РКС
РОССИЙСКИЕ КОСМИЧЕСКИЕ СИСТЕМЫ

EFIR

Multifunctional satellite system

EFIR

The basis of the system is up to 640 communications satellites at the altitude of 1 100 km

- Global coverage
- Intersatellite communication links in the plane
- Ground infrastructure in Russia and abroad
- Traffic routes through ground stations and without using ground facilities
- Competitors: OneWEB and SpaceX


Orbit altitude
EFIR
1 200 km
OneWeb
ACCESS FOR EVERYONE
1 150 km
SPACEX
1 100 km
EFIR

Basic service

EFIR

Low-speed communication link

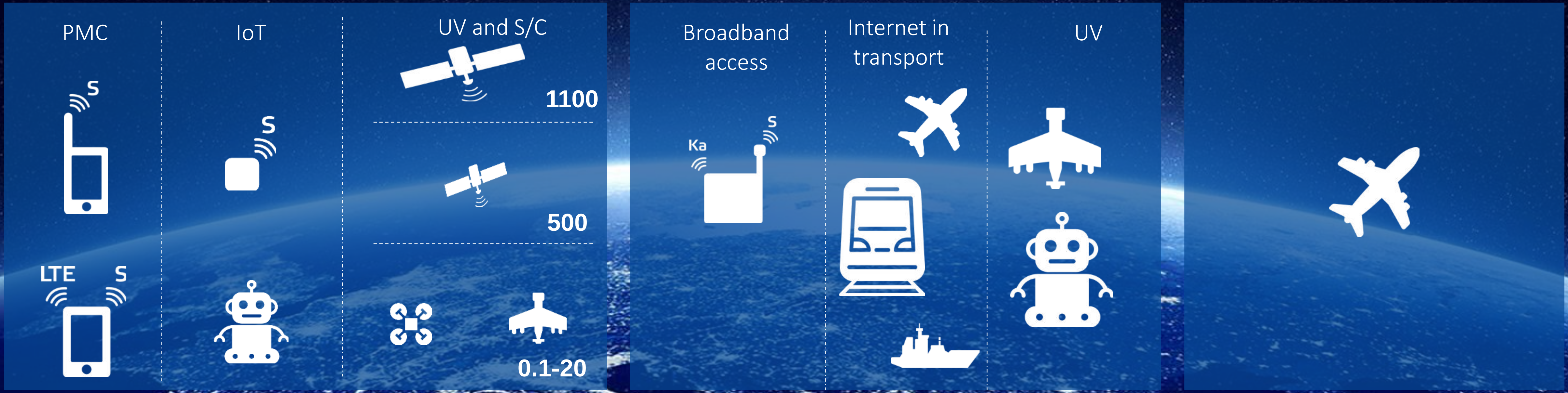
- Personal mobile communication (PMC)
- Communication channels for IoT devices and telemetry in real time
- Control channels of unmanned vehicles (UV) and spacecraft (S/C)

High-speed communication link

- Internet access from a personal mobile terminal
- Internet access in transport
- Data relay from unmanned vehicles and spacecraft

Additional payload

Air transport monitoring (ADS-B)



Multilevel structure

EFIR

Ground objects	100 m	10 km	18 – 20 km	300 – 700 km	1 100 km
	UAV	Aircraft	Troposphere UAV	Orbital Internet	

- Monitoring
- Control
- Relay

Spacecraft

- Weight: 350 – 400 kg
- Power supply system: 1 500 W
- Active service life: 7 years
- Production cost of serial spacecraft is no more than 350 million rubles
- Possibility of a group launch
- Correction system to ensure configuration of the orbital constellation

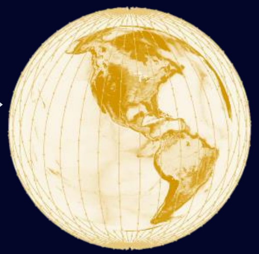
EFIR project realization

EFIR

The Soyuz-2.1 rocket with the upper stage to place into orbit technological S/C as an additional payload

The Soyuz-5 rocket with the upper stage to place into orbit experimental S/C

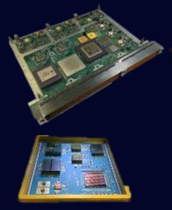
Deployment of the constellation of 23 Soyuz-5 rockets with the upper stage



2020 | 2021 | 2022 | 2023 | 2024 | 2025

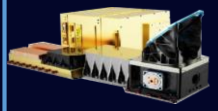
VI. Stage
Serial production of S/C
Ka-band constellation deployment

V. Stage
Serial production plant of S/C
Constellation deployment of S-band S/C



IV. Stage
S/C prototypes
Adjustment of the working construction documentation and giving it "O" and "O1" letters

III. Stage
Device technologies
Implementation of technological routes of UV production



II. Stage
Technological equipment
Full-scale adjustment of the architecture components

I. Stage
Scale modeling
Ground adjustment of the architecture components

Competitor analysis

EFIR

Name	S/C quantity	Orbit altitude, km	Provided services	Radio frequency band
IRIDIUM NEXT	81 (15 backup)	780	- Voice communications (2.4 kbit/s) - Data transfer (1.4 Mbit/s) - AIS - ADS-B	L, Ka
GLOBALSTAR	24	1 400	- Voice communications - Warning system SPOT - M2M	S
ORBCOMM	41	700 – 750	Data transfer M2M (57 kbit/s)	VHF
ONEWEB	648	1 200	Data transfer (50 Mbit/s)	Ku, Ka
SPACEX	4 425	1 150 – 1 350	Data transfer (up to 1 Gbit/s)	S, Ku, Ka, V

Participants of the EFIR project

EFIR

USERS		MANUFACTURERS	ECONOMIC PARTNERS	RETAILERS
B2B	B2G			
• Telecom-operators • Oil and gas companies • Construction companies • Transport companies • Commercial banks	• Ministries • Agencies • Regional centers • Rescue services • State corporations	• Manufacturers of user equipment • Manufacturers of industrial equipment • Space corporations • Transport companies • Construction companies	• Commercial and state banks • Oil and gas companies • Investment funds • Financial companies • Telecom-companies • Content-companies	• Supplying companies of user equipment • Telecom-operators • Virtual operators • Content-companies

РКС
РОССИЙСКИЕ КОСМИЧЕСКИЕ СИСТЕМЫ

EFIR

Multifunctional satellite system

Microsatellites and educational programs.

L. Zelenyi, S. Klimov, A. Sadovski

Space Research Institute RAS (IKI), Moscow, Russia

The First International Aerospace Symposium The Silk Road,
Dolgoprudny, Moscow Region, Russia, MIPT, 06-08 December 2018

Official: Education and PR of space researches

The aim is PR of space research and Russian cosmionautics, scientific experiments and lessons in space for educational purpose.

ISS is the unique laboratory in space and for microsatellites launch.

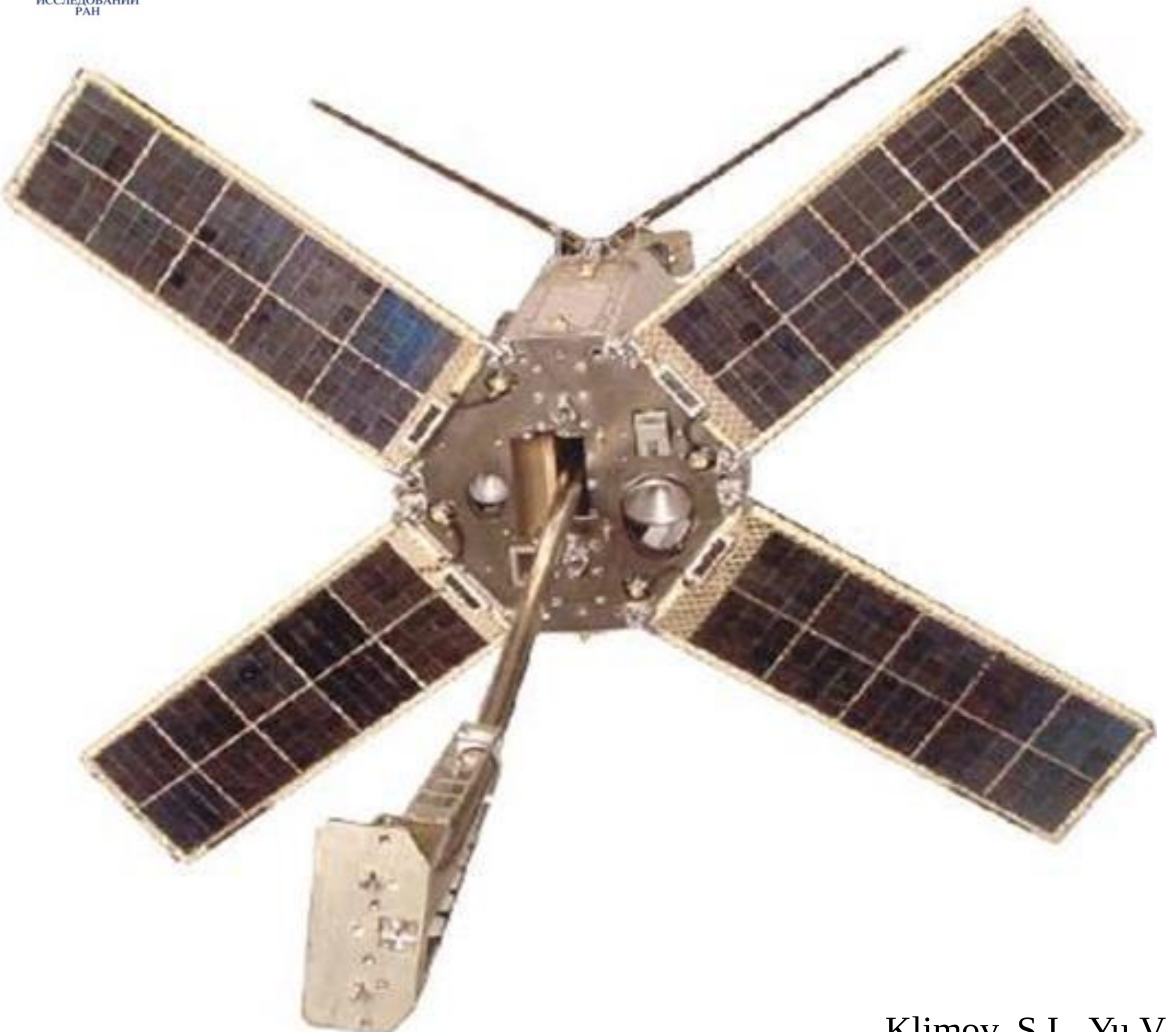
ISS give possibilities:

- to explain what we do in space;
- to show the cosmonautics achievements and perspectives;
- to take part in space experiments.

Microsatellites IKI

	Kolibri-2000	Chibis-M	Chibis-AI	Trabant
time of flight	19.03 – 03.05 2002	25.01.2012 – 15.10.2014	2020 – 2022	2020 – 2022
orbit start, km	368-397	489-513	460-520	480-600
total mass, kg	20,5	40,0	40,0	2x60,0
scientific instrument' (SI) mass, kg	3,6	10.8	10,3	2x17,5
transmitter SI, GHz	0,435	2,27	2,2/8,0	2,2/8,0
reset information, Mbit/s	0,002 ???	1,0	S: 0,064 – 1 X: 0,064 – 10	X: 300,0
capacity of onboard storage , Gbytes		0,5		
Accumulator, Ah		9,5	9,5	18,0

“Kolibri-2000” 19.03 – 03.05 2002



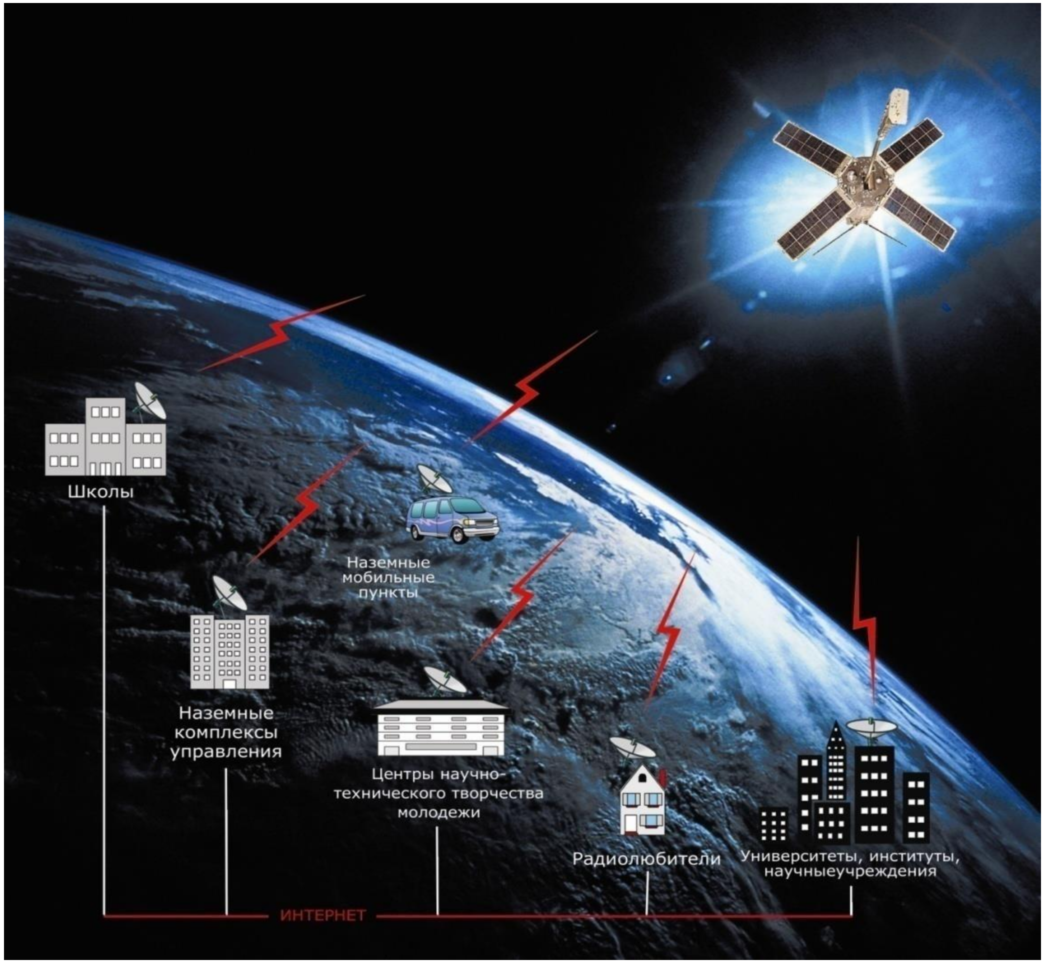
Despite its small size, the microsatellite (MS) “Kolibri-2000” carried 3.6 kg of scientific equipment, which made it possible to conduct a fairly wide range of scientific research in the field of "classical" cosmophysics, and to study space weather, atmospheric and ionospheric processes, presumably associated with thunderstorm activity, manifested in the registration of electrons near the equator, as well as to solve the problems of space education [1].

**Weight 20.5 kg,
scientific equipment 3,6 kg,
30 W**

Klimov, S.I., Yu.V. Afanasyev, N.A. Eismont, E.A. Grachev, O.R. Grigoryan, V.A. Grushin, D.S. Lysakov and M.N. Nozdrachev. Results of in-flight operation of scientific payload on micro-satellite “Kolibri-2000”, ***Acta Astronautica, Volume 56***, *Issues 1-2*, January 2005, Pages 99-106, **2005**

"Kolibri-2000" 19.03 – 03.05 2002

Space education.



School in Sydney

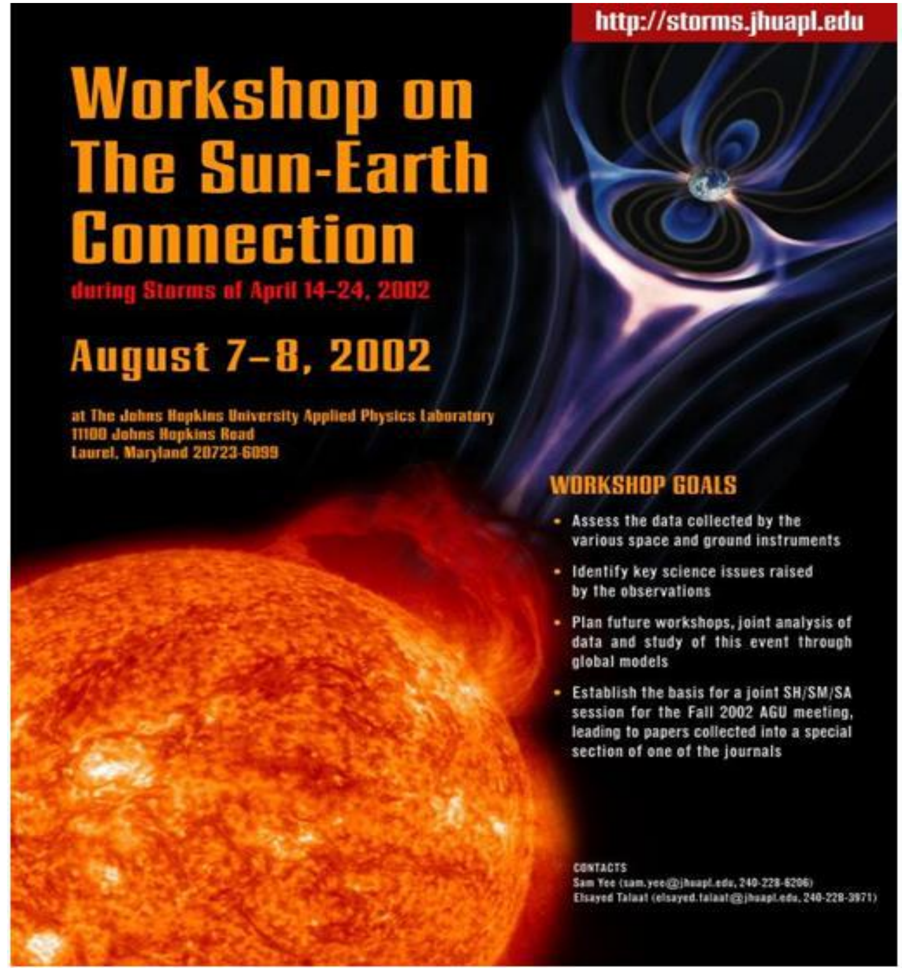
Organization of reception of scientific information by school and University ground stations, first of all, on Amateur radio channels.

ИКИ
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

Space education.

Knox School (Sydney). Opening of the colloquium. The school Director welcomed the School Russian delegation 09.08.2000.

Space education.



School "Helios" IATE (Obninsk, Russia). Discussion of the scientific results of the project “Kolibri-2000".

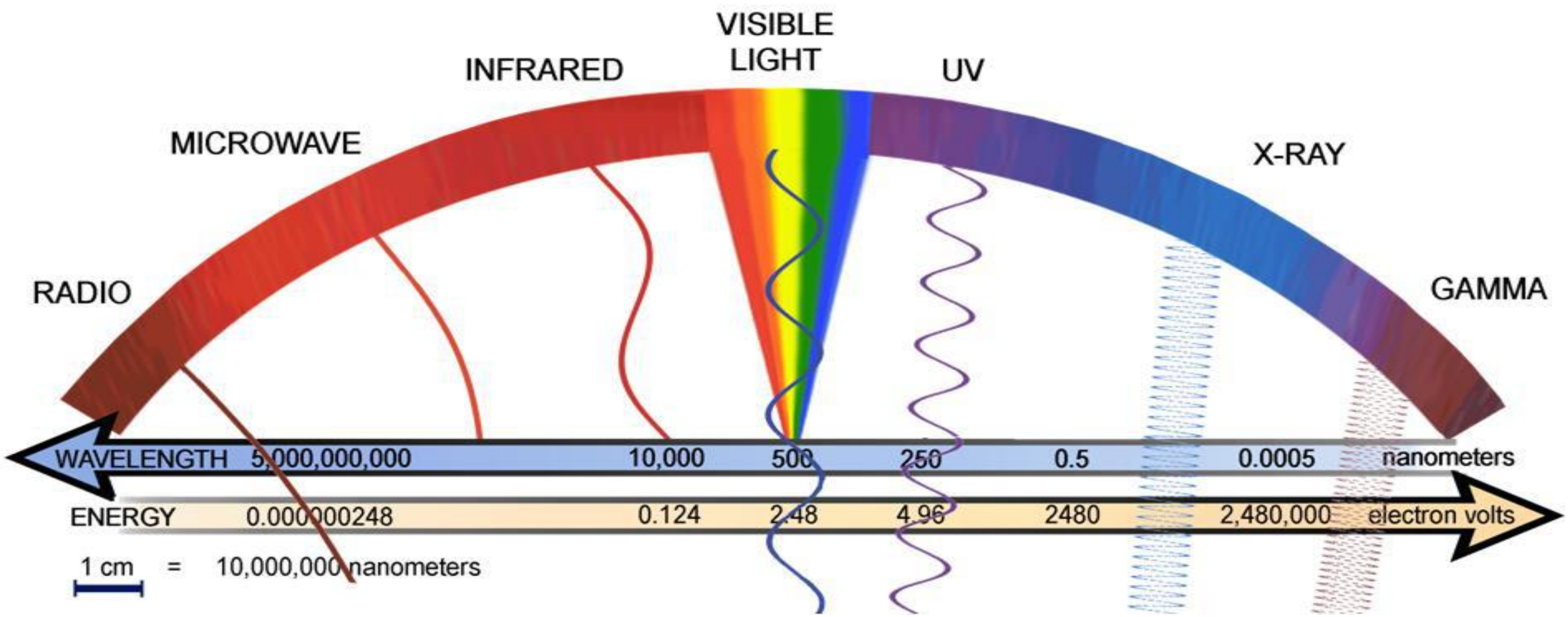
Right - the poster of the International Conference on the events on the Sun 14-24 April 2002.

"Chibis-M" (25.01.2012 – 15.10.2014)

Studies of atmospheric lightning.

For the study of new physical processes in high-altitude atmospheric lightning discharges and mechanisms for their preparation requires a comprehensive study of gamma radiation, infrared and ultraviolet radiation, of electromagnetic waves in a wide frequency range with an unprecedented high (better share microseconds) time resolution.

Since gamma-rays, IR and UV radiation is strongly absorbed in the atmosphere, the land of studies of such processes is very limited. Optimal is their study using low-orbit spacecraft (SC). Unique across the width of the spectrum of the studied electromagnetic radiation, the world's first target Observatory, was created in IKI in cooperation with other academic and University organizations, including international, in the form of complex scientific equipment (KNA) "Groza".



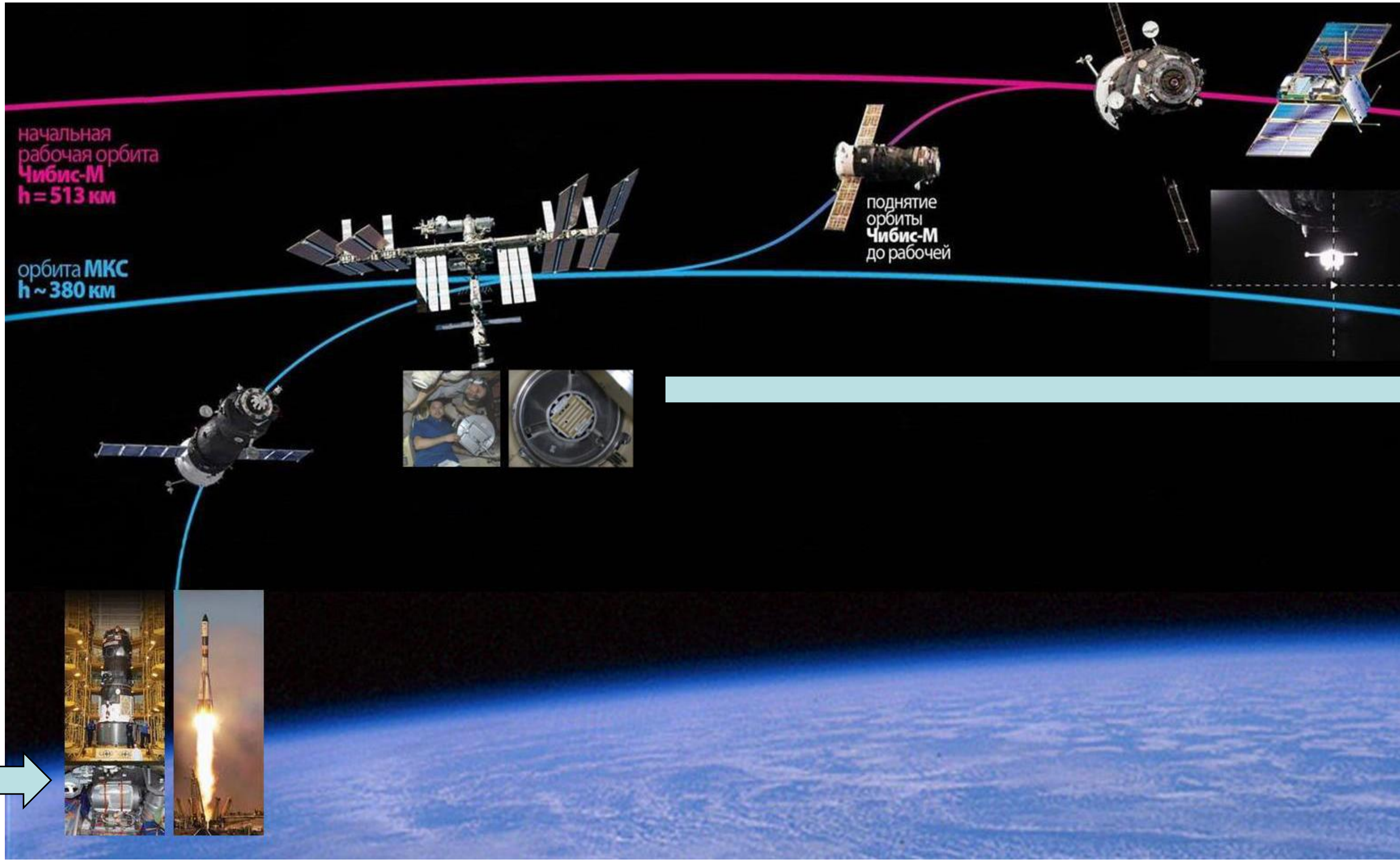
"Chibis-M“

For delivery of the MS on the ISS and subsequent MS separation from TCV are used transport-launch container (TLC).

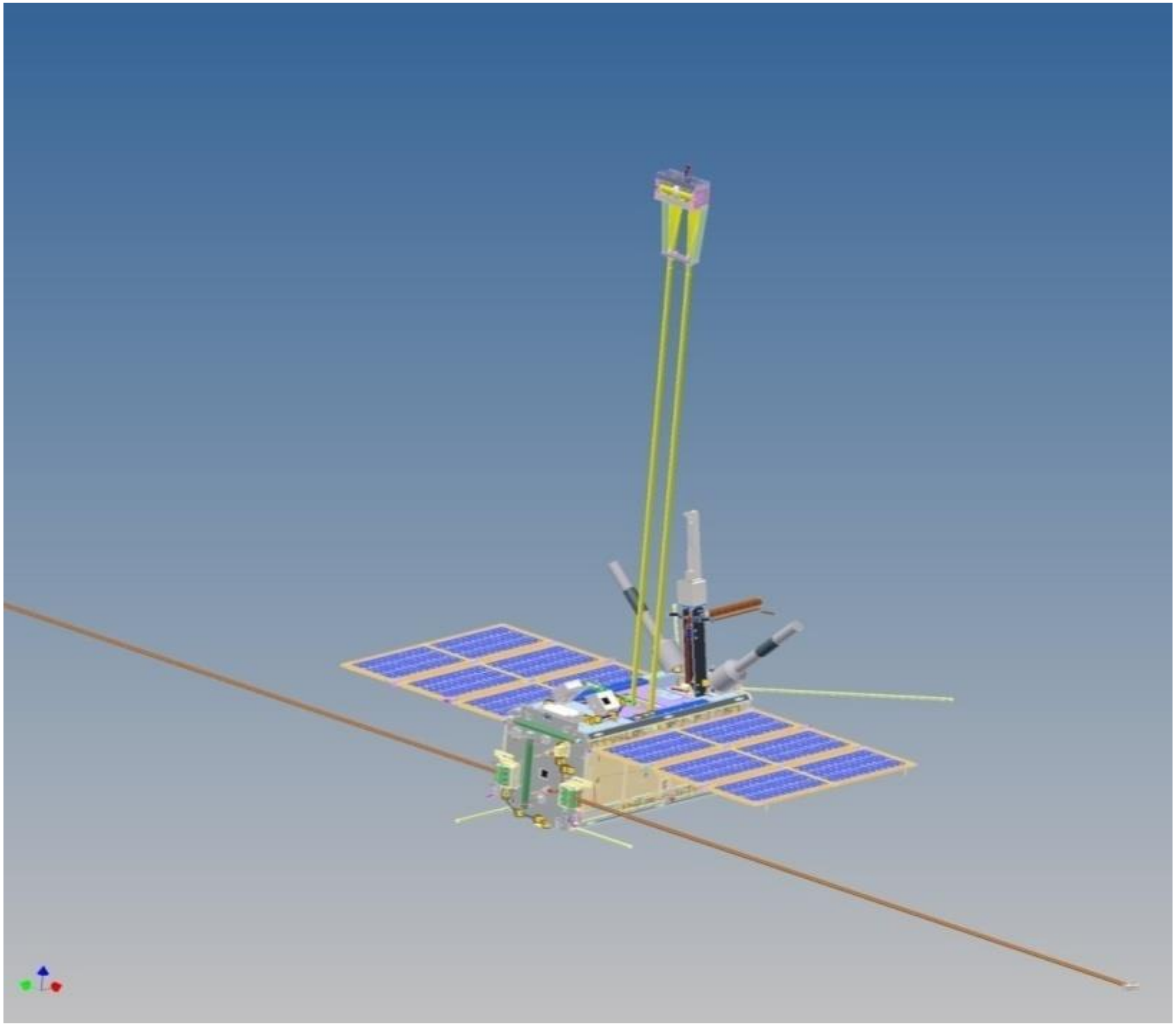
TLC "Chibis-M". Right - comparizen TLC "Kolibri-2000" (left) and "Chibis-M". Due to the thicker the line the Chibis-M" (mass of 40kg.), volume TLC was increased by 10% compared with TLC "Kolibri-2000" (mass 20.5 kg).

Installation of a microsatellites"Chibis-M" in the TLC.

On the experience of space experiments with MS the "double start" technology was developed and implemented “for the first time in the world” with the flight of the Progress spacecraft to a higher orbit (from 380 to 500 km), which increases the residence time of MS in orbit almost in 2 times.



"Chibis-M“ http://chibis.cosmos.ru

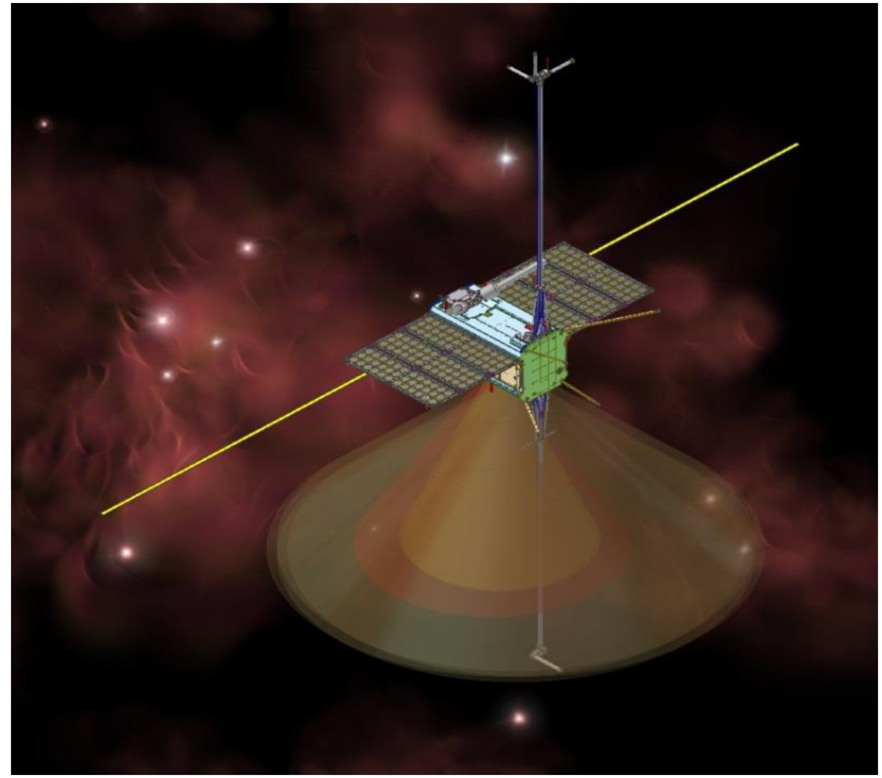


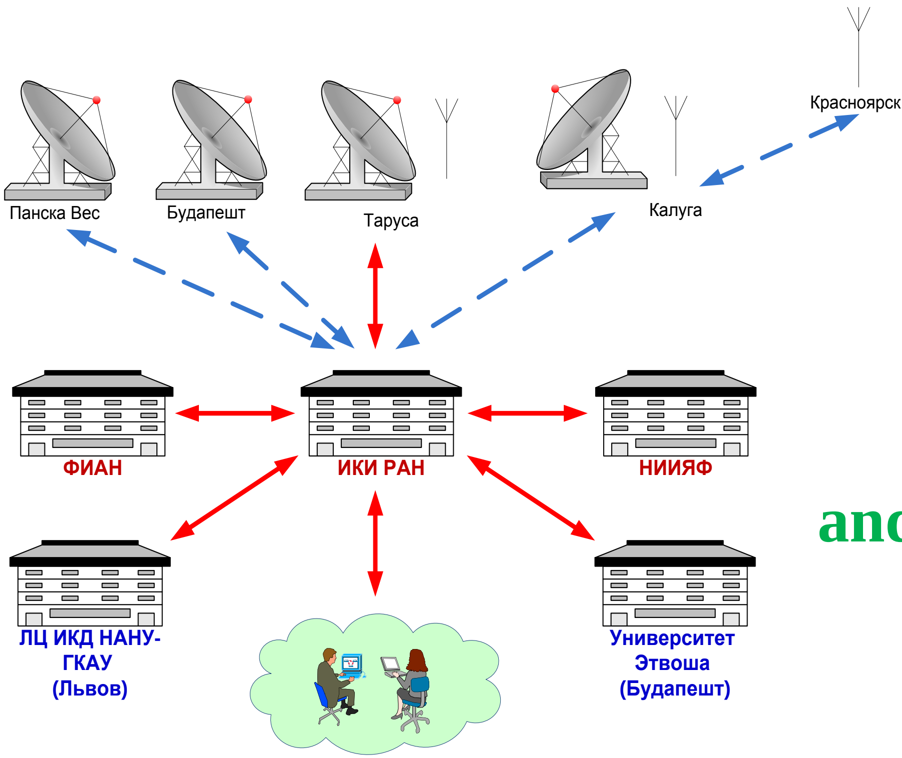
Weight 40 kg, scientific equipment 10.8 kg, 50 W

"Chibis-M“

In IKI
for ~ 3 years
as a whole
successfully operate

cosmic

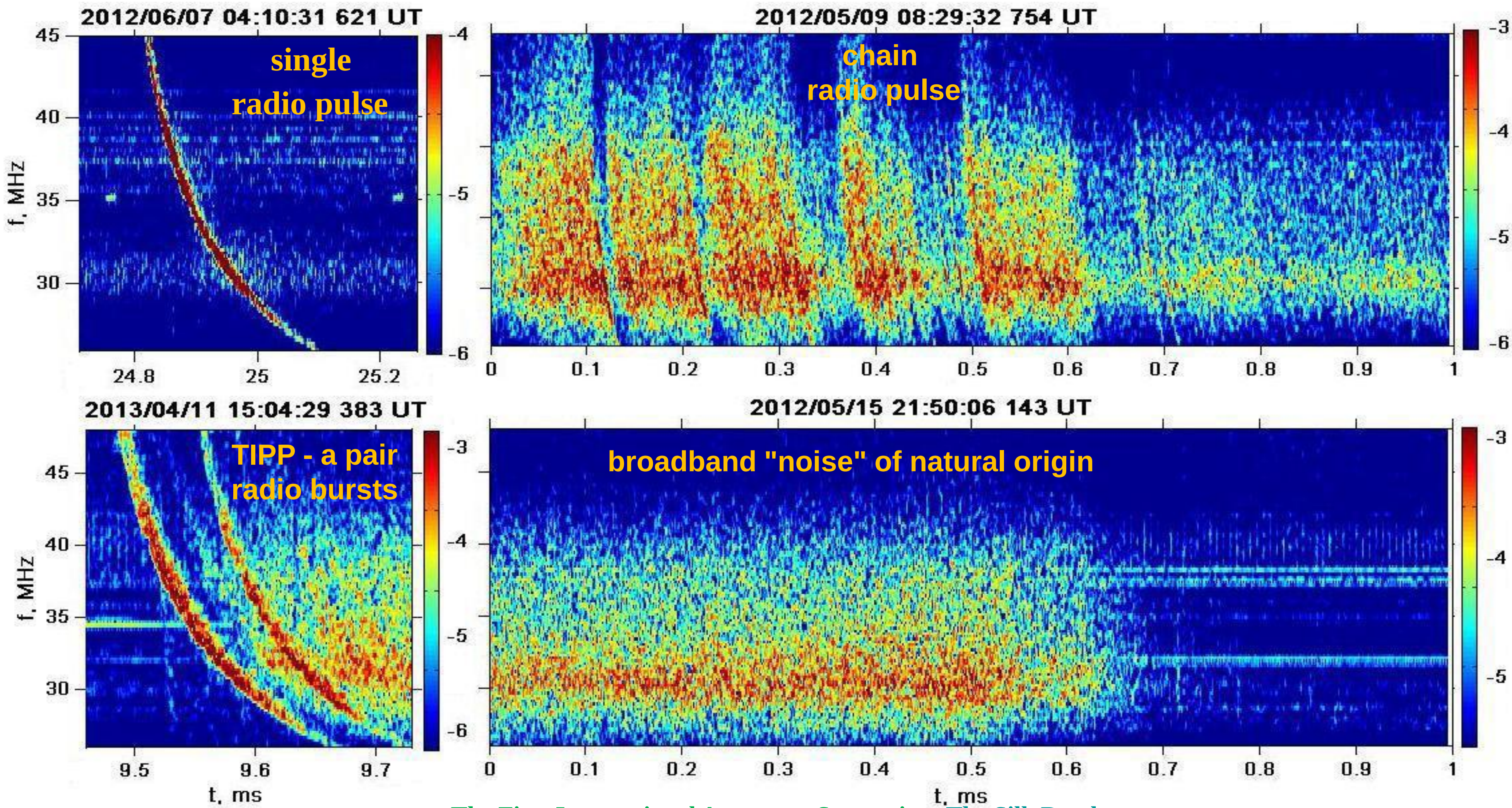




and ground segments

"Chibis-M"

Over the past ~3 years of operation "Chibis-M" recorded several hundred RFA trigger operations, of which more than a hundred associated with short and powerful lightning discharges, also recorded by the sensor of ultraviolet and infrared radiation (DUF).

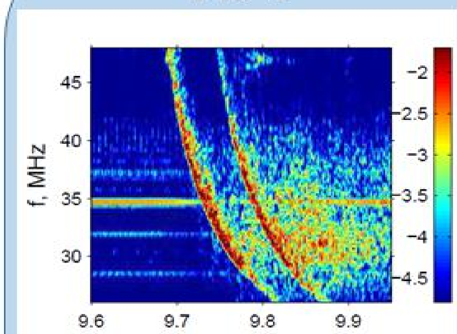


«Chibis-AI»

What is known at the moment:

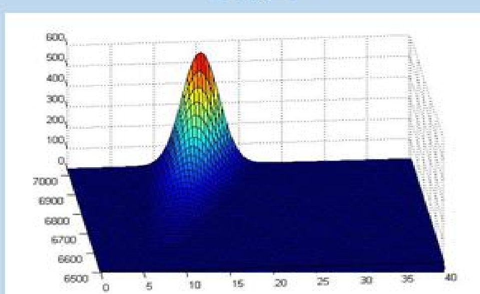
- **3000 events in the gamma range (BATSE, RHESSI, Fermi, AGILE, CORONAS-Photon and Vernov);**
- **1 in synchronous gamma - two different SC;**
- **1 in synchronous gamma - ray optics and different SC;**
- **NO simultaneous observations at gamma - ray and radio!!!**

TIPP



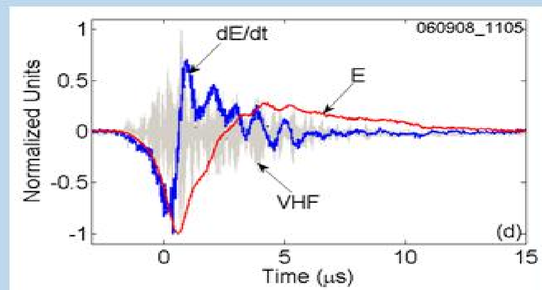
Trans-Ionospheric Pulse Pair

CID

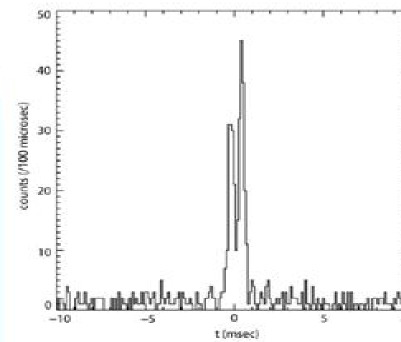


Compact Intracloud Discharge

NBP



Narrow Bipolar Pulse



TGF

Terrestrial Gamma-Flash

чемпионат

СФЕРЫ

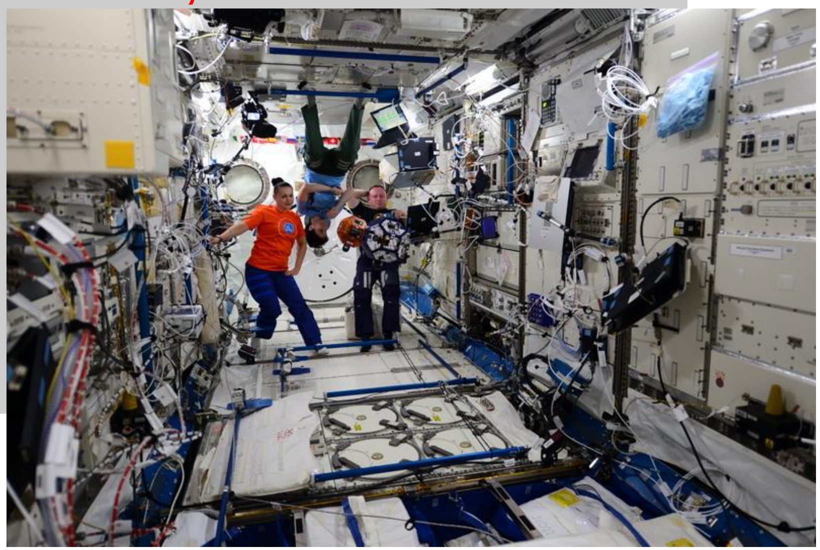
ZERO ROBOTICS

ISS PROGRAMING CHALLENGE

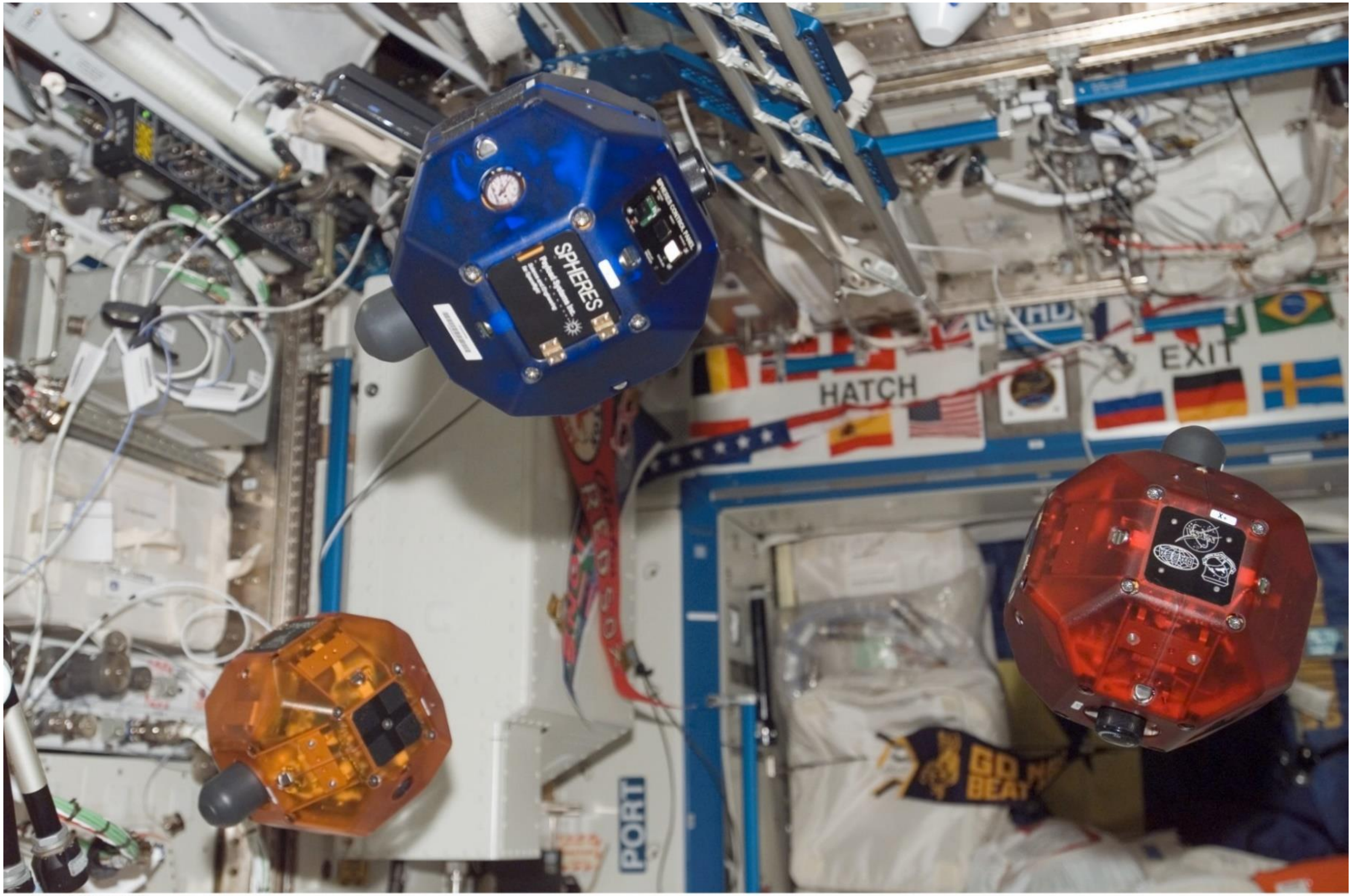
Experiments on ISS – official info

- *EarthKAM* (joint with NASA, photos of Earth from ISS)
- *Great Beginning* (PR)
- *Inter-MAI-75* (educational radio systems – student project)
- *Coulon crystal* (non-ideal plasma in magnetic field)
- *About Gagarin from space*
- *RadioScaf* (MAI student project)
- *Spheres – Zero Robotics* (joint with NASA, orientation satellites in microgravity)

Spheres is the only project for pupils carried from Russian site by MIPT basic department (Space Physics in IKI)



SPHERES on ISS



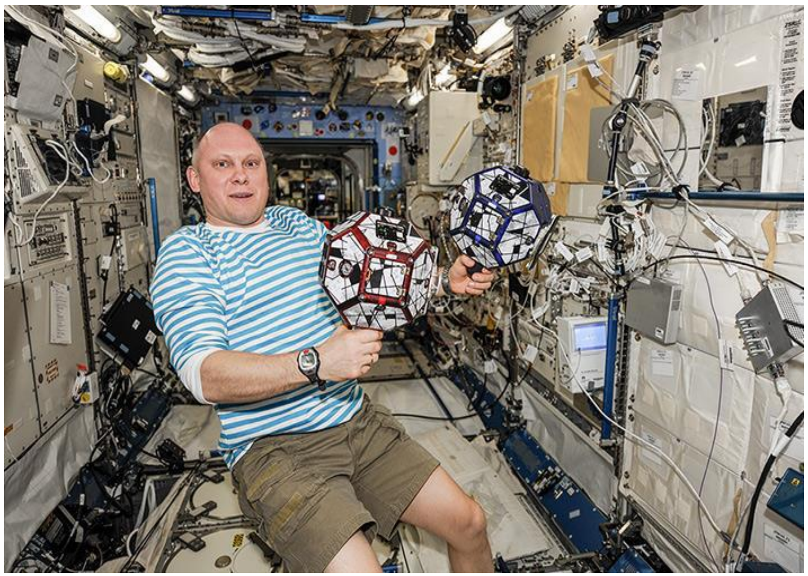
ISS014E17875

What are SPHERES?

- *S*ynchronized *P*osition
- *H*old
- *E*ngage
- *R*eorient
- *E*xperimental
- *S*atellites

Spheres on ISS

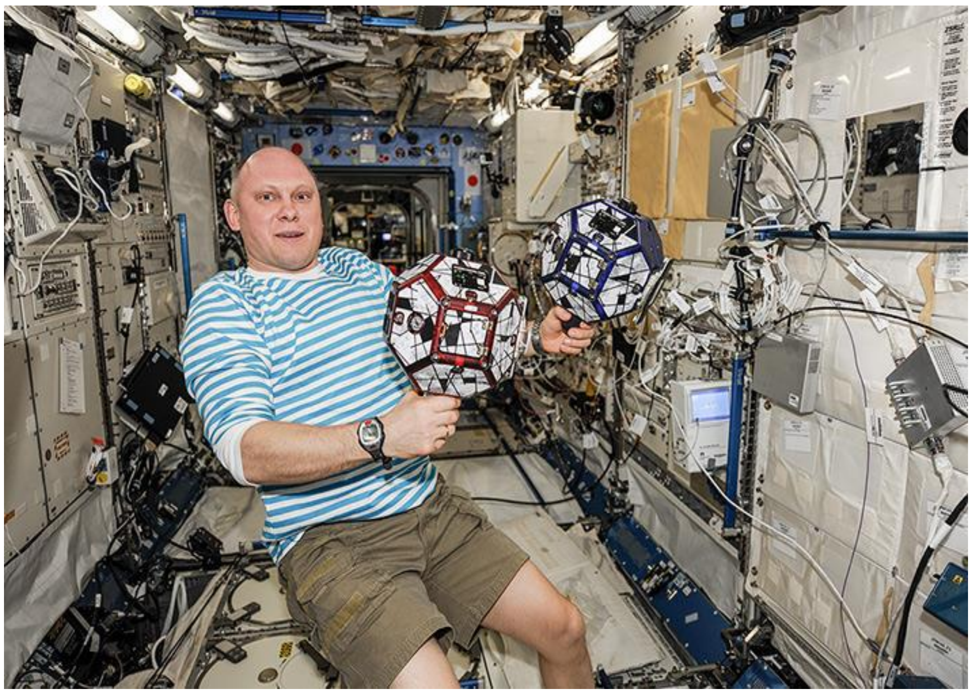





What is Zero Robotics?

ZERO ROBOTICS
ISS PROGRAMING CHALLENGE

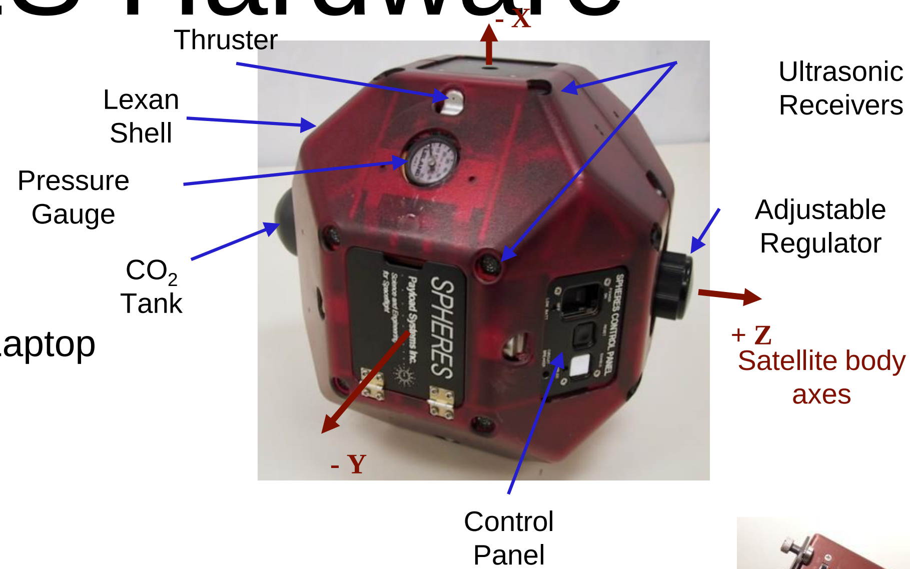
- Schools competition
- Programming game
- Command game



- Zero is for **Zero-G**
  - The finals occur aboard the ISS!!
- Zero is for **Zero Cost**
  - No entry fees
- Zero is for **Zero Configuration**
  - Everything is programed online

SPHERES Hardware

- Propulsion
  - 12 CO2 Thrusters
- Power
  - 16 AA Batteries
- Communications:
  - SPHERE to SPHERE and SPHERE to Laptop
  - 900 MHz TDMA 16kbps
- Processing
  - TI DSP C6701, 167MHz
  - 1 GFLOPS Theoretical Peak
  - 256 kB Flash ROM
  - C RTOS: DSP/BIOS
- Navigation
  - Pseudo-GPS Ultrasonic Metrology
  - Onboard IMU
  - Estimates 6DOF pose at 5Hz
  - Repeatability: ~1-5mm, ~1-2 degrees
- Astronaut Interface with ISS Laptop



Ultrasonic Metrology Beacon

Diameter	0.22 m
Dry Mass	3.5 kg
Wet Mass	4.3 kg
Thrust (single thruster)	0.11 N
CO_2 Capacity	170g

zerorobotics.mit.edu

Zero Robotics | About ZR | Tournaments | Resources | Sign in with Google

Zero Robotics High School Tournament 2017

Info

- Overview
- Game Documents
- Surveys
- ISS Preparation Tips
- MIT Hotel Info
- ISS Finals Packet-MIT

Teams

- Teams
- Teams-3D

Leaderboard

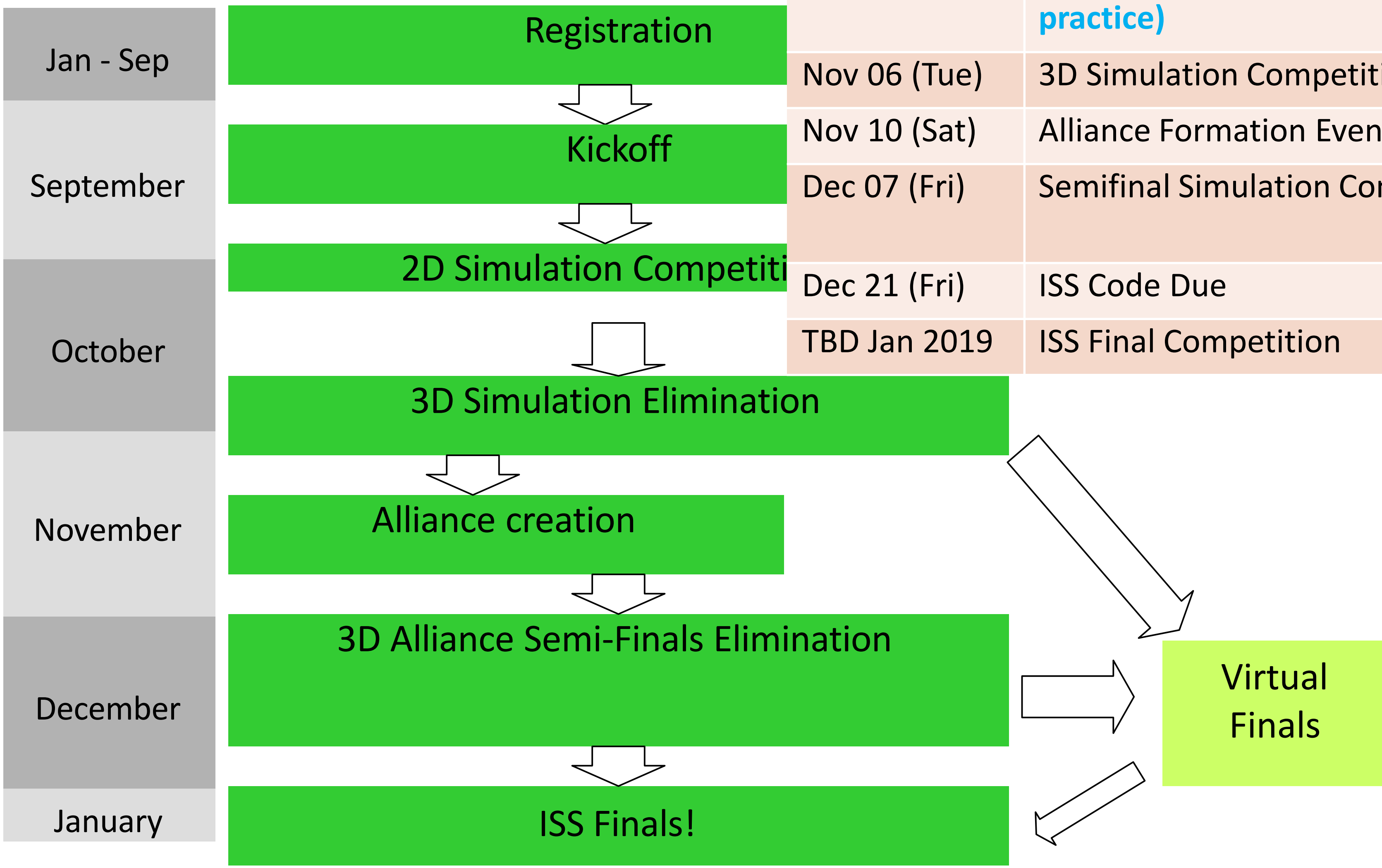
Leaderboard history
(Script provided by Jake Crouch, Robodogs)

These results are based on the codes submitted before 21:59:59 UTC on 2017/10/02

Team	Country	City	Rating	Rank
SuperMajo Bros.	Italy	Grugliasco (TO)	5.9760528423	1
Wall-E 6.0	Italy	Messina	5.6871027384	2
Arclight	Romania	Dej	5.4024471084	3
Zanneio Stardust	Greece	Piraeus	5.2814307424	4
Zagle	Poland	Warsaw	4.8752573767	5
The Drop Bears	Australia	Sydney	4.4345815295	6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

High-school tournament structure

Date (2018)	Event
Sep 8 (Sat)	Kick-off Webcast
Oct 12 (Fri)	**2D Simulation Competition Deadline (end of practice)**
Nov 06 (Tue)	3D Simulation Competition Deadline
Nov 10 (Sat)	Alliance Formation Event
Dec 07 (Fri)	Semifinal Simulation Competition Deadline
Dec 21 (Fri)	ISS Code Due
TBD Jan 2019	ISS Final Competition



2017 Geography

MS Tournament Structure & Timeline

Schedule	Competition Elements	Curriculum Units
Week 1	Introduction	Introduction to Physics and Math
Week 2	Field Day/Practice Regional Competition	Intro to Computer Science, SPHERES & the ZR Game
Week 3	Regional Competition	Time to Play! - Programming and Support
Week 4	ISS Collaboration	Strategies and Testing
Week 5		Finals Prep and My Future in Science & Engineering
Mid- Aug	ISS Finals!	

ZERO ROBOTICS
ISS PROGRAMING CHALLENGE

ИКИ
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

Thank you

for your attention!

Invite to cooperation

Sun-Venus Lagrangian point satellite for the Venera-D mission

Irina Kovalenko[1,2] and Natan Eismont[1]

1. Space Research Institute RAS, Moscow
2. Institute of Astronomy RAS, Moscow

1ST INTERNATIONAL AEROSPACE SYMPOSIUM
THE SILK ROAD

Overview

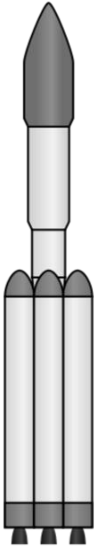
1. Mission overview
2. Earth-to-Venus trajectory
3. Mission scenario. Operational orbit
4. Transfer to Lagrangian point L1
5. Transfer to Lagrangian point L2
6. Conclusions

Mission overview

Mission overview

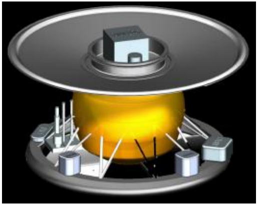
- Launch vehicle: **Angara**
- Launch years: 2026
- Payload: 6900 kg

  OR
- Launch years: 2028 / 2029 / 2031
- Payload: 6200/ 6300 kg / 6900 kg



Mission elements

- Lander
  - Main lander
    2+ hours on surface
  - Small stations
    60 days on surface
- Orbiter
  - Main orbiter
    Lifetime > 3 years
  - Optional element
    Small satellite(s)



Scientific objectives [1]

- Complex analysis of the atmosphere, surface and plasma environment
- To study the origin and evolution of Venus
- To understand the evolution of Earth climate and global warming
- In application to exoplanets: to understand, which processes make planetary systems habitable

[1] Zasova L.V., et al., Venera-D: from science objectives to mission architecture. (2018)

Earth-to-Venus trajectory

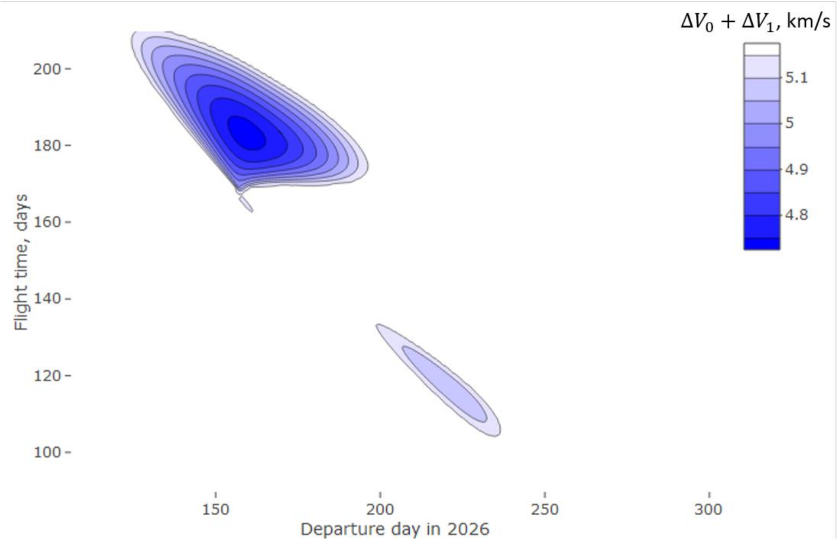
Trajectory characteristics

- Optimisation: minimum energy
  - ΔV_1 from a low Earth orbit to transfer trajectory
  - ΔV_2 from transfer trajectory to Venus' operational orbit

Trajectory characteristics

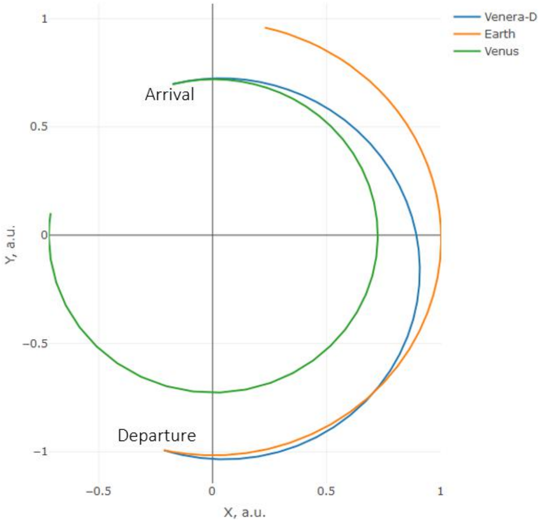
- Optimisation: minimum energy
  - ΔV_1 from a low Earth orbit to transfer trajectory
  - ΔV_2 from transfer trajectory to Venus' operational orbit
- Defined by:
  - Departure date
  - Time of flight

Transfer trajectory opportunities for 2026



Optimal Transfer trajectory for 2026

Date of launch: 09.06.2026 Date of arrival: 09.12.2026



Transfer trajectory

Two types of orbits

Type I: less than halfway around the Sun transfer

($\sim$ 4 months from the Earth to Venus)

Type II: more than halfway around the Sun transfer

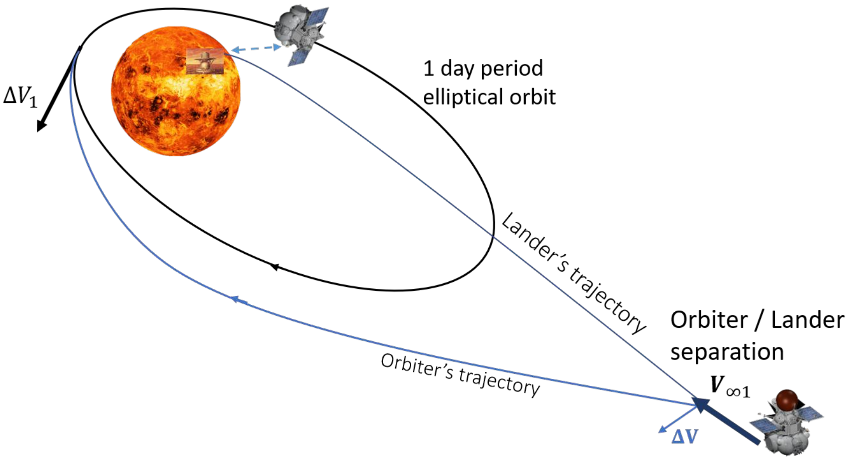
($\sim$ 6 months from the Earth to Venus)

$\rightarrow$ Synodic period intervals: 1.6 years

Mission scenario. Operational orbit

Orbiter and lander transfer scenario

The orbiter will be separated from the lander 3 – 30 days before arrival to Venus.



Main orbiter: operational orbit

Mission requirements:

- Data relay from the landing module
  from parachute opening and after landing
  Duration of mutual visibility: 3 hours
- Scientific measurements
  Mission lifetime: 3 years

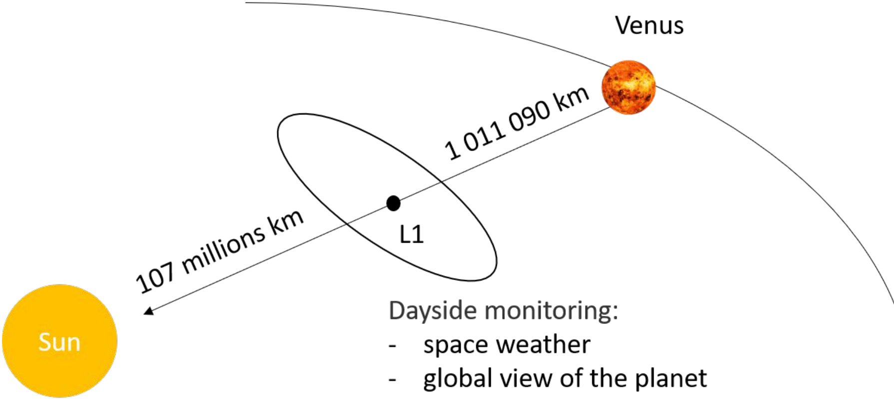
Main orbiter: operational orbit

Highly-elliptical polar orbit

- Inclination: $90 \pm 10°$
- Pericentre altitude: 400 km
- Orbital period: 24 hours
  Apocentre altitude: 66 000 km
- Argument of the pericentre:
  $\pi/2 < \omega < \pi$ and $3\pi/2 < \omega < 2\pi$

Transfer to Lagrangian point L1

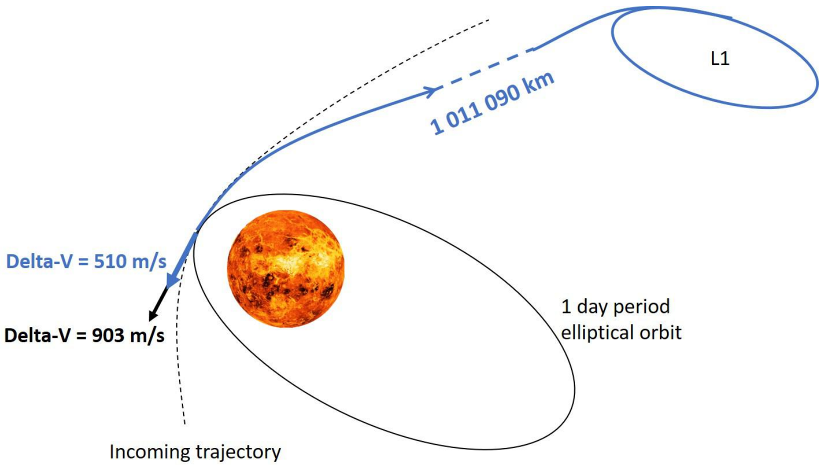
Sun-Venus Lagrangian L1 point



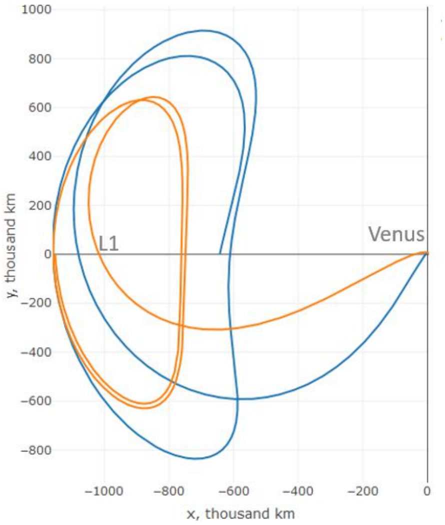
Dayside monitoring:

- space weather
- global view of the planet
- radio occultations with orbiter

Transfer to L1 point

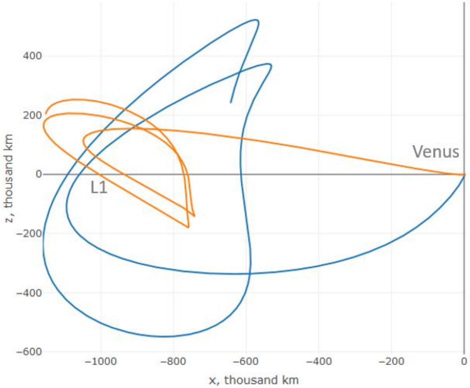


Lagrangian L1 point orbit



- Orbit period around L1: 112.5 days
- Time of flight: ~ 25 – 35 days from Venus

Lagrangian L1 point orbit

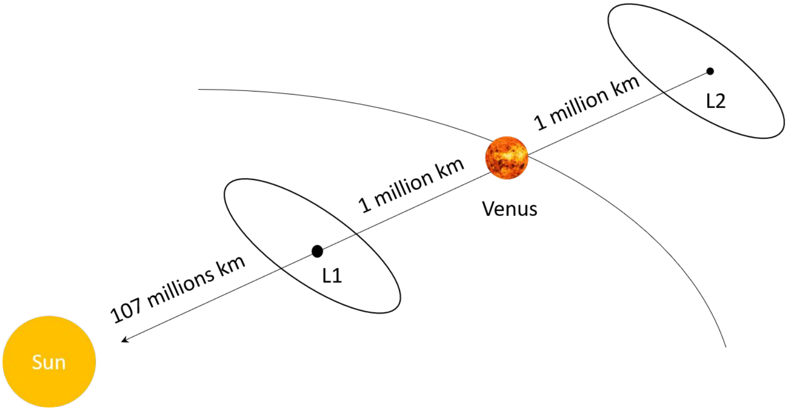


Inclination = 90°

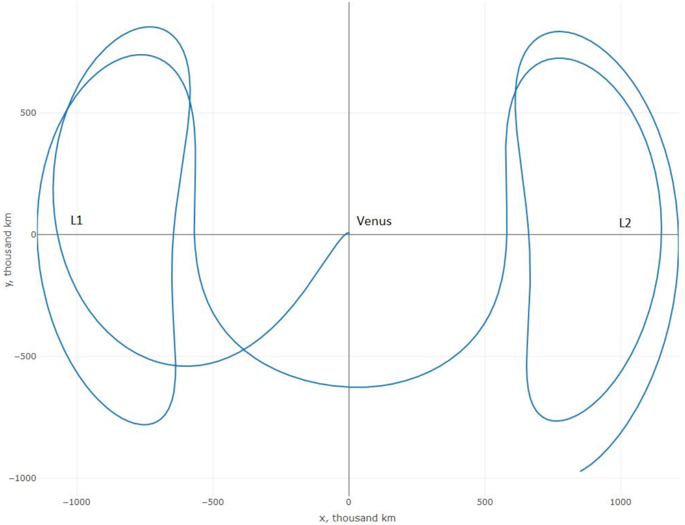
Inclination = 15°

Transfer to Lagrangian point L2

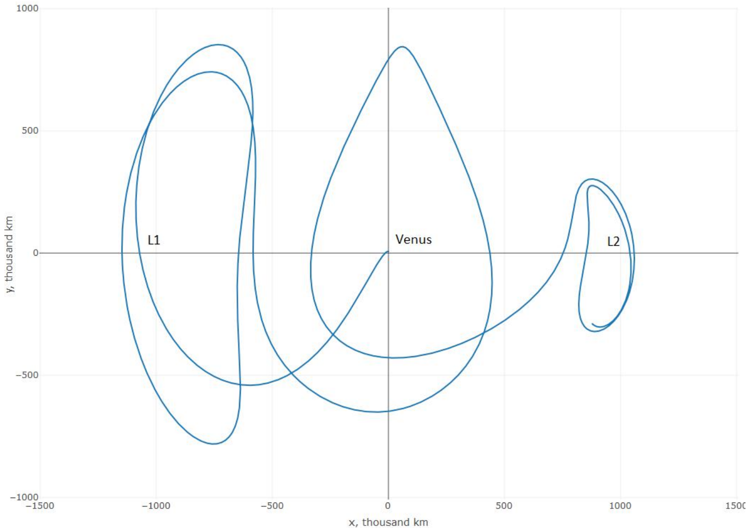
Sun-Venus Lagrangian L2 point



Transfer to L2 point #1

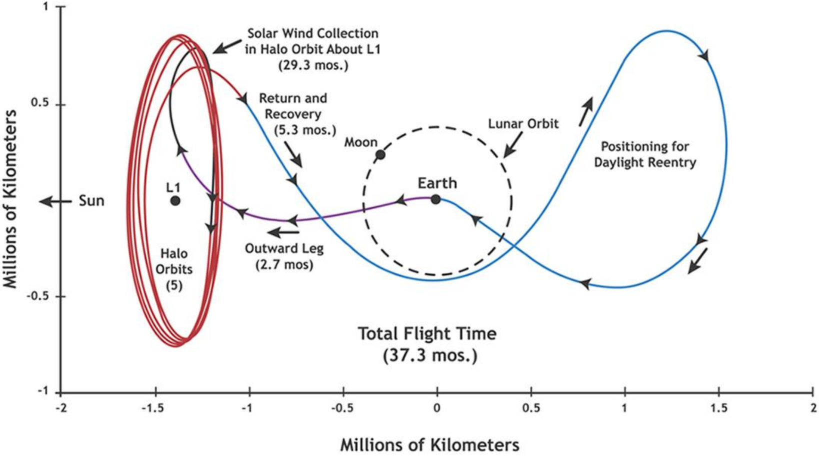


Transfer to L2 point #2



Example: Genesis mission

Total $\Delta V = 6$ m/s



Conclusions

Lagrangian point orbits: advantages

- Low stationkeeping cost: $\Delta V \approx 1$ m/s per year

Lagrangian point orbits: advantages

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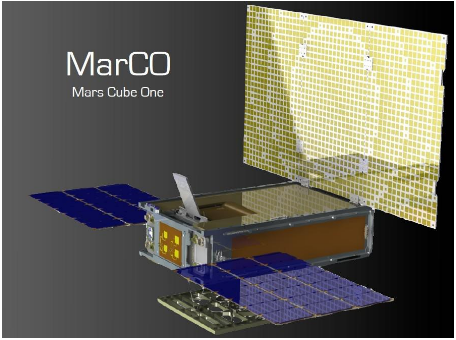
  (solar wind, Venus atmosphere)

Lagrangian point orbits: advantages

- Low stationkeeping cost: $\Delta V \approx 1$ m/s per year
- Low ΔV cost for transfer into L2 point orbit
- Enables new scientific measurements
  (solar wind, Venus atmosphere)
- New concept of Venus mission: first mission to Lagrangian point

Example



- Launch mass: 13.5 kg
- 8 cold gas thrusters
- Total $\Delta V = 40$ m/s

Thank you for your attention!

Тема доклада

Информационный Космический Центр «Северная Корона»

Evaluation of the quality characteristics of satellite systems by mathematical modeling

Оценка качественных характеристик спутниковых систем путем математического моделирования

Гриценко Андрей Аркадьевич

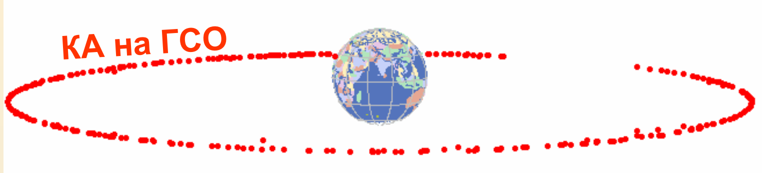
Генеральный директор, кандидат технических наук

The First Aerospace Symposium "The Silk Road«
06-08 December
Dolgoprudny, Moscow Region, Russia
MIPT

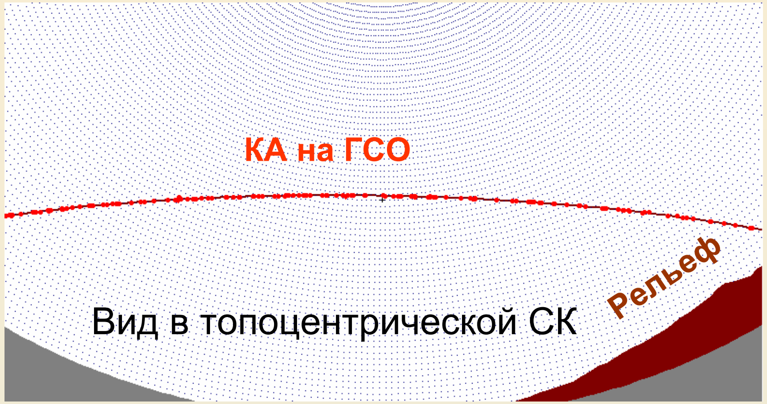
Моделирование работы спутниковых систем

A. Геостационарные спутниковые системы (GEO) – все статично

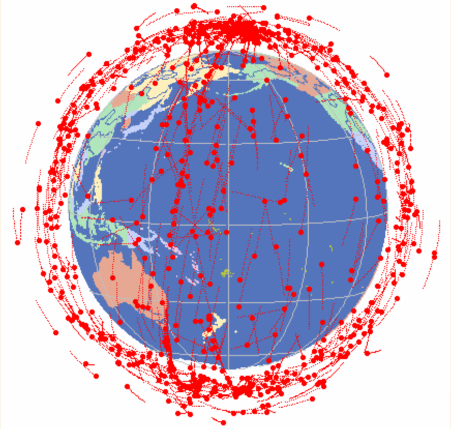
B. Негеостационарные спутниковые системы (NGEO) – все динамично



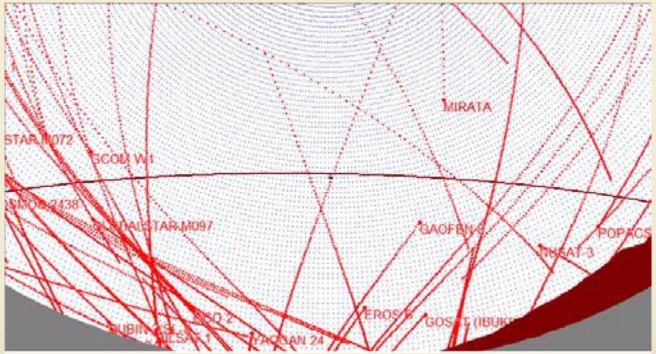
Вид в земной системе координат



Параметры любой GEO системы могут быть определены аналитически (расчетом)



Земная система координат



Топоцентрическая система координат

Детальная оценка параметров NGEO системы даже в составе одного КА может быть проведена практически только путем моделирования

Объект интереса

Объект интереса – спутниковые системы различного целевого назначения

Этапы жизненного цикла: разработка, развертывание, эксплуатация, захоронение

Приоритетные направления:

- Телекоммуникационные системы
- Навигационные системы
- Системы ДЗЗ
- «Связь + навигация + ДЗЗ» (комбинированные системы)

Структура спутниковых систем:

1. Космический сегмент
2. Наземный сегмент управления и контроля
3. Дополнительные подсистемы и службы (повышение эффективности целевого применения)
4. Пользовательский сегмент (наземный и/или космический)

Требования к программно-методическому обеспечению

1. **Универсальность** - учет специфики работы систем связи, навигации и ДЗЗ

2. **Оперативность:**
   - в подготовке исходных данных;
   - при моделировании работы (нужны «быстрые алгоритмы»);
   - при отображении протекающих процессов

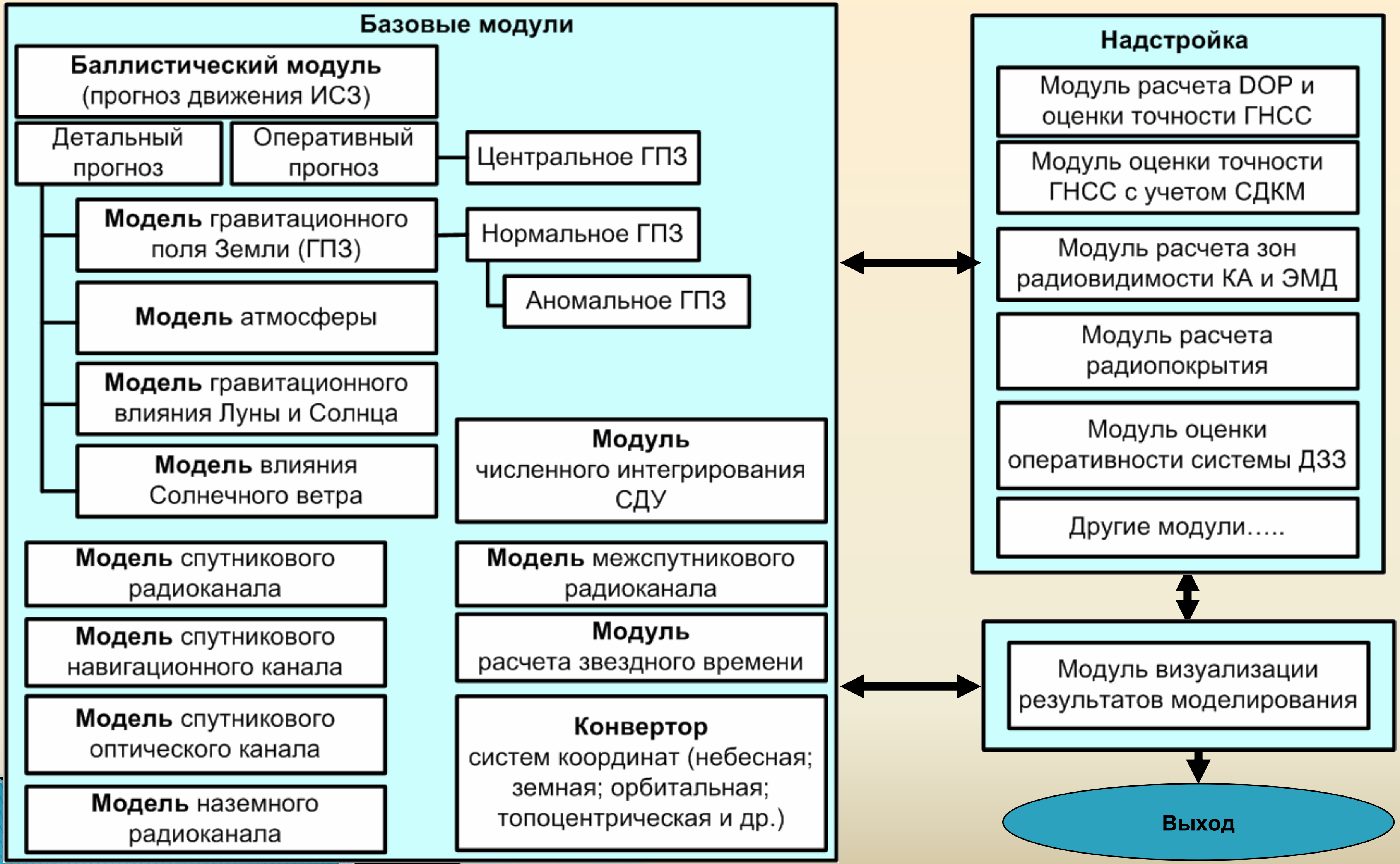
3. **Комплексность** – учет всех сегментов и компонентов системы (космический, наземный, дополнительные подсистемы, включающие наземный и космический сегменты)

4. **Достоверность** – современные апробированные модели, возможна градация уровней сложности

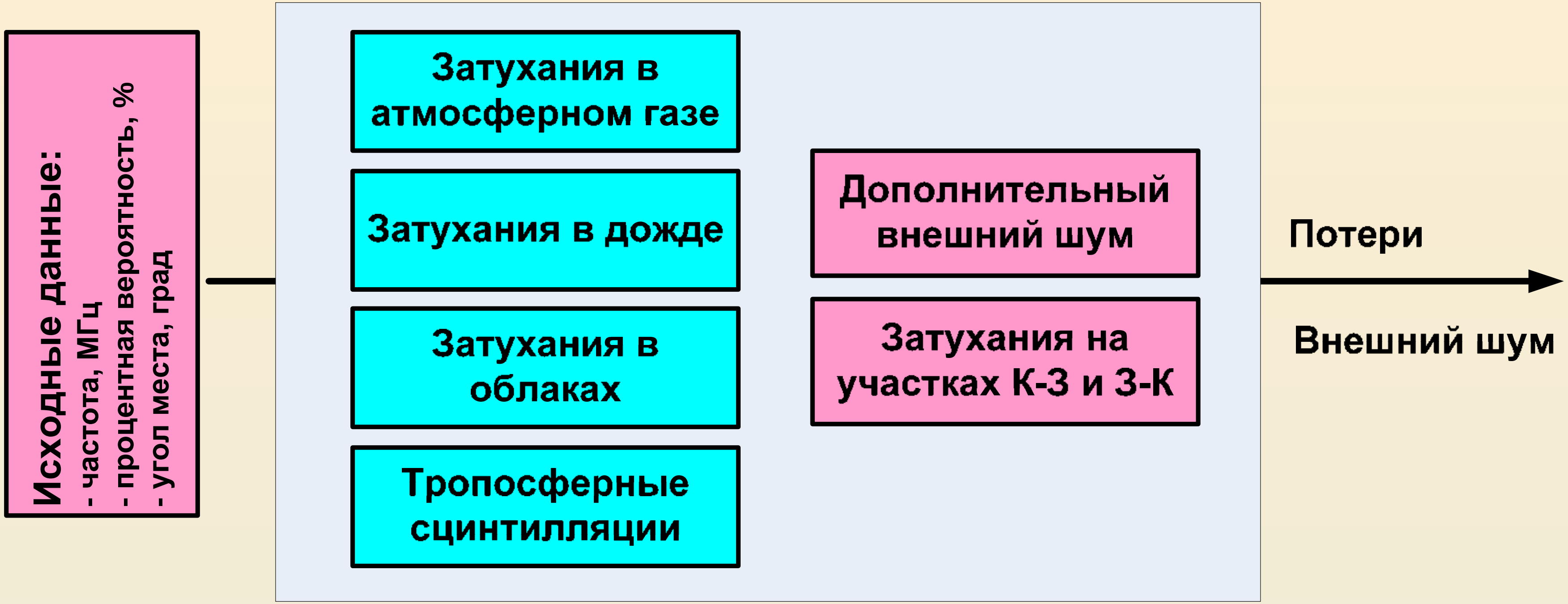
5. **Компактность** – реализация всех возможностей на простых персональных компьютерах, в том числе ноутбуках.

6. **Простота интерфейса** – простой интуитивно понятный интерфейс

САПР «Альбатрос» - основные модули



САПР «Альбатрос» - модель затуханий в спутниковом радиоканале

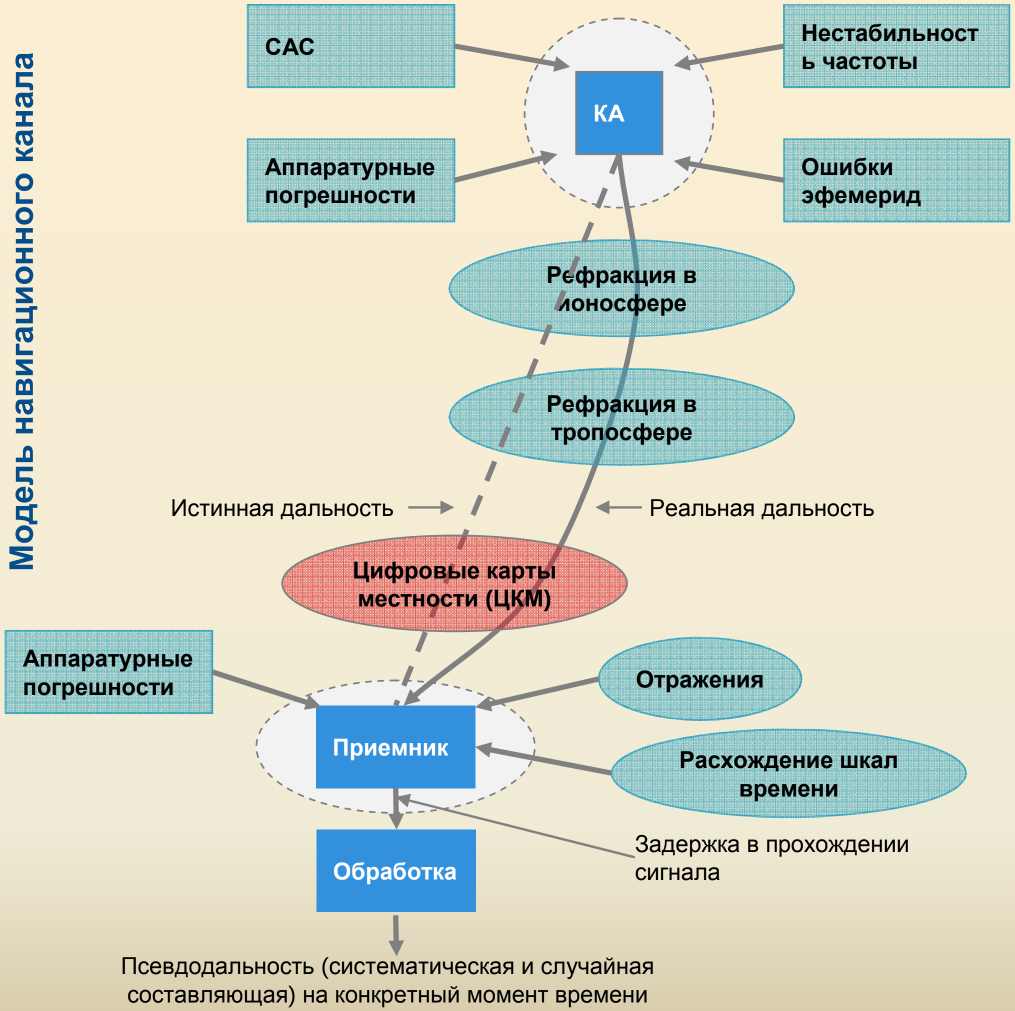


Методический аппарат - Rec. BR ITU

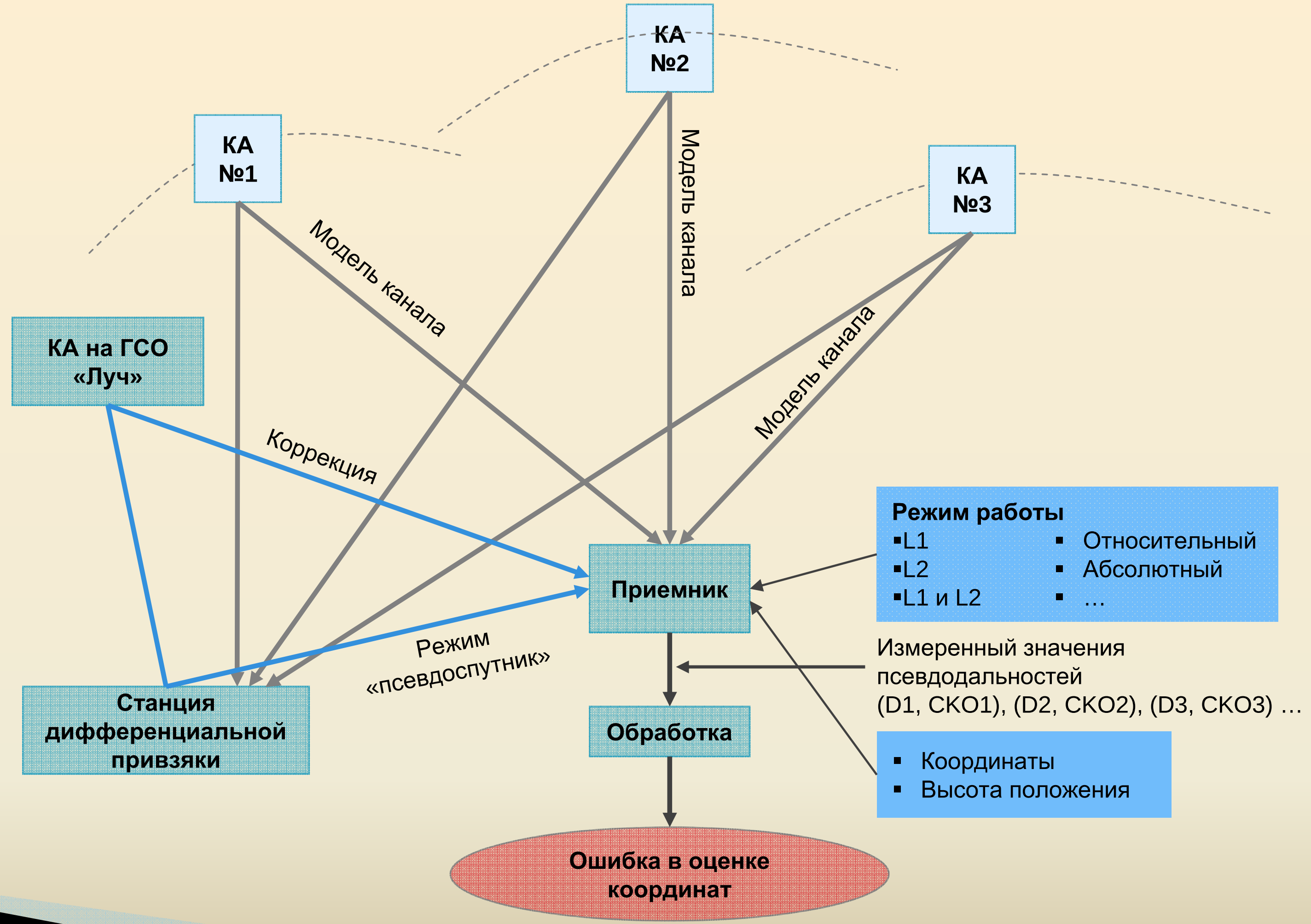
САПР «Альбатрос» - модель навигационного канала

Особенности

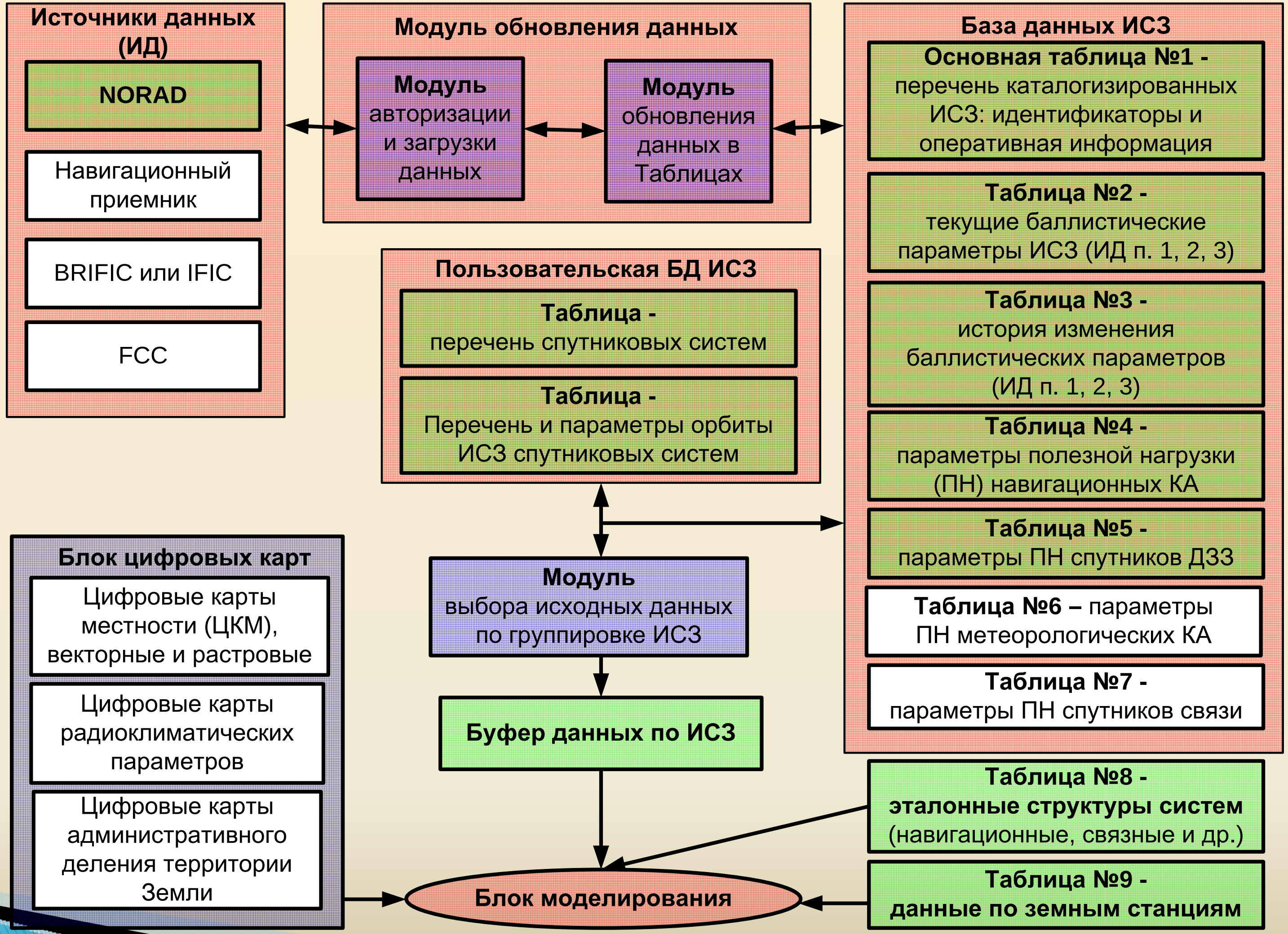
- Учет всех основных составляющих суммарной ошибки измерения псевдодальности
- Учет детальных характеристик каждого КА
- Учет режимов работы аппаратуры потребителя



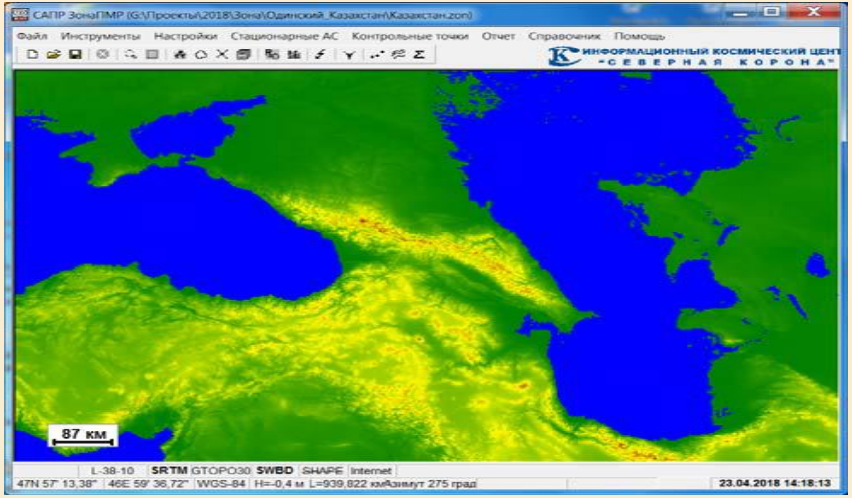
САПР «Альбатрос» - модель навигационной системы



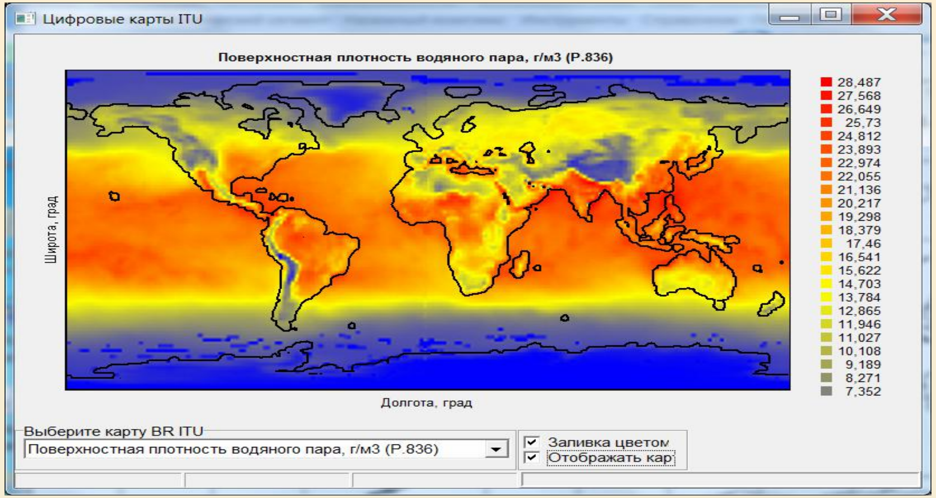
САПР «Альбатрос» - база данных



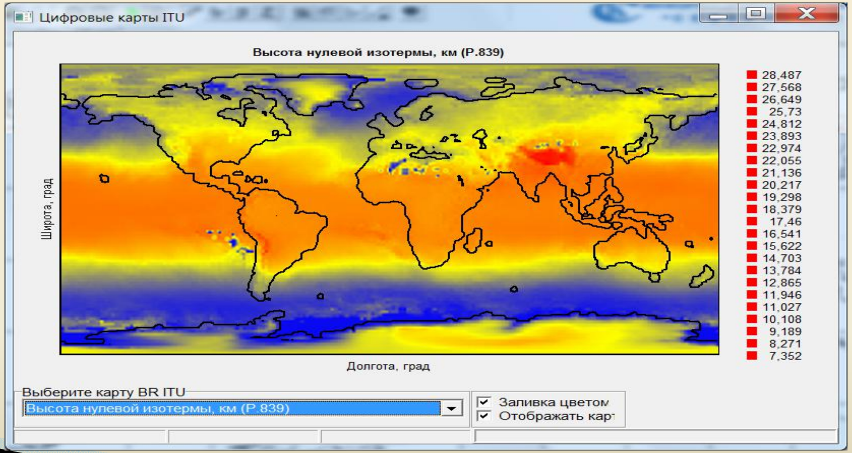
САПР «Альбатрос» - цифровые карты



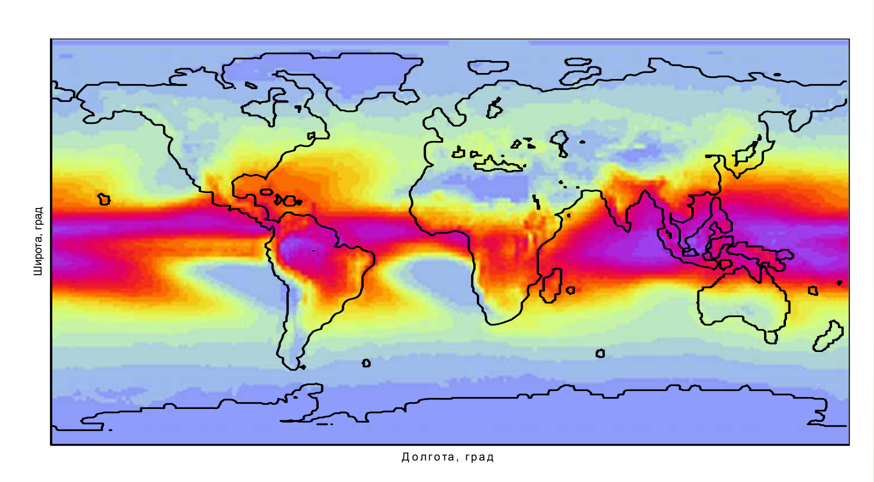
Цифровые карты местности (SRTM3)



Плотность водяного пара



Высота нулевой изотермы



Карта потерь на участке «К-З» (УМ=90 град, P=99.5%)

Особенности построения зон радиовидимости НГСО систем

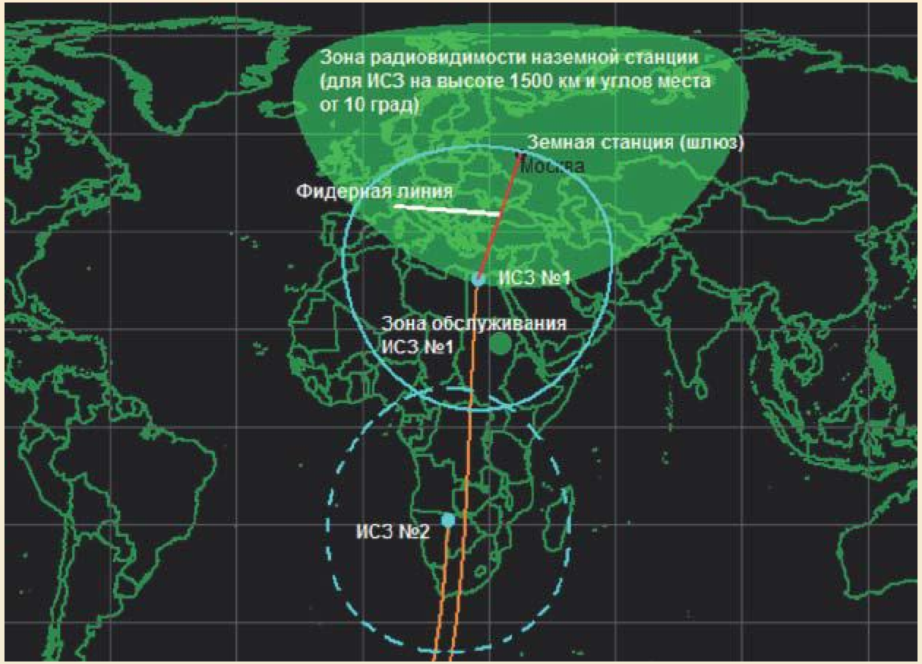
Условия формирования зоны радиовидимости КА:

- есть межспутниковые линии связи, либо;
- угол места направления на КА со стороны наземного шлюза выше минимального значения (т.е. зона обслуживания зависит от сети шлюзов)

Гарантированная зона радиовидимости (ГЗРВ) – часть поверхности Земли, в любой точке которой на углах места (УМ), не ниже требуемого, наблюдается N число КА в течение Р процента времени года.

Примеры для систем:

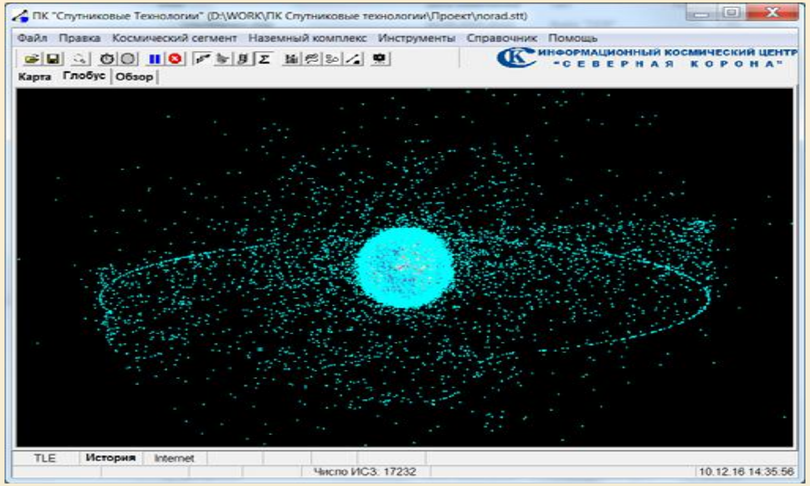
- узкополосной связи: УМ=10 град, N=1, P=100%
- подвижной связи: УМ=45 град, N=1, P=100%
- навигационных: УМ=10 град, N=4, P=100%
- передачи сообщений: УМ=10 град, N=1, P=60%

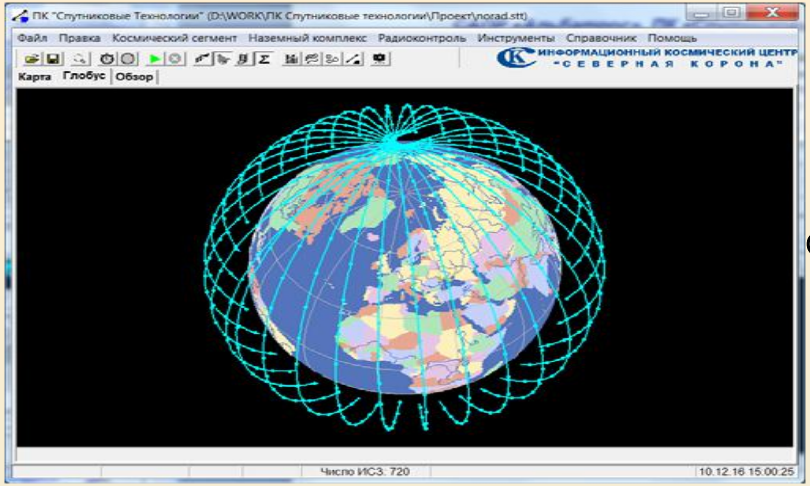


КА №1 – есть зона обслуживания,
КА №2 – нет зоны обслуживания, так как УМ направления от шлюза меньше допустимого

САПР «Альбатрос» - визуализация информации

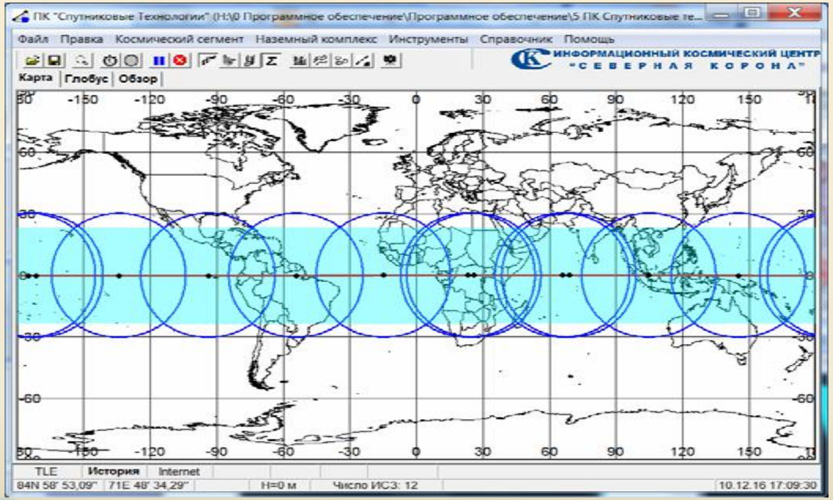
Текущая ситуация
в Космосе
(около 20 тыс. ИСЗ)

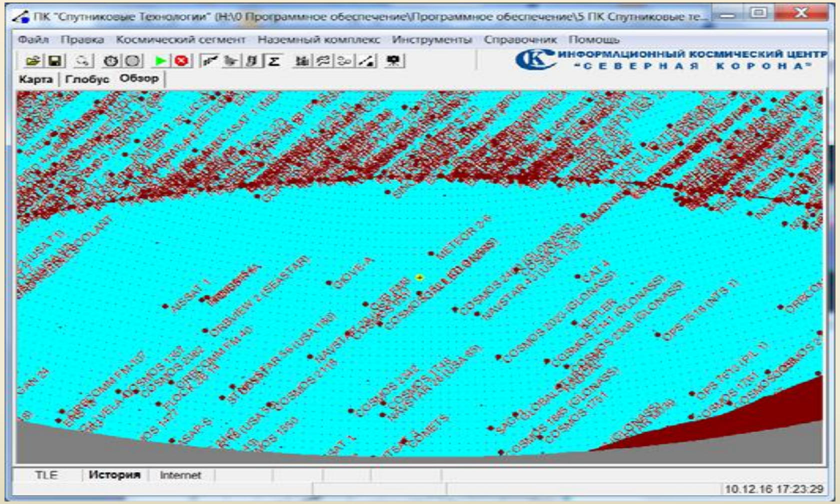




Система
OneWeb (проект)

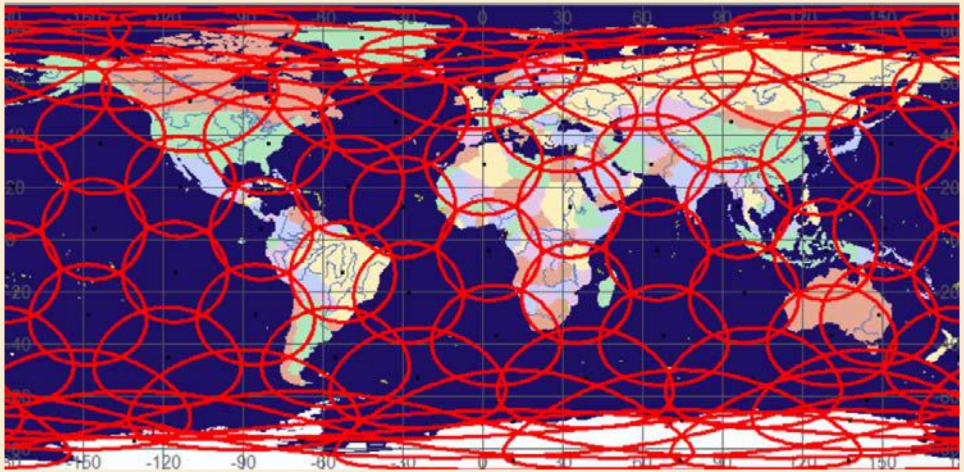
Система ОЗВ



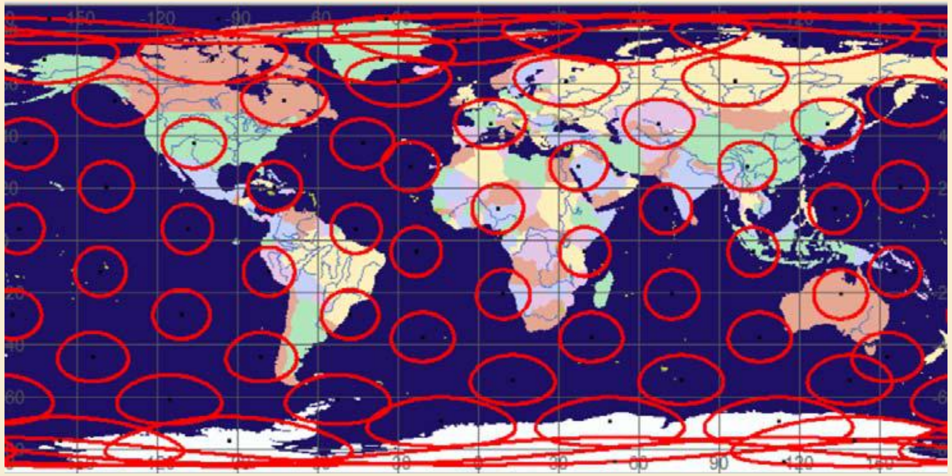


Вид на небо в топоцентрической СК

Система глобальной подвижной спутниковой связи Iridium

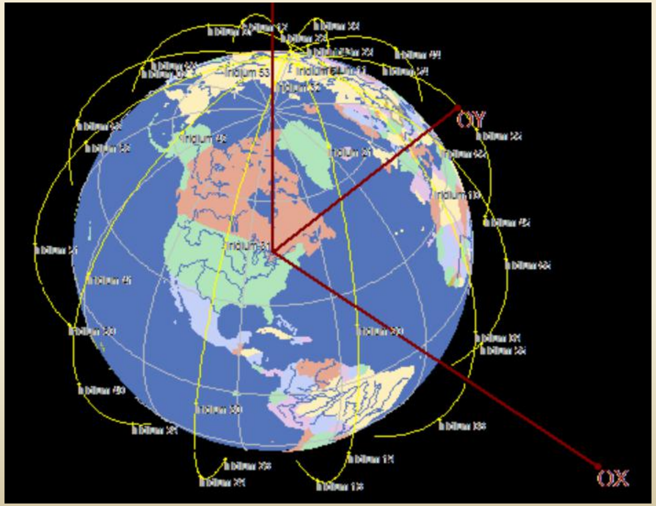


Мгновенная ЗРВ, УМ=8 град
(глобальность обеспечивается)

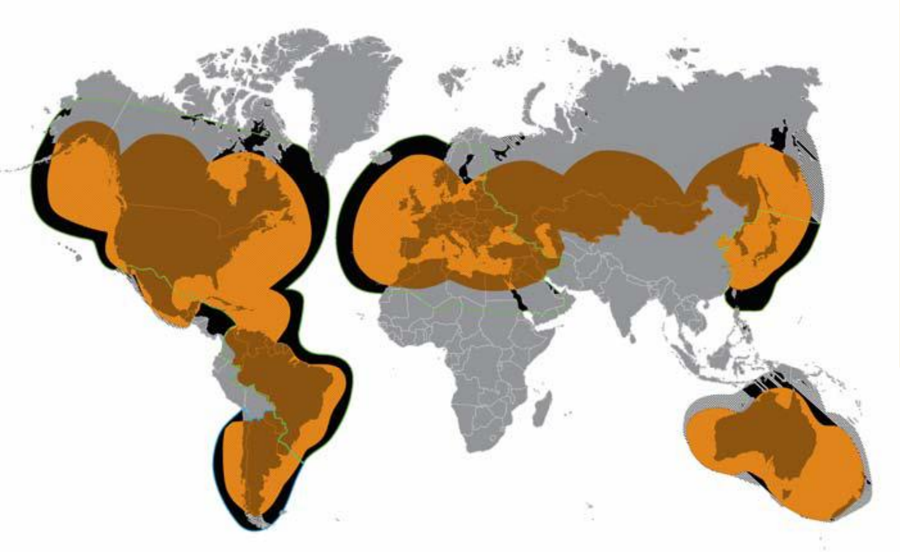


Мгновенная ЗРВ, УМ=30 град
(глобальность не обеспечивается)

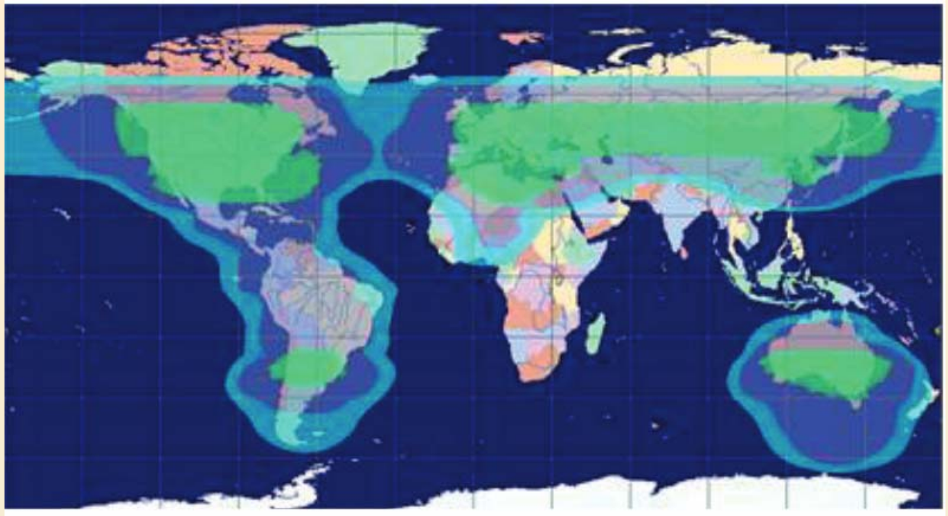
Орбитальная
группировка



Система подвижной спутниковой связи Globalstar



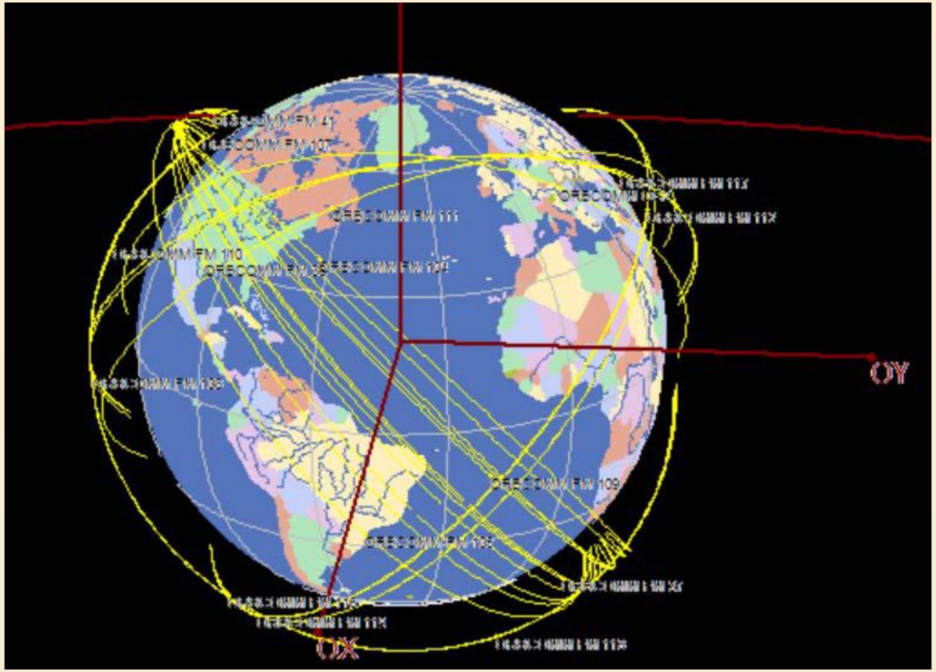
ГЗРВ (источник: web-сайт компании)



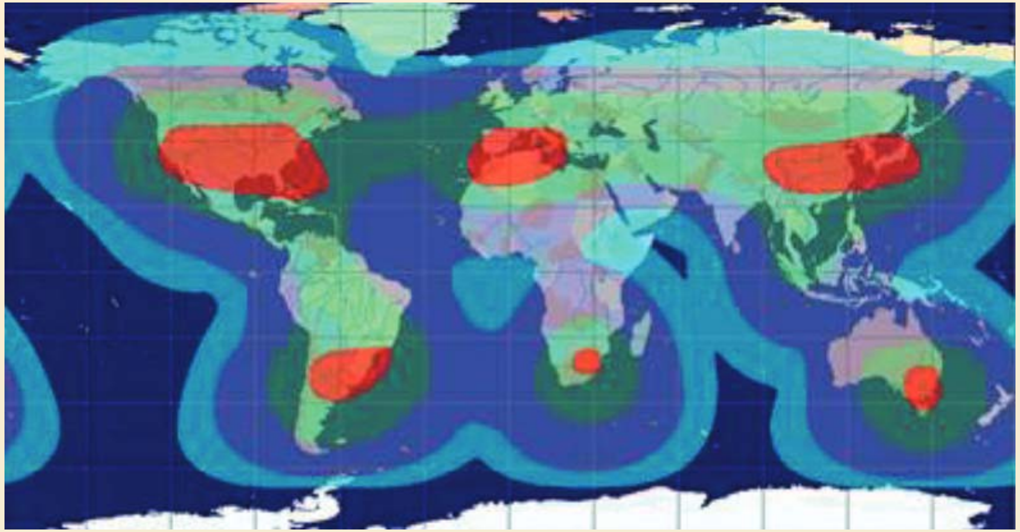
ГЗРВ путем моделирования (надежность 95, 99 и 99.999%)

Мгновенная зона радиовидимости спутников системы

Спутниковая система передачи сообщений Orbcomm

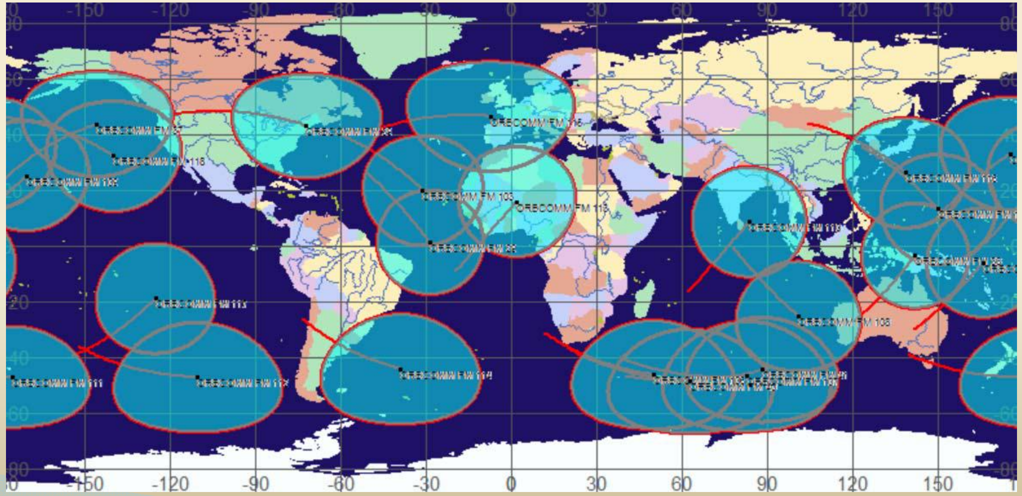


Орбитальная группировка

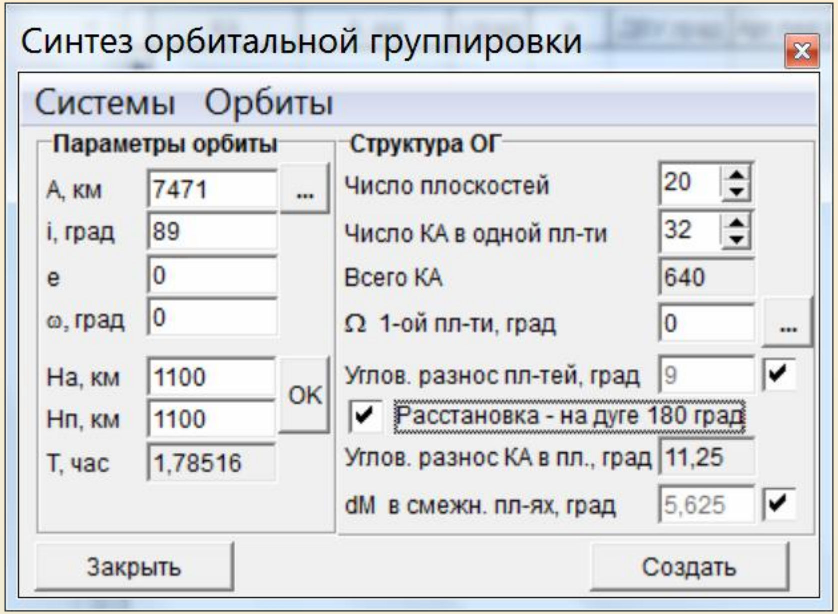


ГЗРВ путем моделирования
(надежность 1, 20, 50 и 70%)

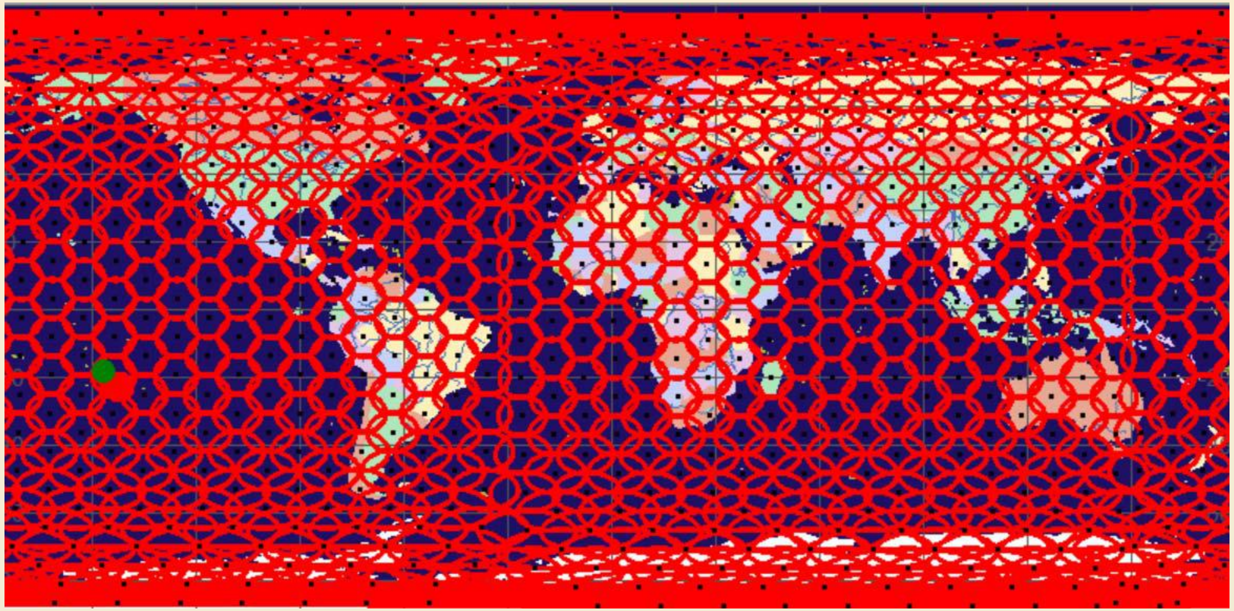
Мгновенная зона
радиовидимости
системы



Система спутниковой связи, вещания и передачи данных «ГМИСС» («Эфир»)



Исходные данные по орбитальной группировке

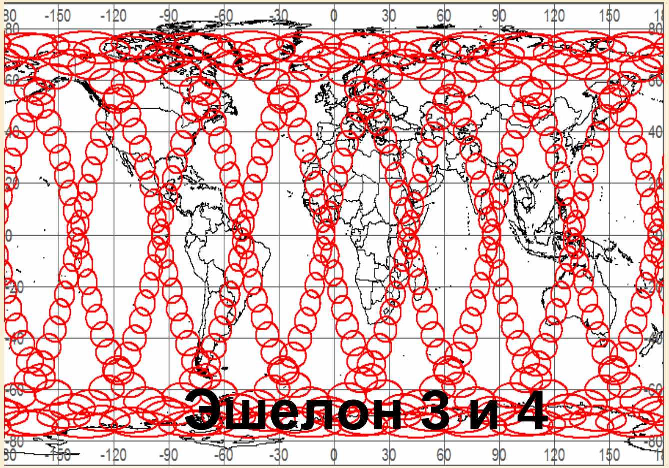


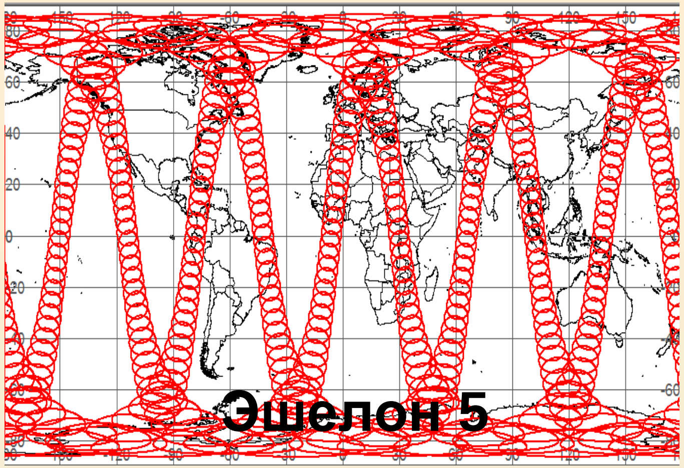
Мгновенная зона радиовидимости системы при УМ=54 град

Проект спутниковой системы ШПД компании SpaceX

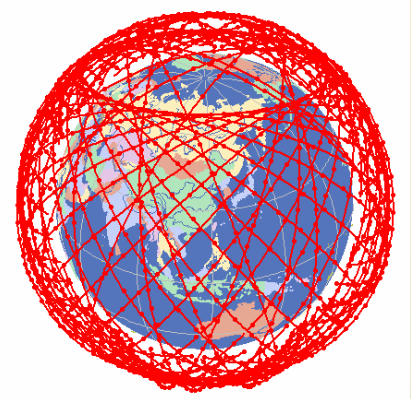
Орбитальная группировка

№ эш.	N пл-ей	N КА в пл	Всего КА	Орбита	
				i, град	h, км
1	32	50	1600	53,0	1150
2	32	50	1600	53,8	1110
3	8	50	400	74,0	1130
4	6	75	450	70,0	1325
5	5	75	375	81,0	1275
Всего	83	–	4425	–	–

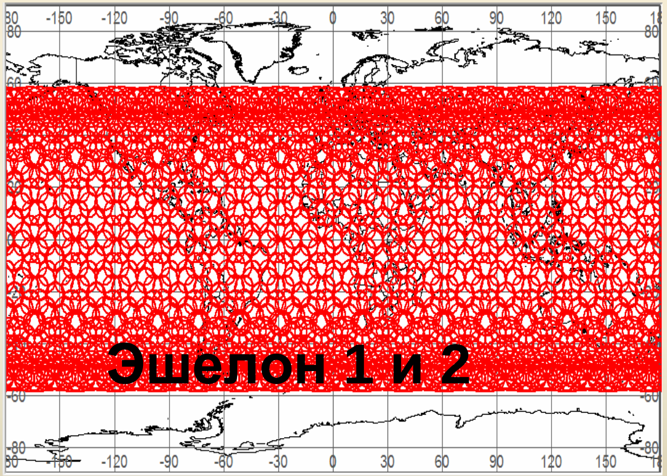




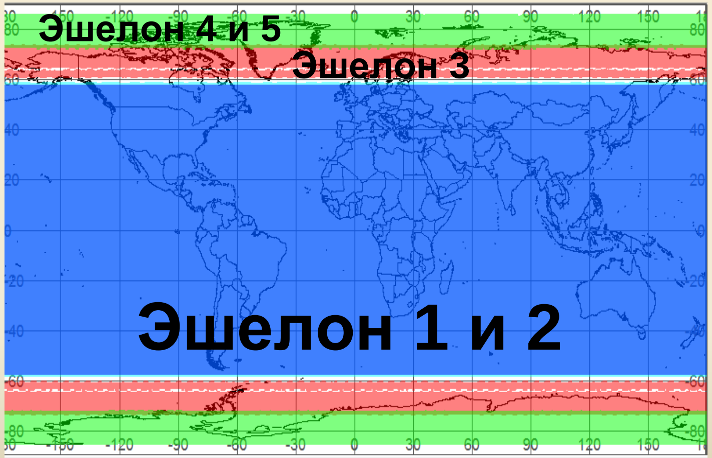
Мгновенная зона радиовидимости эшелонов



Структура ОГ (все эшелоны)



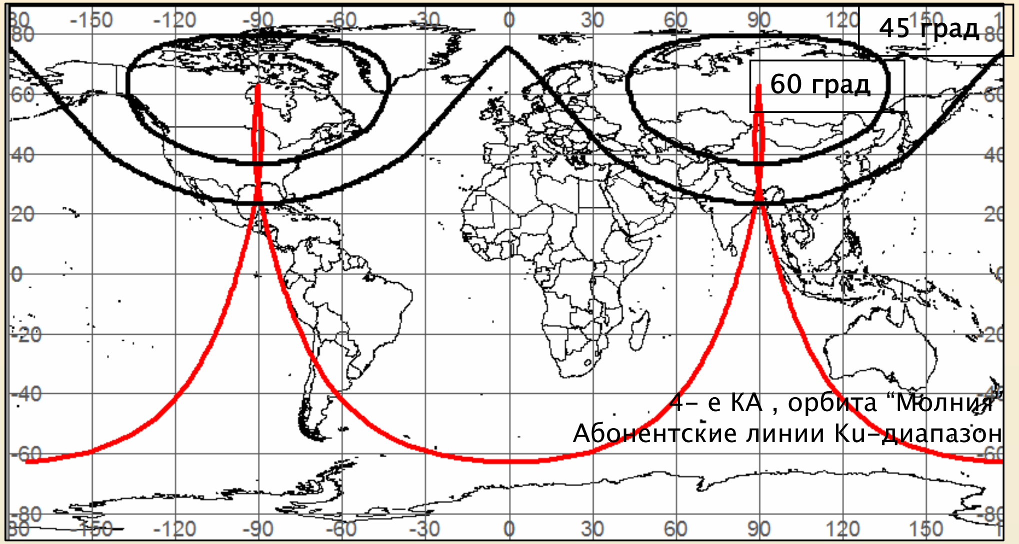
Мгновенная зона радиовидимости эшелона



ГЗРВ системы SpaceX, УМ=60 град.

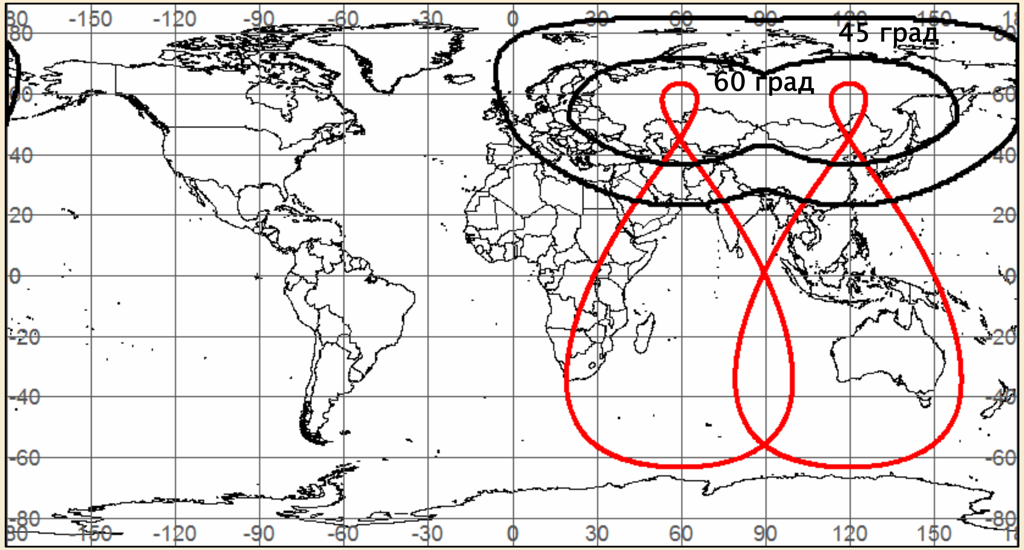
Системы «Экспресс-РВ» и «Росинфоком»

Проект «Экспресс-РВ»



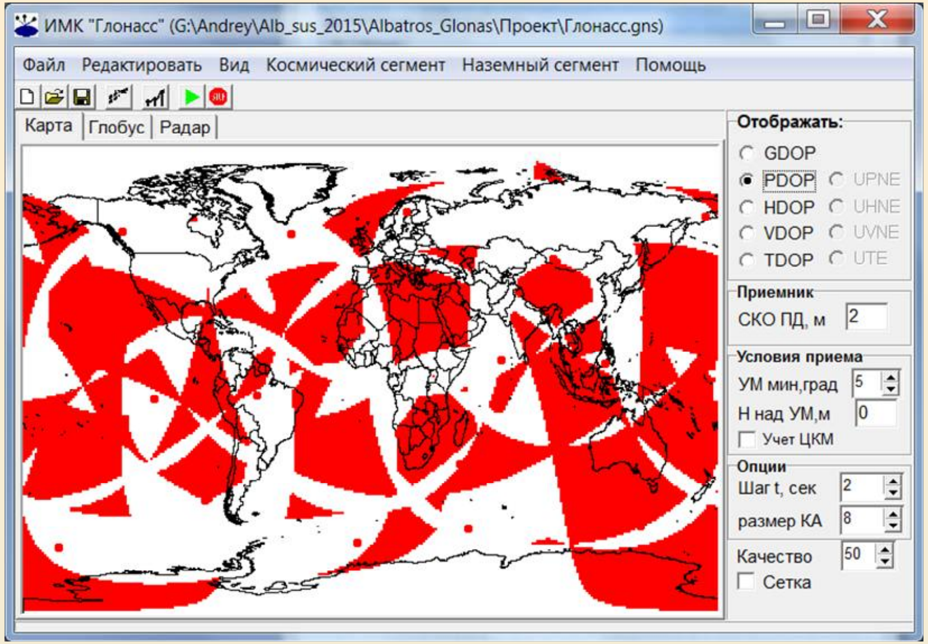
4- е КА , орбита «Молния»
Абонентские линии, Ku-диапазон

Проект «Росинфоком»

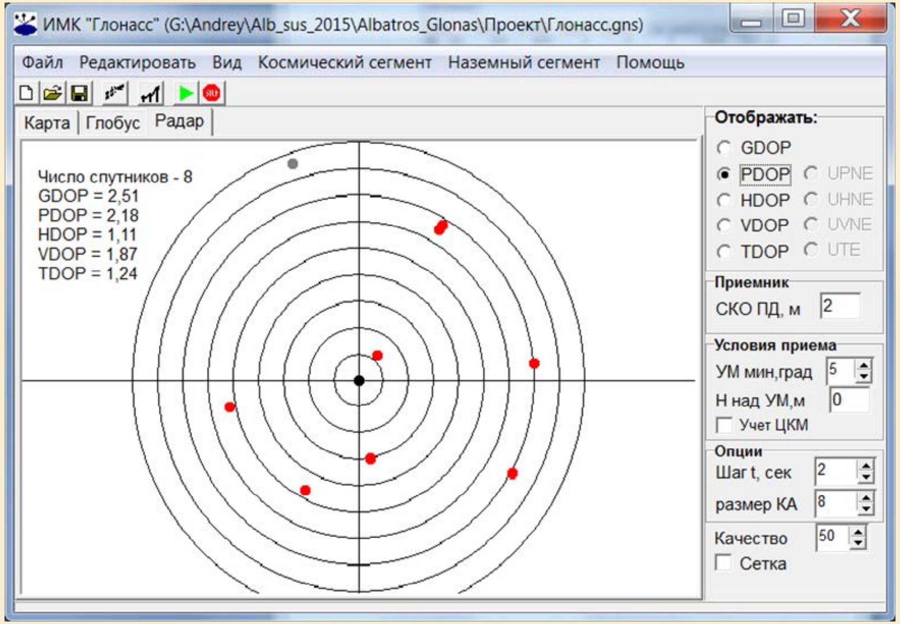


Две группировки по 3-и КА, орбита «Тундра»
Абонентские линии, Ku-диапазон

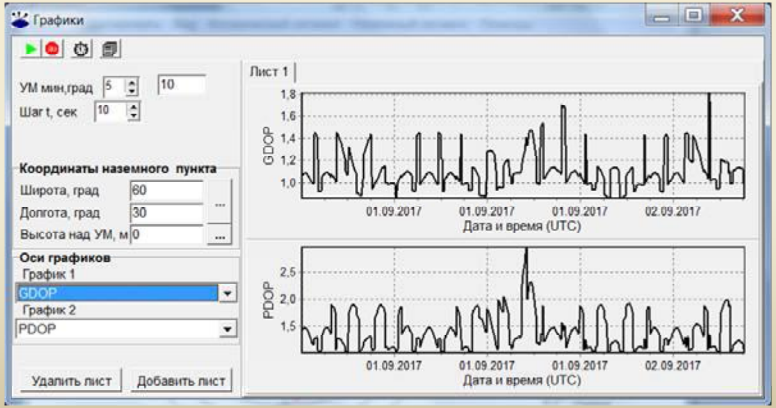
Спутниковые навигационные системы



Карта мгновенного распределения значений параметра «геометрический фактор» (DOP)

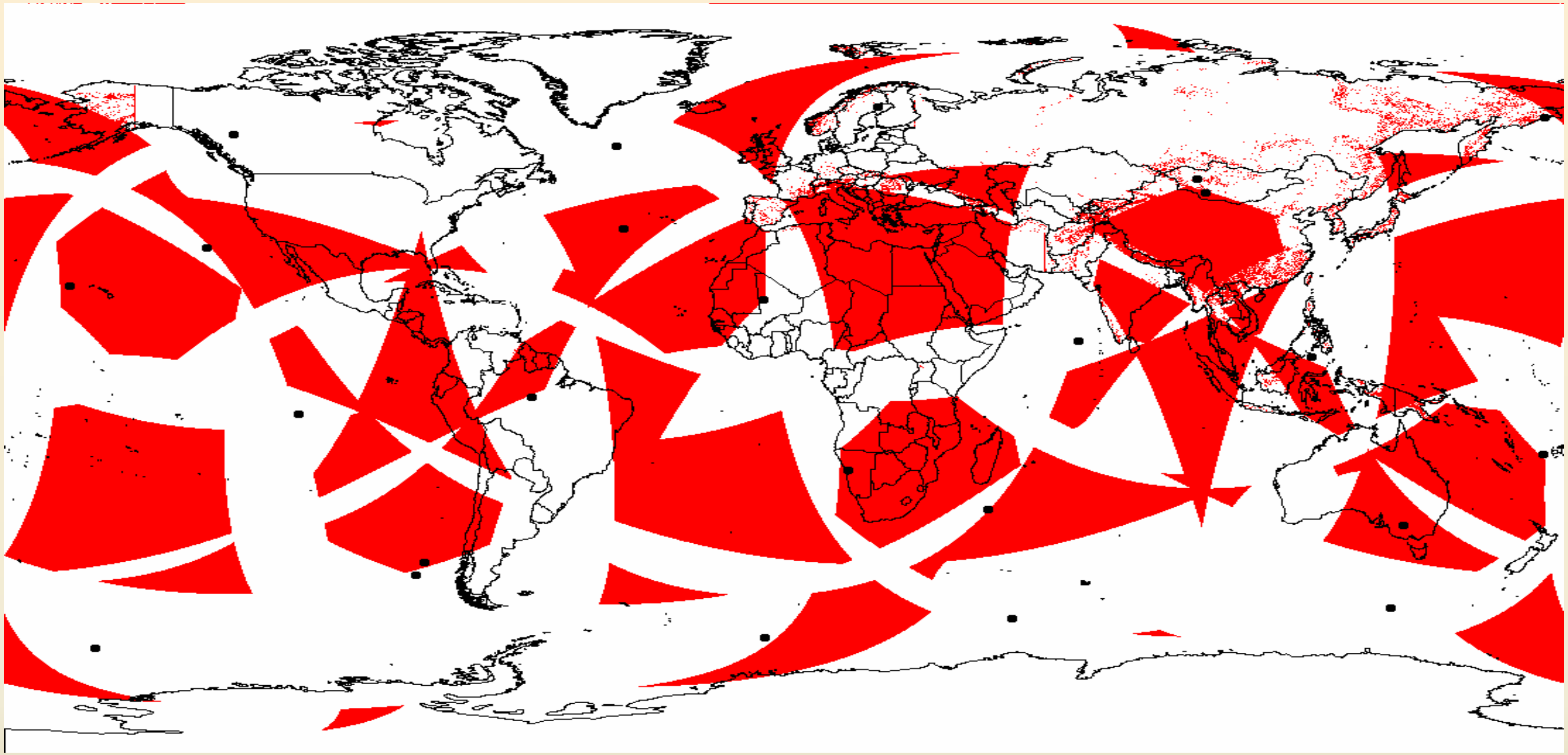


Отображение КА в режиме «Радар»



Построение графика изменения PDOP для конкретной точки

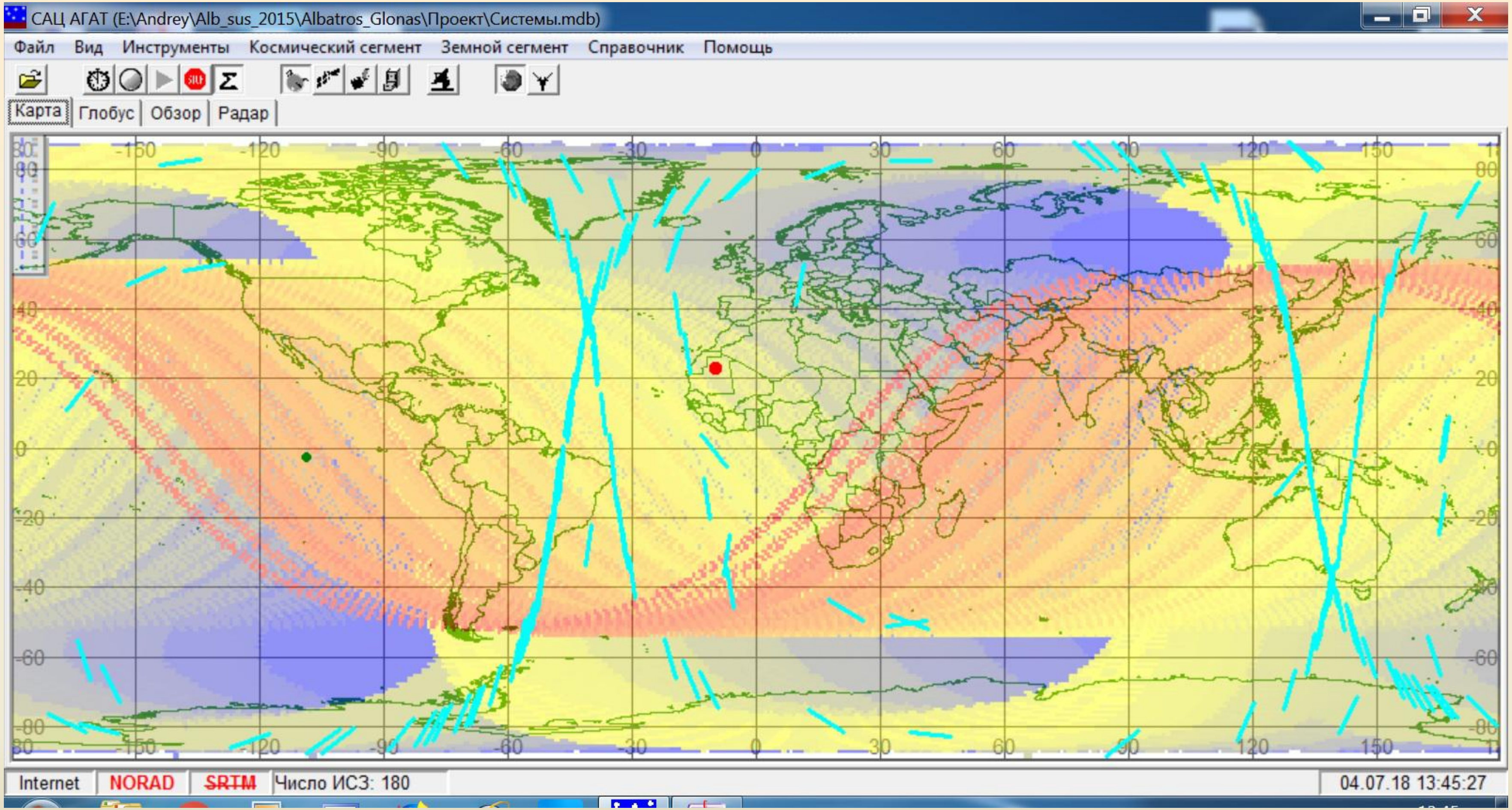
Результаты моделирования работы ГНСС с учетом цифровых карт местности



Минимальный УМ > 5 град, учет перекрытий КА рельефом местности

Моделирование работы системы ДЗЗ

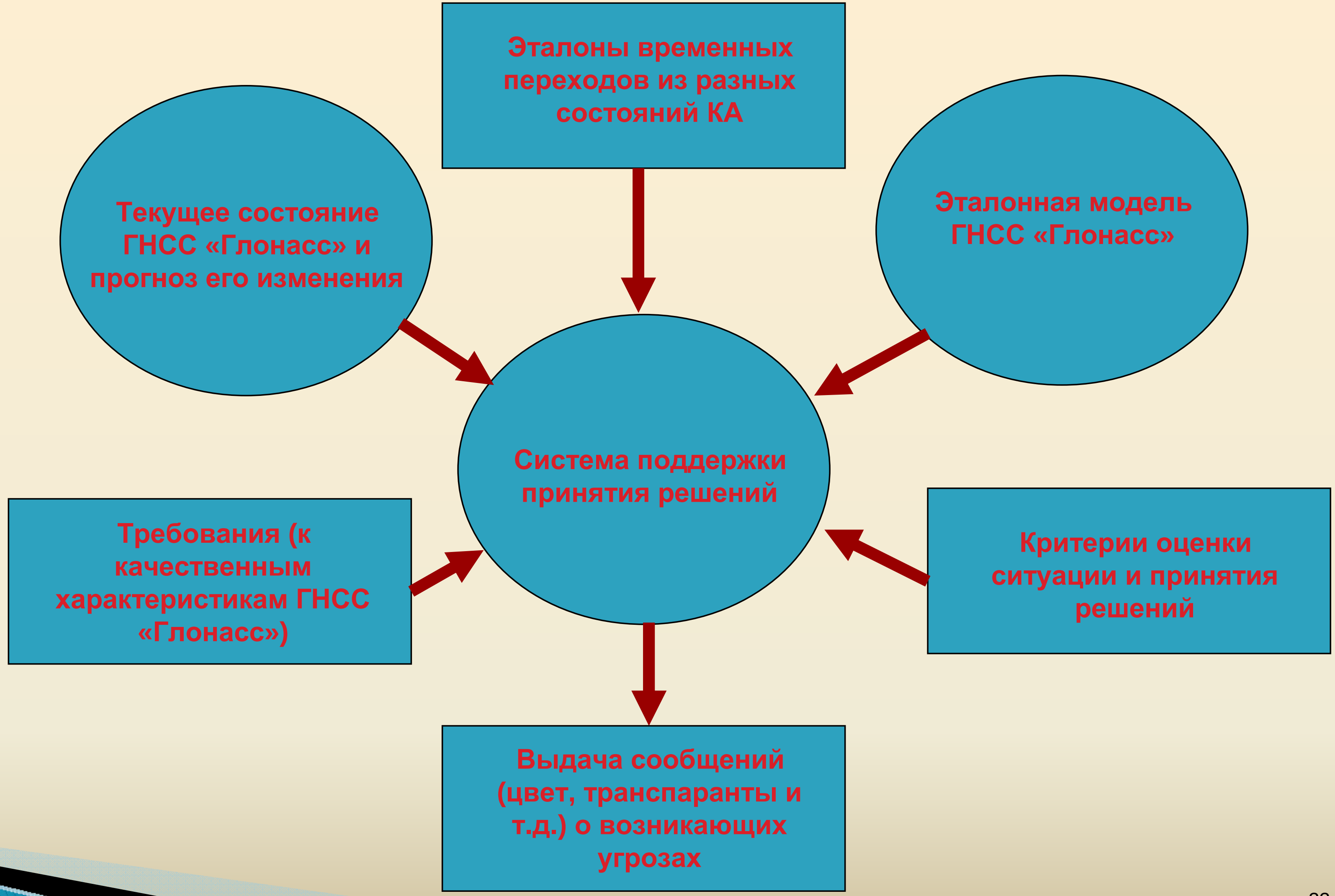
Пример: оценка минимального, максимального и среднего временных интервалов прохода КА разнородной группировки ДЗЗ территории Земли с учетом углов захвата целевой аппаратуры. Цвет – значение интервала времени



Оценка качественных характеристик ГНСС

Моделирование в задачах поддержки принятия решений:

принципы формирования предупреждающих сообщений

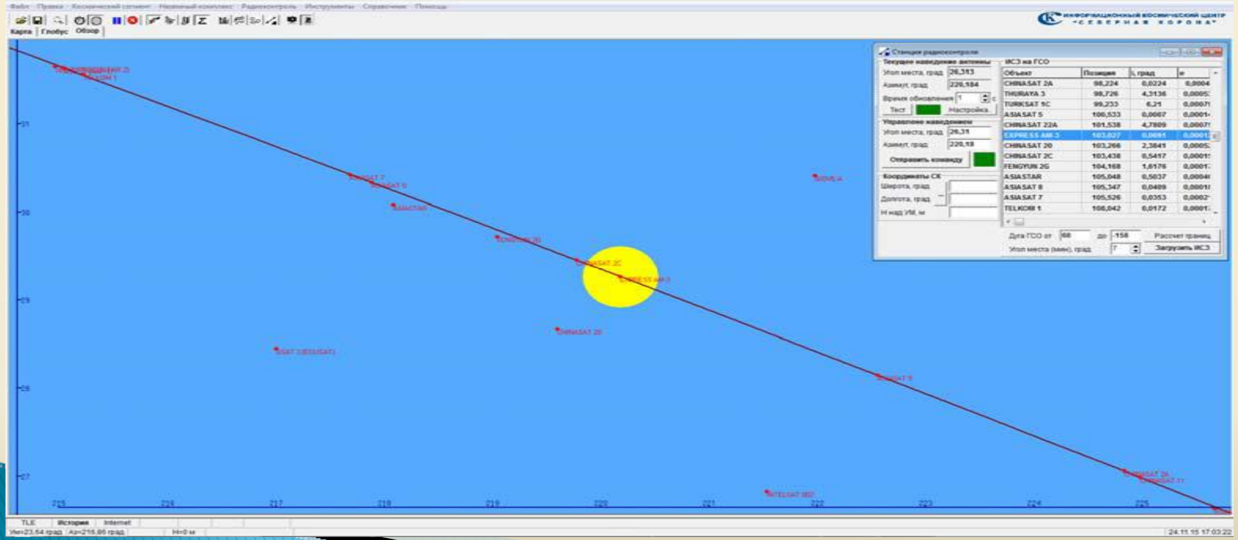


Моделирование в задачах радиоконтроля спутниковых служб

Опыт проработки ситуационного центра в составе РЧЦ ЦФО (СРК г. Хабаровск)

Ситуационный центр в составе СК «Хабаровск» обеспечивает:

- интерактивное отображение ситуации «в луче» антенны, в том числе при изменении ее углового положения;
- оперативный расчет данных целеуказания и выдачу команды наведения;
- автоматическое формирование команды наведения путем указания мышкой на плане объекта контроля (КА);
- ситуационное представление обстановки при планировании и проведении процедур радиоконтроля;
- информационная поддержка (частотно-поляризационный планы, допустимое положение на ГСО и т.д.)



Вид экрана в ситуационном центре

Станция радиоконтроля (г.Хабаровск)

Информационный Космический Центр «Северная Корона»

Спасибо за внимание!

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ИКИ
ИНСТИТУТ
КОСМИЧЕСКИХ
ИССЛЕДОВАНИЙ
РАН

Small Satellites

Microsatellites as a part of the International Space Station Russian Segment infrastructure.

V.N.Angarov, M.S.Dolgonosov, L.M.Zelenyi, S.I.Klimov, V.N.Nazarov, D.I.Novikov, A.A.Petrukovich, V.G.Rodin, and N.A.Eismont

Space Research Institute RAS (IKI), Moscow, Russia

The First International Aerospace Symposium The Silk Road,
Dolgoprudny, Moscow Region, Russia, MIPT, 06-08 December 2018

ИКИ
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

Space Research Institute of the Russian Academy of Sciences (IKI)

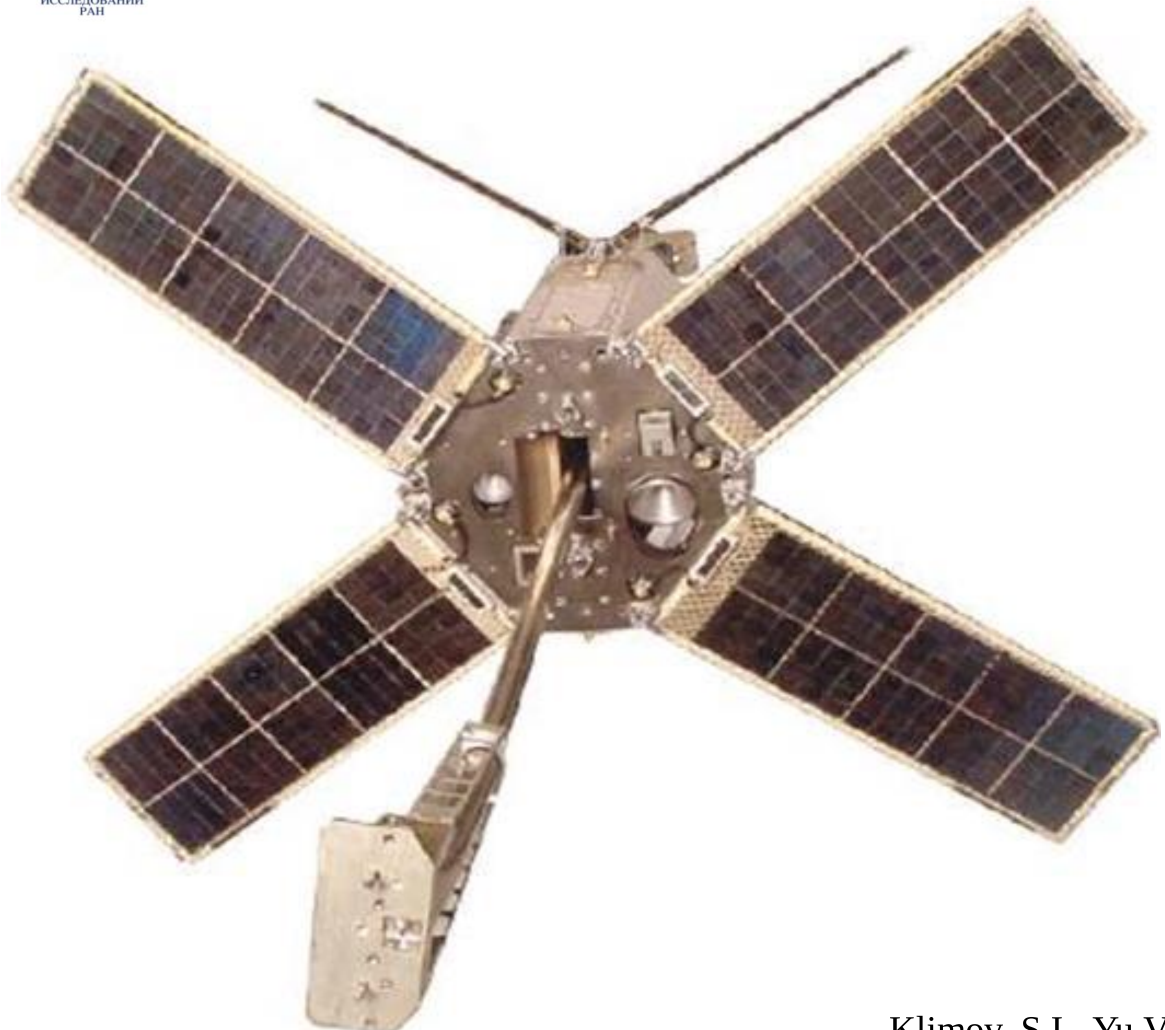
and

S.P. Korolev Rocket and Space Corporation «Energia» (PAO RSC Energia)

has been developed and implemented a joint operation that has resulted in the construction of an experimental microsatellite platform for orbit insertion in the framework of the Russian Segment of the International Space Station (RS ISS) infrastructure.

	Kolibri-2000	Chibis-M	Chibis-AI	Trabant
time of flight	19.03 – 03.05 2002	25.01.2012 – 15.10.2014	2020 – 2022	2020 – 2022
orbit start, km	368-397	489-513	460-520	480-600
total mass, kg	20,5	40,0	40,0	2x60,0
scientific instrument' (SI) mass, kg	3,6	10.8	10,3	2x17,5
transmitter SI, GHz	0,435	2,27	2,2/8,0	2,2/8,0
reset information, Mbit/s	0,002 ???	1,0	S: 0,064 – 1 X: 0,064 – 10	X: 300,0
capacity of onboard storage , Gbytes		0,5		
Accumulator, Ah		9,5	9,5	18,0

“Kolibri-2000” 19.03 – 03.05 2002



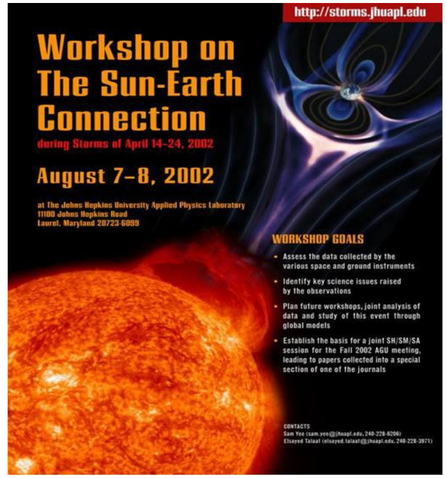
Despite its small size, the microsatellite (MS) “Kolibri-2000” carried 3.6 kg of scientific equipment, which made it possible to conduct a fairly wide range of scientific research in the field of "classical" cosmophysics, and to study space weather, atmospheric and ionospheric processes, presumably associated with thunderstorm activity, manifested in the registration of electrons near the equator, as well as to solve the problems of space education [1].

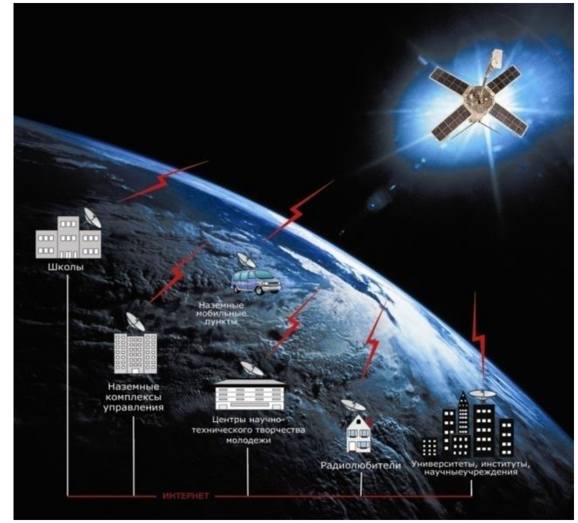
Weight 20.5 kg,
scientific equipment 3,6 kg,
30 W

Klimov, S.I., Yu.V. Afanasyev, N.A. Eismont, E.A. Grachev, O.R. Grigoryan, V.A. Grushin, D.S. Lysakov and M.N. Nozdrachev. Results of in-flight operation of scientific payload on micro-satellite “Kolibri-2000”, ***Acta Astronautica, Volume 56***, *Issues 1-2*, January 2005, Pages 99-106, **2005**

ИКИ
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

Space education.





Knox School (Sydney). Opening of the colloquium. The school Director welcomed the School Russian delegation 09.08.2000.

School "Helios" IATE (Obninsk, Russia). Discussion of the scientific results of the project “Kolibri-2000".

ИКИ
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

"Chibis-M"
25.01.2012 – 15.10.2014

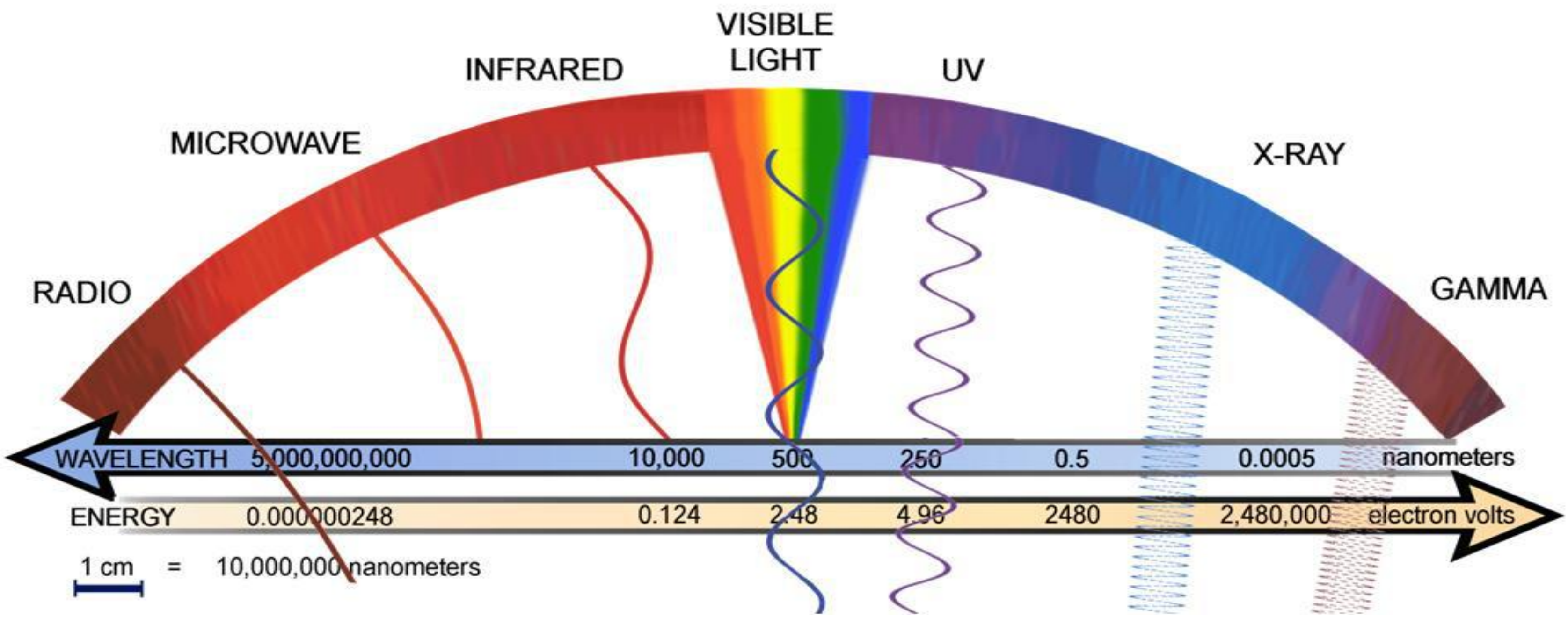
Study of physical processes during the atmospheric lightning discharges conducted using complex of scientific equipment-KNA "Groza", which has been installed on the RAS microsatellite "Chibis-M"

"Chibis-M"

Studies of atmospheric lightning.

For the study of new physical processes in high-altitude atmospheric lightning discharges and mechanisms for their preparation requires a comprehensive study of gamma radiation, infrared and ultraviolet radiation, of electromagnetic waves in a wide frequency range with an unprecedented high (better share microseconds) time resolution.

Since gamma-rays, IR and UV radiation is strongly absorbed in the atmosphere, the land of studies of such processes is very limited. Optimal is their study using low-orbit spacecraft (SC). Unique across the width of the spectrum of the studied electromagnetic radiation, the world's first target Observatory, was created in IKI in cooperation with other academic and University organizations, including international, in the form of complex scientific equipment (KNA) “Groza".



"Chibis-M"

Studies of atmospheric lightning.

Complex of scientific instruments "Groza" - 10.8 kg.

- roentgen-gamma- detector [RGD] (NIIYaF) for registering the splashes of X-ray and gamma-radiation (range of photon energy 0.02-1.0 MeV);
- ultraviolet detector [DUF] (NIIYaF) for registering the splashes of the atmospheric of ¬ ultraviolet (wavelength range 180-400 nm) and red (650-800 nm) emissions;
- radio-frequency analyzer- register [RChA] (IKI) in the radio-frequency band (input frequency 26-48 MHz), analysis and registration on board KA of the electrical activity of the high-altitude lightning discharges;
- digital camera [TSFK] (IKI) with the spatial resolution 300 m for observing the thunderstorm atmospheric discharges;
- magnetic- wave complex [MWC] (IKI, L'vov center IKD NANU-GKAU and the Eotvos University, Budapest] for studying the electromagnetic parameters (frequency band 0.1-40 kHz) and the interrelation of plasma- wave processes in the ionosphere;
- accumulation of data [BND – Ch] (IKI) with the memory of two blocks on 256 Mbytes for the collection and primary information processing, which enters from the transmitter of scientific information from the complex of scientific instruments (IKI);
- transmitter at the frequency 2.2 GHz with a speed of up to 1 Mbit/s and at the distance to 2500 km.

"Chibis-M“

For delivery of the MS on the ISS and subsequent MS separation from TCV are used transport-launch container (TLC).

TLC "Chibis-M". Right - comparizen TLC "Kolibri-2000" (left) and "Chibis-M". Due to the thicker the line the Chibis-M" (mass of 40kg.), volume TLC was increased by 10% compared with TLC "Kolibri-2000" (mass 20.5 kg).

Installation of a microsatellites"Chibis-M" in the TLC.

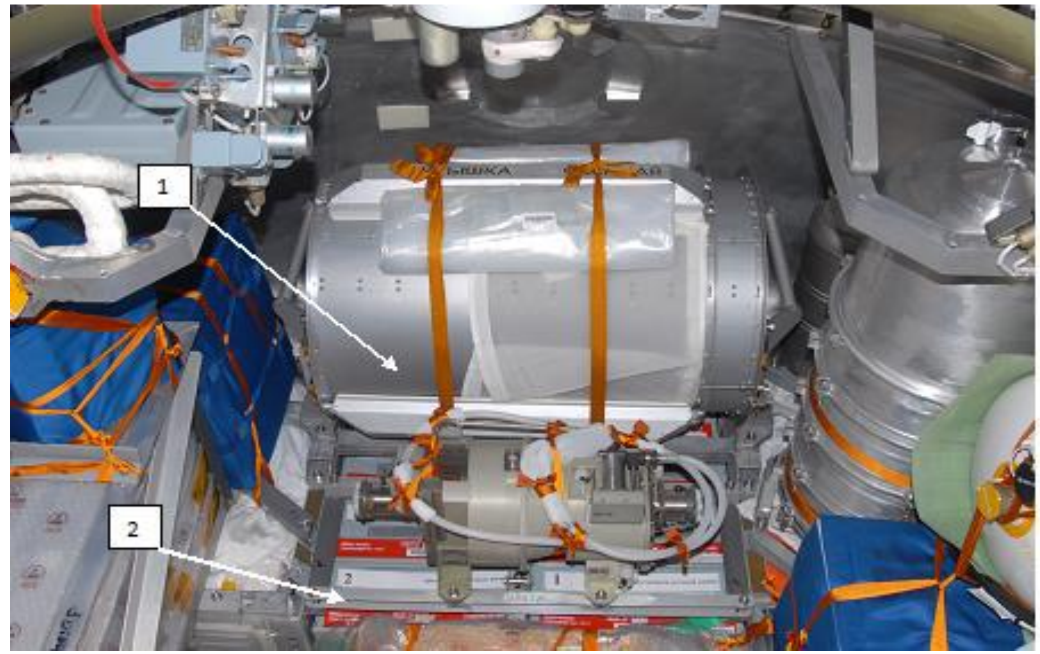
ИКИ
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

РАКЕТНО-КОСМИЧЕСКАЯ КОРПОРАЦИЯ ЭНЕРГИЯ ИМЕНИ С.П. КОРОЛЕВА

“Kolibri-2000”

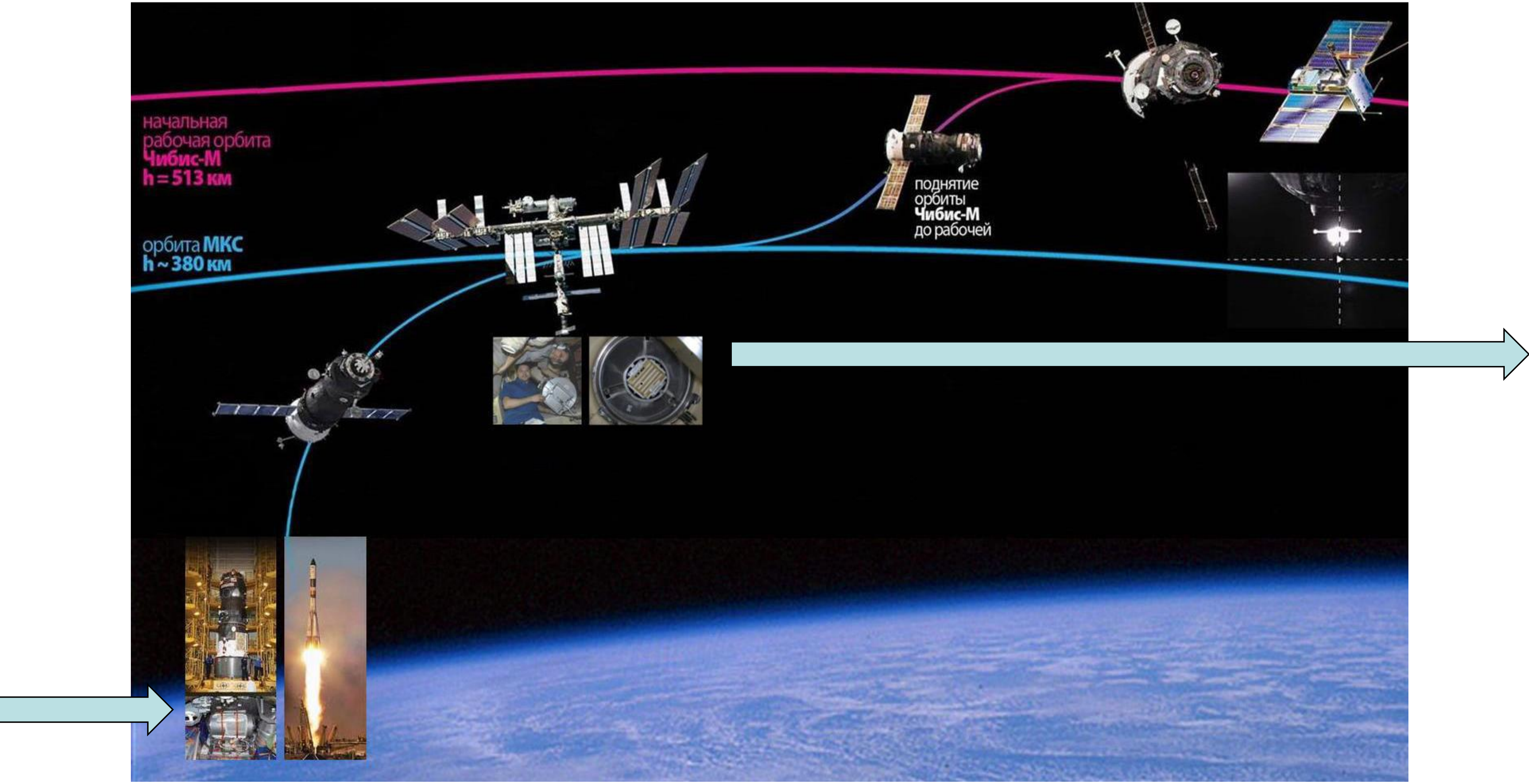
Specificity of space experiments in the infrastructure of the ISS by using the ship "Progress".

Baikonur 2001. TLC with "Kolibri-2000" on the conveyor frame "Progress M1-7.



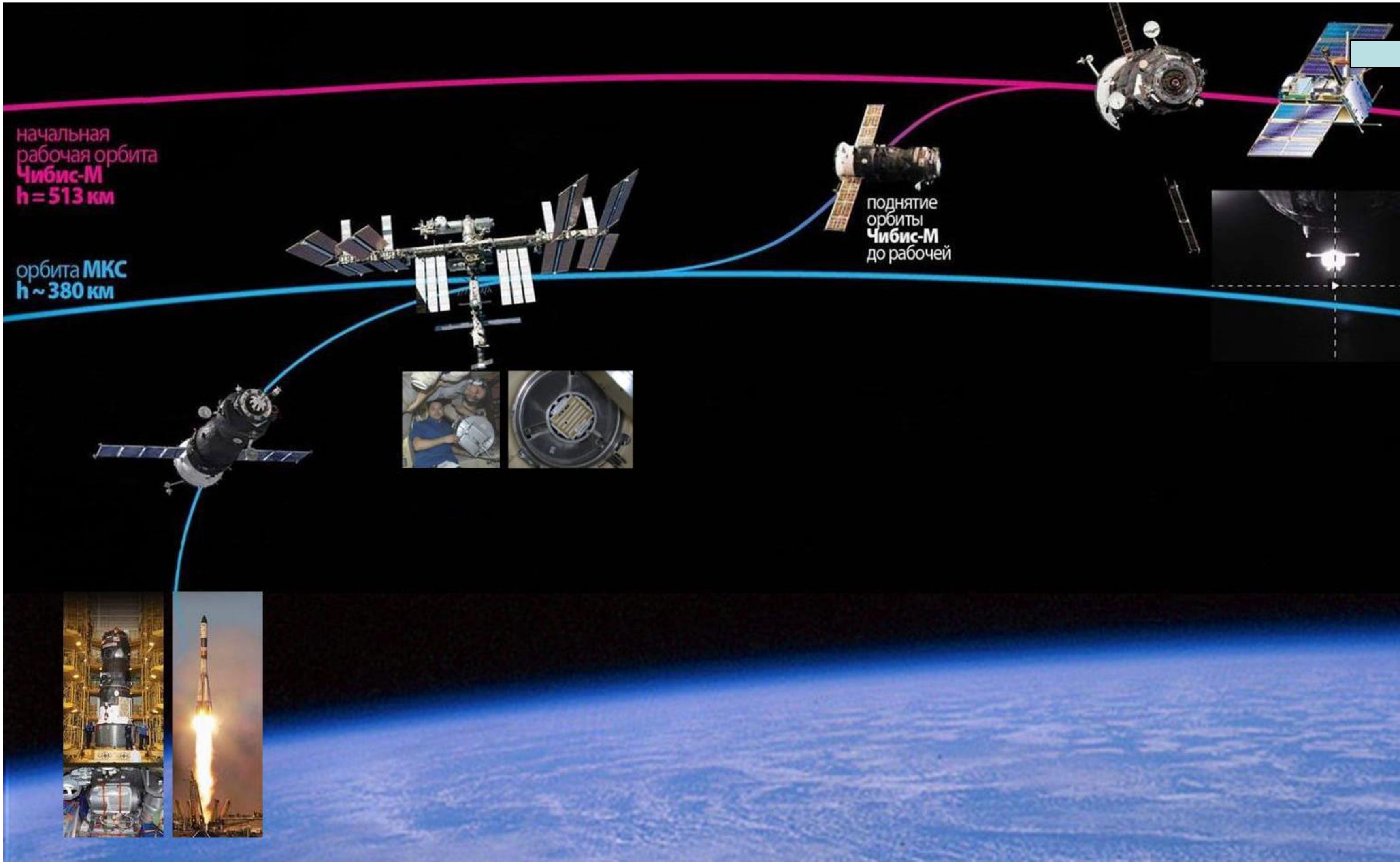
Baikonur 2011. TLC "Chibis-M" on the conveyor frame in Progress M-13M".

On the experience of space experiments with MS the "double start" technology was developed and implemented "for the first time in the world" with the flight of the Progress spacecraft to a higher orbit (from 380 to 500 km), which increases the residence time of MS in orbit almost in 2 times.

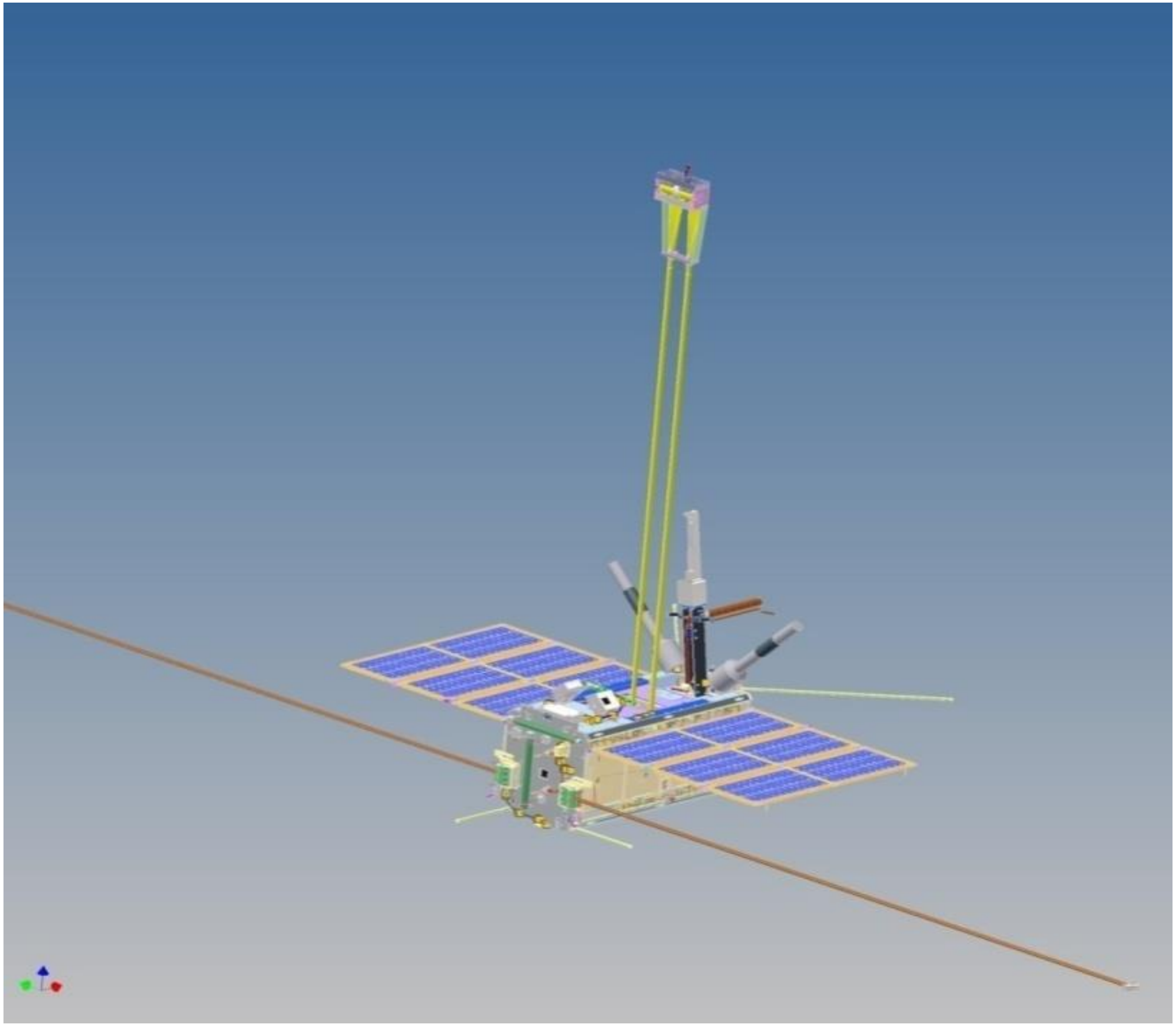


ИКИ
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

The ISS RS. Cosmonauts O. Kononenko and A. Shkaplerov conduct preparatory work with TLC "Chibis-M".


начальная
рабочая орбита
Чибис-М
h = 513 км
орбита МКС
h ~ 380 км
поднятие
орбиты
Чибис-М
до рабочей

"Chibis-M“ http://chibis.cosmos.ru



Weight 40 kg, scientific equipment 10.8 kg, 50 W

ИКИ ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

"Chibis-M“

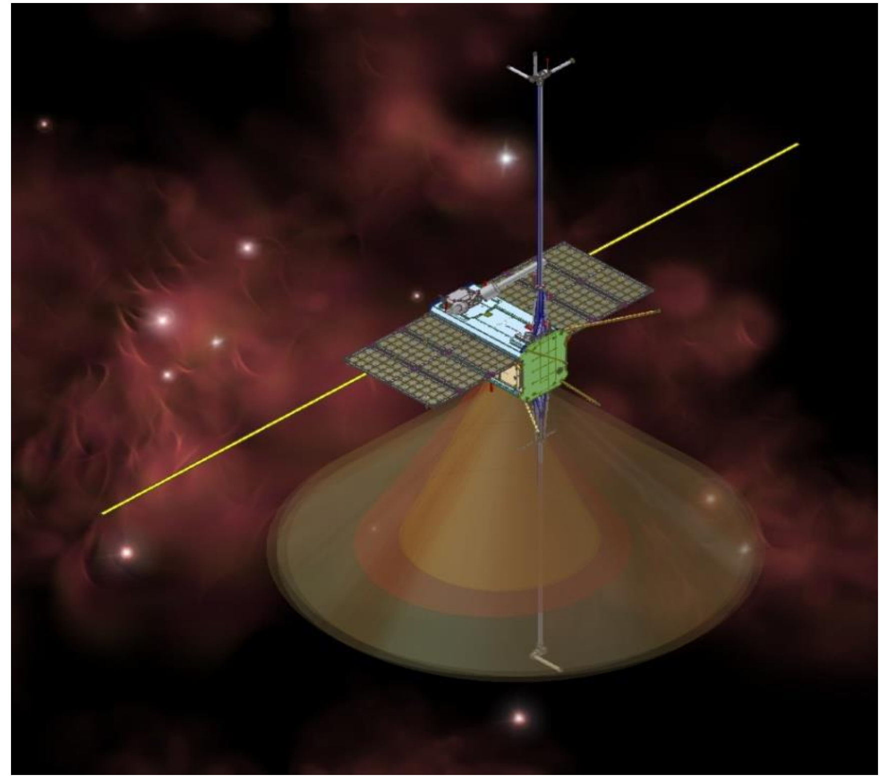
In IKI for ~ 3 years as a whole successfully operate the segments:

cosmic

"Chibis-M“

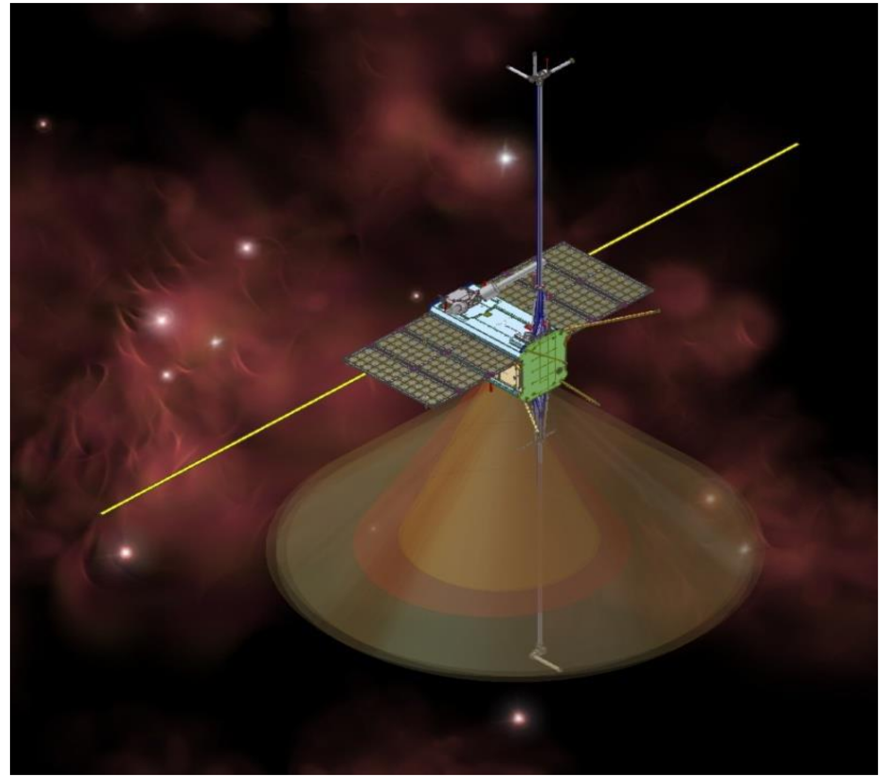
In IKI for ~ 3 years as a whole successfully operate the segments:

cosmic



"Chibis-M“

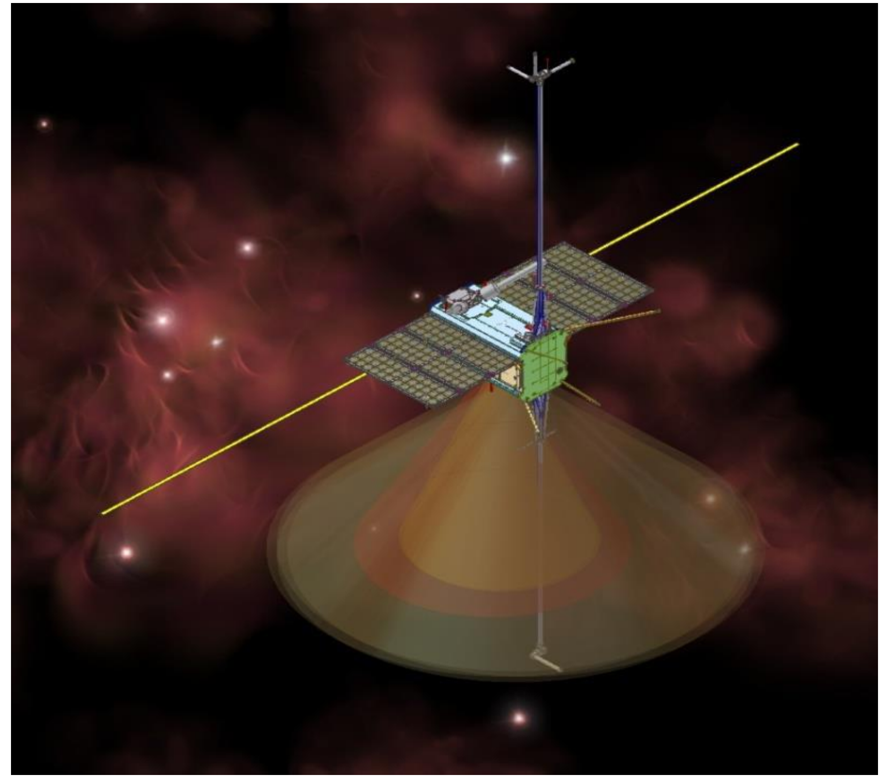
In IKI for ~ 3 years
as a whole successfully operate
the segments:



cosmic

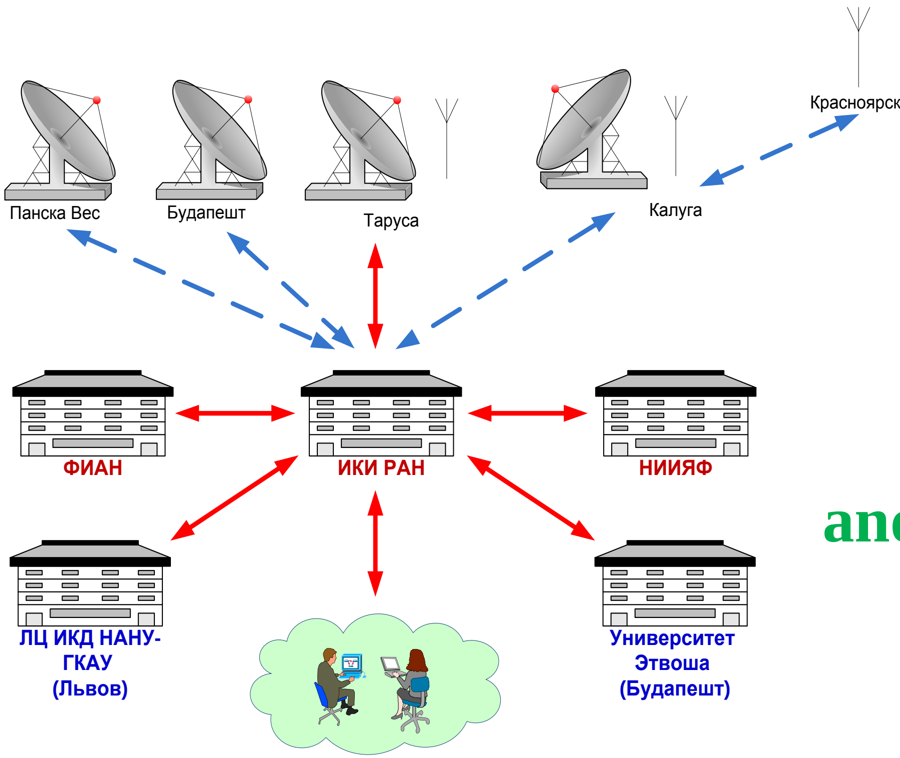
and ground

"Chibis-M“



In IKI for ~ 3 years as a whole successfully operate the segments:

cosmic

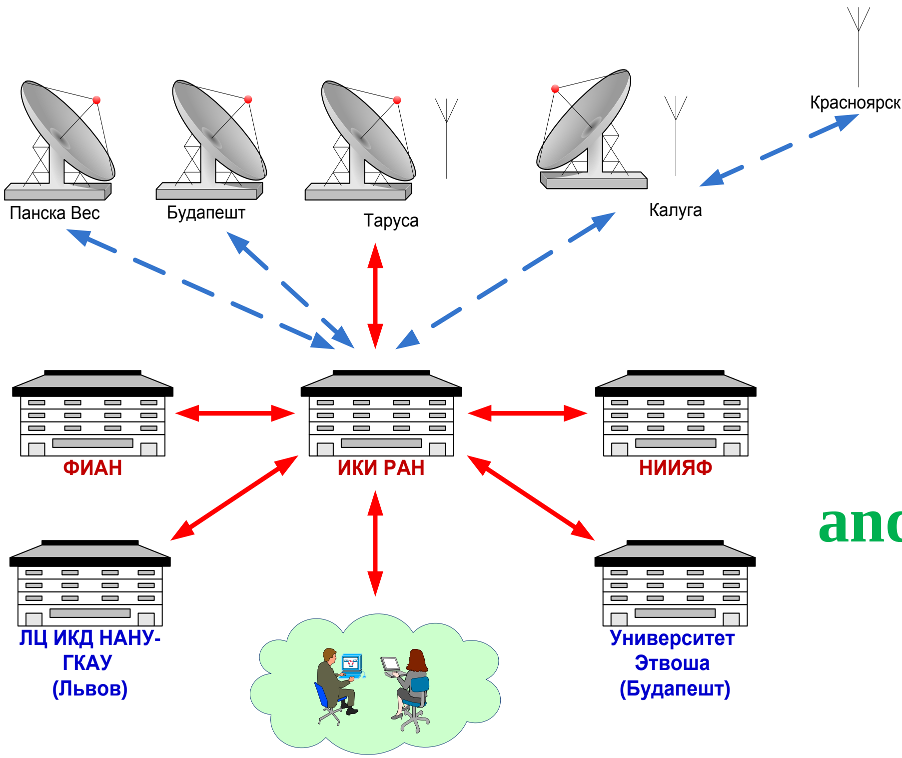


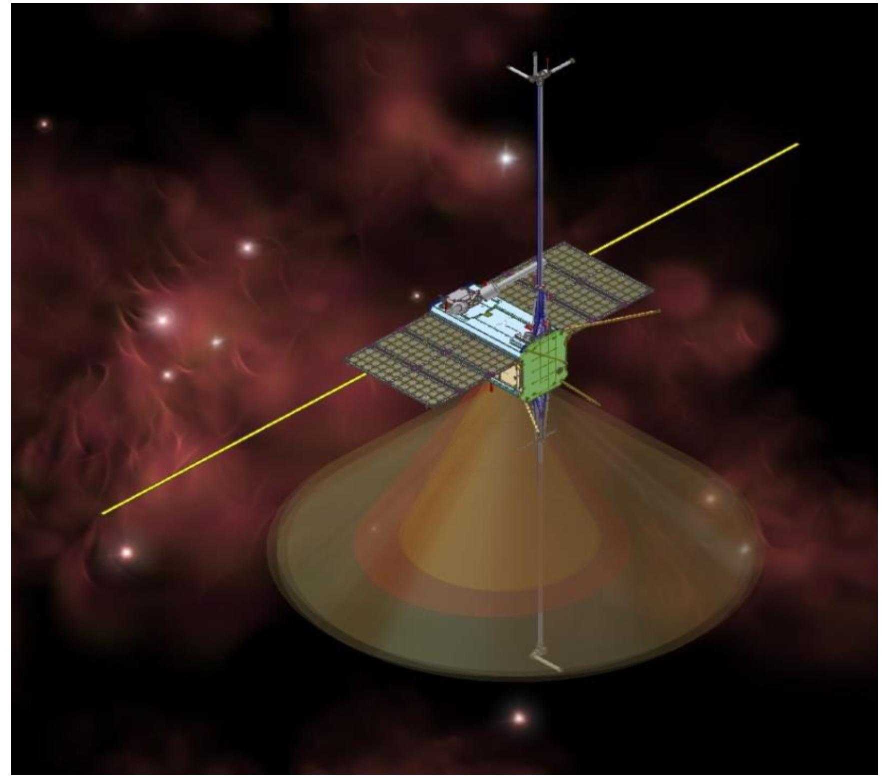
and ground

"Chibis-M“

In IKI
for ~ 3 years
as a whole
successfully operate

cosmic

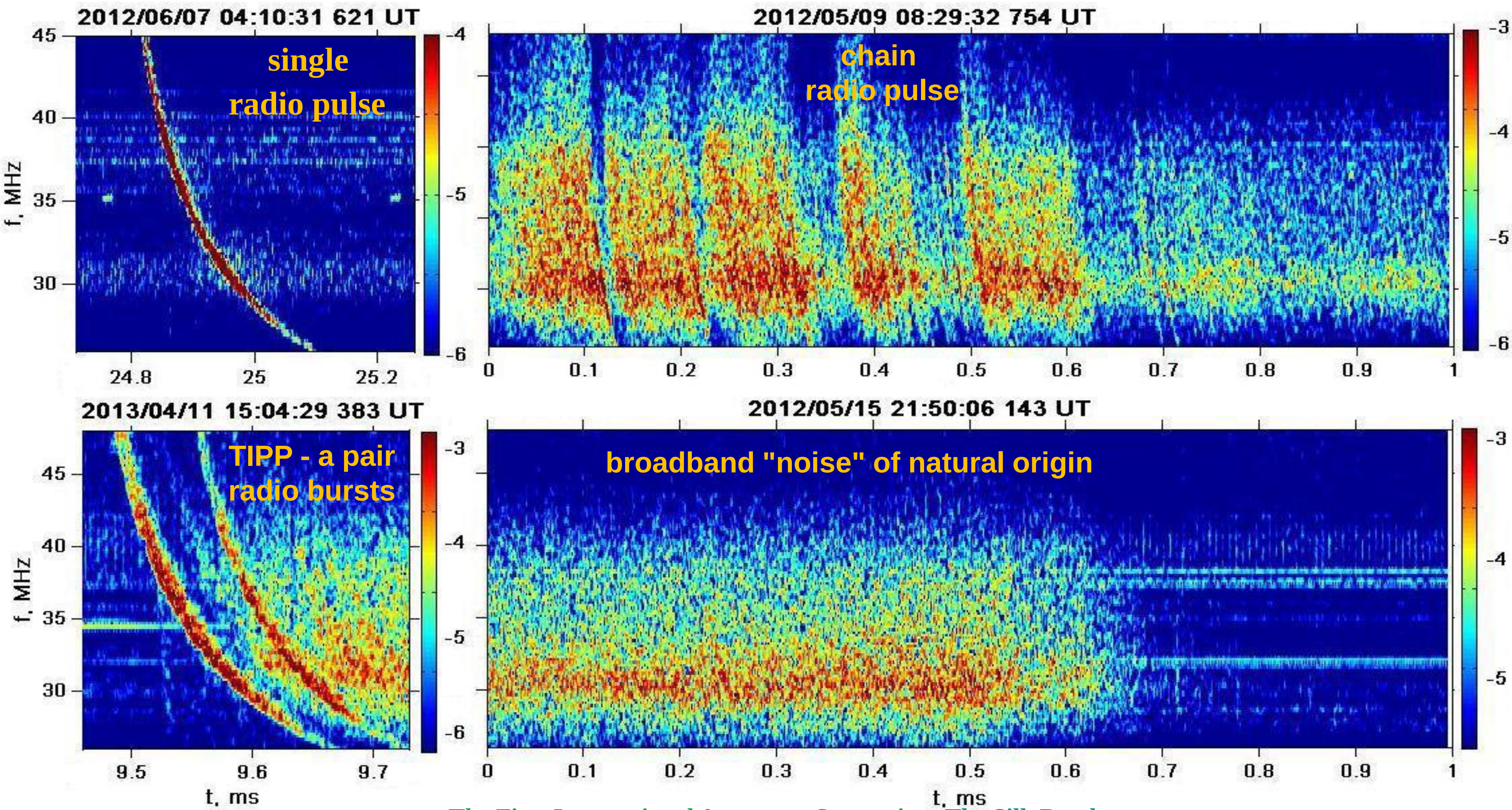




and ground **segments**

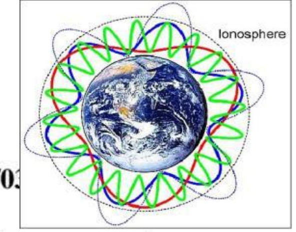
"Chibis-M“

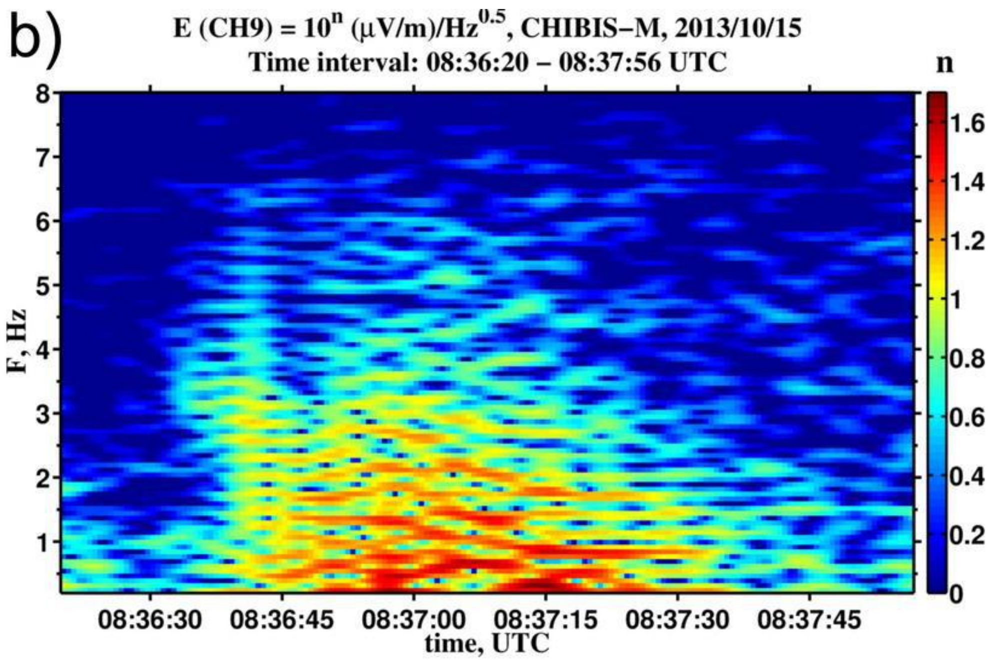
Over the past ~3 years of operation "Chibis-M" recorded several hundred RFA trigger operations, of which more than a hundred associated with short and powerful lightning discharges, also recorded by the sensor of ultraviolet and infrared radiation (DUF).

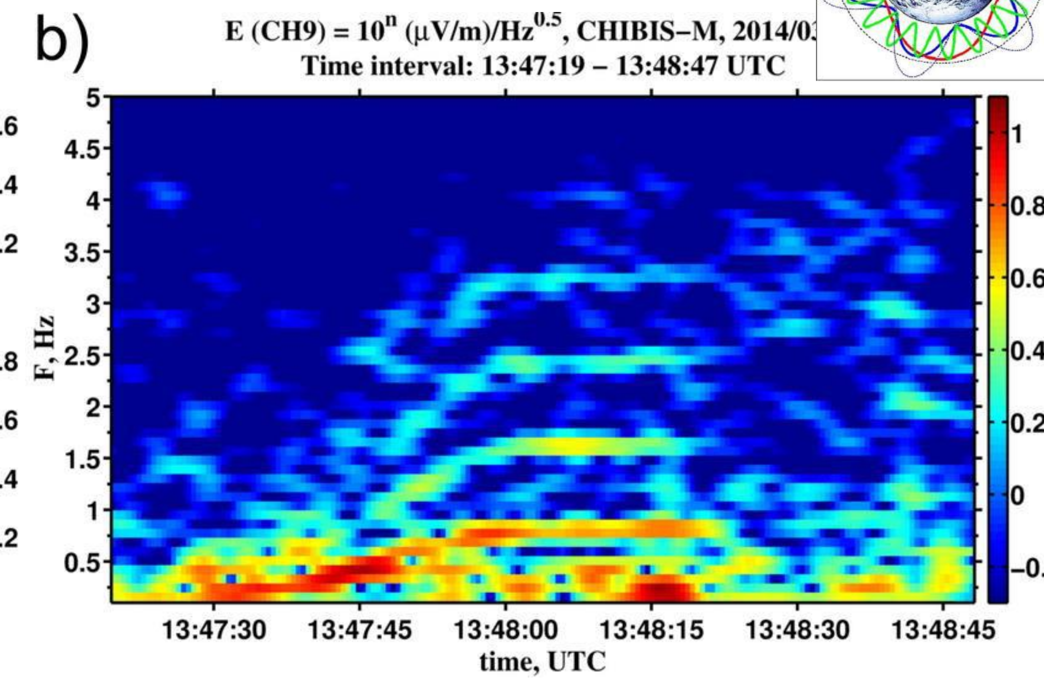


ИКИ
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

"Chibis-M“





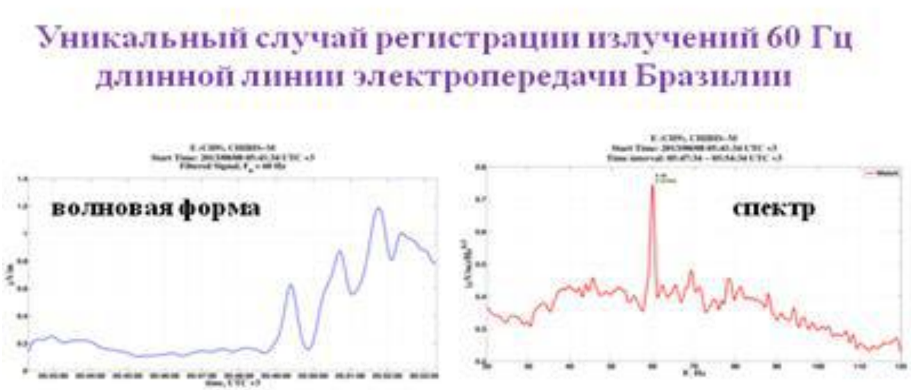


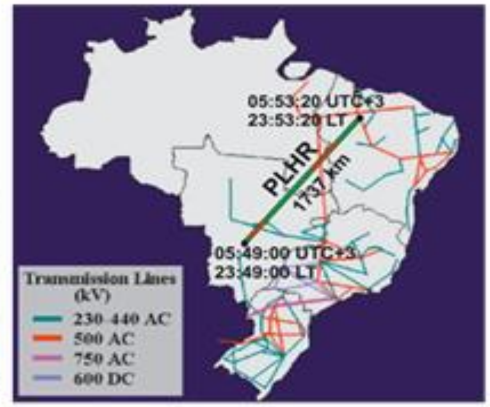
The fact of registration of low-orbit satellites of the Schumann resonance (ShR) gives grounds to assert that the waveguide Earth-ionosphere must be described in the framework of the resonator losses, which allows leakage of ULF waves in the ionosphere. Detection of ShR on "Chibis-M" at local night time is associated with a decrease in the absorption of ELF radiation in the lower layers of the ionosphere. Thus, the electromagnetic coupling of atmospheric and man-made processes with the near-earth environment is more effective than previously thought.

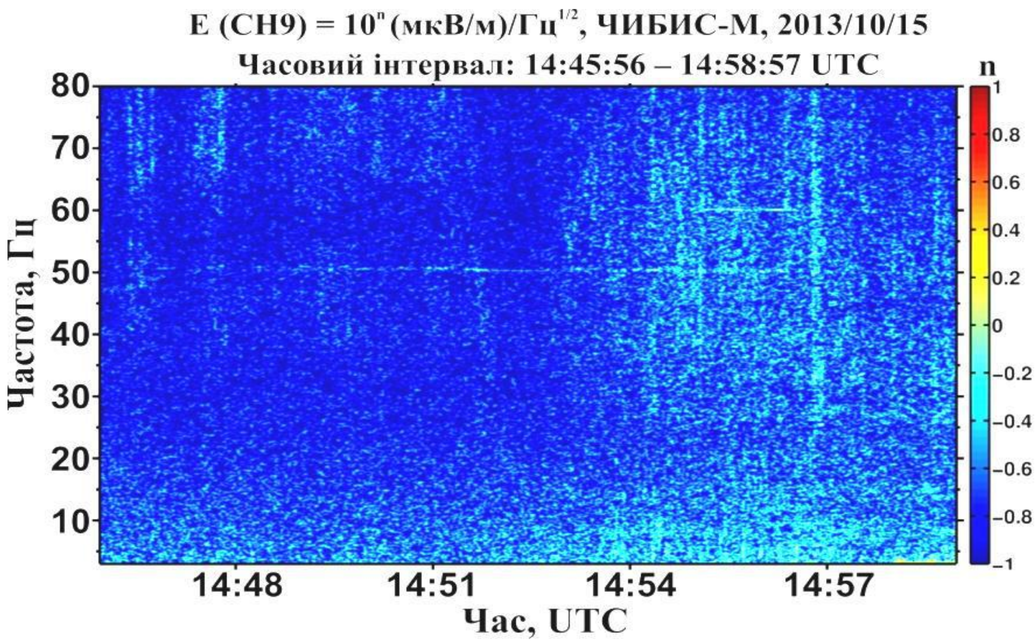
Electromagnetic structures, such as ShR or ionospheric Alven resonator (IAR), are an indispensable part of the cosmic environment of the planets, having as the Earth, ionosphere and signs of electrical thunderstorm activity (Venus, Jupiter, Saturn, Neptune, etc.), which opens up the possibility to use these experiments as a test site for the development of new remote methods for studying thunderstorm activity in the atmospheres of the planets of the solar system.

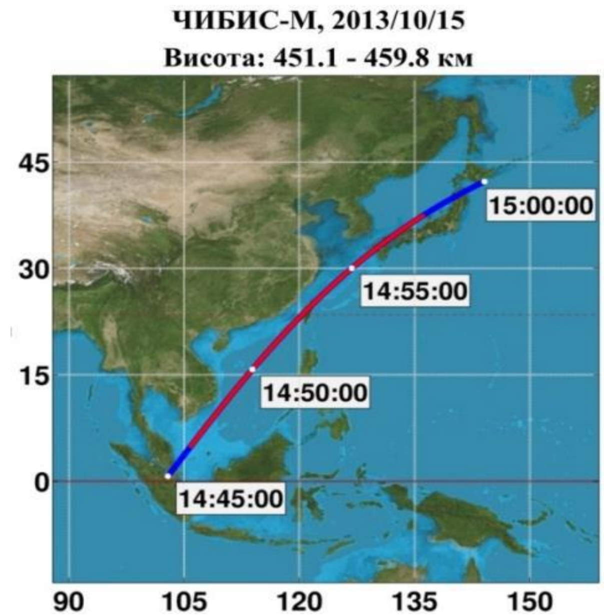
"Chibis-M“

Unique data on extremely low-frequency (ELF) electrical fluctuations reflecting the effect of long power lines (50-60 Hz) were obtained in the ionosphere.









"Chibis-M"

Direct measurements of the KNA "Groza" showed that the characteristic conditions arising in the electrified thundercloud, due to their large dimension are not reproducible in the laboratory.

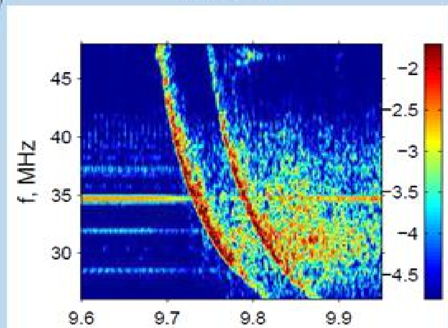
The results of measurements showed the need to take into account the fractal properties (δ-fractals of time series and spatial D-fractals) of charge distribution in the cloud and percolation effects of discharges in a heterogeneous turbulent environment, which previously paid little attention in the study of atmospheric electricity.

«Chibis-AI»

What is known at the moment:

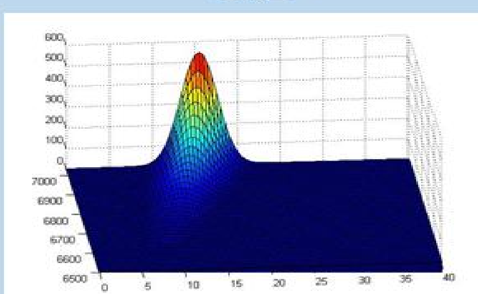
- **3000 events in the gamma range (BATSE, RHESSI, Fermi, AGILE, CORONAS-Photon and Vernov);**
- **1 in synchronous gamma - two different SC;**
- **1 in synchronous gamma - ray optics and different SC;**
- **NO simultaneous observations at gamma - ray and radio!!!**

TIPP



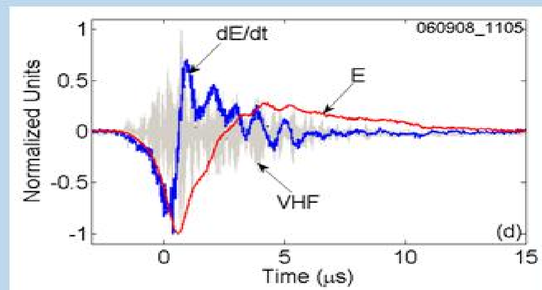
Trans-Ionospheric Pulse Pair

CID

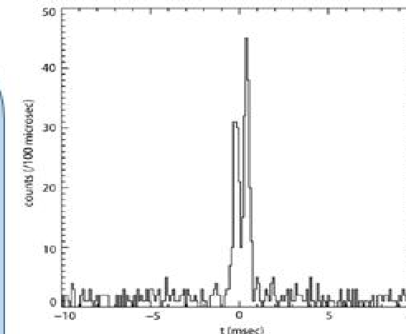


Compact Intracloud Discharge

NBP



Narrow Bipolar Pulse



TGF

Terrestrial Gamma-Flash

"Chibis-M"	"Chibis-AI"	Note
Service system. - Mass, kg - **40** - Mass SI, kg - **10.8** - Cristal cells – **gallium arsenide** -Accumulator, Ah - **9.5** - Orientation system accuracy - **angle.hail units** - Event trigger generation - **from 3 devices**	Service system. - Mass, kg - **40** - Mass SI, kg - **11.4** - Cristal cells – **gallium arsenide** -Accumulator, Ah - **9.5** - Orientation system accuracy - **angle.hail units** - Event trigger generation - **from 3 devices** - MS sample for precision EMC test	**In the "Chibis-AI":** **- increase in observation time;** **- improving the quality of measurements;** **- positioning devices** **- improving the reliability of trigger events, the accuracy of the mutual temporal reference data is not lower than 1 µs**

Hardware complex "Trabant"

Main scientific tasks

Satellite observations, a powerful tool for diagnosing ionospheric plasma, now require increasingly accurate and highly informative instruments. The study of the structure of the ionosphere and the phenomena affecting its state is important both for understanding the physics of the processes occurring in it and for solving various radiophysical problems.

High spatial and temporal resolution of the concentration measurements of the ionospheric plasma, and the spectrometer spectral range of its fluctuations are of high scientific relevance for the global monitoring of the ionospheric plasma. The use of this class of equipment in satellite experiments will allow to accumulate an array of data with sufficient global and temporal overlap for various Geo/Heliophysical conditions, which are important in scientific research to deepen fundamental knowledge about the physics of processes in the ionosphere

Hardware complex "Trabant"

MWC-T must fulfill the following scientific objectives:

□ registration of ***magnetic and electric field*** from the SIM-T and EP-T for the four inputs in the range from ***0.1 Hz to 100 kHz*** with the sampling frequency (programmable) 5 to 200 thousand points per second (default 100 thousand points per second);

□ registration of ***magnetic field*** from the FGM-T for the three inputs in the range ***DC – 125 Hz***;

□ onboard frequency-time signal processing and dynamic spectrum formation in the range from 0.1 Hz to 100 kHz for electric and magnetic field.

DPP-T controlled the following parameters:

□ plasma density Ne in the range from 10*3 to 10*6 cm*-3;

□ plasma density fluctuations in the range from ***1 to 40000 Hz*** with an amplitude of not less 10*3 cm*-3.

The sensitivity of the radio track **RFA-T** in the frequency band from ***15 to 48 MHz*** should be not worse than 30 mV at a signal / noise ratio of 6 dB and at frequencies below 15 MHz not worse than 200 mV.

FIEC-T to measure the integrated electron density between the two MS, equipped with identical instruments FIEC-T, at distances from 100 m to 10 km. Range of measured values of the integral of the plasma ***electron density of the 10*2...10*6 cm*-3***. The measurement accuracy is not worse than 10 cm-3. Time of measurement of the electron concentration ~1 m s.

BAES-T is intended for registration of ***electrons in the energy range from 1 to 10 keV***. Sensitivity shall allow measurements at a frequency of 10 Hz at a particle flow value of at least 10*7 cm*-2.·s*-1. Energy resolution shall be not less than 10 %.

ARIES-T to register positively charged particles in the ***energy range from 10 to 5000 eV*** with the ability to measure the elemental composition of the particle fluxes, studies: characteristics and dynamics of the magnetospheric plasma; distribution functions of magnetospheric ions, especially ***H+, He+ and O+;*** interaction of ions with plasma waves and diagnosis of wave processes; energy resolution 15%; mass range: from ***1 to 100 e.m***; the mass resolution of at least 20 to 1кэВ.

Hardware complex "Trabant"

Two-point measurements

At the stage of the Preliminary design, the methodical aspects of the space-time resolution of the plasma-wave parameters of the ionosphere with the help of two copies of the MS "Trabant", each with a gas-jet propulsion system (GRDU), consistently put into orbit with a height of ~ 500 km (2020-2024).

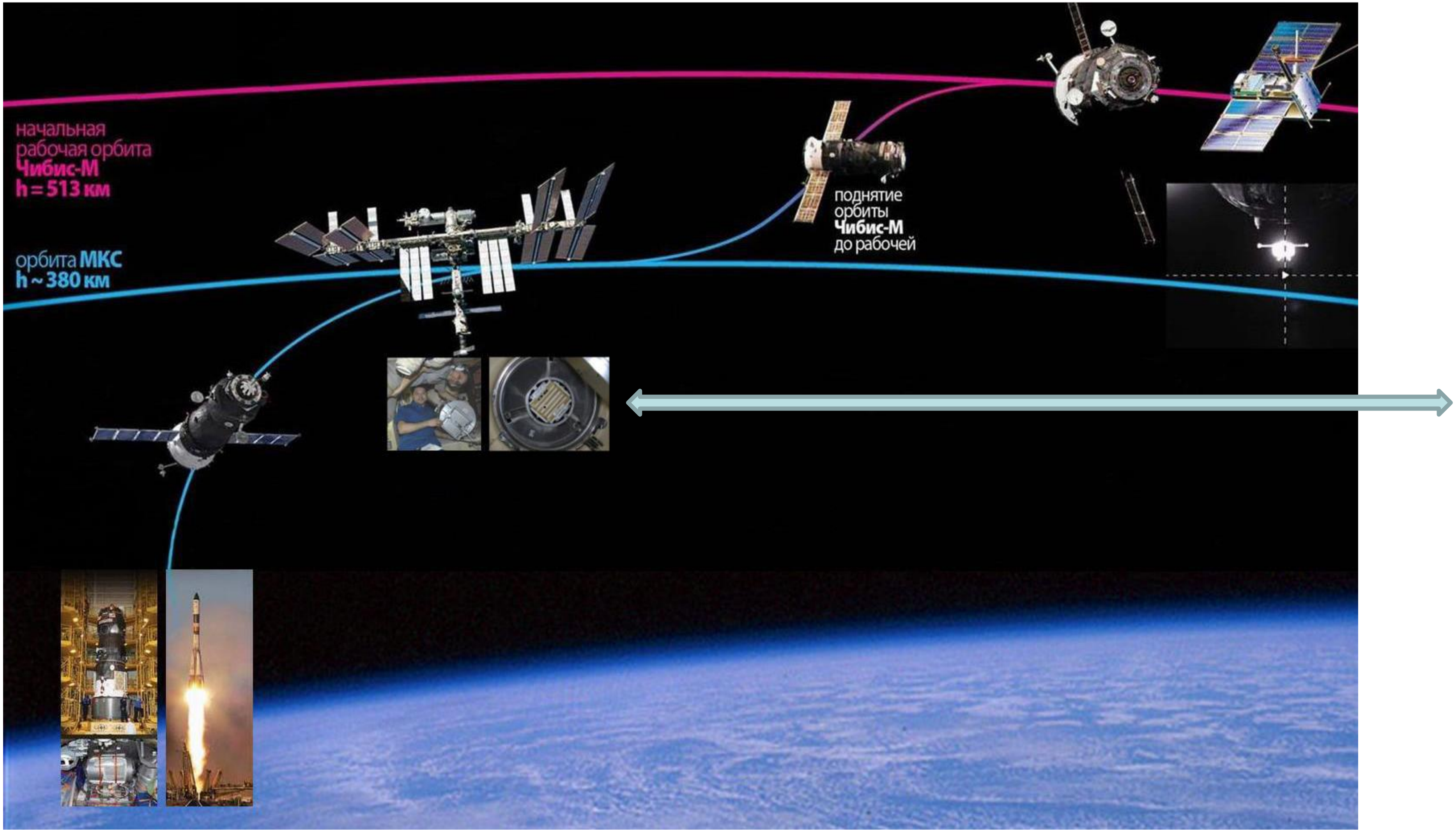
The creation of ionospheric clusters in the F2 layer provides a unique opportunity to open a new page in gradient studies of geophysical fields and low-frequency electromagnetic radiation.

The project is aimed at an experimental study of the fundamental problem of multiscale turbulence in a moving dynamic plasma.

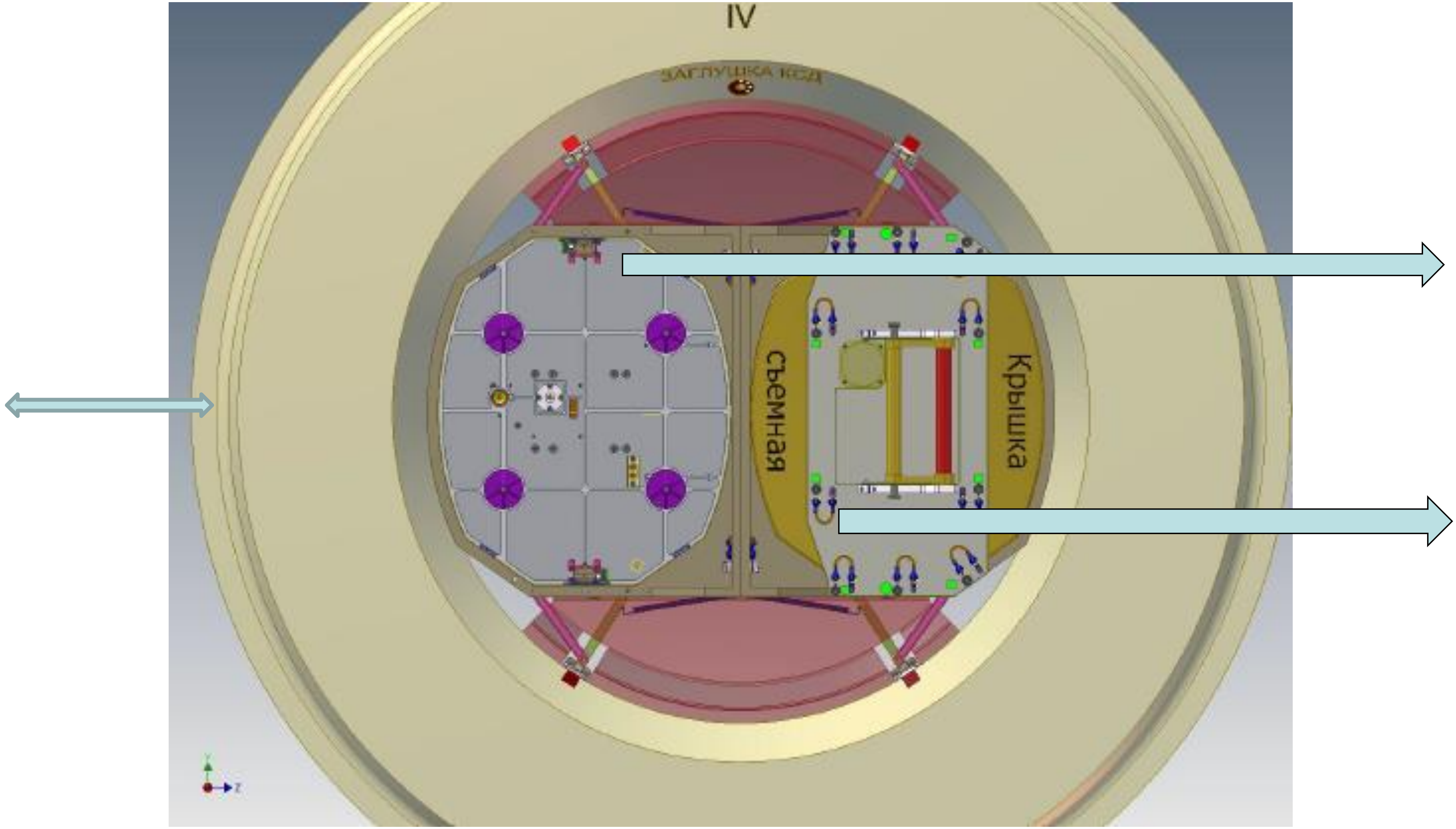
In one satellite version, multi-parameter studies are usually carried out on the same scale.

In the case of two satellites with the GRDU, multiparameter plasma studies will be carried out on a wide range of ionospheric spatial parameters (~ 0.1-10 (100) km).

Hardware complex "Trabant"



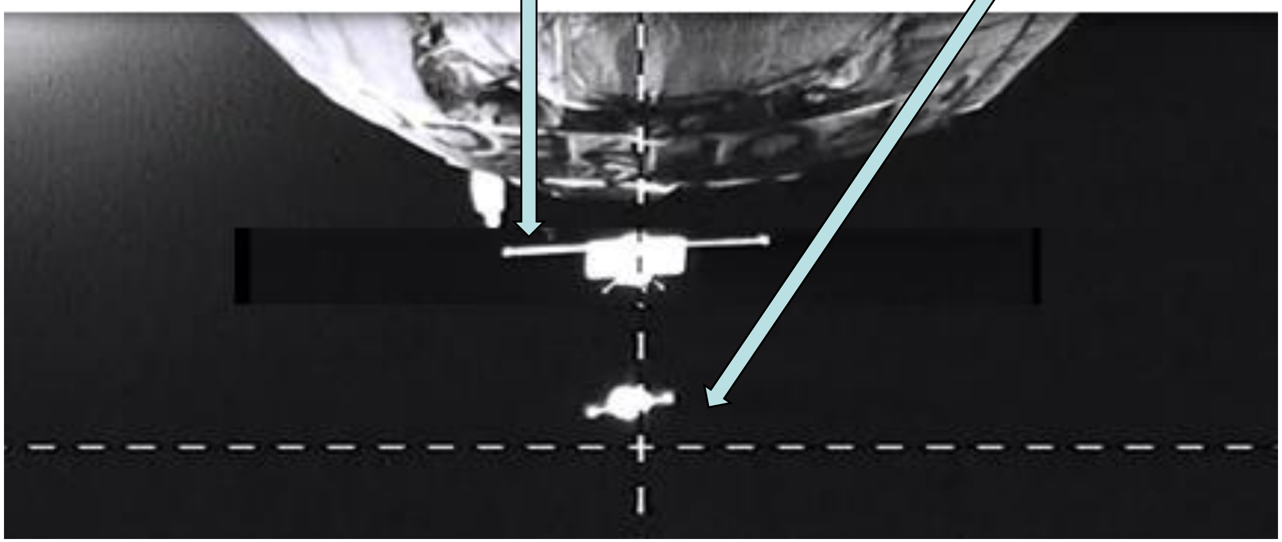
Hardware complex "Trabant"



Hardware complex "Trabant"

The output circuit of the two MS "Trabant" for Autonomous orbit

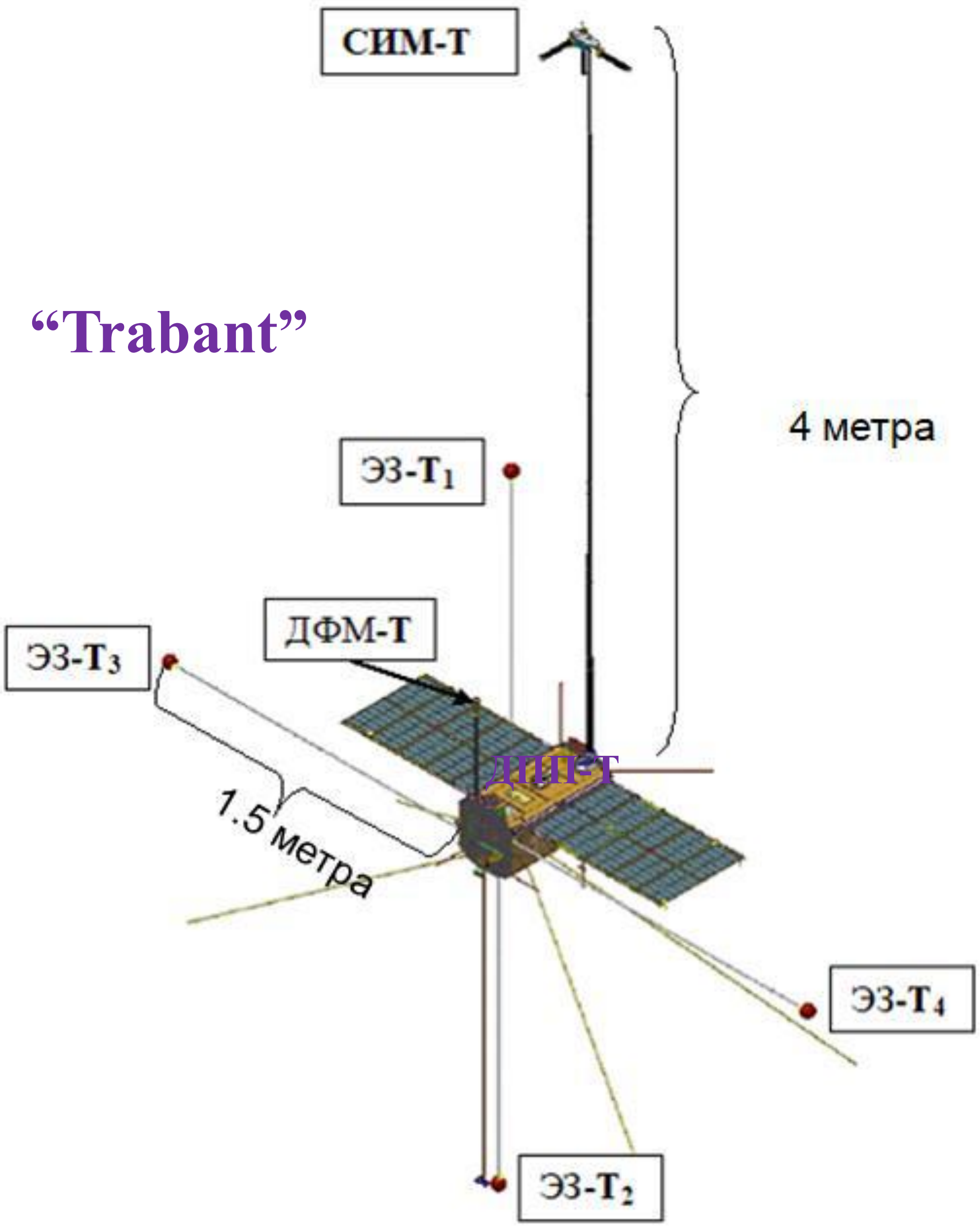
Planned video broadcast of the departure of two MS "Trabant" from " Progress”

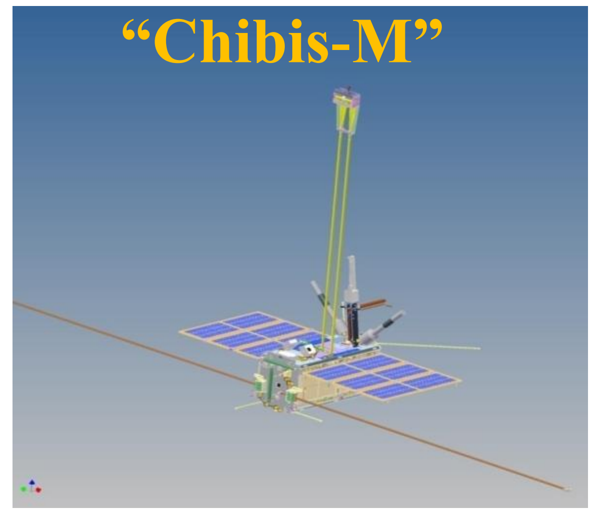


Two-point measurements

ИКИ
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

"Trabant"





Hardware complex "Trabant"

Scientific Instruments (SI)

№	Name of the instrument	Marking	Designation
1 1.1 1.2 1.3 1.4	Magnetic wave complex consisting of: Spectral analysis processor; Fluxgate magnetometer consisting: a) sensor; b) electronics unit . Induction magnetometer system; System of electric probes.	MWC-T SAS-T FGM-T FGS-T EU FGM-T SIM-T EP-T	ELTE, Hungary BL-Electronics, Hungary ELTE, Hungary ELTE, Hungary ELTE, Hungary
2	Plasma parameter sensor	DPP-T	API, Russia
3	Radio frequency analyzer	RFA-T	IKI, Russia
4	Phase meter of electronic concentration	FIEC-T	IKI, Russia
5	Electron spectrometer with narrow field of view	BAES-T	IKI, Russia
6	Ion energy mass spectrometer with wide field of view	ARIES-T	IKI, Russia
7	Memory block includes interfaces to devices MS "Trabant»	BMS-T	Wigner Institute, Hungary
8	SI-T telemetry transmitter (2.2 / 8.0 GHz) with cold standby	FALCON-S/X	BHE, Hungary
9	Test and control equipment	EGSE-T	Wigner Institute, Hungary

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Hardware complex "Trabant"

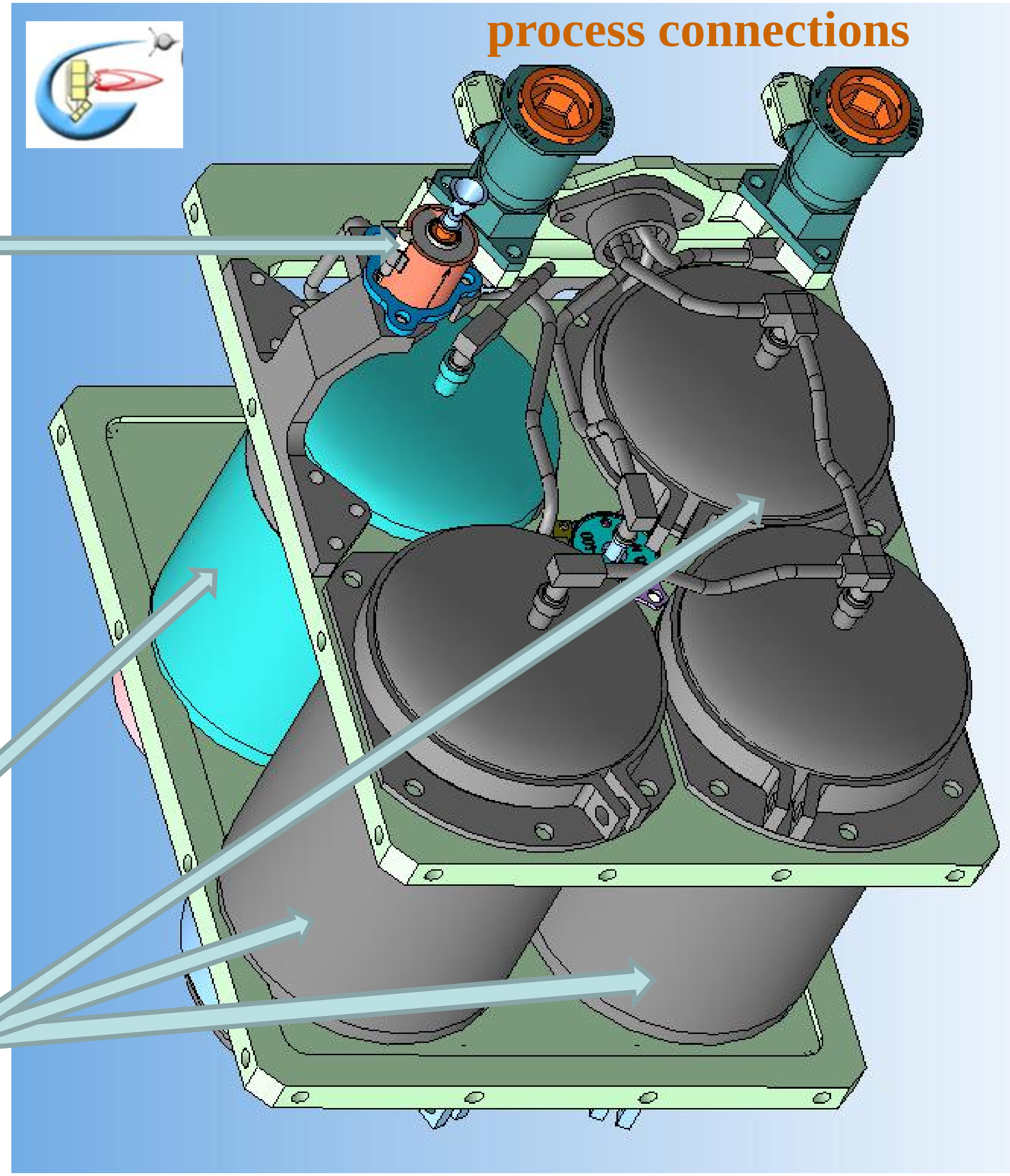
Technical parameters

Name		Value
Total weight of JSC "Trabant" (two sets of TPK-T with MS "Trabant", two cables, mounting mechanism of TPK-T module),	kg	**150**
Weight of one set of TPK-T with MS "Trabant",	kg	**75**
Weight of the MS "Trabant",	kg	**60**
Mass of the TPK-T,	kg	**15**
Mass of the scientific instruments (SI),	kg	**17,5**
Mass of the BSK-T,	kg	**30,5**
Structural weight,	kg	**17**
MS circular orbit, height, not less than,	km	**500**
Primary voltage of onboard power supply MS "Trabant",	V	**12±3**
Average daily power consumption of each MS,	W	**130**
Battery capacity of one MS, not less than,	Ah	**18**
Overall dimensions MS "Trabant" in transport position,	mm	**400x378,5x761**
Overall dimensions MS "Trabant" in the working position,	mm	**4280x6422x1462**

Requirements for the system of orientation and motion control SOUD-T

SOUD-T, during the orbital flight of MS, must provide the following modes of operation:

- **The main mode of operation is the orbital orientation of the MS, in which the first of the construction axes of the MS is directed to the center of the Earth (in Nadir),**
- **The second – on the velocity vector and the third complements them to the right three. Mode of orientation to the Sun-automatic mode, which should be implemented orientation, ensuring timely charging AB (ensuring the maximum possible orientation of solar panels to the Sun).**
- **Three-axis orientation mode, performed by commands from the ground. This mode provides three-axis orientation in any given direction in the inertial space.**



gas engine

Characteristics of GRDU:

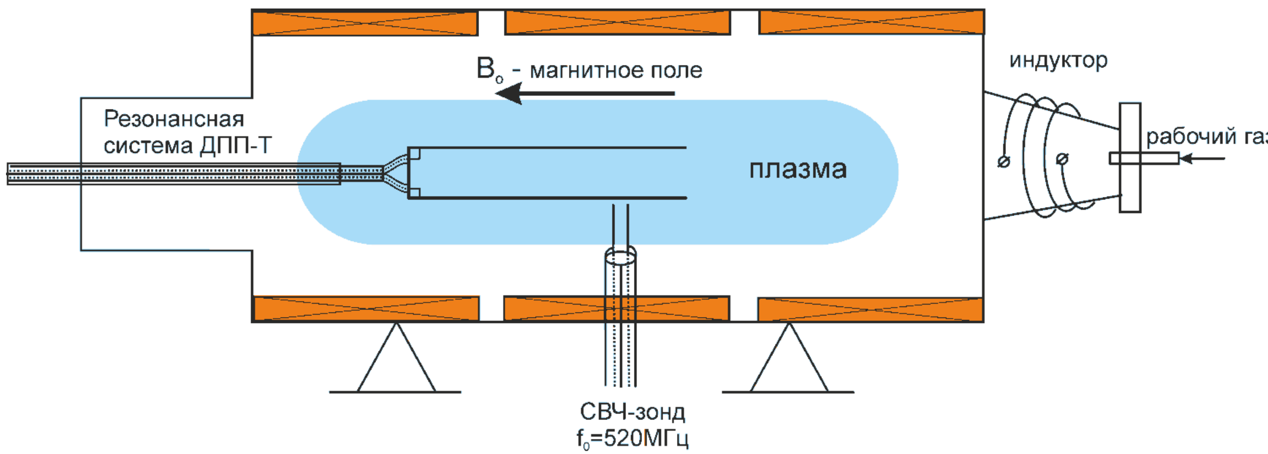
- total mass ~ 2,5 kg;
- the working fluid GRDO - air (nitrogen);
- the specific impulse of ~ 700 m/s;
- characteristic speed - not less than 5 m/ s;
- thrust ~ 0.1 N.

receiver

compressed nitrogen cylinders

Hardware complex "Trabant"

Ground calibration the microwave probe of DPP-T on the stend "IONOSPHERE".



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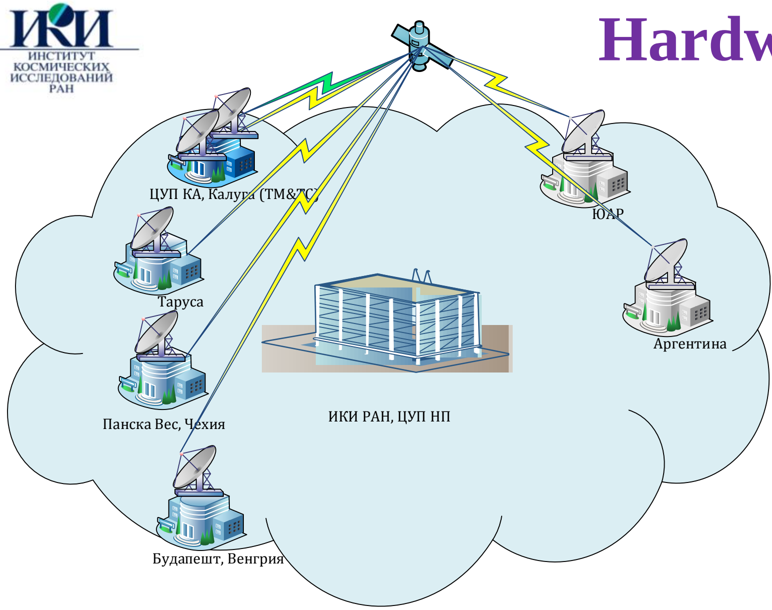
Hardware complex "Trabant"



The information characteristics of the MCC-IKI

Duration of information transfer and number of communication sessions:

to obtain the SI-T data and all the PSA-T data, one ground station will be sufficient only for 2 sessions per day with a transfer rate of 1 Gbit/s.

for data transfer SI-T without all data of PSA-T one ground station will be enough only at carrying out 2 sessions a day with a transfer rate of 10 Mbit/s.

- To solve the scientific problems of the project on board each of the two MS installed SI-T with the following maximum information content:
- RFA-T - 250 MB/day; FIEC-T – 5 MB/day;
- PSA-T:
    - full stream 104 GB / day;
    - waveforms 200 MB / day
- DPP-T – 400 MB/day;
- BAES-T-53 MB / day; ARIES-T-340 MB / day.

Based on the data on the informativeness of the devices, it is possible to calculate the maximum daily informativeness SI-T. It will be:

- 848 MB / day in case of PSA-T wave forms;
- 104648 MB / day in of PSA-T of all data.

	Длительность передачи, мин		Количество сеансов в сутки	
Скорость передачи, Мбит/с	без всех данных ПСА	со всеми данными ПСА	без всех данных ПСА	со всеми данными ПСА
1	113	13953	12	1396
2	57	6977	6	698
5	23	2791	3	280
10	11	1395	**2**	140
50	2	279	1	28
100	1	140	1	14
250	0.5	56	1	6
500	0.2	28	1	3
1000	0.1	14	1	**2**

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Thank you

for your attention!

Invite to cooperation

I[ST] INTERNATIONAL
AEROSPACE SYMPOSIUM
THE SILK ROAD

Mid-IR fiber components for space-borne spectroscopic instruments

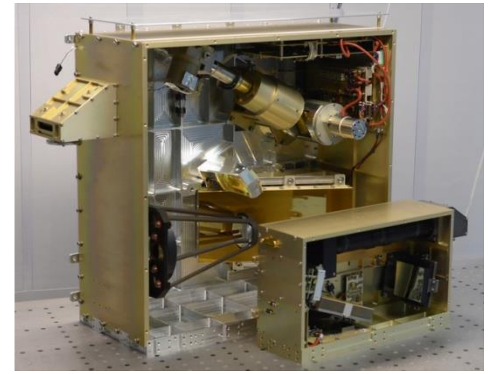
T. Tebeneva, O. Benderov, I. Nechepurenko, B. Stepanov, A. Rodin

Moscow Institute of Physics and Technology
Dukhov Research Institute of Automatics
Highest School of Economy
G.G. Devyatykh Institute of Chemistry of High-Purity Substances
Space Research Institute

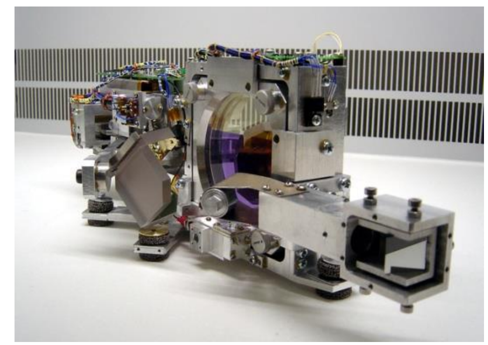
6-8 December 2018

Current on—board spectroscopic instrument types

- Echelle-grating spectrometer (ACS NIR, MIR)
- Fourier transform spectrometer (ACS TIRVIM)
- Tunable laser absorption spectrometer for *in-situ* measurements (SAM Curiosity)
- Mass spectrometers
- Gas chromatographers



ACS NIR, MIR

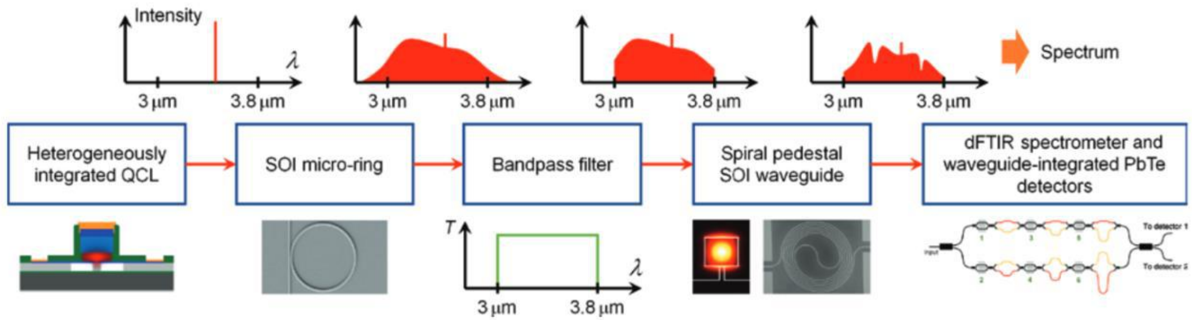


ACS TIRVIM

SAM Curiosity

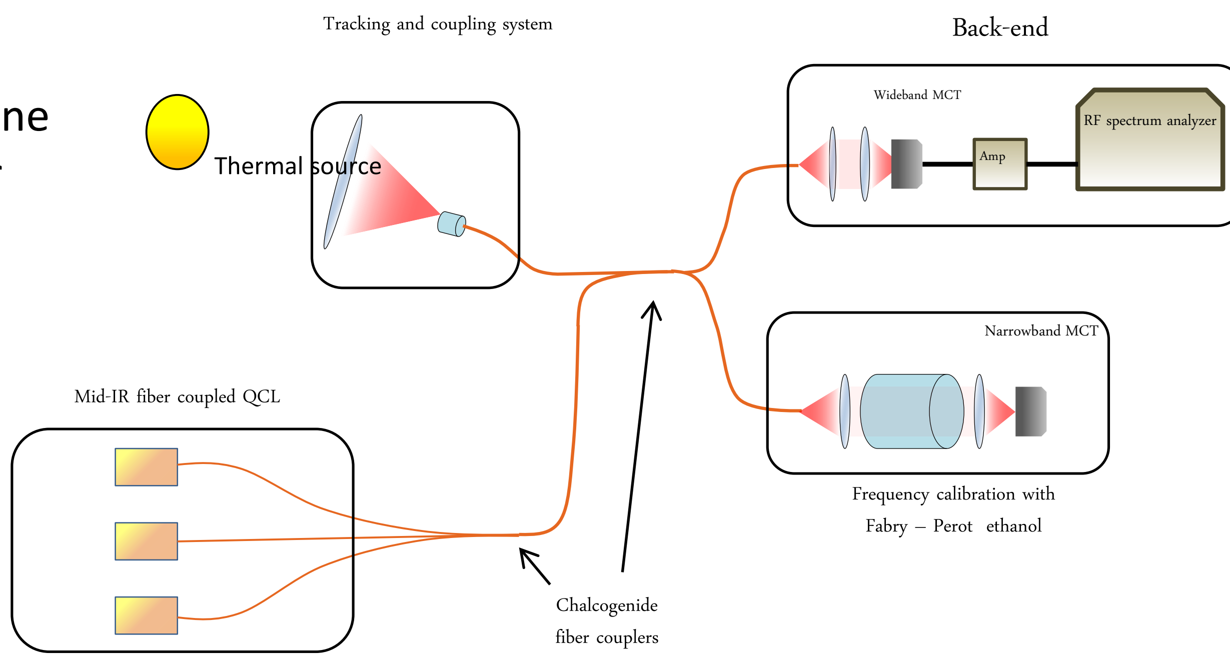
Potential on—board payload

- Integrated photonic chip spectrometers for *in situ* measurements



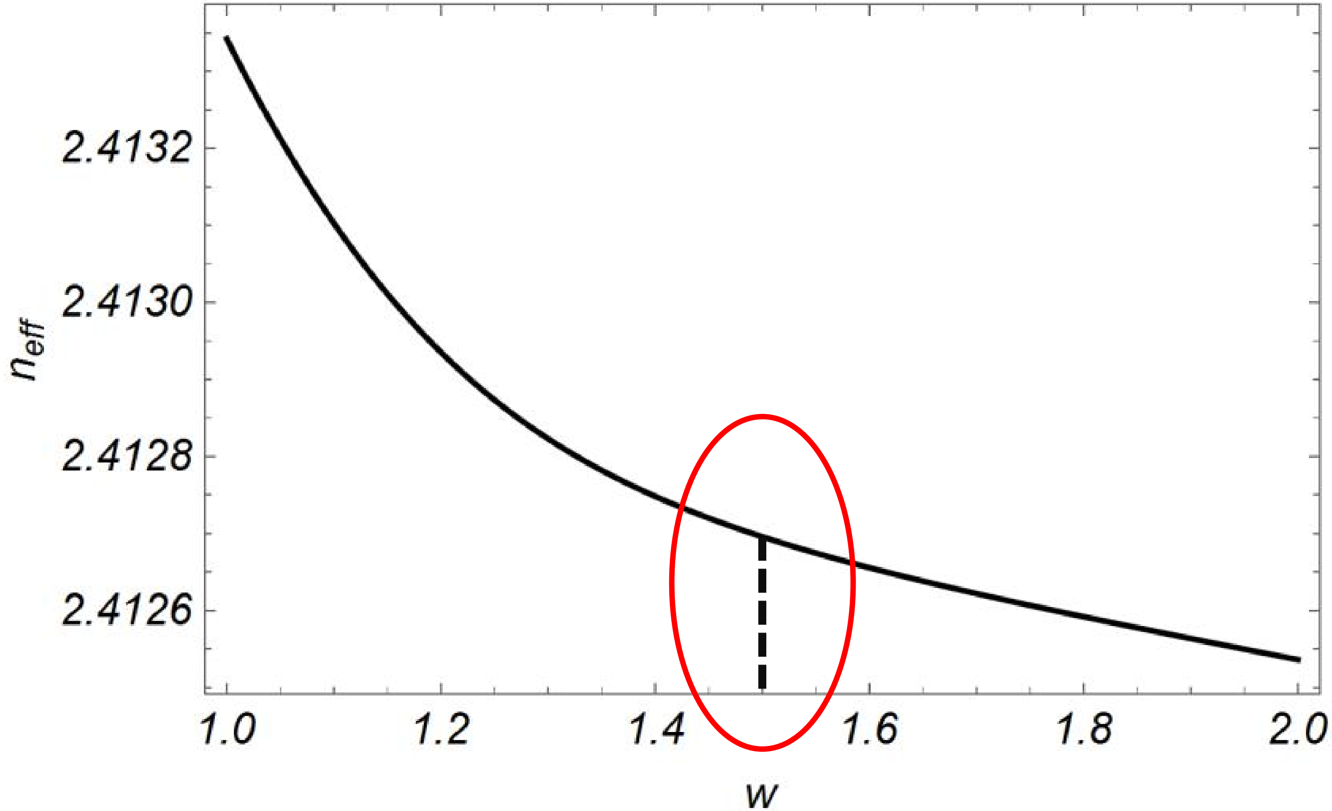
Hongtao Lin et al, *Mid-infrared integrated photonics on silicon: a perspective,* Nanophotonics 2018; 7(2): 393–420

- Fiber-based heterodyne mid-IR spectrometer for remote sensing



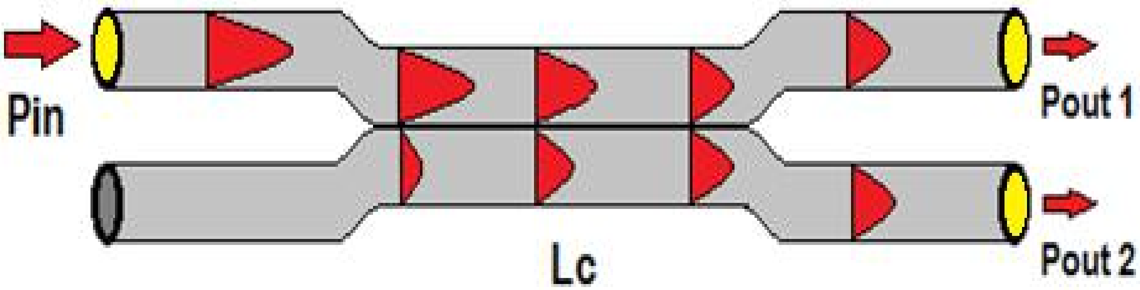
Fibers

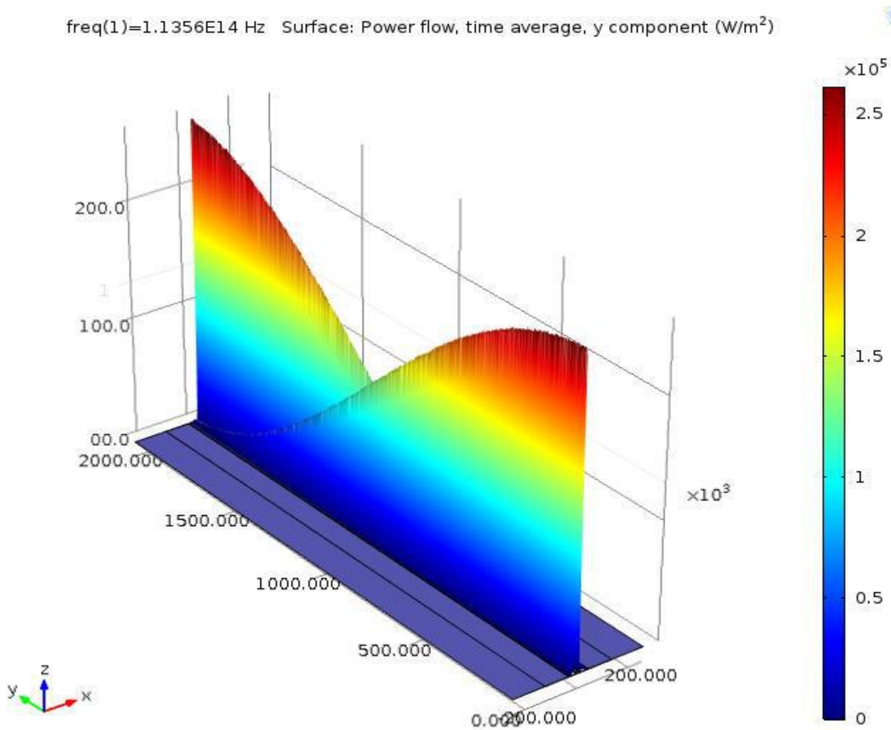
$As_{40}S_{60}$
Core diameter - 6.3 µm
Cladding diameter - 123 µm
NA = 0.17
Optical loss - 400 dB/km (2.1-2.2 µm)
n_core = 2.4186
n_clad = 2.4126



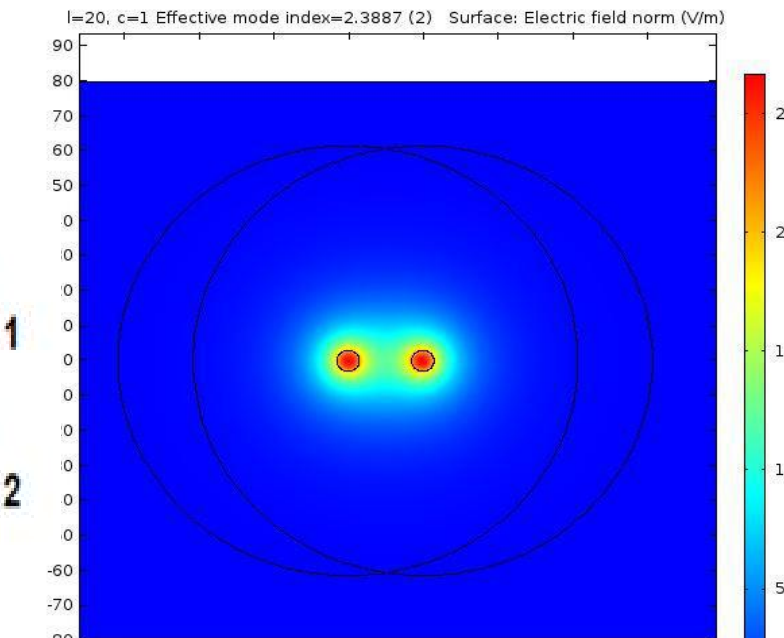
Dependence of the effective index on the waist coefficient of the fundamental mode of chalcogenide fiber

Fiber coupler

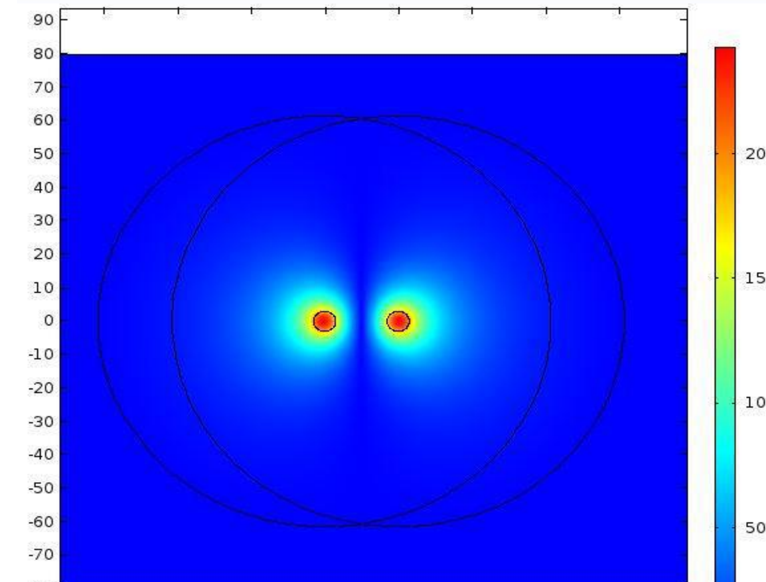




Simulation of the coupler

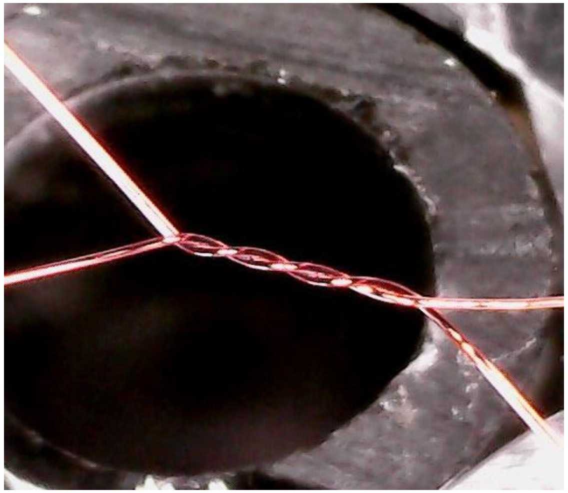


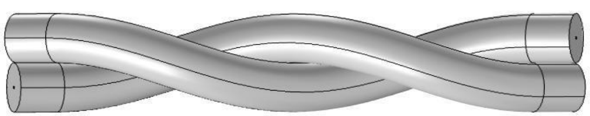
Symmetric mode



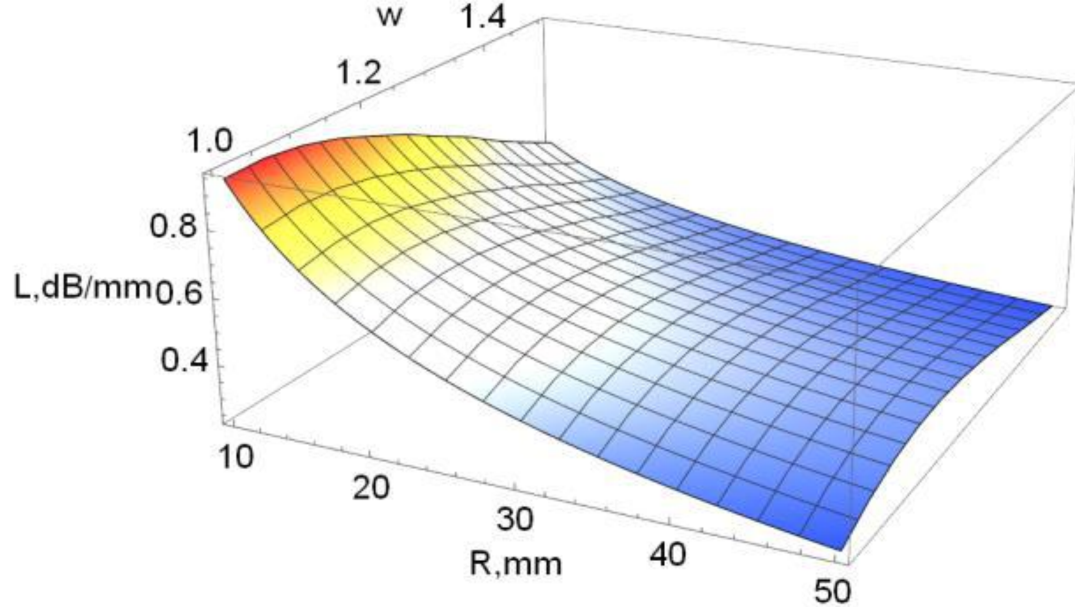
Anti-symmetric mode

Bending loss

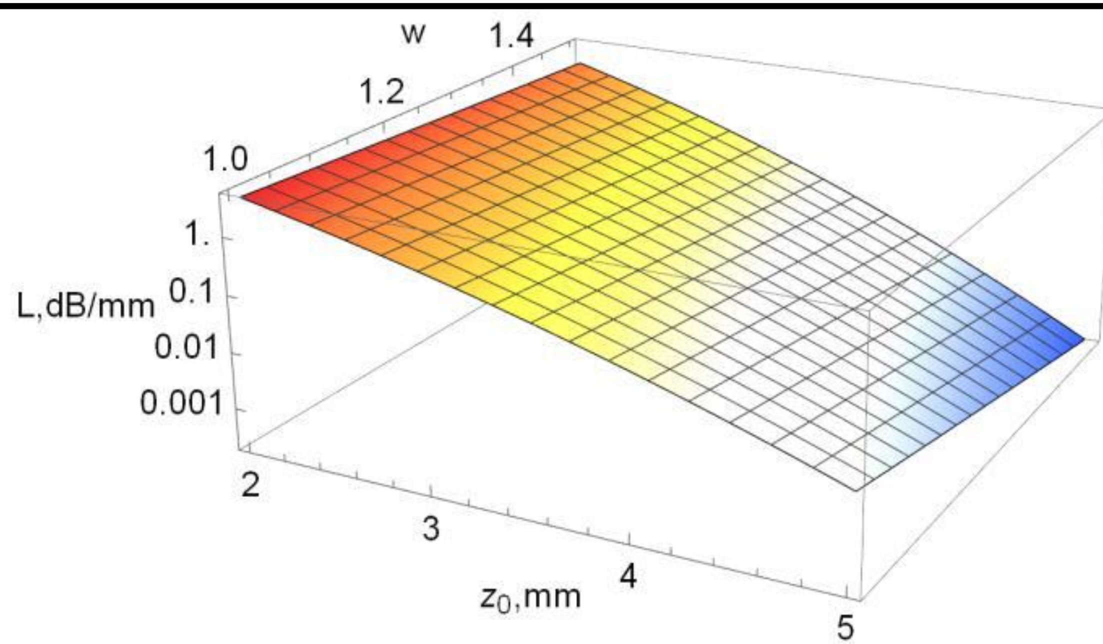




Helix structure of the fibers

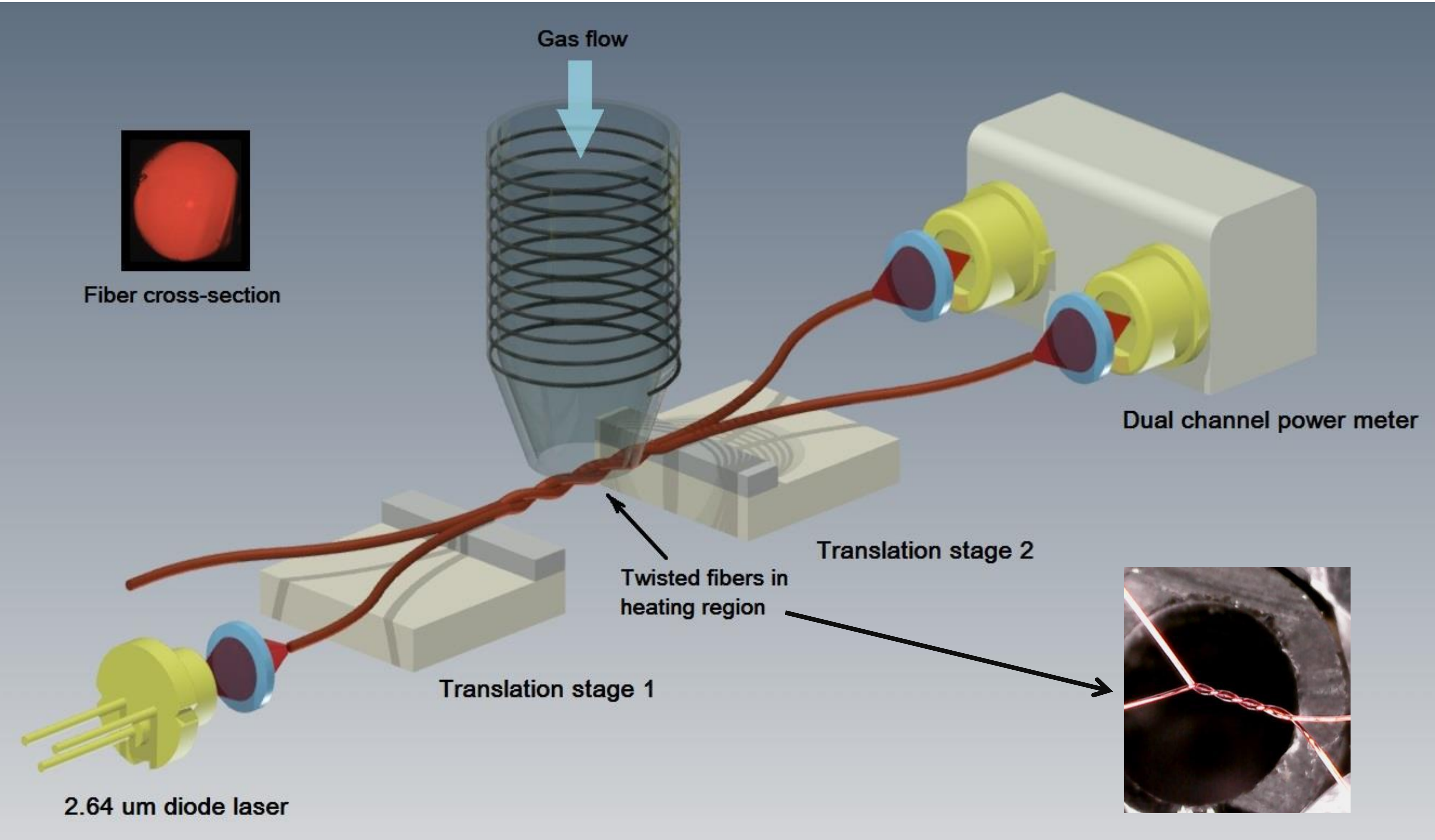


Bending loss on fiber curvature radius



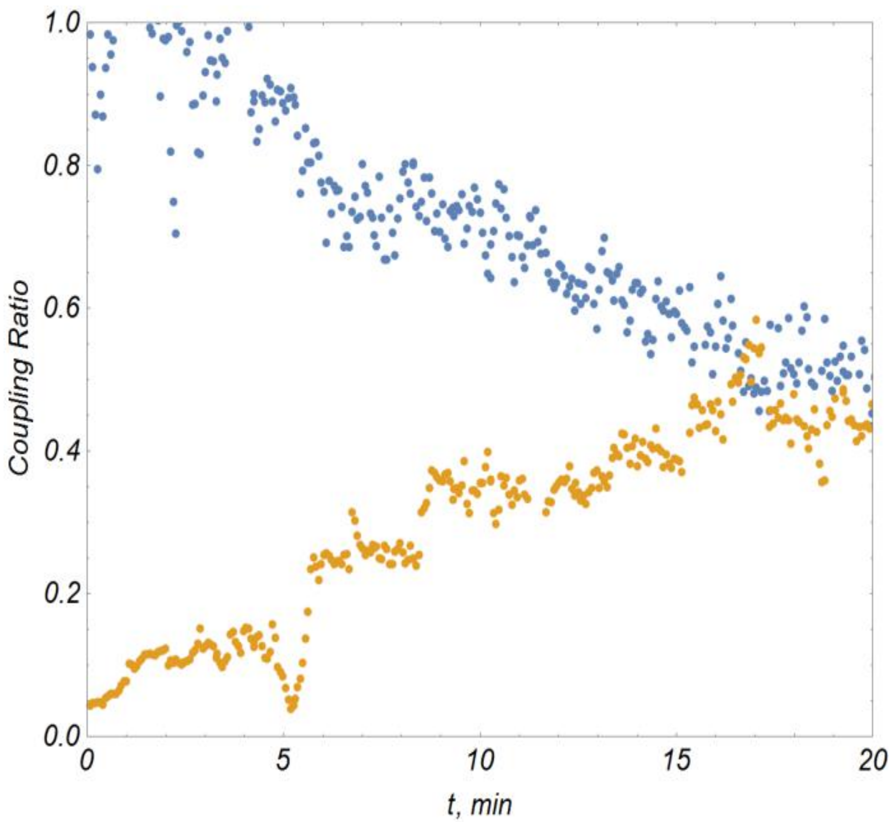
Bending loss for the helix pitch structure

FBT Method. Experimental setup



Results

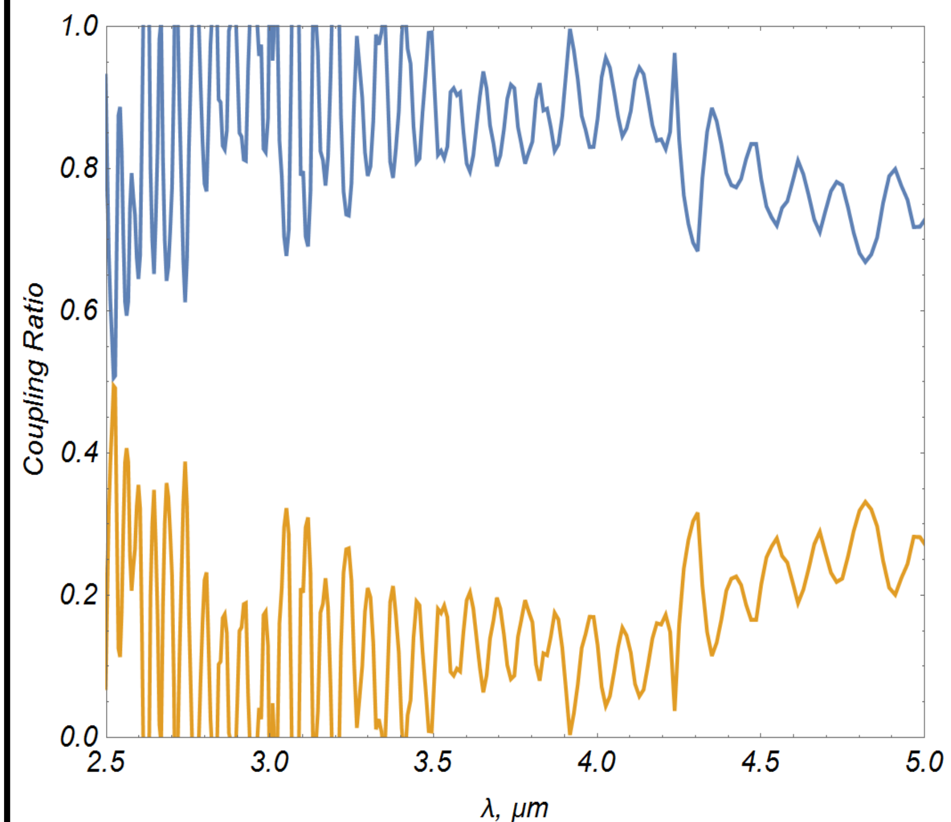
Coupling ratio over time on 2.64 um
50:50 CR was reached on 15 min heating



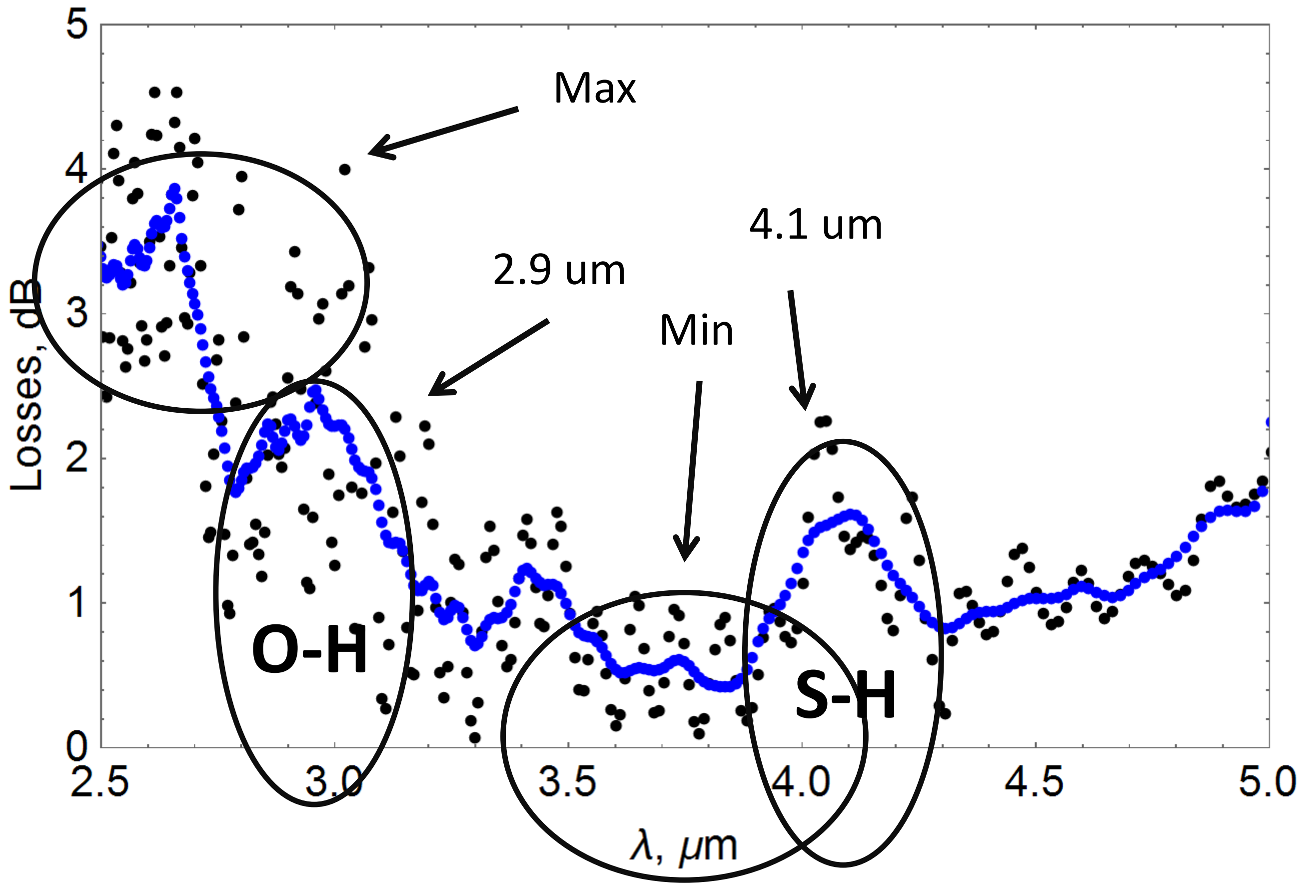
Stabilized – 53:47

Excess loss – 4.6 dB

Broadband coupling ratio measurements
2.5 – 5 um



Results



Broadband excess loss measurements

Min – 0.6 dB
(3.5 – 4.0 um)

Max – 4.5 dB
(2.5 – 3.0 um)

Further plans

- Fiber splitters in the 7 – 12 um range based on As-Se, As-Se-Te fibers
- Integrated optical devices on Ge-S glass
- Approbation in space-borne heterodyne instruments

Thank you for attention!

International Aerospace Symposium
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Active vibration analysis/control of Inflatable Space Antenna Reflectors

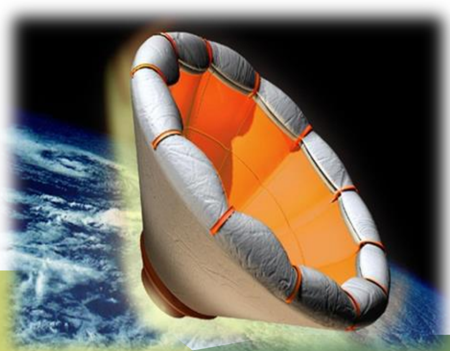
Joshit Mohanty
1st Year, Master of Science
Space Center
SKOLTECH

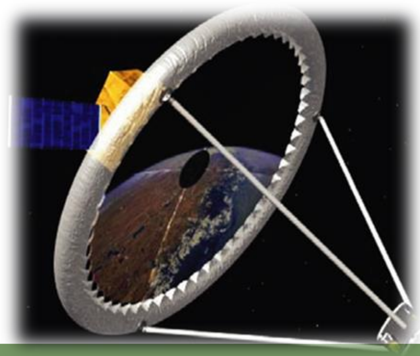
Gossamer Space Structure

Gossamer structure means the general category of space ultra low mass structures, such as inflatable or many other forms of expendables. A space – inflatable structure is a specific application of a membrane structure or any ultra low mass hybrid structure with an extensive use of membranes. We mean by membrane those structures (load carrying artifacts or devices) comprised of highly flexible (compliant) plate or shell like elements. This usually implies thin , low modulus materials, such as polymer films. Membrane structures have very little inherent bending stiffness, nor do they lend themselves well to carrying compressive loads. Thus, they are usually either tensioned – planar or inflated-curved configuration.

Inflatable Structures

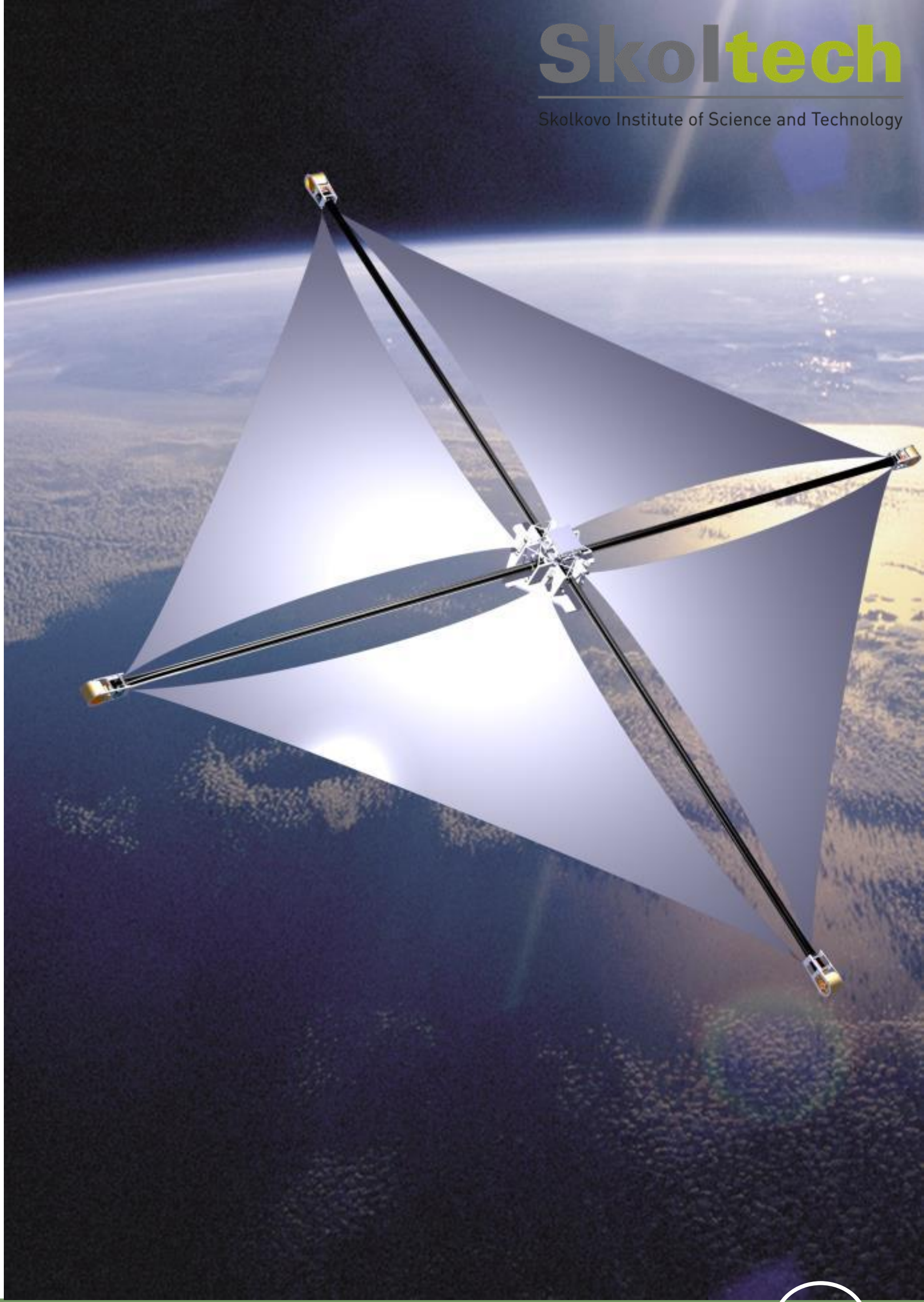
Inflatable space structures are structures which use pressurized air/ other chemicals to maintain shape and rigidity. These structures are extremely light weight and expand after their launch, thus allowing to pack big packages into a small volume. However these are prone to vibrations occurring during launching of space craft and other dynamic vibrations occurring after they are activated. The cause of vibrations include structural, thermal and signal transmission (space particles hitting the reflectors).





Present Day Scenario

- The performance efficiency of these reflective surfaces depends not only on the geometric accuracy of these surfaces but also on their vibration characteristics.
- The surface of the space structures (antenna reflector, telescope mirror, solar sail etc.) must be error free.
- To get high accuracy surface requirements of the space structures, the measurement and analysis of reflector's accuracy are necessary.
- Due to the periodic nature of symmetric reflectors, they will be very sensitive to even small irregularities (due to manufacturing and material tolerances).
- Irregularities can affect the vibration behavior significantly, by localizing the vibration modes and confining the energy to a region close to the source.
- The vibration challenges include: launching by launch vehicle's high frequency and small vibration due to the electronics component of the satellite on orbit.



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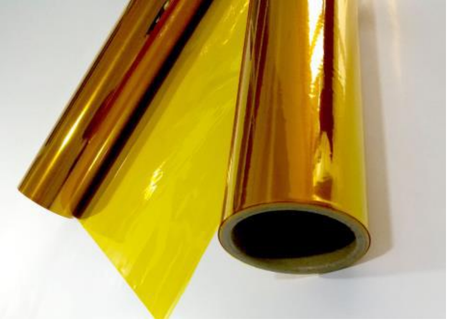
HEXAPOD ADAPTIVE STRUCTURES TESTBED
Membrane Reflector
Inflatable Frame

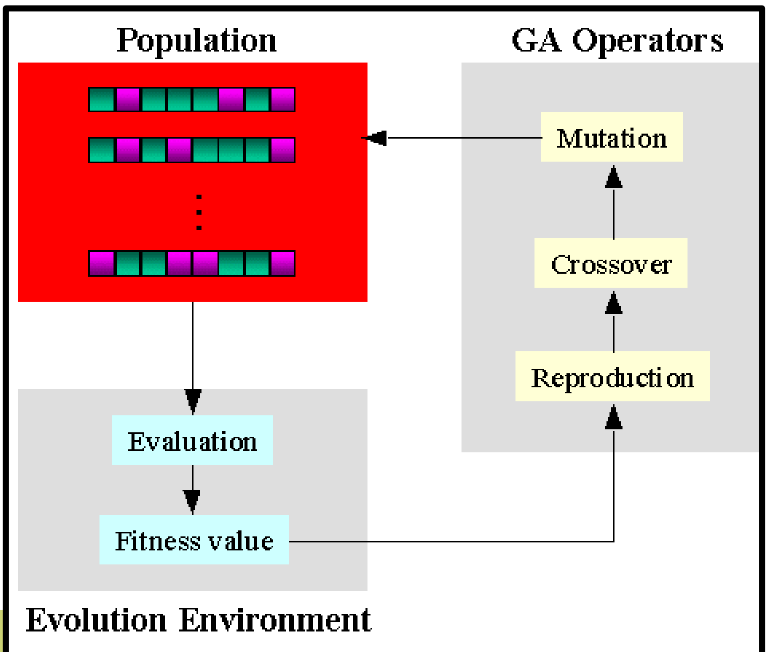
Skolkovo Institute of Science and Technology



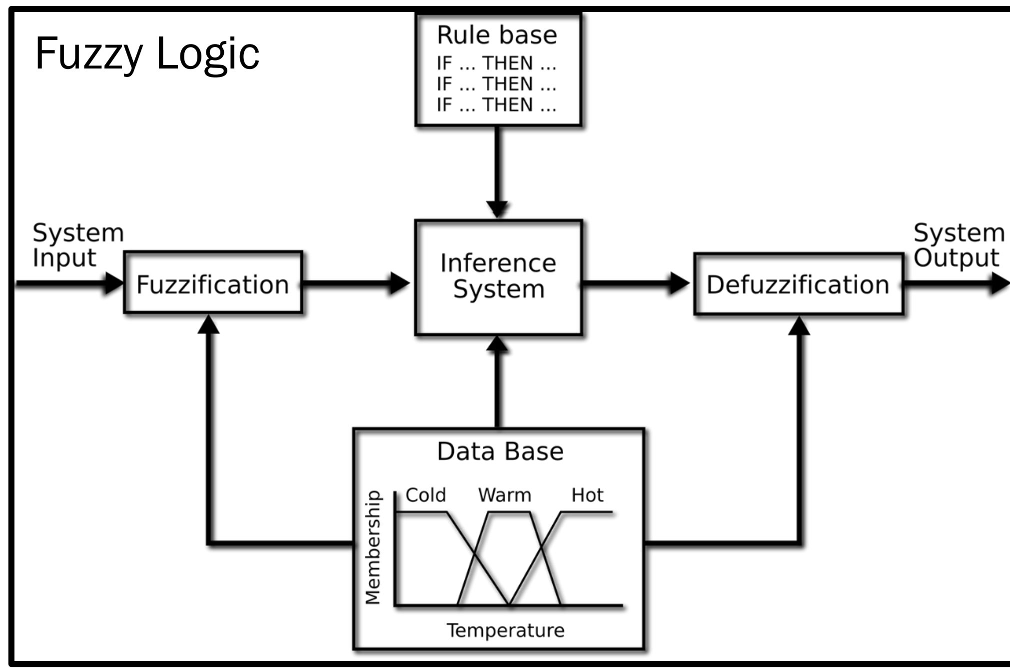
Kapton Sheets

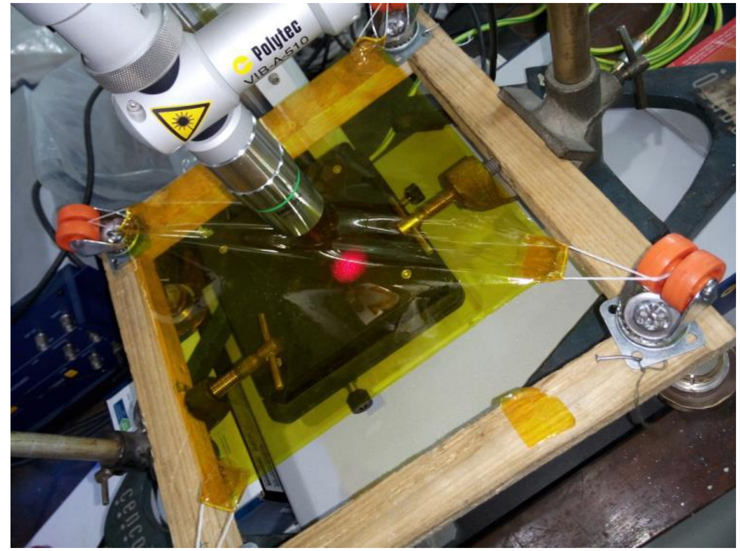
PVDF Actuator

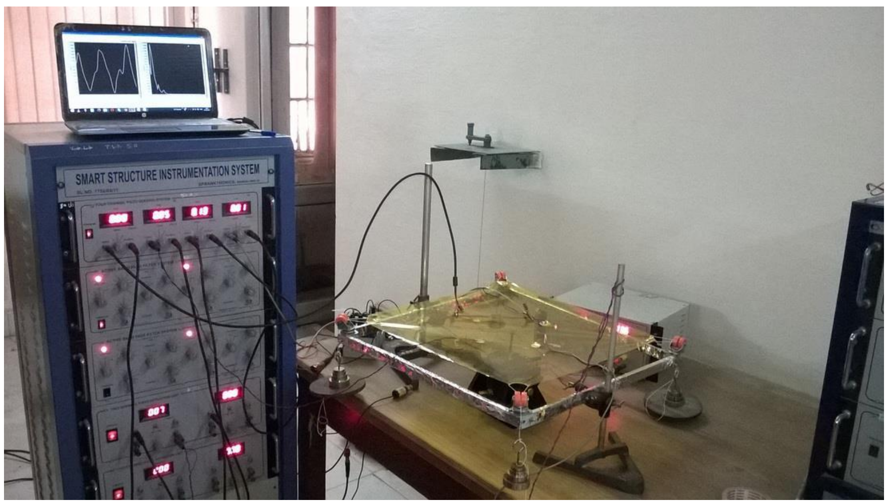
MFC Actuator

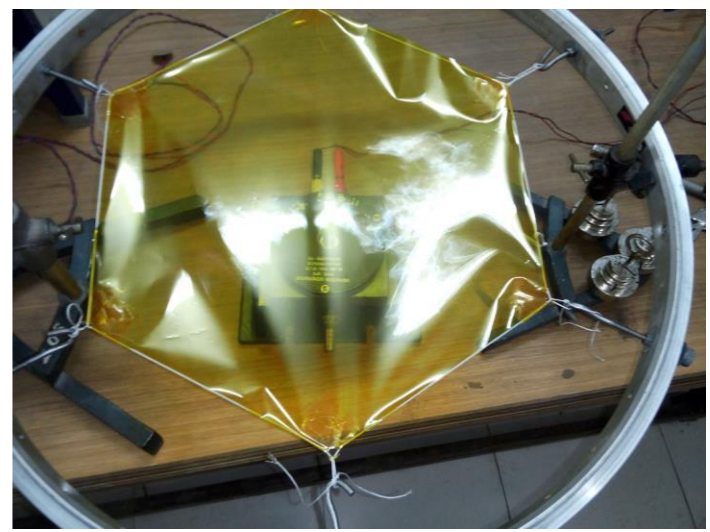


Genetic Algorithm Evolution Flow



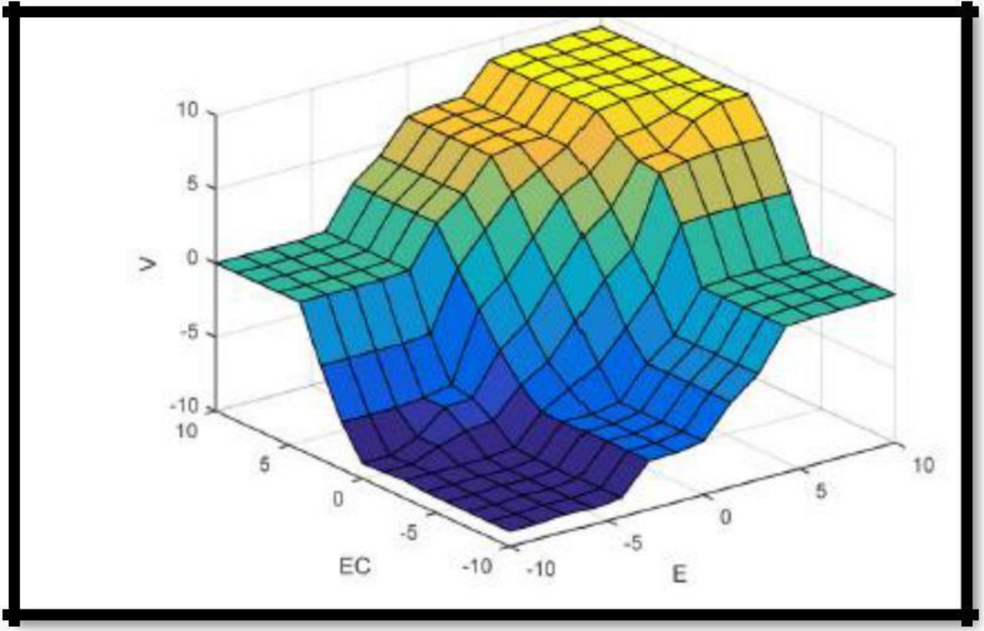






Experimental Set Up

*Work Done at Indian Institute of Technology Roorkee (India)



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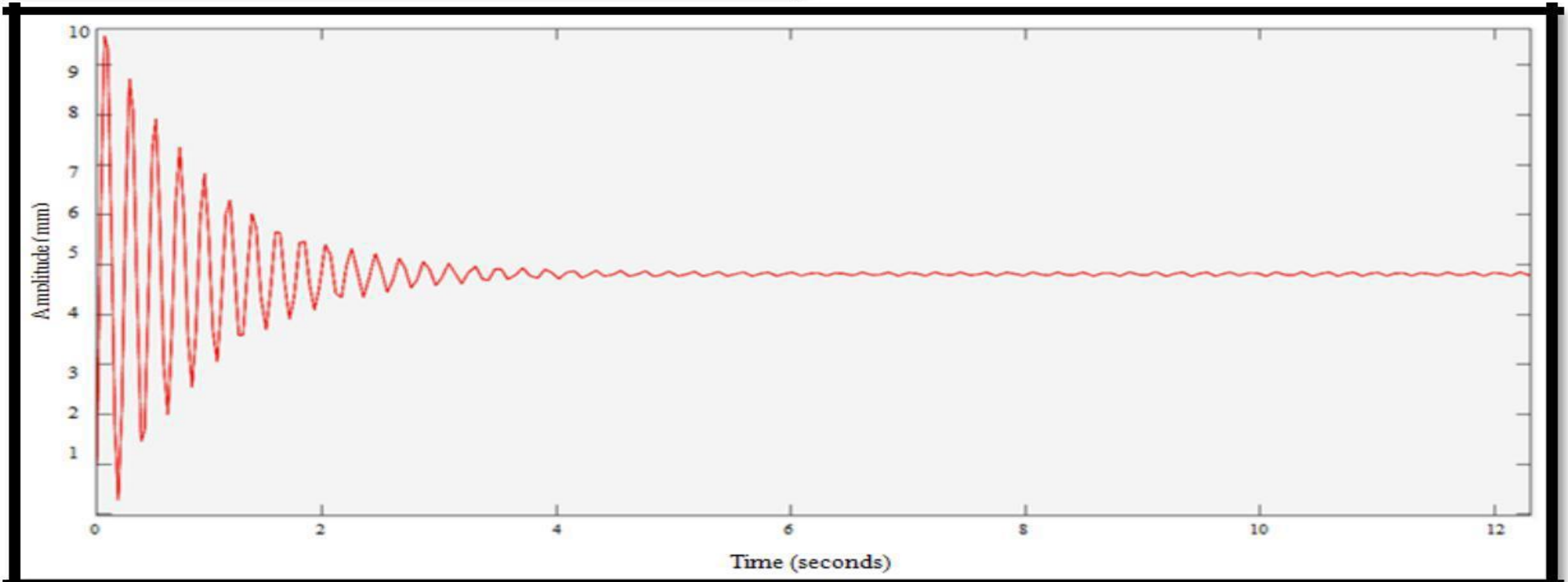
RESULTS



PROBLEM???

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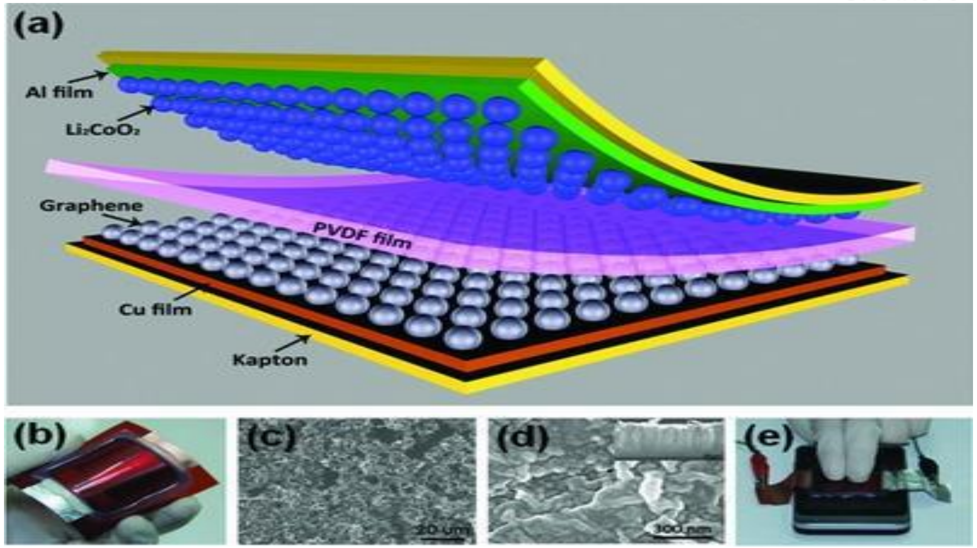
PZTs/MFC Patches	Continuous PZTs/MFCs sheets

- ❑ Optimum places need to be determined by various optimization techniques.
- ❑ To be placed at selective places, for min. number of units to be used
- ❑ Do not skip any place of disturbance, if used in continuous but adds weight to the structure.
- ❑ Need to be structurally attached, to effectively sense vibrations
- ❑ Small disturbances can also be eliminated at any point if used in continuous sheets.
- ❑ Need additional power for operation.
- ❑ Only valid to determine mechanical stress waves but the system fails to determine thermal imbalance.

Solution 1



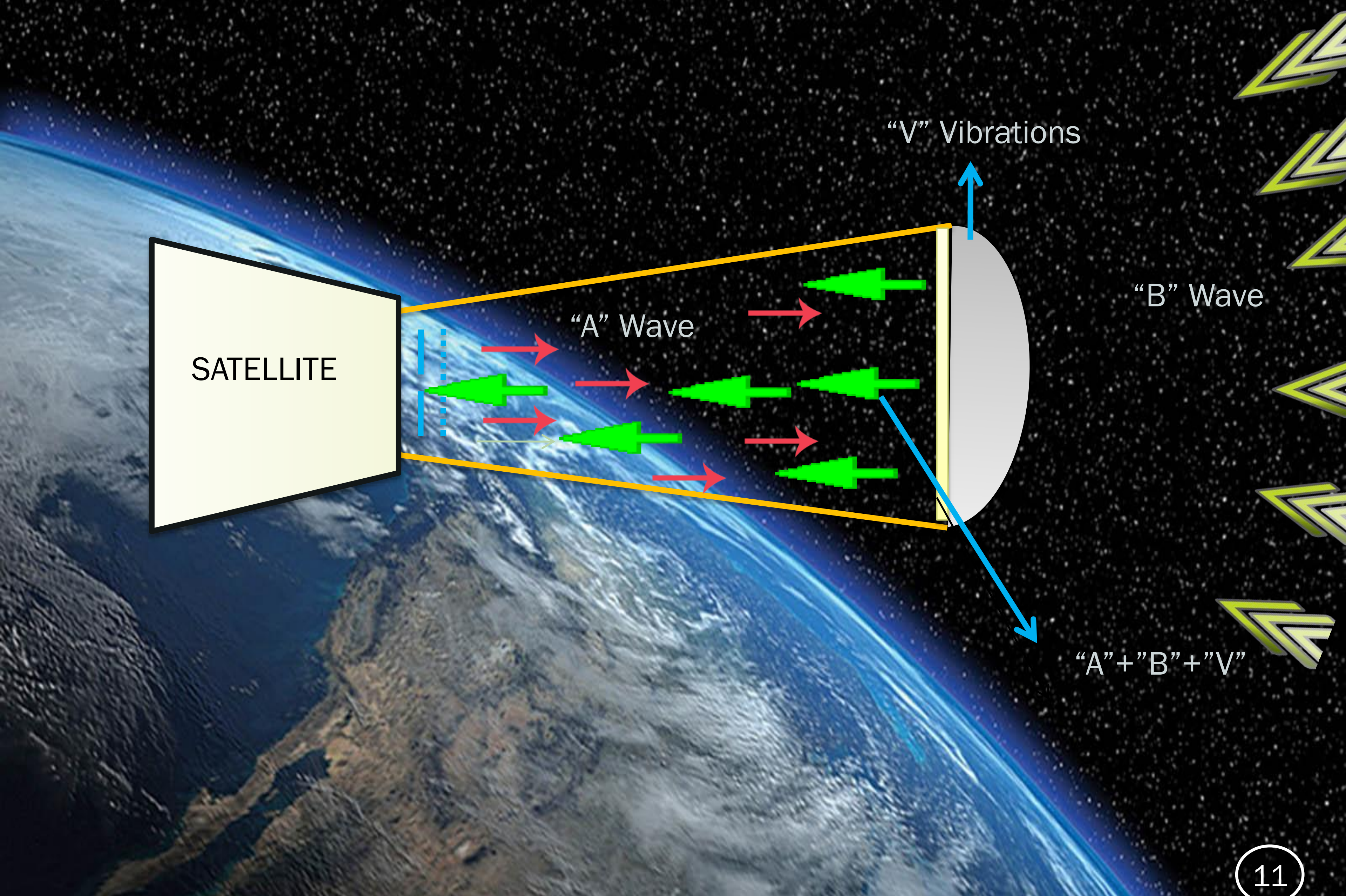
An alternative way of improving the tensile strength and flexibility of PVDF by introducing Graphene layers and self powering module.

(Reference : Flexible Self-Charging Power Cell for One-Step Energy Conversion and Storage Apr 2014 · Advanced Energy Materials)

Advantages:

1. Do not require additional power input to the PVDF for both sensing and actuation purpose;
2. No need to control the input parameters such as voltage and current to damp the vibrations as the necessary step is taken by the device itself by the vibrations occurring on the surface.

Solution 2: PROPOSED SOLUTION



Understanding

A EMW “A” is transmitted from the transmitter which will be used to know the vibration and its characteristics – frequency and amplitude after it reflects from the surface. When “B” EM wave hits the surface of the reflector it adds some noise due to the vibrations of the membrane “V”. After it passes the membrane, we get “B”+”V” at the rear side of the membrane. At this point we get a complicated wave of “A”+”B”+”V” = “C”. A negative feedback from the upper surface is given to this point, which will help in getting “A” from “C”. Now, the information from “A” will determine “V”. Hence, finally will get “B”.

Now, as “A” is all over the surface , it really helps to determine the regions where we need to damp the vibrations. Say “B” is pure form of wave(or maximum obtainable wave) from the outer space, and at regions we are getting “B”+”N” (N-Noise). Lets say “V1” is the vibrations of the region where the obtained “B” is unaffected, than “V1”-”N” is the additional required energy that is needed to damp the additional vibrations in that region. So in this region, firing “A”+(“V1”-”N”) wave will help in damping the disturbed vibrations.

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Advantages!!

1. Non contact monitoring;
2. Making the structure light weight;
3. Entire region can be scanned , rather than specific points or group of points;
4. The damping of any type of vibration is possible (which is restricted as in case of MFC/PZT);
5. It has least possibilities of getting damaged or out of functionality in long run;
6. Can be fined tune at any frequency/ energy level so as to adjust to the vibrations of the membrane, rather than a set of particular values as in PZT/MFC.

May Be More With Time…

There may be instances, where the required energy to damp the vibrations is more than the threshold energy of the surface. In that case, targeting the direct beam of energy might be harmful for the structure. Here we need to use less energy beams to counter those vibrations.

Ex: If the required energy is that of a blue beam of light and that is more than the threshold energy of the surface, we will tune the system for green light (that has considerably lower energy than the threshold energy). The system will take "t1" seconds more to get stable, but all the vibrations will get damp. The "t1" additional seconds corresponds to

1. Number of photons that will reflect after hitting the surface;
2. Number of photons will not resonance with the surface vibration energy in order to transfer their energy to damp those vibrations.

THANK YOU for your patient hearing

The 1st International Aerospace Symposium

The Silk Road

08.01.2018

Small Satellites Structural Elements Tension Control by Quantum Sensor made of Modified Diamond with NV-center

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Novichkov V.M., Moscow Aviation Institute (National Research University) v13217@ya.ru

Content

- Purpose of the Work and Problem Statement;
- Fields of Practical Implementation of Future Sensor;
- Methods and Methodology;
- Sensing Element made of Modified Diamond with NV-center;
- Properties of Diamond Plates with NV-center;
- Principle of NV-center Operation;
- Types of Resonators for Quantum Sensor;
- Sensor Structures and Measuring Channel;
- Static Sensor Curve Determination;
- Examples of Possible Sensor Designs;
- Conclusions and perspectives

Purpose of the Work

To get closer to practical implementation of quantum technologies in sensors made of modified diamond with NV-center for tension control of small satellites structural elements

Problem Statement

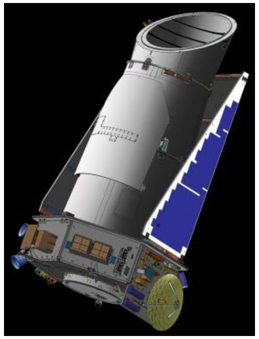
Structural elements of small satellites needs to be tested before and during usage in space.

In this case, the intensively developed quantum technologies in sensors have a bright prospect.

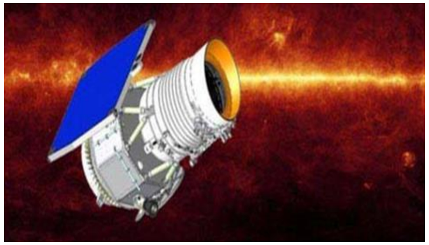
Researchers study quantum processes that occurring in materials, but they do not show how this technology may be used in practical applications.

Fields of Practical Implementation of Future Sensor

assess the accuracy of the mechanical positioning of lenses and antennas



Kepler space observatory, NASA



Wide-Field Infrared Survey Explorer (WISE), NASA

Chandra space observatory, NASA

checking the absence of a structural deformations of elements of a space telescope objectives and an antennas

assessment of tension force of ropes in space tether systems

Photo by NASA

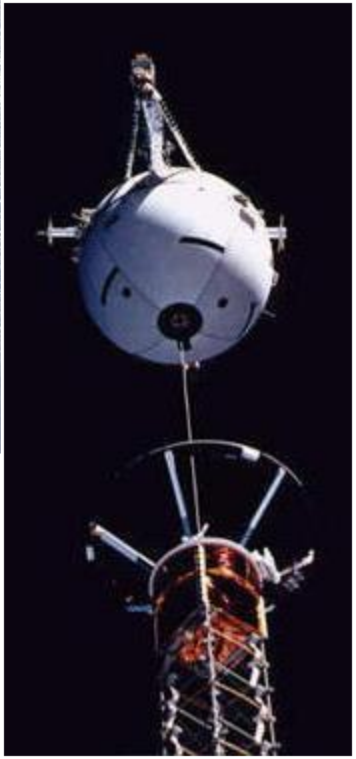
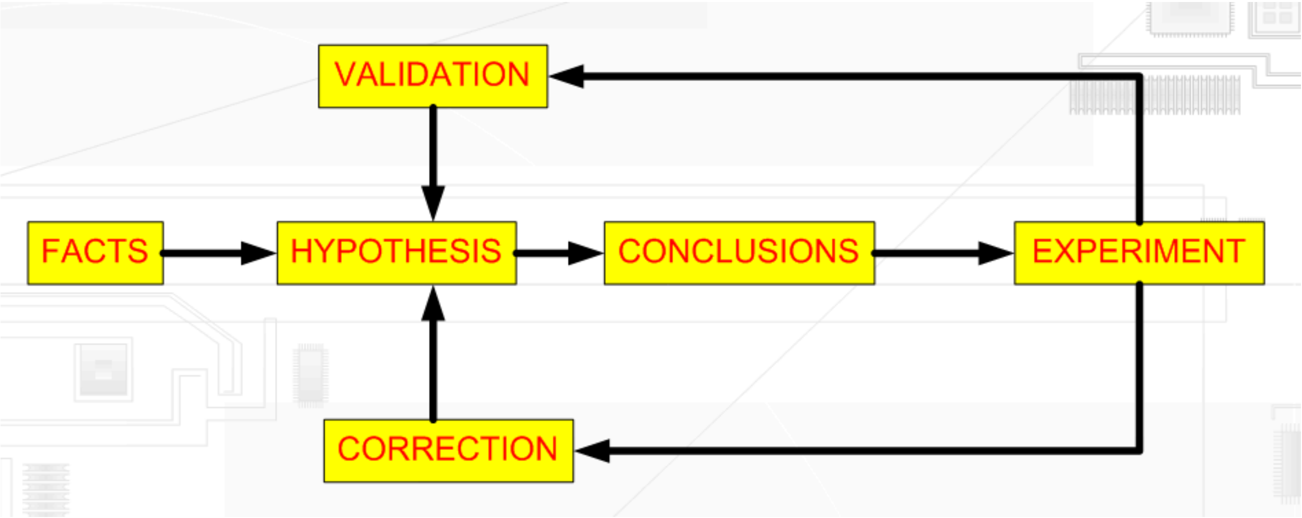


Photo by NASA

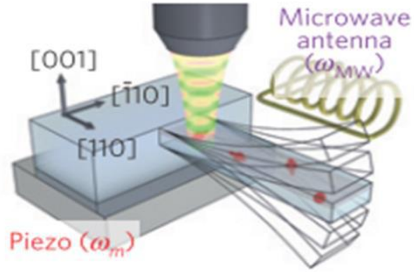
Methods and Methodology

Research methods are based on hypothetical-deductive method and systematic approach to sensor design for tension control of small satellites structural elements

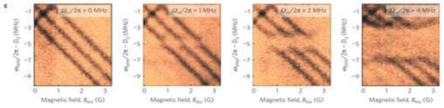
Hypothetical-deductive method



example of modified diamond operation in the sensor

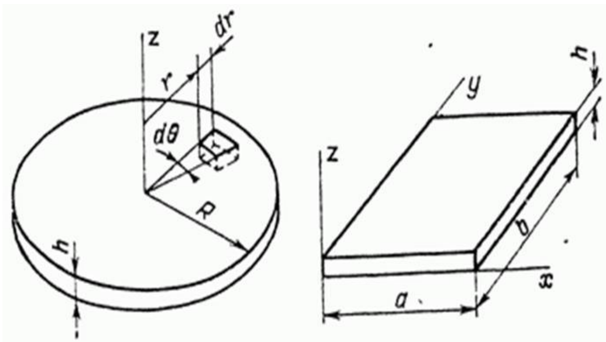


Experimental data (obtained before): sensitive energy gap



Sensing Element made of Modified Diamond

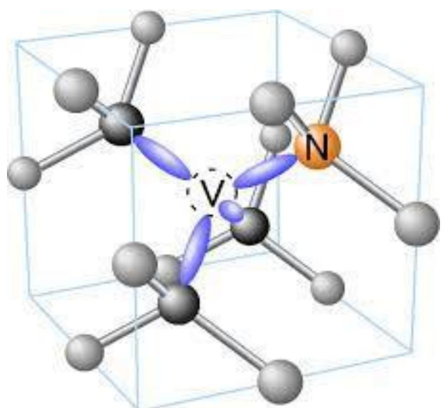
Types of Sensing Element



Sensor's vibration frequency depends on its size, shape, and method for attaching

There is the method for calculate the sizes of diamond plates with chosen natural frequency for different kind of shape and method for attaching

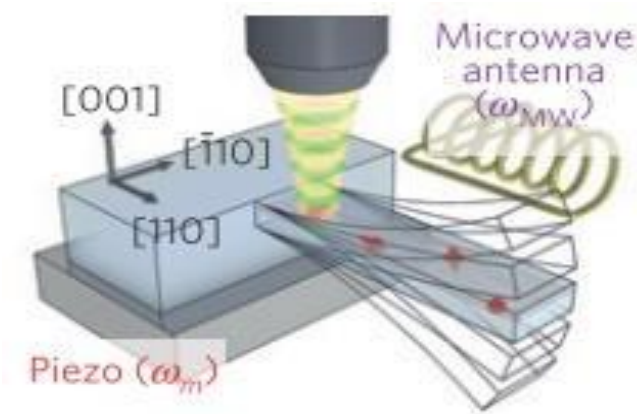
NV-center in Modified Diamond



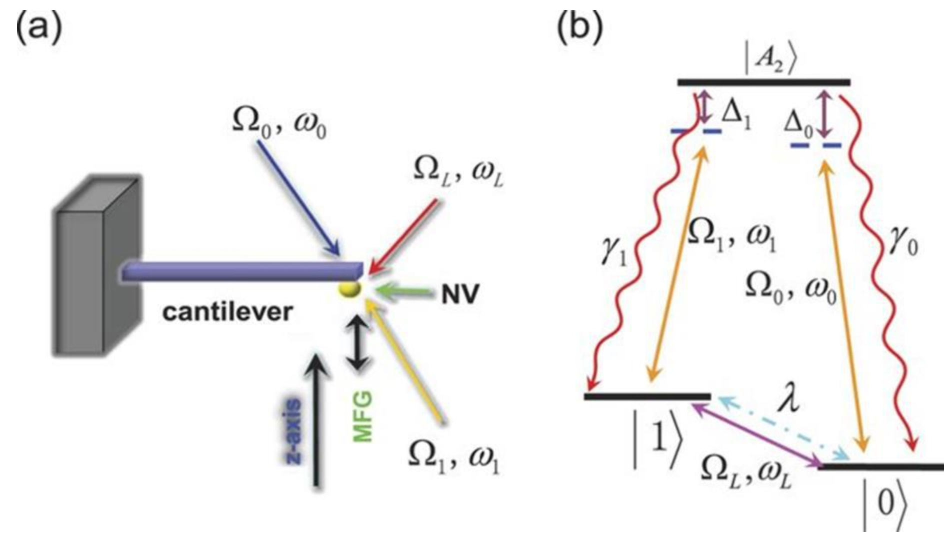
Modified diamond with NV-center is the diamond with broken structure where one atom of carbon replaced for the nitrogen and the other one neighbor atom is extracted and its place is vacant (empty)

Properties of Diamond Plates with NV-center

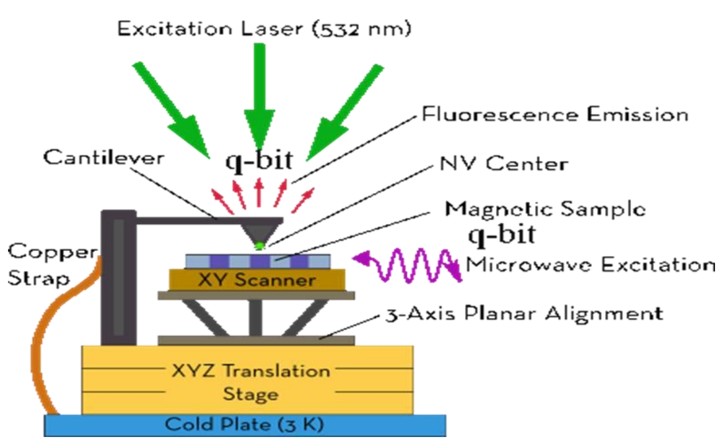
Strain effects on NV-center electronic spin



The dual nature of the sensor



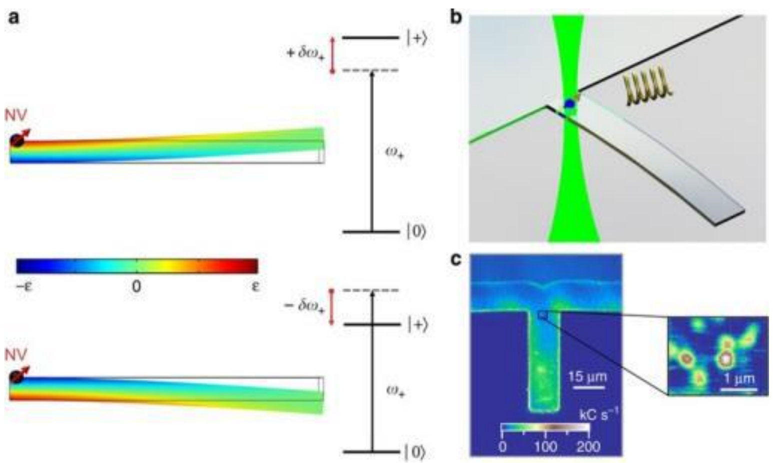
Quantum data



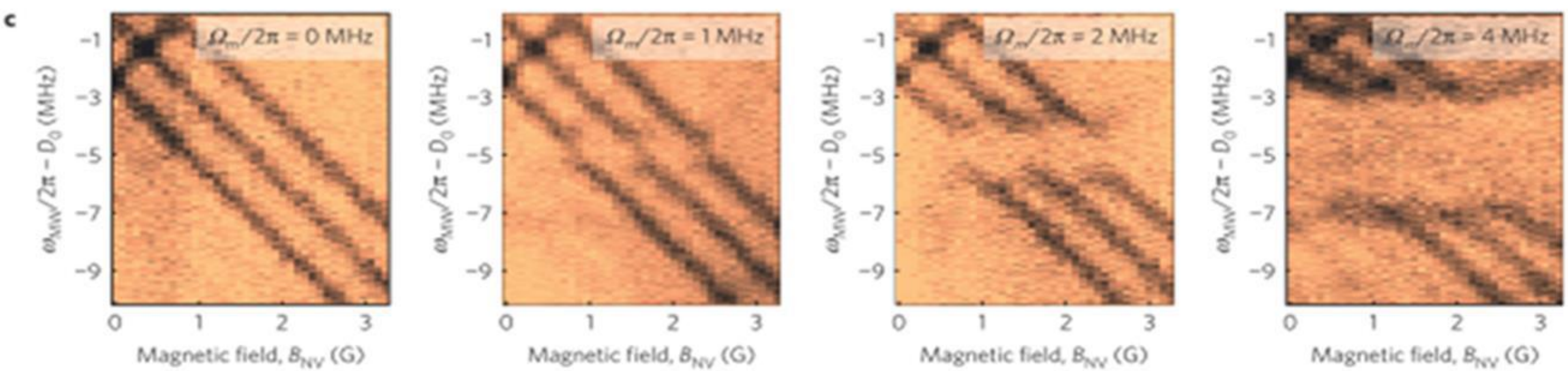
Sensing plate made of diamond with NV-center can be used as a traditional measuring transducer and a measuring transducer for a quantum computer system

The diamond with NV-center can produce photon/phonon under strain influence

Principle of NV-center Operation



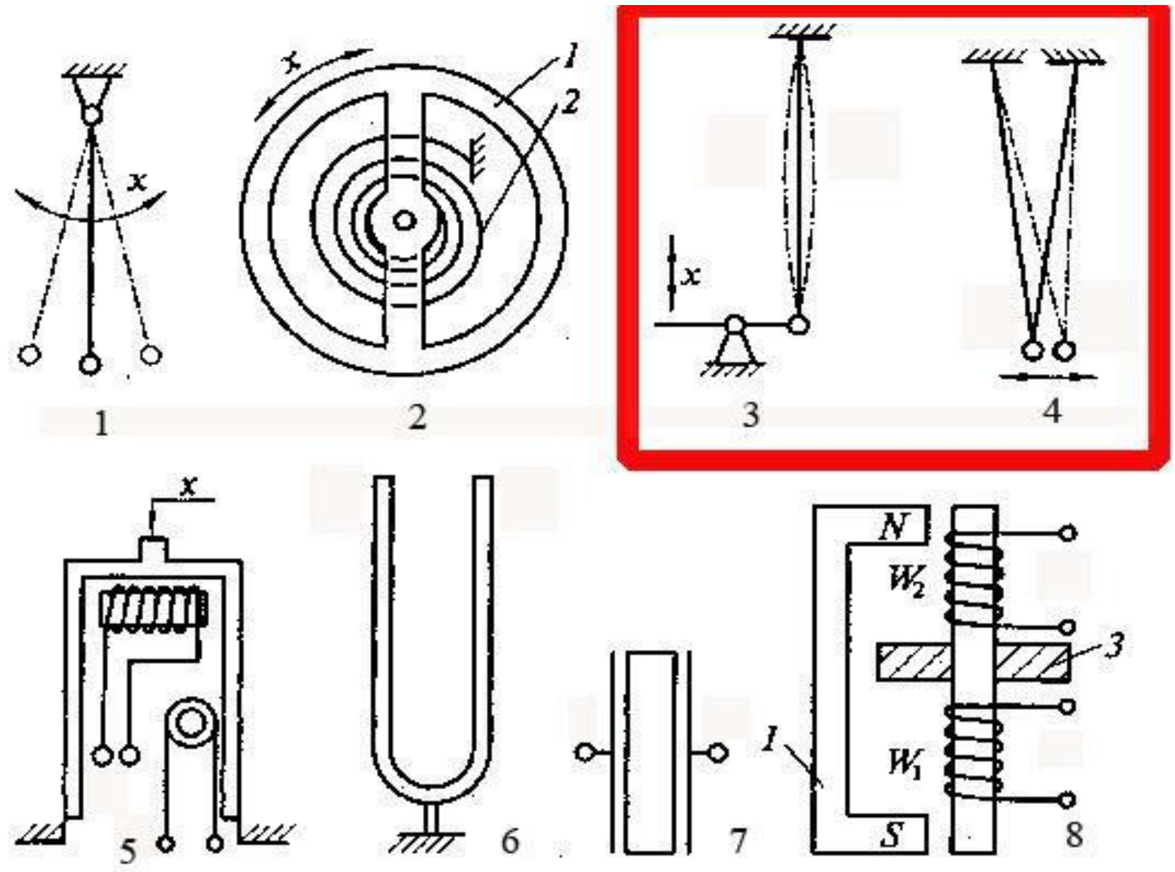
The carbon plate is the element that sense the measured physical parameter. NV-center in diamond plate is subsequent converter. The vibration is input value that depends on physical parameter. NV-center is initialized by laser green light. The output is the photons/phonons which are under magnetic field influence.



Strain changes the rigidity of the diamond plate and consequently changes its natural frequency. If vibration of sensor matches its natural frequency the energy gap in NV-center spin states could be seen. The energy gap (Autler-Townes effect) is output parameter of the sensor and can be used directly as input data for quantum computer.

The energy gap is between eigenstates |+ (N)) and |− (N)) on mechanical driving strength

Types of Resonators for Quantum Sensor

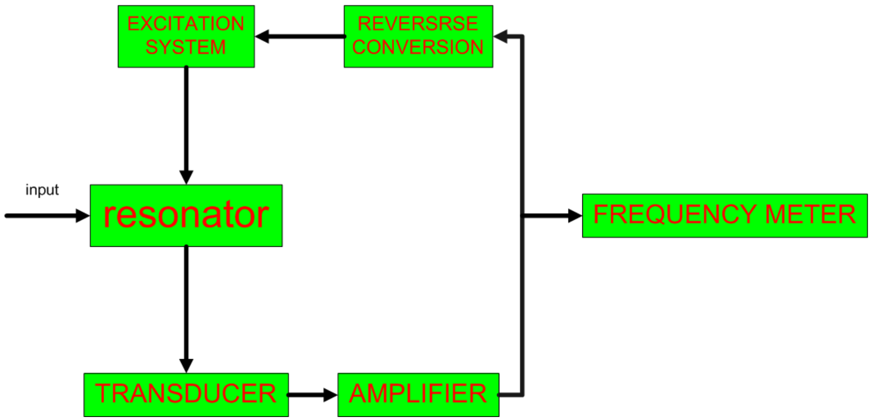


1. Pendulum
2. Balance-spring
3. Stringed resonator
4. **V-shape plate**
5. Cylinder shell
6. Tuning fork
7. Quartz resonator
8. Magnetostrictive core (magnet and isolator)

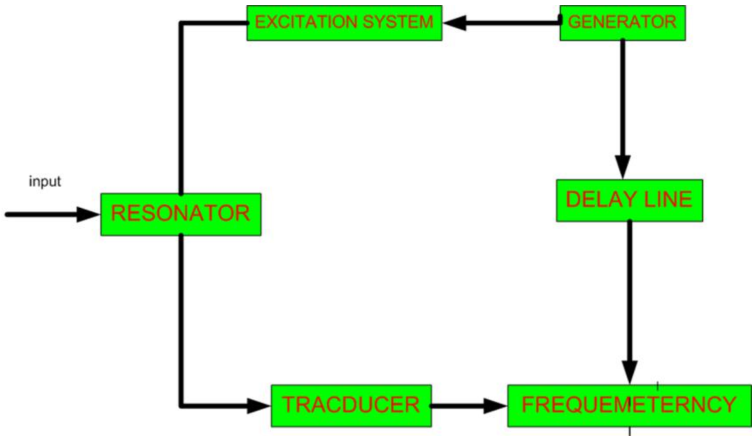
X – is a measured parameter

Sensor Structures

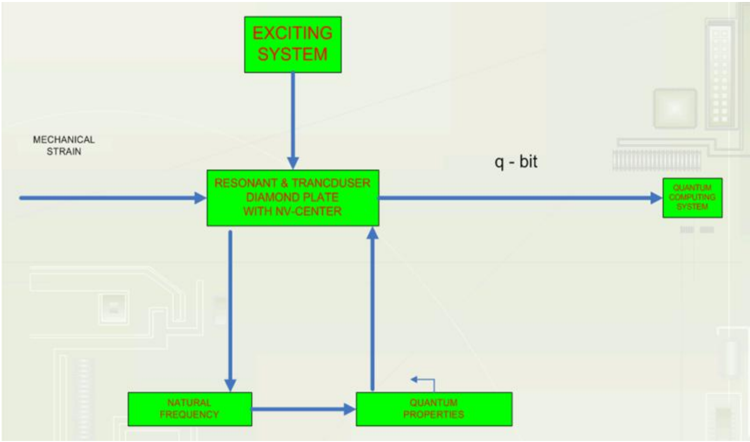
auto-oscillation



free vibrations



Measuring Channel



Static Sensor Curve Determination

Sensor curve is $f = f_m\sqrt{1+kx}$

where $$f_m^2 = \frac{\sum_{i=1}^{n} f_i^2 \sum_{i=1}^{n} x_i f_i^2 - \sum_{i=1}^{n} f_i^4 \sum_{i=1}^{n} x_i}{n\sum_{i=1}^{n} x_i f_i^2 - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} f_i^2};\ k = \frac{n\sum_{i=1}^{n} f_i^4 - (\sum_{i=1}^{n} f_i^2)^2}{\sum_{i=1}^{n} f_i^2 \sum_{i=1}^{n} x_i f_i^2 - \sum_{i=1}^{n} f_i^4 \sum_{i=1}^{n} x_i}$$

The curve should be found from experiment as follows

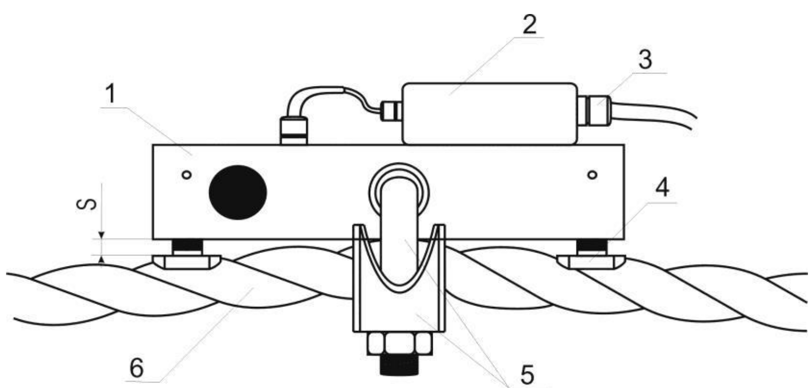
$x = bf^2 - a$ where $a = k^{-1};\quad b = \dfrac{1}{f_m^2 k} = \dfrac{a}{f_m^2}.$

The criteria to found best parameters is

$$J = \sum_{i=1}^{n}\left[x_i - (bf_i^2 - a)\right]$$

Examples of Possible Sensor Designs

The strain gauge for plate and for tether



load cell design

S-shape design

Conclusion

Main result of the work shows that it is necessary analytically divide modified diamond with NV-center that is used as sensing device into two parts: 1) a sensing element made of specially formed vibrating diamond plate, 2) quantum NV-center specially created in this plate. This approach to sensor design allows implement known theory of vibrating converters for quantum sensors made of modified diamond with NV-center for their use in applications concerned with tension control of small satellites structural elements.

Novelty and relevance of results consist in new, previously unpublished knowledge about a need to analytically divide primary converter made of modified diamond crystal into two parts to get possibility to measure a force or control a tension of small satellites structural elements.

Practical significance lays in getting possibility to assess the accuracy of the mechanical positioning of lenses and antennas or tension force of ropes in space tether systems.

Application possibilities consist in using future quantum sensors during calibrating radar and optical systems and study of tether systems.

Thank you for your attention!

The 1st International Aerospace Symposium
The Silk Road
08.01.2018

Information-Measuring System for Endurance Test of Small Satellites Structural Elements

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Mishin Yu.N., Moscow Aviation Institute (National Research University) & Lavochkin Research and Production Association, geo375@rambler.ru

Content

- Purpose of the Work and Problem Statement;
- Problem Solution, Methods and Methodology, Practical Advantage of New Sensors;
- Small Satellites and Space Tether Systems (Examples);
- Tension and Stresses Determination in Structural Elements of Small Satellites;
- Types of Sensors for Identifying Tensions and Stresses of Structures;
- Characteristics of Samarium Monosulfide;
- Manufacturing Strain Gauges Made of Samarium Monosulfide by the Method of Explosive Evaporation;
- Design of Strain Gauges Made of Samarium Monosulfide;
- Means to Study Properties of Strain Gauges;
- Characteristics of New Strain Gauges Made of Samarium Monosulfide;
- Scheme of Information-Measuring System with Auto-Calibration Module;
- Prospects for Future Implementation of Information-Measuring System with Strain Gauges Made of Samarium Monosulfide
- Conclusion

Purpose of the Work

To design small size strain gauge for information-measuring system in order to provide endurance test of structural elements of small satellites

Problem Statement

Structural elements of small satellites needs to be tested before and during use in space.

Mathematical apparatus of deformed bodies' mechanics has limited accuracy of mathematical description of complicated loading processes in frequency ranges of a small satellite operation.

Traditional strain gauges are too large for the task.

Problem Solution

Use samarium monosulfide (SmS) strain gauges (semiconductor resistors) as sensors for information-measuring system for endurance test of small satellites structural elements

Methods and Methodology

analytical mechanics, experiment planning, probability theory and mathematical statistics

Practical Advantage of New Sensors

+ Mounting on previously inaccessible places because of small base;
+ Minimization of connecting wires influence on the measurements' results because of sensors high ohmic resistance;
+ Linear characteristic;
+ Resistance to radiation;
+ Wide temperature range

Examples of Space Tether Systems and Small Satellites

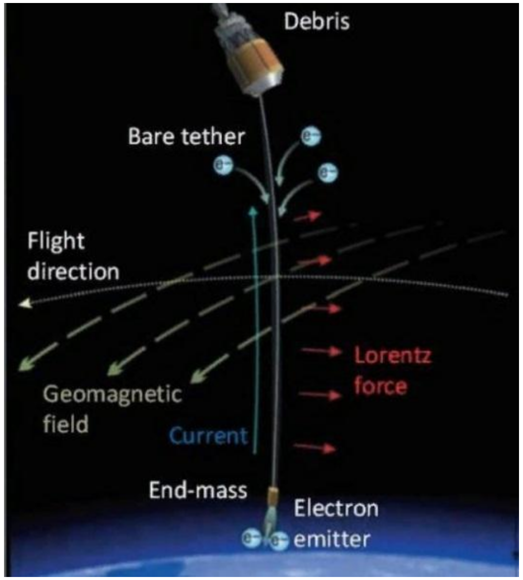
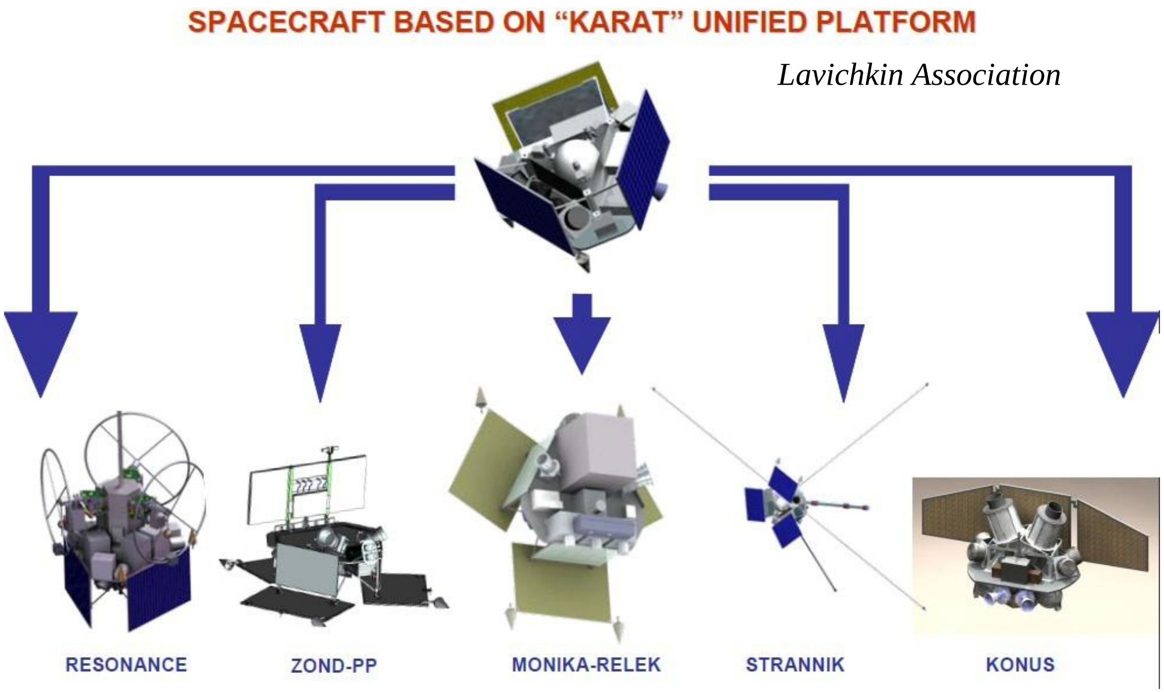


Photo by JAXA

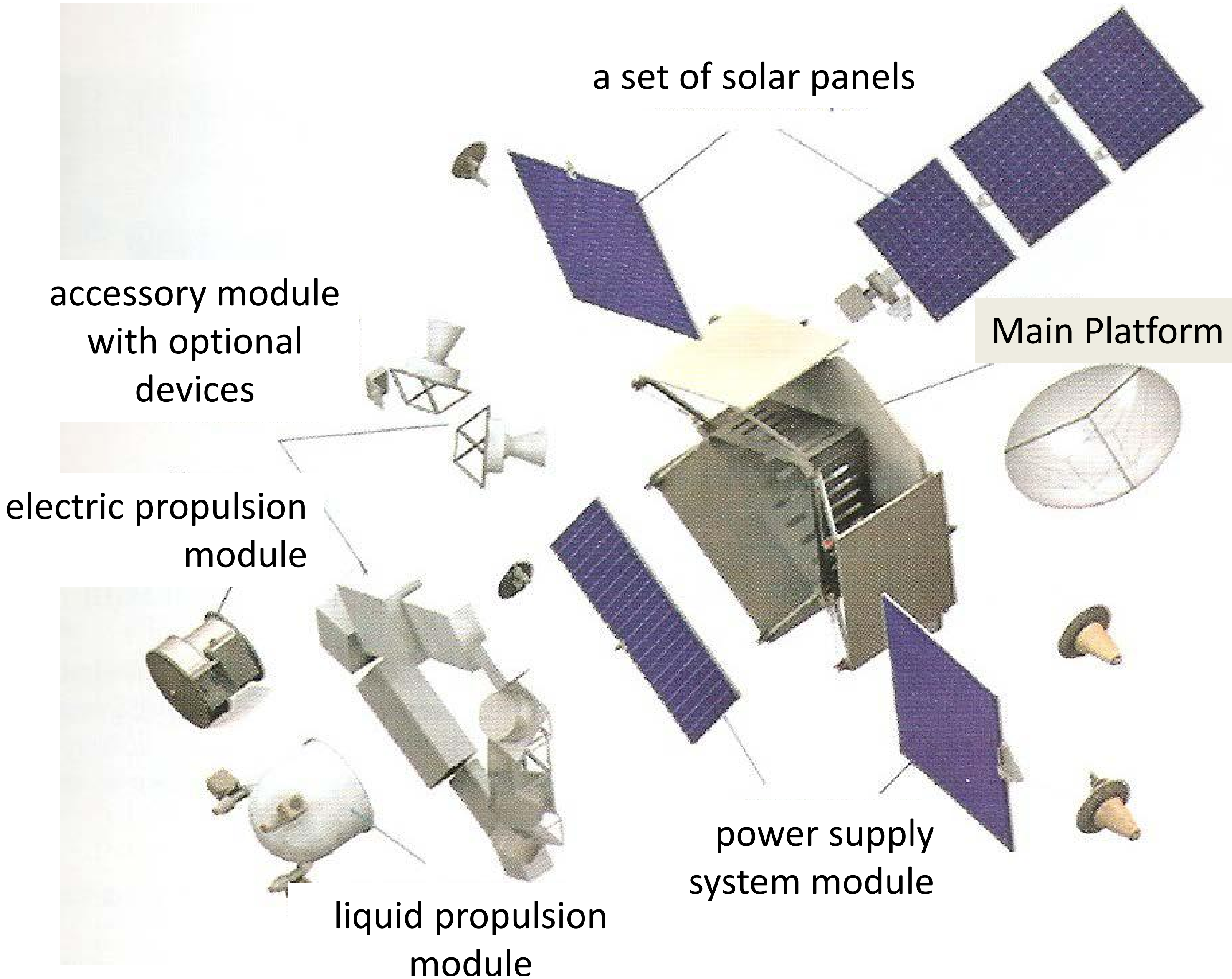
Photo by NASA

https://habr.com/post/401513/ (date of access 03.12.2018)

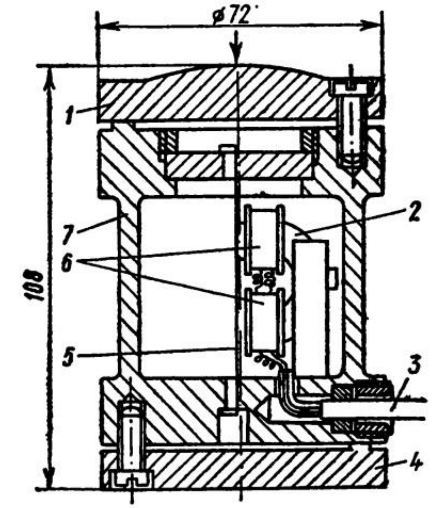


http://www.thespacereview.com/archive/1980.pdf (date of access 03.12.2018)

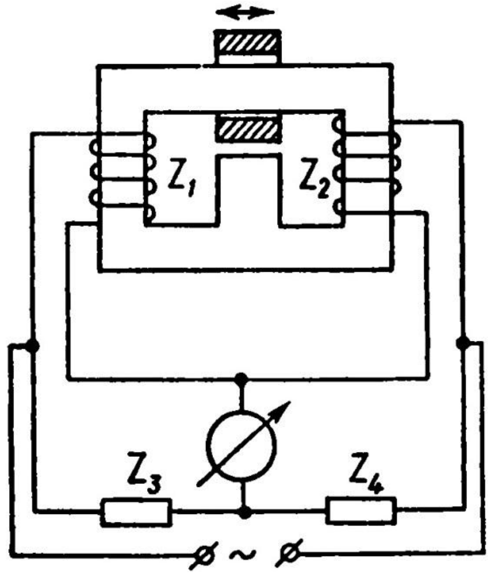
Tension and Stresses Determination in Structural Elements of Small Satellites



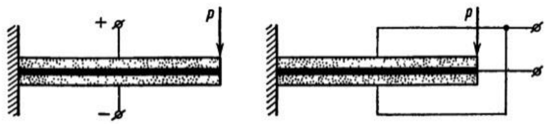
Types of Sensors for Identifying Tensions and Stresses of Structures

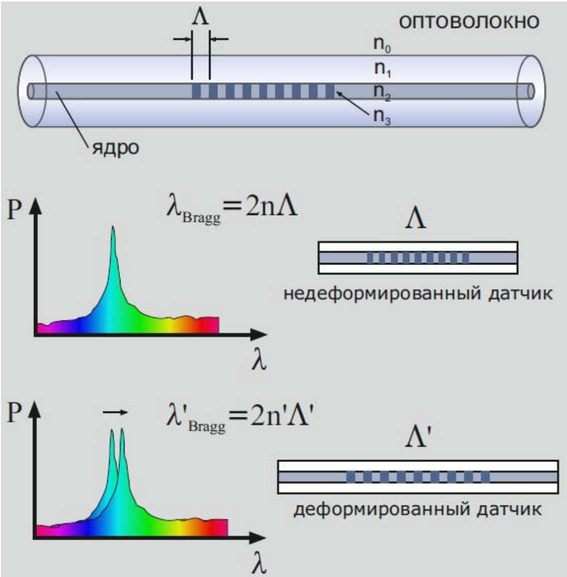


String Strain Gauge

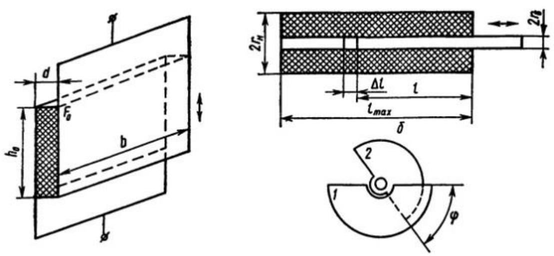


Inductive Transducer


Piezoelectric Transducers



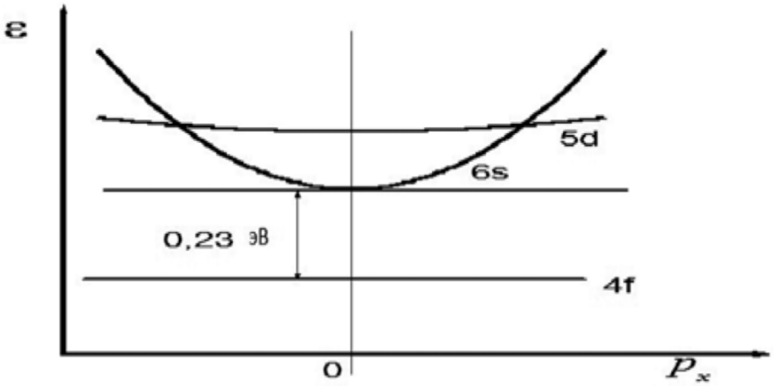
Fibre-Optic Strain Gauges


Capacitive Sensors

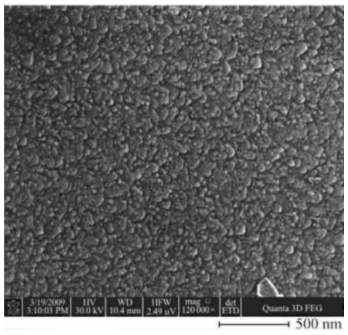
Kasatkin B.S., Kudrin A.B., Lobanov L.M., Pivtorak V.A., Poluxin P.I., Chichenev N.A. E`ksperimental`ny`e metody` issledovaniya deformacij i napryazhenij. Kiev: Naukova dumka, 1981. 583 p.

http://www.hbm.ru/upload/iblock/cbb/monitoring-nagruzki-s-ispolzovaniem-volokonnoy-opticheskoy-tekhnologii.pdf (date of access 03.12.2018).

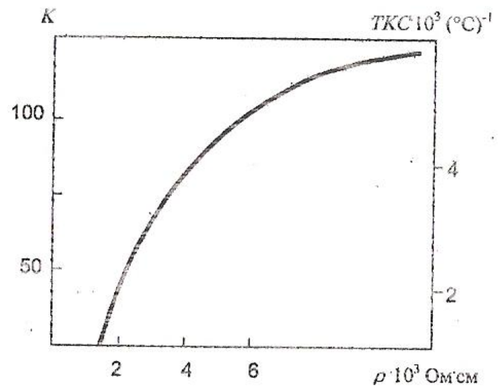
Characteristics of Samarium Monosulfide (SmS)



Zone Structure of Samarium Monosulfide



Polycrystalline Film of Samarium Monosulfide (photo)



K & *TCR* for Polycrystalline Film of Samarium Monosulfide

Physical properties of samarium sulfide

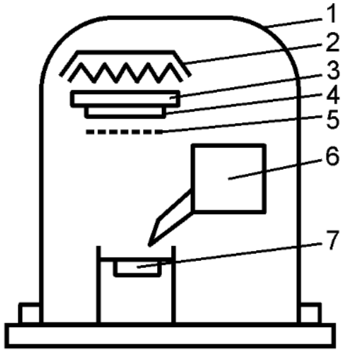
№	Physical properties	Value
1	Type conductivity semiconductor	n-type
2	Specific gravity	5.7 g/cm^3
3	Thermal conductivity	0.05 W/cm·°C
4	The specific heat	1.8 J/cm^3·°C
5	Specific electrical resistivity	0.01÷ 0.05 Ω·cm
6	Concentration of charge carriers	~10^{19} cm^{-3}
7	Young's modulus	1.2·10^6 kg/cm^2
8	Tensile strength	4000 kg/cm^2
9	Melting point	2300 °C

Vasil`ev L.N., Kaminskij V.V. Koncentracionny`j mexanizm p`ezosoprotivleniya SmS // Fizika tverdogo tela, t.36, No4, 1994. Pp. 1172-1175.

Kaminskiy V.V., Stepanov N.N., Volodin N.M., Mishin Yu.N. Baroresistor effect and semiconductor thin film baroresistors based on samarium sulfide for spacecraft applications // Solar System Research. 2014. Vol. 48. No7. Pp.561-567.

Manufacturing Strain Gauges Made of Samarium Monosulfide by the Method of Explosive Evaporation

Explosive Evaporation Method



1 - Vacuum Cap
2 - Base Holder
3 - Base Heater
4 - Base
5 - Template
6 - Dosing Unit
7 - Evaporator

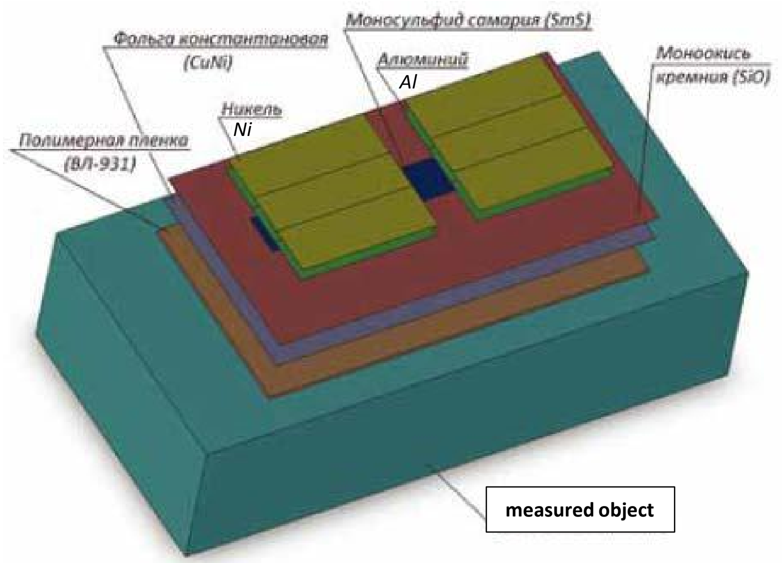
Kaminskij V.V., Volodin N.M., Solov`yov S.M., Mishin Yu.N., Sharenkova N.V. Vakuumny`e texnologii izgotovleniya tonkoplenochny`x tenzorezistorov na osnove sul`fide samariya dlya ae`rokosmicheskix apparatov. Vestnik FGUP «NPO im. S.A. Lavochkina». No2. Khimki. 2013. Pp.26-30.

Modified Vacuum Evaporation Unit УВН-74П2

Samarium Monosulfide Thin Film Parameters:
- Thickness …………………………………………… up to 3 µm
- Specific resistance ……………………………… 0.02…0.05 Ohm·cm
- Concentration of conduction electrons … 1020...1021 cm^{-3}
- Strain sensitivity coefficient …………………. up to 100
- TCR ………………………………………………….. -10^{-4} … -5×10^{-3} 1/°C

Novichkov V.M., Mishin Yu.N. Ocenka e`ffektivnosti i provedenie texnologicheskogo e`ksperimenta pri proektirovanii tenzorezistorov na osnove monosul`fida samariya // Sbornik trudov XX mezhdunarodnoj nauchno-texnicheskoj konferencii «Sistemny`e problemy` nadezhnosti, kachestva, komp`yuternogo modelirovaniya, informacionny`x i e`lektronny`x texnologij v innovacionny`x proektax (Innovatika-2014)». Pp.54-55.

Design of Strain Gauges Made of Samarium Monosulfide

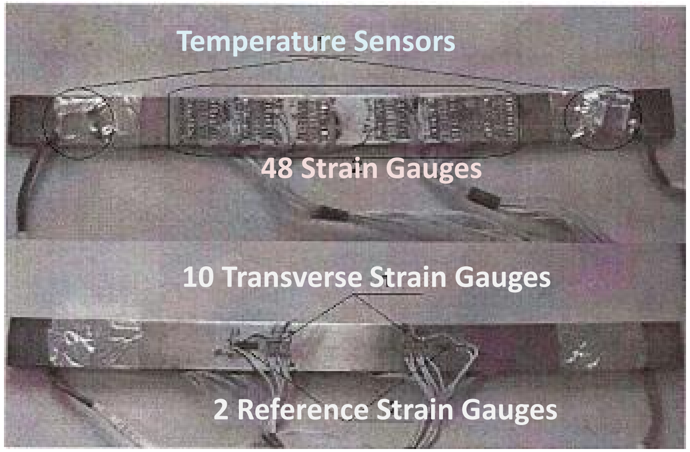


Layer No	Material	Layer Thickness, mm	Thermal Conductivity, W/(m·K)
1	Aluminum Alloy AL19	1	117
2	Polymer Film VL-931	0,03	0,034
3	Constantan Foil	0,003	22
4	Silicon Monoxide	0,002	1,38
5	Samarium Monosulfide	0,0005	20
6	Aluminum	0,0005	120
7	Nickel	0,002	94

Poluprovodnikovy`e tenzorezistory` na osnove monosul`fida samariya dlya KA. Samorazogrev. / Volodin N.M., Mishin Yu.N., Tulin I.D., Markacheva A.Yu., Kaminskij V.V. // Vestnik FGUP «NPO im. S.A. Lavochkina». 2012. No3. Pp.69-75.

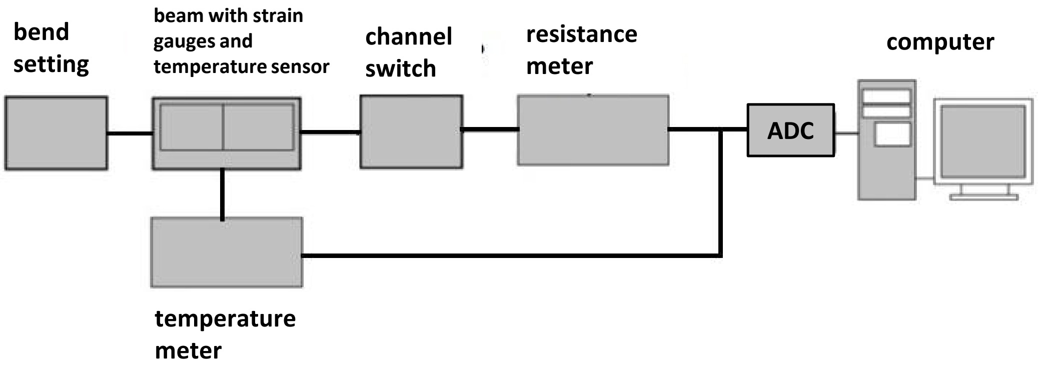
Means to Study Properties of Strain Gauges

calibration device with beam on two supports



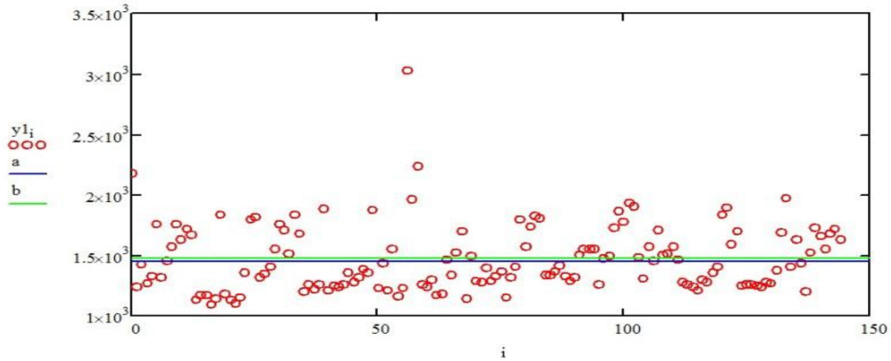
Beam with Strain Gauges

Climate Chamber TABAI MC-71

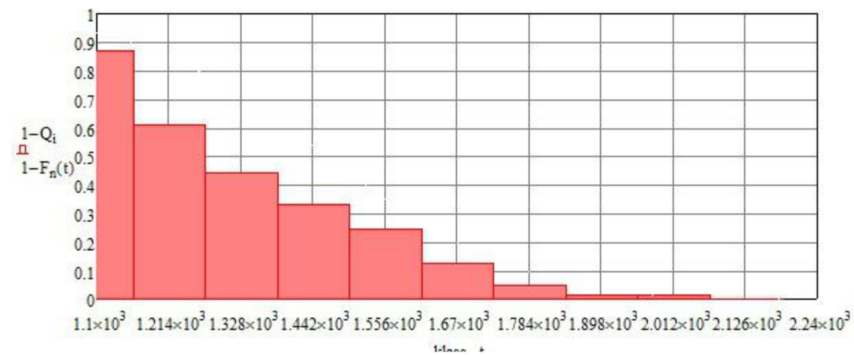


Strain Block Diagram of Means for Research

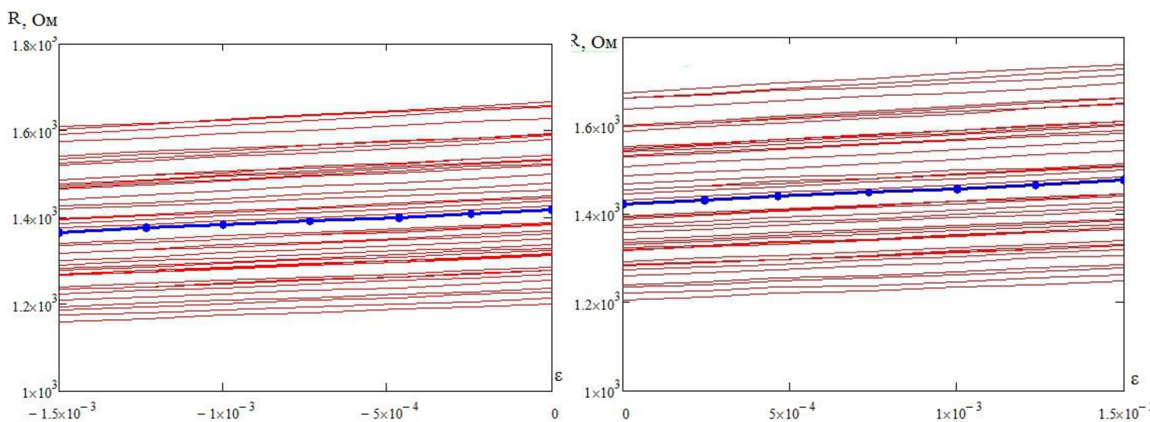
Characteristics of New Strain Gauges Made of Samarium Monosulfide



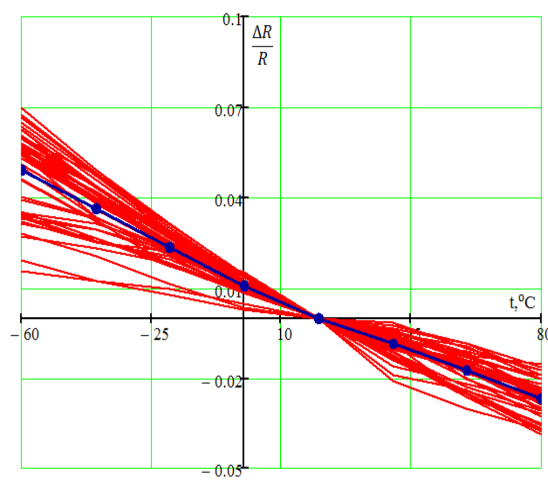
A representative sample of 145 strain gauges, Mean value is 1453 ohm



Resistance Distribution

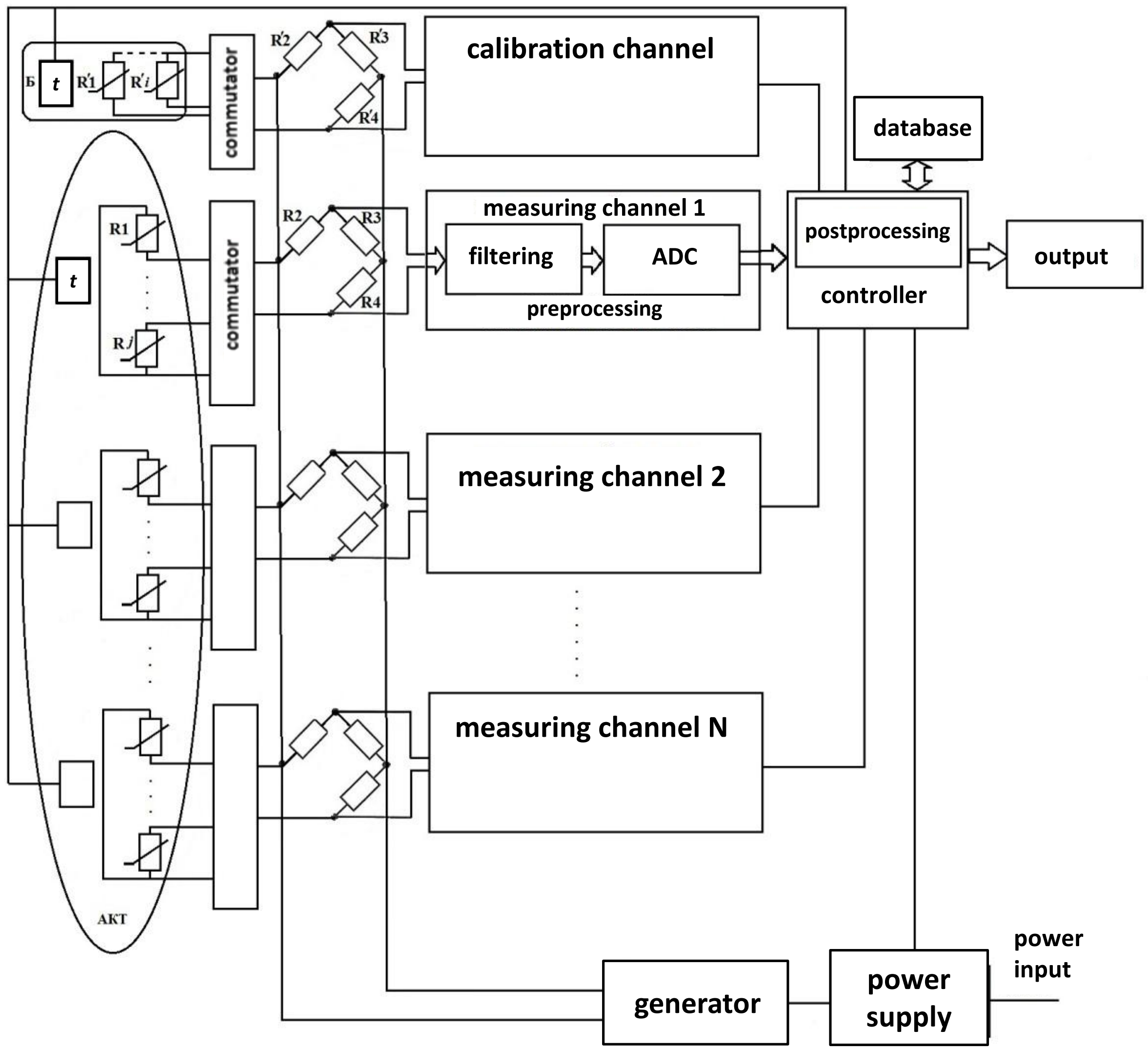


Resistance Variation due to Compression and Tensile, $\varepsilon = \pm 1500 \cdot 10^{-6}$



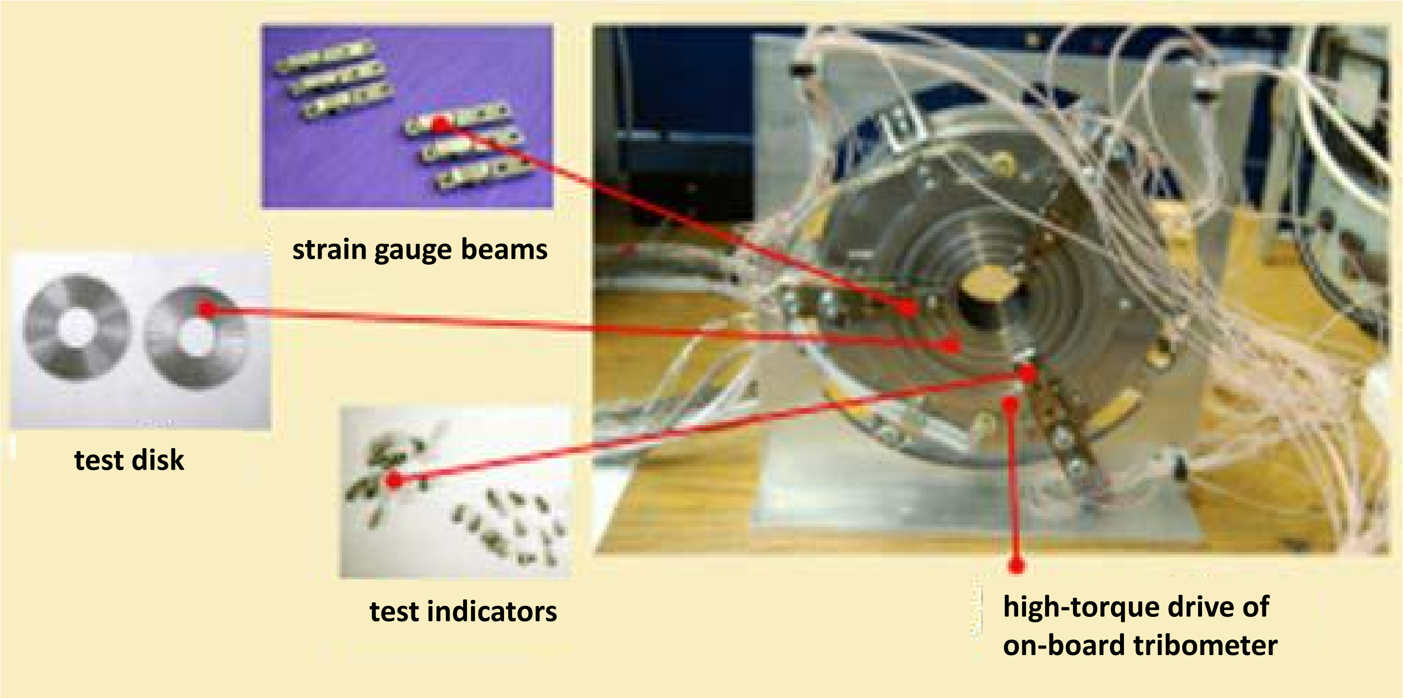
TCR, Sample Size = 44

Scheme of Information-Measuring System with Auto-Calibration Module



Prospects for Future Implementation of Information-Measuring System with Strain Gauges Made of Samarium Monosulfide

Tribometer for Space Research



https://www.energia.ru/ru/iss/researches/techn/54.html
(date of access 02.12.2018).

Conclusion

Main result of the work is technology of production and design of new strain gages made of samarium monosulfide (SmS) that are applicable for mounting near small radii of small satellites structural elements during endurance test. The other result is specially structured information-measuring system that is based on the strain gages and has ability to settings auto-adjust.

The novelty of the results is that for the first time the experimentally confirmed descriptions of main output characteristics of the strain gauges made of samarium monosulfide were obtained. This allow to increase accuracy of stress-strain state measurements by the system in stress concentration zones of small satellite structural elements.

Main practical significance of the results lies in the fact that new opportunities for experimental study of stress-strain fields of small sized structural elements of satellites are now open in endurance tests.

Application possibilities of the developed strain gauges made of samarium monosulfide as parts of information-measuring system allow solving complicated experimental tasks associated with investigation of structural elements endurance by studying tensions in condition of large gradients in strain and stress measurements.

Thank you for your attention!

High throughput X-band transmitters for the small satellites

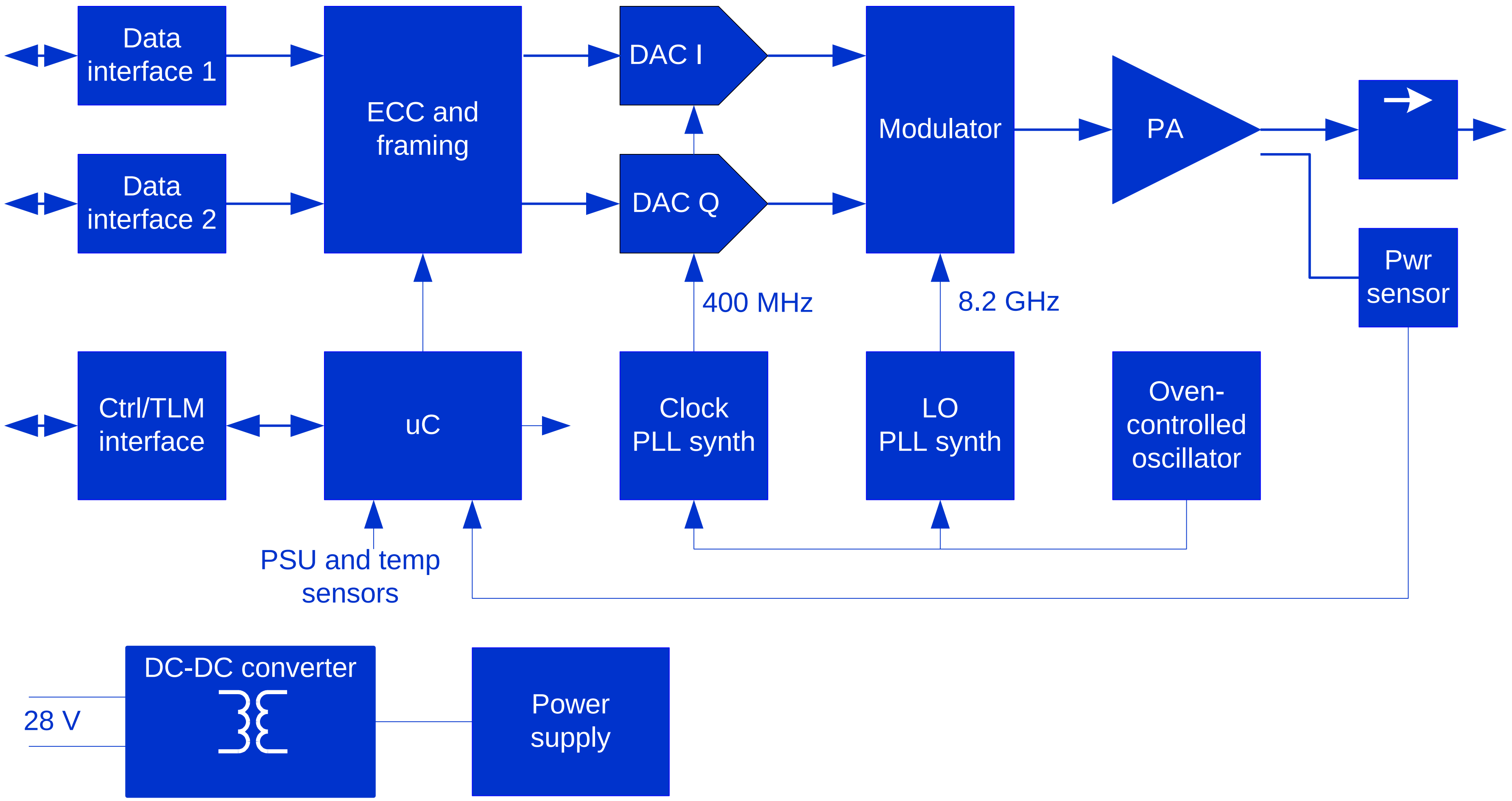
Eugene Kruglik

NPP «SAIT»

Main Goals

- High throughput. We Must Have Benefit from Each dB.
- Data Receiving to Ground Station Anywhere Where It Possible
- Minimum Time to Produce

Transmitter block diagram



TRANSMITTER PERFORMANCE

- Any X-band frequency with step 0,1 MHz
- Symbol Rate: 0,1 – 200 Mbaud
- Modulation: QPSK, 8PSK, 16QAM
- Coding Scheme: LDPC, Convolution, RS, BCH
- Output power: 10 W
- Weight: 1,75 kg
- Leadtime 9 months

Transmitter «PRD3»

FLIGHT EXPERIENCE

- ISS (Jan 2011)
- AIST-2D (Apr 2016)
- MKA-FKI1 (1 year) - Satellite Is Out of Explatation
- and 2 others

Завершен полный цикл наземной отработки

- EgyptSAT (1 Gbit/s)
- Kanopus-ST (Rocket Crash)
- Baumanec-1, 2 (Rocket Crash)
- Soyuz-SAT-O
- and 2 others

В стадии испытаний

- LUNA 25-27
- ISS (1 Gbit/s)
- and 5 others

Disadvantage (Little Disadvantage)

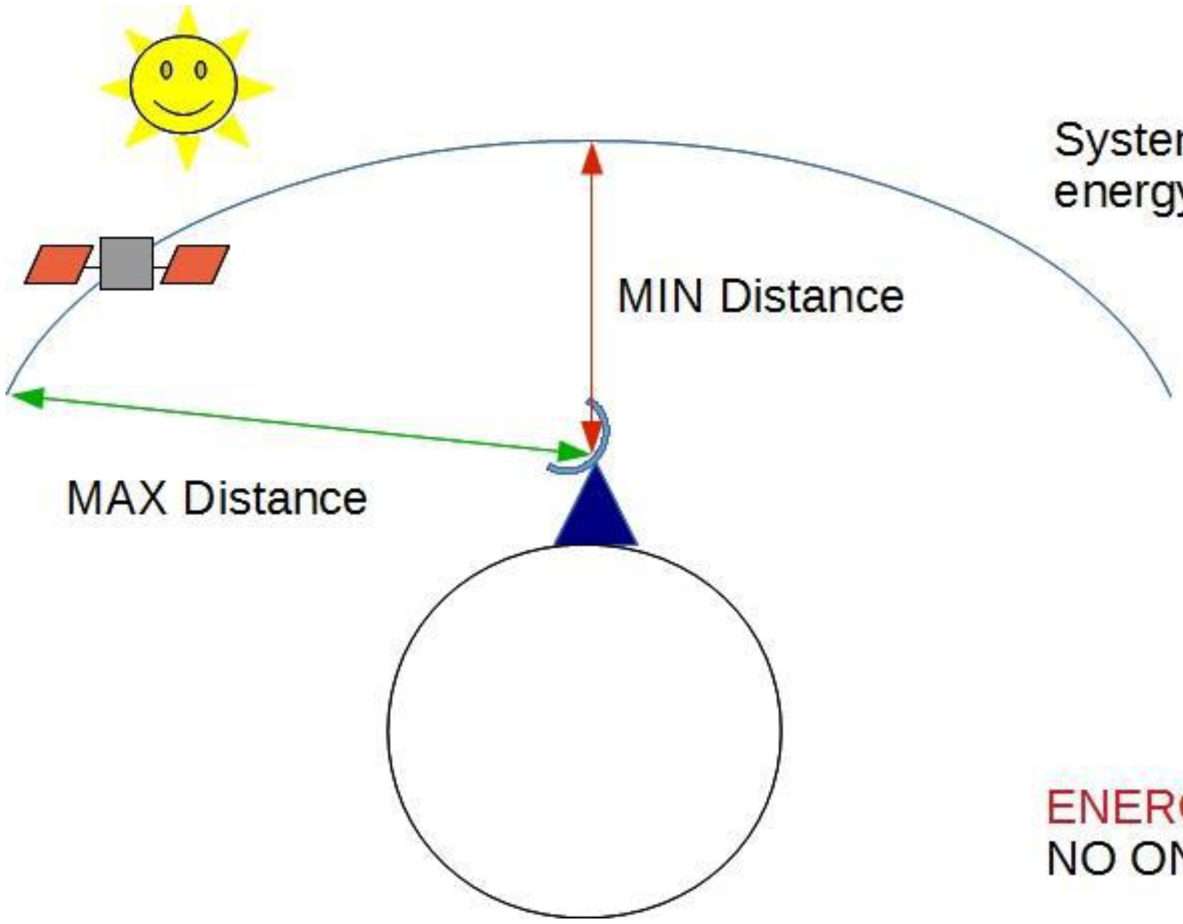
ONE PROJECT

ONE FIXED MODULATION

ONE FIXED CODE SCHEME

ONE FIXED DATA RATE

Ordinary Approach To Develop



System is developed for worst energy case (for MAX distance)

For Example:
Satellite Orbit = 800 km

MAX Distance
-
MIN Distance

ENERGY EXCESS = 10 dB !!!
NO ONE USE IT

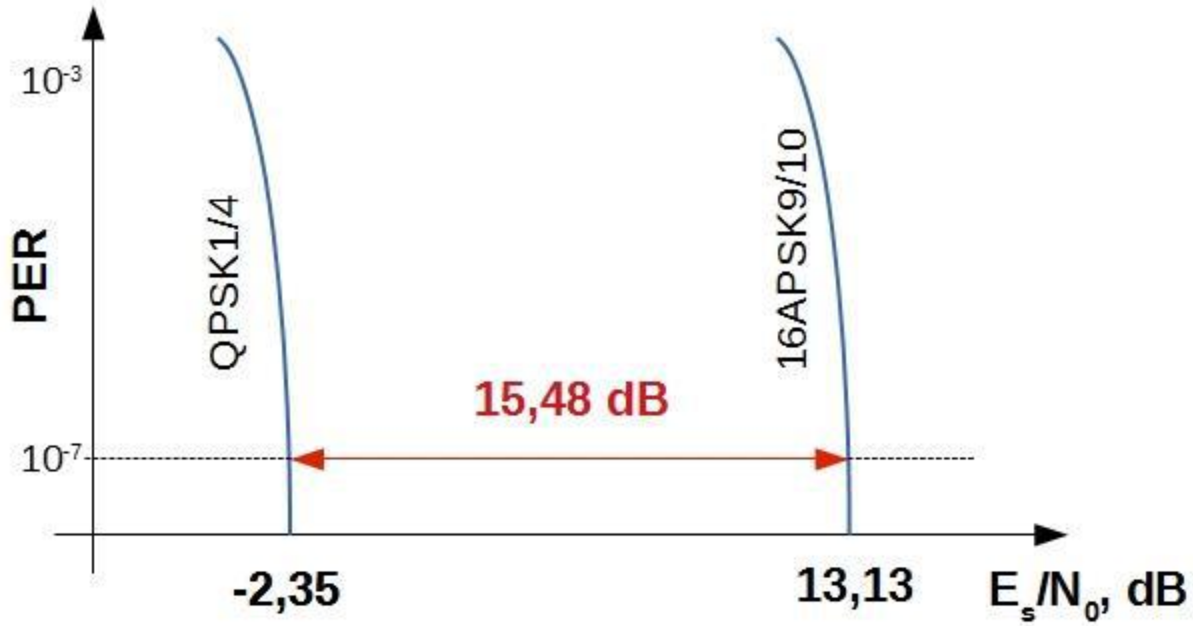
DVB-S2 Data Frame

PLHEADER	HEADER	DATA	CODE

PLHEADER = {Modulation, Code Scheme}

DVB-S2 Stream

8PSK5/6	Data Frame	QPSK1/2	Data Frame	16APSK8/9	Data Frame



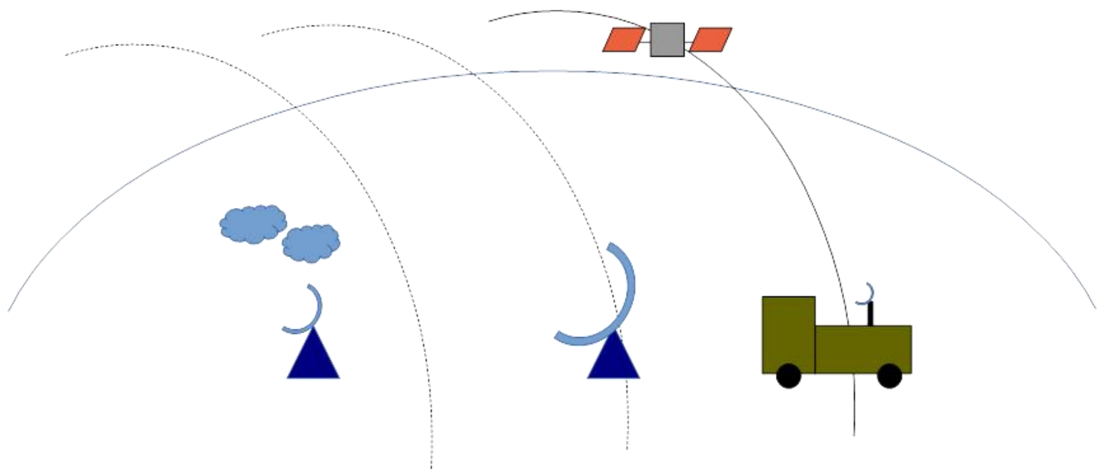
Mode	Spectral efficiency	Ideal E_s/No (dB) for FECFRAME length = 64 800
QPSK 1/4	0,490243	-2,35
QPSK 1/3	0,656448	-1,24
QPSK 2/5	0,789412	-0,30
QPSK 1/2	0,988858	1,00
QPSK 3/5	1,188304	2,23
QPSK 2/3	1,322253	3,10
QPSK 3/4	1,487473	4,03
QPSK 4/5	1,587196	4,68
QPSK 5/6	1,654663	5,18
QPSK 8/9	1,766451	6,20
QPSK 9/10	1,788612	6,42
8PSK 3/5	1,779991	5,50
8PSK 2/3	1,980636	6,62
8PSK 3/4	2,228124	7,91
8PSK 5/6	2,478562	9,35
8PSK 8/9	2,646012	10,69
8PSK 9/10	2,679207	10,98
16APSK 2/3	2,637201	8,97
16APSK 3/4	2,966728	10,21
16APSK 4/5	3,165623	11,03
16APSK 5/6	3,300184	11,61
16APSK 8/9	3,523143	12,89
16APSK 9/10	3,567342	13,13

Adaptive Stream Performance

- Satellite orbit – 800 km
- Ground Station Antenna Diameter – 2 m
- Adapitve Stream Performance – 50,5 Gbytes
- Fixed Stream Performance – 26,7 Gbytes
- 50,5/26,7 = 1,89

	Вариант	1	2	3	4
1.1	Модуляция	QPSK	8PSK	16APSK	16APSK
1.2	Мощность передатчика, Вт	10	10	10	10
1.3	КНД антенны, дБ	15	15	15	15
1.4	Потери в фидере, дБ	1,5	1,5	1,5	1,5
1.5	ЭИИМ передатчика, дБ-Вт	23,5	23,5	23,5	23,5
2.1	Частота, ГГц	8,2	8,2	8,2	8,2
2.2	Угол места начала сеанса, град	5	20	45	70
2.3	Высота орбиты, км	800	800	800	800
2.4	Дальность связи, км	2782,52	1768,3	1074,3	845,14
2.5	Потери в свободном пространстве, дБ	179,67	175,73	171,4	169,31
3.1	Диаметр антенны земной станции, м	**2,0**	**2,0**	**2,0**	**2,0**
3.2	КНД антенны, дБ	42,1	42,1	42,1	42,1
3.3	Шумовая температура антенны, К	50	50	50	50
3.4	Коэффициент шума приемника, дБ	0,8	0,8	0,8	0,8
3.5	Шумовая температура системы, К	108,66	108,66	108,66	108,66
3.6	Добротность (G/T)	21,74	21,74	21,74	21,74
4.1	Символьная частота, Мсимв/с	200	200	200	200
4.2	Скорость кода	3/4	8/9	4/5	8/9
4.3	Скорость передачи данных, Мбит/с	**300**	**533,33**	**640**	**720**
4.4.	Полоса частот, МГц	250	250	250	250
5	Отношение сигнал/шум на демодуляторе, дБ	10,19	14,13	18,46	20,54
6	Требуемое отношение сигнал/шум на демодуляторе, дБ	4,03	7,91	11,03	13,13
6.1	Превышение треб.отношения сигнал/шум, дБ	**6,16**	**6,22**	**7,43**	**7,41**
6.2	Потери в атмосфере, дБ	0,69	0,69	0,69	0,69
6.3	Потери на дождь (доступность 99,5%), дБ	0,56	0,56	0,56	0,56
6.4	Потери в облаках, дБ	0,56	0,56	0,56	0,56
6.5	Потери на наведение, дБ	0,5	0,5	0,5	0,5
6.6	Потери на поляризацию, дБ	0,25	0,25	0,25	0,25
6.7	Потери на реализацию демодулятора, дБ	1	1,5	2	2
7	**Итого запас, дБ**	**2,6**	**2,16**	**2,87**	**2,85**

Adaptive Frame Performance

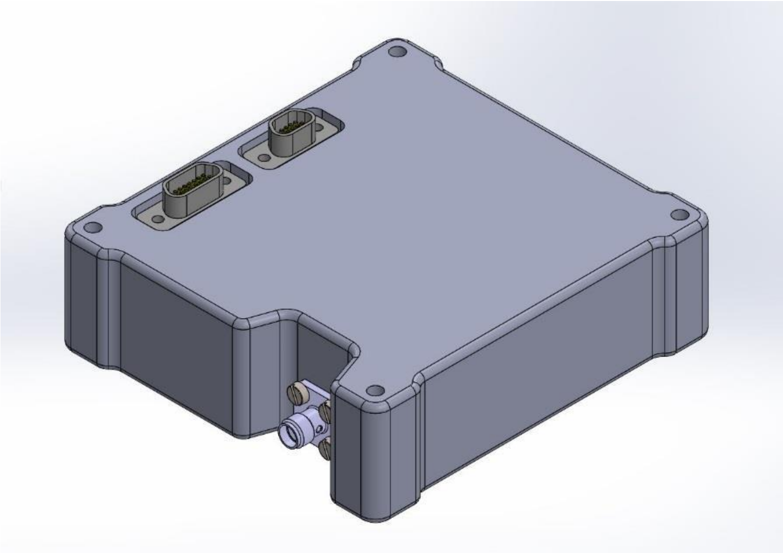


Data Receiving by the Ground Stations with Different Technical Specifications

Demodulators

	Custom design	Cortex Low Speed (LS)	Cortex High Speed (HS)	DVB-S2 LS	DVB-S2 HS
Data Protocol	Custom	CCSDS	CCSDS	DVB-S2	DVB-S2
Stream		Fixed	Fixed	Adaptive	Adaptive
Data Rates, Mbaud		50-150	150-200	50-100	100-300
Price*, Euro	>130 000	100 000	150 000	10 000	40 000
Delivery time	3 years	3-6 months			
* Rough estimate					

CubeSAT (and Small Satellite)



- Any X-band frequency with step 0,1 MHz
- Modulation: QPSK, 8PSK, 16APSK
- Symbol Rate: 0,1 – 260 Mbaud
- Bit Rate: up to 1040 Mbit/s
- Coding Scheme: LDPC, BCH (DVB-S2)
- Stream: Adaptive
- Output power: Cubesat - 2,5W, SS – 10 W
- Power Consumption: Cubesat - 16 W, SS – 70 W
- Weight: 0,380 kg

Conclusion

- High Throughput up to 2,08 Gbit/s (Using two carriers with polarization diversity)
- Adaptive Stream
- Data Recieving by the Ground Stations with Different Technical Specifications
- Using Commercial Satcom Demodulator at the Ground Station
- Delivery Time – 9 months