National Space Agency of the Republic of Kazakhstan
National Center of Space researches and Technologies
Institute of space technique and technologies

Radio occultation experiment onboard first Kazakhstan's nanosatellite

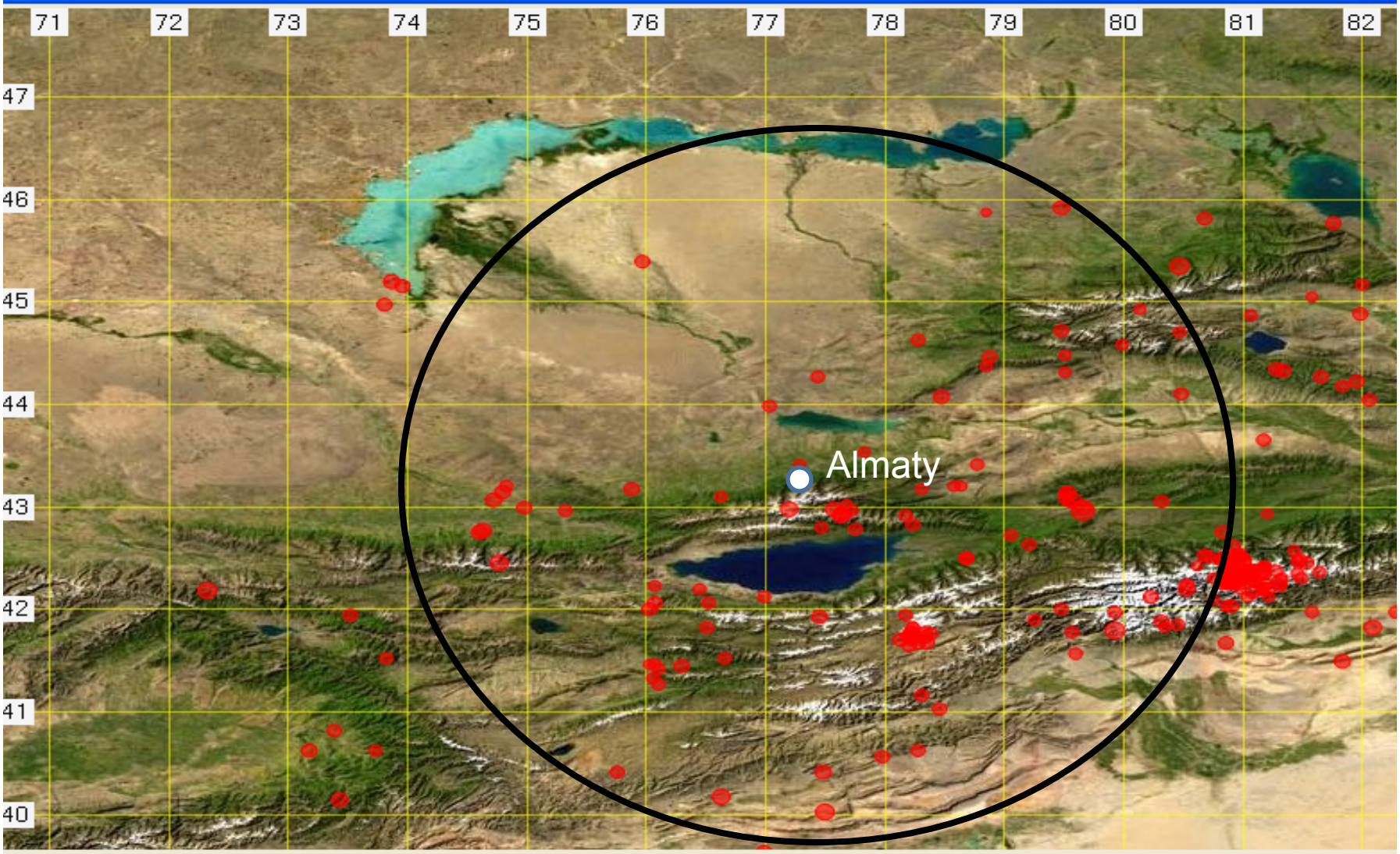
Trieste, 3 December 2014

Outline

1. Space activities in Kazakhstan
2. Radio occultation technique
    1. Past
    2. Future
    3. Nanosatellites
3. Payload prototype of kazakh nanosat
4. Selective RO approach for nanosatellite

National Space Agency of the Republic of Kazakhstan

- JSC National Company Kazakhstan Gharysh Sapary
- RSE Infracos
- National Center of Space researches and Technologies
  - Astrophysical institute after V.G. Fesenkov
  - Institute of Ionosphere
  - Institute of Space Technique and Technology
- JSC Republican center of space communication
- RSE Research center Gharysh Ecology
- JSC Kazakh-Russian JV Bayterek

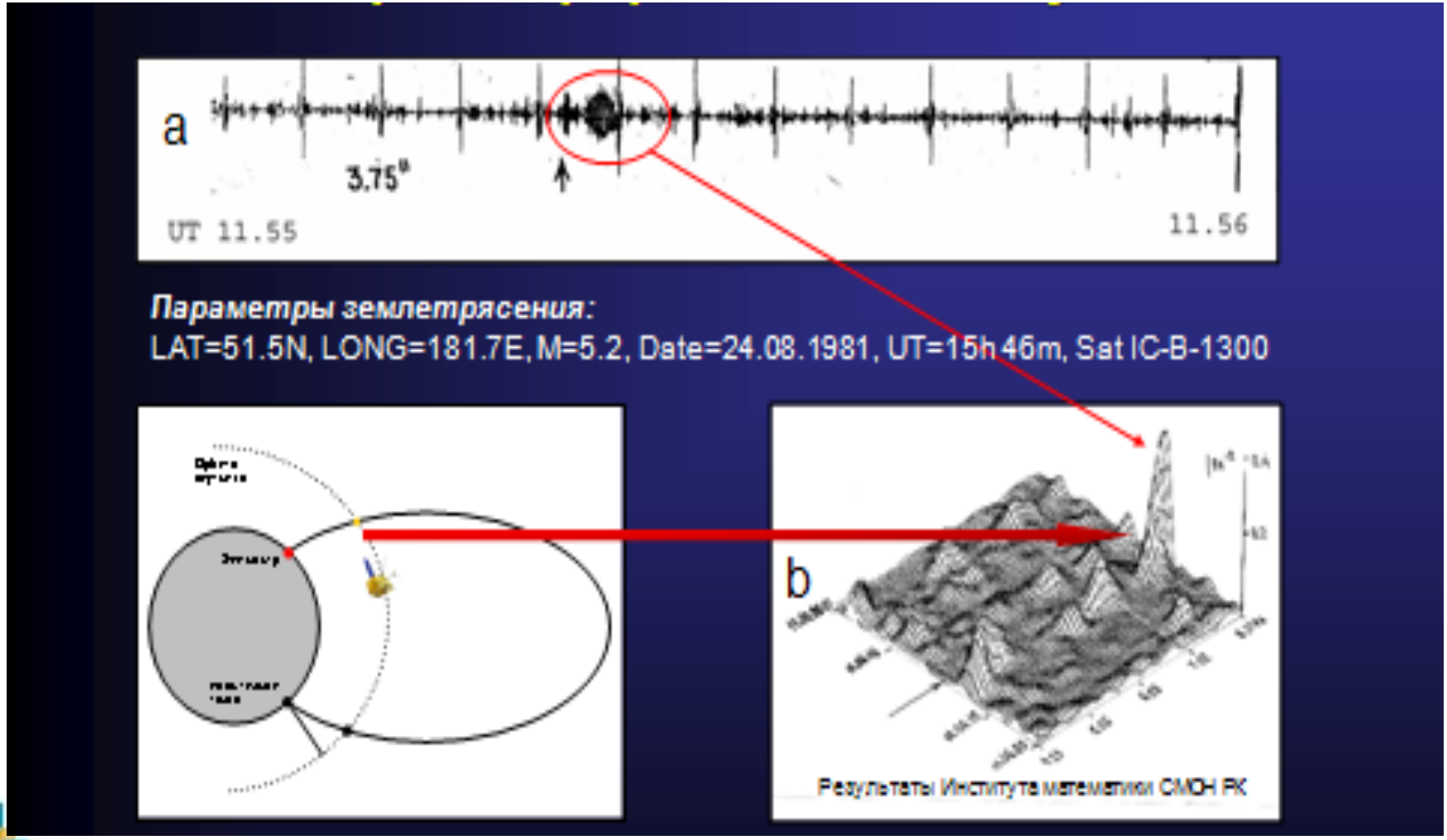


Seismology of South-East Kazakhstan region, earthquakes 2005-2010 (M>3)

Radio occultation experiment onboard first Kazakhstan's nanosatellite

Seismology of South-East Kazakhstan region, earthquakes 2005-2010 (M>3)

Magnetic field anomaly up to 4 hours "Intercosmos-Bulgaria-1300" (1981)

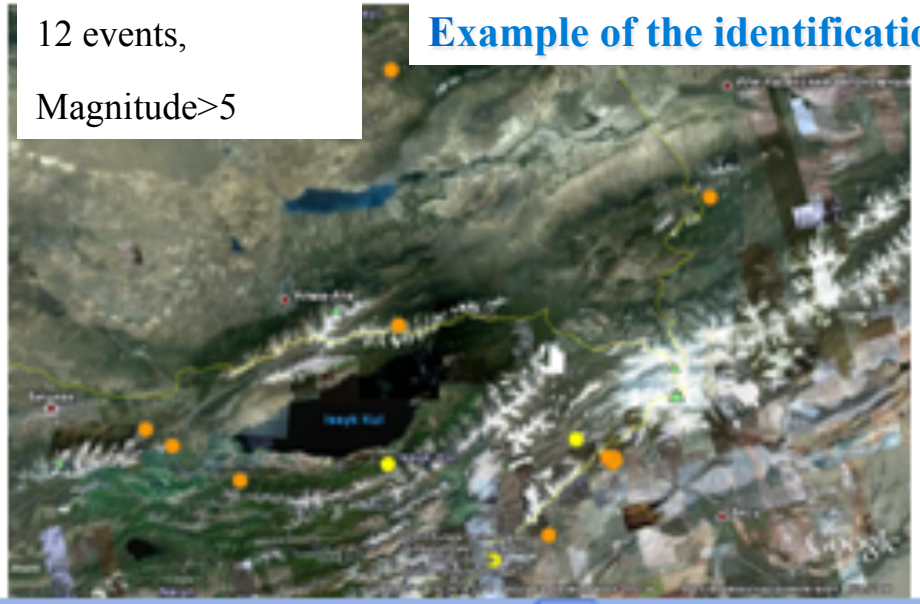


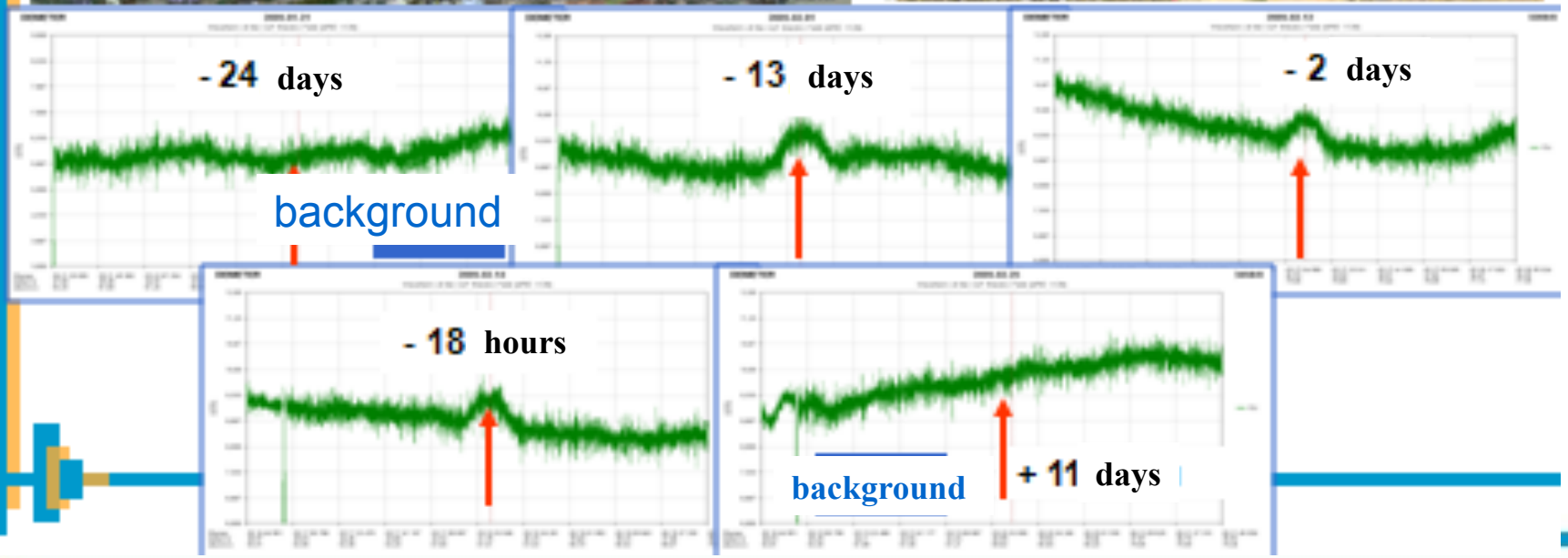
Radio occultation experiment onboard first Kazakhstan's nanosatellite

12 events,

Magnitude>5

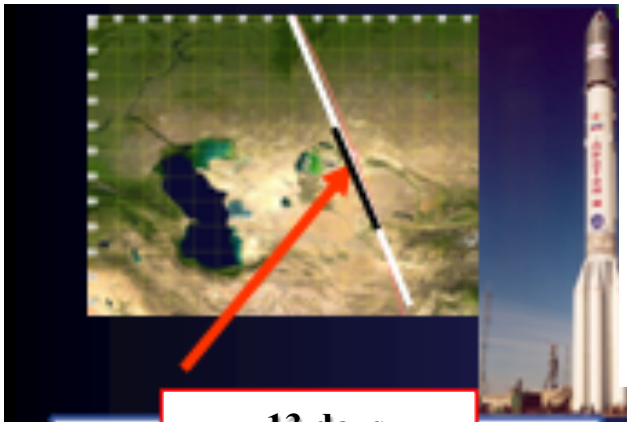
Example of the identification of regional earthquakes

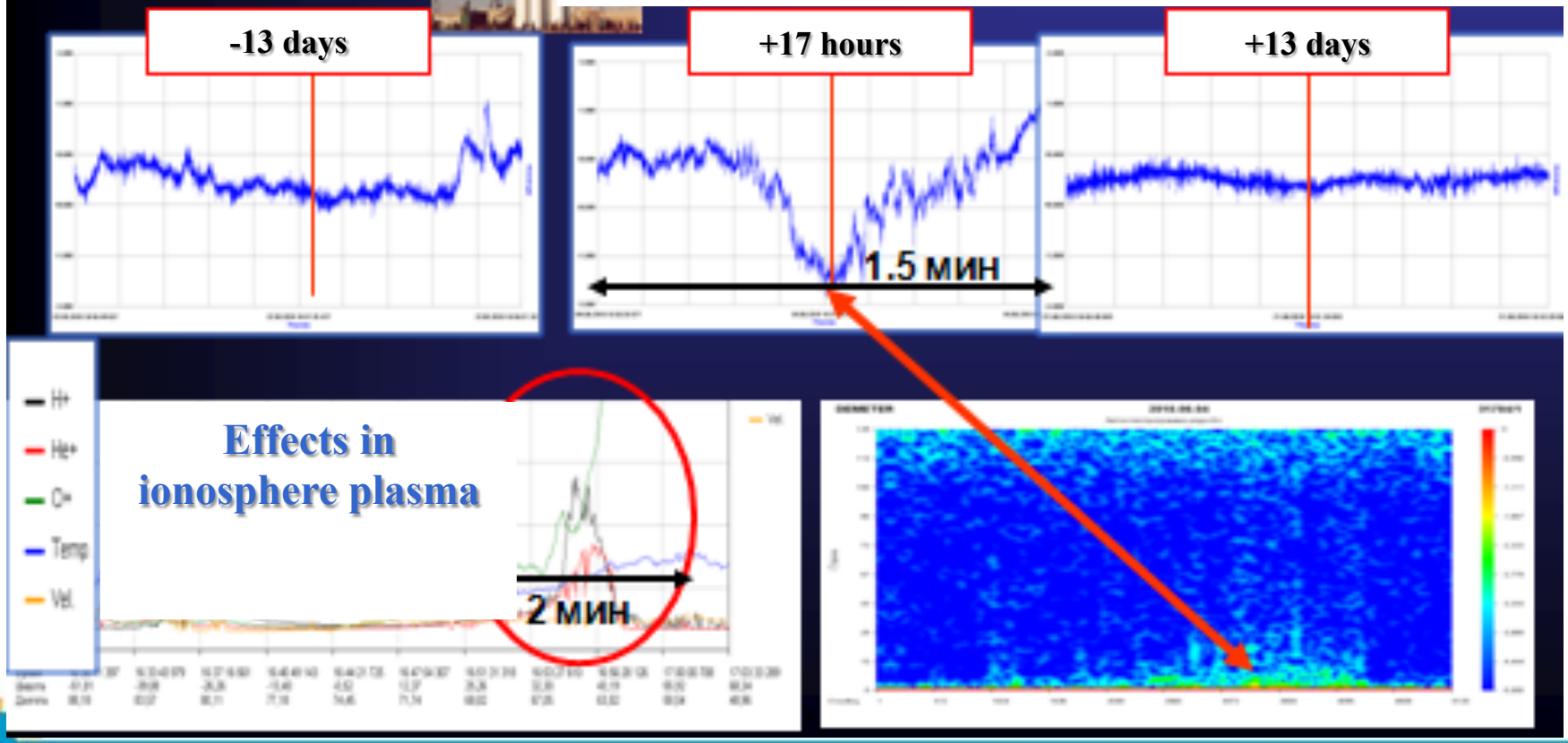




Launch "PROTON-M" 04/06/2010

E-field "Demeter"



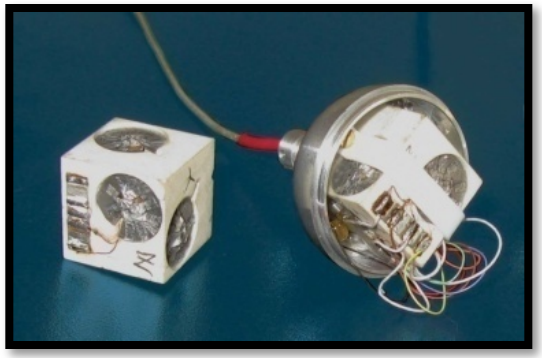


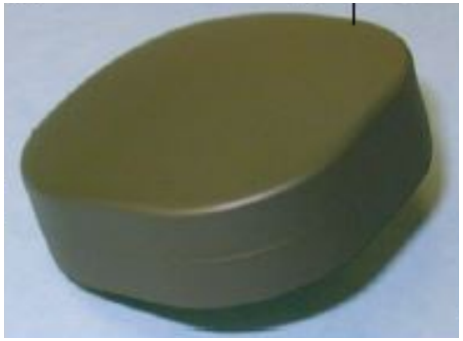
Scientific Tasks

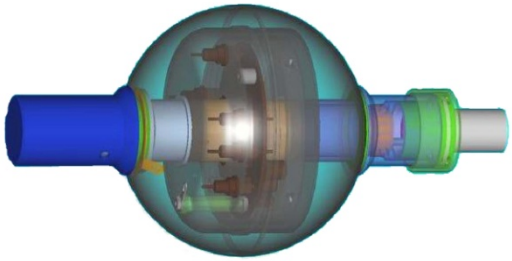
The mission of Scientific Space System is monitoring and study of the disturbances in the interplanetary environment due to natural and man-made radiation sources in wide-range of spatial and time scales.

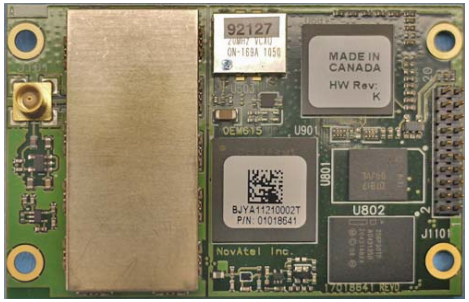
The application task of SSS is earthquake prediction investigation using satellite and ground-base facilities.

Scientific instruments

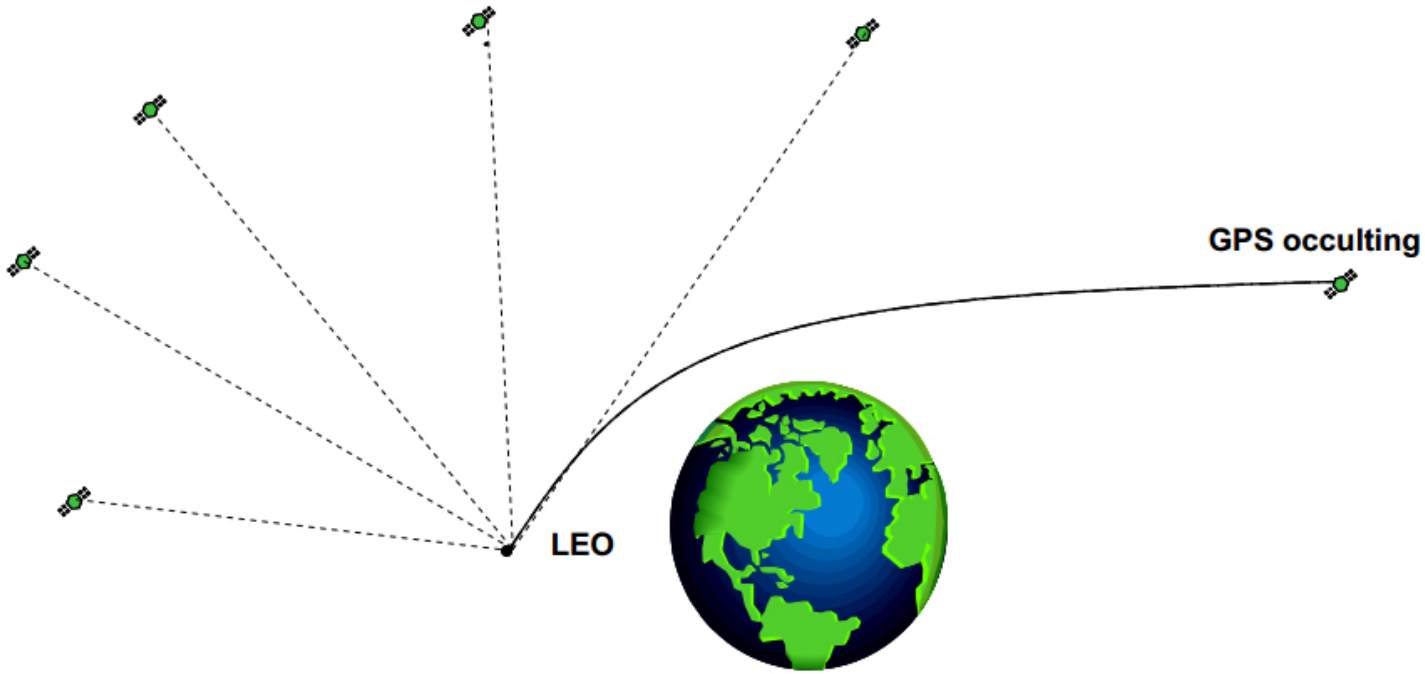








What is a radio occultation method?



How the paths of radio signals are bent by refractive index gradients in the atmosphere and the ionosphere

Credits to: www.plan.geomatics.ucalgary.ca

What can we obtain?

PROFILES OF:

TEMPERATURE

MOISTURE

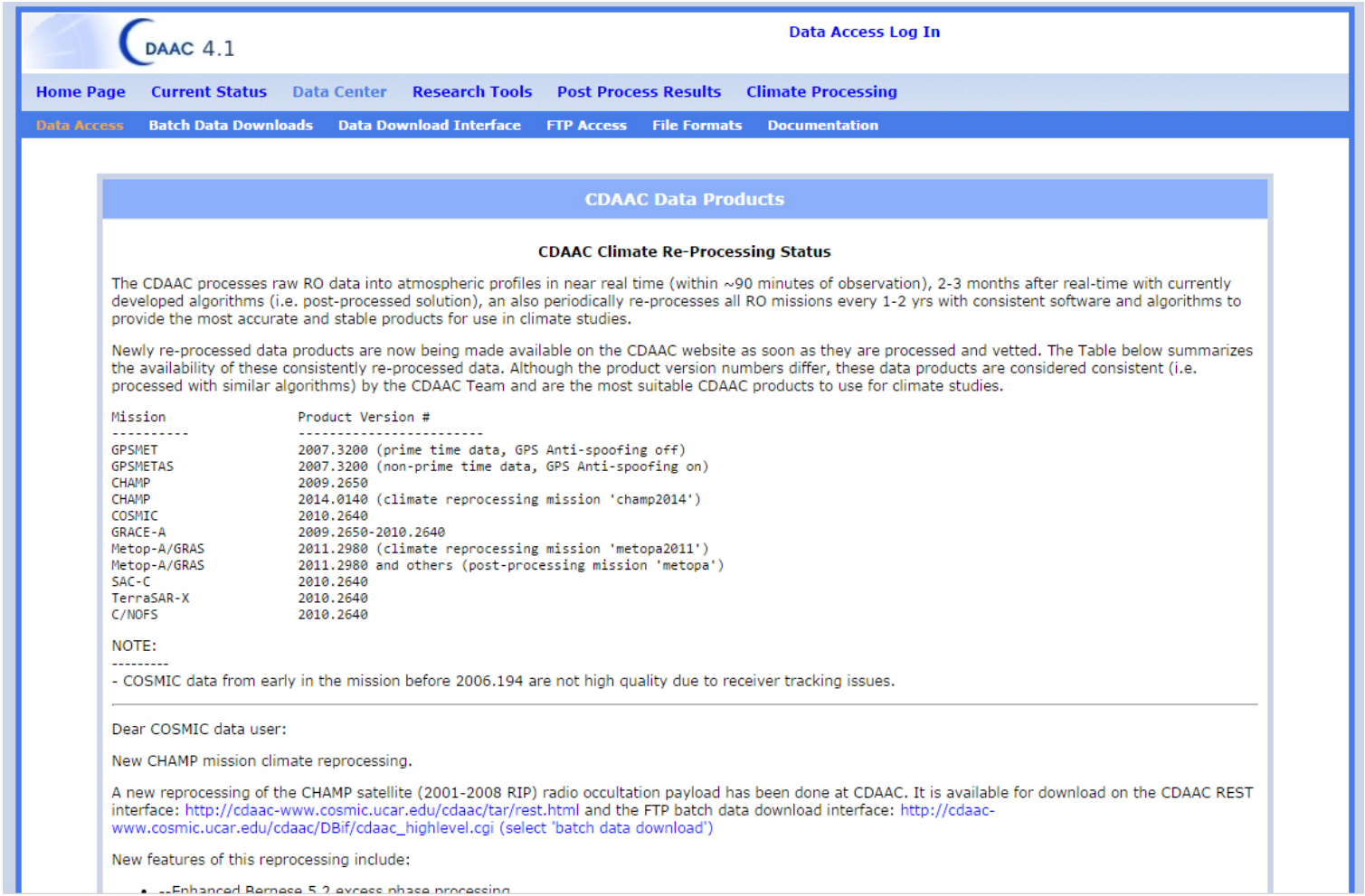
PRESSURE

TOTAL ELECTRON CONTENT

IONOSPHERE SCINTILLATION

….

Data available



DAAC 4.1

Data Access Log In

Home Page | Current Status | Data Center | Research Tools | Post Process Results | Climate Processing

Data Access | Batch Data Downloads | Data Download Interface | FTP Access | File Formats | Documentation

CDAAC Data Products

CDAAC Climate Re-Processing Status

The CDAAC processes raw RO data into atmospheric profiles in near real time (within ~90 minutes of observation), 2-3 months after real-time with currently developed algorithms (i.e. post-processed solution), an also periodically re-processes all RO missions every 1-2 yrs with consistent software and algorithms to provide the most accurate and stable products for use in climate studies.

Newly re-processed data products are now being made available on the CDAAC website as soon as they are processed and vetted. The Table below summarizes the availability of these consistently re-processed data. Although the product version numbers differ, these data products are considered consistent (i.e. processed with similar algorithms) by the CDAAC Team and are the most suitable CDAAC products to use for climate studies.

Mission	Product Version #
GPSMET	2007.3200 (prime time data, GPS Anti-spoofing off)
GPSMETAS	2007.3200 (non-prime time data, GPS Anti-spoofing on)
CHAMP	2009.2650
CHAMP	2014.0140 (climate reprocessing mission 'champ2014')
COSMIC	2010.2640
GRACE-A	2009.2650-2010.2640
Metop-A/GRAS	2011.2980 (climate reprocessing mission 'metopa2011')
Metop-A/GRAS	2011.2980 and others (post-processing mission 'metopa')
SAC-C	2010.2640
TerraSAR-X	2010.2640
C/NOFS	2010.2640

NOTE:

- COSMIC data from early in the mission before 2006.194 are not high quality due to receiver tracking issues.

Dear COSMIC data user:

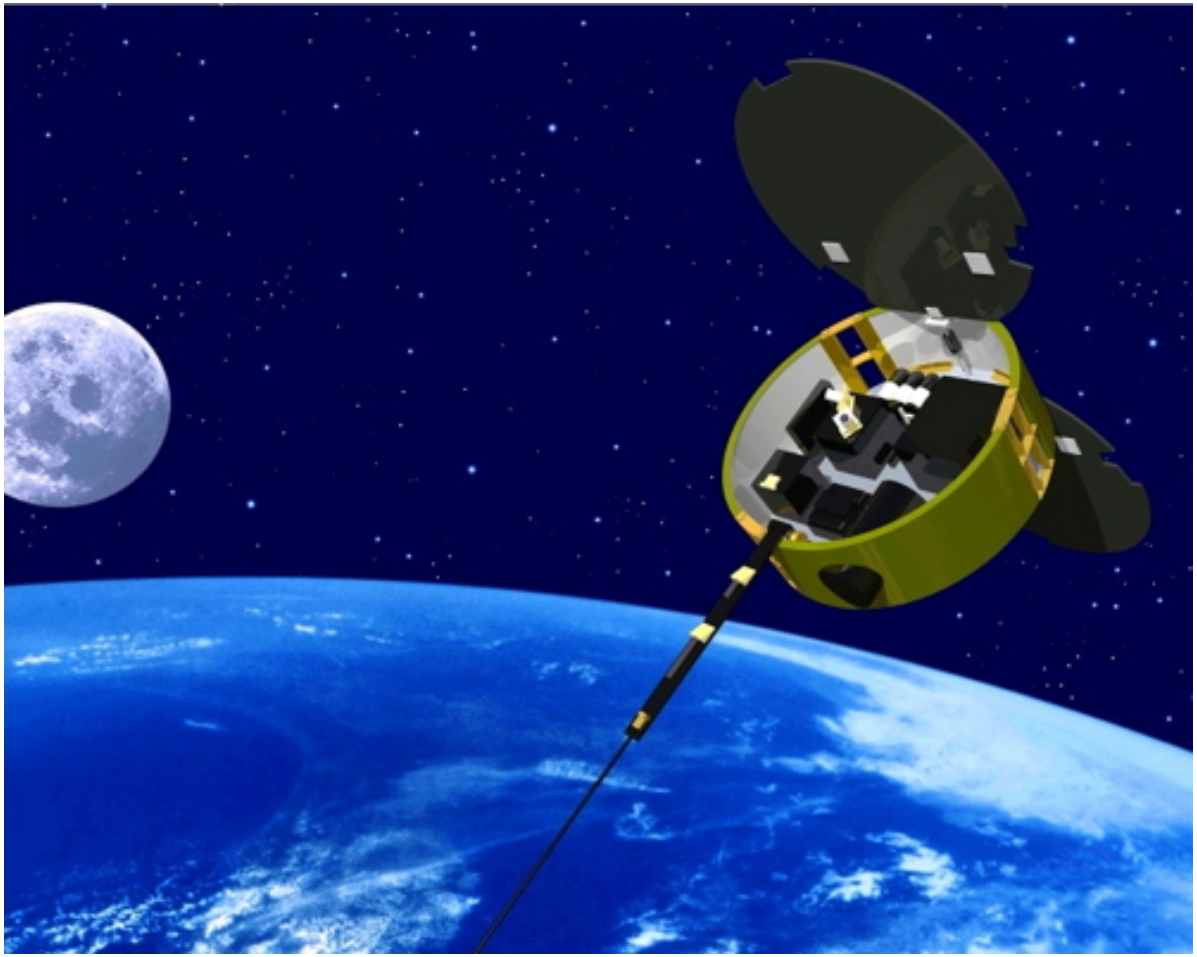
New CHAMP mission climate reprocessing.

A new reprocessing of the CHAMP satellite (2001-2008 RIP) radio occultation payload has been done at CDAAC. It is available for download on the CDAAC REST interface: http://cdaac-www.cosmic.ucar.edu/cdaac/tar/rest.html and the FTP batch data download interface: http://cdaac-www.cosmic.ucar.edu/cdaac/DBif/cdaac_highlevel.cgi (select 'batch data download')

New features of this reprocessing include:

- --Enhanced Bernese 5.2 excess phase processing

Past missions



GPS-MET

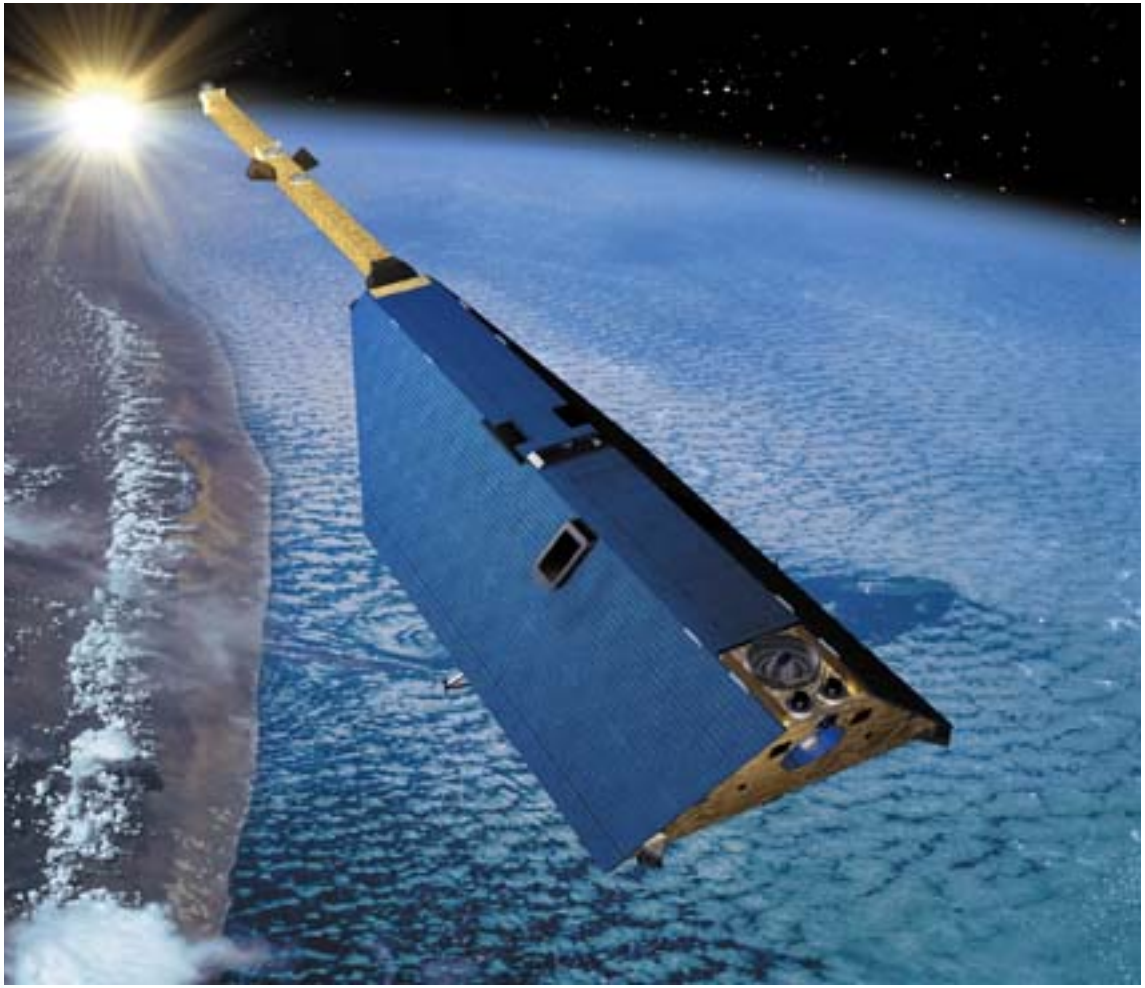
Radio occultation (RO) measurements have been used to study planetary atmospheres, such as Mars and Venus, since the 1960's.

In **1996** the proof of concept "GPS/MET" experiment demonstrated useful temperature information could be derived from the GPS RO measurements.

Mission duration: 2 years
Inclination: ~70 degrees

www.genesis.jpl.nasa.gov/genesis/gpsmet

Past missions



CHAMP

With the radio occultation measurements onboard the spacecraft and the infrastructure developed on ground, CHAMP had become a pilot mission for the pre-operational use of space-borne GPS observations for atmospheric and ionospheric research and applications in weather prediction and space weather monitoring.

Mission duration: 10 years
Inclination: 87.18 degrees
Mass: 500 kg

www.op.gfz-porsdam.de/champ

Past missions

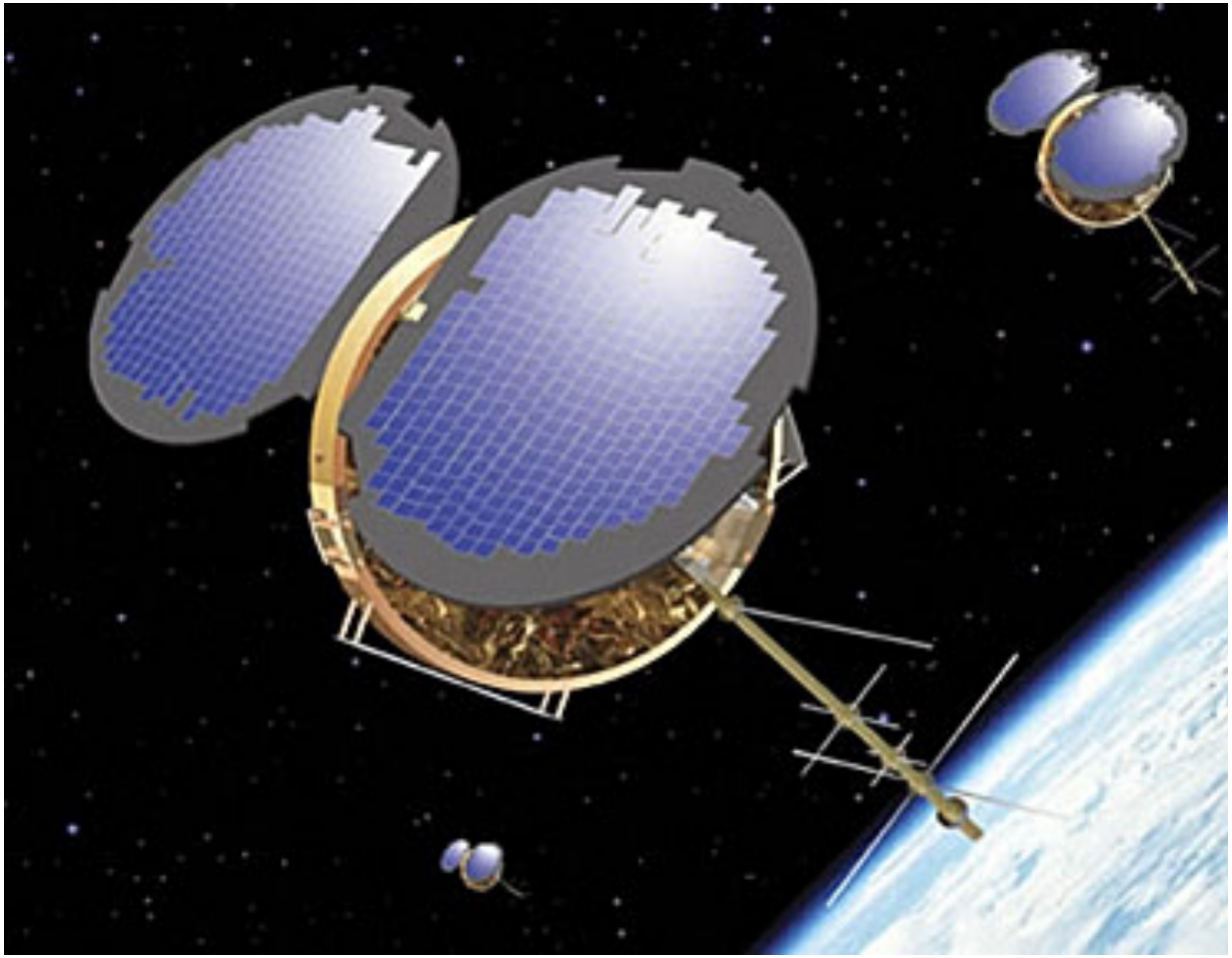
METOP A-B-C

To provide more detailed observations of the global atmosphere, oceans and continents.

Mission duration:
A from 2006
B from 2012
B in 2017
Inclination: polar orbit
Mass: ~ 4 tons

www.eumetsat.int

Past missions



COSMIC

to provide advances in meteorology, ionospheric res earch, climatology, and space weather by using GPS satellites in conjunction with low Earth orbiting (LEO) satellites.

Mission duration: from 2006
6 LEO satellites
Inclination: 72 degree
Mass: 70 kg

www.cosmic.ucar.edu

Future missions

Planet IQ

PLANETiQ
CRITICAL DATA FOR A SMARTER PLANET

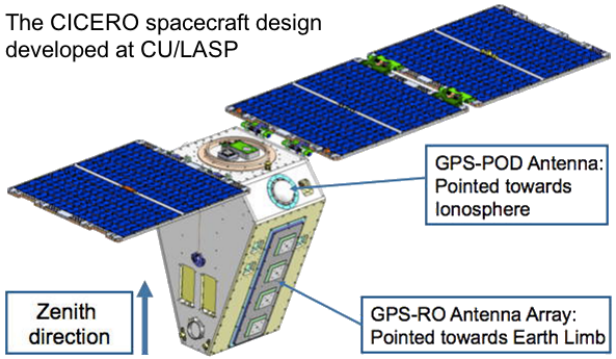
- 12 LEO satellites launch by 2017 + 6 by 2019
- GPS, Galileo, GLONASS, BeiDou
- > 30,000 occultations per day
- 50-75 kg microsatellite

www.planetiq.com

Future missions

CICERO

- 12 LEO micro-satellites (full constellation CICERO-I) launch by 2017
- The First CICERO satellite launch – October 2014
- 50 Hz measurements



www.geooptics.com

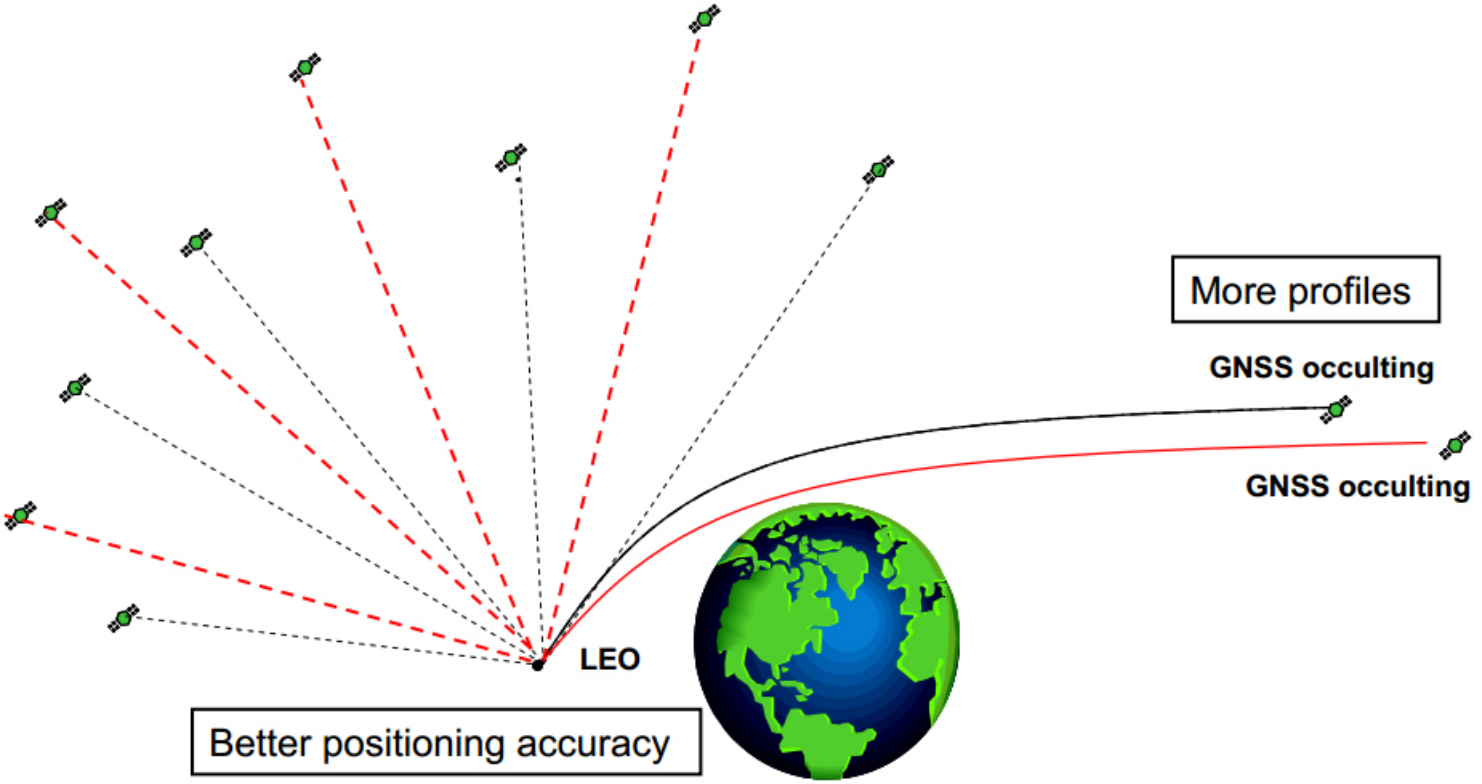
Future missions

COSMIC-2

- 12 LEO satellites by 2017
- The first launch of 6 satellites is planned in 2014
- 5 times increase in number of measurements
- GPS, Galileo, GLONASS
- >8,000 profiles per day
- 200 kg satellites

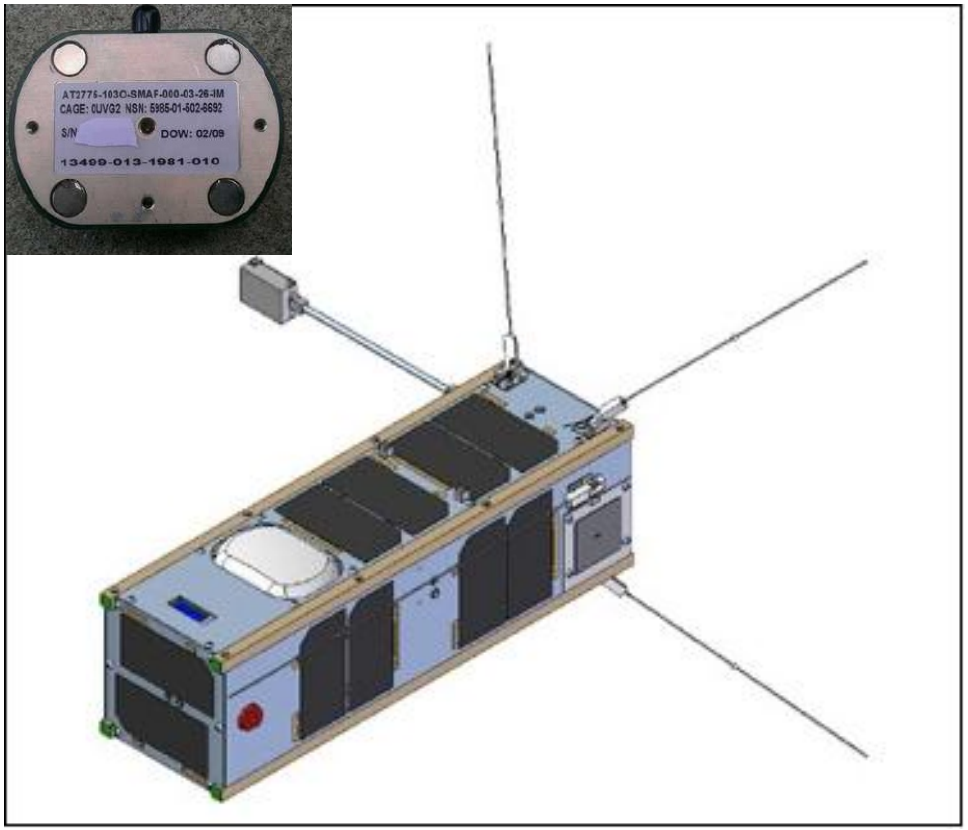
www.cosmic.ucar.edu/cosmic2/

Future missions



Credits to: www.plan.geomatics.ucalgary.ca

Radio occultation experiments onboard nanosatellites – CANX-2

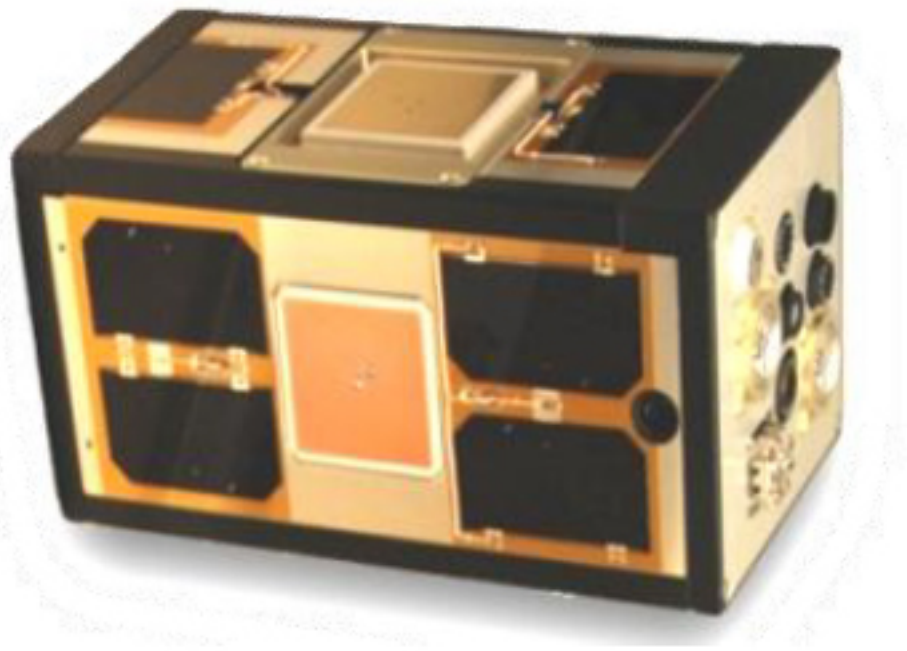


First nanosatellite with Dual-Frequency receiver onboard for RO experiment. Launch 2008.

Instruments:

- NovAtel OEM4-G2L
- AeroAntenna AT2775-1030

Radio occultation experiments onboard nanosatellites – PSSCT-2



Deployed from a Space Shuttle.
Instruments:

- NovAtel OEMV-2
- Custom designed antenna (Aerospace)
- Finished mission after 5 months

- 4 hour of CTECS operation max supported by the power system
- First satellite lock – 8 seconds
- 4 satellite lock – 4 minutes
- 97 Clean Occulting tracks

Radio occultation experiments onboard nanosatellites

SENSE (Launch 19 Nov 2013)

OSIRIS-3U

TSAT

CUNYSAT-1

ARMADILLO

CAT-1

MiRaTA

+ tons of ideas, publications and talks

Nanosat advantages

- COTS technologies / Inexpensive

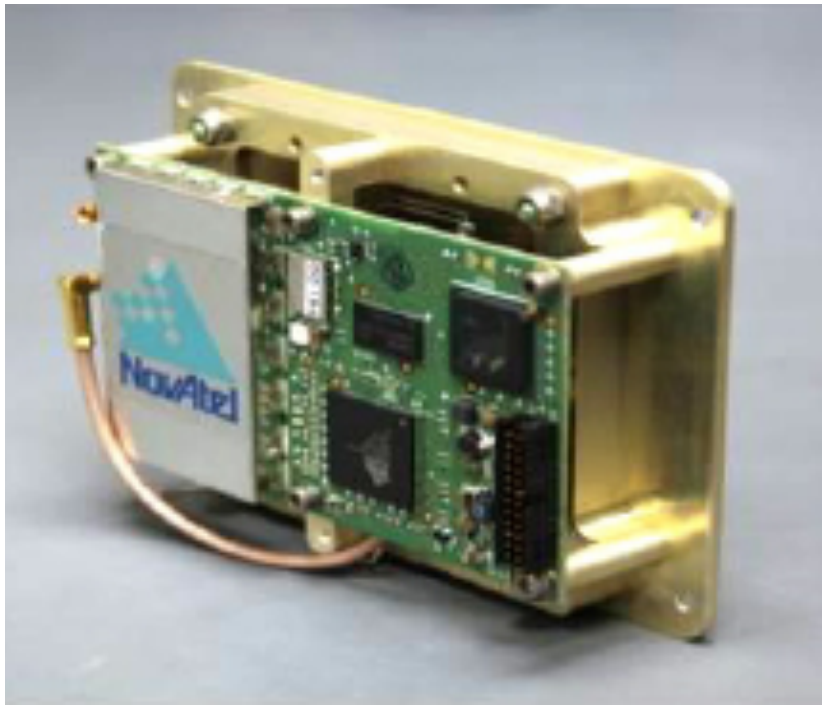
About 30 nanosats can observe the atmosphere and ionosphere constantly

- Interest in RO from scientific community
- Variety of vehicles for launch (Cost ~ $150-300K)

Receivers prices comparison

Receiver	Channels	Signals	PS, Mass	Cost	Mission
BlackJack (JPL)	16x3	C1, P1, P2, LA, L1, L2 (+L2C)	10W, 3.2 kg		SAC-C, CHAMP, GRACE, Jason-1
IGOR (BRE)			16W, 4.6 kg	500 000 Euro	TanDEM-X, COSMIC
PYXIS	96	L1, L2, L5, GPS+Galileo	12-18W, 2 kg		
GRAS (Saab)	12x3	C1, P1, P2, LA, L2	50W, 10-30kg	2 mil. Euro	METOP
Lagrange (Laben)	12x3	C1, P1, P2 LA, L2	30W, 5.2kg	700 000 Euro	ENEIDE, Radarsat-2, COSMO-Skymed GOCE
TopStar 3000G2 (Alcatel)	6x2	C1, L2C LA, L2			Proba-2
IGPS-A (AAE)	8x3	C1, P2, P3 LA, L2			SWARM, Sentinel-1/2/3
OEM4-G2I	12x2	C1, P2 LA, L2	1.5W, 50g	10 000 Euro	CanX-2, CASSIOPE
PolaRx2 (Septentrio)	16x3	C1, P1, P2 LA, L2	5W, 120g	10 000 Euro	TET-1
Javad TR-G2T (Javad)	256	C1, P1, P2, LA, L2C, L5	1.6W, 34r	10 000 Euro	

RO instruments for nanosatellites missions - CTECS



OEMV-2 NovAtel receiver

72 channels (L1,L2,L2C, GLONASS)

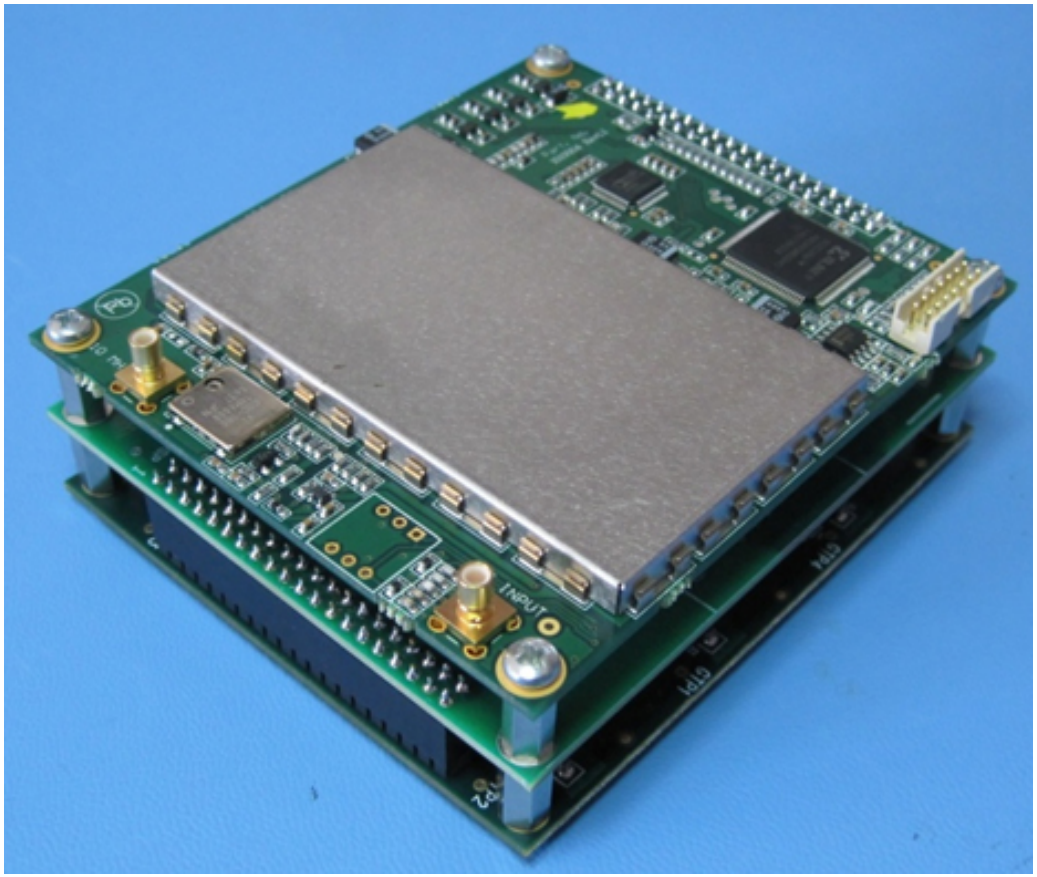
Power consumption ~1.2

1 Hz measurements for GPS satellites below horizon

Installed on PSSCT-2

Aerospace corporation

RO instruments for nanosatellites missions - FOTON



Signals: GPS L1CA, L2C (60 channels)

Precision: <0.5 mm carrier phase

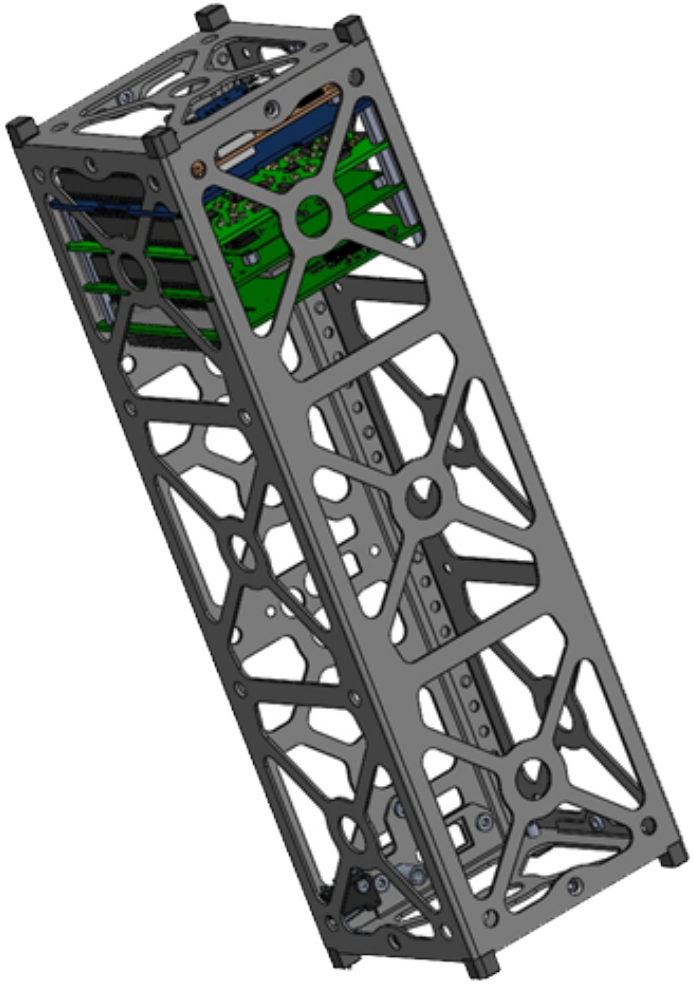
2 Antennas inputs possible

Open-loop tracking

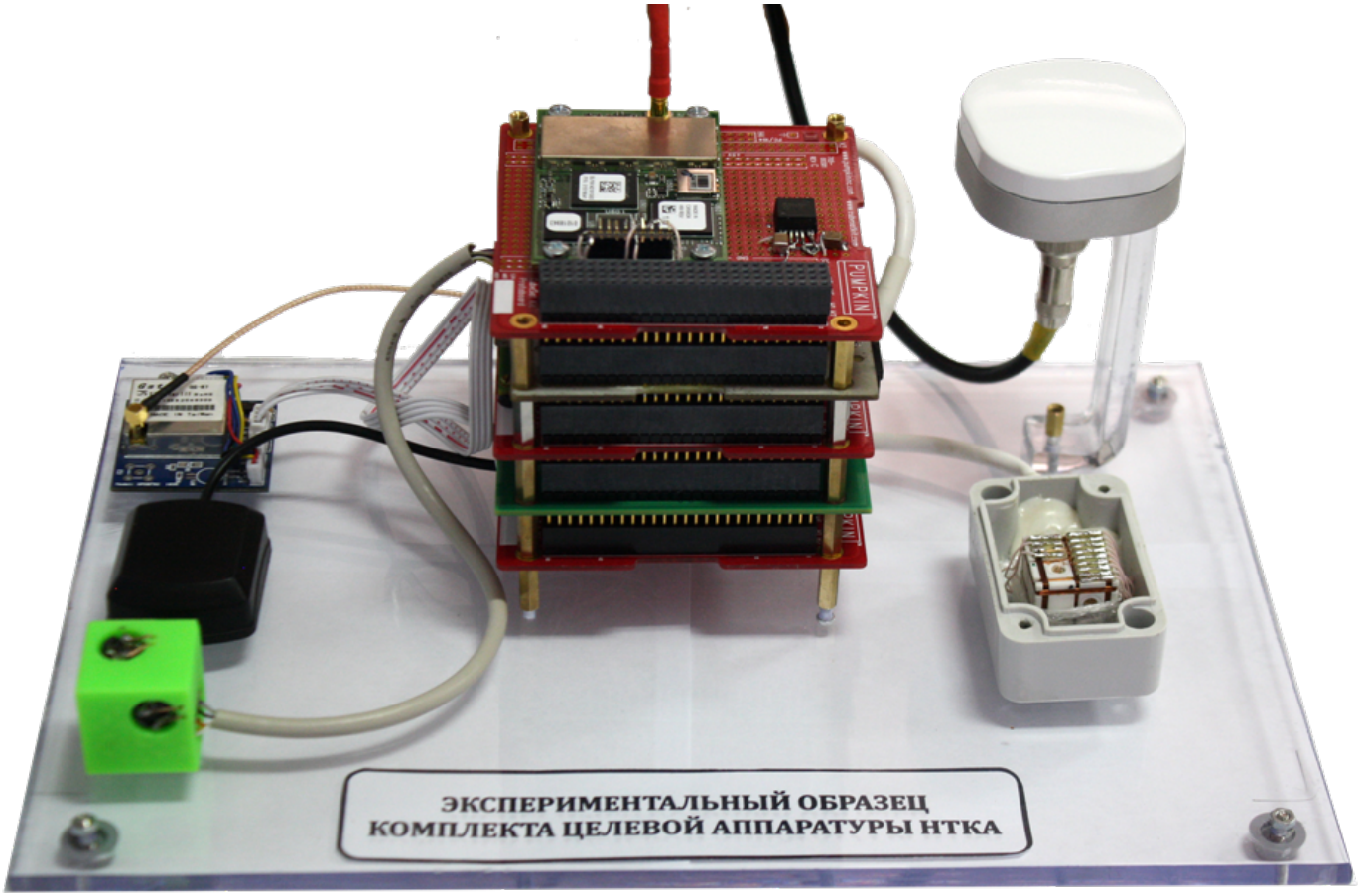
On-board estimation of Space Weather Products

Power consumption ~5 W

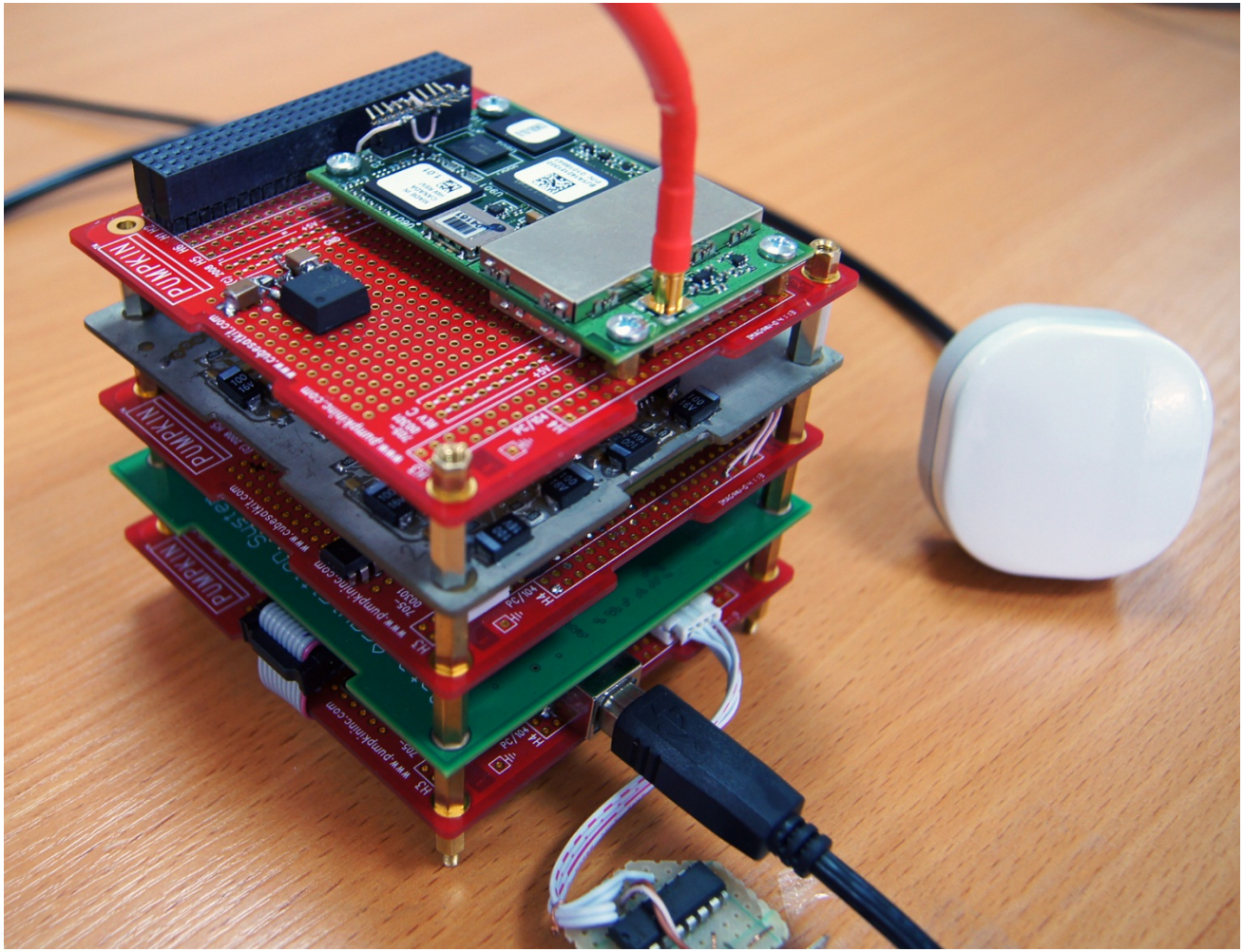
TEC measurements onboard Kazakhstan's nanosatellites – payload prototype



TEC measurements onboard Kazakhstan's nanosatellites – payload prototype



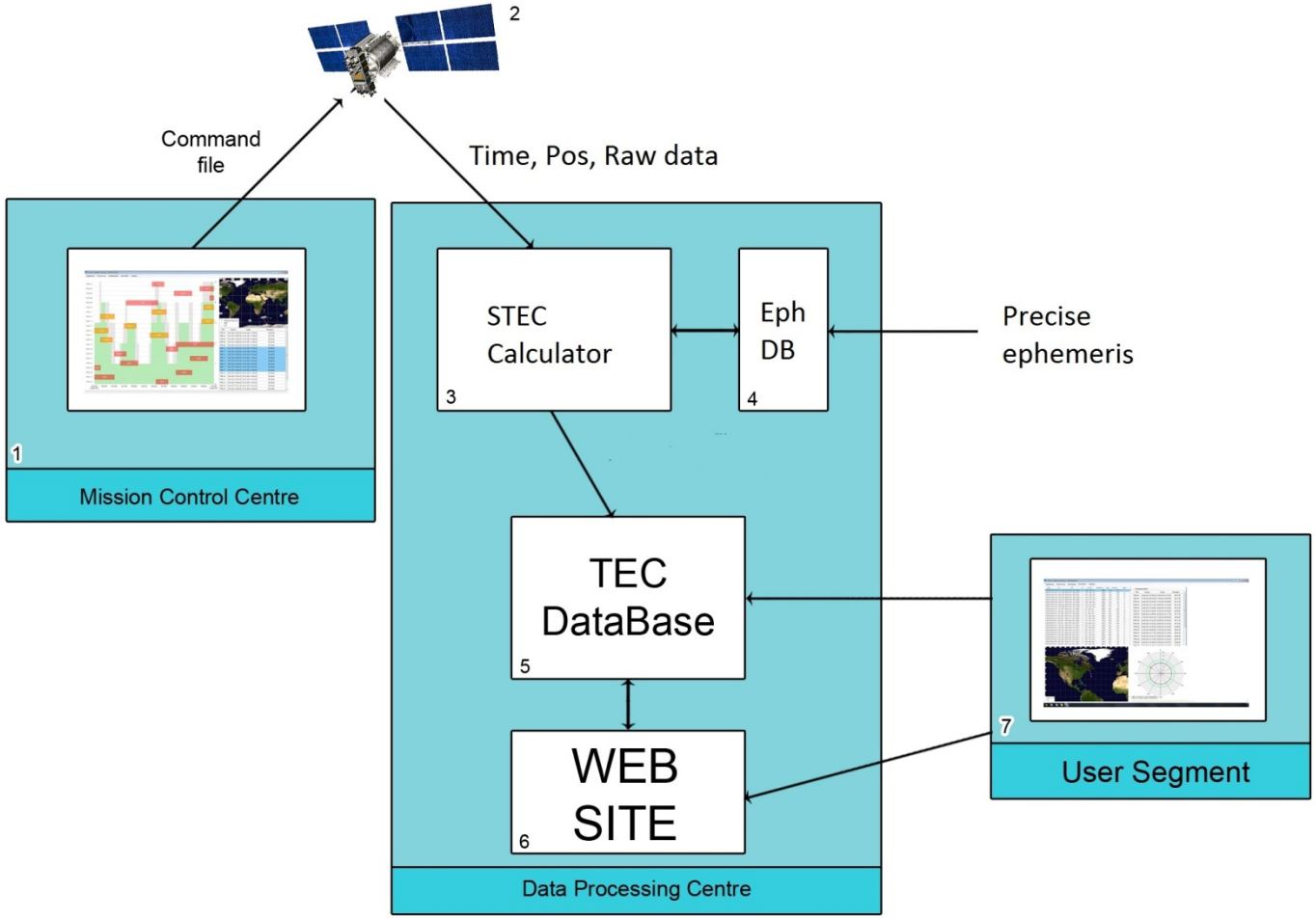
TEC measurements onboard Kazakhstan's nanosatellites – payload prototype



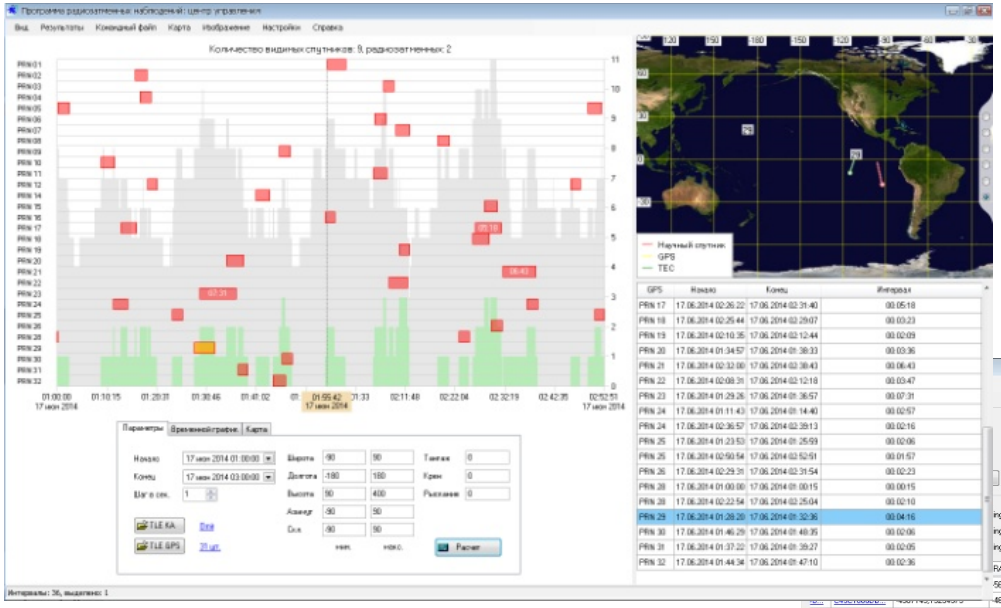
NovAtel OEM615-V (L1/L2 GPS + GLONASS, 50Hz raw data & position output

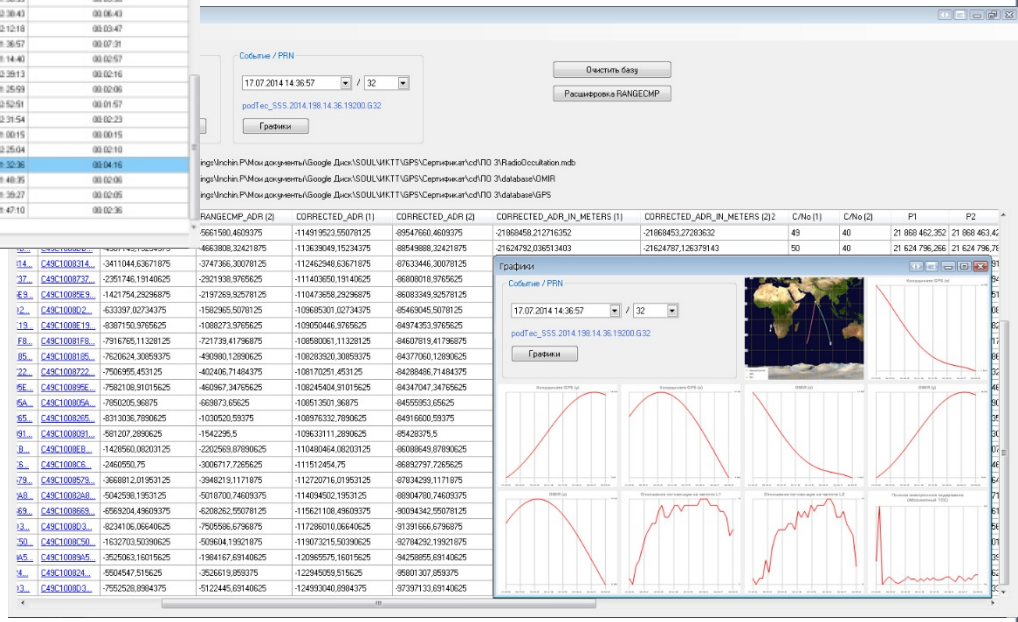
Antenna:
Antcom G5ANT-1AS1
2-inch square
LNA Gain: 33 dB

TEC measurements onboard Kazakhstan's nanosatellites - scheme



TEC measurements onboard Kazakhstan's nanosatellites - software





TO-DO List

1. Implement software to DAS
2. Implement NeQuick
3. On-board data processing
4. Test,
5. Test,
6. Test (GPS simulator, real-life conditions)

Thank you for attention!

Inchin Pavel
Institute of space technique and technologies
050061, Almaty, st. Kislovodskaya, 34
Phone: 8 (727) 2-76-21-67
inchin.p@istt.kz
www.istt.kz