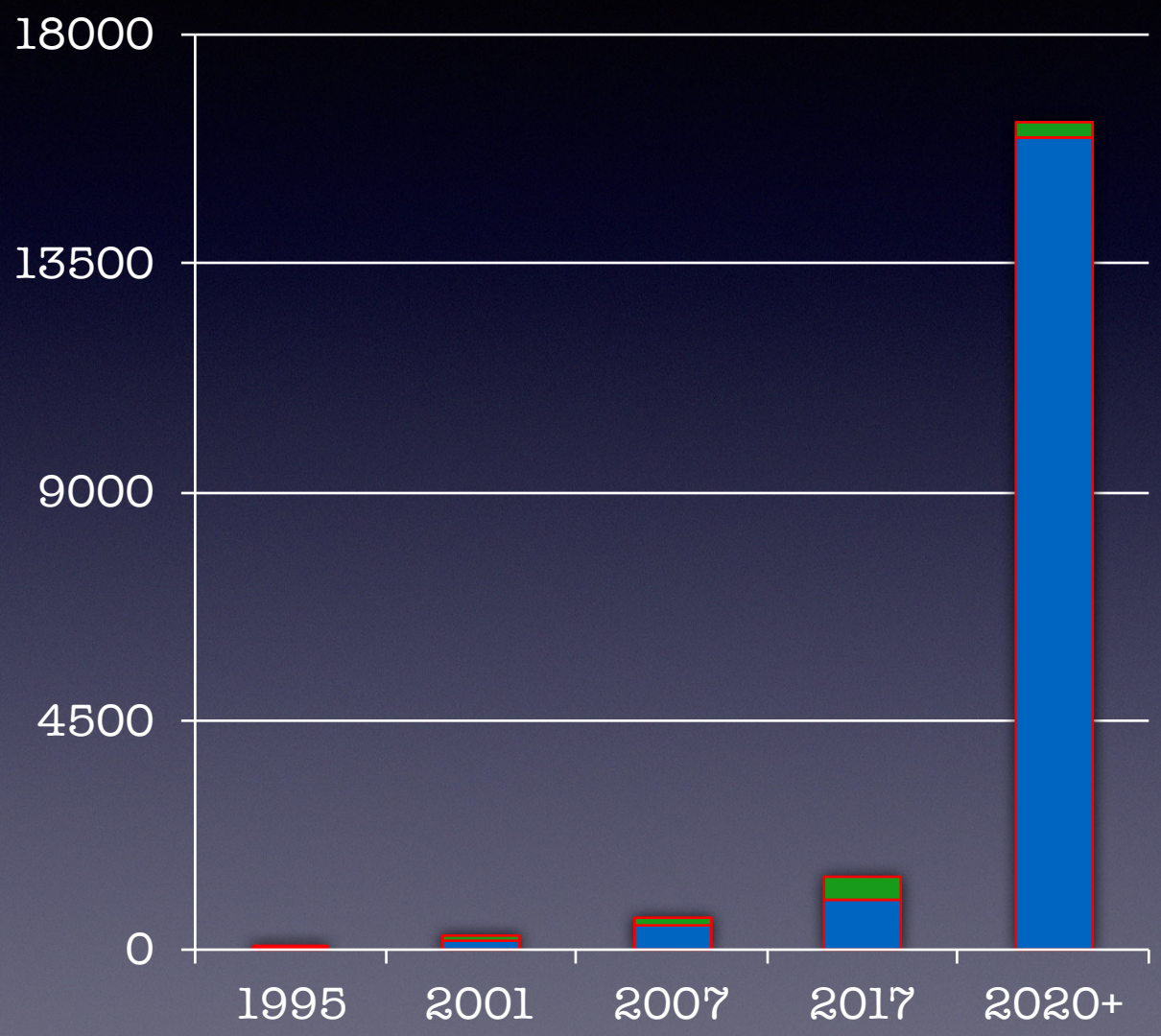
Networked Constellation One Instrument



RO Tech Quality Metric



RO Tech Quality Metric



Thank You