SPORT

The Scintillation Prediction Observations Research Task: An International Science Mission using a CubeSat

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What is SPORT?

A science mission to understand the preconditions leading to equatorial plasma bubbles and scintillation

6U CubeSat deployed from ISS

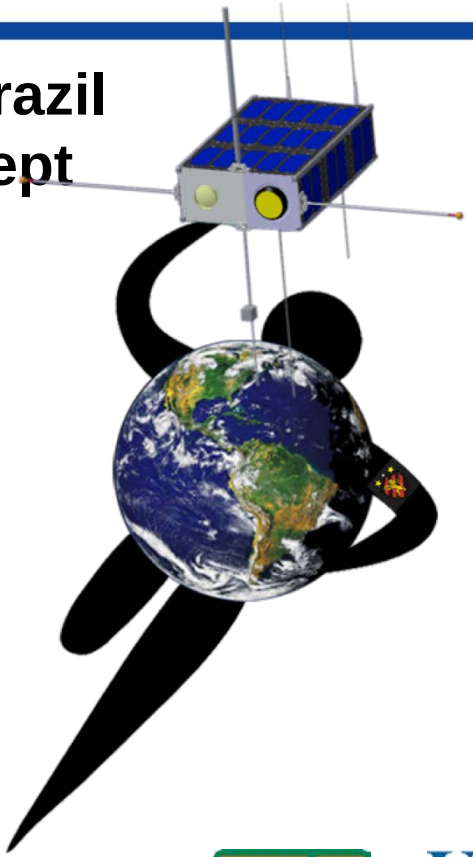
International partnership between NASA, the Brazilian National Institute for Space Research (INPE), and the Technical Aeronautics Institute under the Brazilian Air Force Command Department (DCTA/ITA)

Value: $7.5M mission - cost to NASA: $3M

Significant DoD interest

SPORT

- **Joint United States / Brazil Science Mission Concept**

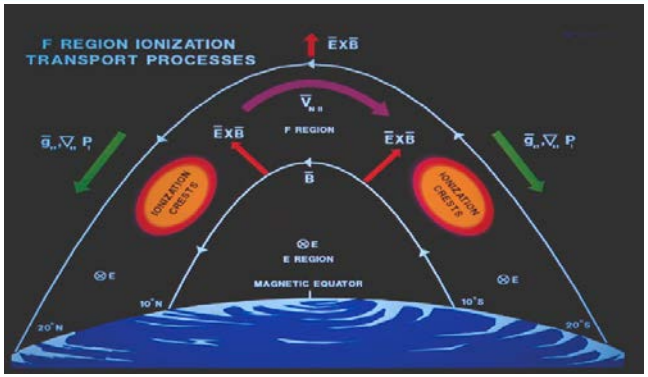


- **United States**
  - Science Instruments
- **Brazil**
  - Spacecraft
  - Operations

Joint Science Data Analysis

Science

- **The equatorial ionization anomalies**



Bela Fejer, The Equatorial Ionosphere: A Tutorial
CEDAR Meeting, Seattle Washington, 2015

- **Plasma Bubbles**

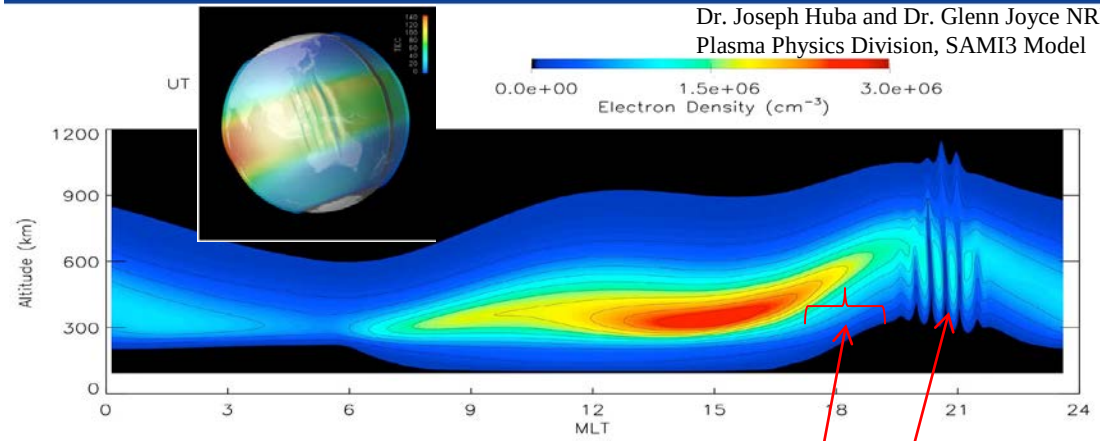
GUVI (Same Local Time, Different Longitudes)

Why do bubbles form and sometimes not at Different Longitudes?

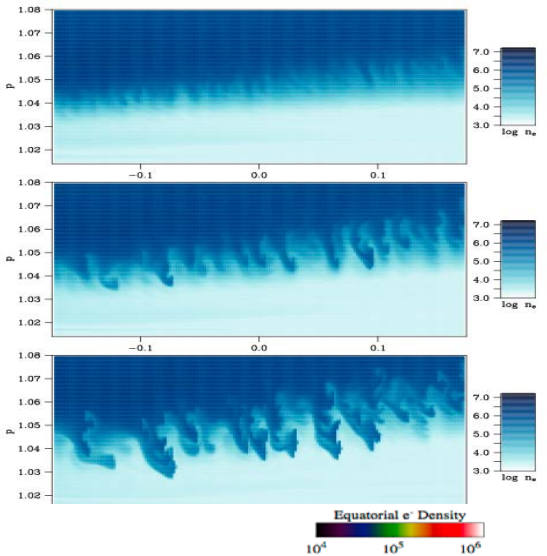
Kil, Hyosub, et al. "Coincident equatorial bubble detection by TIMED/GUVI and ROCSAT-1." Geophysical research letters 31.3 (2004).

Plasma Bubbles

About 1.5 Hours to form a bubble



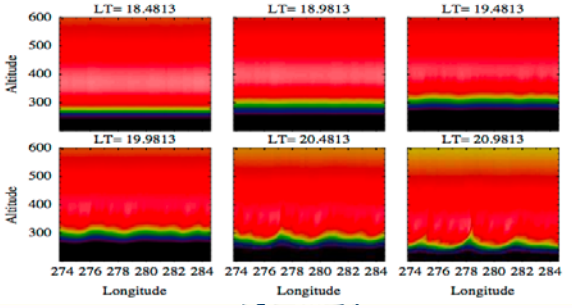
Dr. Joseph Huba and Dr. Glenn Joyce NRL
Plasma Physics Division, SAMI3 Model



What is the state of the ionosphere here?

That leads to bubbles here ?

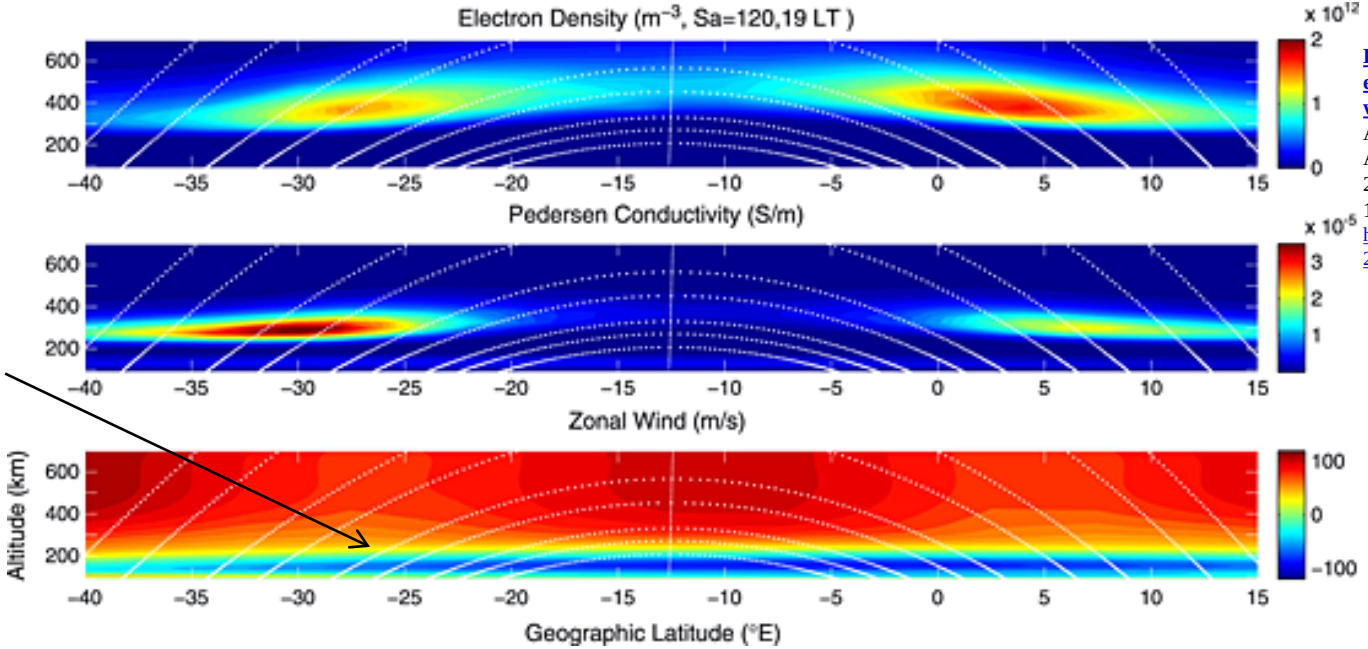
When bottom side seeding perturbations seem to always be present



Retterer, J. M., and P. Roddy. "Faith in a seed: on the origins of equatorial plasma bubbles." Annales Geophysicae. Vol. 32. No. 5. Copernicus GmbH, 2014.

Neutral Winds and Conductivities

The importance of winds in different regions to triggering EPB particularly wind shears on the bottom of the ionosphere



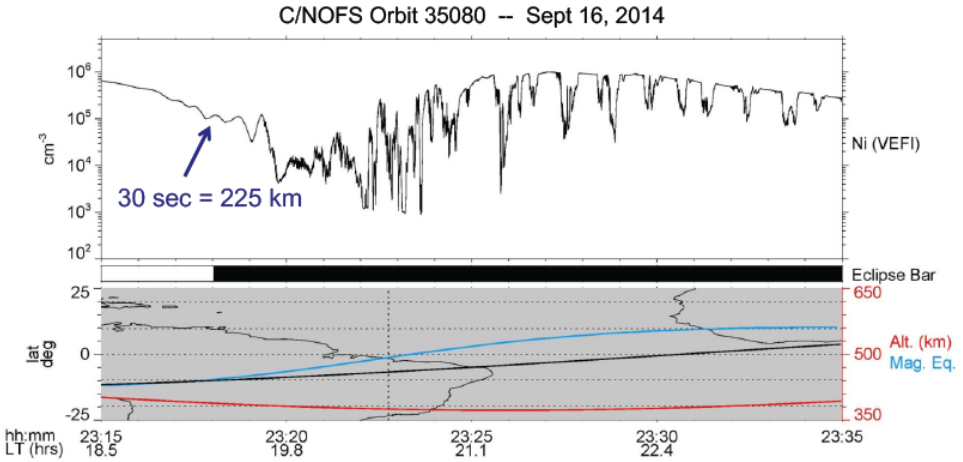
Vertical Wind Shear

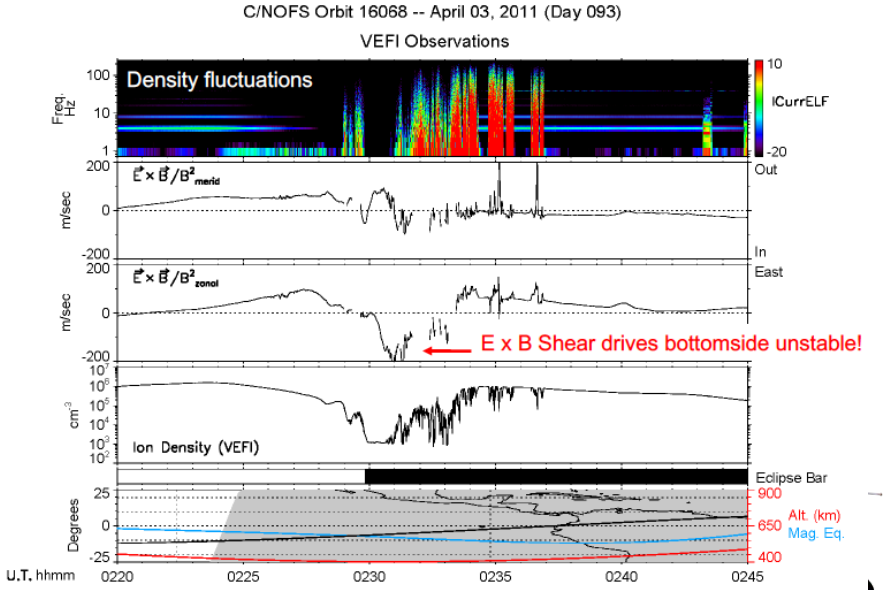
[Electrodynamics of the equatorial evening ionosphere: 1. Importance of winds in different regions](http://onlinelibrary.wiley.com/doi/10.1002/2014JA020934/full#jgra51625-fig-0001)
Authors A. D. Richmond, T.-W. Fang, A. Maute First Published: 7 March 2015 Vol: 120, Pages: 2118–2132 DOI: 10.1002/2014JA020934
http://onlinelibrary.wiley.com/doi/10.1002/2014JA020934/full#jgra51625-fig-0001

C/NOFS Observations

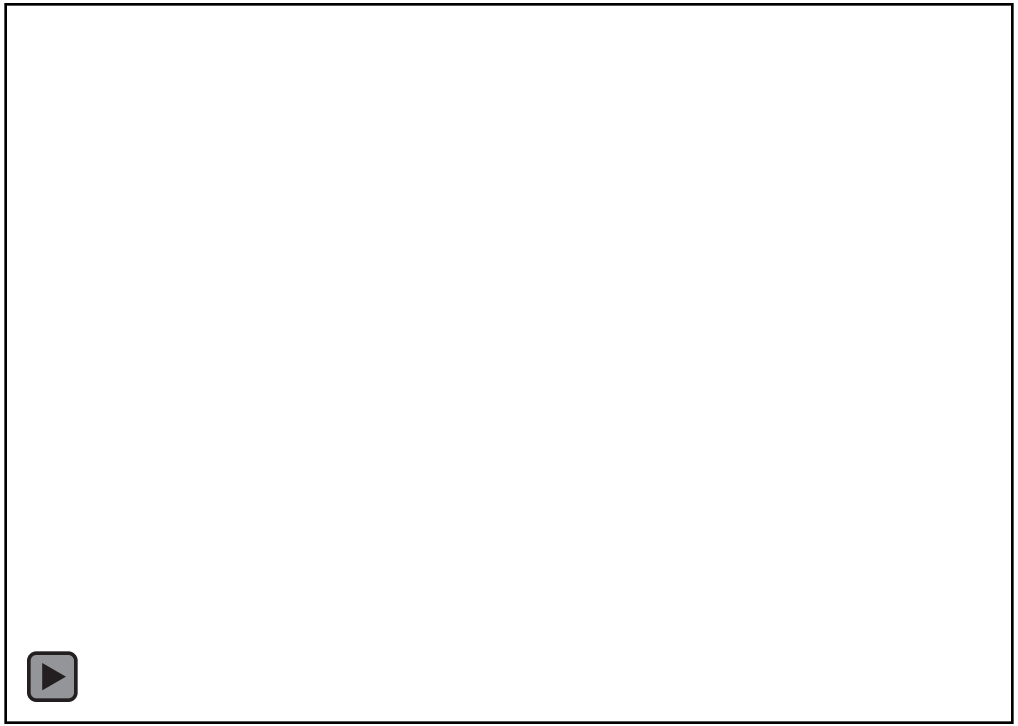
Pfaff, R. F., et al. (2017), Measurement of reversals in the horizontal plasma drifts below the elevated, low latitude F-region at sunset and their implication for the creation of large scale plasma undulations and spread-F irregularities, Journal of Geophysical Research.

Large Scale "Undulations" (100's of km) at Lower Ledge of Ionosphere at Sunset





Scintillation and GPS



Courtesy Keith Groves
Boston University

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Science Goals

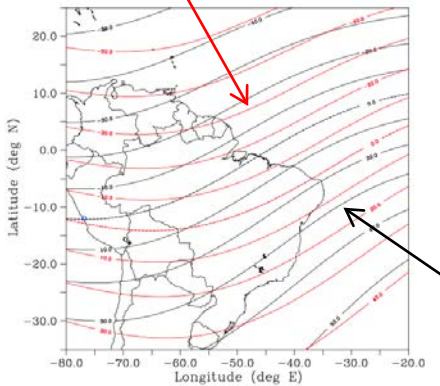
1) What is the state of the ionosphere that gives rise to the growth of plasma bubbles that extend into and above the F-peak at <u>different longitudes</u>?

2) How are plasma irregularities at <u>satellite altitudes</u> related to the radio scintillations observed passing through these regions?

Magnetic Field

Most ground/radar observations come from the American sector of unique magnetic geometry

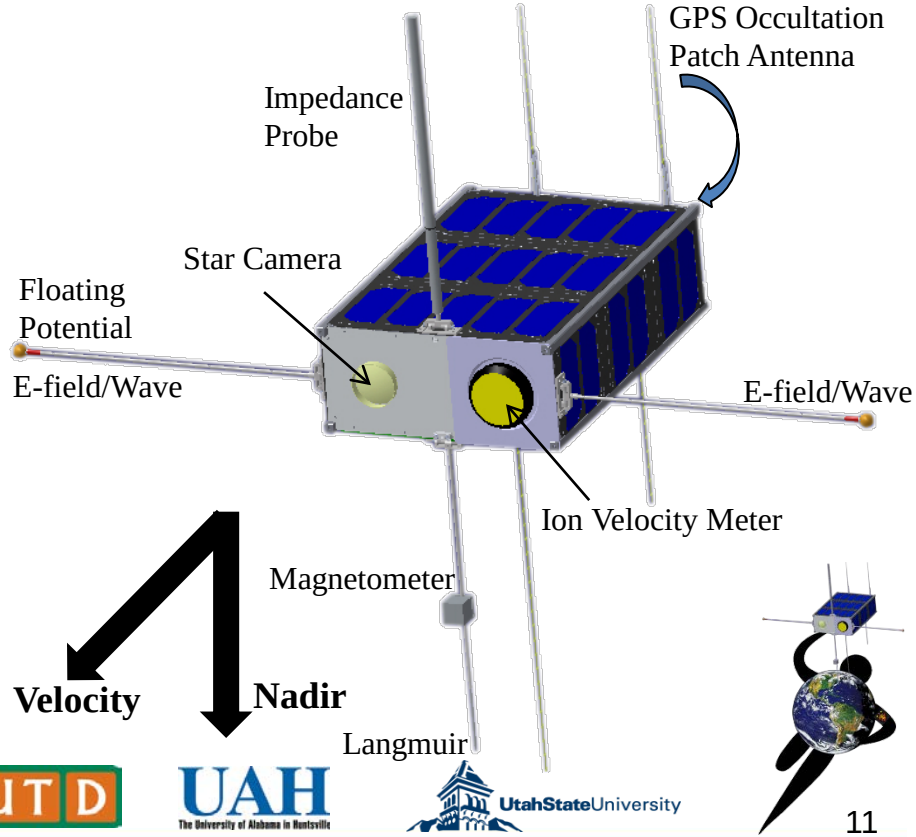
IRGF 1960



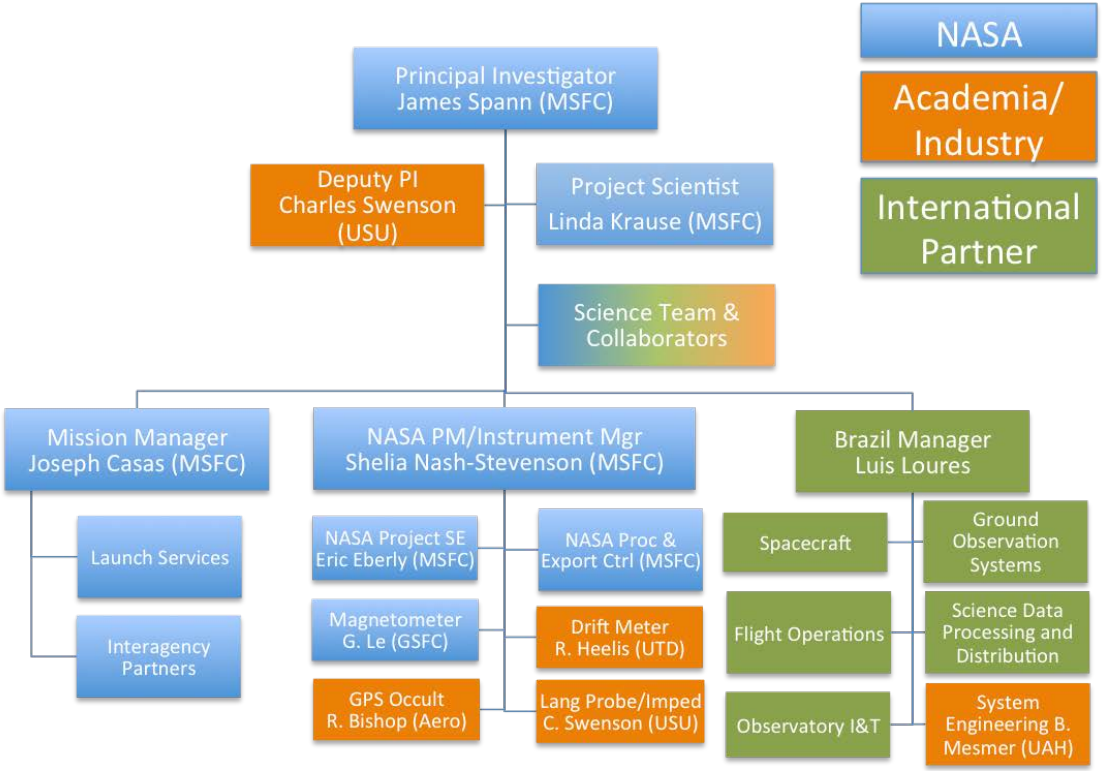
IRGF 2010

Measurement and Instrumentation

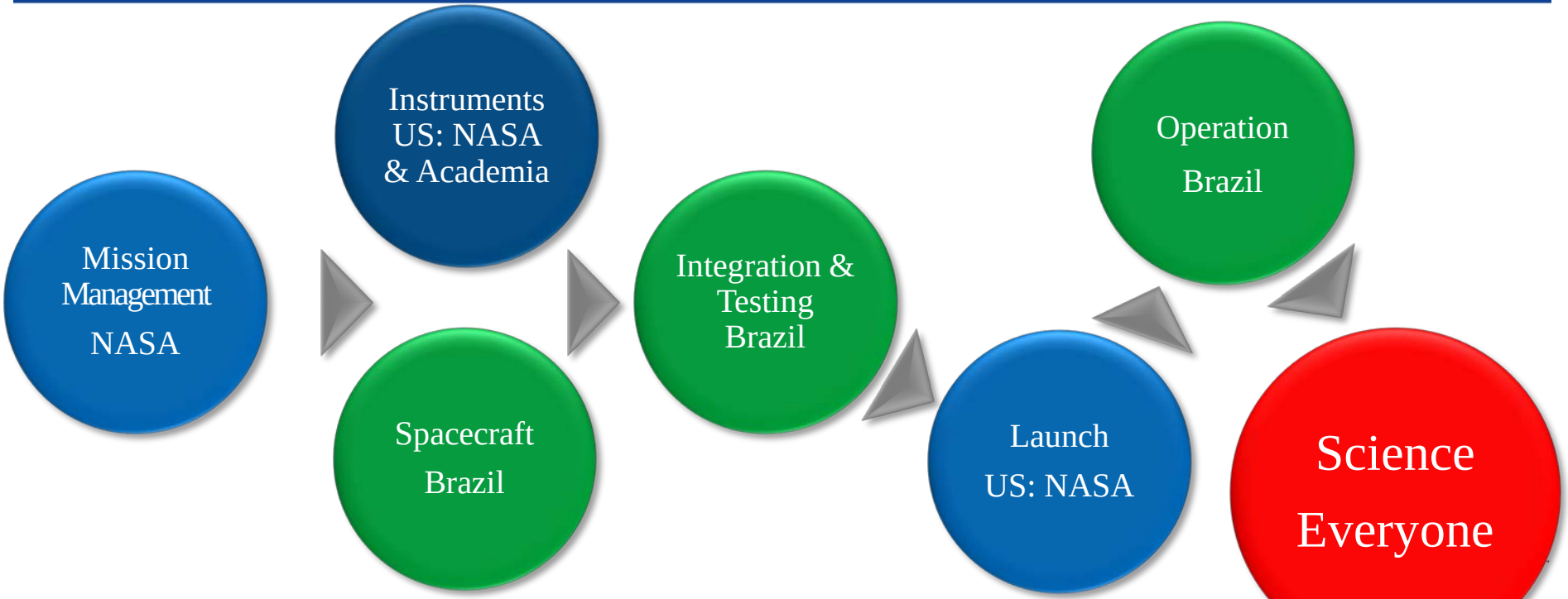
Measurement	Instruments
Plasma motion	RPA/Drift meter
Plasma density / density profiles	GPS Occultation
Small scale structures and waves	Langmuir
Scintillation Index	Impedance
Magnetic field structure	E-Field
Plasma temperature	Magnetometer



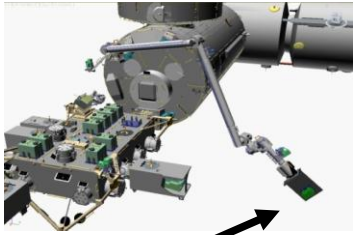
Organization



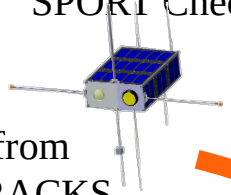
SPORT


Mission Management
NASA
Instruments
US: NASA
& Academia
Spacecraft
Brazil
Integration & Testing
Brazil
Launch
US: NASA
Operation
Brazil
Science
Everyone

Mission ConOps

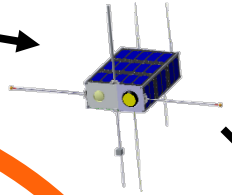


SPORT Checkout



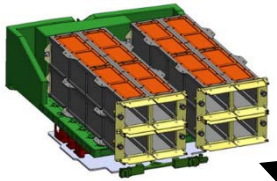
SPORT Operations

On-orbit Operations
(> 12 months)



Deploy from
NANORACKS
400 km alt

Installation



Disposal
300 km alt

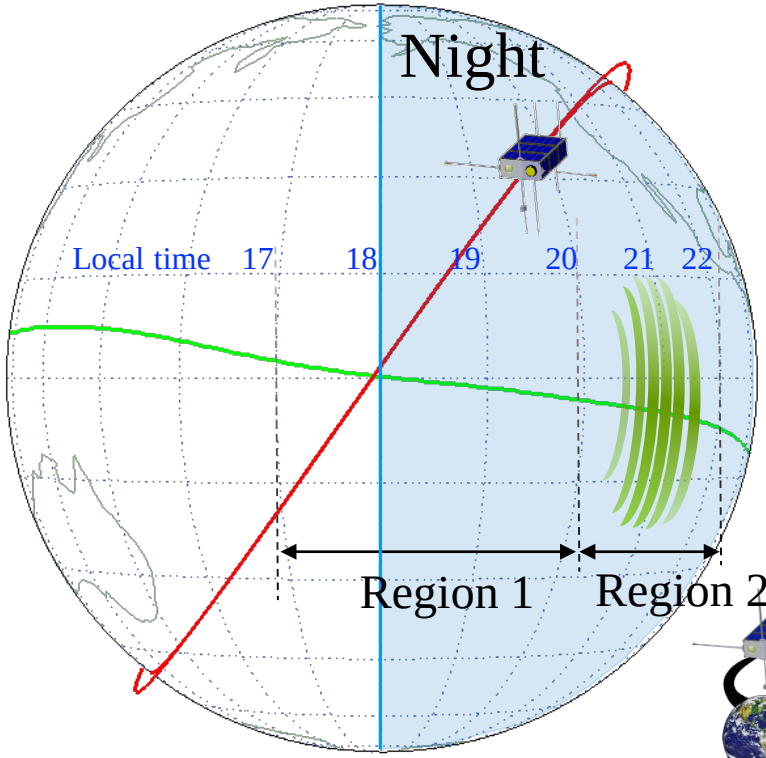
Soft
Package

Images: Charlie Gray

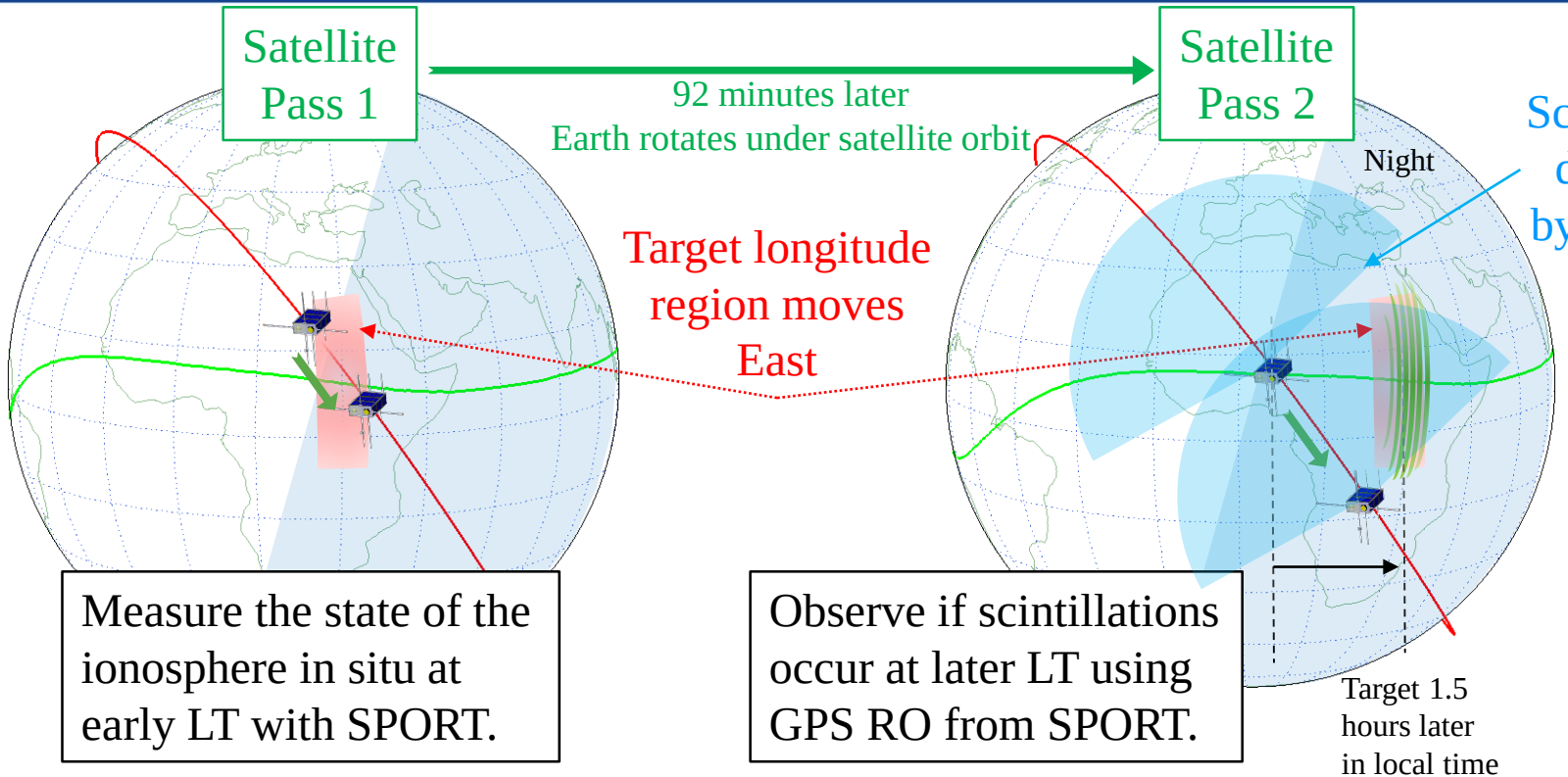
Launch

SPORT Methodology

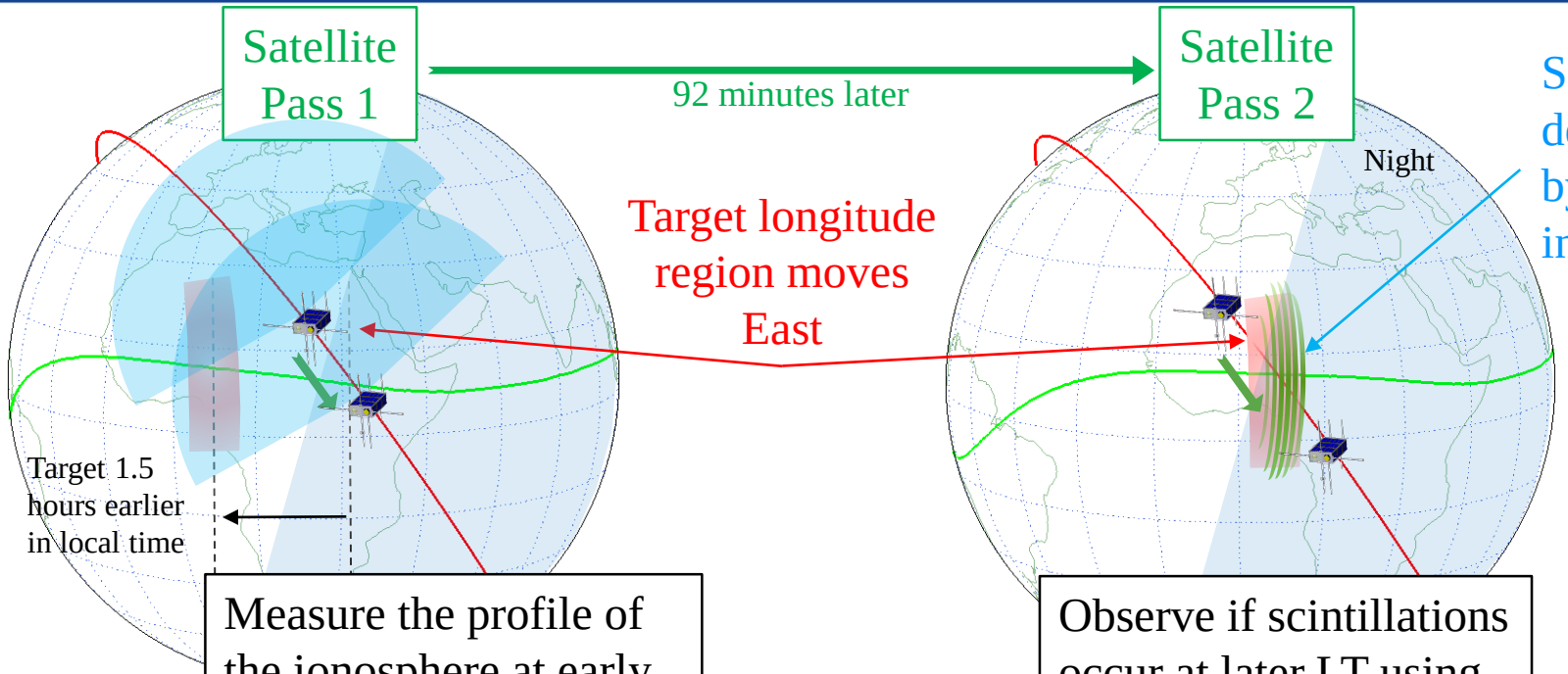
- **The state of the ionosphere at early local times is related to the occurrence of scintillations at later local times.**
  - How does this relation vary with longitude?
- **Use case studies when SPORT ascending or descending node is within 17 to 24 LT sector.**
- **Examine ~15 degree longitude sectors**



Methodology Strategy 1



Methodology Strategy 2

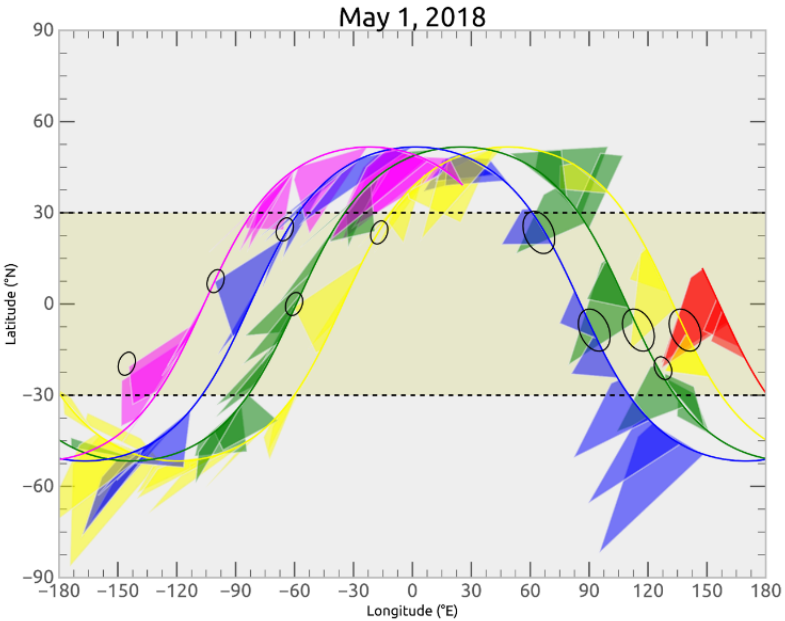


Measure the profile of the ionosphere at early LT with GPS RO.

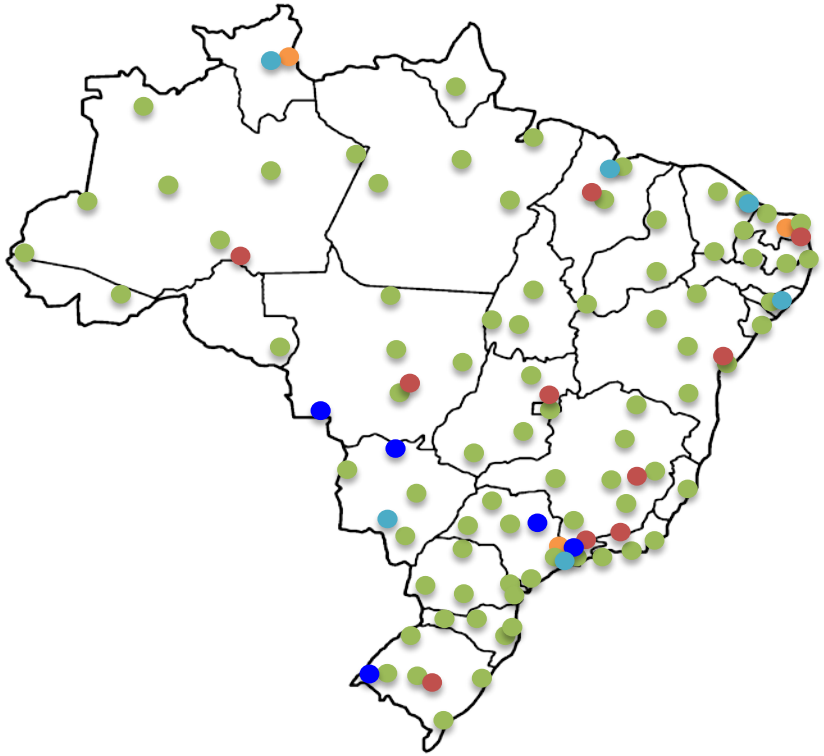
Observe if scintillations occur at later LT using in situ instruments.

How often are ideal occultation

- **Study using SPORT in ISS orbit.**
- Over one orbit in the region within ±30°
  - ~2 profiles over the previous orbit traces
  - ~2 profiles occur over successive orbit traces.

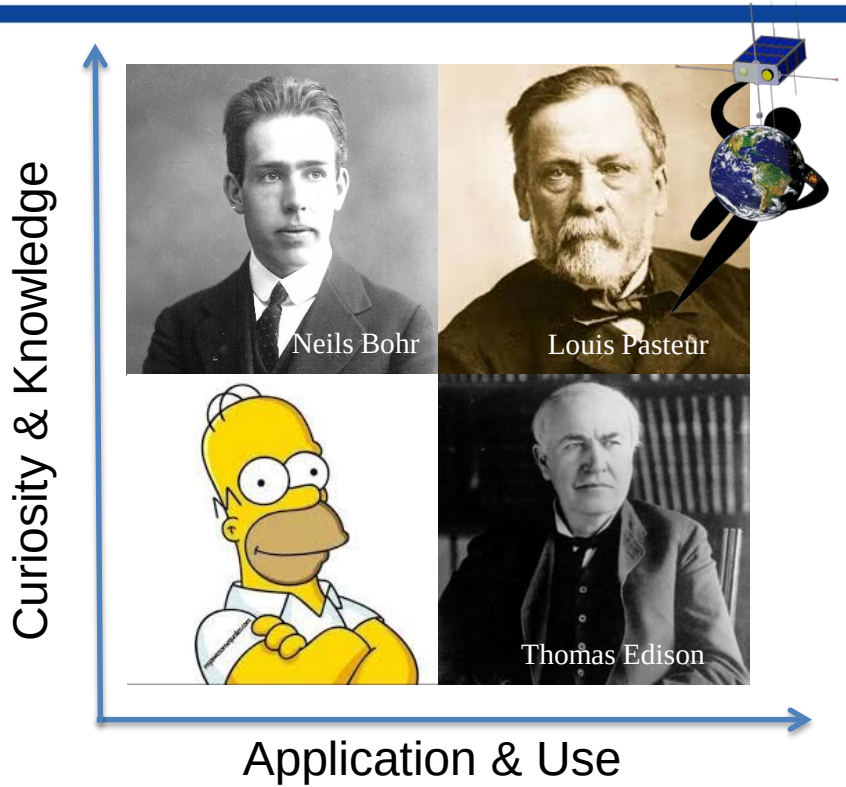


Ground Network



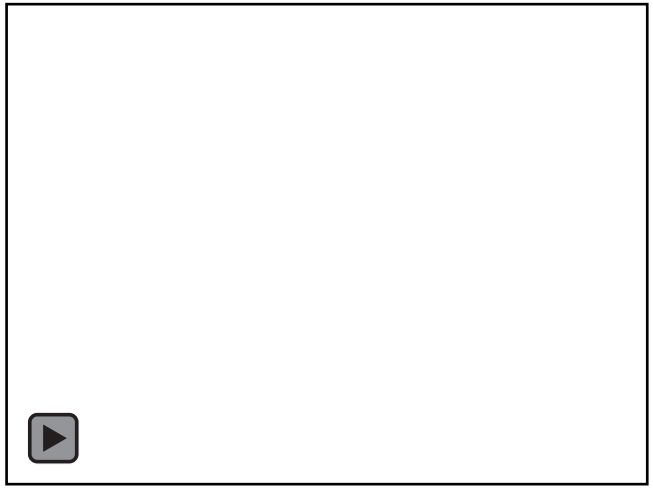
- Magnetometers
- Scintillation sensors
- TEC stations
- Imagers
- Ionosondes

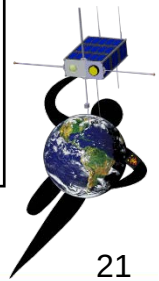
Value of Science



Conclusions

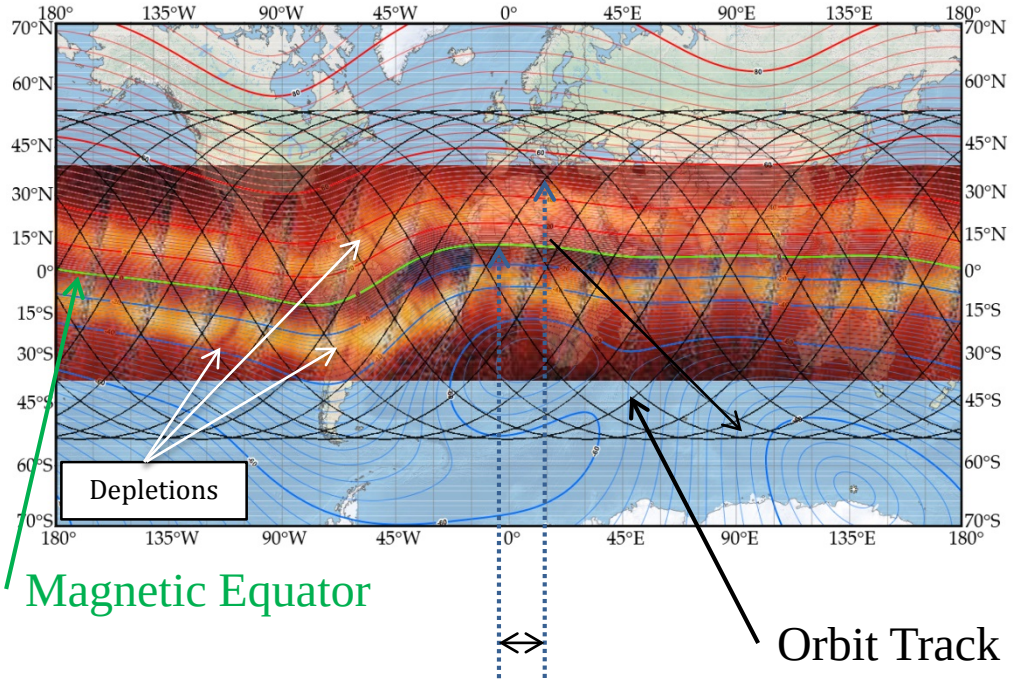
- **CubeSat missions can be developed with a full/regular suite of science instruments.**
- **Mid inclination ISS orbits allow for the deconvolution of local time and longitude at low-latitudes**
- **A String of pearls mission to increase time resolution**



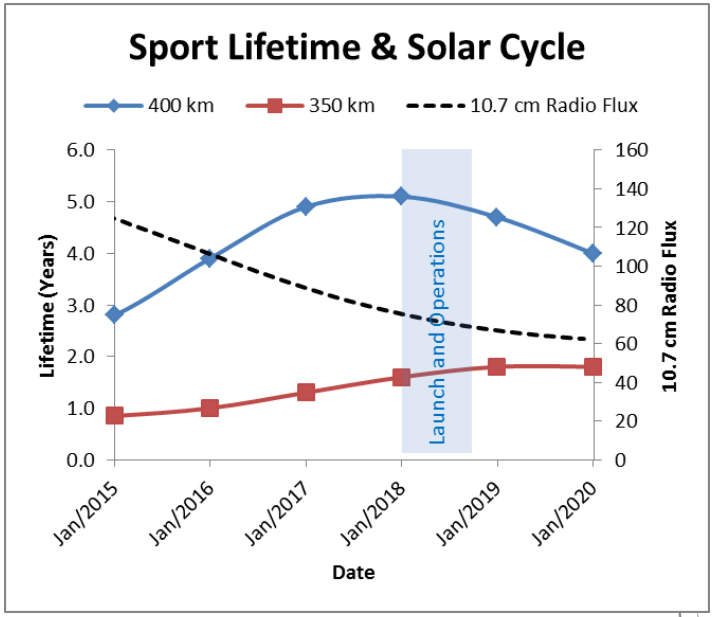


Backup

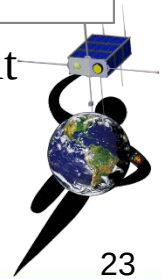
SPORT Mission and ORBIT



20° latitude or 1.3 hr LT across an EIA arc

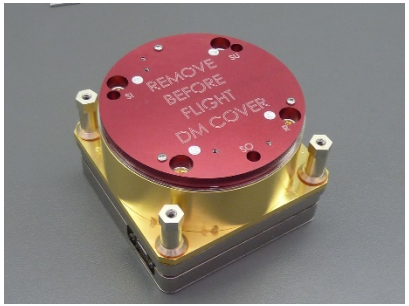


Launch from ISS, 400 km Alt
~3 year life

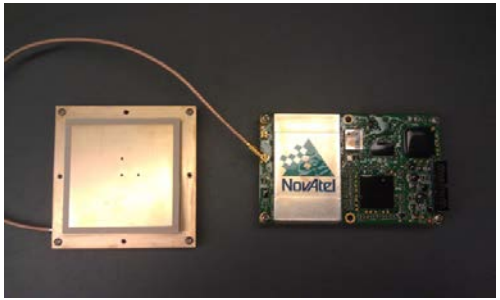


SPORT Instruments

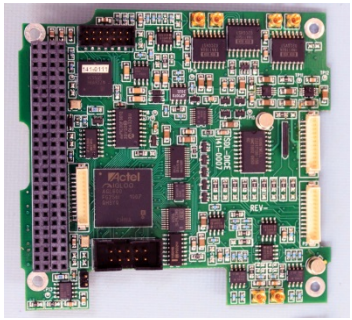
Ion Velocity Meter
UTD



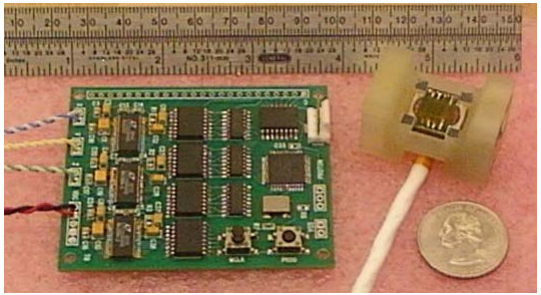
GPS Occultation
Receiver
Aerospace

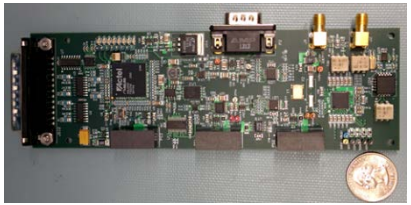


Langmuir, E-field,
Impedance Probe
USU



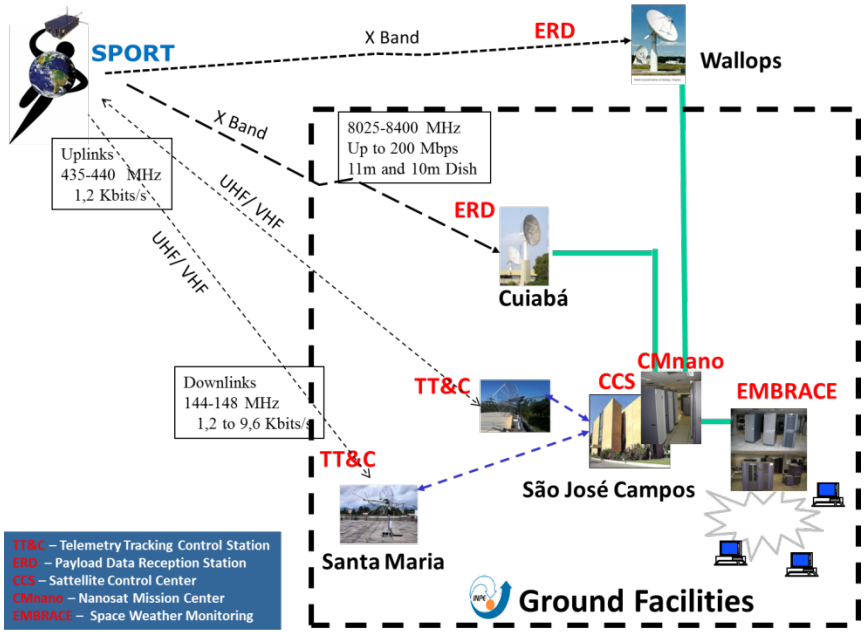
Fluxgate Magnetometer
NASA Goddard





SPORT Telemetry

Channel Name	Duty %	Rate Hz	Bit Rate bps	Alongtrack km
Ion Velocity Meter			**1824**	
Drifts	100%	2.00	288	3.83
Composition Sweeps	100%	2.00	1536	3.83
GPS RO			**16000**	
Dayside Tracking	50%	1.00	1000	7.66
Nightside Tracking	50%	50.00	15000	0.15
Langmuir Probe			**1984**	
DC Probe	100%	40.00	960	0.19
IV Sweeps	100%	0.04	491.52	191.43
Floating Probe Sweeps	100%	0.04	491.52	191.43
N_e Wave Power	100%	0.04	40.96	191.43
E-Field			**1321**	
DC field	100%	40.00	1280	0.19
E-Field Wave Power	100%	0.04	40.96	191.43
Impedance Probe			**197**	
I & Q Sweep	20%	0.04	196	191.43
Tracking	20%	40.00	192	0.19
Fluxgate Magnetometer			**2880**	
DC field	100%	40.00	2880	0.19
Star Imager			**1500**	
Star Subimage	100%	1.00	1500	7.66
Other			**2624**	
Science GPS timeing	100%	40.00	2560	0.19
Science Housekeeping	100%	0.10	64	76.57
Rate collected on orbit			**31210**	



50 Mbit/second Downlink giving a safety factor of 14