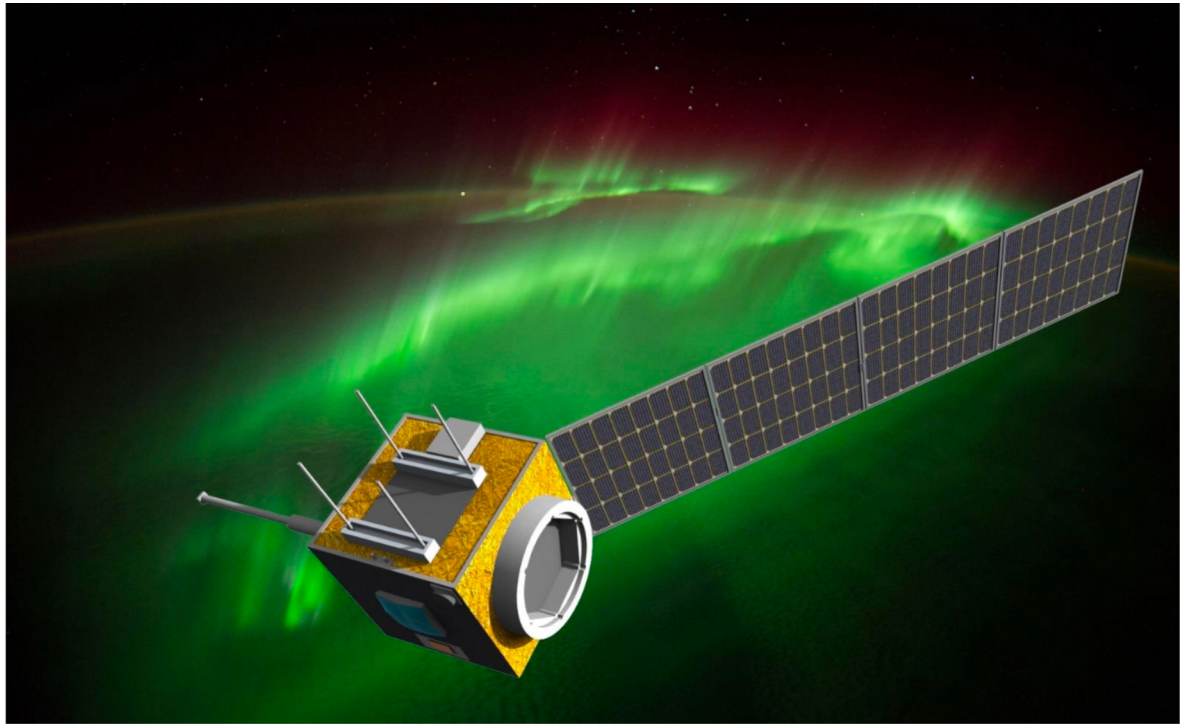
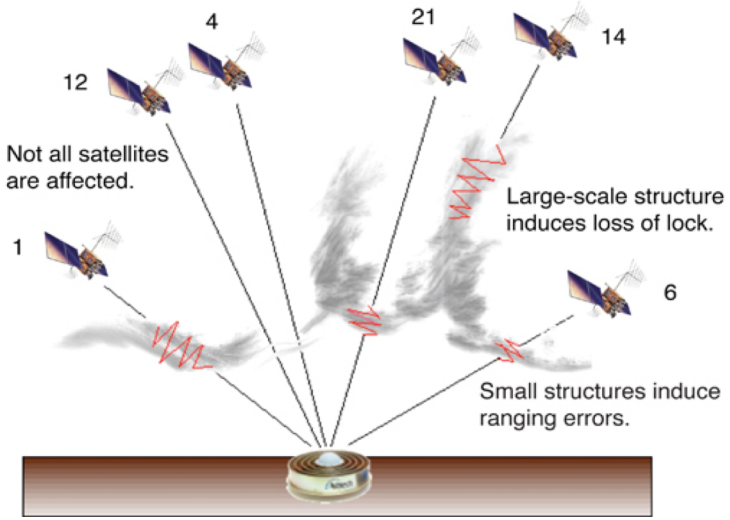
multi-Needle Langmuir Probe invented for space weather satellites

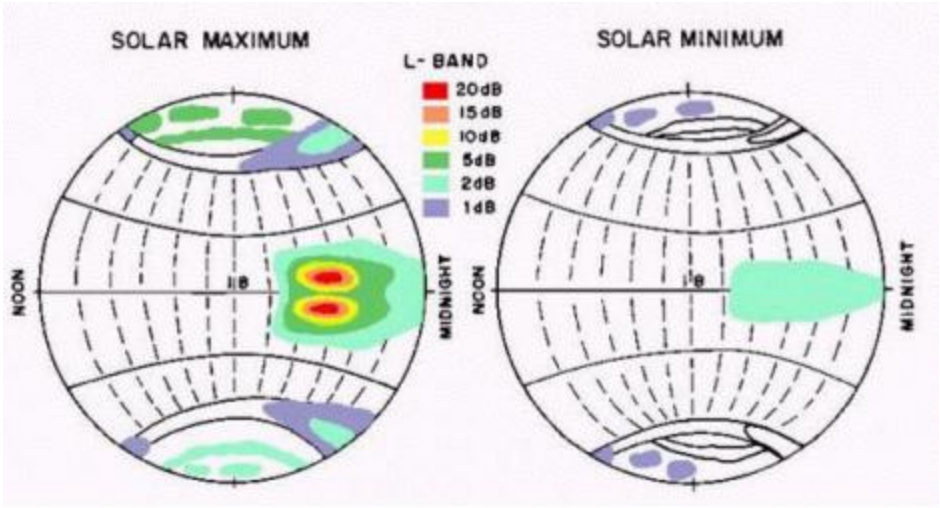
Jøran Moen University of Oslo & Tore Andre Bekkeng Eidsvoll Electronics AS
Lasse Clausen, University of Oslo & Espen Trondsen, University of Oslo

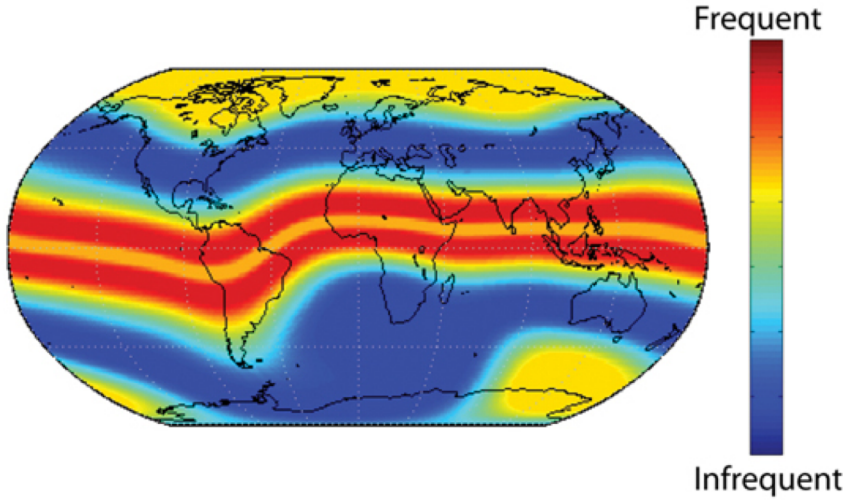
D3S : ESOC 23.10.2019



Plasma irregularities and ionospheric scintillations



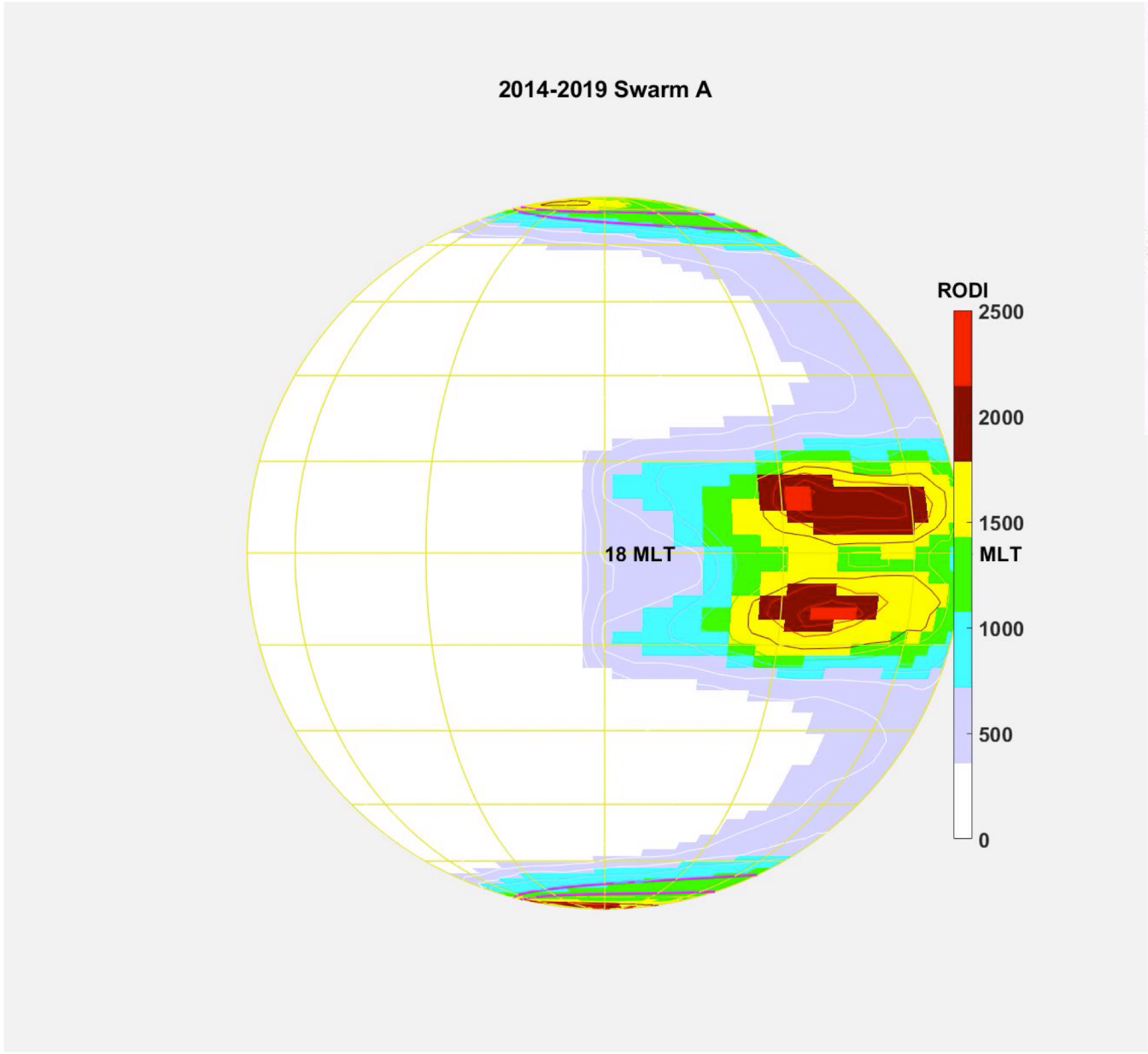


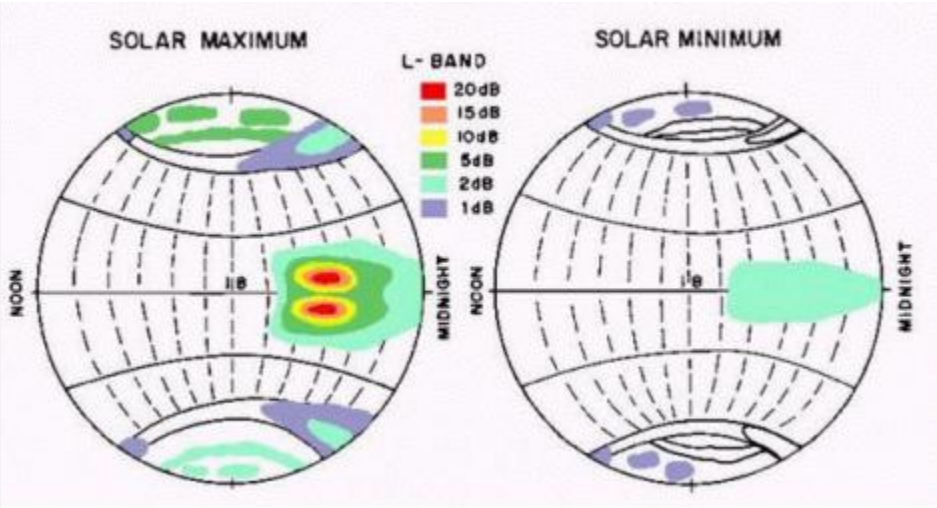


Global morphology of ionospheric scintillation (after Basu and Groves, 2001)

$$\widetilde{\sigma_\phi} = \sqrt{< \phi^2 > - < \phi >^2},$$

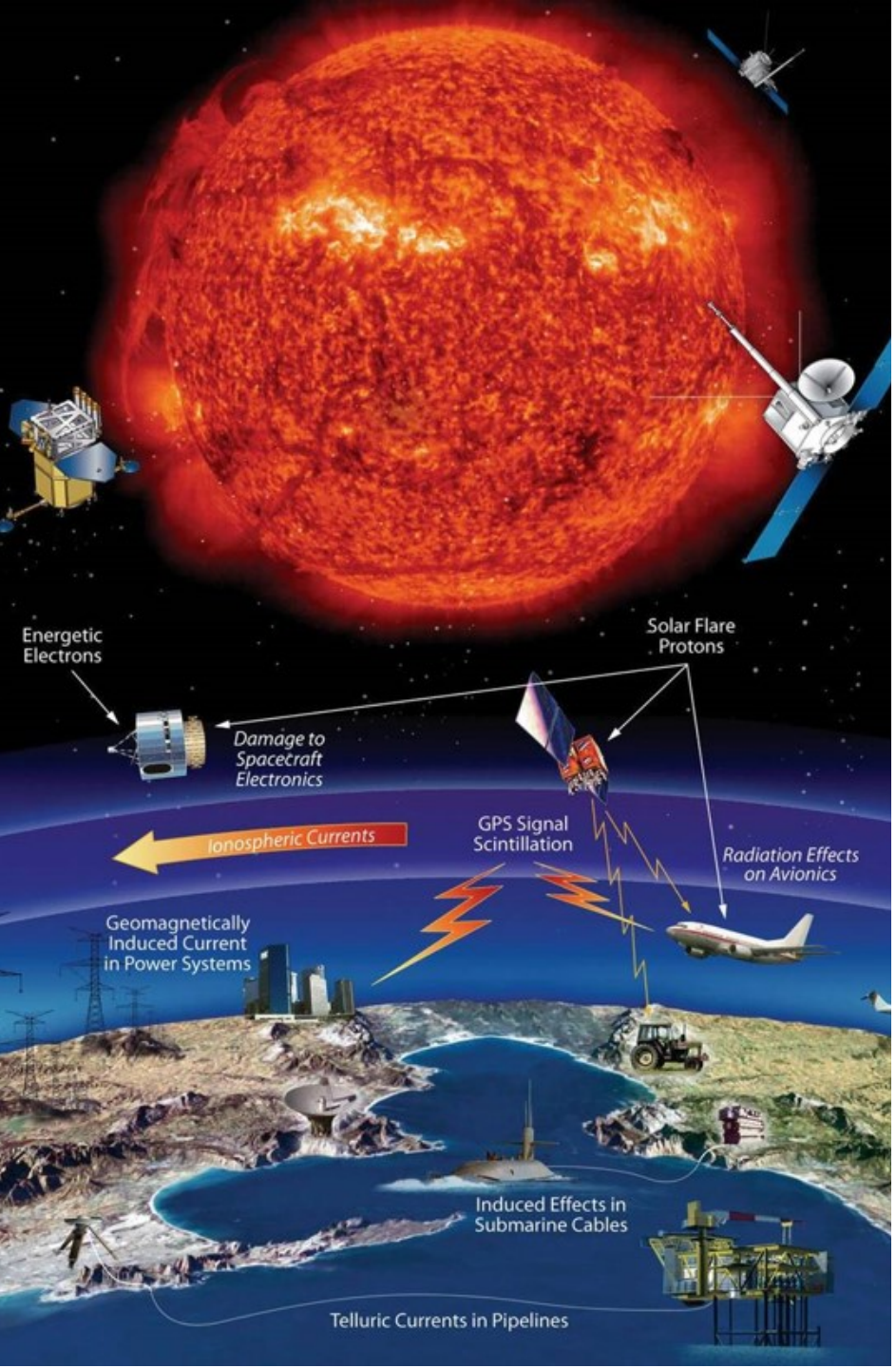
$$S_4^2 = \frac{(< I^2 > - < I >^2}{< I >^2}$$





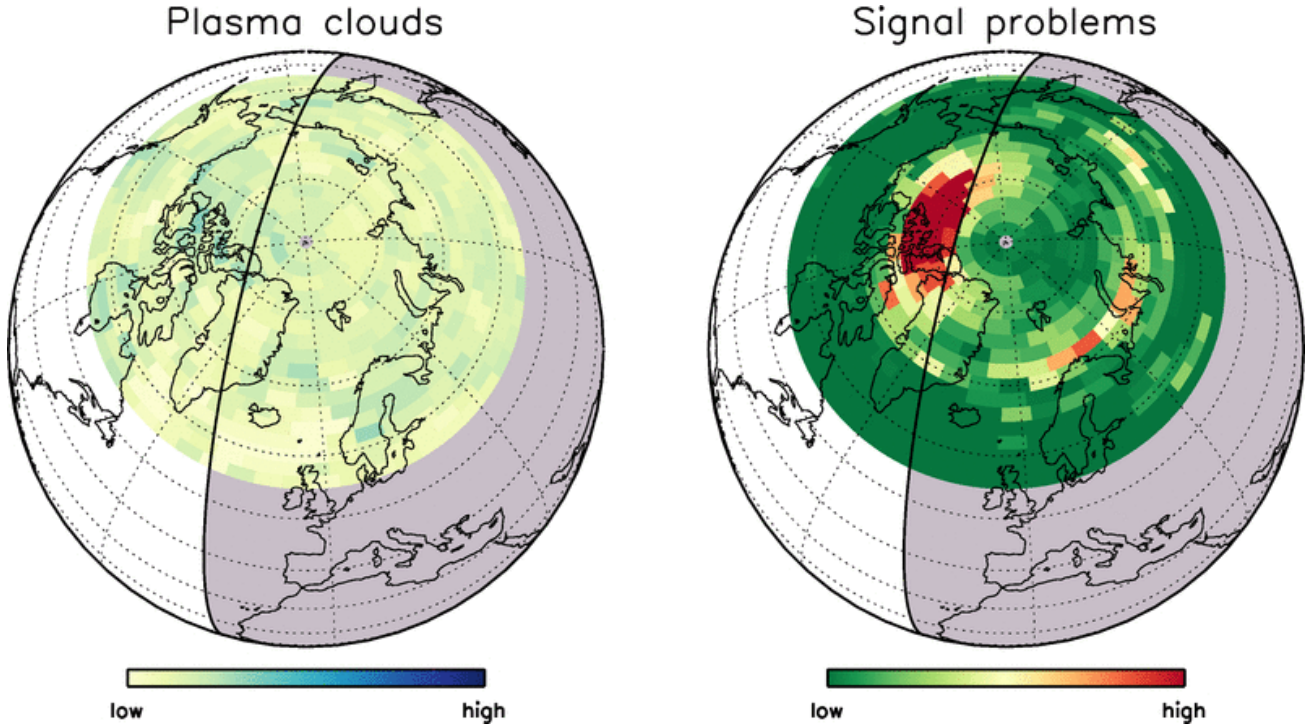
Swarm A
Ne-measurements

Animation: Yaqi Jin



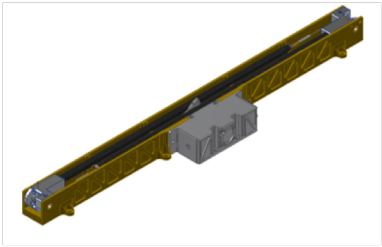
EIDSVOLL ELECTRONICS AS

GPS disturbances at high latitudes



The strongest GPS-scintillations occur when plasma clouds enter the polar cap through the auroral oval on the dayside, and exits the polar cap through the auroral oval on the nightside.

Animation: Clausen et al., JGR, doi: 10.1002/2015JA022199, 2016



m-NLP: What is it?

Developed as a part of the ICI sounding rocket program (University of Oslo, 4DSpace Initiative)

Parameters: electron density and spacecraft floating potential down to meter scale

Low-cost UiO-version onboard NORSAT-1 satellite, launched on 14 July 2017.

EIDEL
EIDSVOLL ELECTRONICS AS

M-NLP measurement principle

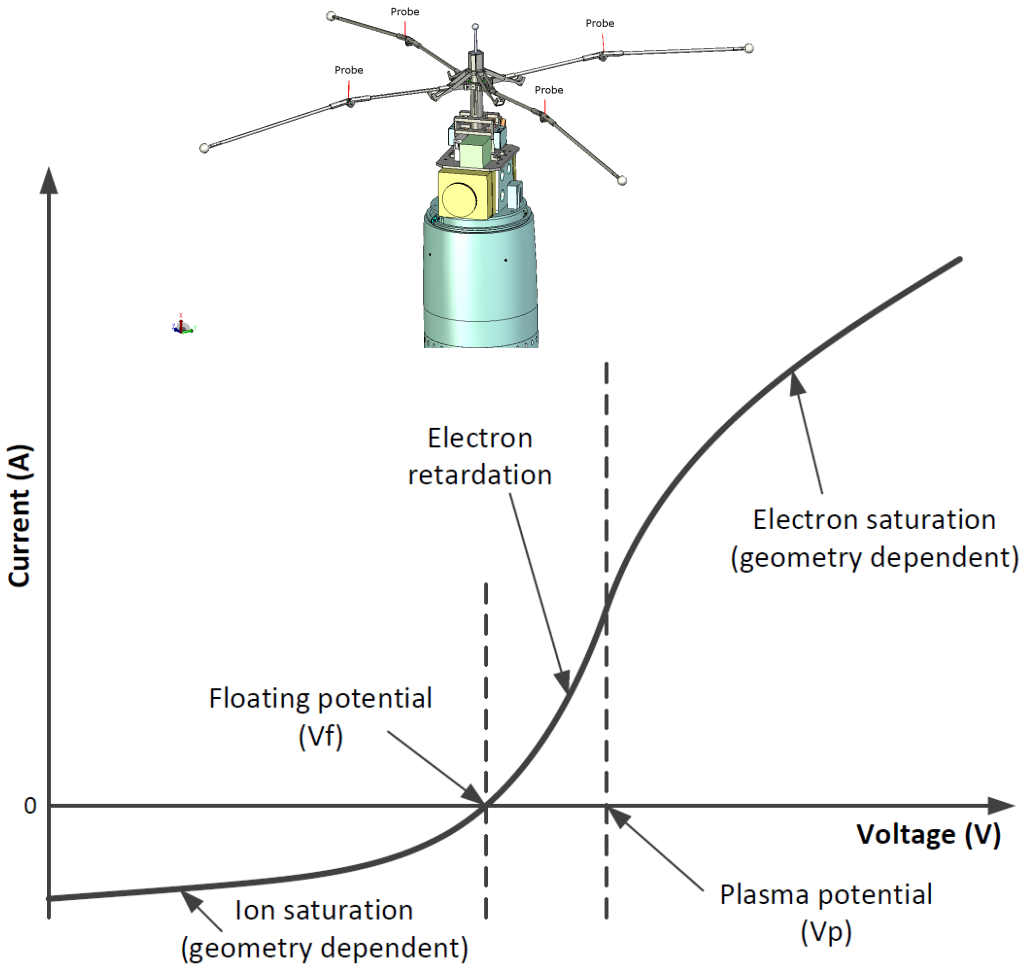


Figure: UiO

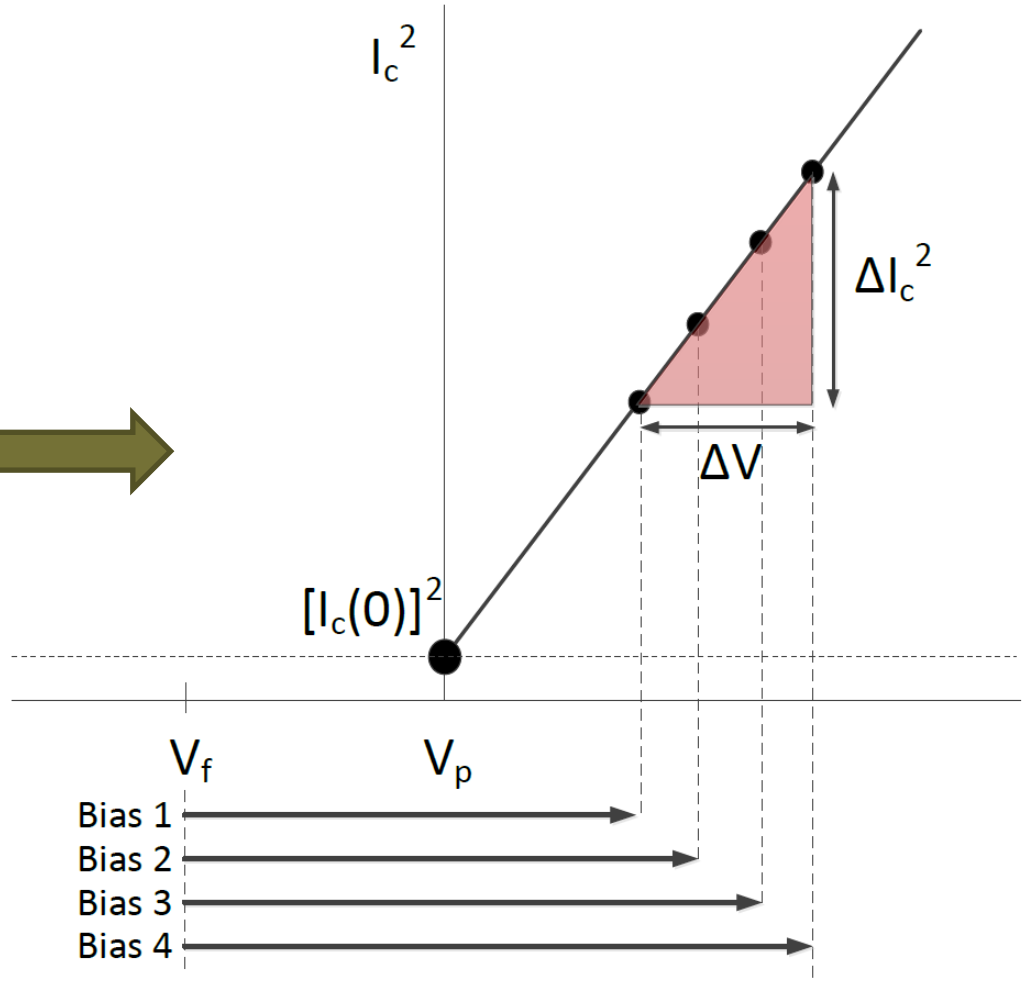
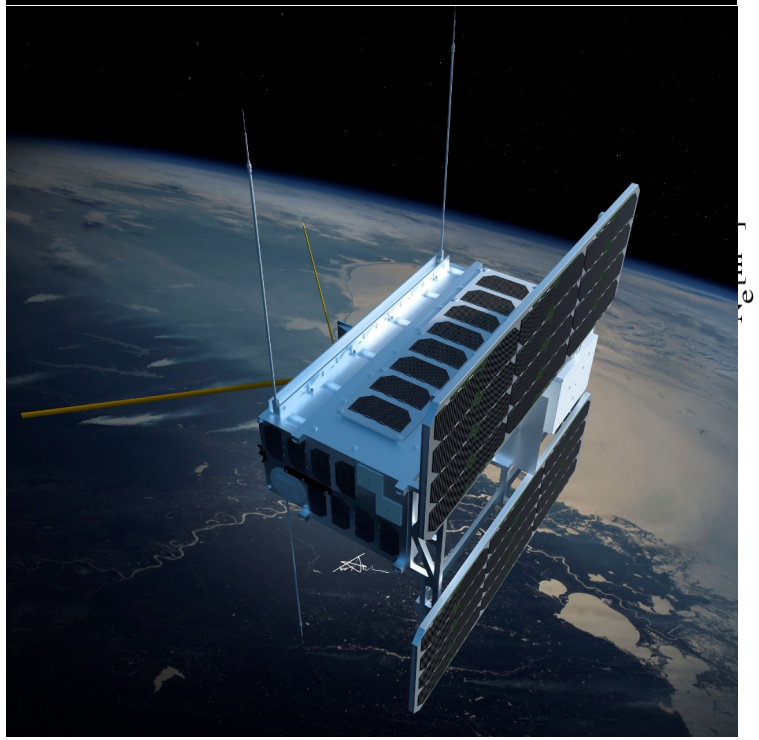
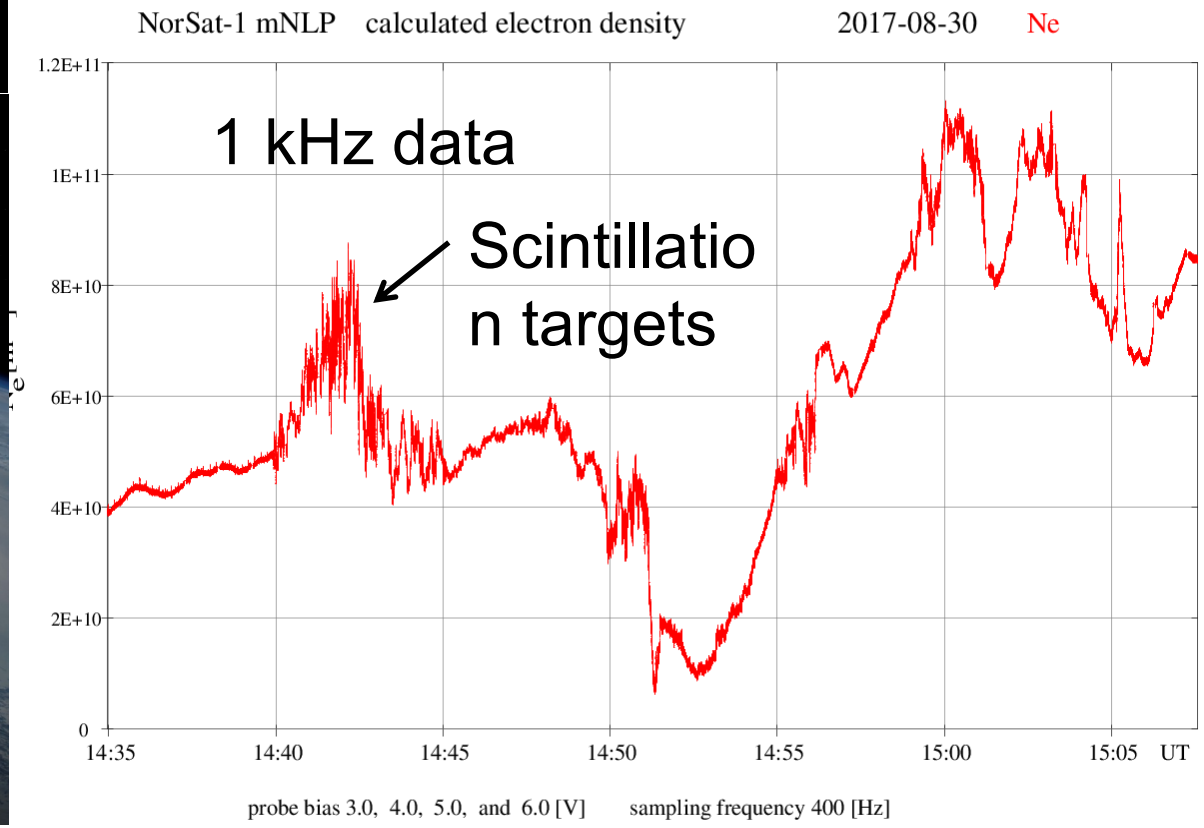
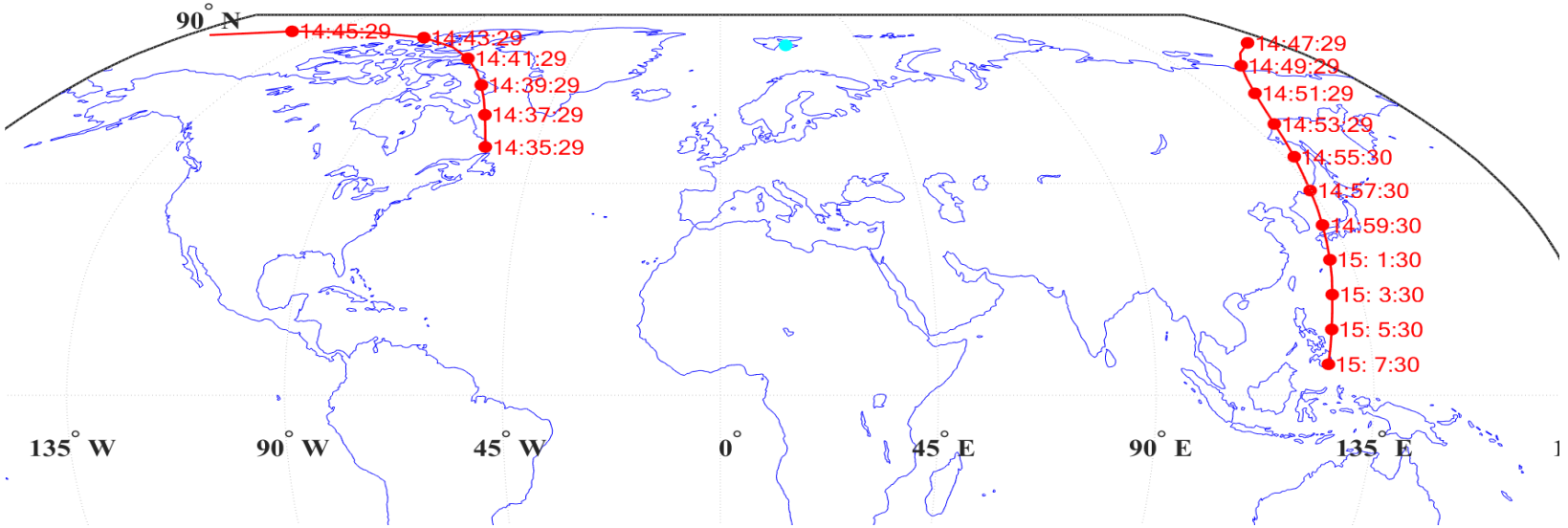


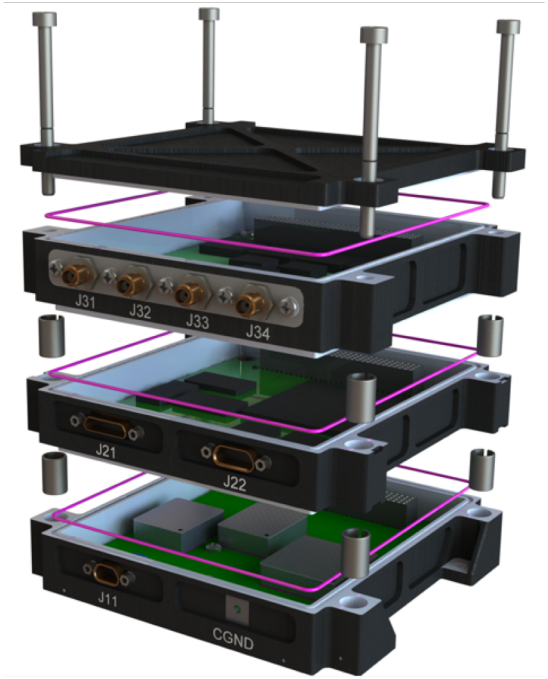
Figure: UiO

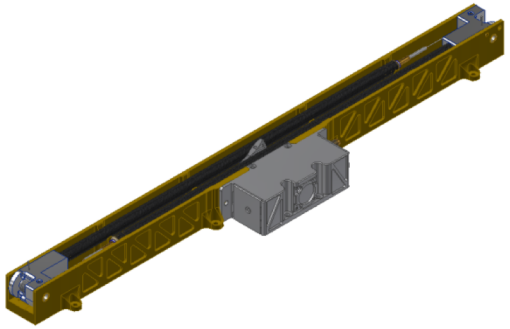
NORSAT-1

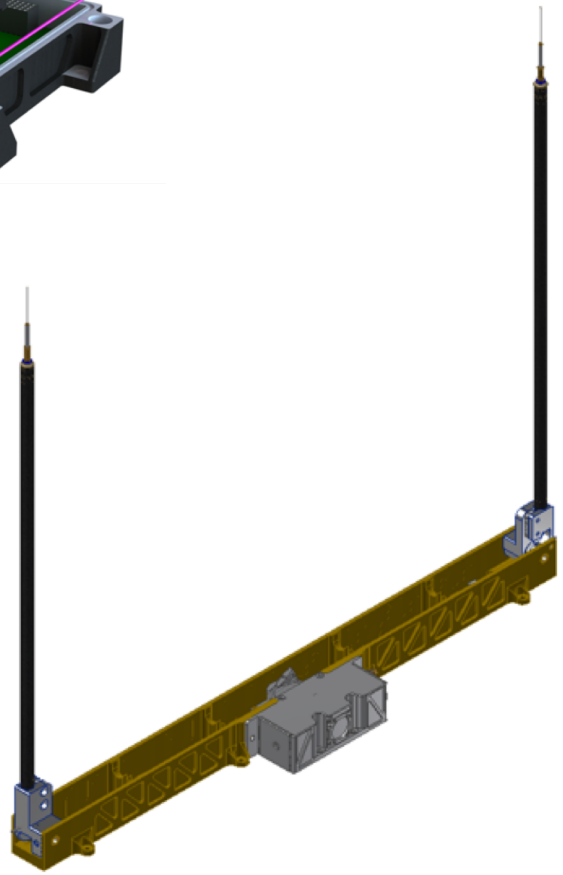



NorSat-1 mNLP calculated electron density 2017-08-30 Ne
1 kHz data
Scintillation targets
1.2E+11
1E+11
8E+10
6E+10
4E+10
2E+10
0
14:35
14:40
14:45
14:50
14:55
15:00
15:05 UT
probe bias 3.0, 4.0, 5.0, and 6.0 [V] sampling frequency 400 [Hz]


90° N
14:45:29
14:43:29
14:41:29
14:39:29
14:37:29
14:35:29
14:47:29
14:49:29
14:51:29
14:53:29
14:55:30
14:57:30
14:59:30
15: 1:30
15: 3:30
15: 5:30
15: 7:30
135° W
90° W
45° W
0°
45° E
90° E
135° E

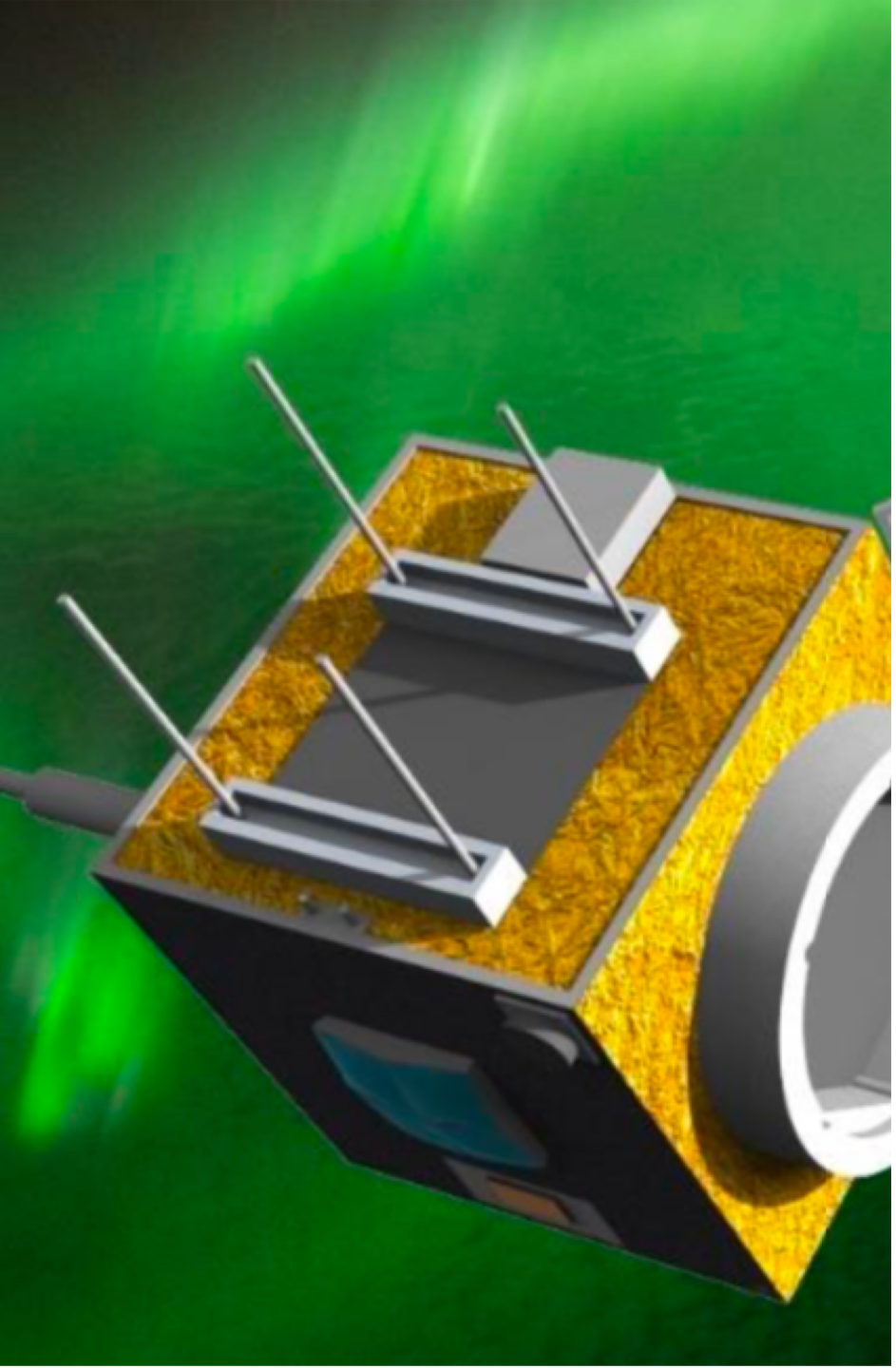






Key numbers

Parameter	Min	Nom	Max	Unit
Power Input				
Input voltage	22	28	38	V
Input power, normal operation	4.5	4.65	5.1	W
Input power, boom deployment (nominally 25 ms)	16	-	43	W
Electical Interfaces				
RS422 baud rate	19 200	460 800	921 600	bps
Electron density range	10^8	-	10^{12}	m^{-3}
Mechanical weights and dimensions				
Mass of electronic unit	-	0.813	-	kg
Total mass of boom system (two cassettes)	-	0.676	-	kg
Mass of harness (belonging to electronics unit)	-	0.265	-	kg
Mass of harness (belonging to two boom systems)	-	0.400	-	kg
Electronic unit dimensions (W x H x D)	-	122x61x109	-	mm
Boom dimensions, deployed (W x H x D)	-	400x384x65	-	mm
Harness lengths	-	1.5	-	m
Operational Environment				
Electronics unit temperature, operational	-30	-	55	°C
Electronics unit temperature, non-operational	-40	-	60	°C
Boom system pre-deployment	-50	-	60	°C
Boom system deployment	-50	-	60	°C
Boom system post-deployment	-50	-	60	°C
Spacecraft floating potential wrt. plasma potential	-7.5	-	+7.5	V



Key aspects

EIDSVOLL ELECTRONICS AS

On-board storage for > 24 hours of processed density and potential data at the highest sampling rate

Radiation tolerant up to >50 krad

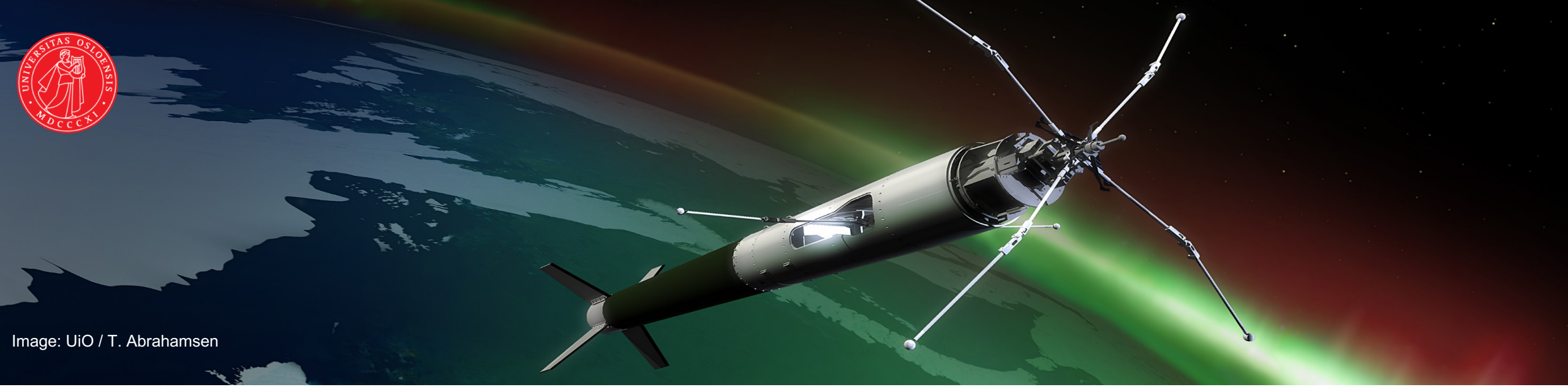
Examples of data rates for different operational modes:

Mode	Sample rate		
	100 Hz	1 kHz	5 kHz
Processed data	1 619 bps	16 185 bps	80 926 bps
RAW data	6 462 bps	64 616 bps	323 083 bps

Accumulated data per orbit (800 km altitude, 1h 41min orbit time):

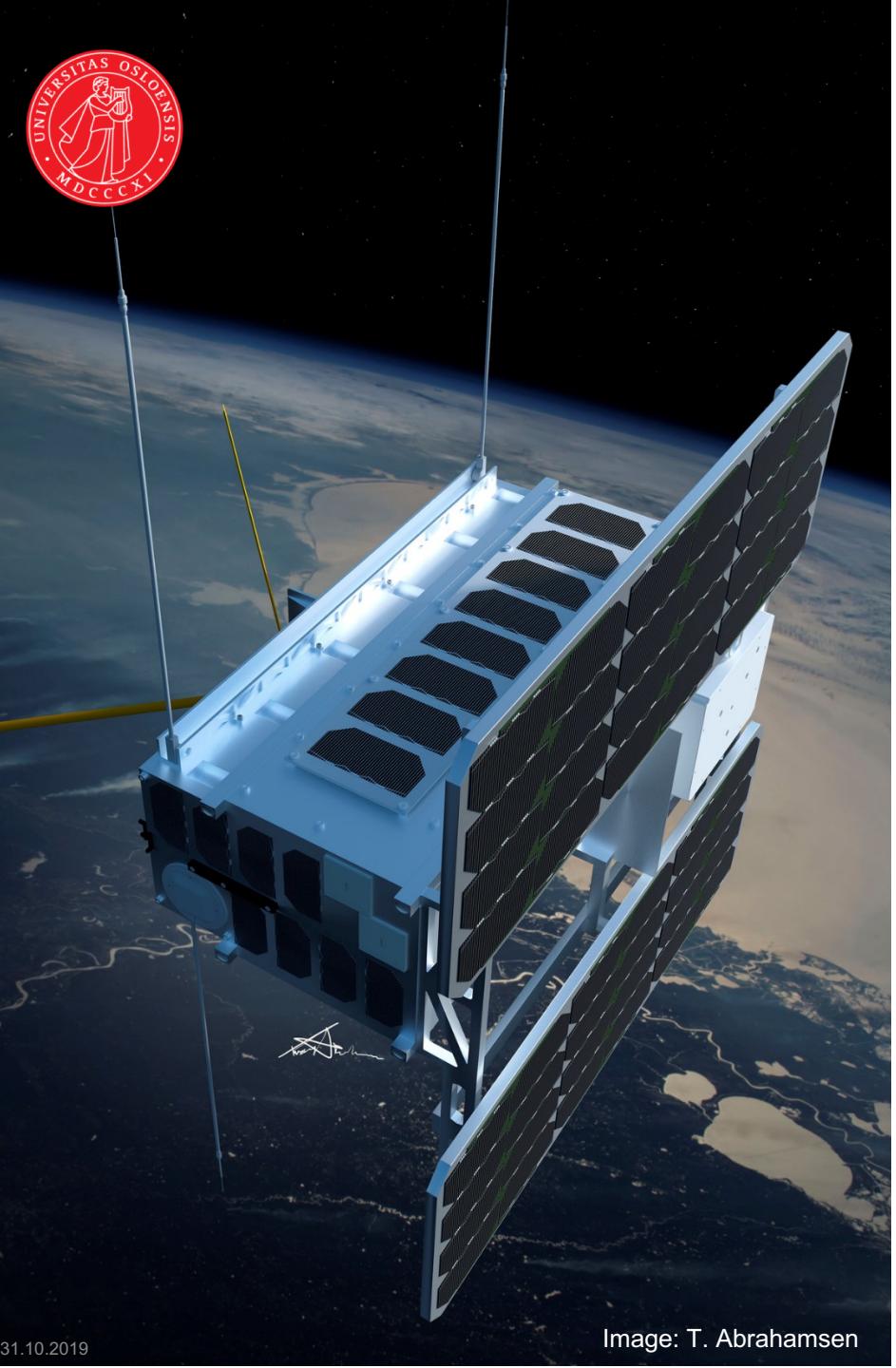
Mode	Sample rate		
	100 Hz	1 kHz	5 kHz
Processed data	1.17 MB	11.7 MB	58.5 MB
RAW data	4.67 MB	46.7 MB	233.4 MB

TRL - 7



Flight Heritage

Mission name	Launch date and site	Mission type
ICI-2	December 2008, Svalrak Launch Facility, Svalbard	Sounding rocket, 350 km apogee
ECOMA 7, 8 and 9	December 2010, Andøya Space Centre, Norway	Sounding rockets, 135 km apogee
ICI-3	December 2011, Svalrak Launch Facility, Svalbard	Sounding rocket, 350 km apogee
NASA 36.273 MICA	February 2012, Poker Flat Research Range, Alaska	Sounding rocket, 350 km apogee
ICI-4	February 2015, Andøya Space Centre, Norway	Sounding rocket, 350 km apogee
Maxidusty 1 and 1b	June/July 2016, Andøya Space Centre, Norway	Sounding rocket, 135 km apogee
NORSAT-1	July 2017, Baikonur Cosmodrome, Kazakhstan	Satellite, 586 x 608 km, 97.61º
NASA ViSIONS-2	December 2018. Svalrak Launch Facility, Svalbard	Sounding Rocket, 600 km apogee
NASA TRICE-2	December 2018, Andøya Space Centre, Norway	Sounding Rocket, 755 km & 1040 km apogee
CAPER-2	January 2019, Andøya Space Centre, Norway	Sounding Rocket, 774 km apogee

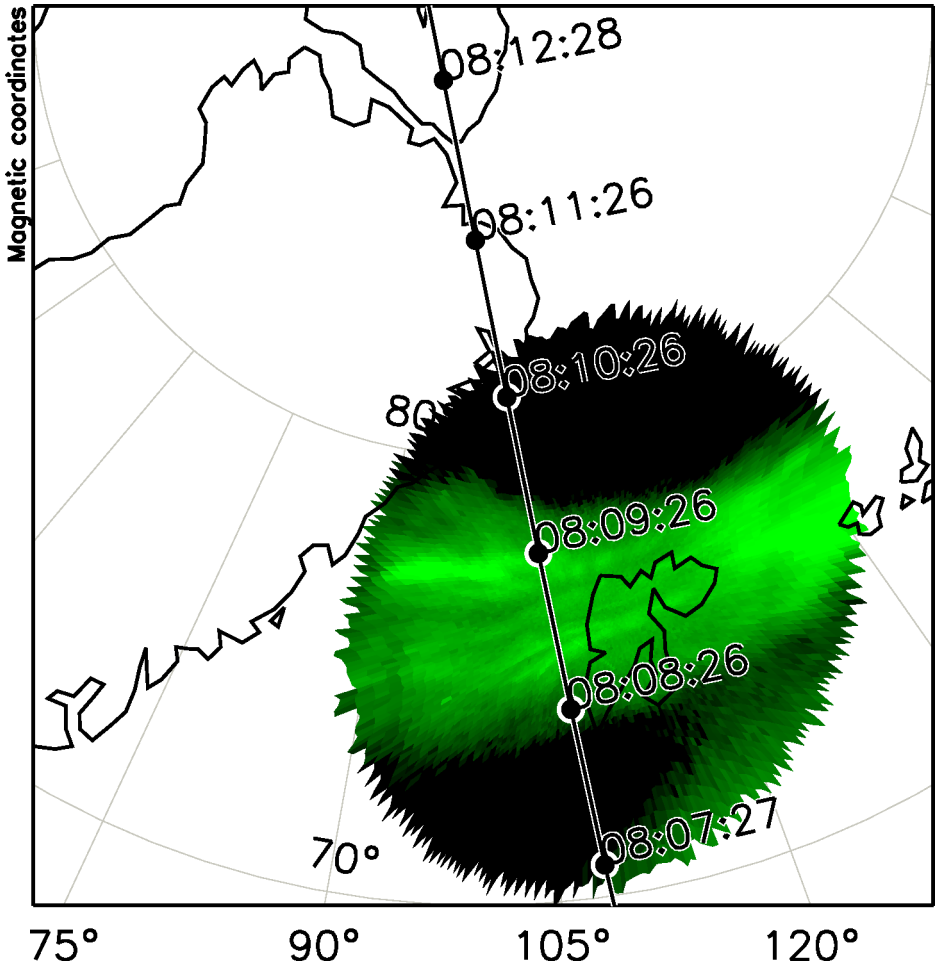


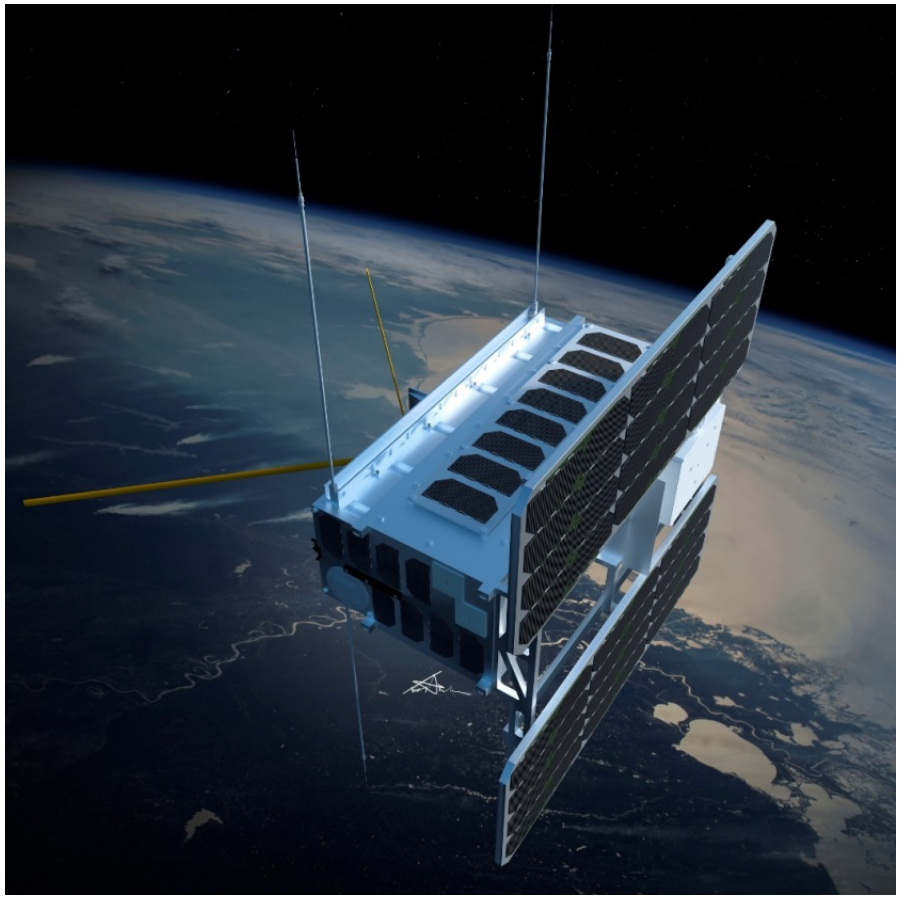
EIDSVOLL ELECTRONICS AS

Orbital considerations and instrument accommodation

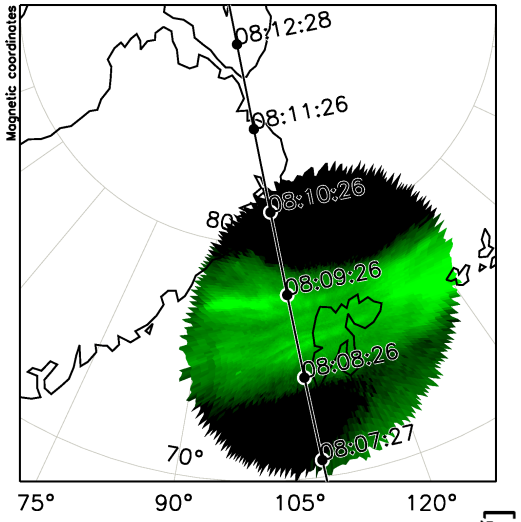
- Preferred orbital height is 350 to 800 km
- Probes preferentially placed in the same **orientation w.r.t. the magnetic field**
- Boom system should be mounted to **avoid wake** regions
- Probe potential needs to be above the space craft potential -

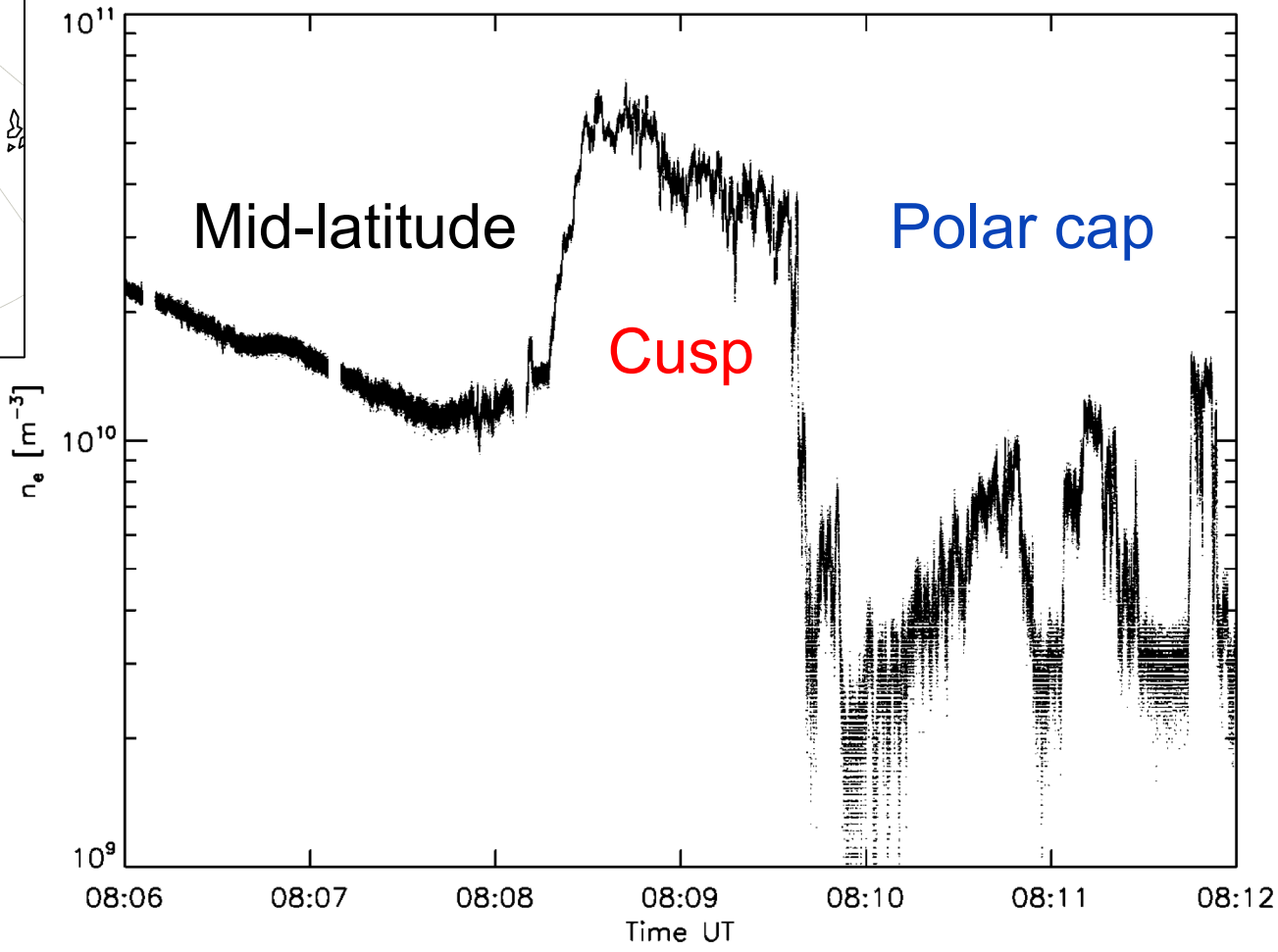
Norsat-1


Magnetic coordinates
08:12:28
08:11:26
08:10:26
80°
08:09:26
08:08:26
08:07:27
70°
75°
90°
105°
120°

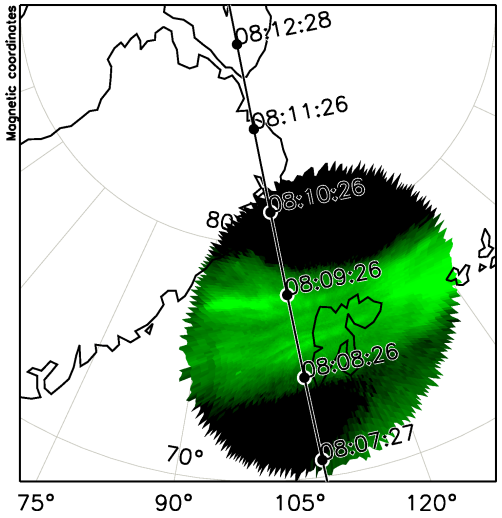


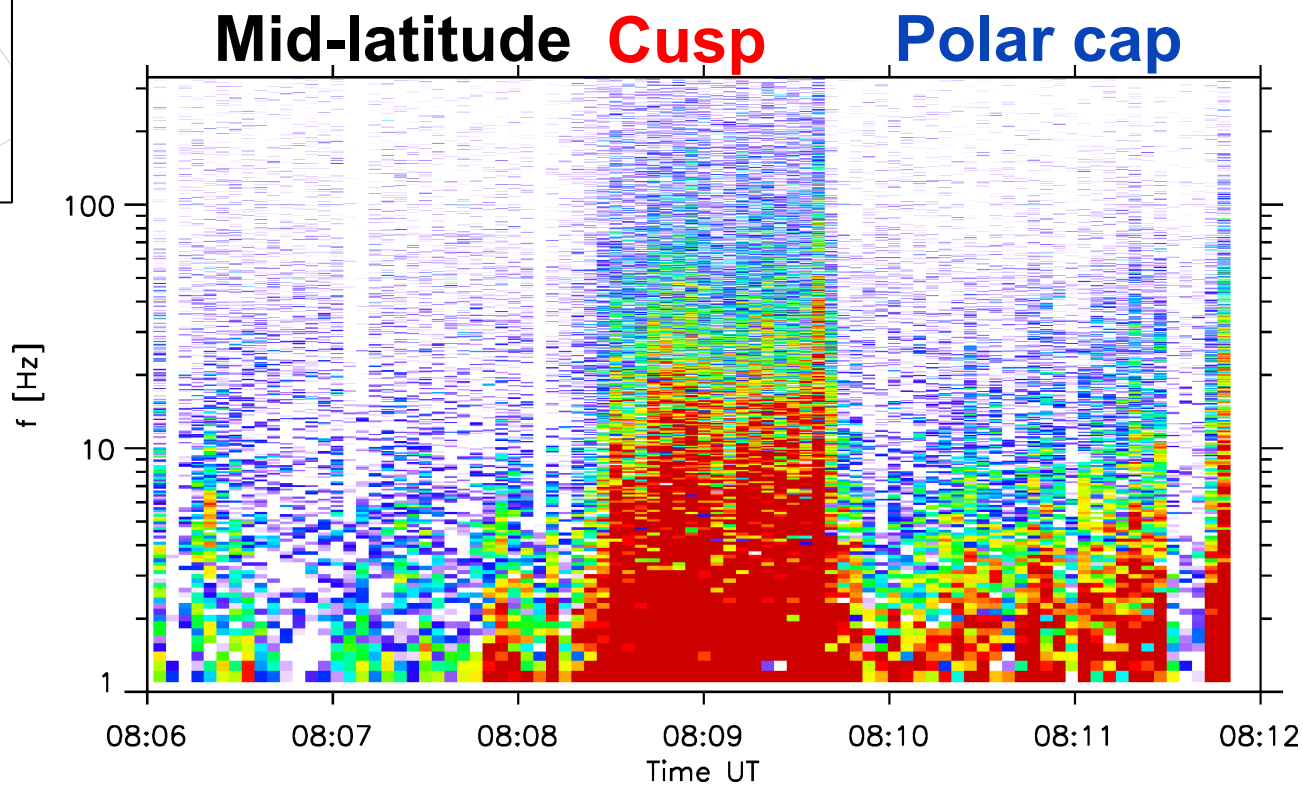
NorSat-1 measurements



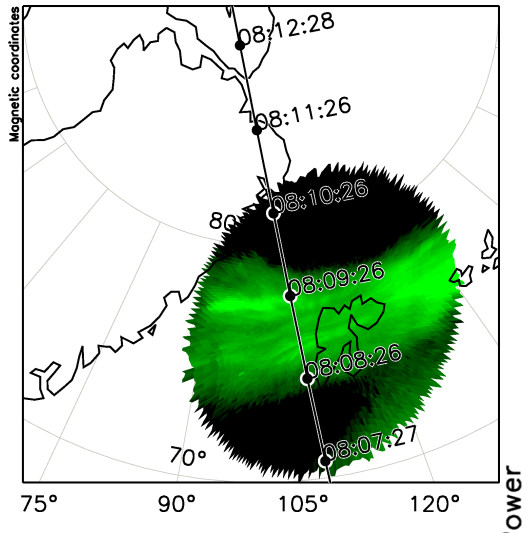


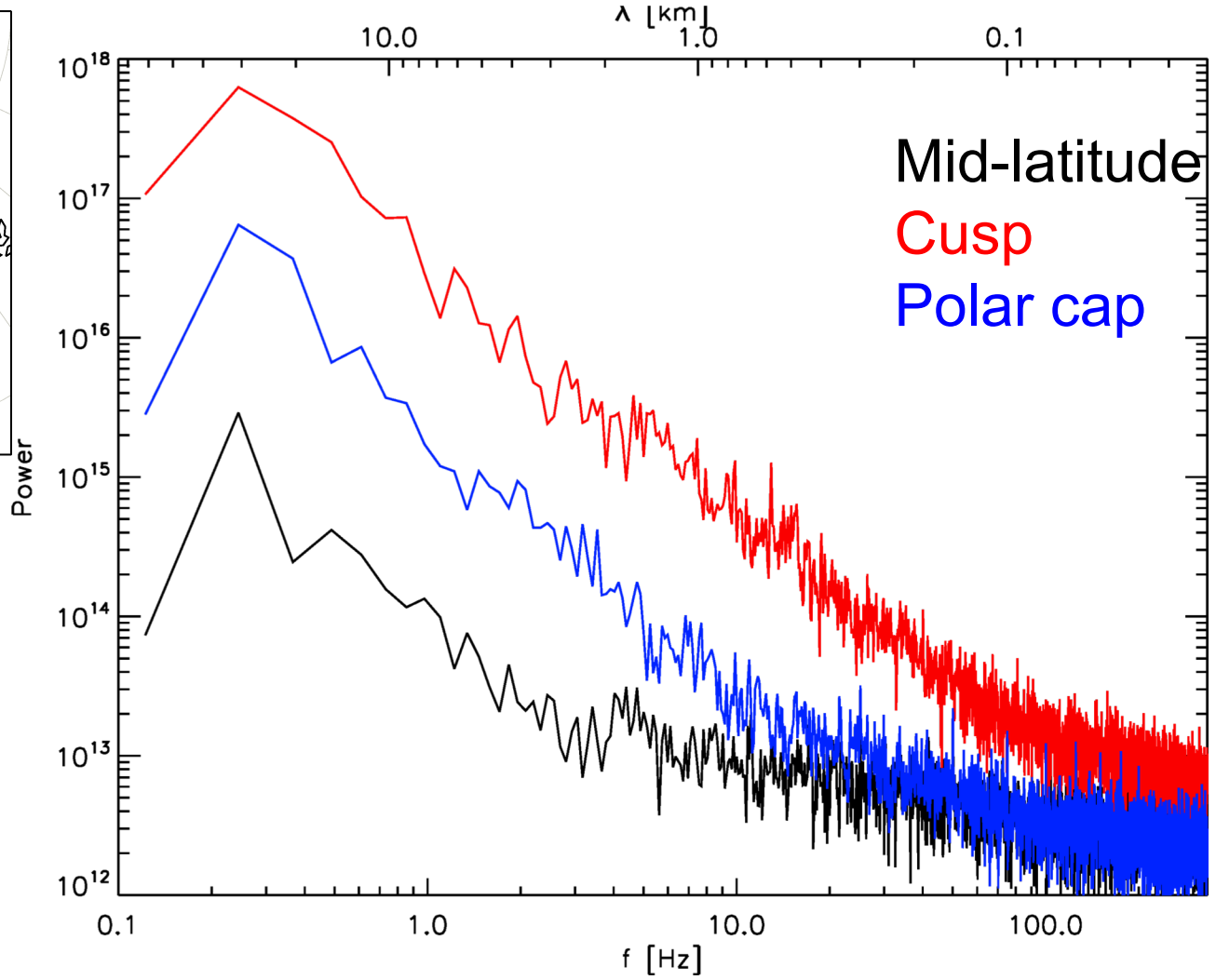
NorSat-1 measurements

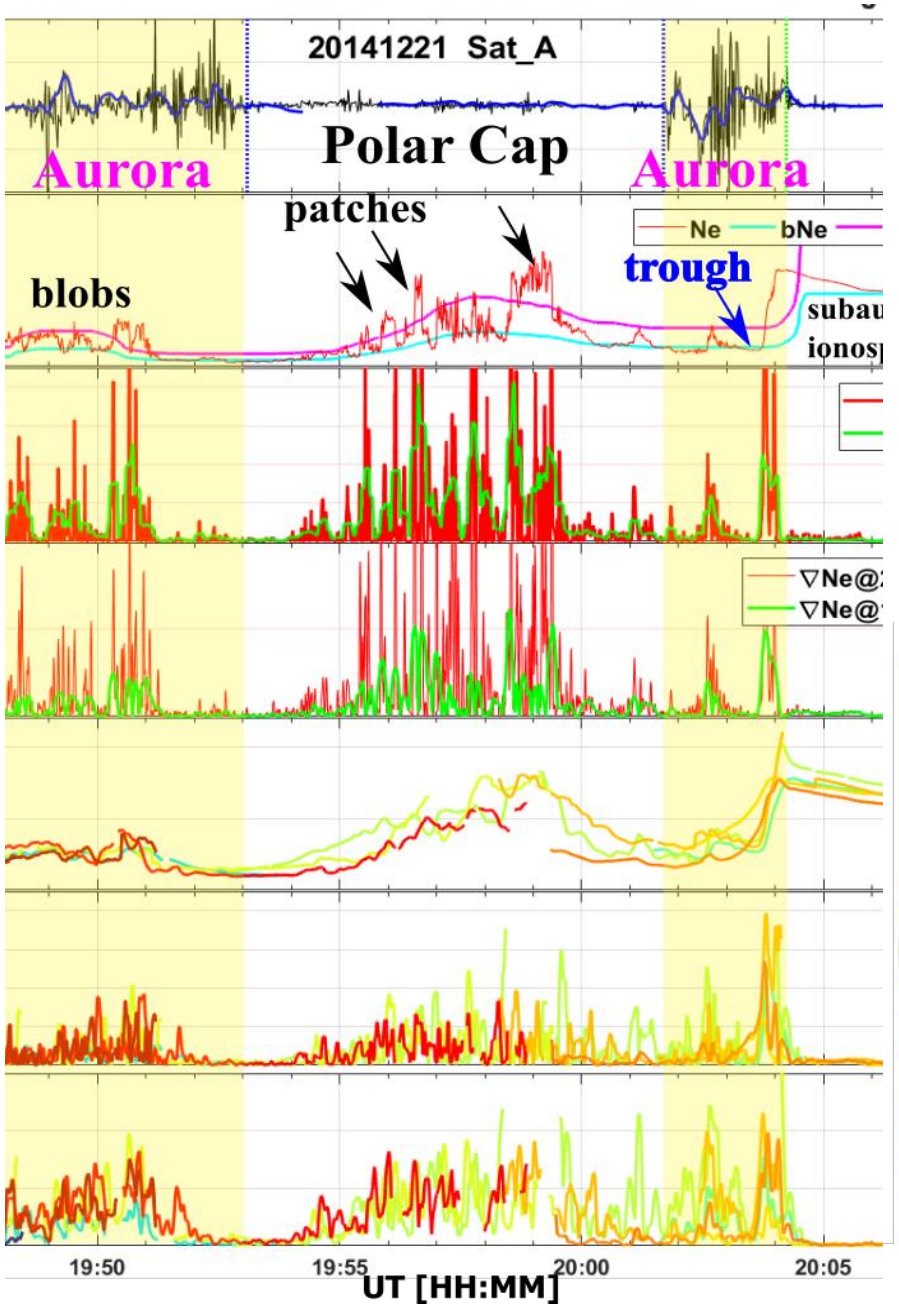




NorSat-1 measurements





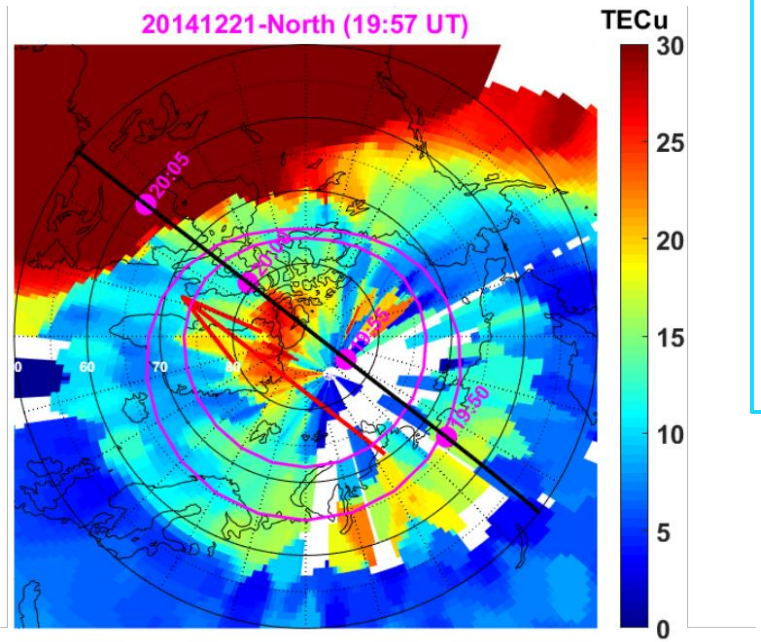


Jin et al., JGR, 2019

For GNSS Space weather services:

Key prameters:

- Electron density/gradients (Ne- meter-scale)
- Magnetic field (B-few nT)



Nice to have:

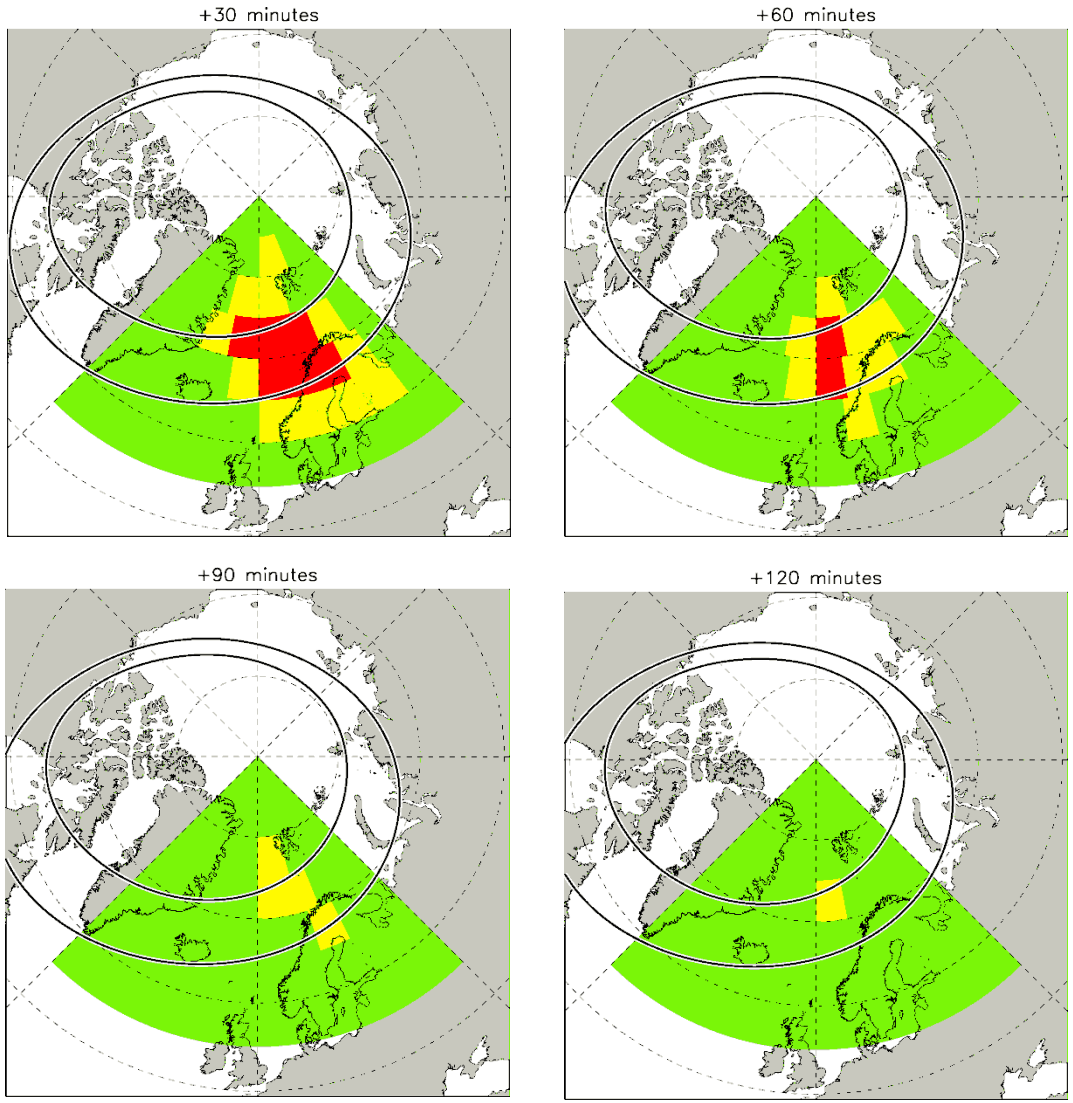
GNNS Scintillation/TEC

Auroral imager (oval)

Plasma Flow (Vi)

10eV-10 keV Electrons

Operational forecast

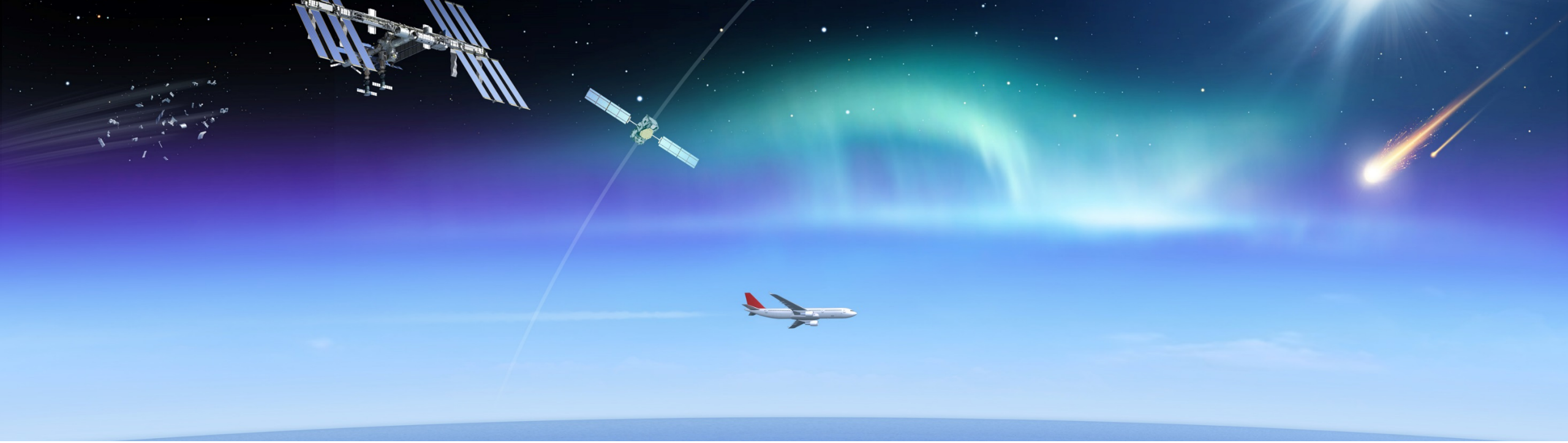


4DSpace group at UiO :

Proto-typing space weather forecast model for GNSS signal integrity in the European Arctic Sector

This model will need data input

D3S should do in flight data processing and transmit space weather parameter inputs to running models



Future prospects

- The m-NLP Instrument is currently a part of the ESA SSA D3S study
- On-ground forecasting services for radio communication / GNSS signal integrity and availability are being researched and developed
- Develop onboard processing capabilities for indices and parameter inputs to space weather models