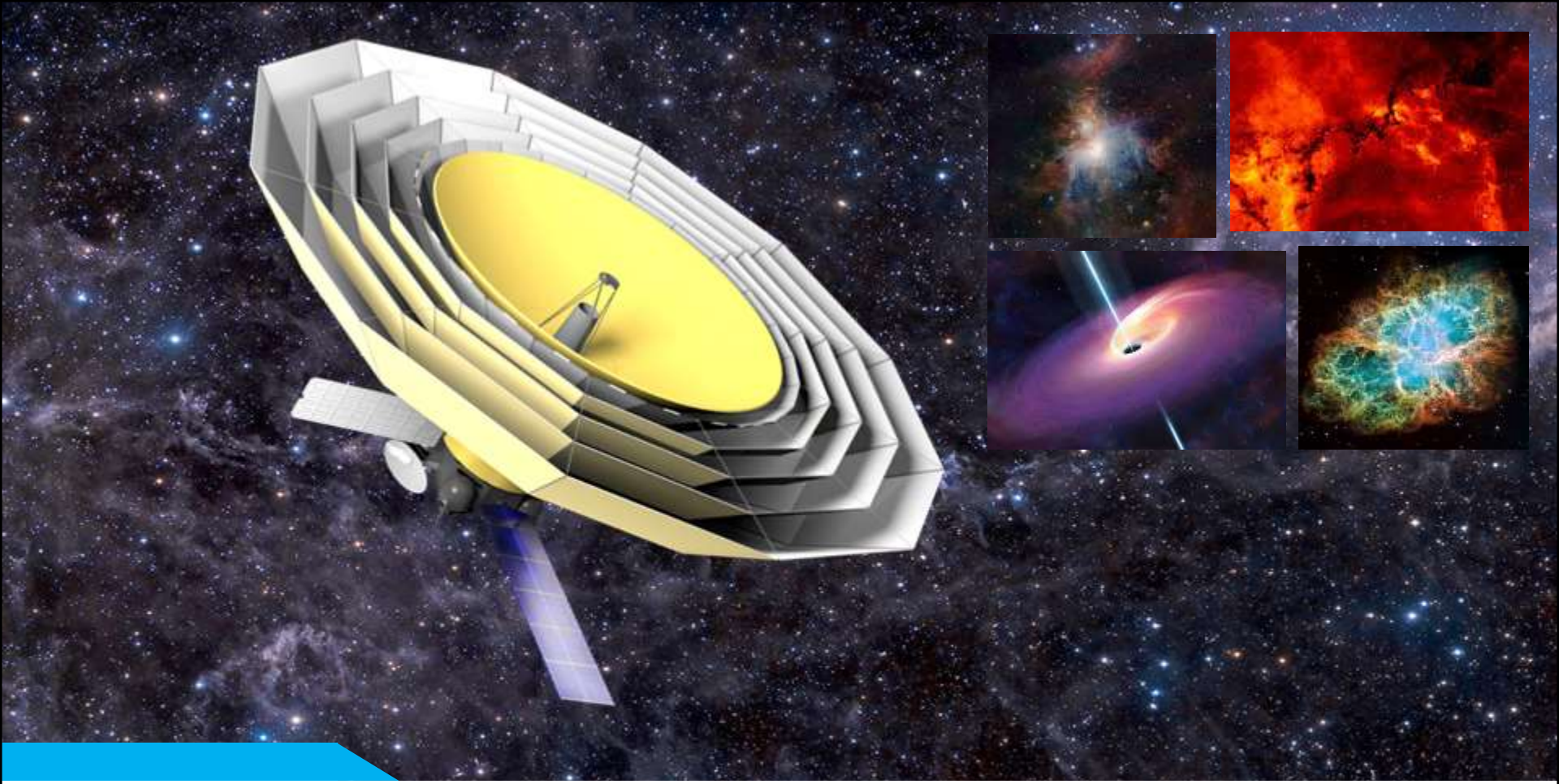

Millimetron Spacecraft Structure and Technical Requirements

Andrey Smirnov on behalf of the Millimetron team

ASC LPI

Outline

1. **Structure of the spacecraft**

- ✓ Launcher Vechicle
- ✓ Transport and working configuration
- ✓ Mass and power budget

2. **Key systems of the payload module**

- ✓ Antenna
- ✓ Thermal system
- ✓ Scientific Instruments
- ✓ Cryo instrument container
- ✓ High-speed data link
- ✓ Spacecraft Bus - “Navigator-SM”

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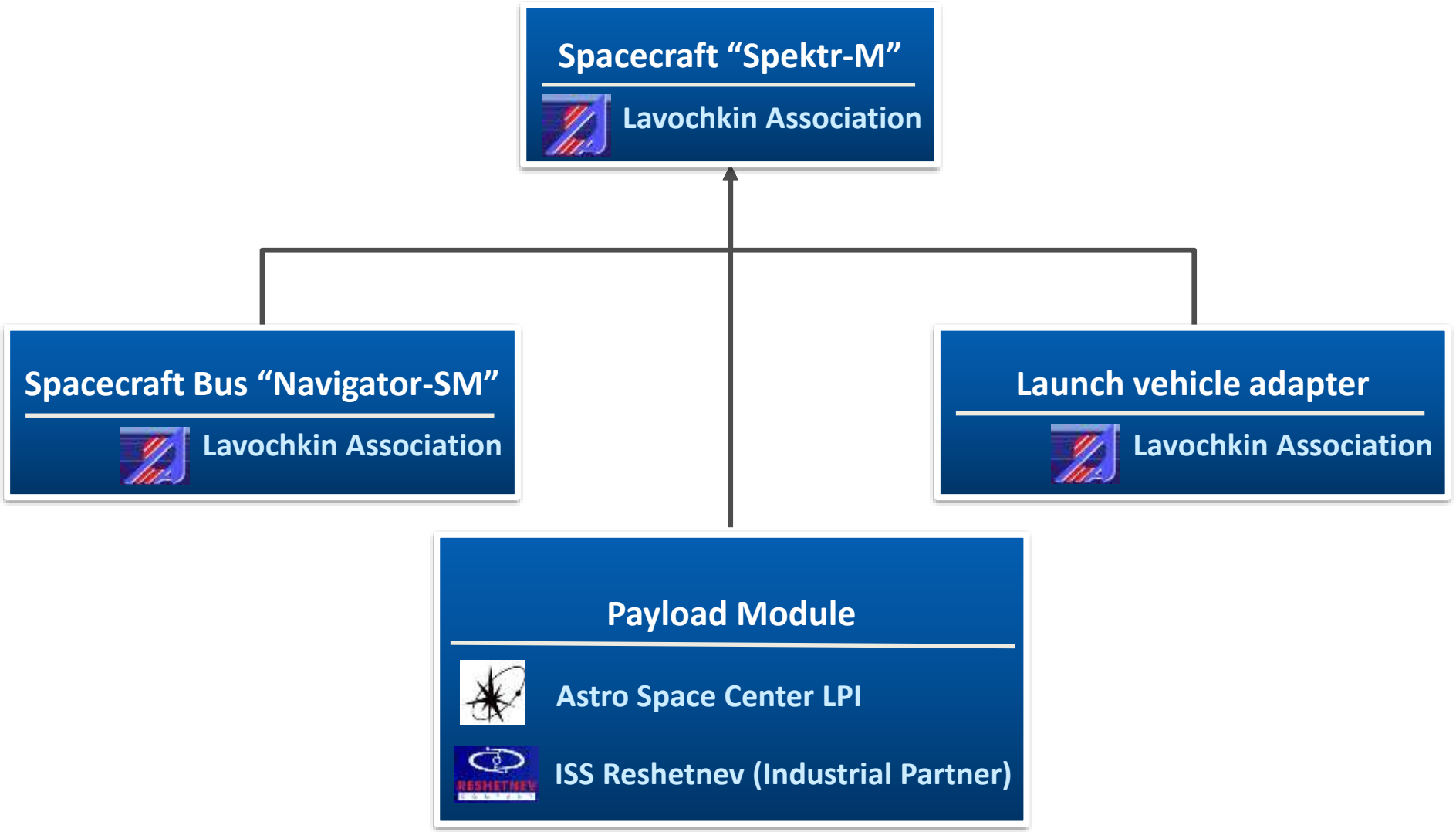
Structure of the Spacecraft “Spektr-M”



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Russian Heavy Launchers

In Russia, there is a program for the development heavy lift class launchers

Launch Vehicle	Booster	Launch mass to L2, kg	Diameter of the fairing, m	Year of flight
«Angara-A5»	DM-03	7,2	4.35	2023
«Angara-A5M»	DM-03	8,1	5.2	2024
«Angara-A5M»	KVTK	9,35	5.2	2026

*** present launchers will start from Vostochny Cosmodrome (Russia)**

DM – more than 320 launches (98% success rate) TRL9

KVTK- Liquide Oxygen/Hydrogen upper stage booster

Launch Configuration in the Fairing

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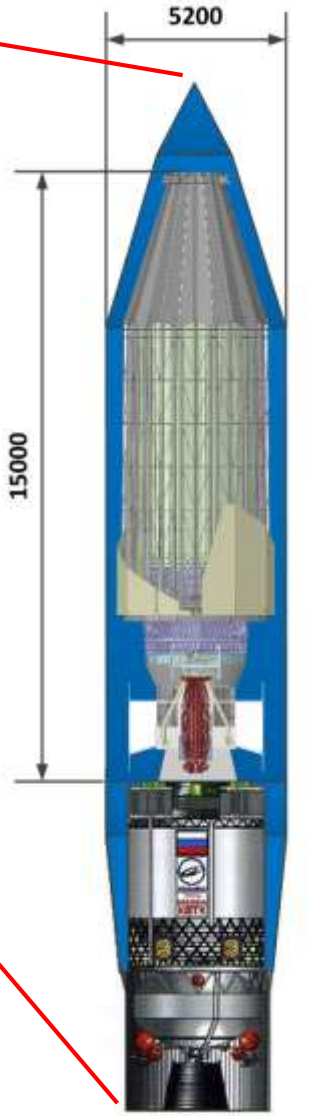
General view of LV «Angara-A5» with KVTK upper stage



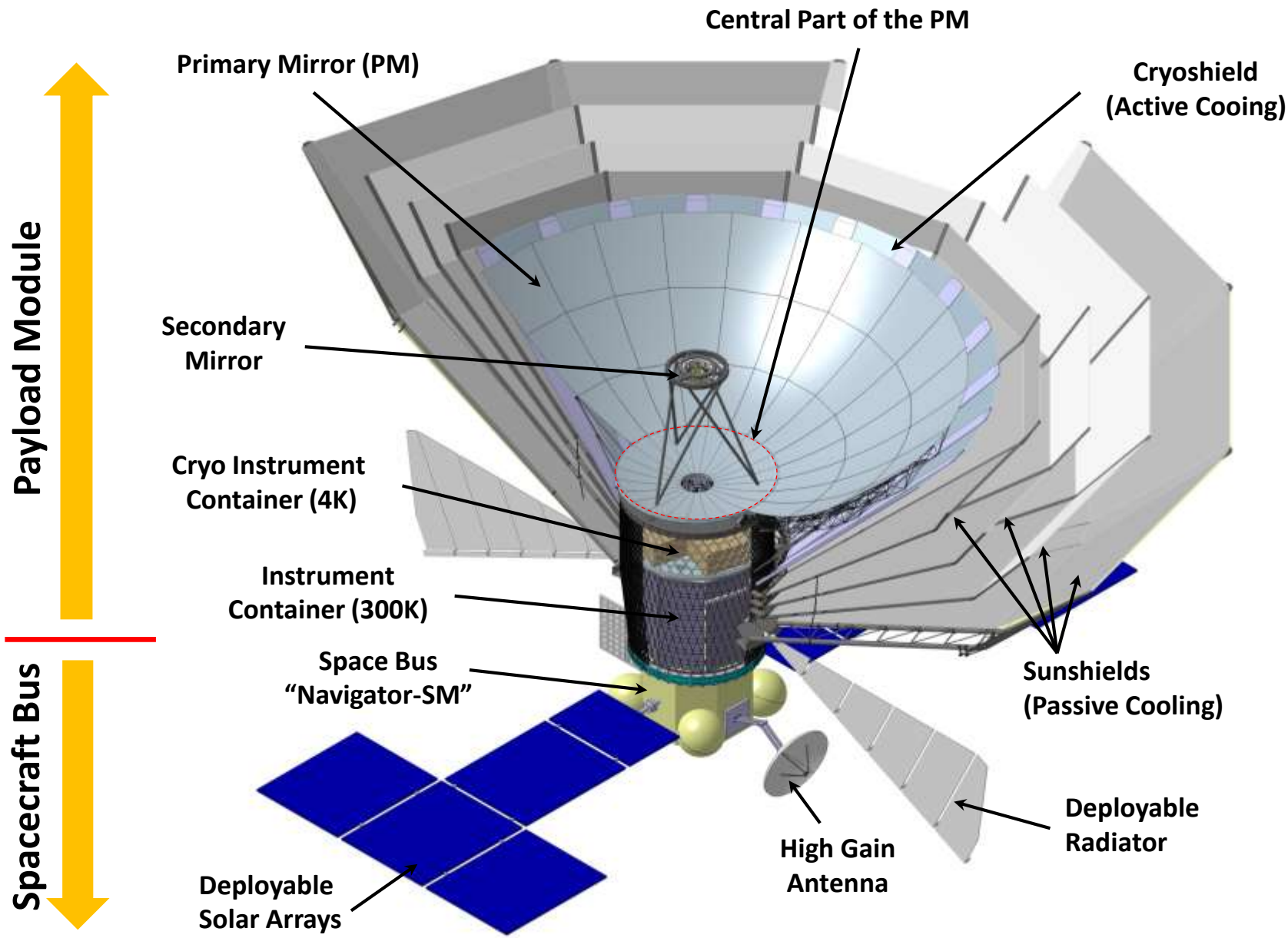
Head fairing with booster and MSO in launch configuration

Millimetron

Booster KVTK

ASC LPI

Working Configuration



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Preliminary Mass and Power Budget

Launch Vehicle	Mass, kg	Power, W
Payload module	6500	4500
Space Bus	1770	2500
Launch vehicle adapter	115	-
Fuel	900	-
Total Spacecraft (included margin 10%)	9285	7000

Specification	9350	7500 (end of life)

* We are continue work to reduce mass and power consumption of the systems

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Antenna requirements

- The antenna of the MSO has a Cassegrain design composed of a fast and large (10-m) parabolic primary mirror and a hyperbolic secondary mirror
- Unfolded 3m aperture central part of the PM
- The requirement for the WFE of the whole antenna is 6μm RMS (goal)
- The operating wavelength of antenna is aimed from 80 μm to 7 mm
- A surfaces reflectivity of the mirrors has to be kept above 0.98 for the whole lifetime of the mission – 10 years
- An equivalent focal length is about 70m, FOV about 7 arcmin
- Operational temperature of < 10K (4K goal)
- Industrial partner responsible for antenna i… …ite Systems Reshetnev

More details in the presentation of Y. Podobedov

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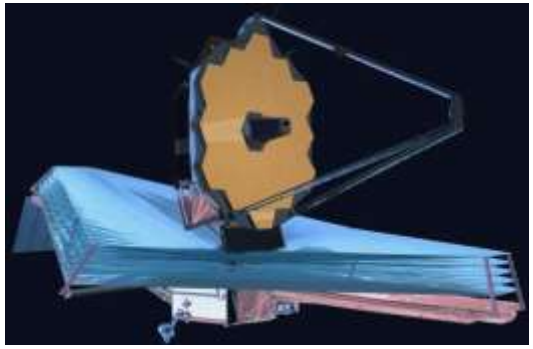
Thermal system

Requirements: 10-m space telescope cooled down to 4K & on-board cooled instruments

Spitzer

Plank



JWST

Spica

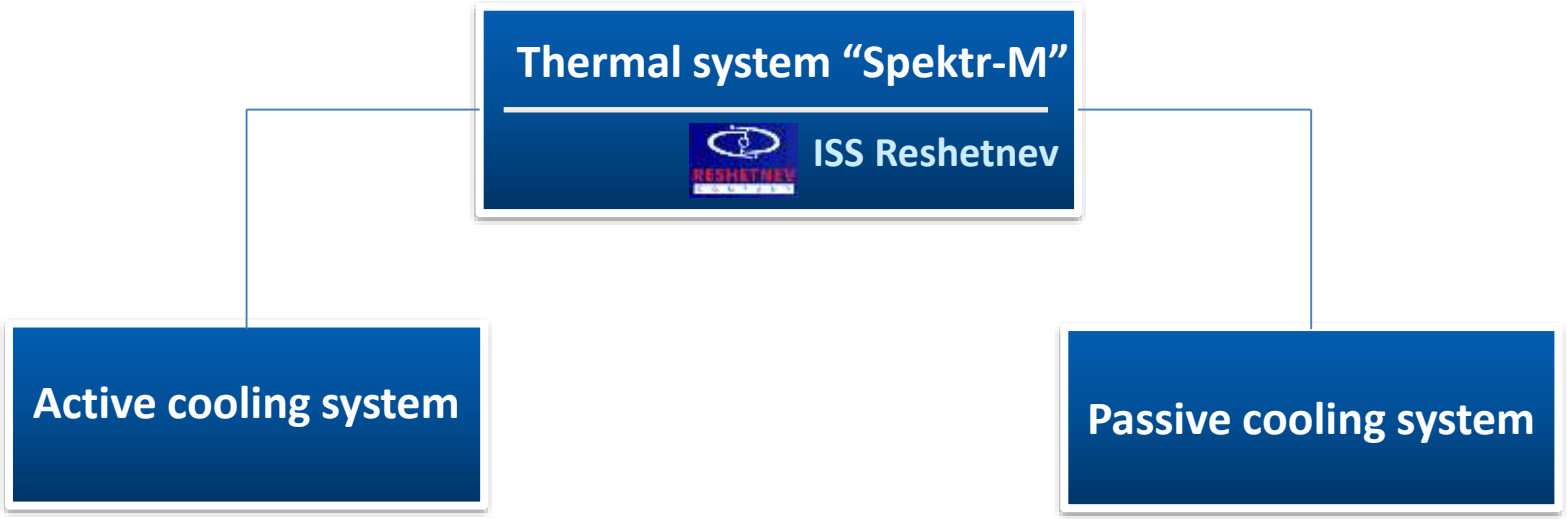
EXPERIENCE

Critical milestones to achieve the requirements:

- ✓ the telescope will have location with best environment for radiation cooling
- ✓ maximum effectively use radiation cooling
- ✓ avoid place warm elements in cold parts
- ✓ minimize heat flows from warm to cold parts
- ✓ stage temperature level cooling structure
- ✓ design should be based on use of a space mechanical cryocoolers

ASC LPI

Thermal system



Requirements:

- 100K temp. level
- 20K temp. level
- 4K temp. level
- 1K temp. level
- Input power ≤ 2500 W

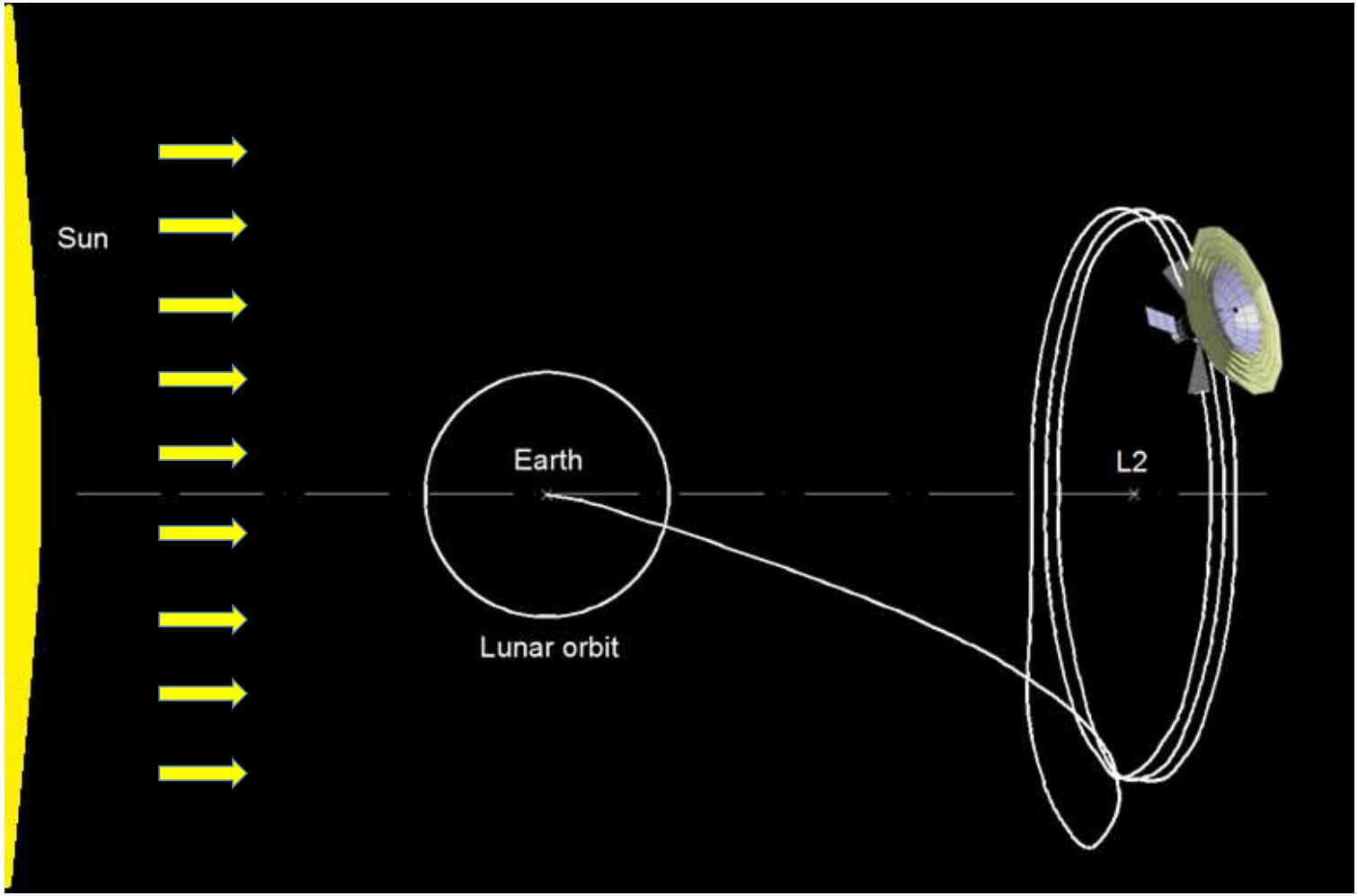
Requirements:

- 50K on the inner sunshield

More details in the presentation of E. Golubev

ASC LPI

Best Environment for Radiation Cooling



Illustrative picture of Halo orbit around the Sun-Earth L2 point

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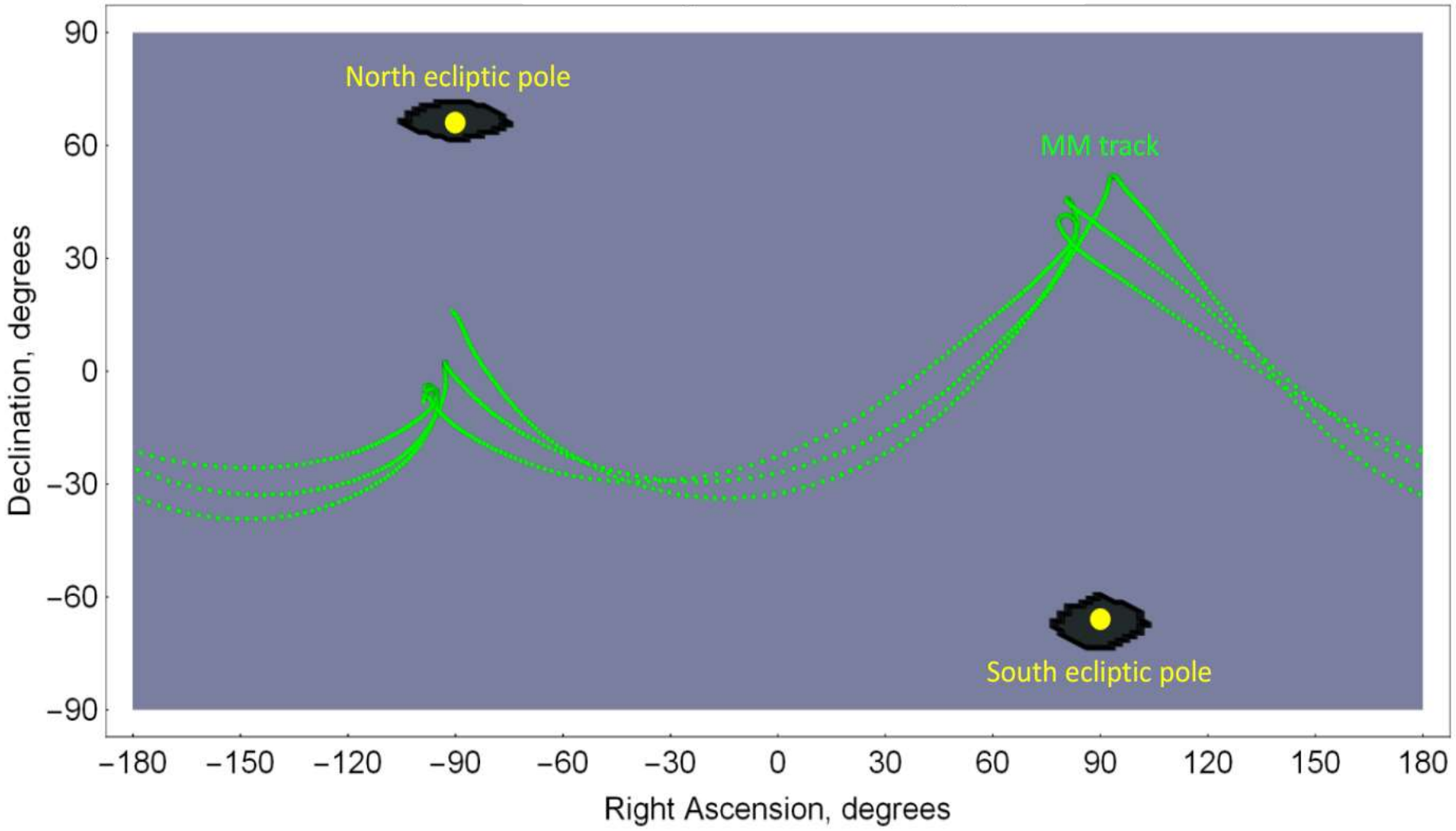
Visibility of the Sky During 1 Year



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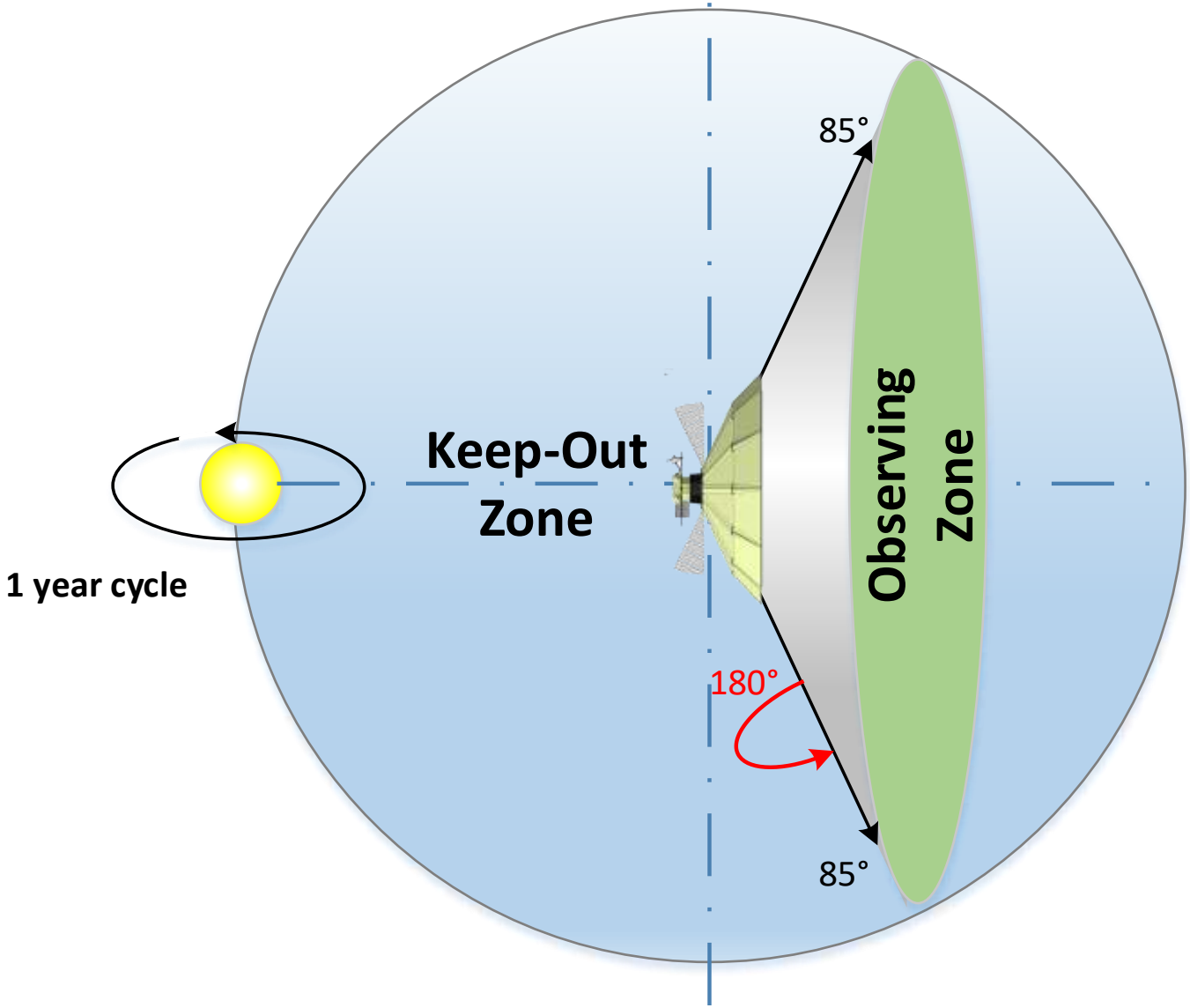
Visibility of the Sky at the Moment



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Scientific Instruments

1) **S**pace-**VLBI** receivers (**S-VLBI**)

2) **M**illimetron **H**eterodyne **I**nstrument for **F**ar-**I**nfrared (**MHIFI)**

3) **S**hort-wave **A**rray **C**amera **S**pectrometer **(SACS)**

4) **L**ong wave-**A**rray **C**amera **S**pectropolarimeter **(LACS)**

More details in the presentation of A. Baryshev

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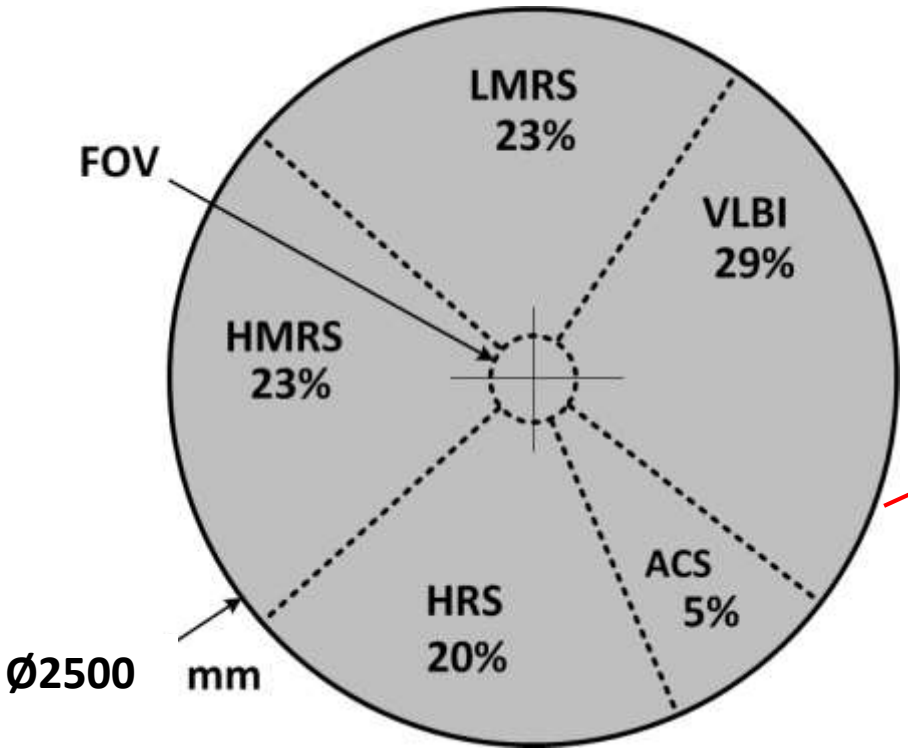
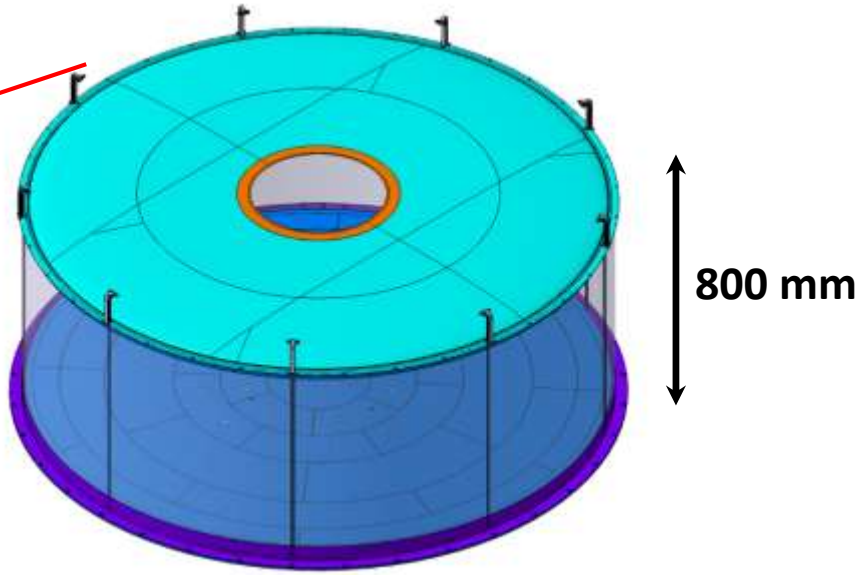
Cryo Instrument Container

An example of the assembly of instruments in cryo container





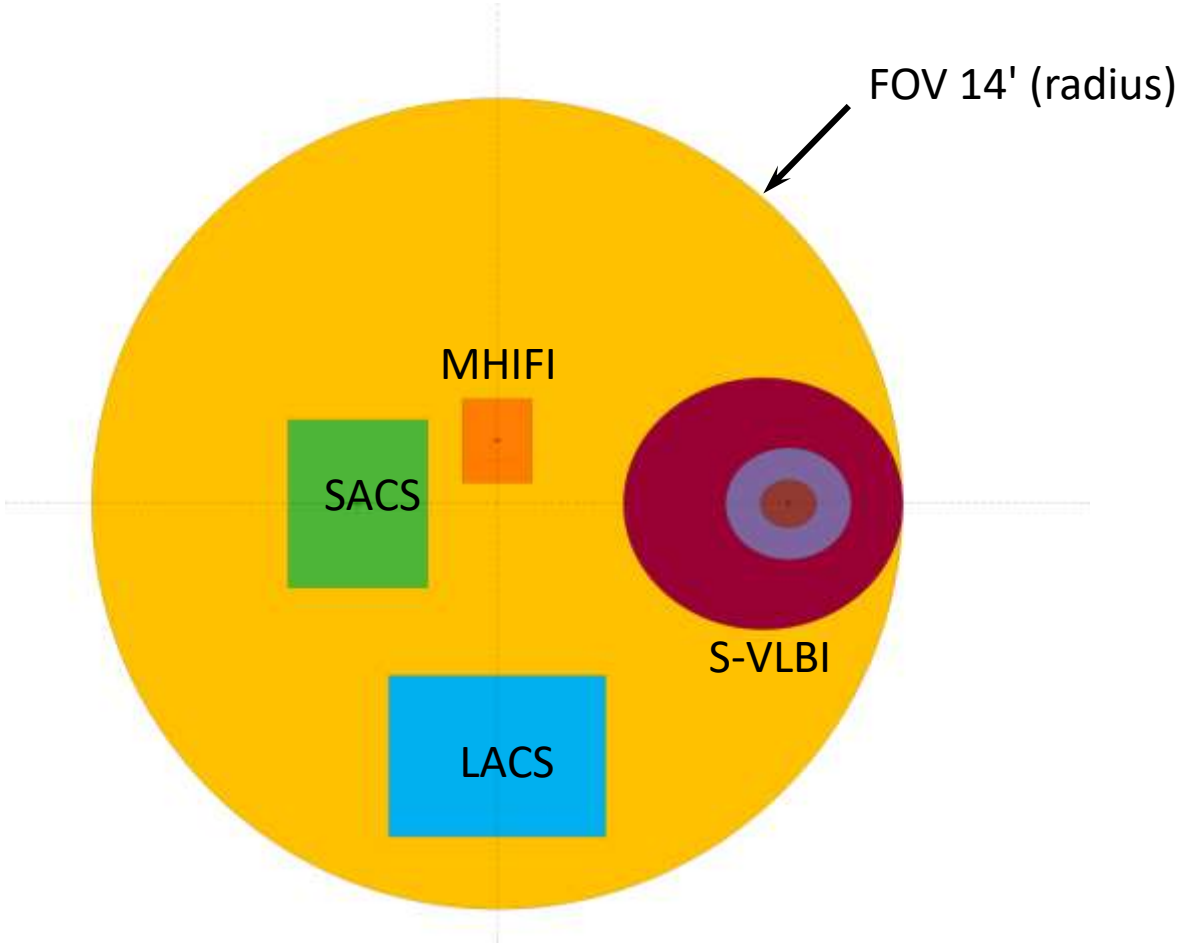
Resources of the Container:

- **100 K @ ≤ 10 W (intercept level)**
- **20 K @ ≤ 500 mW**
- **4 K @ ≤ 100 mW**
- **1 K @ ≤ 10 mW**

ASC LPI

Instruments Focal Plane Allocation Layout

Very preliminary!



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High-speed data link

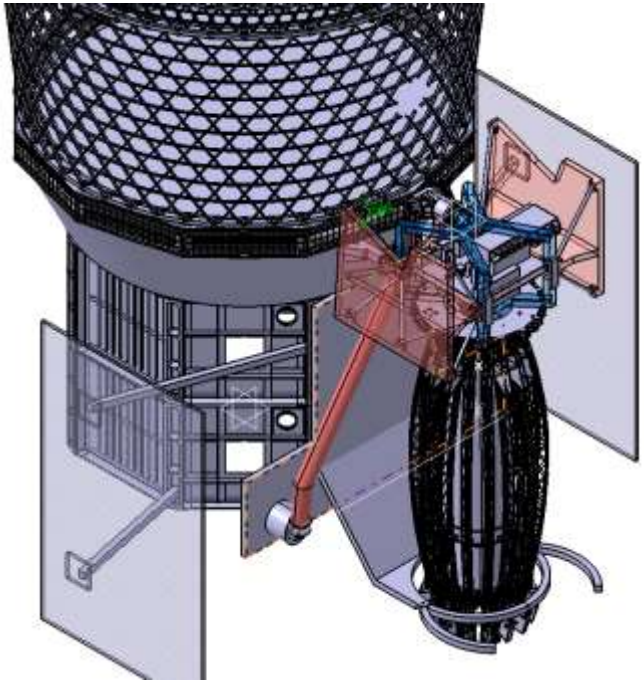
Requirements:

- Frequency - 15GHz
- Deployable antenna – 4 m

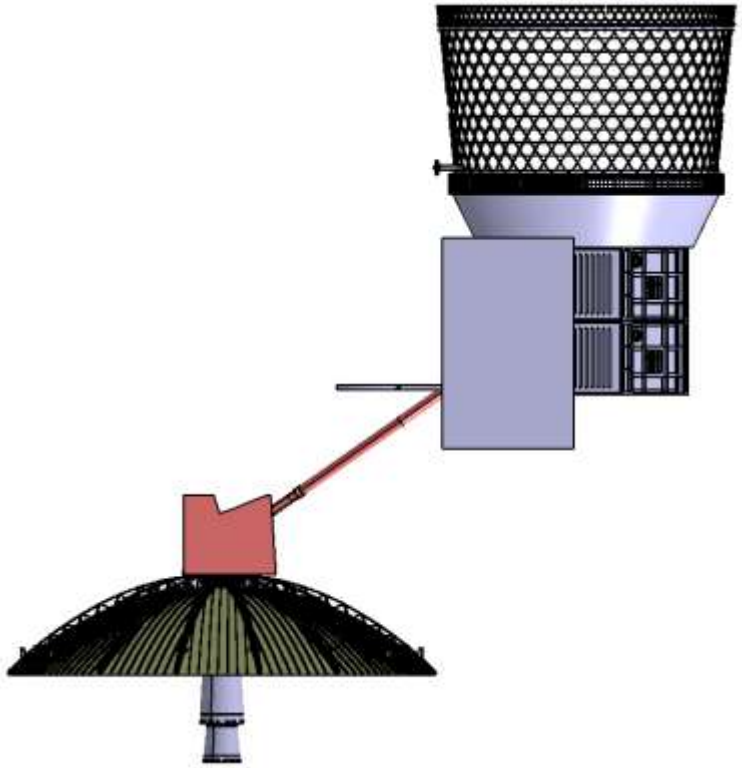
} tracking station ≥ 30m antenna

TRL9

- Data rate up to 1.2Gb/s



Launch configuration

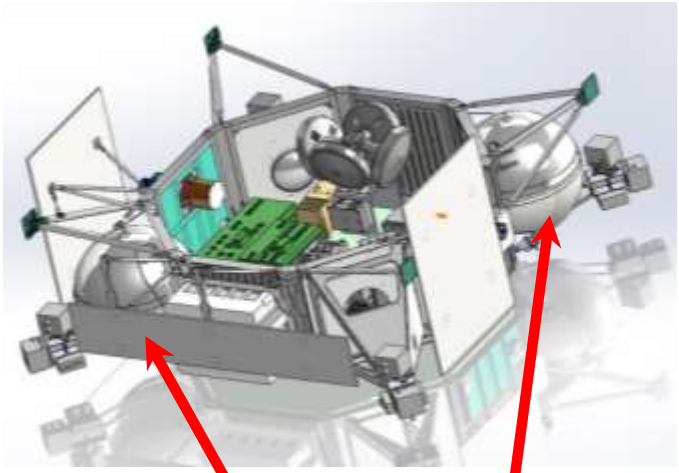


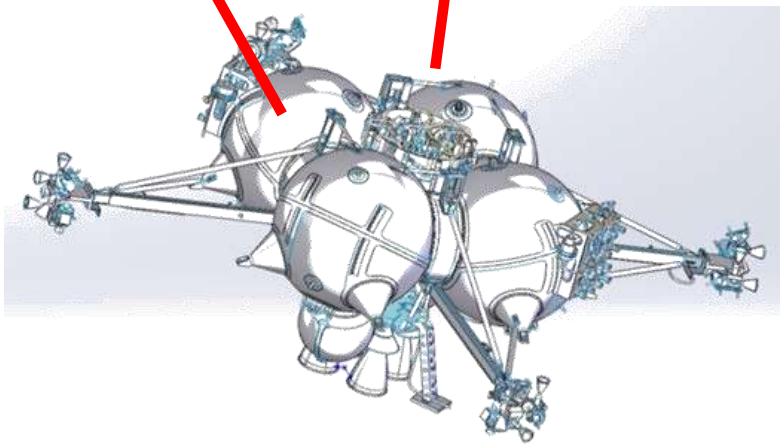
Working configuration

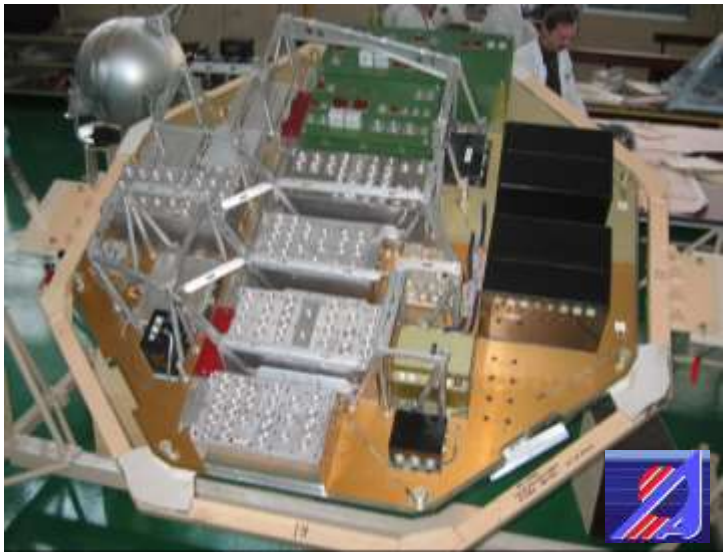
ASC LPI

Spacecraft Bus - “Navigator-SM”

The “Navigator-SM” for Millimetron will be based on the “Navigator” module







TRL9

Main changes:

- **propulsion system will be changed onto double fuel component liquid propulsion system of capillary type**
- **SC power supply system will be changed onto energetic module, located at separate thermal panel**

ASC LPI

Conclusions

- ✓ Currently Millimetron not only a concept it's real project in under development
- ✓ Many parts of Millimetron use technology with a high TRL
- ✓ Mission requirements and launch date make the project very promising for many scientific and technological aspects
- ✓ Up to date we are still open to a new participants and collaborators

Thank you for your attention