IONOSAT

– ionospheric satellite cluster scientific premises and proposed configuration

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"Ionosat". HISTORY

Space experiments with the participation of Ukraine

1. Kosmos 484	Satellite	1972	Electric field measurements
2. Interkosmos-10	Satellite	1973	Electric field measurements
3. Firework	Rocket MP-12	1973	Injection of electron beam
4. Zarnitsa - 1	Rocket MP-12	1973	Artificial aurora
5. SAMBO	Balloons	1974	Electric field measurements
6. ARAKS	Rocket	1975	Injection of electron beam
7. Kosmos-721	Satellite	1975	Electric field measurements
8. Zarnitsa -2	Rocket MP-12	1975	Injection of electron beam
9. Spolokh -1	Rocket MP-12	1975	Injection of barium cloudes
10. Spolokh -2	Rocket MP-12	1977	Injection of barium cloudes
11. Prognoz -8	Satellite	1981	Waves in magnetosphere
12. Mars-6	Satellite	1984	Electric field and plasma waves measurements
13. Venus – Halley	Interplanetary stations Vega-1, -2	1984	Plasma waves analysis

"Ionosat". History

Last results and plans

Interball	Satellites	1995	Waves in the magnetosphere
Variant	Satellite "Sich-1M"	2004	Fields and currents in the inonosphere
Kompas-2	Microsatellite	2005	Ionospheric earthquake precursors
Environment	ISS	2008	Space weather, plasma flow around super large body
Potential	Remote sensing satellite "Sich-2"	2009	Neutral atmosphere and ionosphere parameters registration
Radioastron	Satellite	2009	Radio astronomy, plasma physics
Chibis	Microsatellite	2009	Lightning activity
Phobos-Grunt	Interplanetary station	2009	Phobos study, space plasma physics
Ionosat	3 microsatellites	2012	Ionosphere, space weather, seismo-ionospheric coupling
Resonance	4 satellite	2012	Mazer effects in magnetosphere

IONOSAT experiment

GMES – oriented ionospheric multi-satellites mission

National Space Agency of Ukraine proposal for First European Space Program

IONOSAT project main tasks

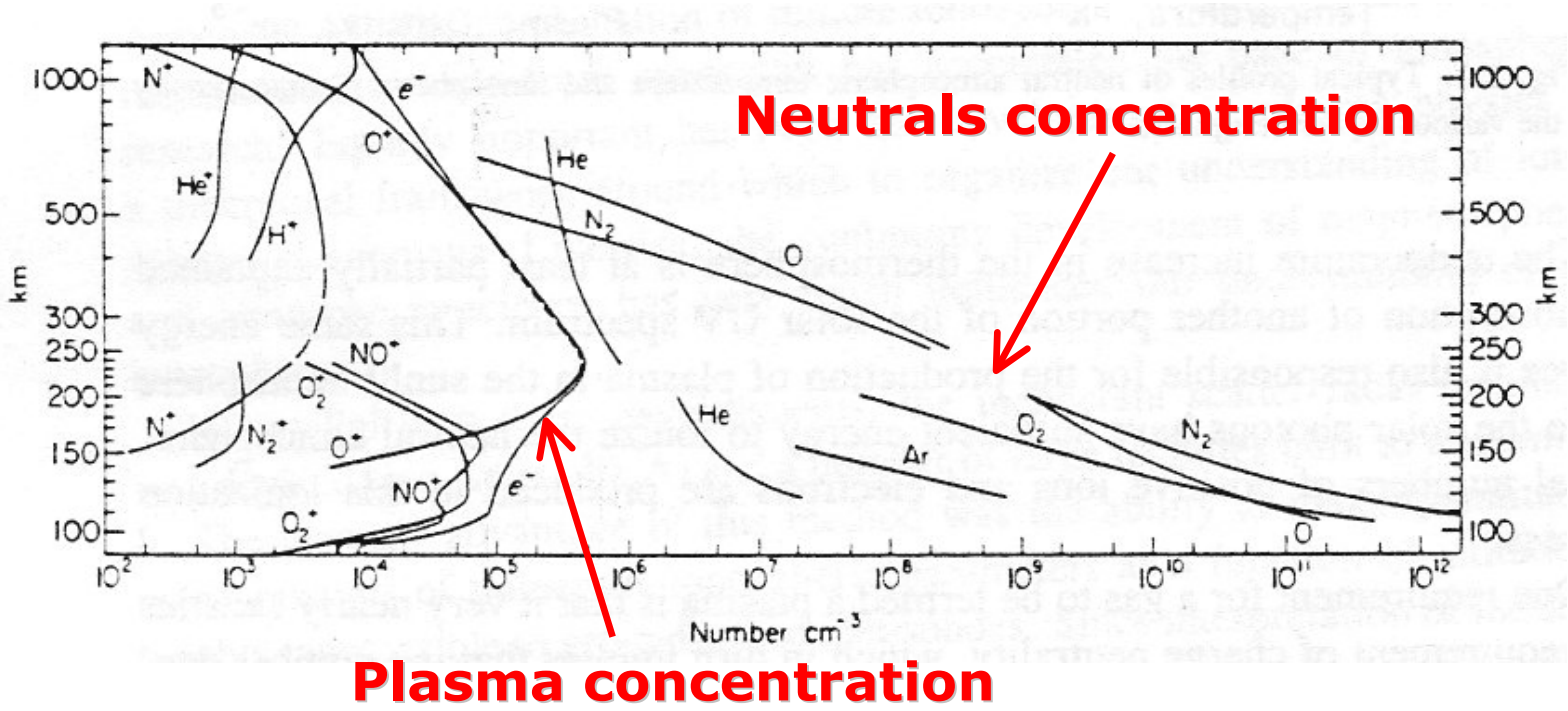
- **Scientific and methodological substantiation of the efficiency of the LEO satellites use for SW monitoring, corresponding technological realization development and tests.**
- **Systematic study of the dynamic response of the ionosphere to the influences “from above” (solar and geomagnetic activity) and “from below” (meteorological, seismic and technologic processes), seismo-ionospheric coupling.**
- **Synchronous operation with the existing sub-satellite electromagnetic and meteorological polygons.**
- **Calibration of modern prognostic models of quiet and disturbed ionosphere.**

Possible mechanisms of energy transfer from lithosphere to ionosphere

- **Fair weather currents** → **affecting ionized ionosphere component**

- **Atmospheric gravity waves (AGW)** → **affecting neutral ionosphere component**

AGW preference



- Ionosphere is a small chemical additive to the neutral atmosphere.
- That is why any even minor movements of neutral gas at ionospheric heights are strongly influencing ionospheric dynamics.
- Because of this AGW propagation are accompanied by corresponding periodic variations of plasma parameters.

"Ionosat": Main features

1. Orbit group is the cluster of three satellites with identical payload composition– ***multipoint measurements***

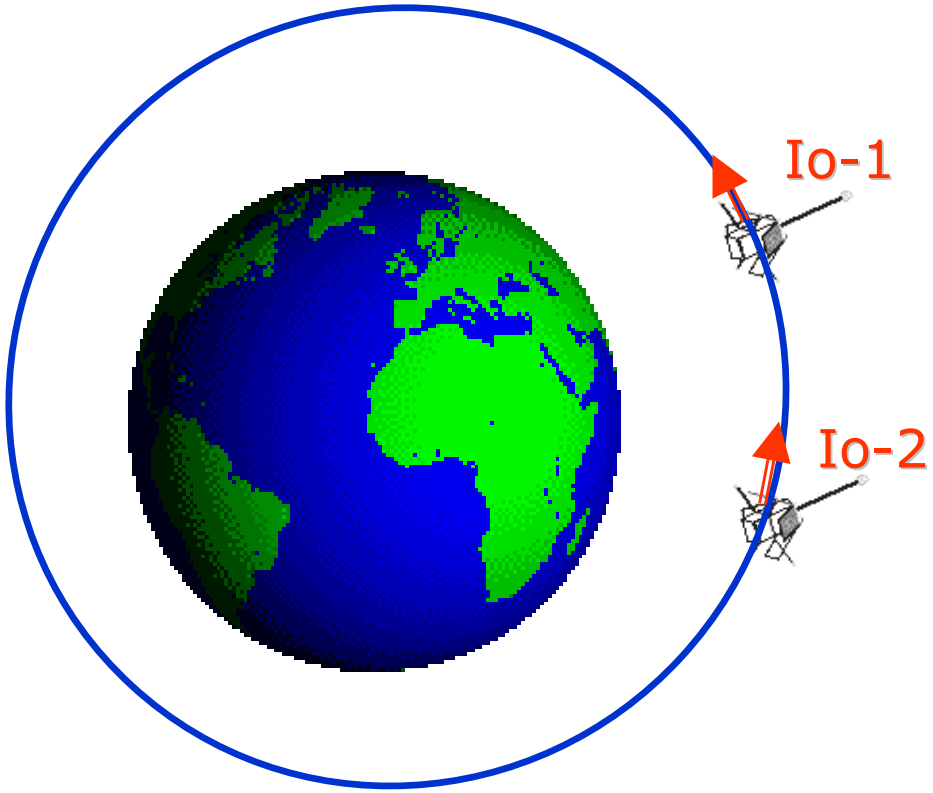
2. Satellite group is at the orbit with ~ 400 km perigee– ***ionospheric project***

3. The orbit of satellite group is polar but is not solar-synchronous one– ***covering of all the Globe at all range of local time***

4. Mutual distance between satellites changed in the range 50 – 3000 km– ***multipoint diagnostics of medium- and big-scale disturbances***

"Ionosat": Orbital cluster

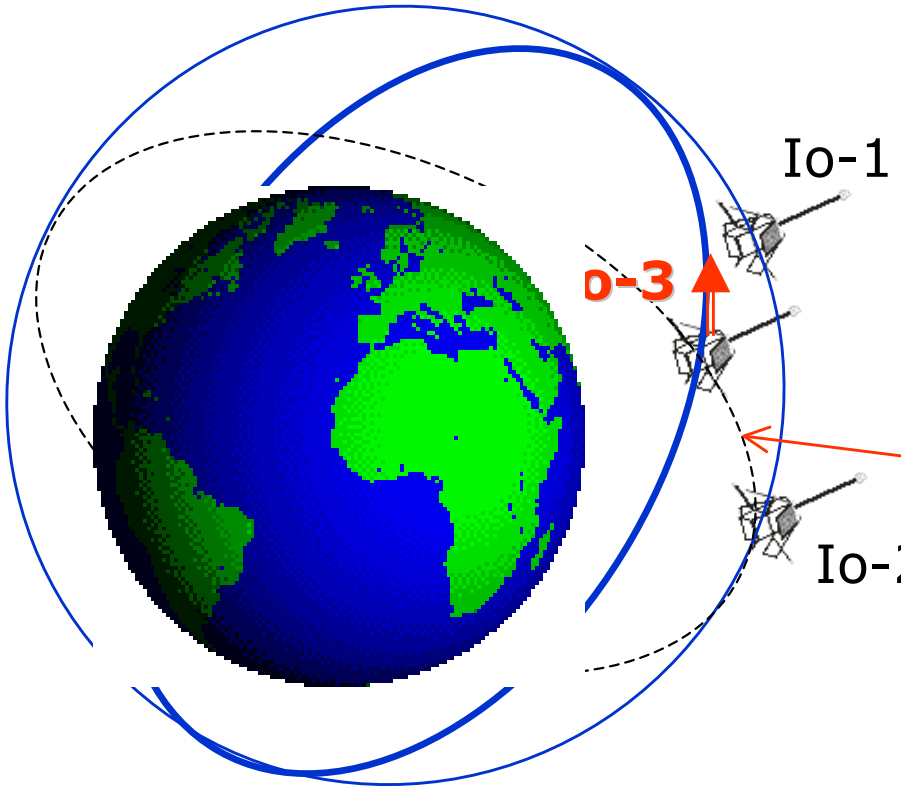
Basic orbit for two space vehicles (SV)



Io-1:
liftetime = 2 years,
perigee = 400 km,
apogee = 780 km,
inclination = 82.5°

Io-2:
The same,
Moving off from Io-1
increase up to 2000 km

“Ionosat”: Orbital cluster

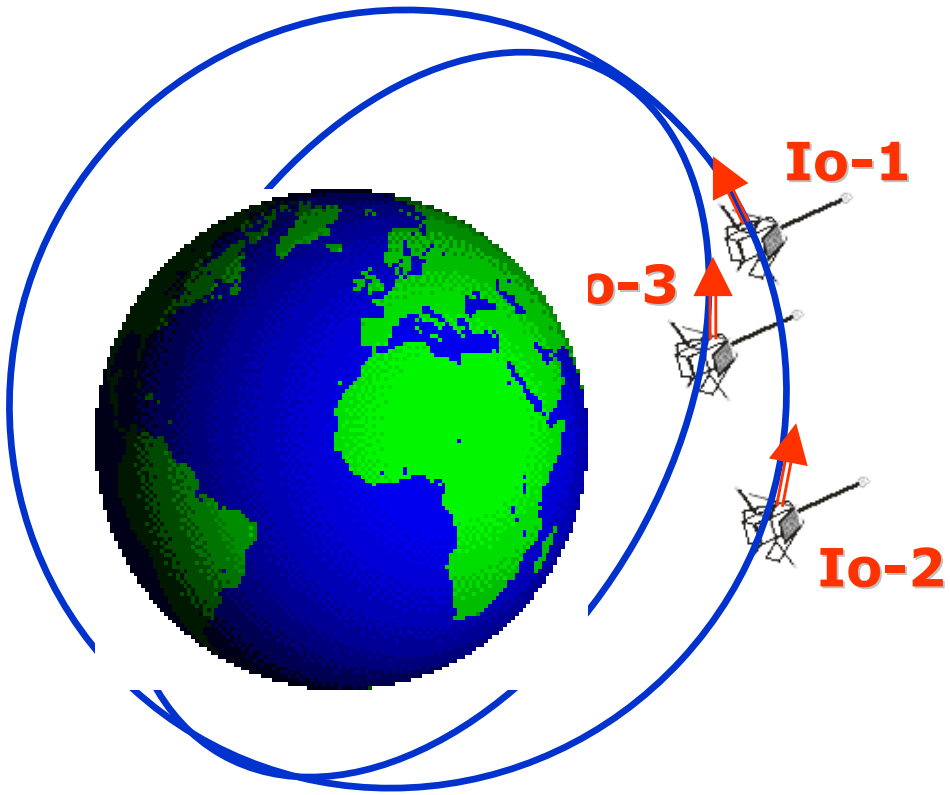


Third SV:

has the same operational orbit as Io-1 and Io-2, but with another argument of a latitude:

$\Delta\varphi \sim 2°$

“Ionosat”: Orbital cluster



Group lifetime = 2 years

For high solar activity period:
perigee = 400 km,
apogee = 780 km

Orbit inclination = 82.5°

Moving off of Io-1 – Io-2:
up to 2000 km
Io-1 – Io-3: up to 3000 km

SV positioning accuracy – less than 20 m
SV attitude accuracy – less than 10°
SV attitude determination accuracy – less than 0.1°

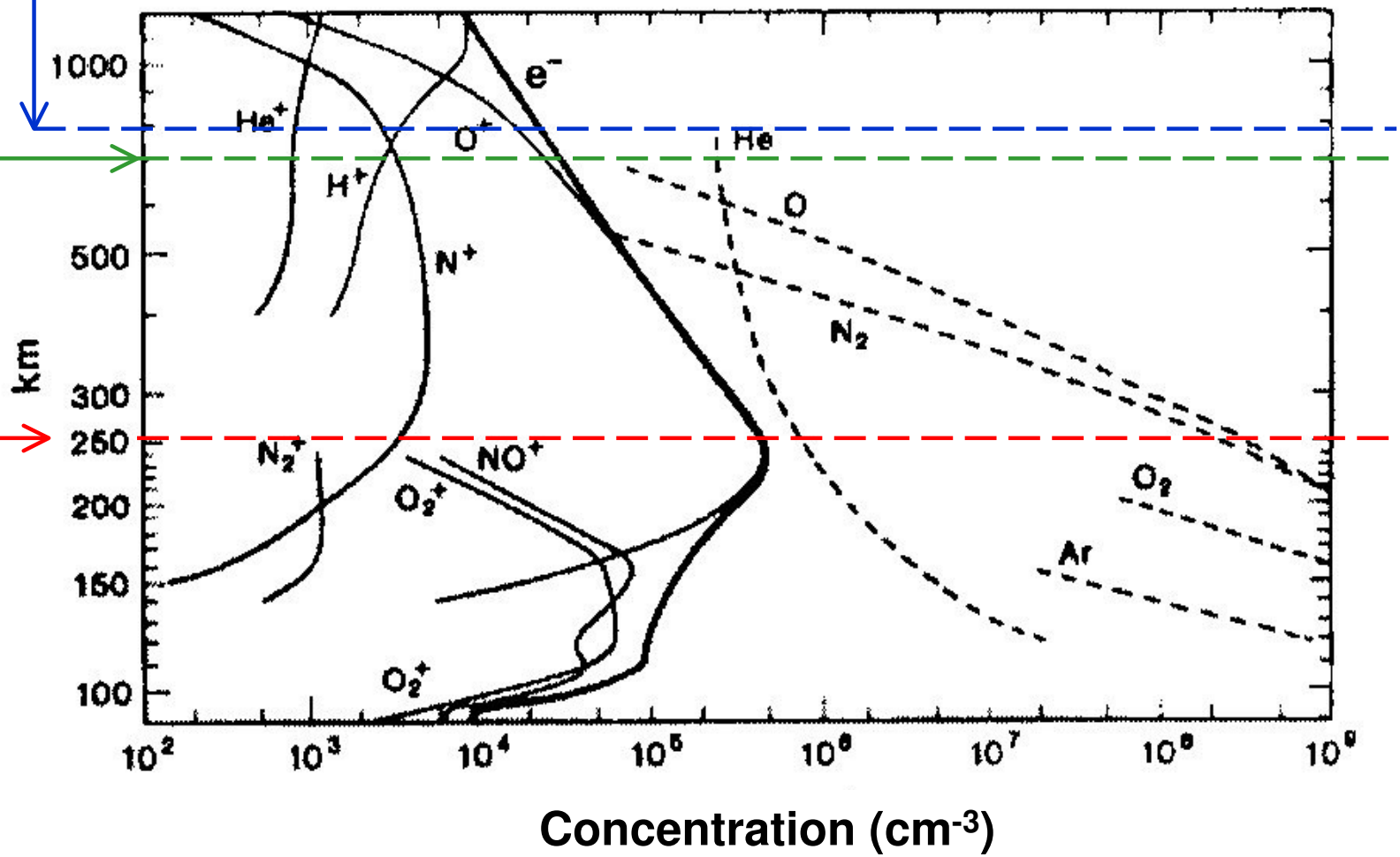
"Ionosat". Scientific tasks

✓ *This is an ionospheric project*

magnetosphere

"DEMETER"

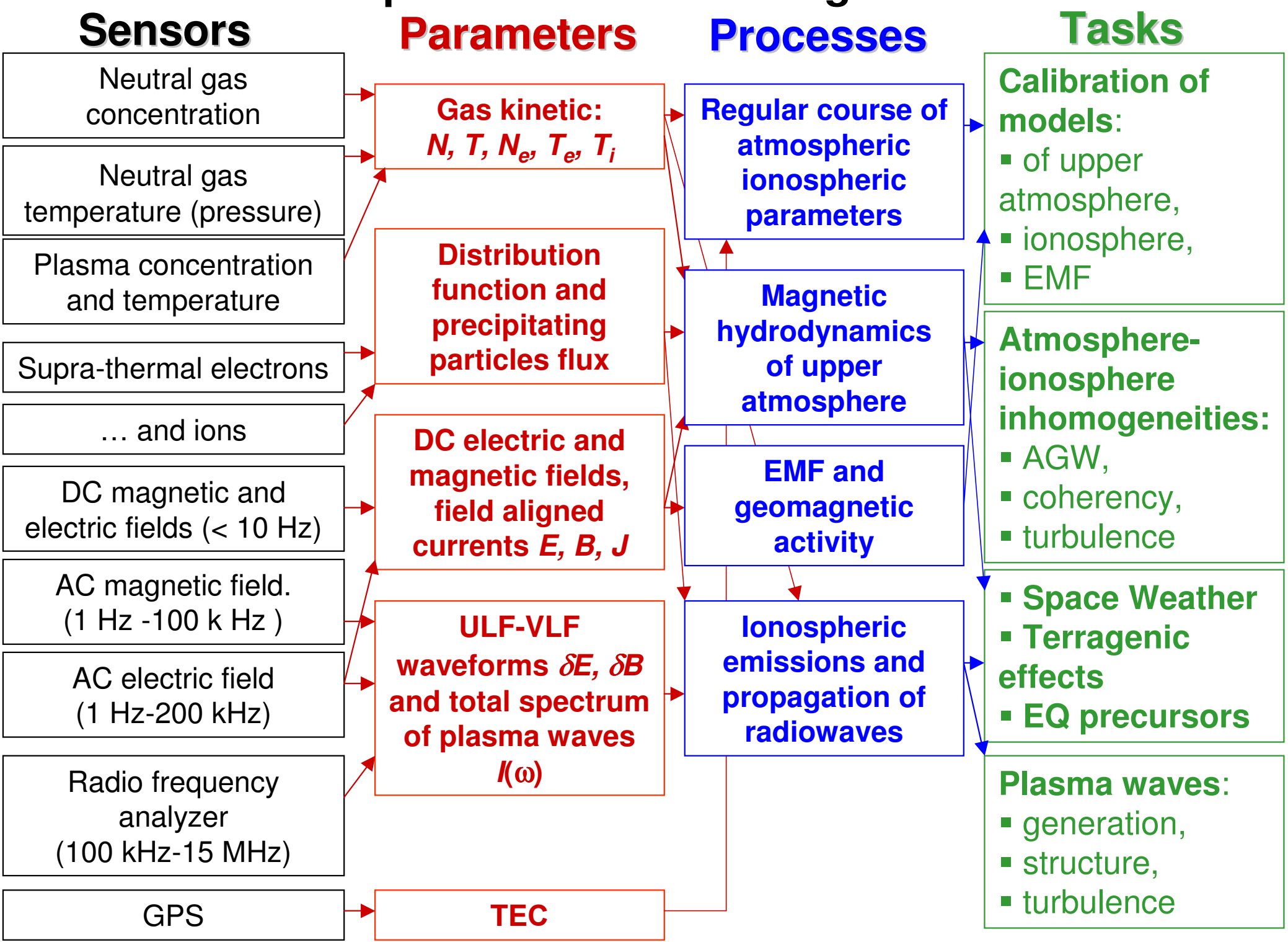
$h_{max}F2$



EXPECTED PARAMETERS OF ELECTROMAGNETIC AND PLASMA DISTURBANCES AT HEIGHTS ~ 400 KM

Particles	
Maximal disturbances of neutral particles concentration and temperature	$n_n \sim 10^7$ cm^{-3} $\delta n_n \sim 10^5$ cm^{-3}, $\delta T_n \sim 10^3$ K
Maximal disturbances of ion and electron concentration and temperature	$n_i \sim 10^5$ cm^{-3} $\delta n_i \sim 10^4$ cm^{-3}, $\delta T_e \sim \delta T_i \sim \delta T_n \sim 10^3$ K
Level of non-isothermicity	T_e / T_i = 1-4
Fields	
Electric field:	
Quasi-stationary fields, ionic sound, MHD structures	1- 1000 mV/m, DC-40 kHz
Whistlers, wide-band electrostatic noise	10-100 μV/Hz$^{1/2}$m, 1-200 kHz
Magnetic field:	
MHD structures	0,1 - 100 nT, DC-100 Hz
Whistlers:	10^{-1} – 10^{-4} nT,100 Hz-40 kHz
Electric current	
Quasi-stationary structures:	1 – 10 μA/m^2, DC-100 Hz
Whistlers:	1 – 200 mV/m, 100 Hz-40 kHz

Ideal composition of electromagnetic satellite



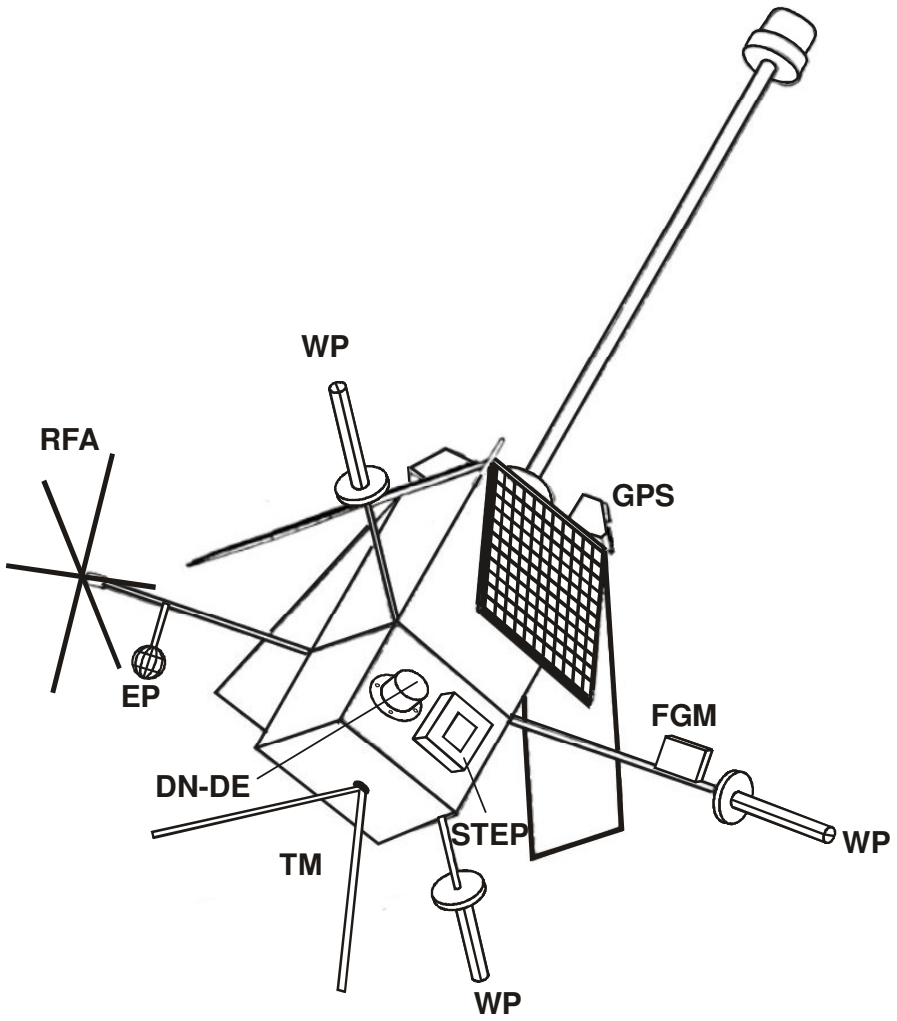
Special requirements

- Requirements to the satellite orientation error ~ 10°
- Requirements to the precision of satellite orientation determination : ~ 0.1°
- Requirements to the precision of satellite position determination : ~ 20 m
- Very high requirements to the measurement synchronization at all three satellites
- Wide range of sampling frequencies: from 100 Hz ($\leftrightarrow$ λ min = 160 m) in monitoring mode to 100 kHz in burst mode

Minimized payload model structure

SENSOR	MEASURED VALUE	SPESIFICATIONS	DESIGNERS
WAVE PROBES	Electric current density J: Frequency range 0,1Hz – 40 kHz Noise 10^{-12} A\cm^{2}Hz$^{1\2}$ Magnetic field B: Frequency range 0,1 Hz - 40 κHz Noise 10^{-13} T\ Hz $^{1\2}$ Electric potential φ: Frequency range 0,1 Hz ÷ 40 kHz Noise 10^{-6} V\ Hz $^{1\2}$	Power consumption: < 0.25W. Weight: 0, 225 kg.	LC ISR, Lviv
ELECTRIC PROBES	Electric potential: Frequency range DC - 200 kHz Noise 10^{-6} V/Hz$^{1/2}$	Power consumption: ≤ 0.2 W. Weight: <0.2 kg. Distance between probes less than 2 m	LC ISR, Lviv
FLUXGATE MAGNETOMETER	Magnetic field vector B Frequency range DC - 1 Hz	Power consumption: < 0.4 W. Weight: sensor <0.2 kg, electronics <0.5 kg.	LC ISR, Lviv
RADIO FREQUENCY ANALYZER RFA	Frequency spectrum of electric field component in the range of 0,1 – 10 MHz	Under development	CKB PAN
KINETIC PLASMA PARAMETERS SENSOR DN-DE	Neutral component pressure (P_n): Range of measurements – 10^{-2} – 10^{-8} Pa Concentration of neutral particles (N_n): Range of measurements – 10^4 – 10^{10} cm^{-3} Concentration of charged particles (N_i, N_e): Range of measurements – 10^3 – 10^{11} cm^{-3} Ion and electron temperature (T_i,T_e): Range of measurements – 0.1 eV – 1.5 keV Temperature of heavy particles (T_z): Range of measurements – 400 – 2500 K Velocity of heavy particles (V_z): Range of measurements of mass velocity – 10^{-4} – 10^{-6} cm/s	Dimensions (without cable): DN: ∅ 50×85 mm DE: ∅ 12×248 mm Power consumption - < 2 W	ITM, DNIPROPETROVSK
ENERGETIC PARTICLES SENSOR STEP-E	Flow density and energetic spectrum of superheat particles	Under development	KHARKIV UNIVERSITY
DATA COLLECTION AND PROCESSING UNIT	Under development		LC ISR, Lviv

IONOSATS on MC2- 8 platform
Sensors layout



STEP – energetic particles sensor
DN-DE – neutral particles sensor
EP – electric probe
FGM – flux-gate magnetometer
WP – wave probe
TM – telemetric antenna
RFA – radio frequency analyzer
GPS – for TEC monitoring

"Ionosat". Scientific payload

Devices	Weight	Power cons.
3 wave probes WP	0.7 kg	< 0.5 W
Electric probe EP	< 0.2 kg	< 0.2 W
Flux-gate magnetometer FGM	< 0.7 kg	< 0.6 W
Radio frequency analyzer RFA	3 kg	3 W
Sensor of kinetic parameters DN-DE	1.07 kg	< 2 W
Energetic particles sensor STEP-E	2 kg	6 W
DCPU	2 kg	4 W
Booms	~ 12 kg	-
Total:	**~ 22 kg**	**~ 16 W**

ELECTRIC PROBE

MAIN TECHNICAL PARAMETERS

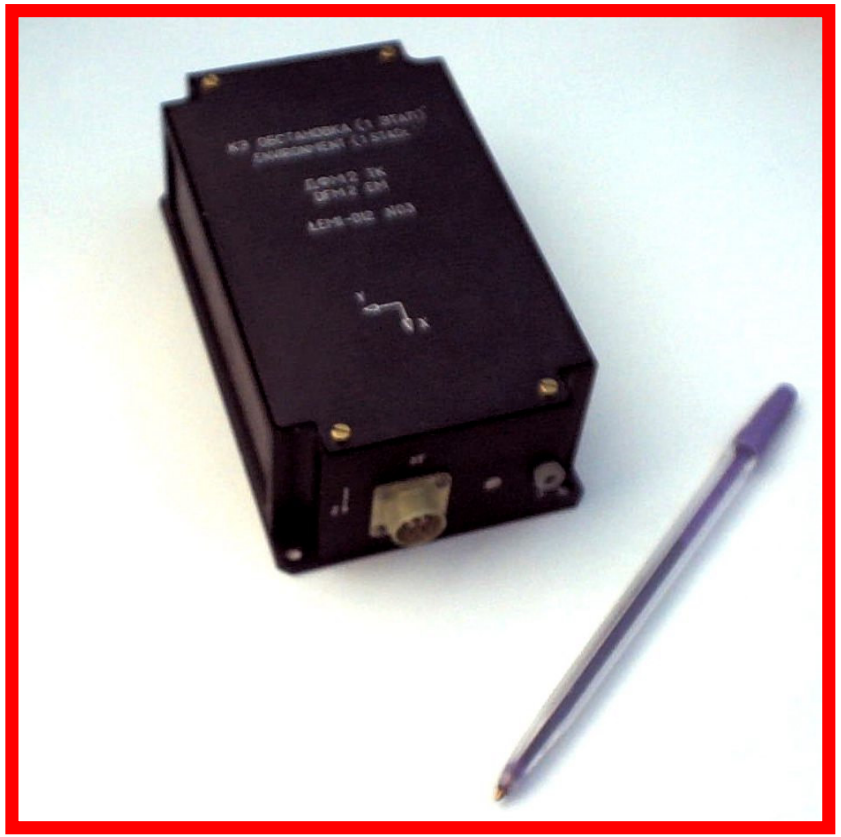
Frequency band, Hz	0 … 50000
Noise level of output amplifier at 2 kHz, $\mu V/Hz^{1/2}$	1,0
Dynamic range, dB	120
Temperature range, °C	±80
Power consumption, W	< 0.15
Dimensions, mm	∅76 × 183
Weight, g	160

Kinetic plasma parameters sensor DN - DE

TECHNICAL SPECIFICATIONS

Neutral components pressure
measured range 10^{-2} – 10^{-8}Pa
Neutral particles concentration
measured range 1010 – 10^{4}cm^{-3}
Heavy particles temperature
measured range 400 – 2500 °K
Charged particles concentration
measured range
(ions and electrons) 10^{3} – 10^{11}cm^{-3}
Measured ions and electrons
temperature range 0,1 – 1,5eV
Heavy particles mass velocity range
10^{-4} –10^{-6}cm.$^{s-1}$
Dimensions (without cables)
DN Ø 50 x 85 mm
DE Ø 12 x 248 mm

THREE-COMPONENT FLUX-GATE MONOBLOCK MAGNETOMETER LEMI-012

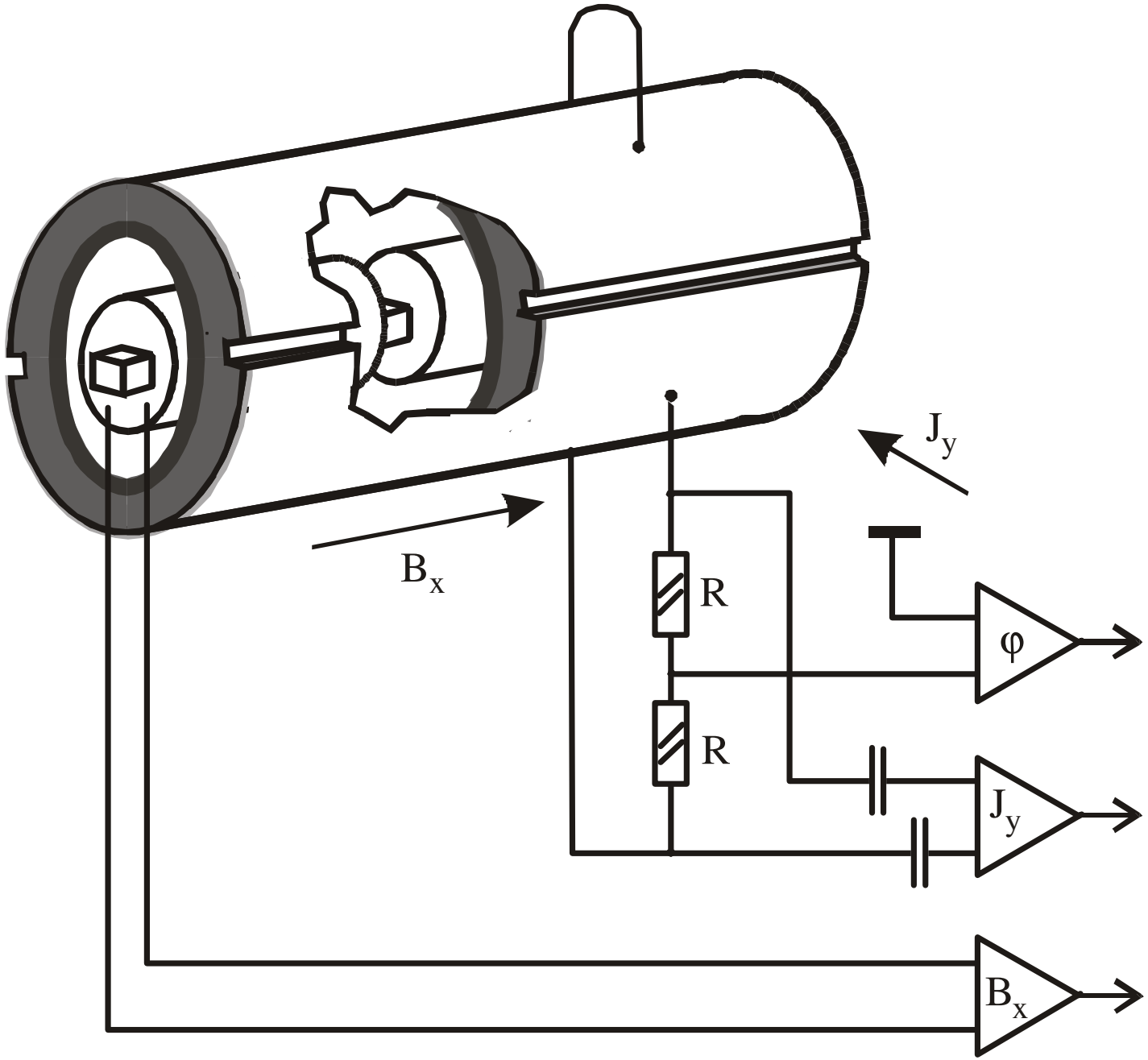


TECHNICAL SPECIFICATIONS

Measurement range, nT	±60000
Resolution, nT	< 0.1
Transfer error, % of reading	< 0.1
Transfer drift over temperature, % of reading /℃	< 0.005
Operation temperature range, °	- 40…+80
Power consumption, W	< 0.6
Overall dimensions, mm	150x90x45
Weight, kg	0.7

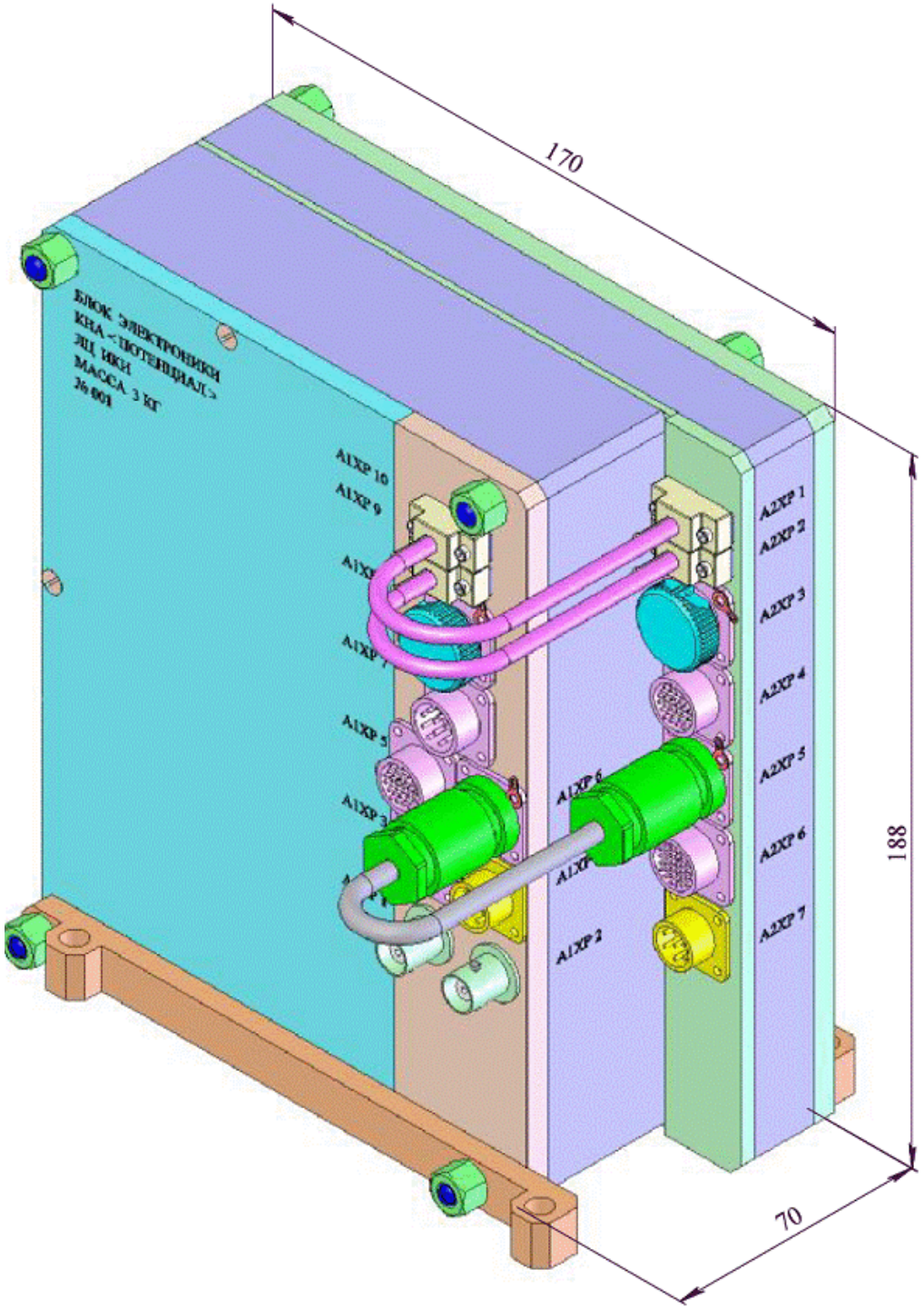
WAVE PROBE LEMI-603

WAVE PROBE



TECHNICAL SPECIFICATIONS

Frequency range for all channels	**0,1…40000**
Dynamic range, dB	**120**
Noise level of measuring channels at 1 kHz	
- electric current density channel, $A/cm^{-2}Hz^{-1/2}$	**$\leq 10^{-13}$**
- magnetic induction channel, $pT \cdot Hz^{-1/2}$	**≤ 0,02**
- electric potential channel, $B \cdot Hz^{-1/2}$	**$\leq 10^{-6}$**
Current density transformation factor, $V/mA/cm^2$	**77**
Magnetic induction transformation factor, mV/nT	**100**
Temperature range, °C	**± 50**
Power consumption, W	**< 0.25**
Dimensions, mm	
sensor	**Ø 24 x 294**
preamplifier	**136x43x28**
Weight, kg	
sensor	**0,225**
preamplifier	**≤ 0,125**



DATA COLLECTION AND PROCESSING UNIT

MAIN PARAMETERS:

- SciWay interface with data transmission rate up to 50 Mb/s,
- 3 ports,
- Up to 32 requesters at each port,
- 4 GB memory,
- consumed power 4 W,
- weight < 2kg

“Ionosat”. Working shedule

2008-2009	2009-2010	2011-2012
Decision-making, sending of invitations, feasibility study. (Stage A)	Development and manufacturing of the devices, autonomous tests. (Stage B)	Assembling, full-scale test and launch. (Stage C)

PARTICIPATION PROPOSALS ARE WELCOME

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THANK YOU
FOR ATTENTION!