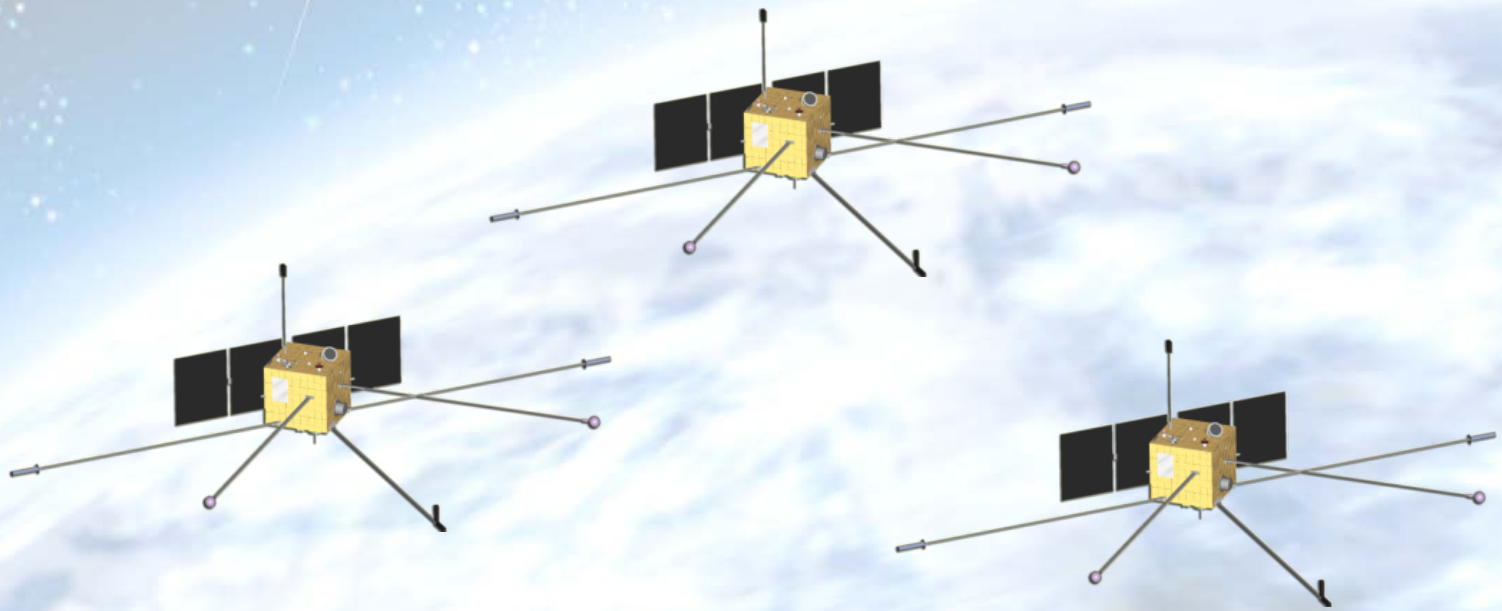
International Academy of Astronautics

GLOBAL SATELLITE SYSTEM FOR MONITORING AND FORECASTING OF THE EARTH SEISMIC ACTIVITY



Dr Oleg Ventskovsky

State Enterprize "Yuzhnoye Design Office"

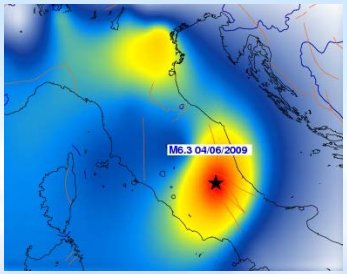
Ukraine

UNCOPUOS STSC

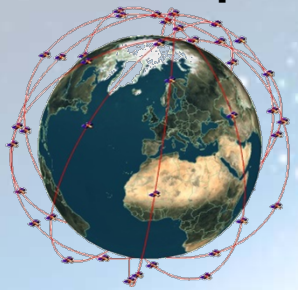
55th session

7 February 2018

PURPOSES



Identification of characteristics of the observed from space phenomena occurring on the surface, in the atmosphere and ionosphere of the Earth, which would allow with sufficient degree of authenticity to find responses to the following key questions: where, when and how strong an earthquake will be.



Establishment of principles of designing the global satellite system for monitoring those characteristics, determination of the system architecture and necessary composition of scientific instrumentation, development of approaches to conducting measurements and processing of the acquired data.

Key goals of the study:

1. Searching and identification of seismic activity precursors including ionosphere disturbances.

2. Studying physical mechanisms of interaction within the system «lithosphere-atmosphere-ionosphere-magnetosphere».

3. Development of principles of seismic activity satellite monitoring for earthquakes forecasting.

4. Establishment of composition of satellite instrumentation.

5. Selection of satellite orbit, cluster configuration, architecture of the satellite constellation and ground segment of the system.

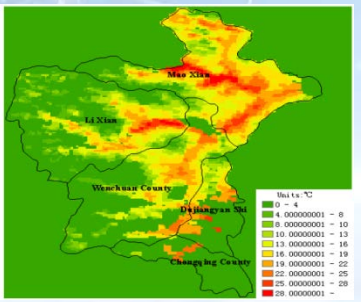
STUDY CONTENT

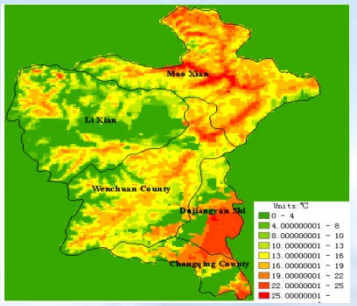
1. Introduction
2. Ionosphere precursors of increasing seismic activity
3. Theoretical study of mechanisms of generation and propagation of the earthquake precursors
4. Analysis of satellite data on possible earthquake precursors
    - 4.1. Data of the atmosphere observations
    - 4.2. Data of the ionosphere observations
5. Principles of creation and operation of the satellite system for seismic activity monitoring and forecasting. Schemes of observations
    - 5.1. Structure and functions of the system
    - 5.2. Composition and configuration of the system orbital constellation
    - 5.3. Composition and main characteristics of the satellite
    - 5.4. Schemes of observations and measurements
    - 5.5. Composition and configuration of the system ground segment
    - 5.6. Scheme of interaction of the system components and involved facilities at operation
6. Conclusions and way forward

STUDY OF PRECURSORS OF SEISMIC ACTIVITY

GROUND PRECURSORS:

- Deformations of the Earth crust
- Earth surface temperature anomalies



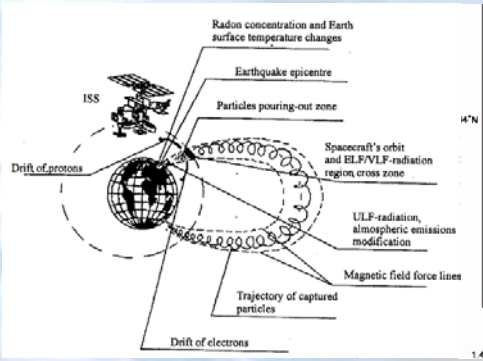


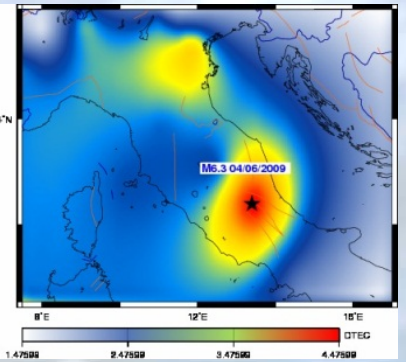
ATMOSPHERE PRECURSORS:

- Change of humidity
- Anomalies of air temperature
- Forming linear clouds structures
- Atmosphere electric field gain

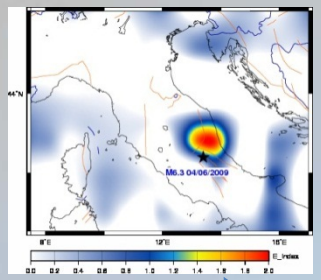
IONOSPHERE PRECURSORS:

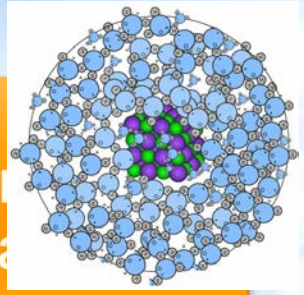
- Electrons concentration variations
- Night time attenuation of electric field
- Energetic particles precipitation
- Atmosphere gravitational waves

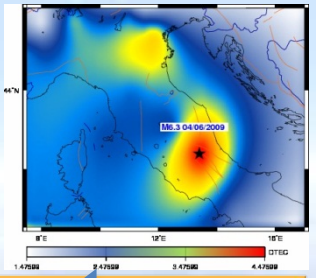




STUDY OF MECHANISMS OF GENERATION AND DISTRIBUTION OF EARTHQUAKE PRECURSORS







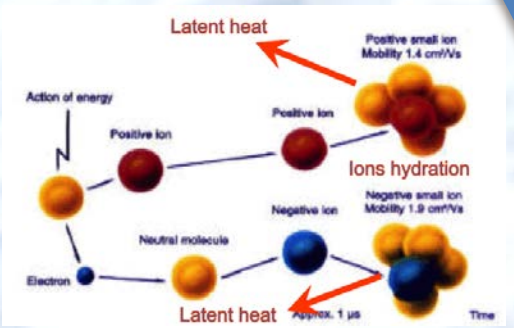
Ther
anoma

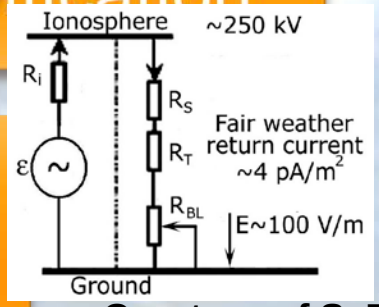
Ionospheric
anomalies

Latent heat
release

Boundary layer
conductivity
modification

Ion induced
nucleation
INN





Courtesy of S. Pulinets

FORMATION OF THE SATELLITE SYSTEM CONSTRUCTION AND OPERATION PRINCIPLES

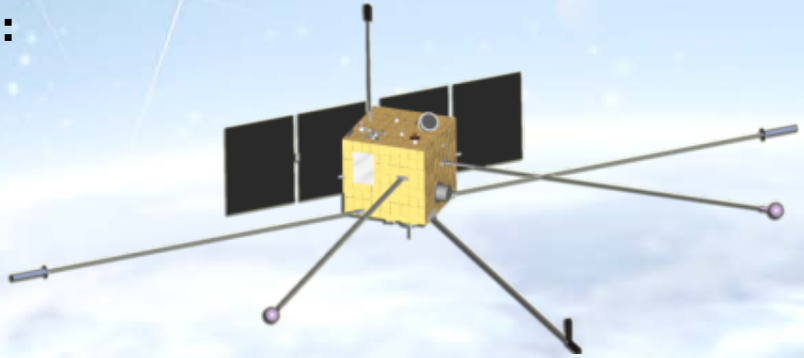
System structure and functions

The main composition of the system shall be as follows:

- orbital constellation of satellites;

- ground segment, including:

- **flight control center;**
- **ground control stations;**
- **ground data receiving station;**
- **data processing, analysis, and interpretation center.**



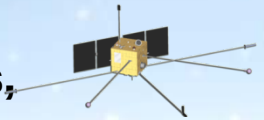
For more accurate interpretation of satellite observation and measurement data it is possible to involve various ground radiotechnical and optical means for atmosphere and ionosphere observations.

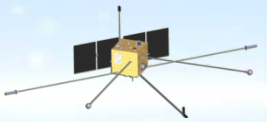
For revealing anomalies of the atmosphere electrical field it is possible to involve airplanes for synchronous subsatellite measurements.

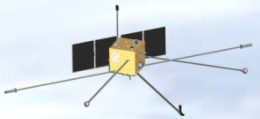
The system shall ensure processing, analysis, and interpretation of data on objects, phenomena, and processes taking place on the Earth surface, in the atmosphere, and ionosphere.

As a result, forecasts of seismic activity will be prepared with evaluation of possible earthquake dangers and elaboration of recommendations on minimization of the earthquakes possible consequences.

FORMATION OF THE SATELLITE SYSTEM CONSTRUCTION AND OPERATION PRINCIPLES
Orbital constellation configuration

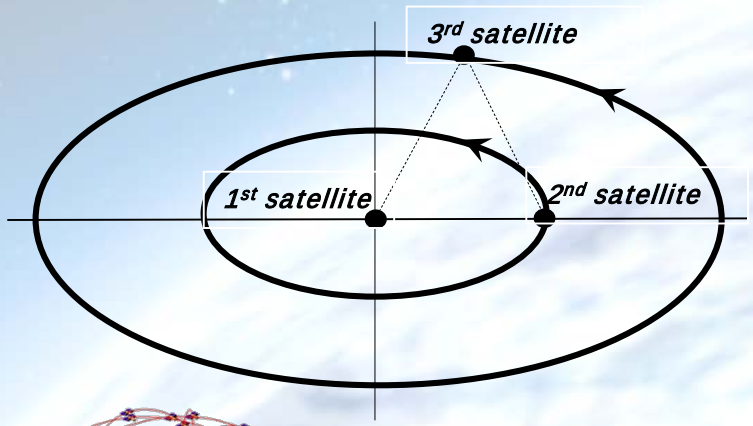




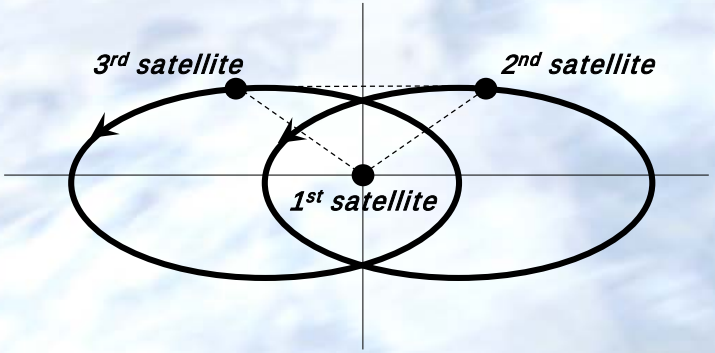


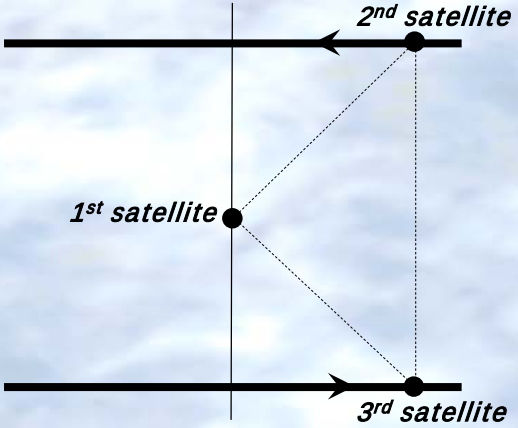
Proceeding from necessity of global observations and measurements, satellites orbits shall be close to polar ones. Satellites orbital altitude shall be within the limits from 400 km to 800 km.

Proceeding from necessity of multi-positional synchronous measurements of the ionosphere parameters, the satellite constellation shall include clusters of 3…4 satellites each.



Cluster configurations





The number of clusters in the constellation is determined by the needed periodicity of observations and measurements in the same given space regions; the number of clusters can be sequentially increased up to 6…8, i.e. total number of satellites in the constellation can be 18…32.

FORMATION OF THE SATELLITE SYSTEM CONSTRUCTION AND OPERATION PRINCIPLES

Typical composition of payload for ionosphere observation satellite

Sensors	Measurement characteristics
Wave probes (3 items)	Electric current density: frequency band 0.1 Hz – 40 kHz, noise 10^{-12} A/cm^2 Hz$^{1/2}$ Magnetic field: frequency band 0.1 Hz – 40 kHz, noise 10^{-14} T/Hz$^{1/2}$ Electric potential: frequency band 0.1 Hz – 40 kHz, noise 10^{-6} V/Hz$^{1/2}$
Electrical probe	Electric potential: frequency band – 200 kHz, noise 10^{-6} V/Hz$^{1/2}$
Fluxgate magnetometer	Magnetic field: frequency band – 1 Hz, resolution 0.01 nT
Electric field spectrum analyzer	High frequency variations of electric component: frequency band 0.1 – 15 MHz
Probes of neutral and charged particles	Density: neutral particles N_n: 10^5 – 10^{12} cm^{-3}, charged particles N_i: 10^3 – 10^{11} cm^{-3} Electrons temperature 0.1 – 1.5 keV
Full electron content meter	Frequency band: L1 = 1217 – 1265 MHz, L2 = 1565 – 1615 MHz 20 channels

FORMATION OF THE SATELLITE SYSTEM CONSTRUCTION AND OPERATION PRINCIPLES

Typical composition of payload for Earth surface and atmosphere observation satellite

Sensors	Measurement characteristics
Far infrared band camera	Spectral channels TBD Swath width TBD Geometrical resolution TBD Temperature resolution TBD
Multichannel scanning polarimeter	Spectral channels 370, 410, 555, 865, 1380, and 1610 nm of 10...20 nm width Angle of scanning ±60° from nadir Geometrical resolution 6 km in nadir Photometrical accuracy 4% Polarimeter accuracy 0.2%
Panoramic camera	Spectral channels 440, 555, 865, and 1378 nm of 5...10 nm width Swath width ±200 km from track Geometrical resolution 0.5 km

FORMATION OF THE SATELLITE SYSTEM CONSTRUCTION AND OPERATION PRINCIPLES

Typical composition of satellite platform

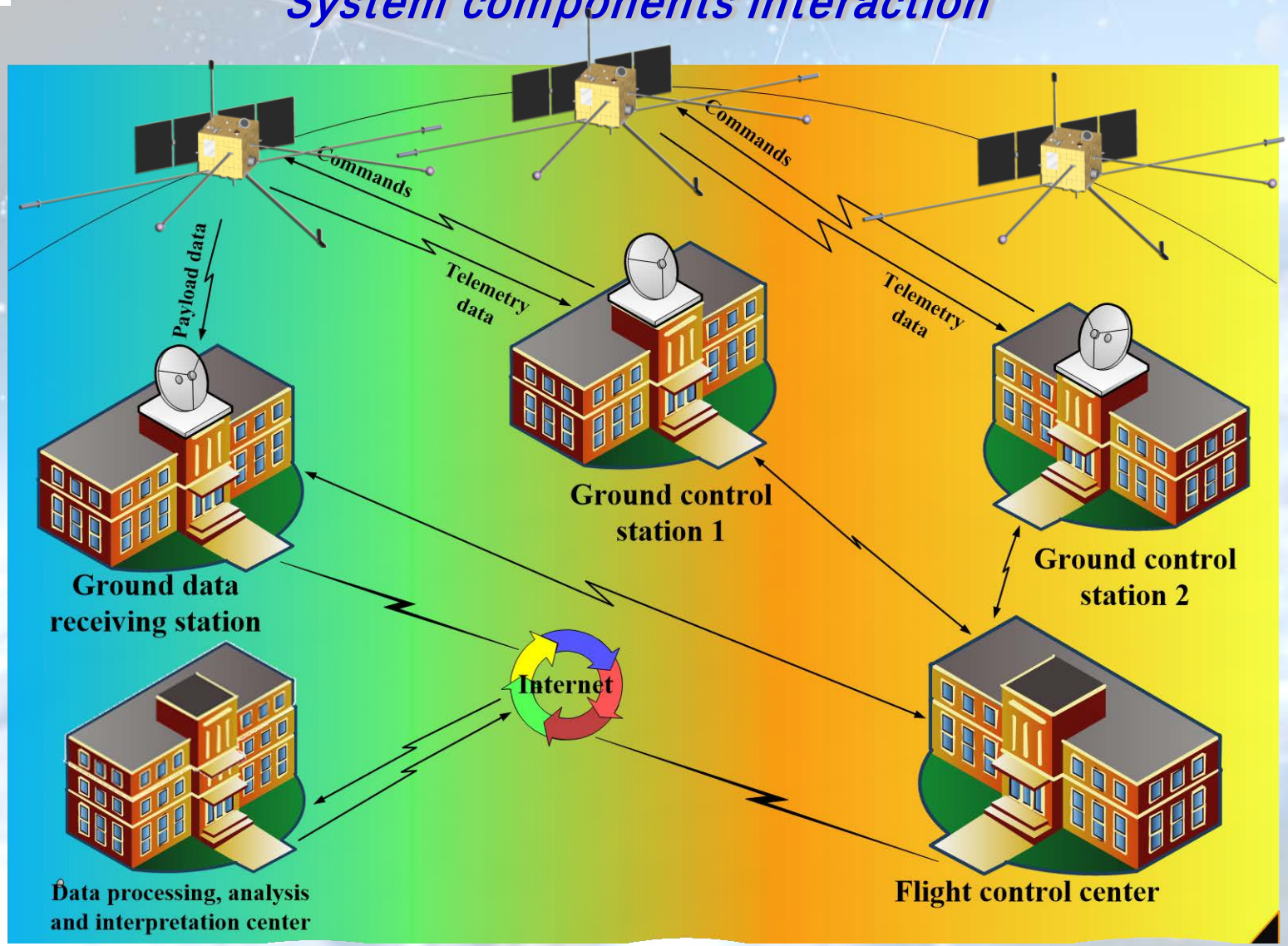
The satellite platform shall include the following typical systems:

- **payload data handling system, ensuring acquisition, memorizing and storage of payload data;**
- **X-band communication system, ensuring transmission of payload data to ground data receiving stations;**
- **S-band communication system, ensuring reception by satellite of command data from ground control stations and transmission of telemetry data on satellite systems health to ground control stations;**
- **control system, ensuring control of satellite systems operation, acquisition of telemetry data from satellite systems, orientation and stabilization of satellite in all modes of its functioning;**
- **satellite navigation system, ensuring autonomous determination of satellite center-of-mass motion parameters;**
- **propulsion system, ensuring all needed movements of the satellite;**
- **electric power system, ensuring uninterrupted power supply of satellite onboard equipment;**
- **thermal system, ensuring keeping satellite instruments and structure elements temperature in needed ranges;**
- **intersystem electric harness, ensuring electrical connection of satellite instruments through power, control, data exchange and telemetry circuits;**
- **structure, ensuring given relative spatial position of satellite instruments.**

FORMATION OF THE SATELLITE SYSTEM CONSTRUCTION AND OPERATION PRINCIPLES

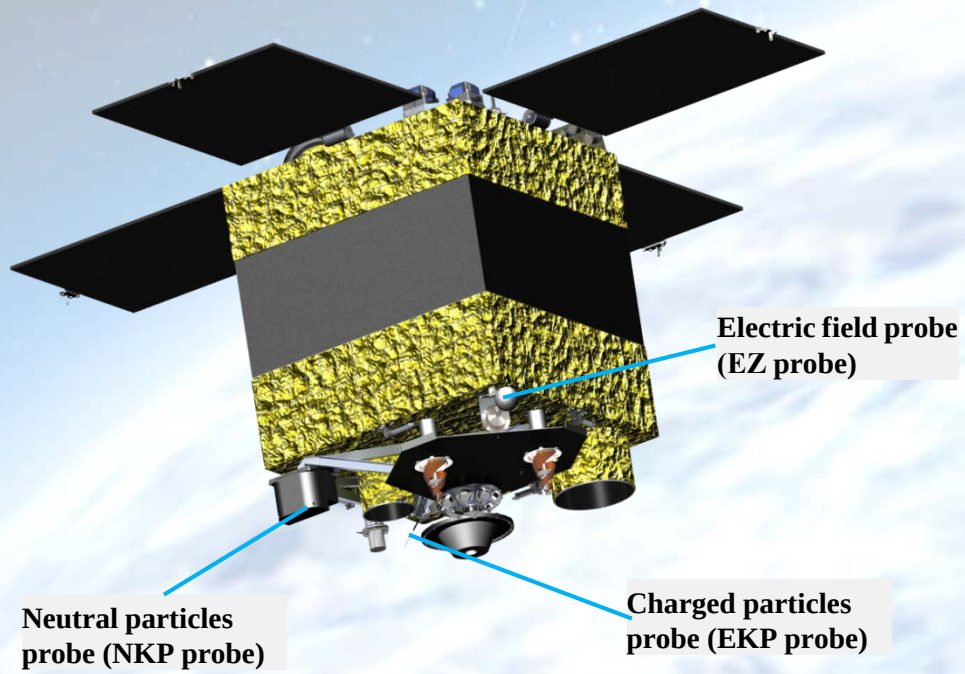
Ground segment configuration

System components interaction



SICH-2 SATELLITE IONOSPHERE STUDY

“Potentsial” scientific equipment of the Sich-2 satellite provides monitoring of neutral and charged particles parameters as well as electric and magnetic fields in the ionosphere

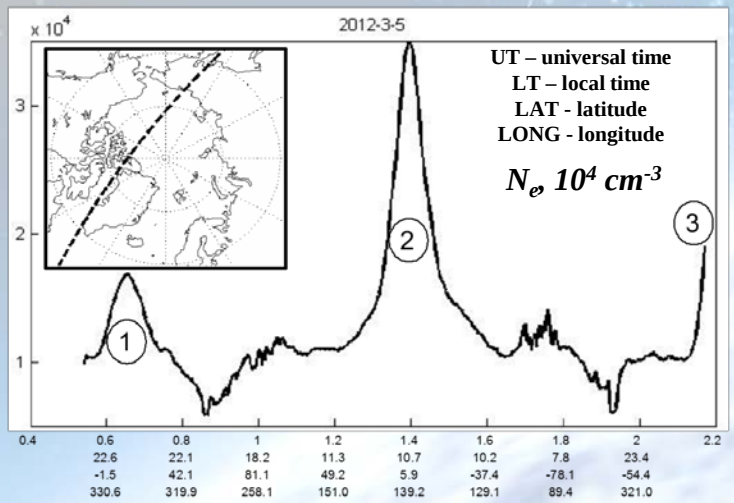


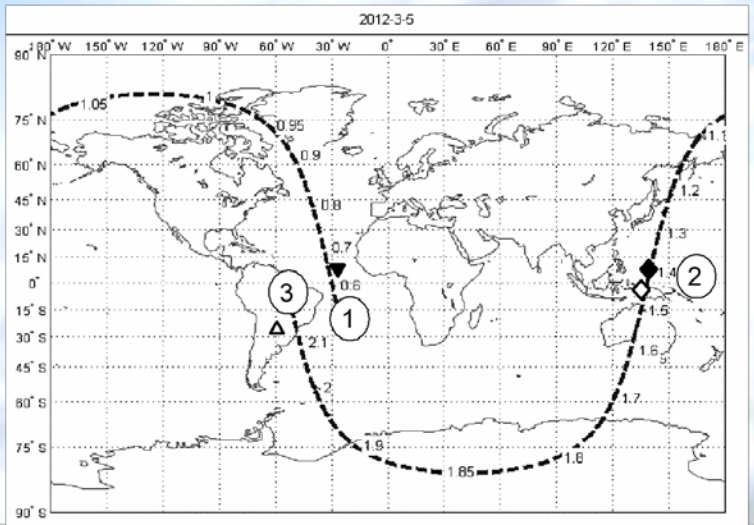
Potentsial scientific equipment:	
Neutral particles probe (NKP probe):	
•*particles content*	$10^5…10^{12}$ cm^{-3}
• *pressure*	$10^{-7}…10^{-2}$ *Pa*
Charged particles probe (EKP probe):	
• *particles content*	$10^4…10^7$ cm^{-3}
• *electrons temperature*	*0.1…1.5 eV*
Electric field probe (EZ probe):	
•*frequency band*	*0…1000 Hz*
•*noise*	*0.4* $\mu V/Hz^{1/2}$
Scientific data acquisition system:	
•*memory*	*50 GB*

ANALYSIS OF SICH-2 SATELLITE DATA ON POSSIBLE EARTHQUAKE PRECURSORS

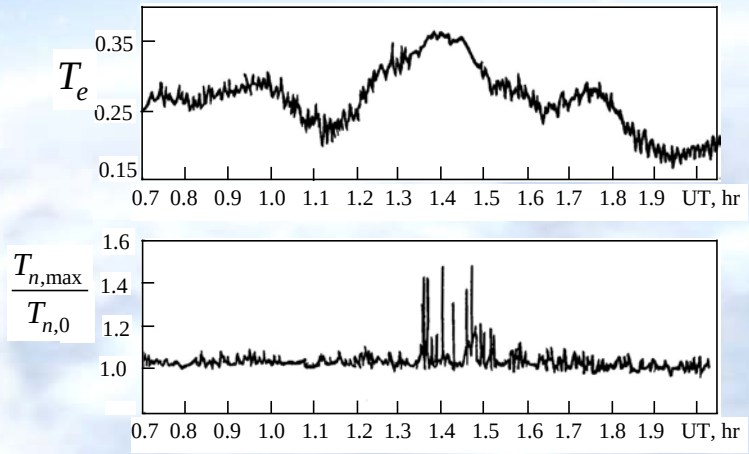
Earthquake monitoring using measurements on 05.03.2012

Identification of epicenters using disturbances of content of charged particles (electrons, ions)





Identification of epicenters using disturbances of temperature of heavy particles (ions, neutrals)



1

▼ **-04.03.2012, UT=12.50, M=4.6 (before reception of data by satellite)**

2

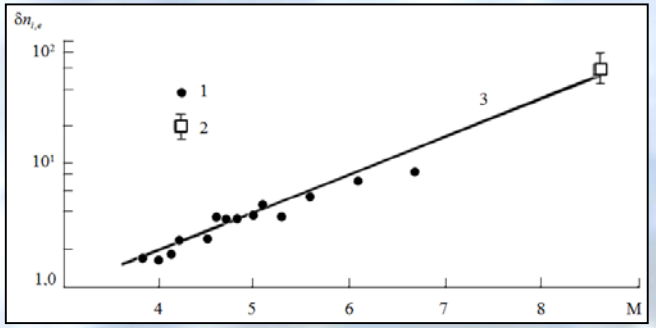
◆ **- 06.03.2012, UT=6.53, M=5.3**

◇ **- 07.03.2012, UT=12, M=5.6 (after reception of data by satellite)**

3

△ **- 05.03.2012, UT=14.53, M=4.7 (after reception of data by satellite)**

Forecast of magnitude (M) using ratio (δn_e) of content maximum amplitude to non-disturbing value

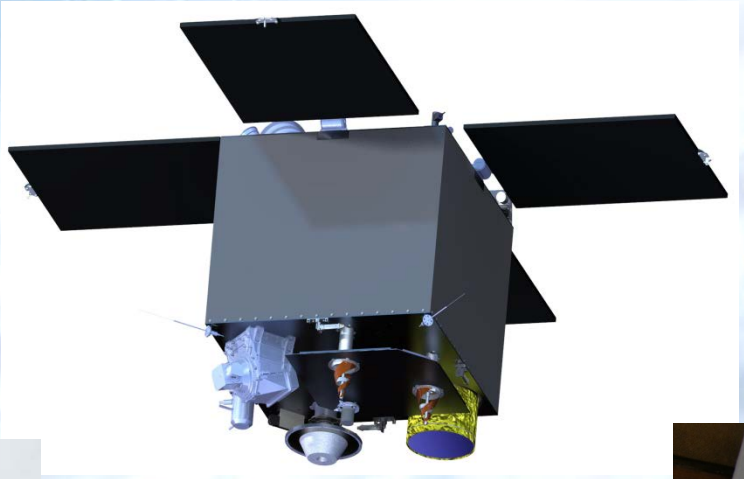


1 – SICH-2, 2 – DEMETER

Courtesy of V. Shuvalov

SICH-2-1 SATELLITE IONOSPHERE STUDY

Scientific equipment of the Sich-2-1 satellite provides monitoring of neutral and charged particles parameters in the ionosphere. To be launched in 2018.



MIKROSAT SATELLITE IONOSPHERE STUDY

Purpose – observation of dynamic processes in the Earth ionosphere

Ionosat-Mikro scientific equipment:
Magnetic-Wave Complex:
• *wave probes*
• *electrical probe*
• *fluxgate magnetometer*
• *electronics unit*
Sensors of Kinematic Parameters of the Ionosphere Plasma Particles:
• *neutral particles sensor*
• *charged particles sensors*
• *electronics unit*
Electric Field Spectrum Analyzer:
• *antennas unit*
• *electronics unit*
Scientific Data Acquisition System

CUBESAT SATELLITES IONOSPHERE STUDY

6x3U, 8h revisit, modified Sich 2 sensors of neutral and charged particles parameters in the ionosphere

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THANK YOU FOR YOUR ATTENTION!