MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

COSPAR Symposium on "Space weather and small satellites"

"Combined small satellites and ground based instrumentation for Space Weather studies in Brazil."

Presented by

Clezio Marcos De Nardin

On behalf of

EQUARS Mission Team, SPORT Mission Team, Embrace Team and , and CGCEA Research Team

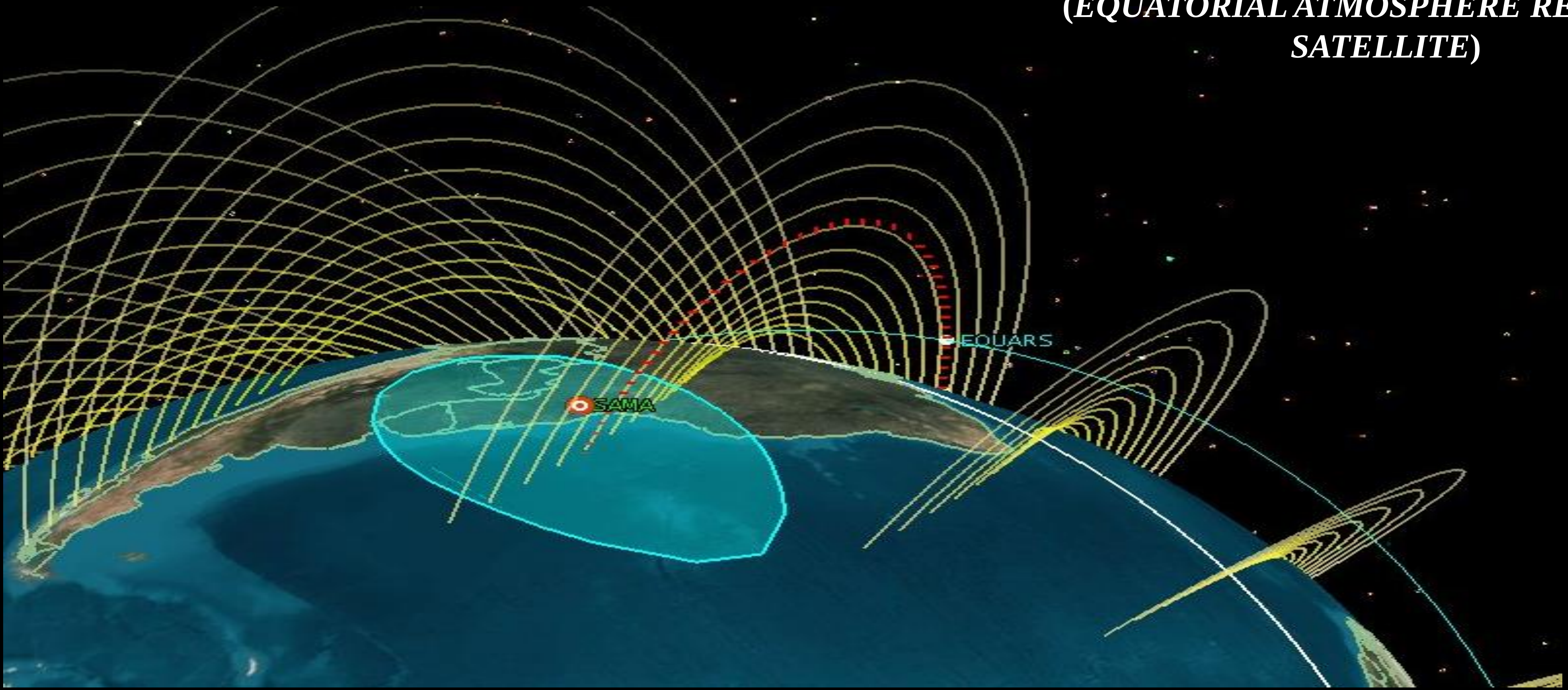
on Feb. 11th 2019 for the occasion of the
56th Session of the Technical and Scientific Subcommittee of COPUOS
held in Vienna, Austria from February 11th to 22nd 2019.

Outline

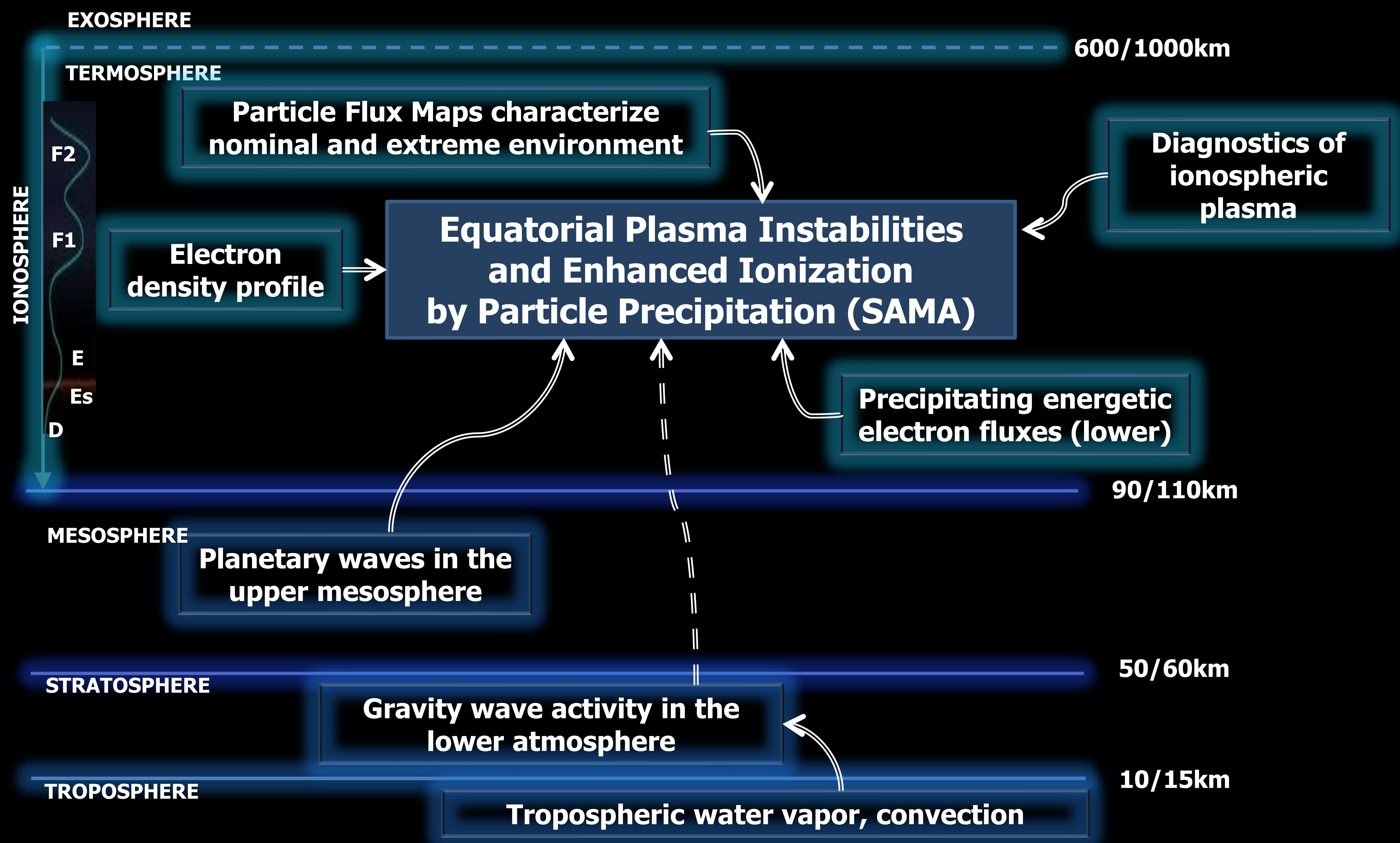
1. Equars
2. Opportunities with small/cubesats

EQUARS Satellite

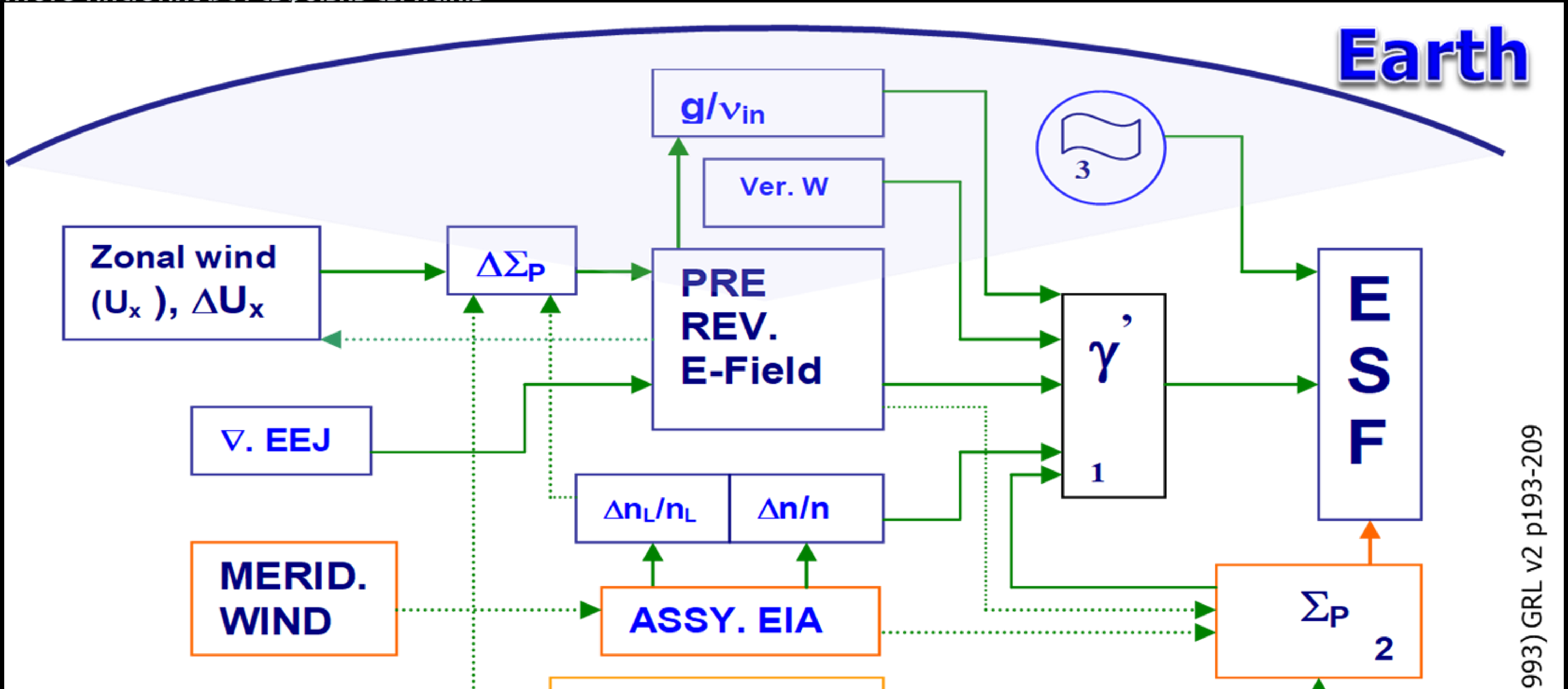
THE CURRENT CONCEPTION OF THE SCIENTIFIC SATELLITE EQUARS (*EQUATORIAL ATMOSPHERE RESEARCH SATELLITE*)



EQUARS Satellite Scientific Concept



EQUARS Satellite Scientific Concept

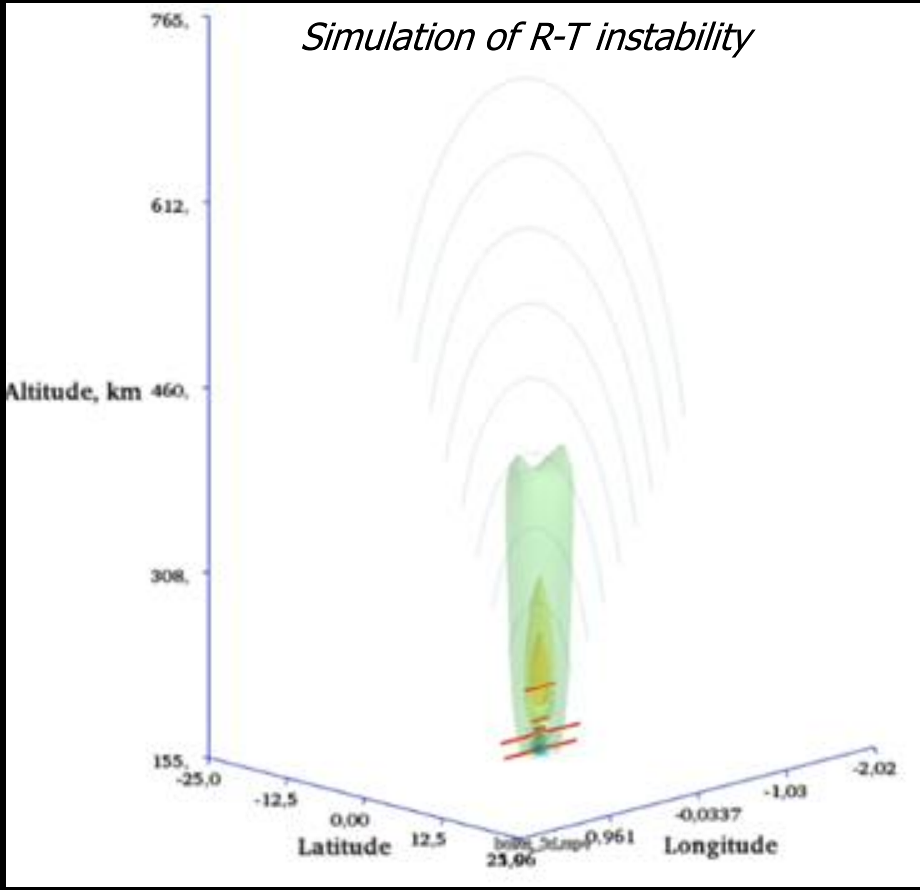


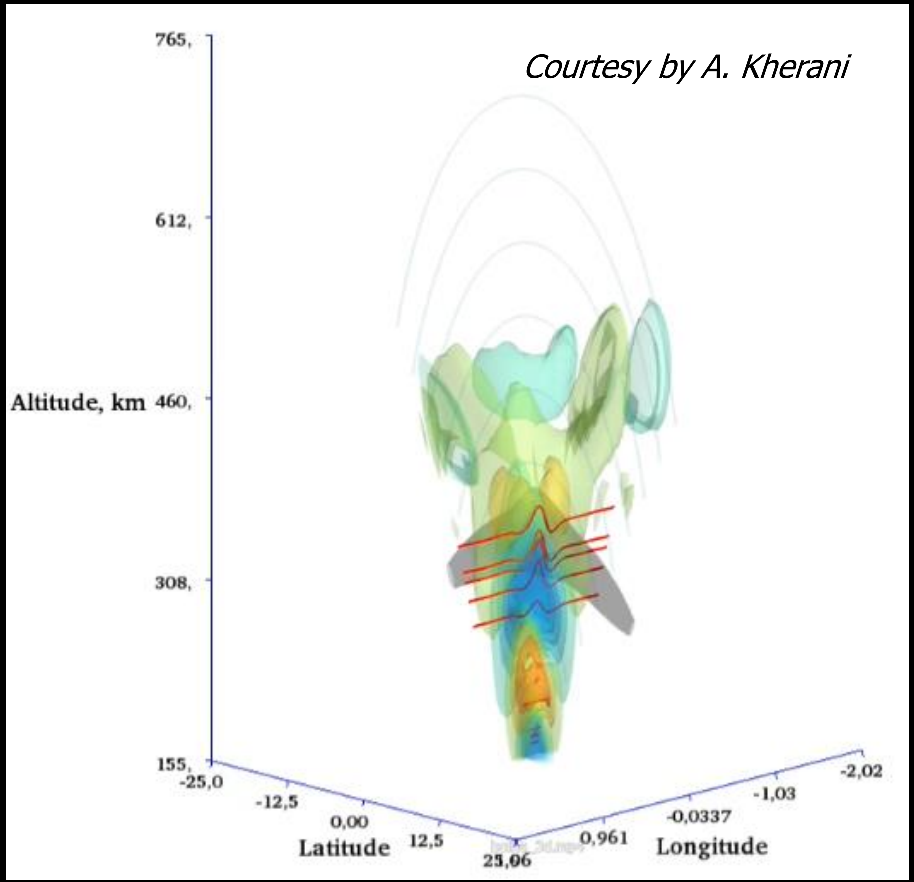
$$\gamma'_L = \frac{\Delta n}{n}\left(\frac{E}{B} - \frac{g}{\nu_{in}}\right) - \beta_L$$

$$\gamma'_{FT} = \frac{\Sigma_P^F}{\Sigma_P^E + \Sigma_P^F}\left(\frac{E}{B} - U_L^P - \frac{g_e}{\nu_{eff}}\right)\frac{1}{R_E L^3 N_0^F}\frac{\partial}{\partial L}\left(L^3 N_0^F\right) - \beta_{FT}$$

EQUARS Satellite Scientific Concept

1. Characterization of the Equatorial Spread-F:
2. Ionospheric scintillation via GPS radio occultation data;
3. Airglow radiance of the Oxygen (OI 630 nm);
4. Kinetic electron Temperature;
5. Plasma numerical density;
6. Identifying the operating instability mechanisms from their spectral characteristics (spectral power of plasma density).



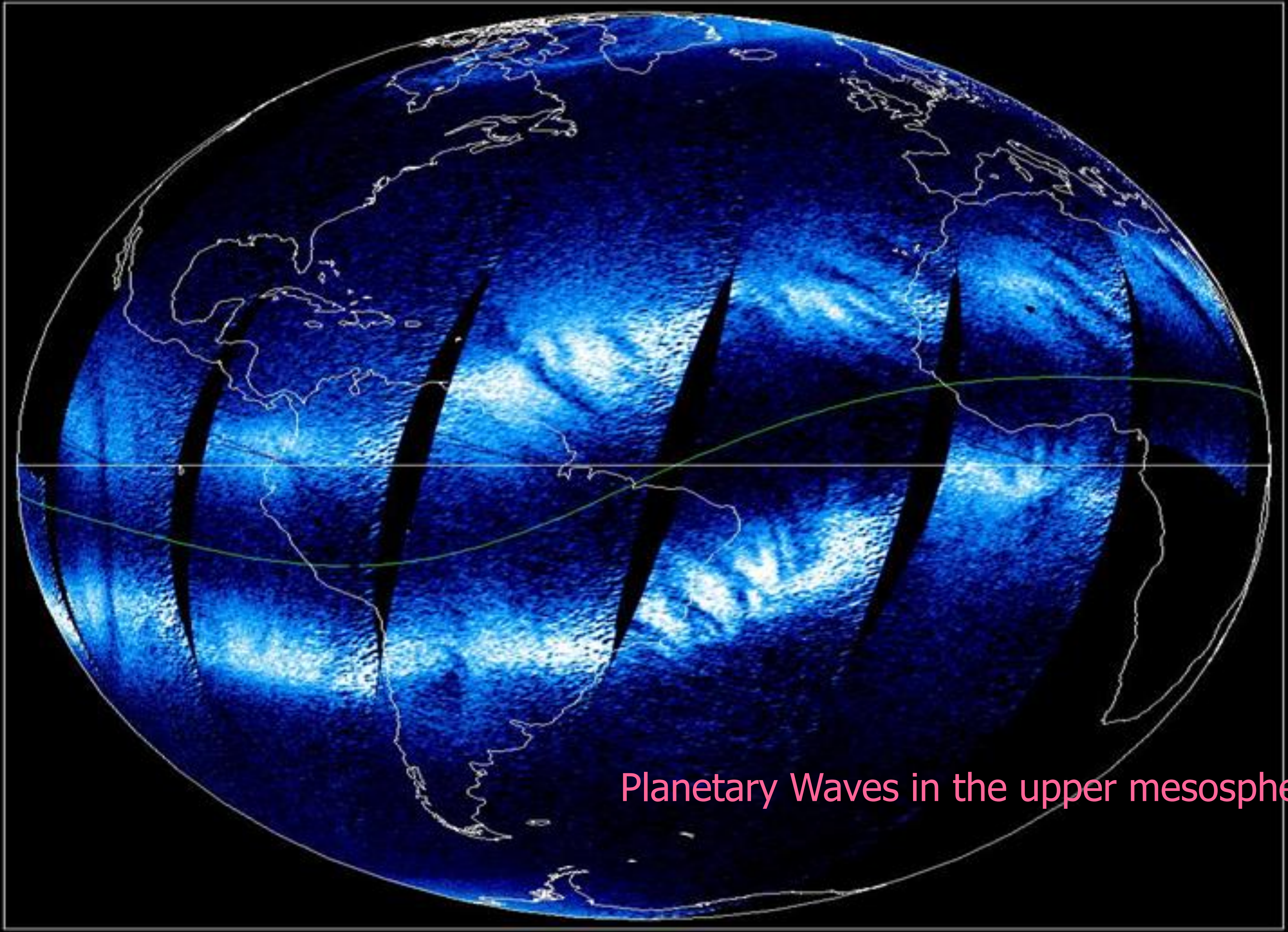


EQUARS Satellite Scientific Concept

1. Studies of planetary waves in airglow and temperature data — The planetary wave activity as a function of time, latitude and longitude;

2. Identification of propagation modes (freely propagating and trapped);

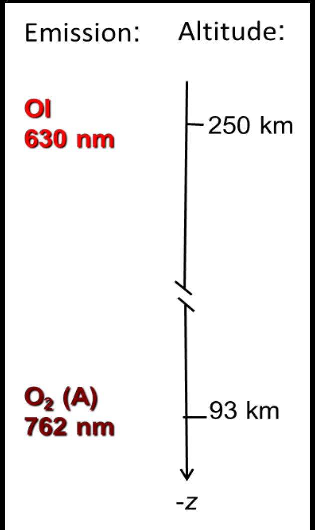
3. The effects on the development of small- and large-scale structures and the formation of Equatorial Spread-F and plasma bubbles.

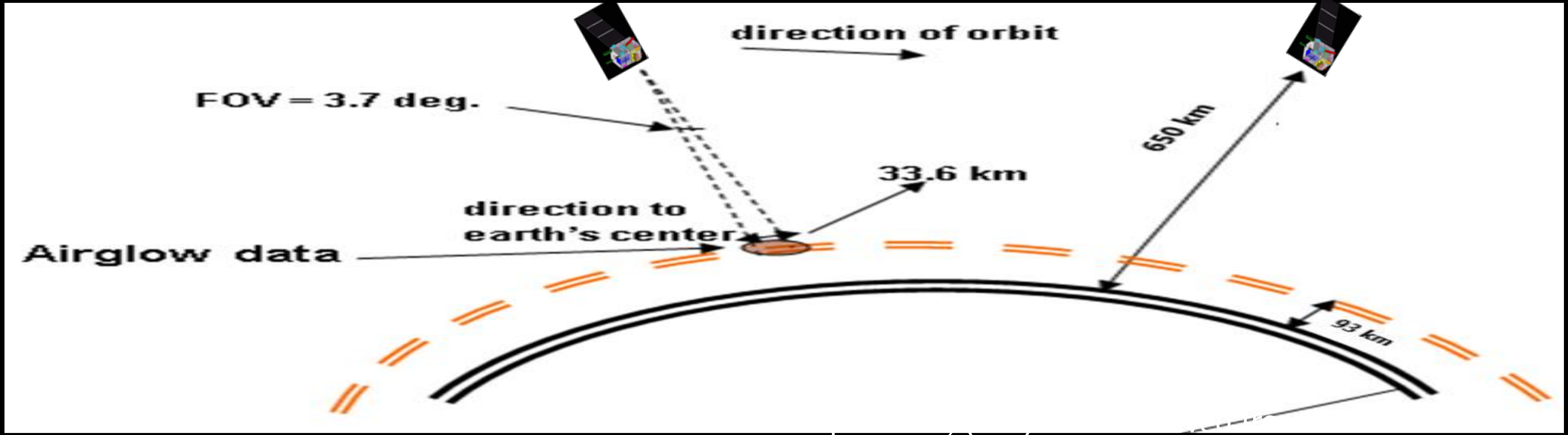


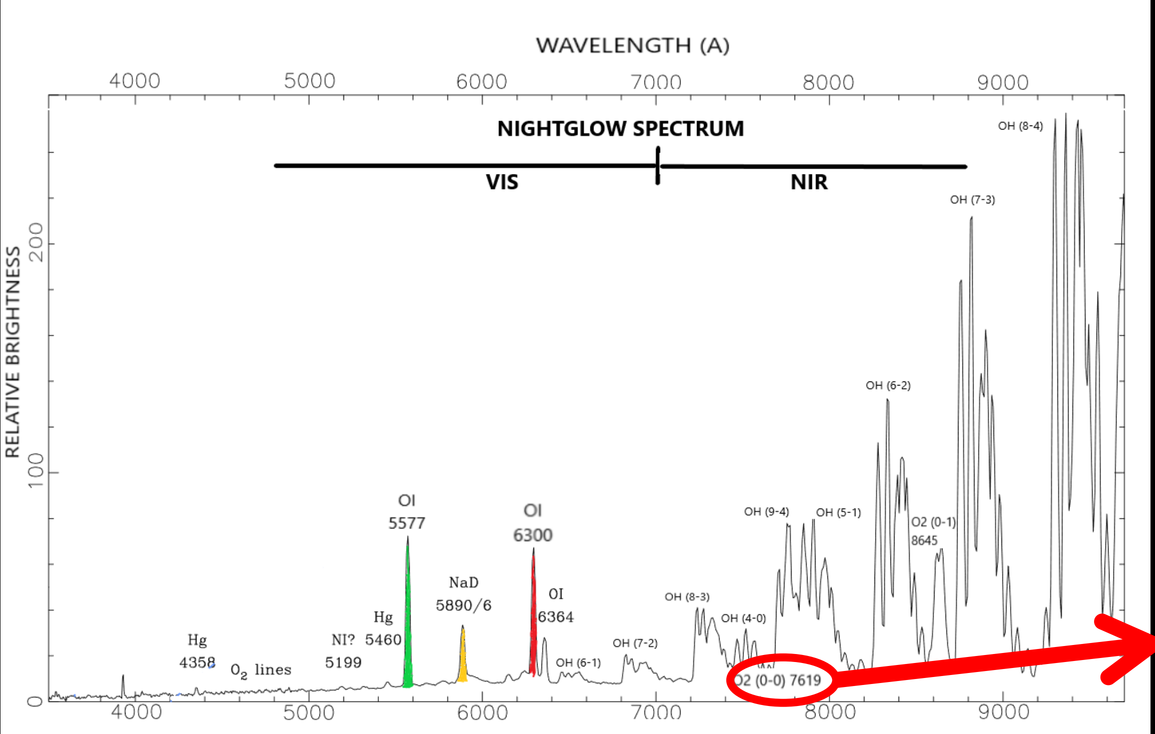
Planetary Waves in the upper mesosphere

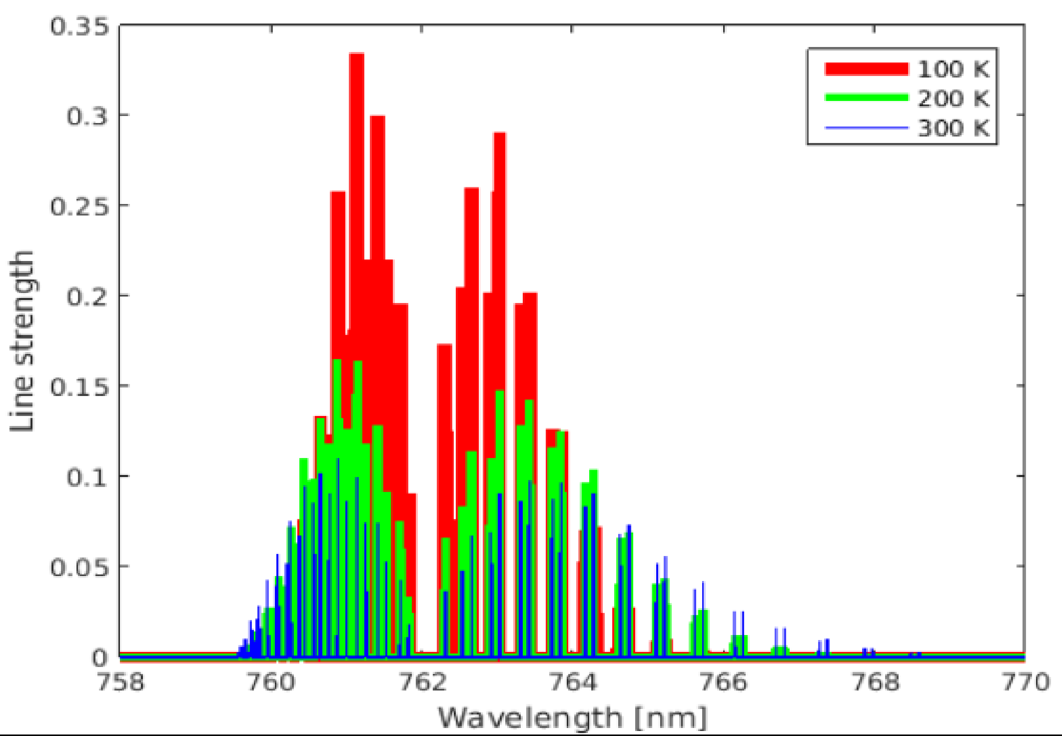
EQUARS Satellite Scientific Concept

Radiometric measurements of airglow



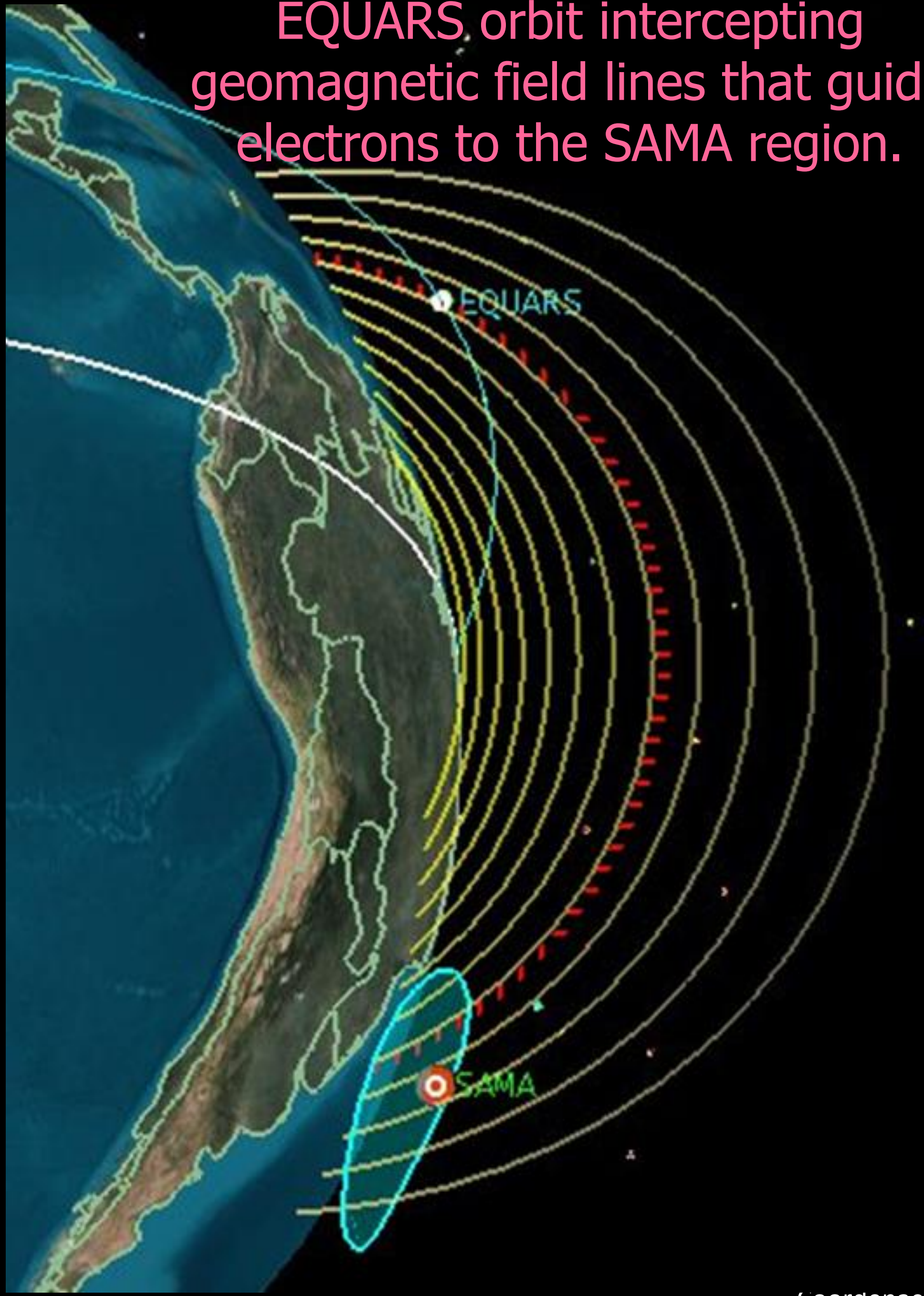






EQUARS Satellite Scientific Concept

EQUARS orbit intercepting geomagnetic field lines that guide electrons to the SAMA region.



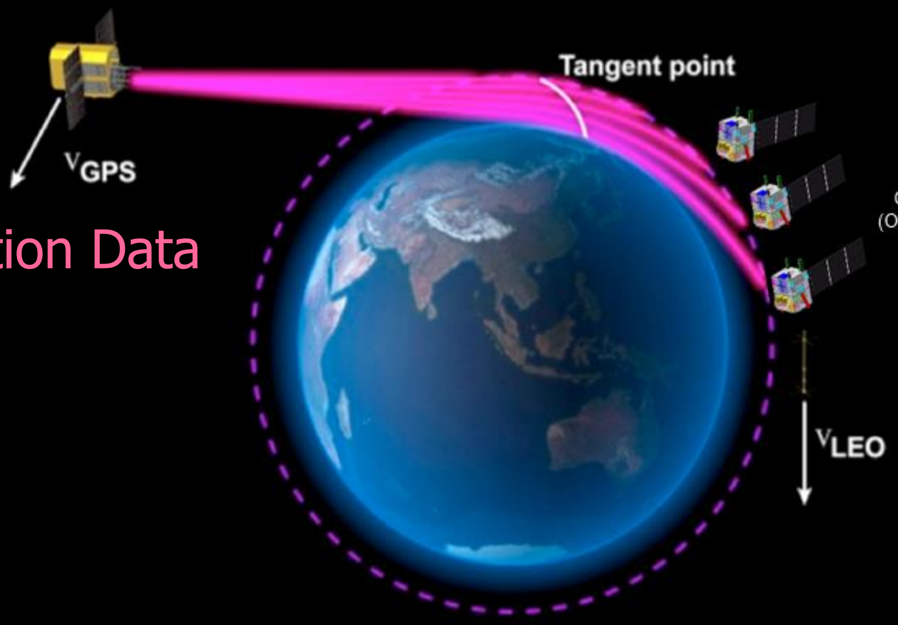
1. Determine how the electron precipitation in the South Atlantic Magnetic Anomaly (SAMA) affects the formation of the equatorial ionosphere:

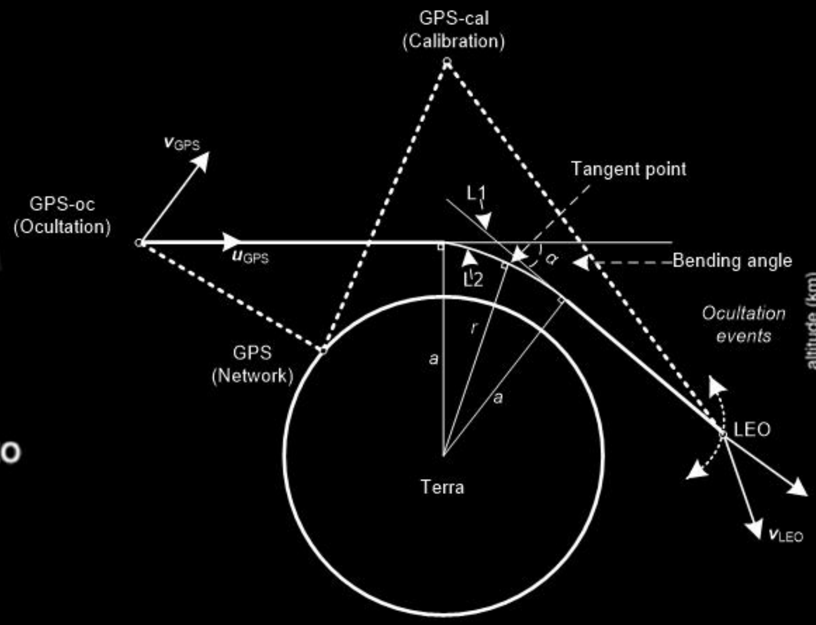
a) Sporadic E layers due to electron precipitation;
b) Determination of the Hall conductivity produced by enhanced ionization in the E region; (e.g. SUPIM-INPE model)
c) Increased the conductivity can affect the development and evolution of ionospheric bubbles.

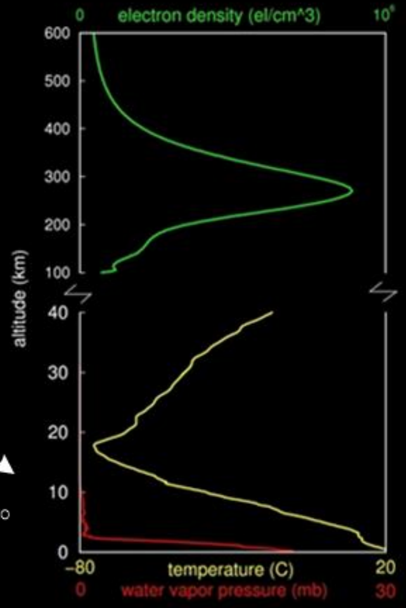
2. Directional fluxes of the electron used in the SUPIM-INPE model assume extrapolated values below to 90keV. It is important to confirm (or not) the presence of such precipitating electrons and determine their real fluxes.

EQUARS Satellite Scientific Concept

Radio Occultation Data







VARIABLE:

PROPOSAL:

VARIABLE		PROPOSAL
- Total Content Electronic (TEC) - Profiles of electronic density	~ 90-600 km	Ionospheric irregularities
- "Dry" profiles of Temperature	~ 0-40 km	Gravity wave propagations in the stratosphere
- "Wet" profiles of Water Vapour	~ 0-10 km	Water vapor in the troposphere – convective systems
- Ionospheric Scintillation	~ 90-600 km	small scale structures *

Hydrostatic balance — water vapor pressure — ionosphere

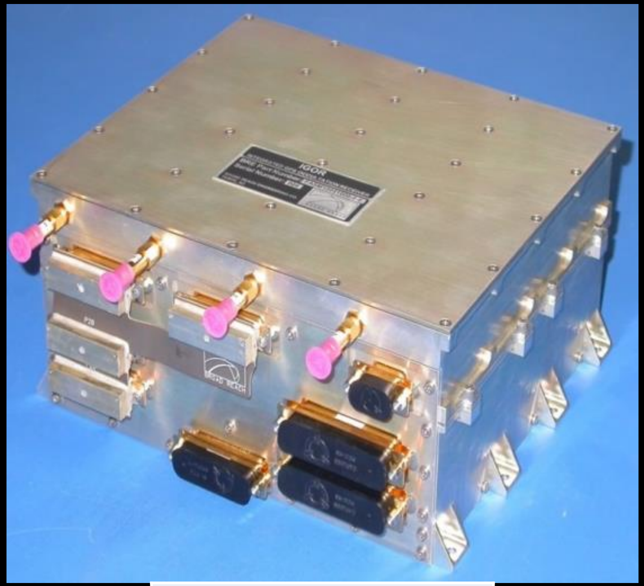
$$N = (n-1)\times 10^6 = a_1 \frac{p}{T} + a_2 \frac{p_w}{T^2} - b \frac{n_e}{f^2}$$

*Does not measure the S4 index directly. S4 index provided by CDAAC is not a true S4 index but is derived using the raw GPS signal intensity fluctuations, in addition to the assumption that the fluctuations have a Gaussian distribution

EQUARS Satellite Instruments

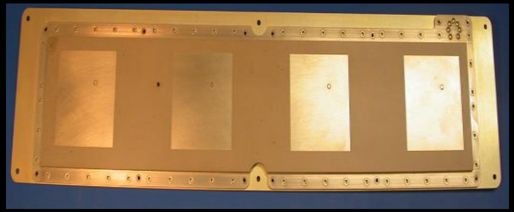
GROM (GPS Radio Occultation Measurement)

Receiver



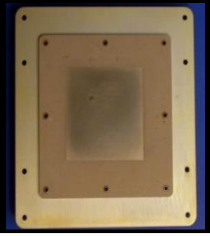
240x201x105

Occultation Antennas



455x105x6

Precision Orbit Antennas



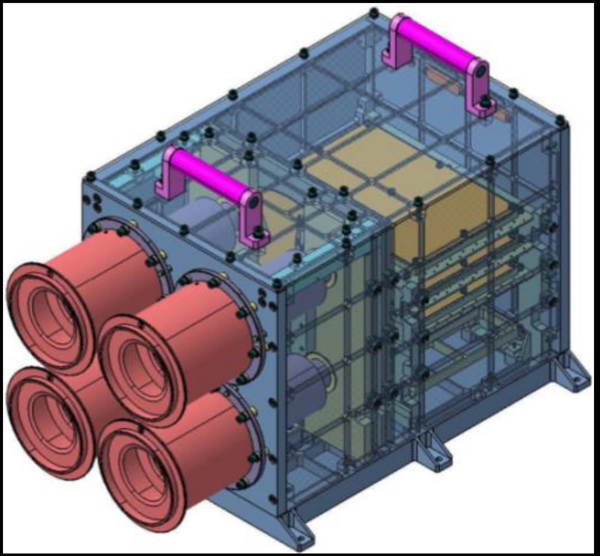
130x130x5

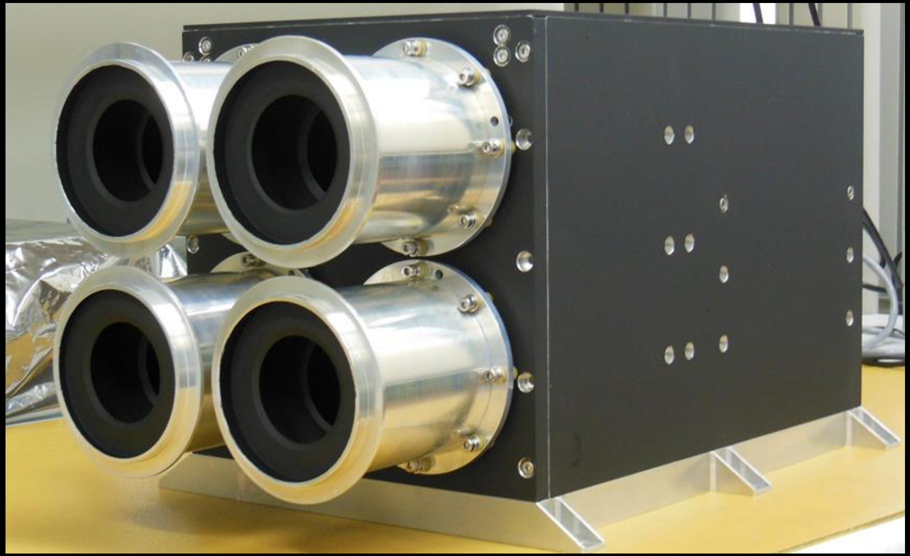
Mass (kg)	6.1
Dimension (mm)	Refer to figures
Power (W)	23
Op. Temperature (^{0}C)	-10 to 40
Sensor	IGOR™ Integrated GPS Occultation Receiver
Viewing	-Oz (25 deg) (antenna diagrams)
Duty Cycle	100%
Data Rate (per orbit)	72.61 Mbits
Development	Flight Model*

EQUARS Satellite Instruments

GLOW (Airglow Photometer)

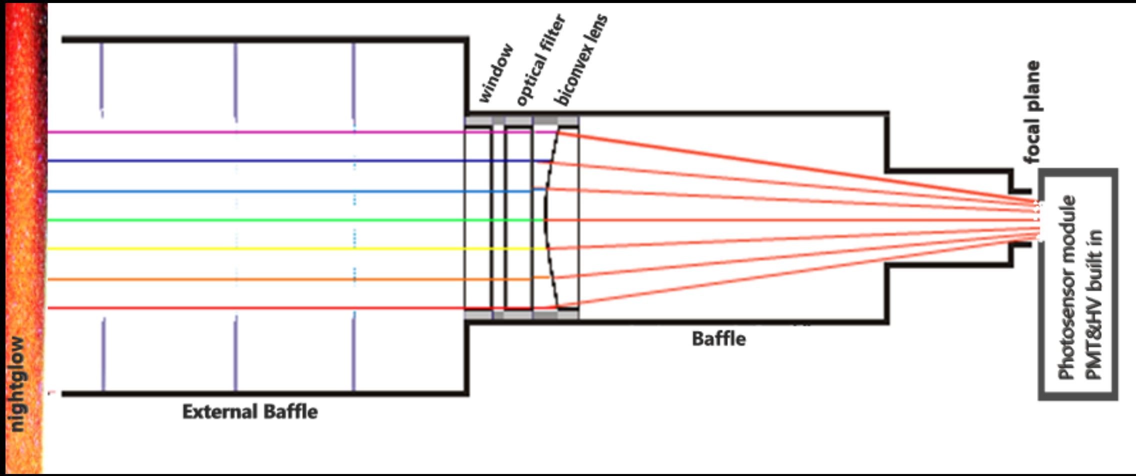
Mass (kg)	12 ± 0.5
Dimension (mm)	462.9 × 274.0 × 266.0 (±0.1)
Power (W)	9.9
Op. Temperature (°C)	-10 to 35
Sensor	4-Photosensors by Hamamatsu (photocounting mode)
Viewing	Nadir / FOV: 3.75 deg.
Duty Cycle	< 50% (nightside orbit)
Data Rate (per orbit)	7.2 Mbits
Development	Flight Model*

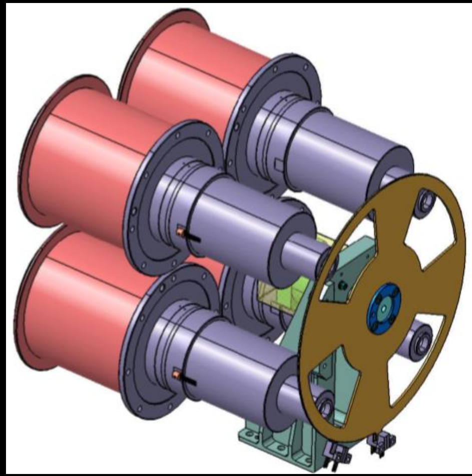




Optical Filter

Channel	Airglow	CW (nm)	HPBW (nm)
1	OI Red-Line	630.3	2.0
2	Background	710.0	10.0
3	O_2 A (0-0)	761.7	1.0
4	O_2 A (0-0)	764.2	1.5





EQUARS Satellite Instruments

IONEX (Ionosphere Experiment)

Mass (kg)	4.2
Dimension (mm)	Refer to figures
Power (W)	7.5
Op. Temperature (°C)	-10 to 50
Sensor	**LP**: Langmuir Probe **HFCP**: High-Frequency Capacitance Probe **ETP**: Electronic Temperature Probe
Viewing	(in situ) Orbital velocity vector
Duty Cycle	100%
Data Rate (per orbit)	13.1 Mbits
Development	Engineering Model

The HFCP technique:

Capacitance $C(\omega)$ of a spherical electrode immersed in the plasma

↓

Dielectric of the plasma is function of electronic density (n_e)

↓ ← Circuit oscillator $\Delta\omega/\omega_0$

$$n_e(\omega) = C_{equ.} \frac{\omega^2 \Delta\omega}{\omega_0}$$

The LP technique:

Current (I) e/ions depends on: geometry (A); potential-applied (V); plasma ambient; sensor speed (v)

↓

The sensor I measured, for a bias ΔV negative, gives n_e

↓

$$n_e = \frac{I}{eA}\left(v_{satellite} - \langle v_e \rangle \exp(-eV / k_B T_e)\right)^{-1}$$

The ETP technique:

I/V-Langmuir is deformed by superposing a RF-signal V_{RMS} over potential-applied to the sensor

↓

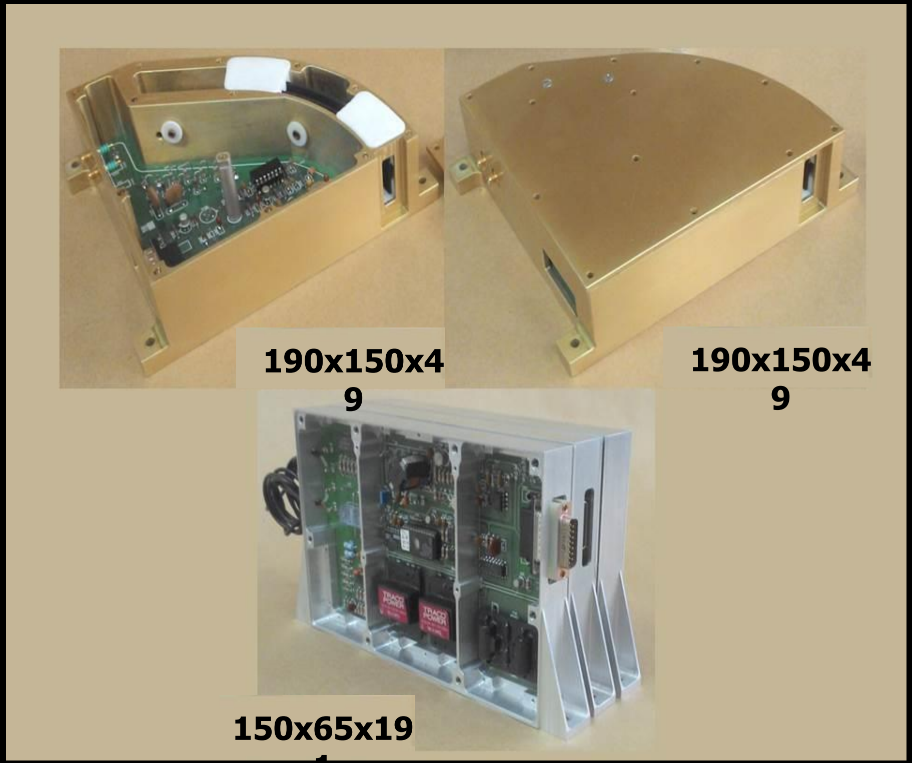
The ΔV bias between two sensors can be related to the electron kinetic temperature T_e

↓

$$-\frac{e\Delta V}{k_B} = T_e \ln\left(\mathrm{BesselI}[0, eV_{RMS} / (k_B T_e)]\right)$$

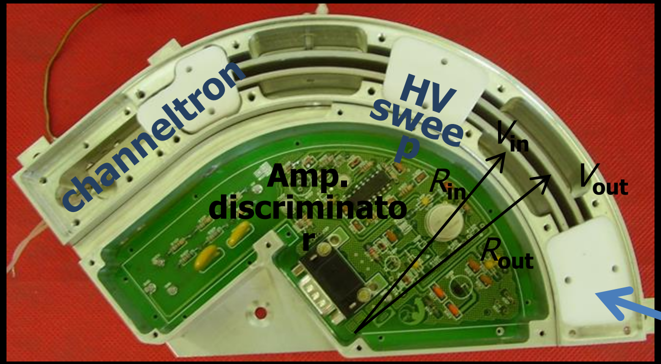
EQUARS Satellite Instruments

ELISA (Electrostatic Energy Analyzer)



Mass (kg)	5.2
Dimension (mm)	**Refer to figures**
Power (W)	6.4
Op. Temperature (ºC)	-10 to 50
Sensor	2-Channeltron® Electron Multipliers
Viewing	(in situ) ‖ B_{earth} and perpendicular to each other / FOV: 60deg.
Duty Cycle	100%
Data Rate (per orbit)	3.8 Mbits
Development	Engineering Model

Cylindrical electrostatic analyzer



Particle beam (entrance)

The technique:

Energies for electrons incident normally:

$$E \cong q(V_{out} - V_{in}) / 2\ln(R_{out} / R_{in})$$

Range: 861.0 eV to 25.8 keV

Energy for other angles of incidence:

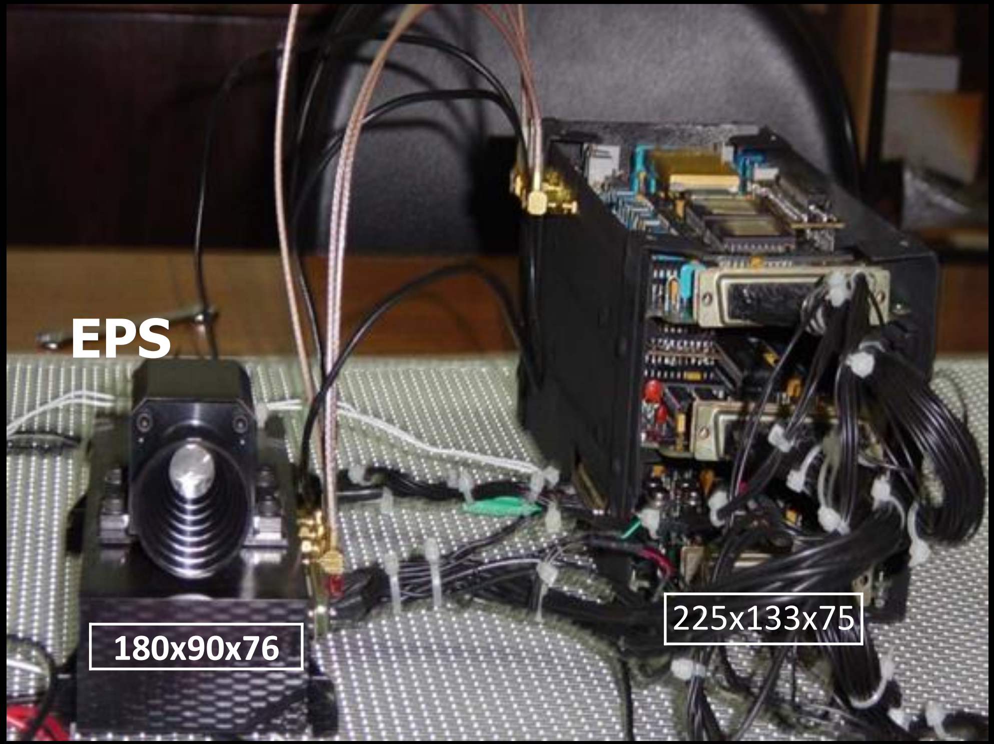
edge effects

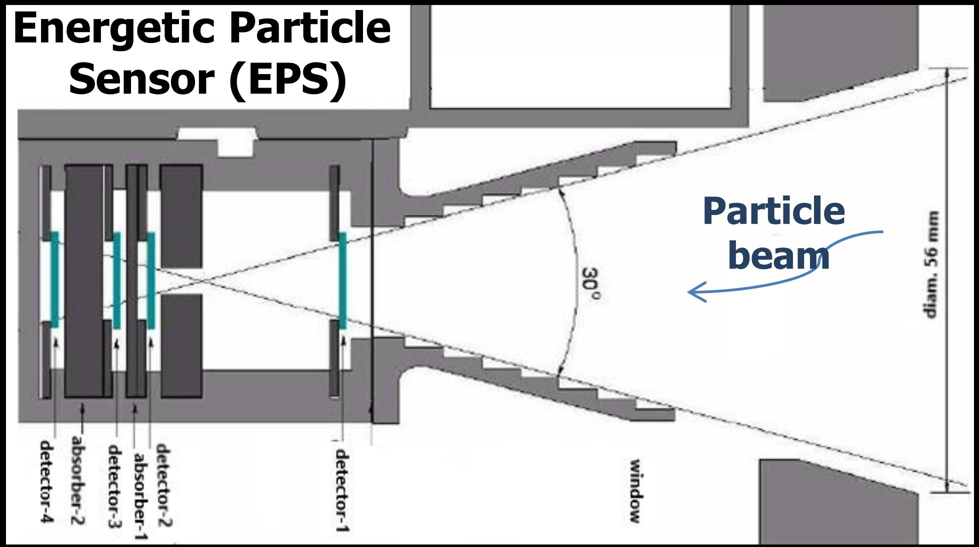
- The field and particle trajectory simulator - SIMION 8.1
- Experimental - Particle beams in the laboratory

Range: ~700.0 eV to ~29.0 keV

EQUARS Satellite Instruments

APEX (Alpha, Proton and Electron monitoring Experiment)





Particle	E_1 (MeV)	E_2 (MeV)	E_3 (MeV)	E_4 (MeV)	E-loss (MeV)
electron	> 0.1	> 0.3	> 1.2	> 3.4	0.15
proton	> 3.5	> 8.2	> 24.	> 42.	0.6
alfa	> 14.	> 31	> 92.	> 170.	10.0

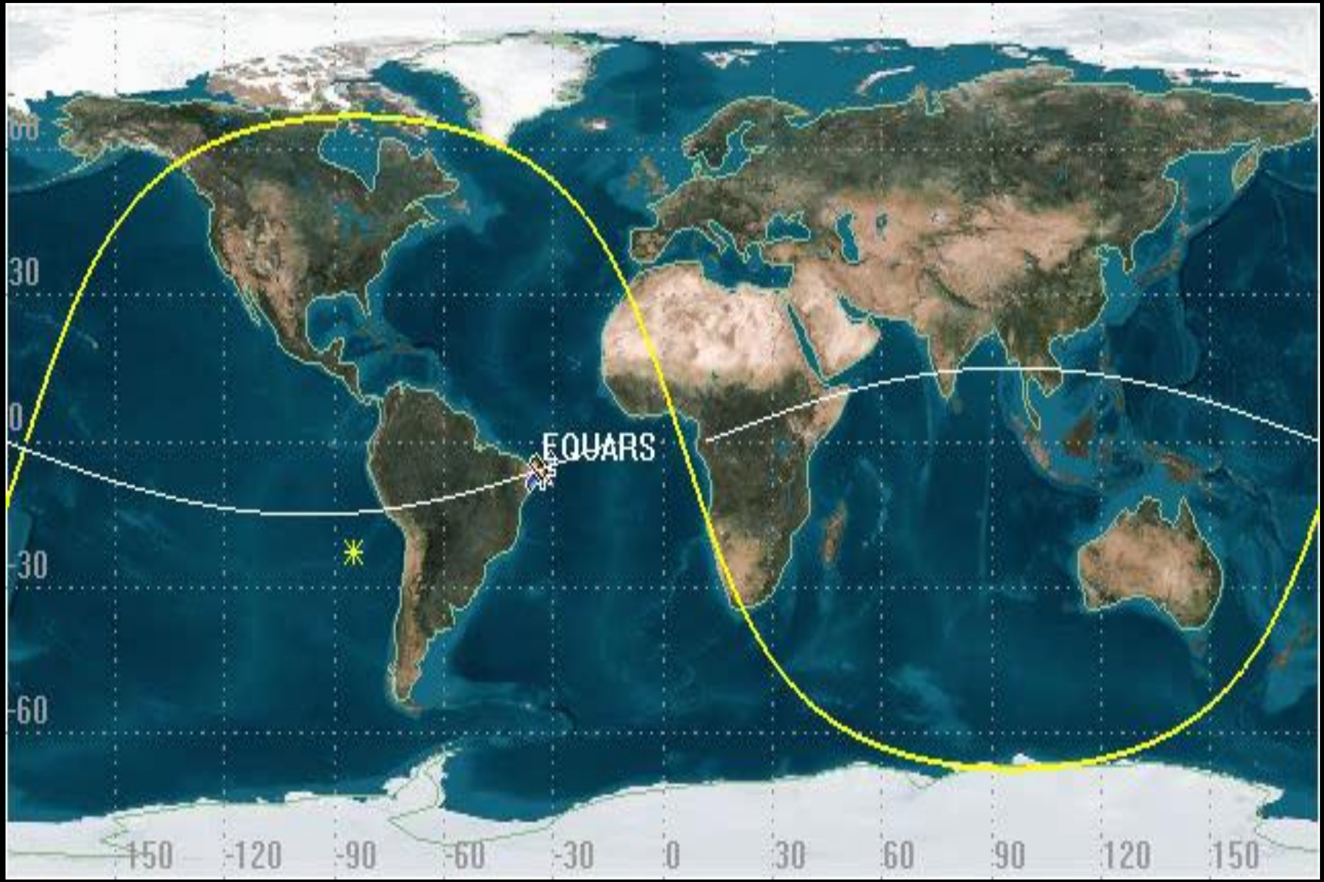
Mass (kg)	3.0
Dimension (mm)	Refer to figures
Power (W)	3.2
Op. Temperature (^{0}C)	+10 to 40
Sensor	Silicon Detectors (PIN diodes) / Aluminum Absorbers
Viewing	(In situ) -Oy / FOV: 30 deg.
Duty Cycle	100%
Data Rate (per orbit)	1.7 Mbits
Development	Engineering Model

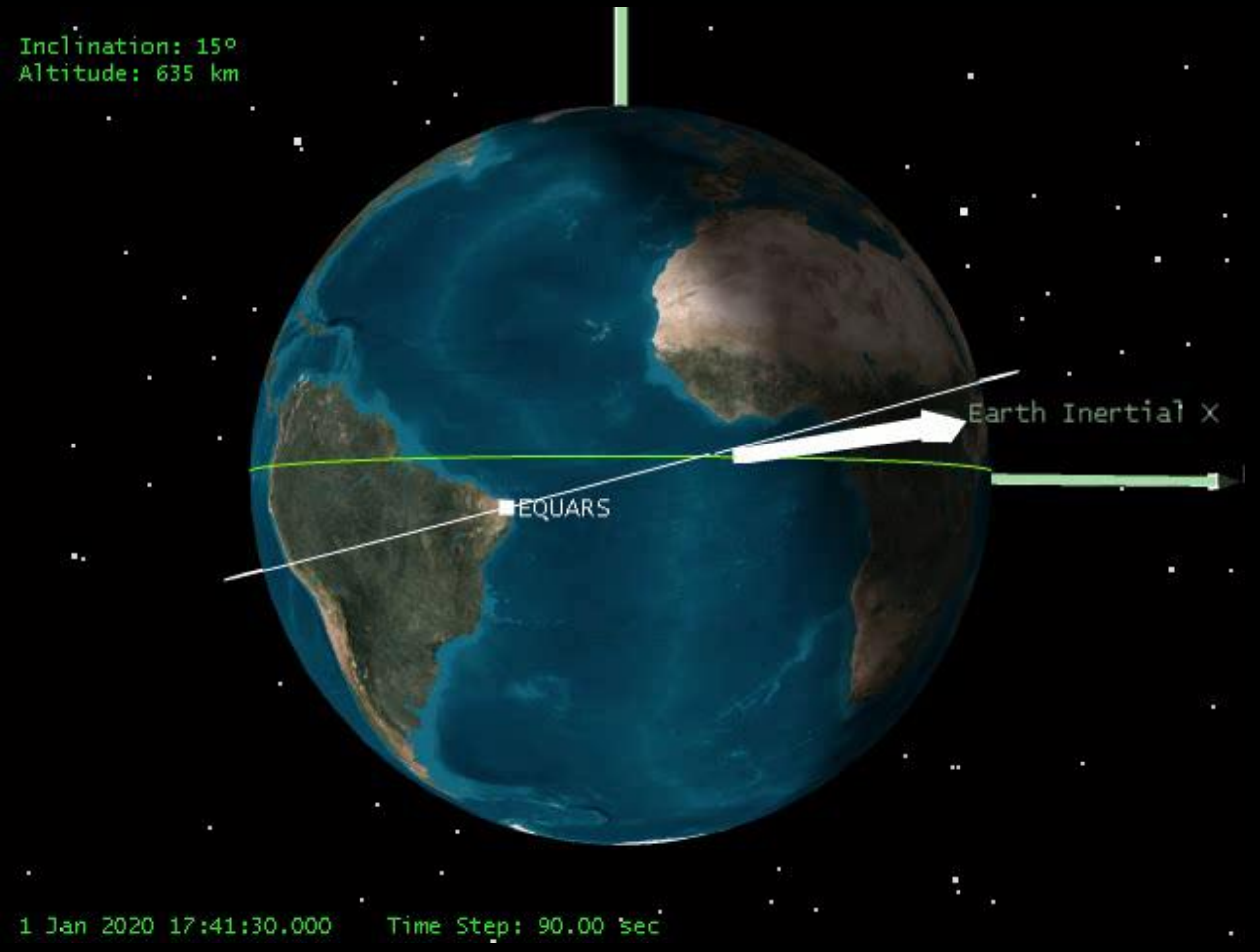
EQUARS Satellite Orbit

Instrumento	Faixa de altitude desejada (km)	Faixa de altitude aceitável (km)	Faixa de latitude de interesse (graus)
GROM	800	600 a 800	-20º a +20º
GLOW	700 a 800	600 a 800	-15º a +15º
IONEX	400 a 650	300 a 700	-15º a +15º
ELISA	700	600 a 800	-16º a +16º
APEX	650 a 750	-	-15º a +15º

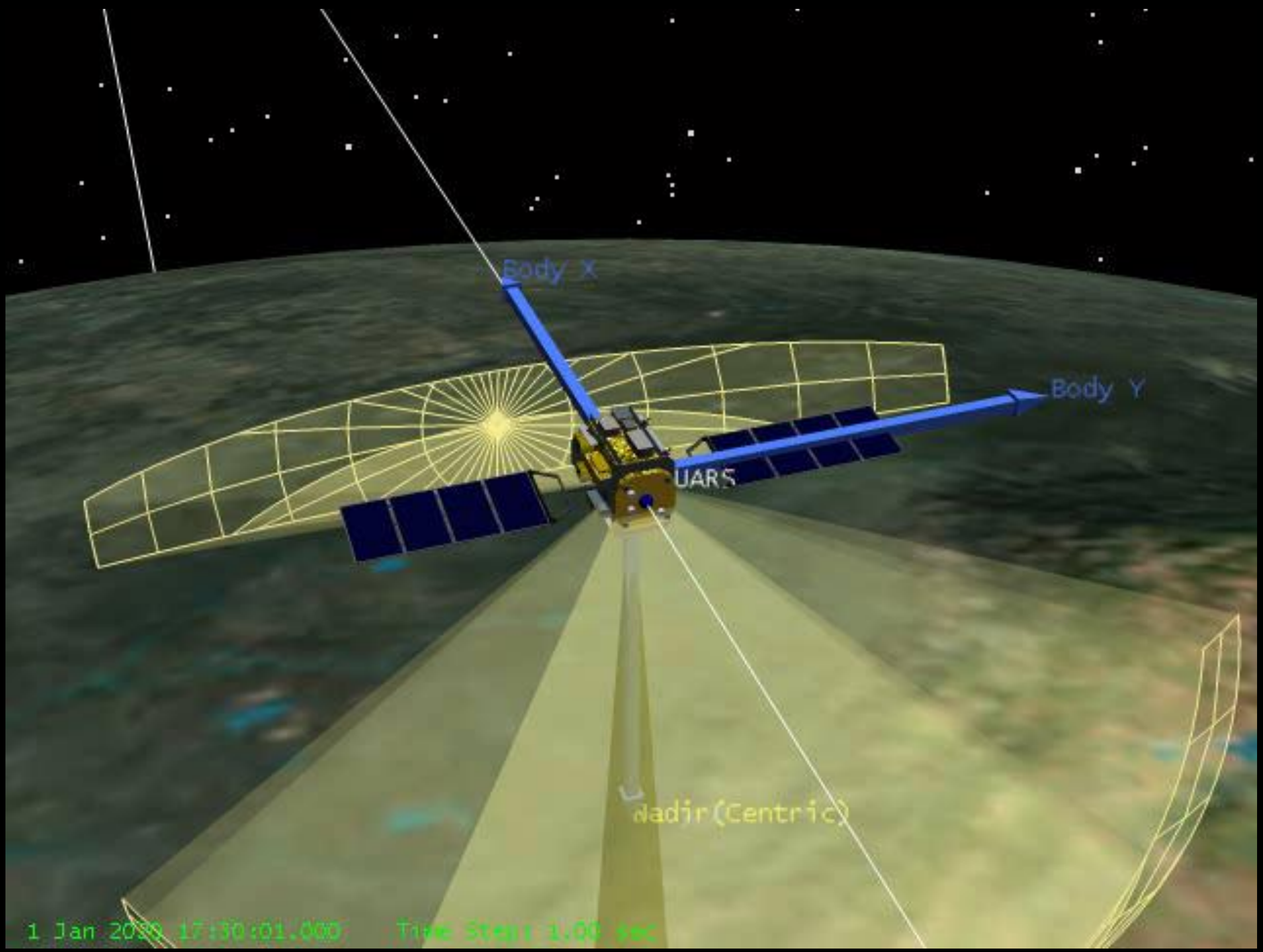
Inclination = 15º

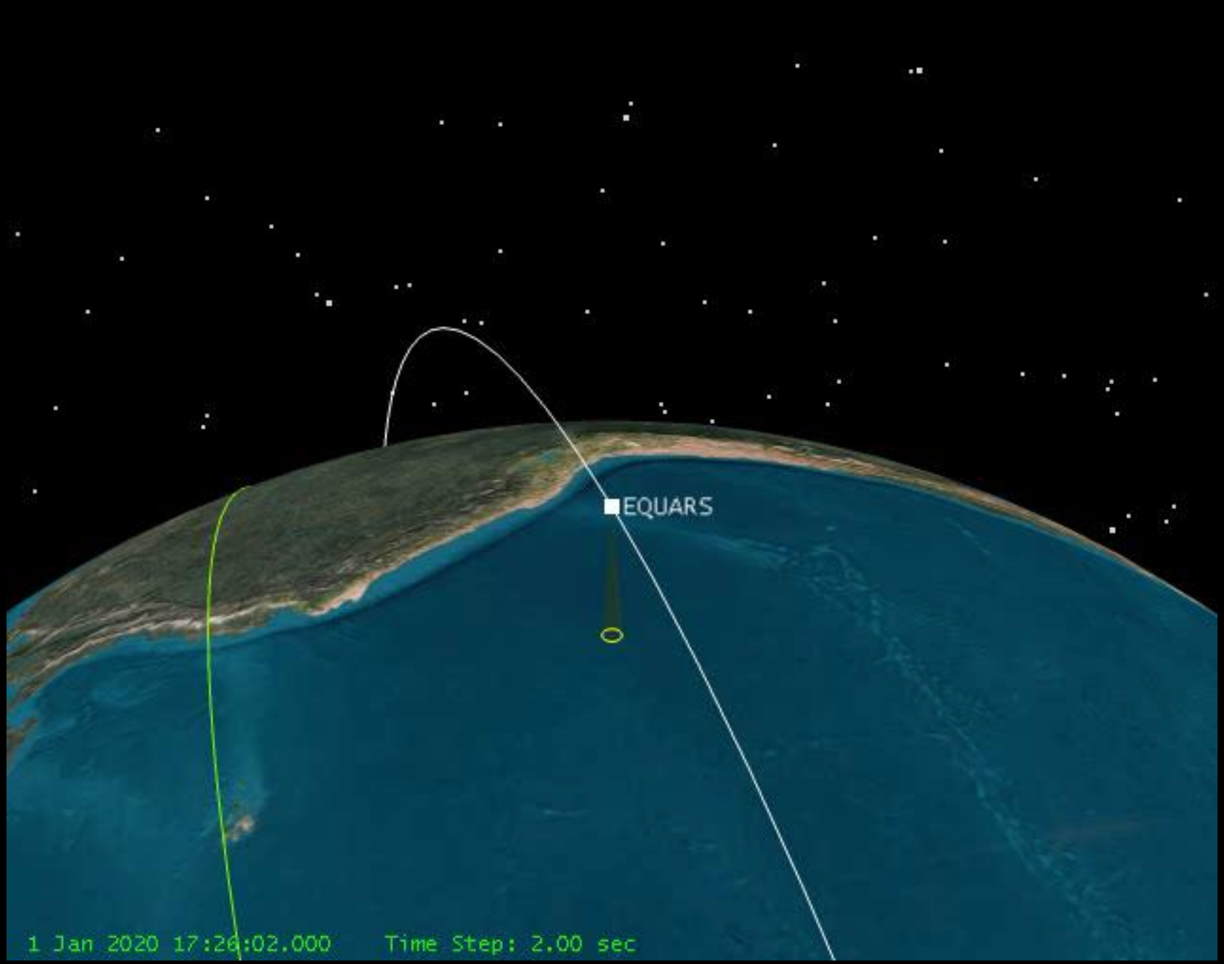
Altitude = 635km





EQUARS Satellite Attitude





3 axis control
Pointing to Nadir

Instrumento	Tipo Medida	Orientação Instrumento
GROM	Indireta, rádio ocultação	Limbo terrestre
GLOW	Remotamente	Nadir
ELISA	Indireta, *In situ*	Norte/Sul
IONEX	Direta, *In situ*	Vetor velocidade orbital
APEX		

EQUARS Satellite TT&C

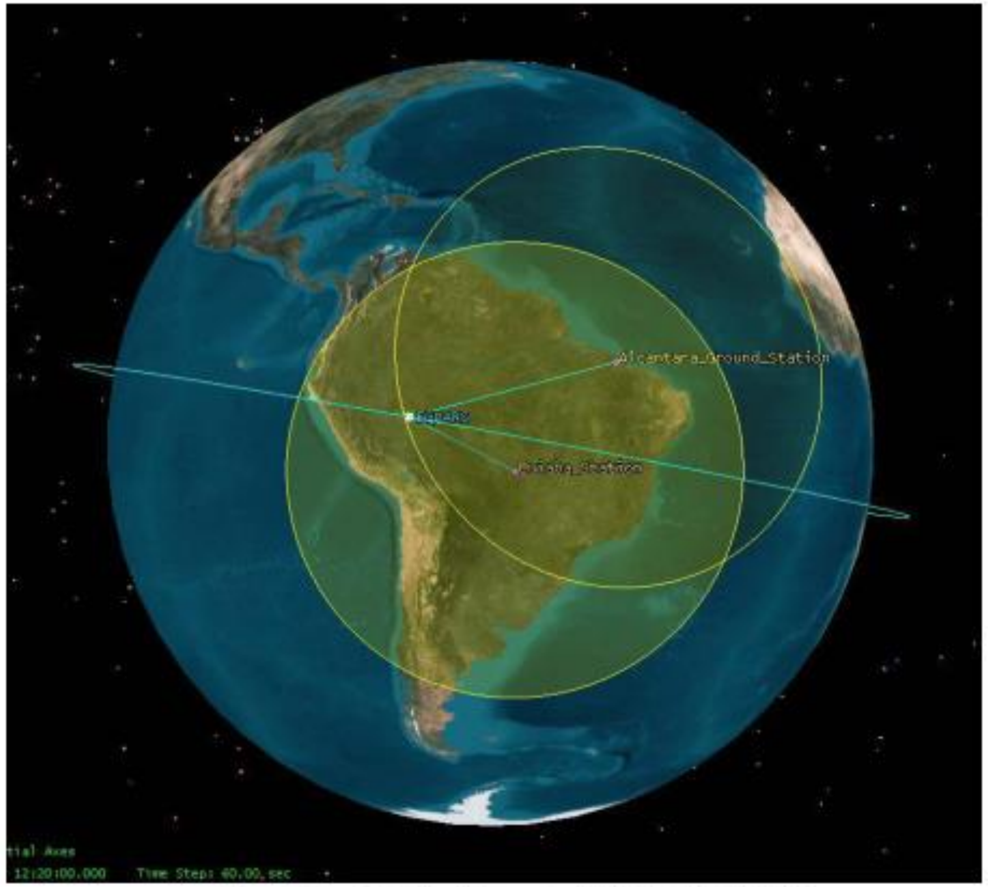
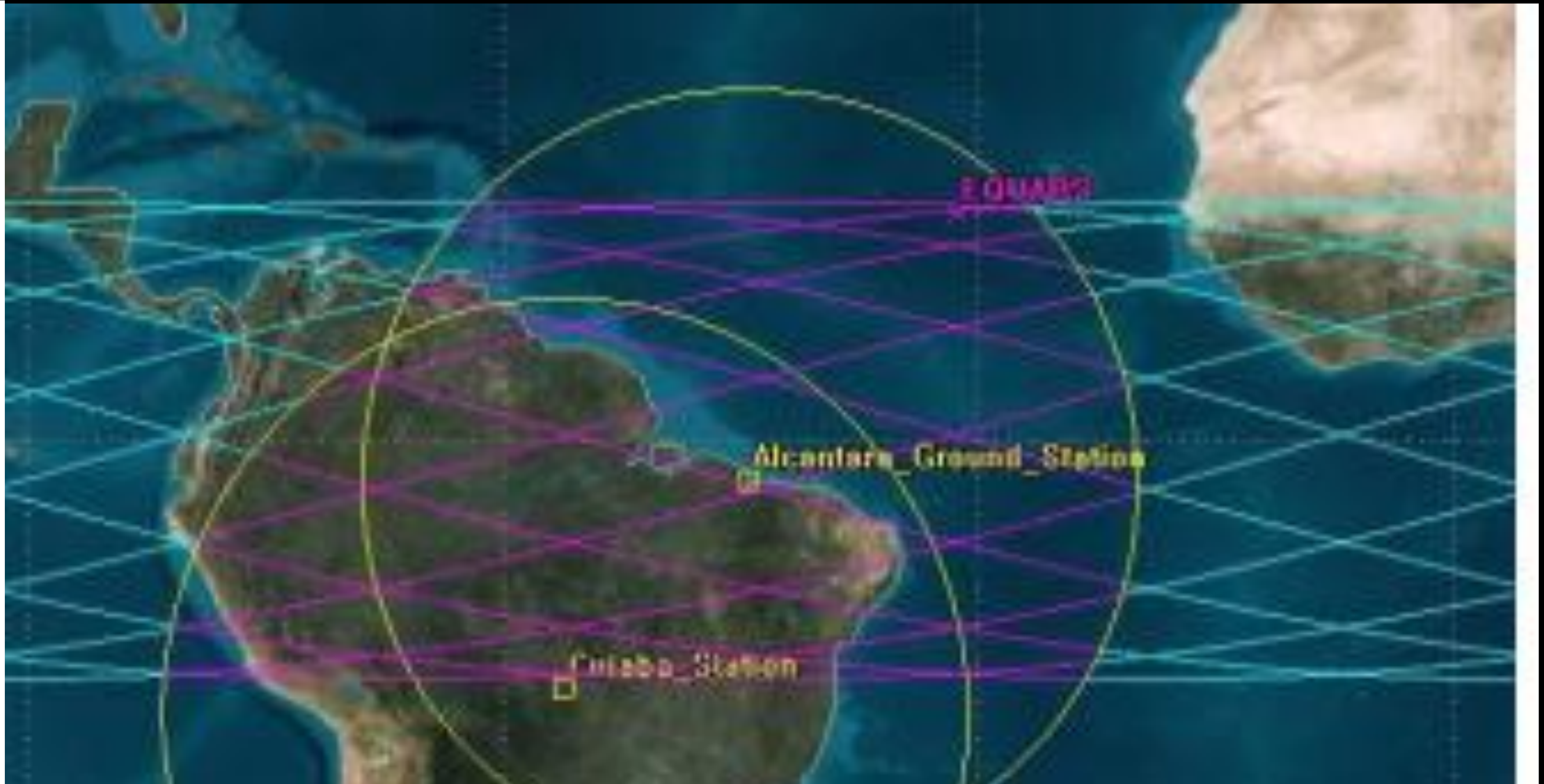


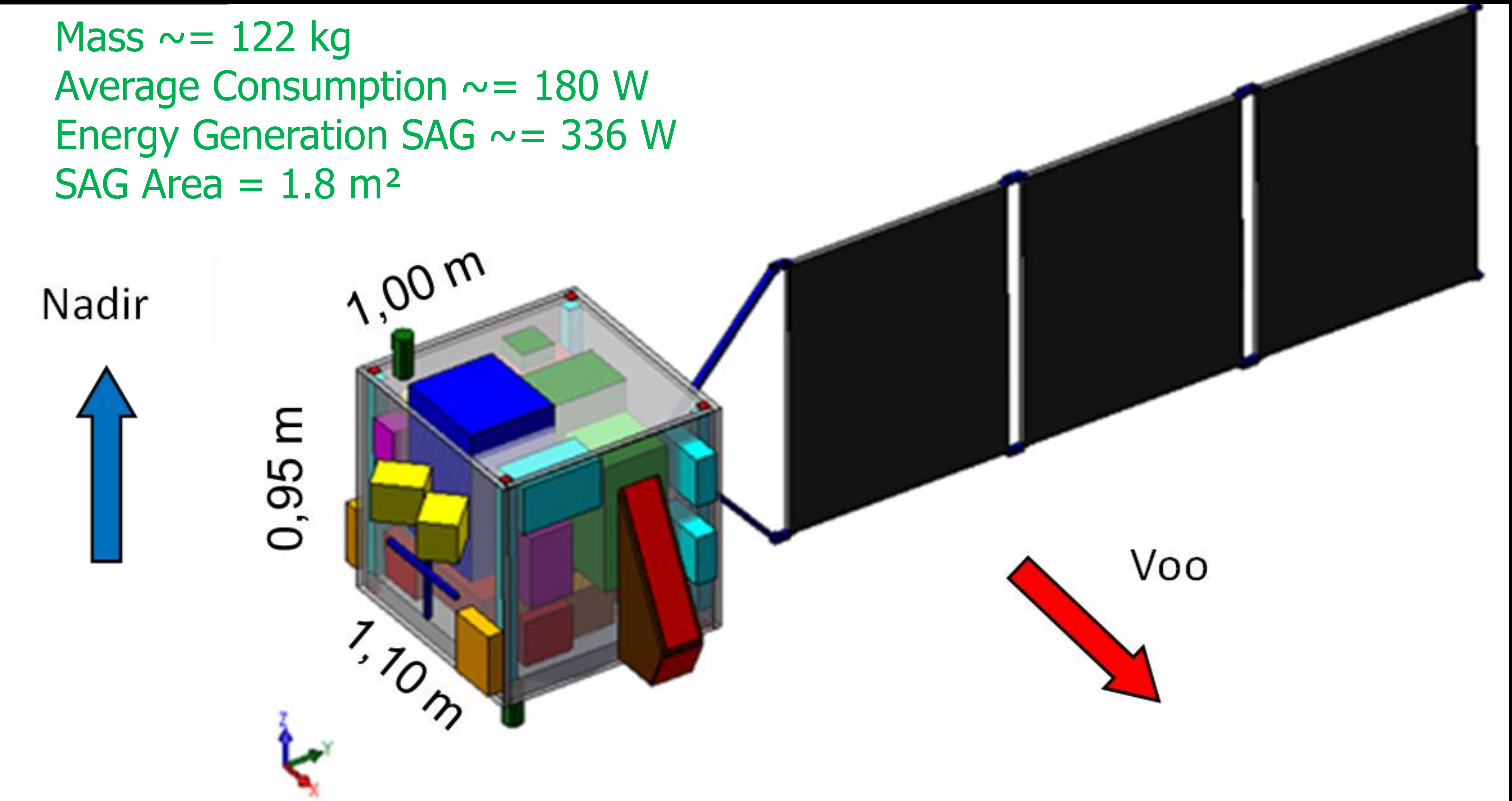
Figura 35 Estações Terrenas – Visibidade EQUARS.



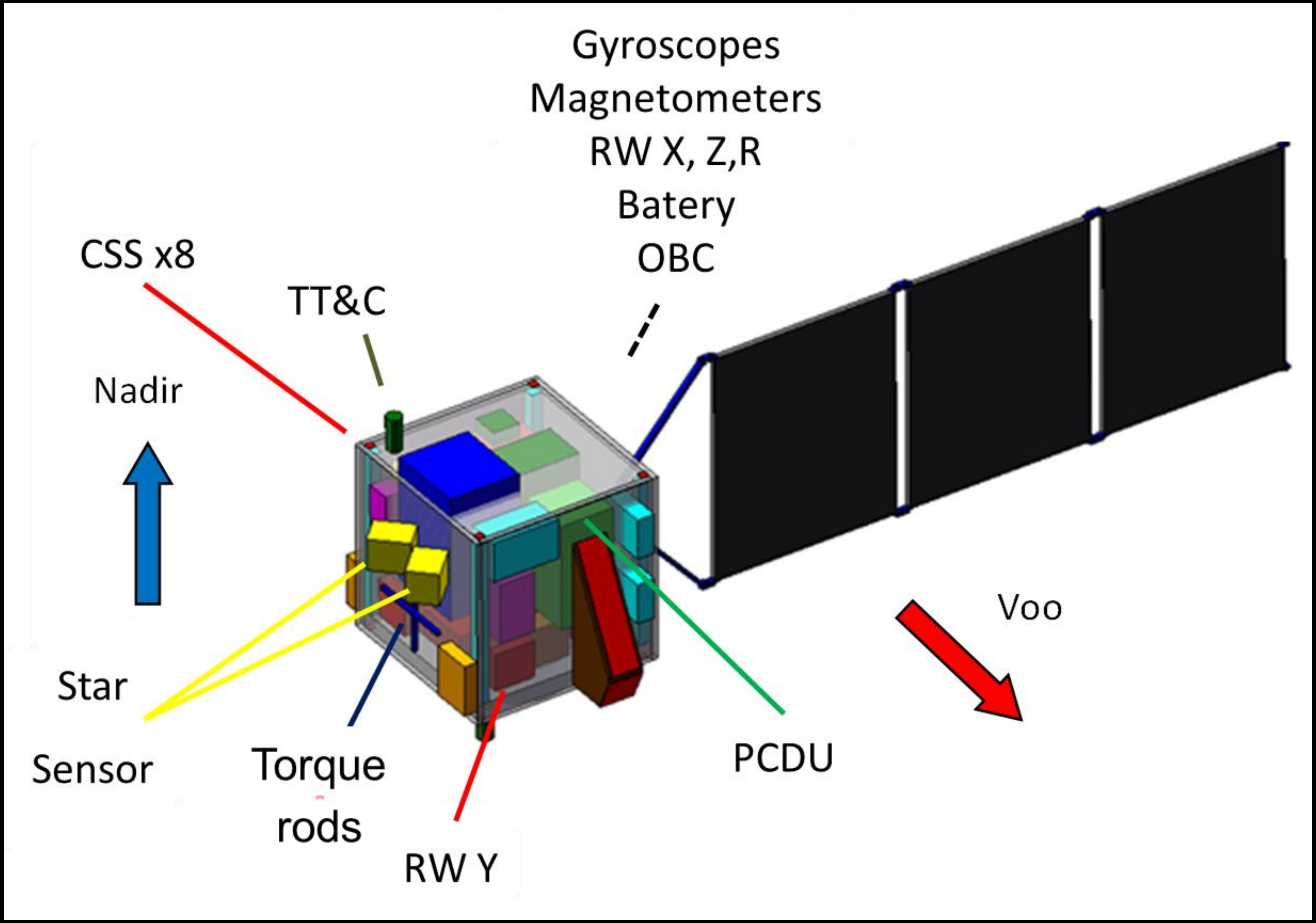
Estação Terrena	Passagens em Visibilidade/Dia (Média)	Tempo de visibilidade por passagem (Média - min)	Total/Dia (Média - min)
Alcântara	13,8	9,6	133,04
Cuiabá	8,4	9,5	77,75
		TOTAL	210,80

EQUARS Satellite Genereal Specification

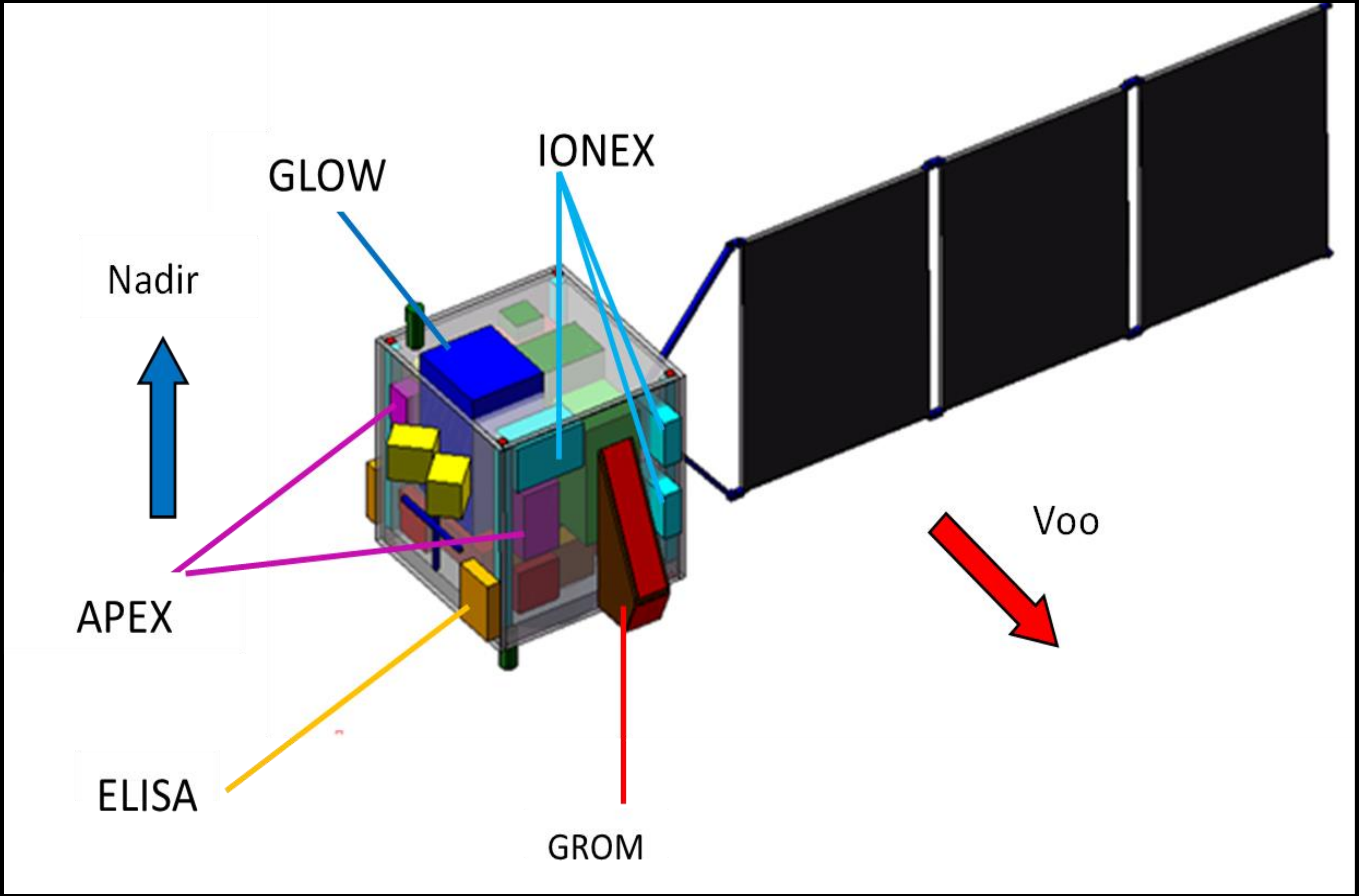
Mass ~= 122 kg
Average Consumption ~= 180 W
Energy Generation SAG ~= 336 W
SAG Area = 1.8 m²



EQUARS Satellite Control Configuration



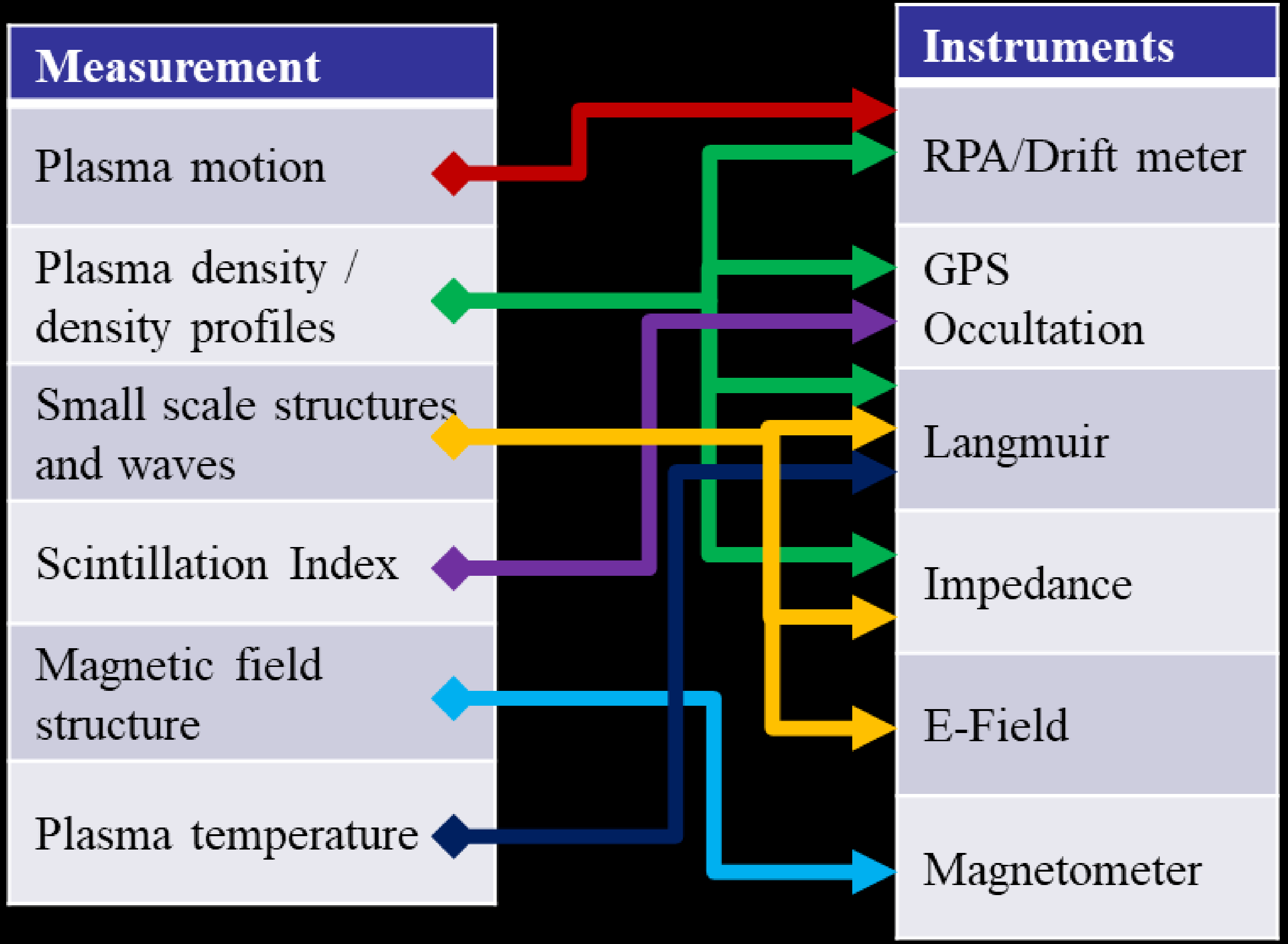
EQUARS Satellite Intrument Configuration

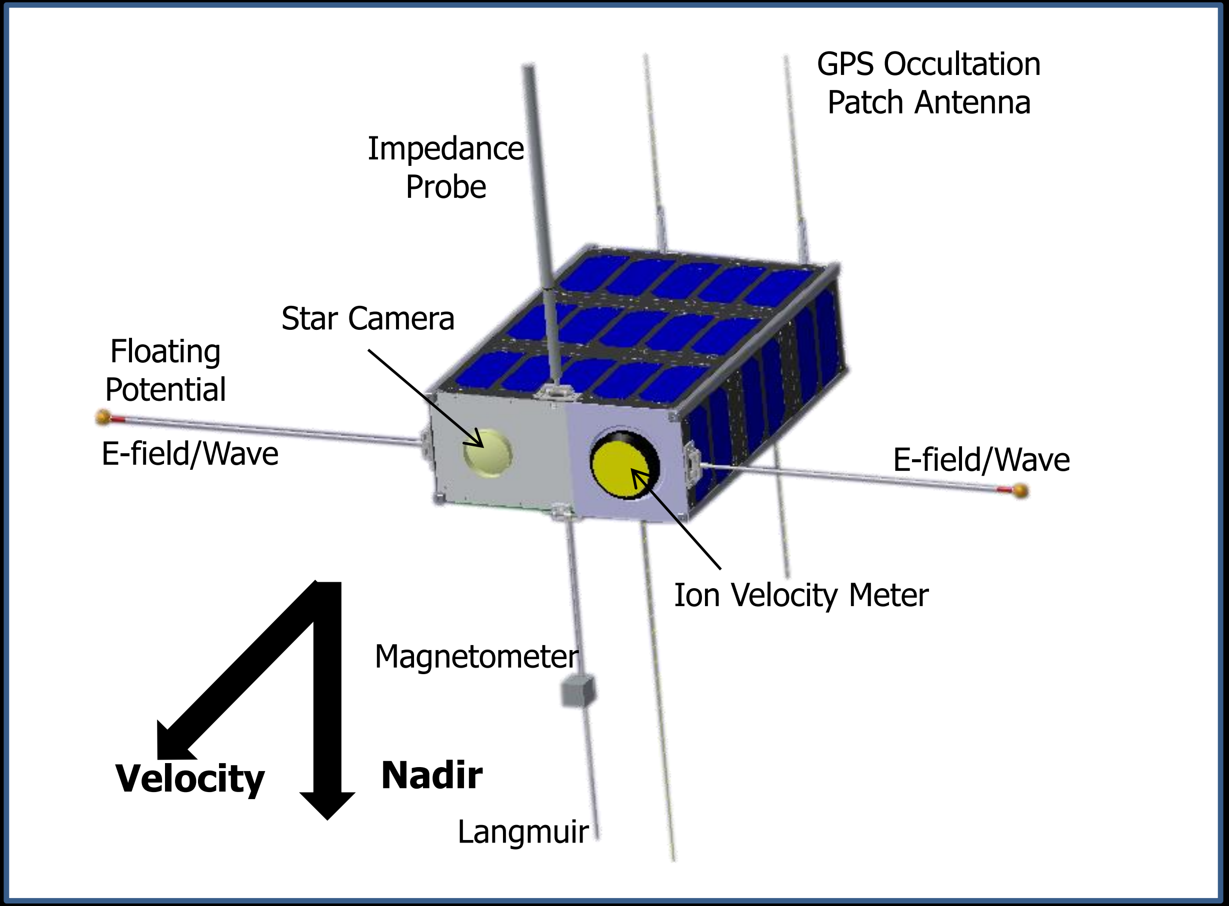


1) What is the state of the ionosphere that gives rise to the growth of plasma bubbles that extend into and above the F-peak at different longitudes?

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

SPORT Mission Measurement and Instrumentation





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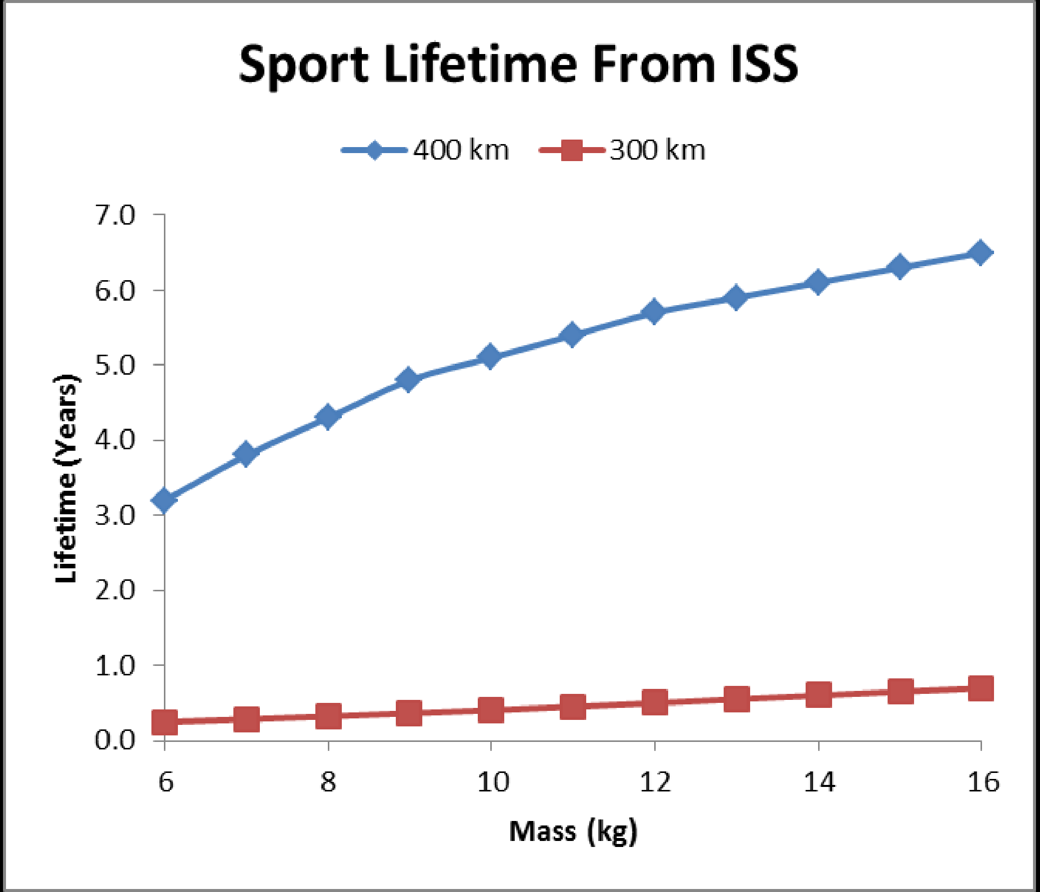
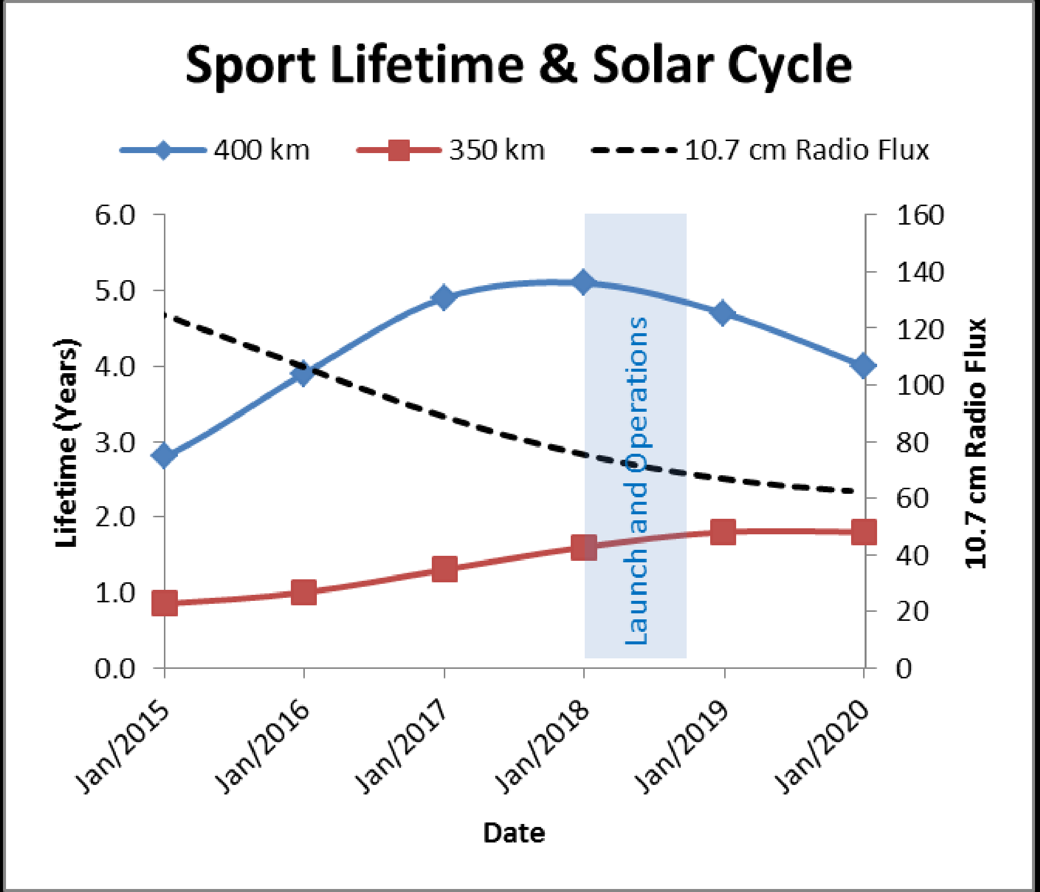
SPORT Mission Lifetime Tool (ISS Launch)

Starting Altitude



Maximum Mass 6U CubeSat
12 kg (6U Standard)
16.9 kg (NANORACKS)

10 kg, 6U Spacecraft



Minimum Drag Orientation
STK Lifetime Tool, NRL MSIS 2000
1 Sigma Solar Flux

LECX Satellite

CubeSats

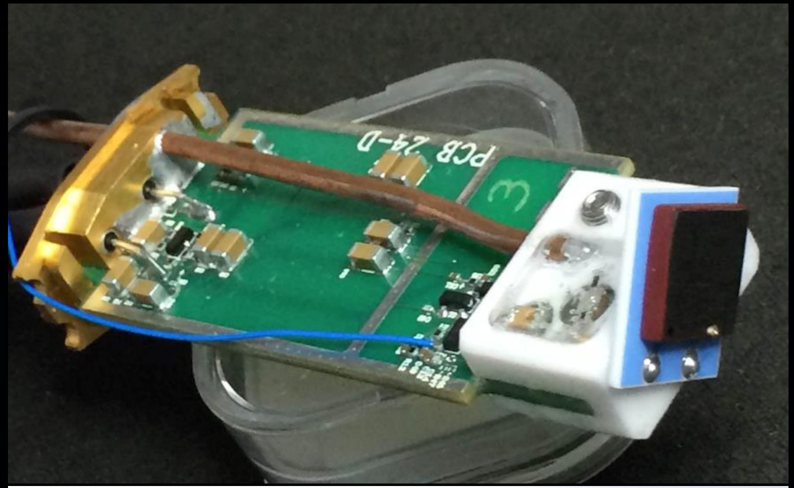
L E C X

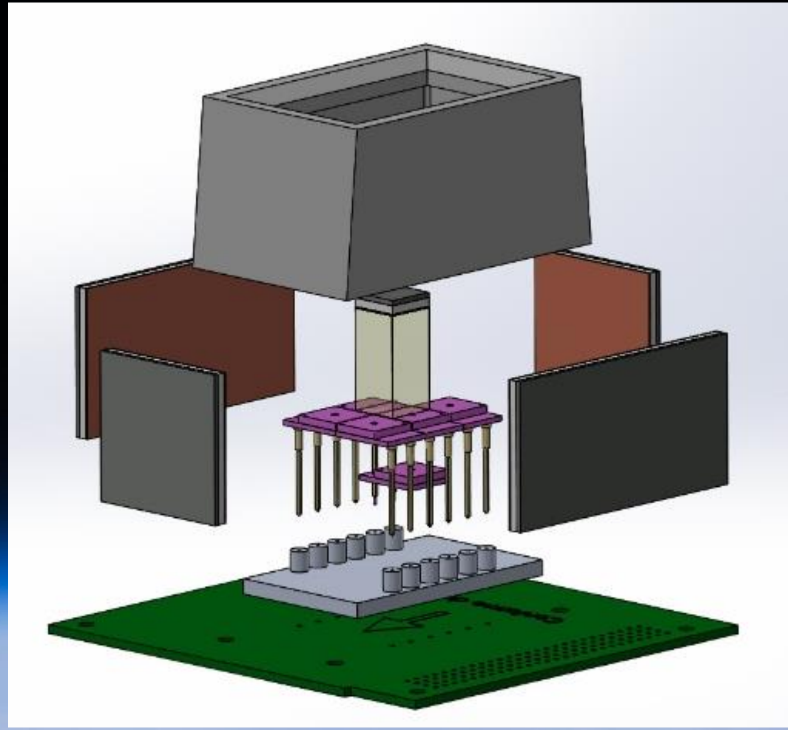
Payload of the nanosat CRON-1 (2U)
Projeto PIPE FAPESP

1. It can detect one cosmic explosion per month and locate it within few degrees of precision.

2. It can be uses for locate of electromagnetic counterparts sources due to gravitational waves.

4 CZT detectors
(tested in the protoMIRAX)





Exploded Model of the LECX

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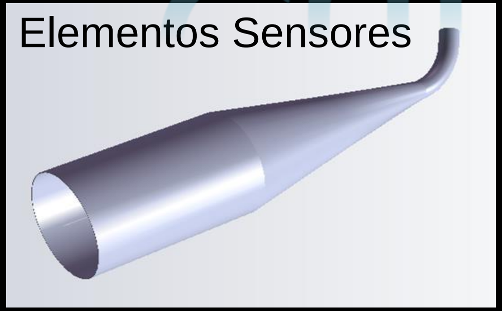
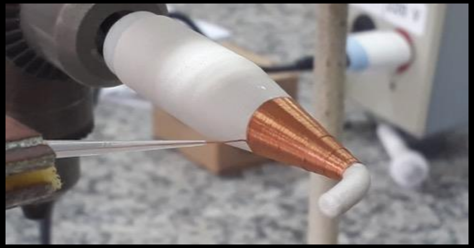
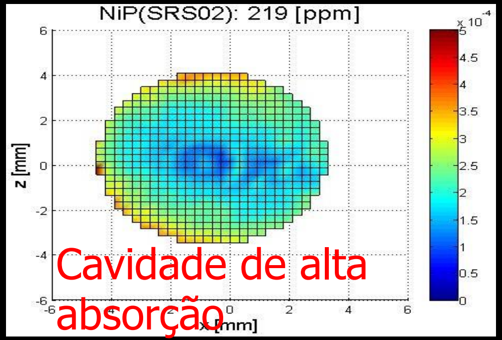
CubeSats

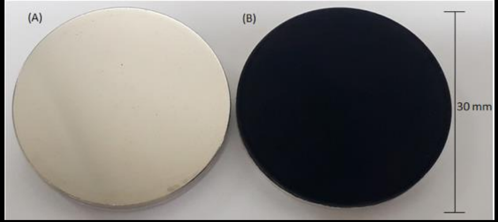
Wide Range Radiometer

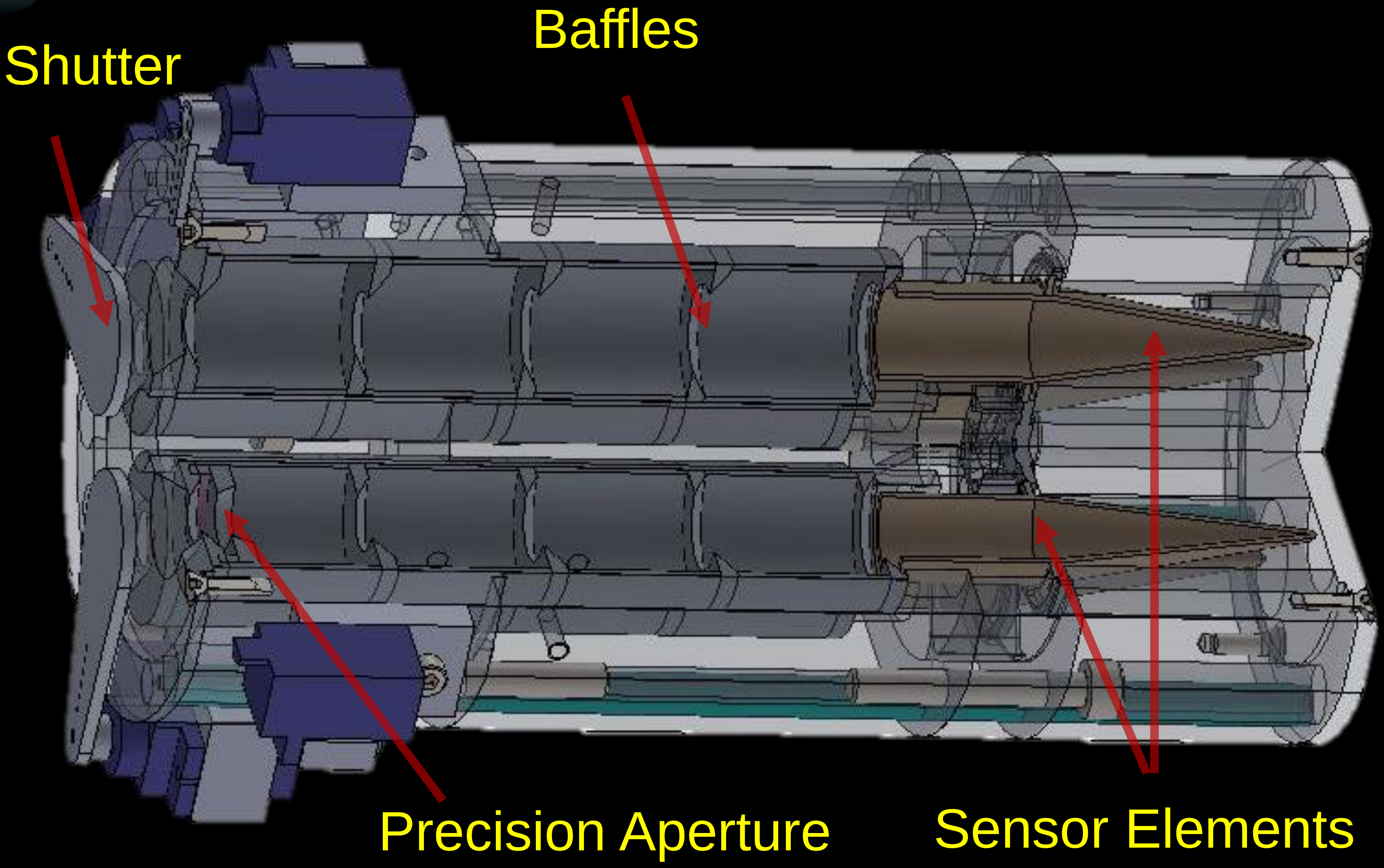
Observation of the variability of total solar irradiance
Instrument: Absolute Radiometer
Approach: Electrical Replacement Radiometer












OBRIGADO
рахмат
danke
謝謝
ngiyabonga
teşekkür ederim
Баярлалаа
mersi
barka
welalin
tack
спасибо
faafetai lava
vinaka
blagodaram
dank je
misaotra
paldies
grazzi
mahalo
tapadh leat
kiitos
dankie
matondo
thank you
gracias
хвала
dhanyavad
asante
manana
bedankt
hvala
mauruuru
obrigada
enkosi
djiere dieuf
mochchakkeram
dziękuję
mamnun
chnorakaloutioun
gratias ago
gracies
sulpay
go raibh maith agat
sobodi
dekuji
sukriya
kop khun krap
obrigado
arigatô
dakujem
trugarez
mèsi
ありがとう
tanemirt
grazie
najis tuke
terima kasih
rahmet
shukriya
мерси
kam sah hamnida
diolch
dhanyavadagalu
감사합니다
xiexie
ευχαριστώ
merci