Small-sat Ionosphere Exploration at Several Times and Altitudes (SIESTA)

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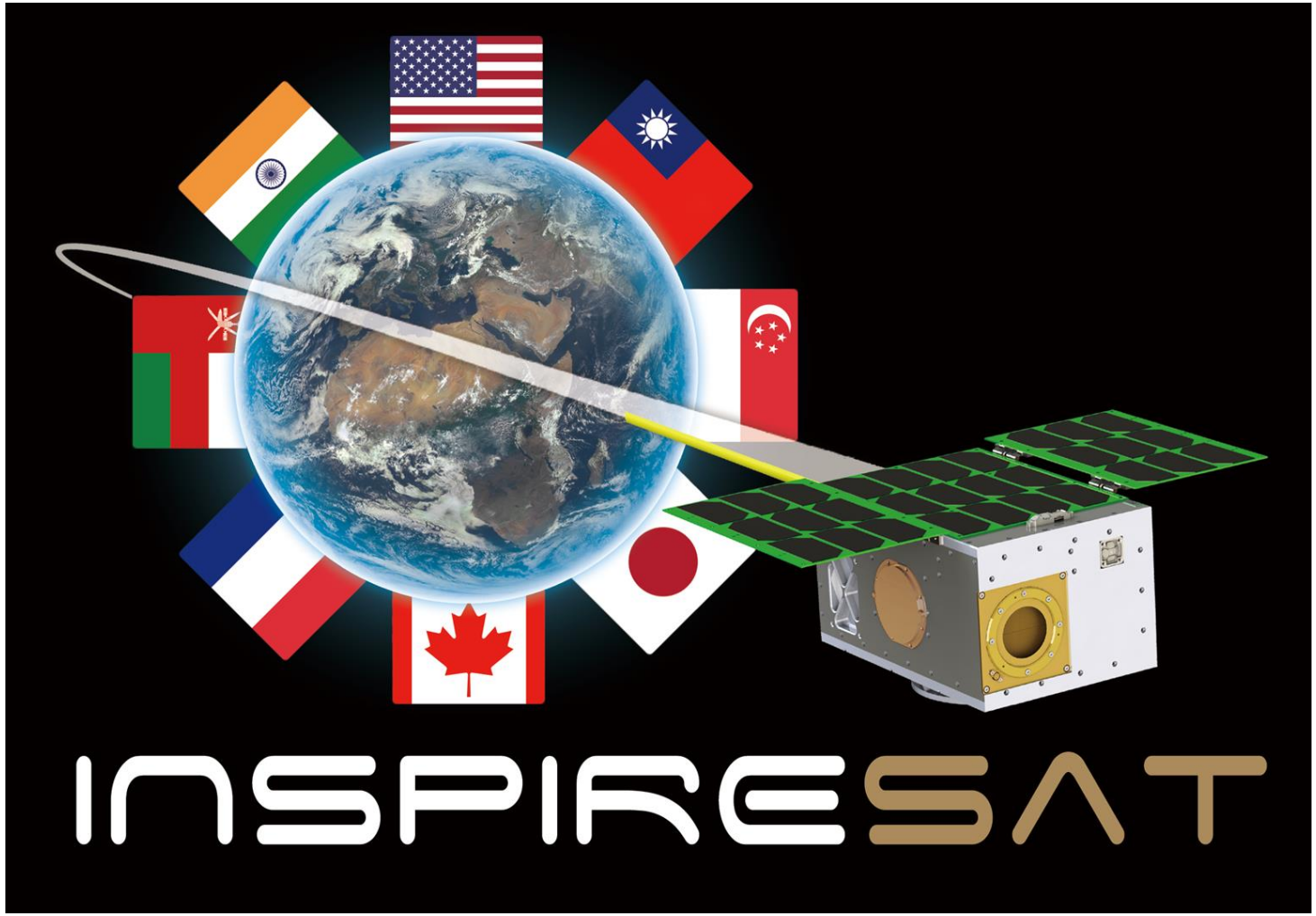
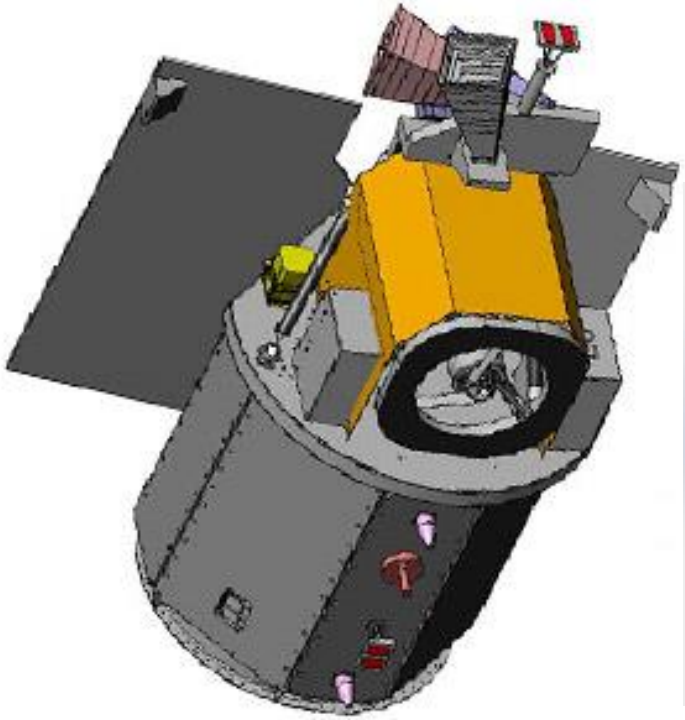
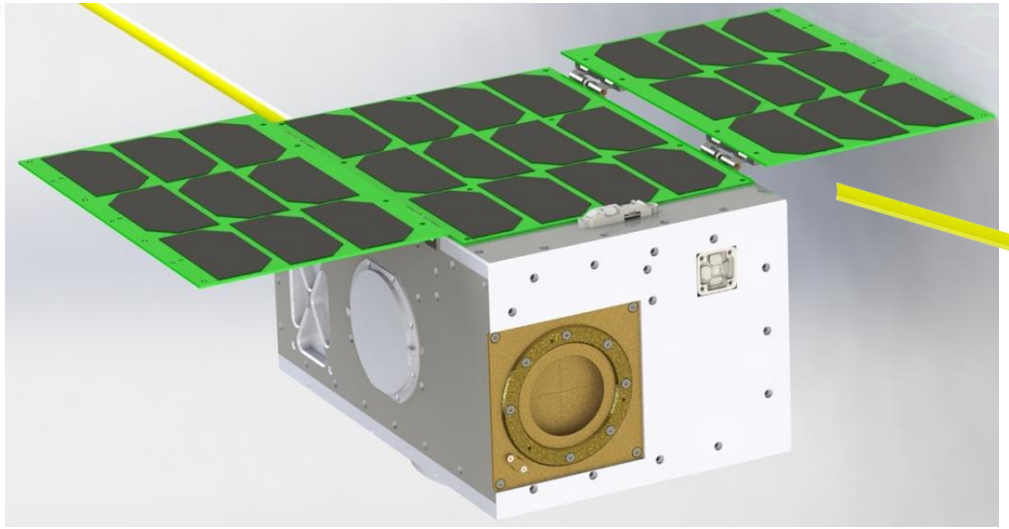
- Kaustubh Kandi, Indian Institute of Space science & Technology, Thiruvananthapuram, India
- William Evonosky, University of Colorado, Boulder, USA



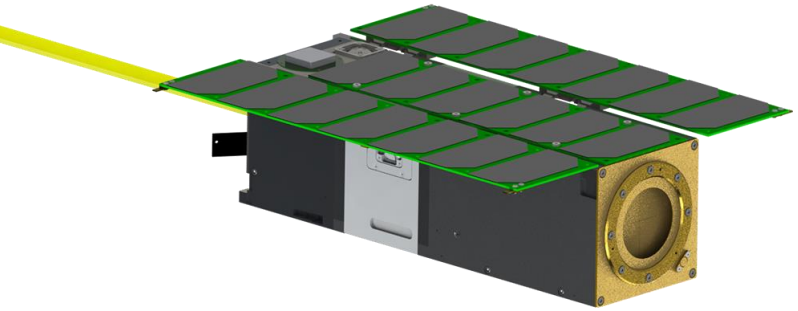
Satellite Overview



FORMOSAT-5



INSPIRESat-1

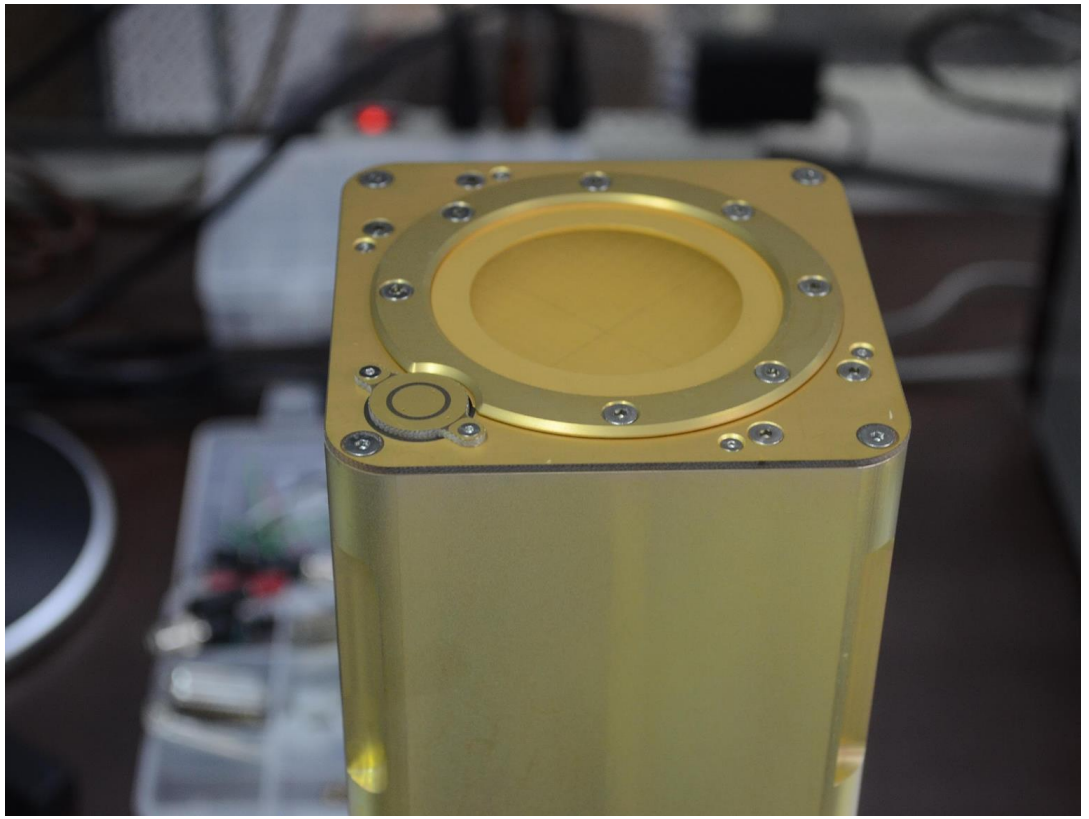


IDEASSat

	FORMOSAT-5	INSPIRESat-1 (Custom)	IDEASSat (3U)
Mass (kg)	475	8	4
Orbit Altitude (km)	720	500	500
Orbit Inclination (deg)	98	50	97
Launch Date	August 24, 2017	November, 2019	2020

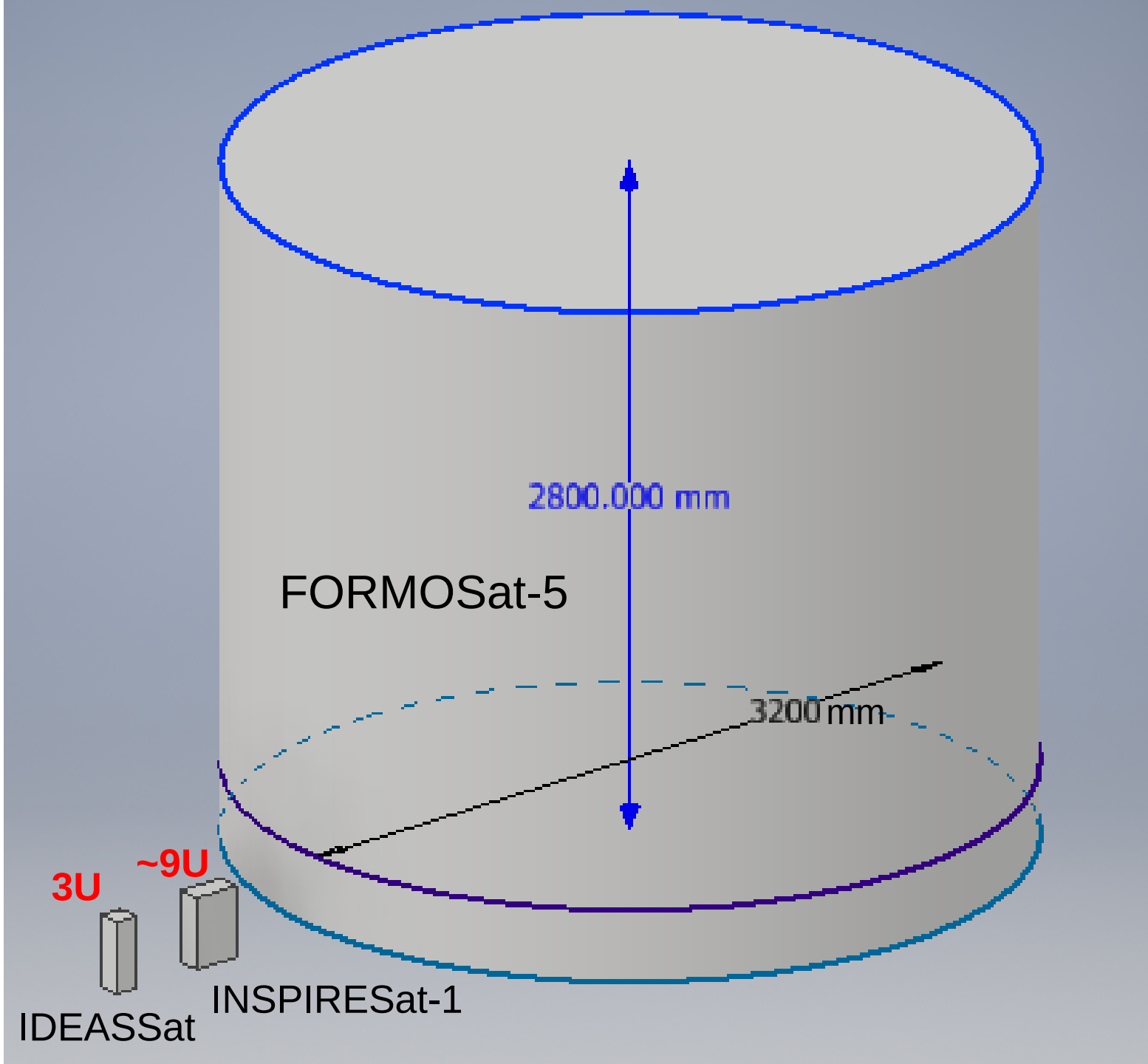
AIP/CIP Overview

- Advanced/Compact Ionosphere Probe
- Four measurement modes
  - Planar Langmuir Probe (PLP)
  - Retarding Potential Analyzer (RPA)
  - Ion Trap (IT)
  - Ion Drift Meter (IDM)
- With the following measurements
  - Ion density
  - Ion drift velocity
  - Ion and Electron Temperature
  - Ion Composition
- Duty Cycles
  - FORMOSAT-5 – Always On
  - IDEASSat/INSPIRESat-1 – Eclipse Only

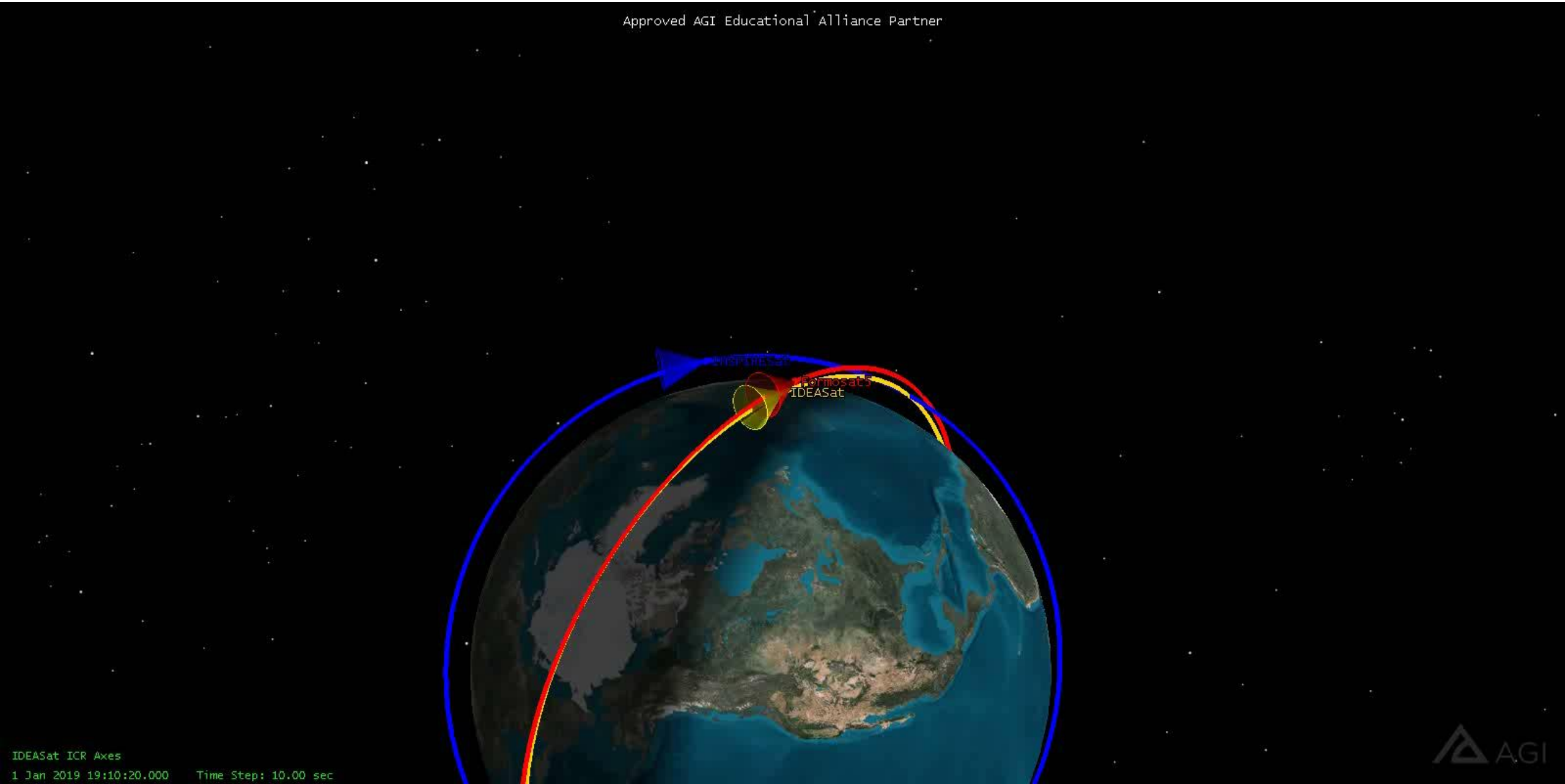


AIP : Photo courtesy of Ya-Chih Mao
National Central University, Taiwan

Size Difference

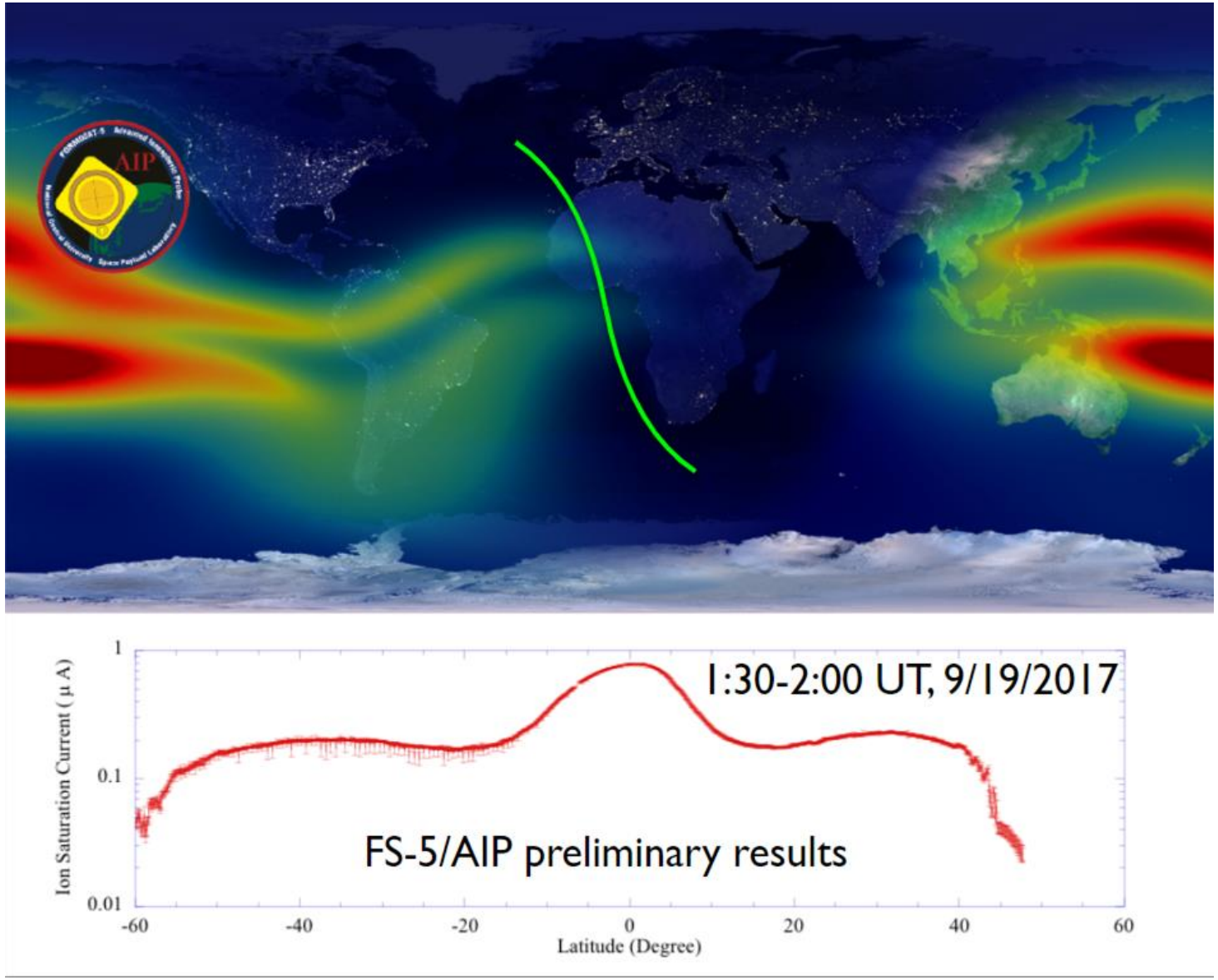


FORMOSat, INSPIRESat, IDEASat Mission Design



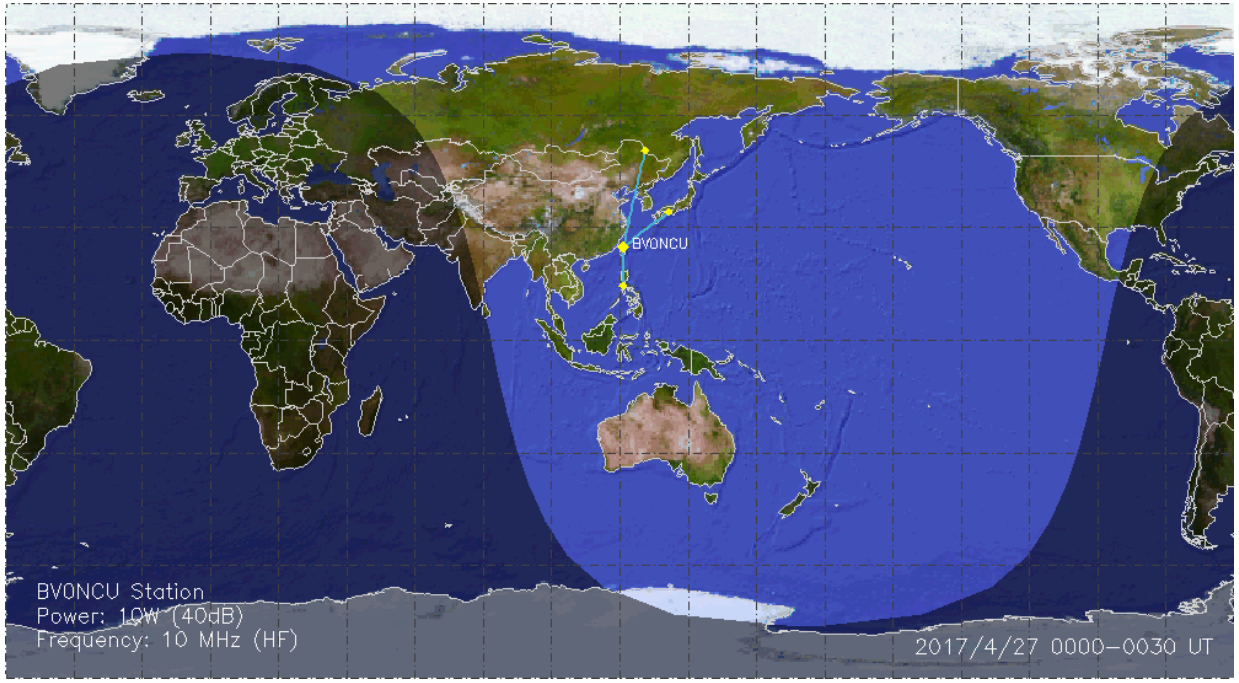
FORMOSAT-5 AIP First Data

- First measurements from the AIP instrument
- Courtesy Dr. Chi-Kuang from NCU
- Vertical axis can be converted to ion density



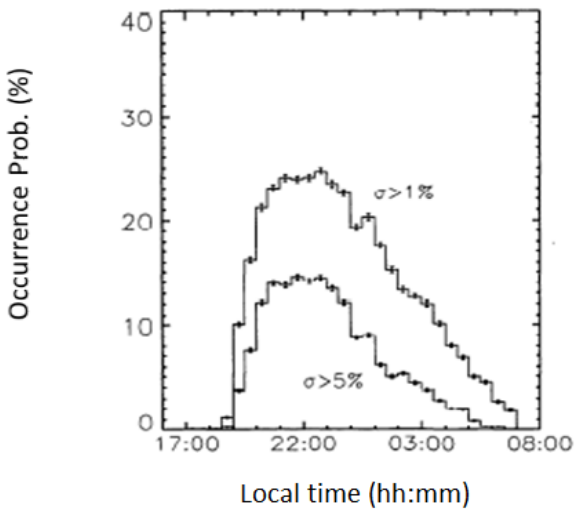
SIESTA Objectives

1. Characterize the temporal and spatial distribution of plasma irregularities
2. Characterize the four-dimensional structure of plasma bubbles
3. Characterize the spatial and temporal distribution of the Midnight Temperature Maximum
4. Educate students while developing scientific spacecraft and payloads

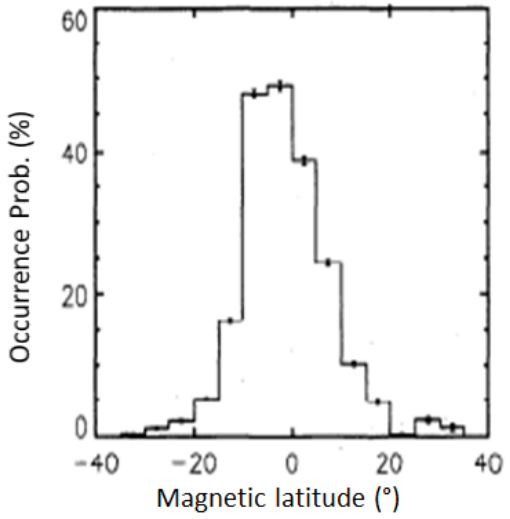


GIF courtesy of Chi-Ting Liao

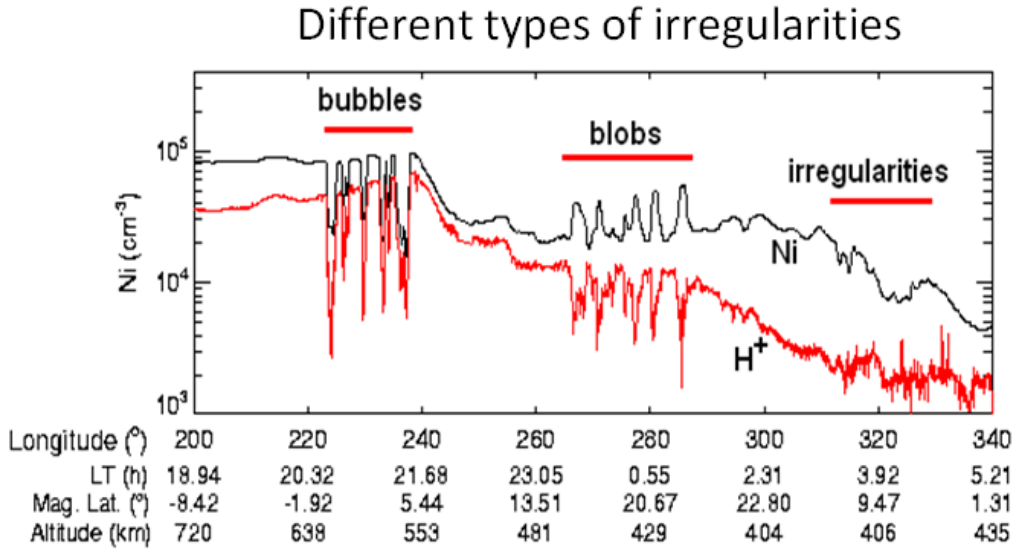
SIESTA Objectives 1 and 2: Plasma Irregularities



[Kil and Heelis, JGR, 1998]



AE-E, 400 km

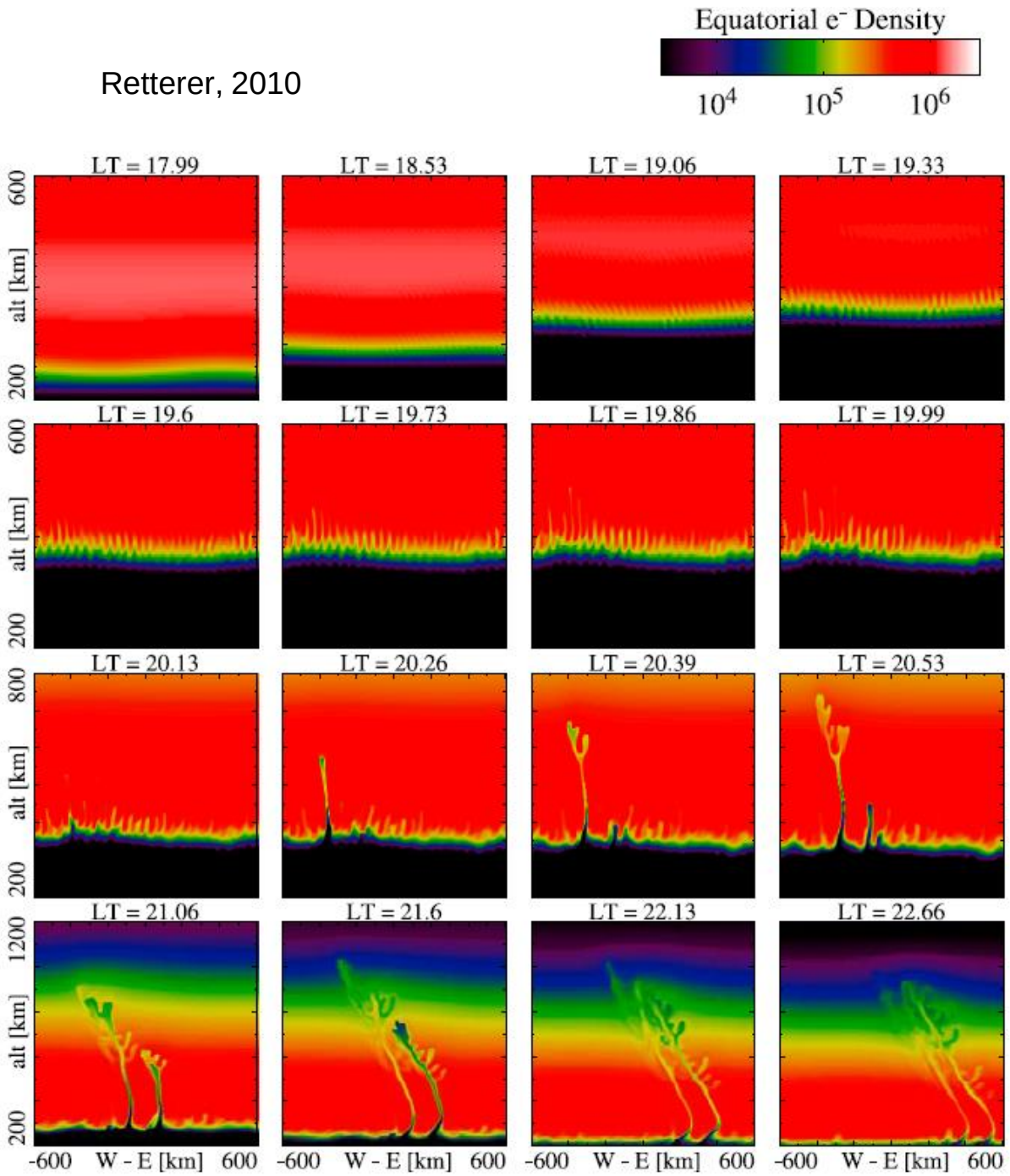


CNOFS/CINDI March 2, 2009

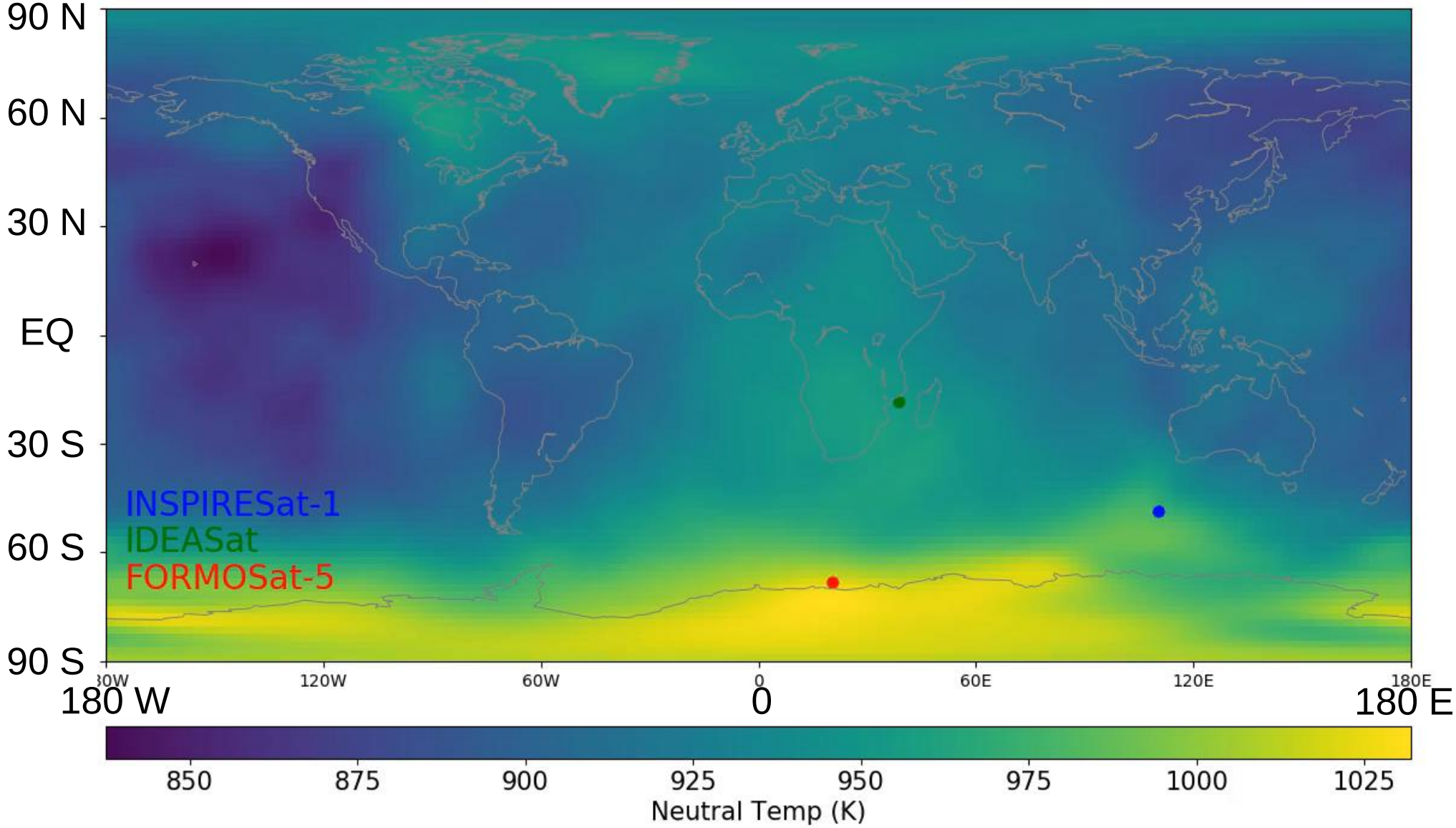
- Plasma bubbles form around the magnetic equator in the early evening and propagate along magnetic field lines extending far from their initiation site (Kil, 2015)
- Bubbles can be hundreds of kilometers across and extend hundreds of kilometers up in altitude above the F-layer (> 150km) (Kil, 2015)
- A satellite passing through a plasma bubble will sense a sharp decline in density from the background level thus enabling a 1D perspective of the bubbles shape

Science Objective 1 and 2: Plasma Irregularities

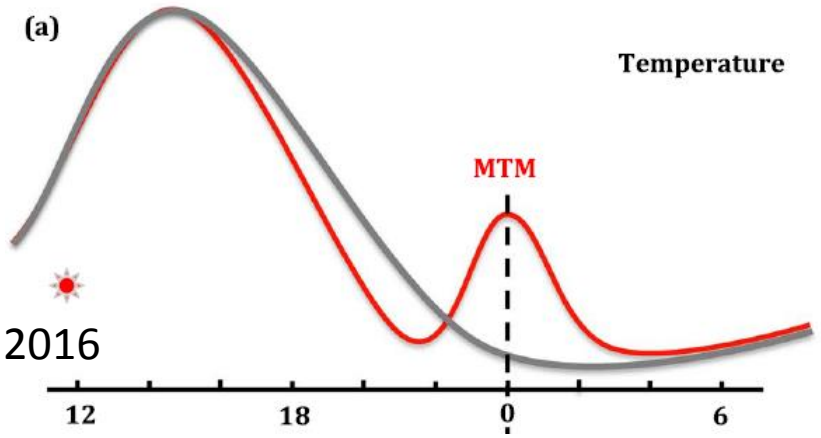
- Plasma bubbles form around the magnetic equator in the early evening where there is a density gradient and the magnetic field lines don't extend to upper parts of the ionosphere (Kil, 2015).
- Bubbles propagate along magnetic field lines allowing the bubble to expand to latitudes far from their initiation site (Sultan, 1996).
- Bubbles can be hundreds of kilometers across (in longitude) and extend hundreds of kilometers up in altitude above the F-layer (>150 km)(Kil, 2015)
- Bubbles can cause communications disruptions via scintillation (large drops in signal intensity and a shift in phase)



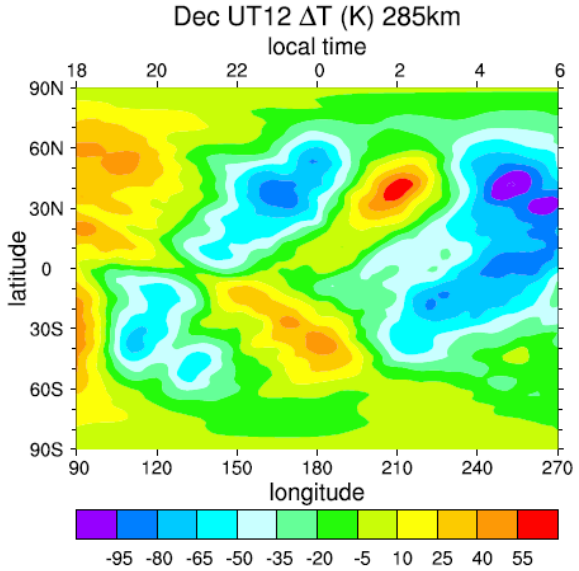
SIESTA Objectives 1 and 2: Plasma Irregularities



SIESTA Objective 3: Midnight Temperature Maximum



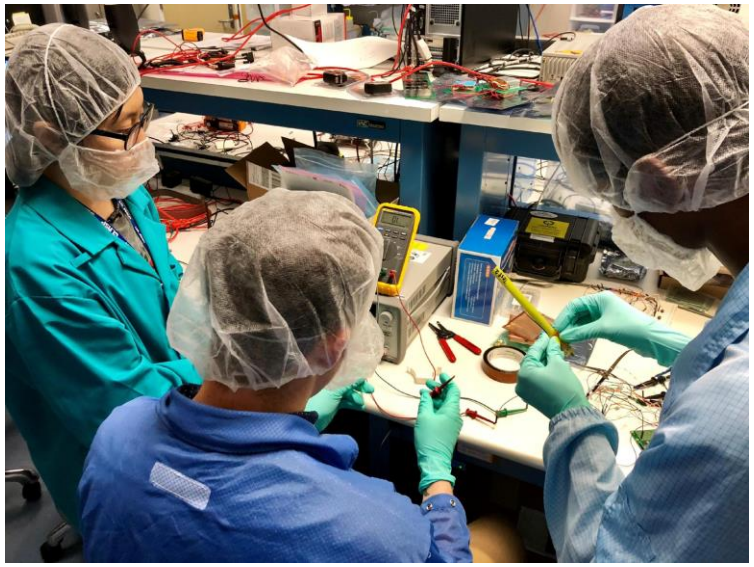
Fang et al, 2016

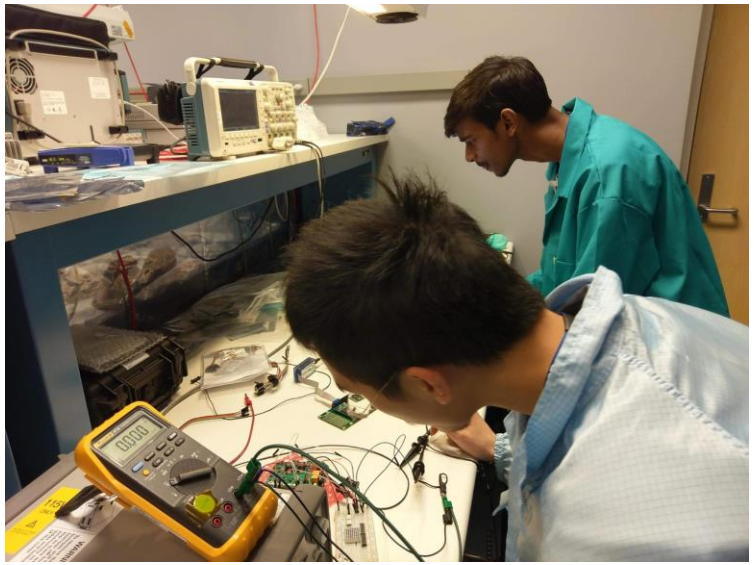


Akmaev et al, 2009

- Around midnight at F region heights, the MTM is a neutral temperature increase which varies in season and solar activity
- Only a few models accurately capture the MTM including the coupled Whole Atmosphere Model (WAM) with the Global Ionosphere Plasmasphere (GIP) model.
- The MTM is transient and so any one satellite might see the signal one pass and miss it completely the next
- The MTM can be studied statistically to account for its transient nature and measurement noise thus 3x data from SIESTA is extremely beneficial

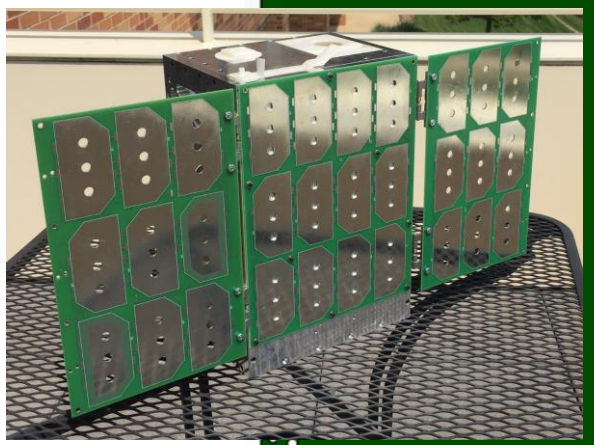
SIESTA Objective 4: Educate Students





- The INSPIRE program teaches students real world space engineering and encourages international cooperation.
- Students meet each summer in a 10-week intensive workshop where rapid spacecraft development takes place in Boulder, Colorado and missions are put through design reviews.

The INSPIRESat-1 at CDR



The IDEASSat CDR

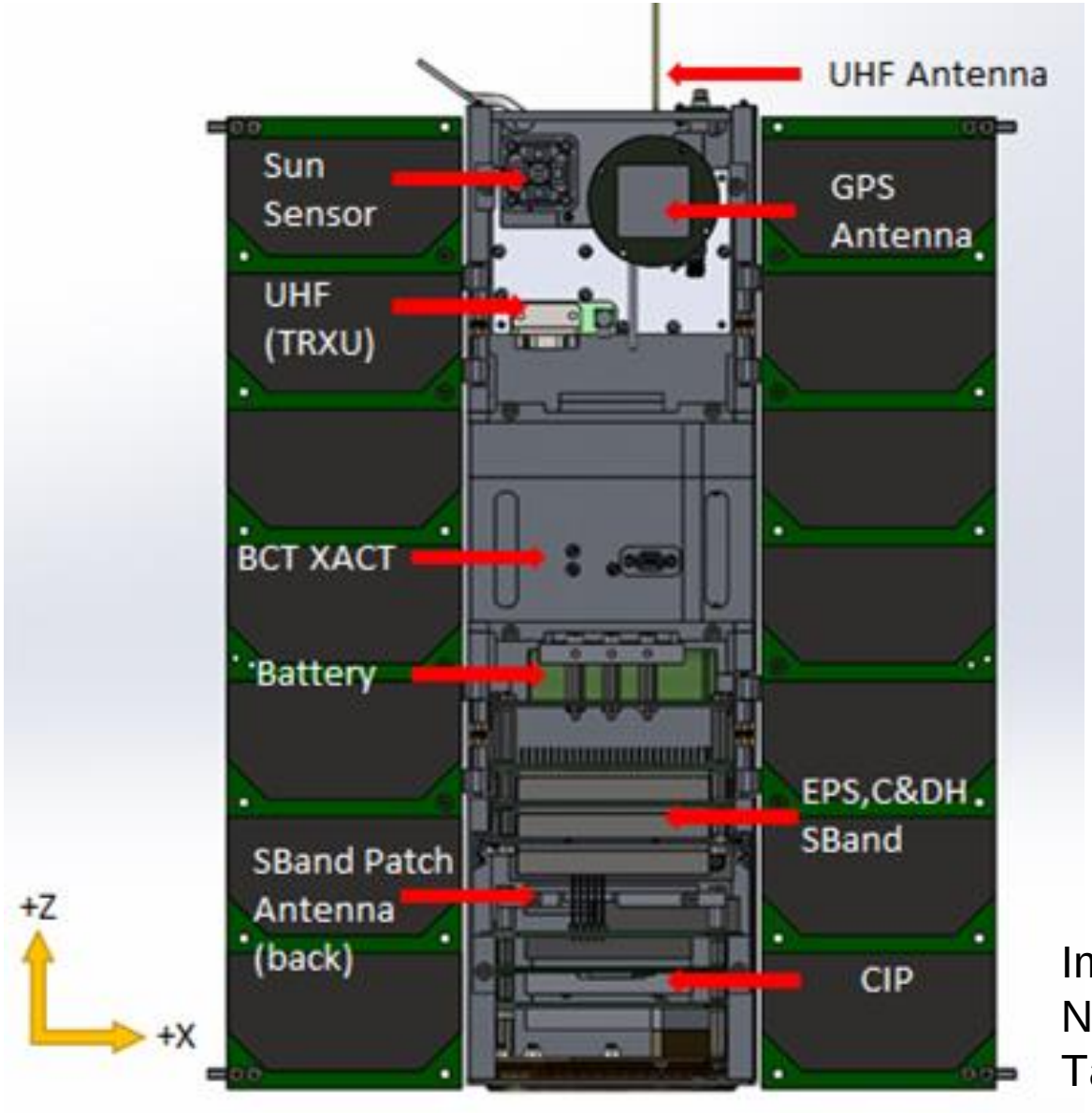
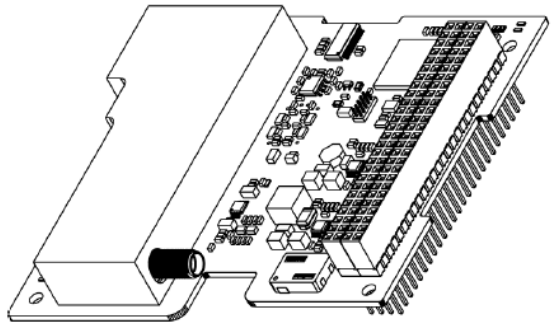


Image by Liu Hsin Tzu
National Central University, Taiwan

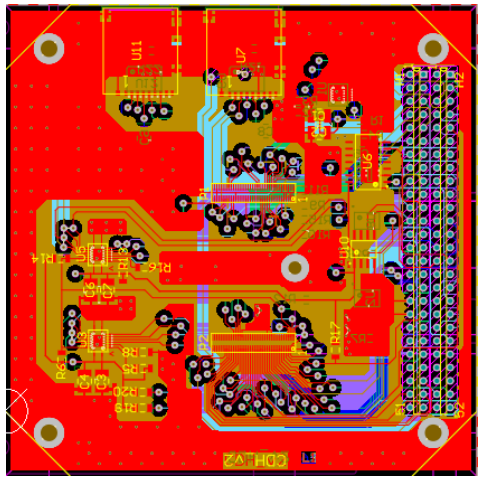
IDEASSat C&DH card

(Developing)

CPUT STX
S-band
Transmitter

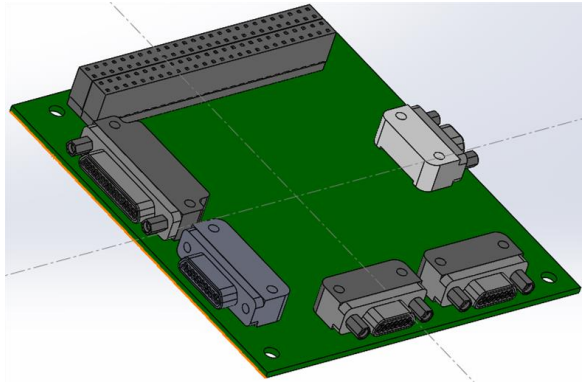


The size of new C&DH board is customized to fit with CPUT STX S-band Transmitter.



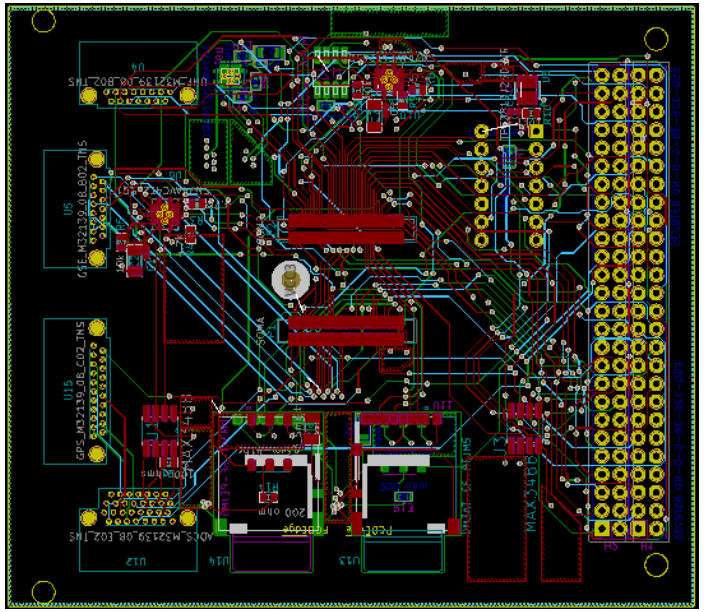
INSPIRESat-1
C&DH Card

+



INSPIRESat-1
Interface Card

=

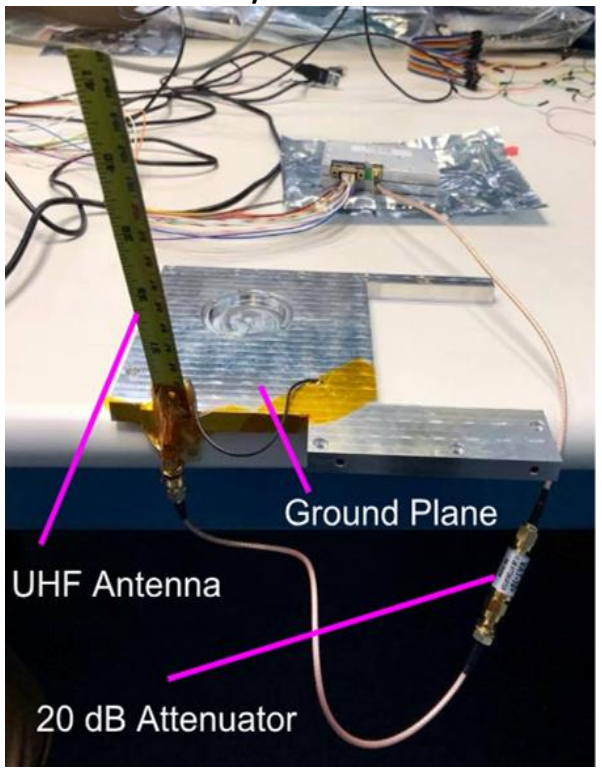


IDEASSat
C&DH Card

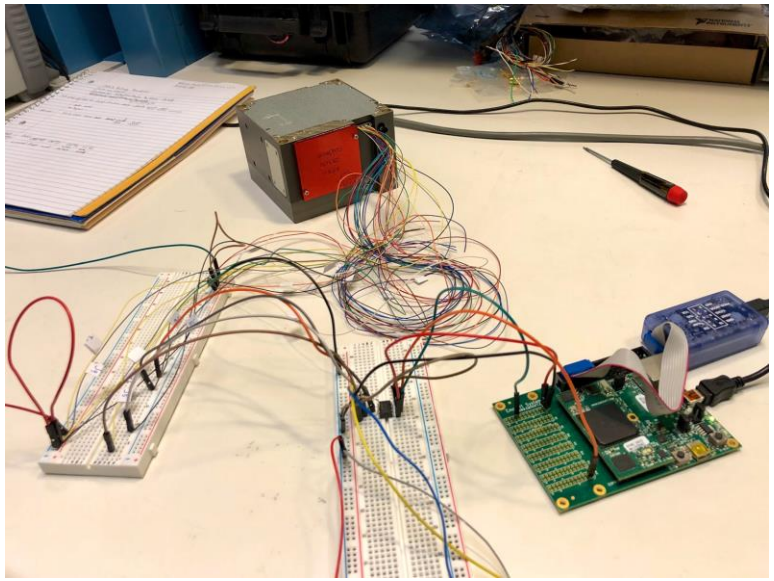
The INSPIRESat-1 Testing Status

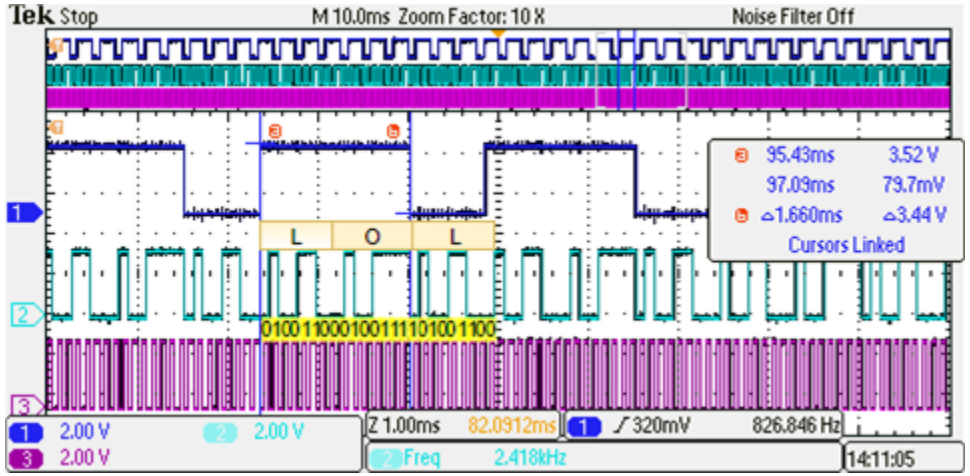
- All subsystems have been tested and version two of EPS, CDH, and Interface have either been designed or are already on order
- Successfully sent known bit stream from software defined radio to UHF and received correct bits at C&DH
- Next steps include full flat sat tests with fully integrated flight software, as well as communications test with LASP UHF ground station

UHF Send/Receive Test

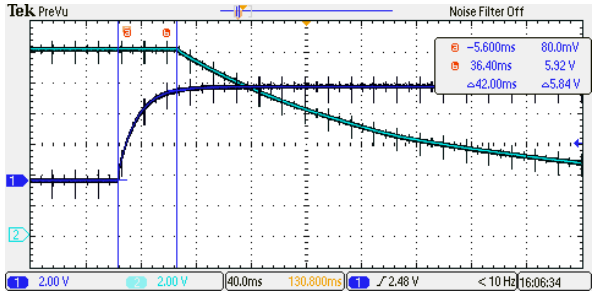


ADCS Command/Receive Test





UHF Sync Word Receipt



System Restart Test

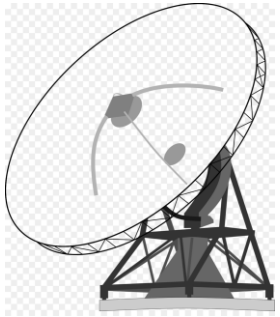
Battery Charge Testing

INSPIRESat-1 Budgets

Subsystem	Mass (kg)	Nominal Power (W)	Volume (cm^3)
CIP	0.60	2.30	829
ADCS	0.94	4.32	681
COMM	0.34	1.01	131.2
C&DH	0.07	0.95	721
Structure	5.9	-	316
Power	0.07	1.78	-
Battery	0.25	-	288
Solar Arrays	0.5	-	-
Total	8.67	10.36	2966
Available	10	17.1	7096
Margin (%)	15	65	139

Sequence of Operations

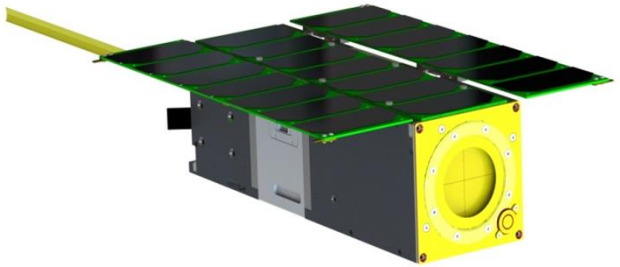
Ground Station



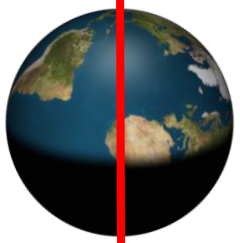
Command

Enter Orbit: Phoenix Mode

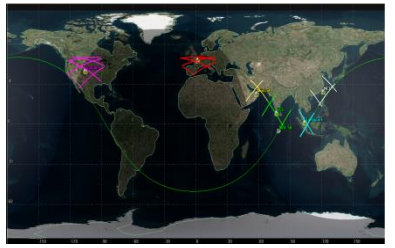
Sun pointing to gain battery charge. Safe mode



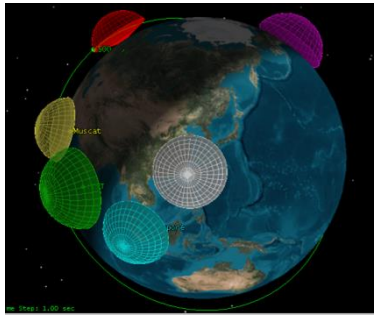
SUNLIT period
Charge mode, Payload off



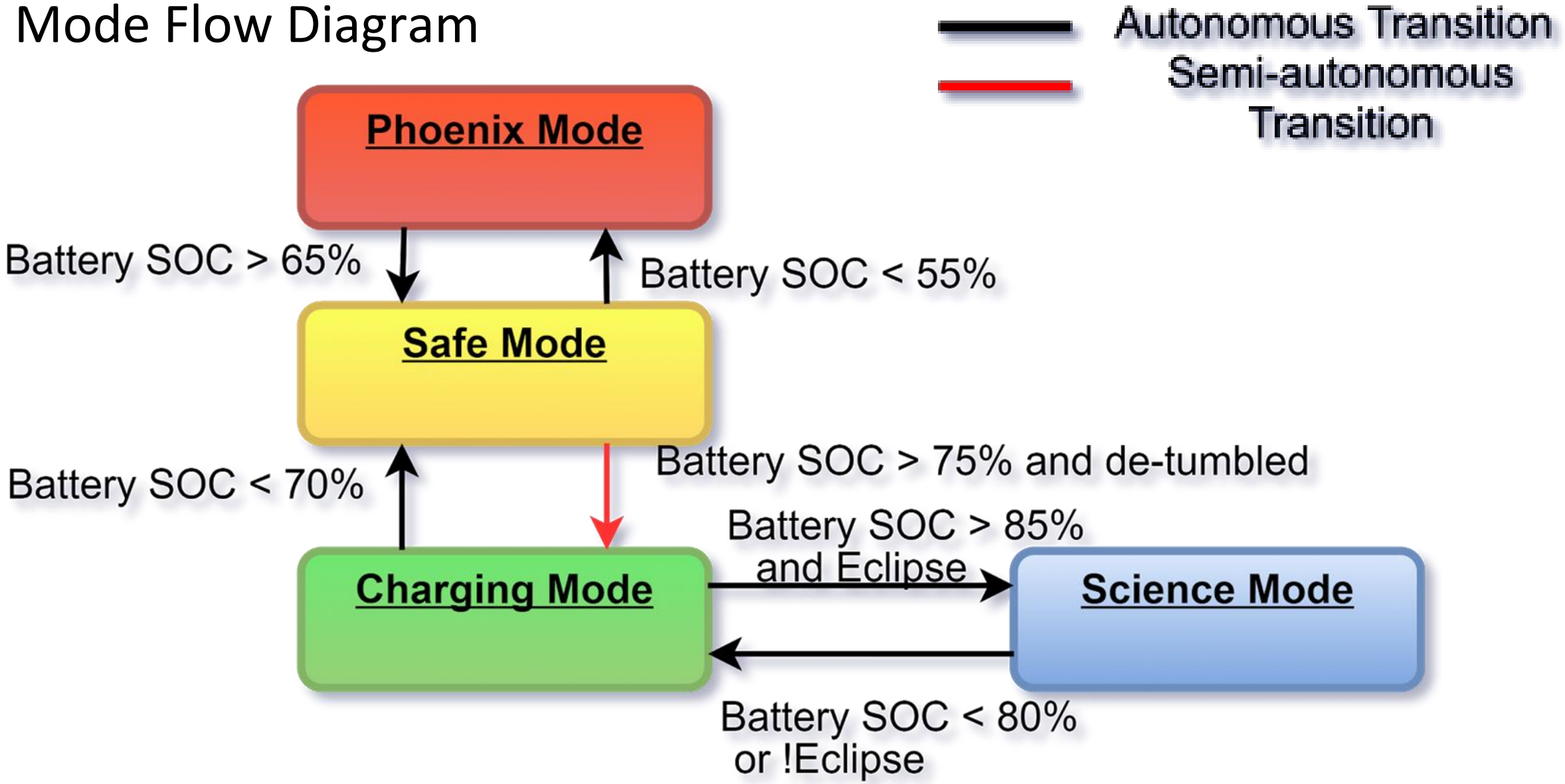
ECLIPSE period
Science Mode
Payload on



Send data down to ground during access



Mode Flow Diagram



Spacecraft Modes

Subsystem	Emergency Modes		Nominal Modes	
	Phoenix	Safe	Charging	Science
C&DH	ON			
EPS	ON			
ADCS	OFF	Coarse Sun	Fine Ref	
CIP-Payload	OFF			ON
UHF Rx	ON			
UHF Tx	Beacon			
S-band Tx	OFF		As Required	
Battery Heater	As Required			

UN Sustainable Development Goals

The INSPIRE program is a consortium of institutions from all around the globe whose goal is research and education among participating universities. **The INSPIRE program provides practical space engineering education to students in six different countries.**

The 9th UN SDG states that investments in communication technology are crucial for sustainable development. The INSPIRESat-1 aims to **illuminate disturbances to communications caused by ionospheric variability** and thus **strengthen our ability to provide reliable communication technology**.

Summary

- Three platforms flying the same instrument provides a depth of data not normally seen in space science
- The goal of the SIESTA concept is to characterize small-scale plasma irregularities and the MTM
- The INSPIRESat-1 and IDEASSat have both completed CDR and data continues to stream in from the AIP onboard FORMOSAT-5

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References

Akmaev, R. A., Wu, F., Fuller-Rowell, T. J., & Wang, H. (2009). Midnight temperature maximum (MTM) in Whole Atmosphere Model (WAM) simulations. Geo*physical Research Letters, 36(7).* https://doi.org/10.1029/2009GL037759

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Kil, H., and R. A. Heelis (1998), Global distribution of density irregularities in the equatorial ionosphere, *J. Geophys. Res*., 103(A1), 407–417, doi: 10.1029/97JA02698.

Questions?