Fourier-spectrometers in ExoMars missions:

TIRVIM/ACS (2016)

and

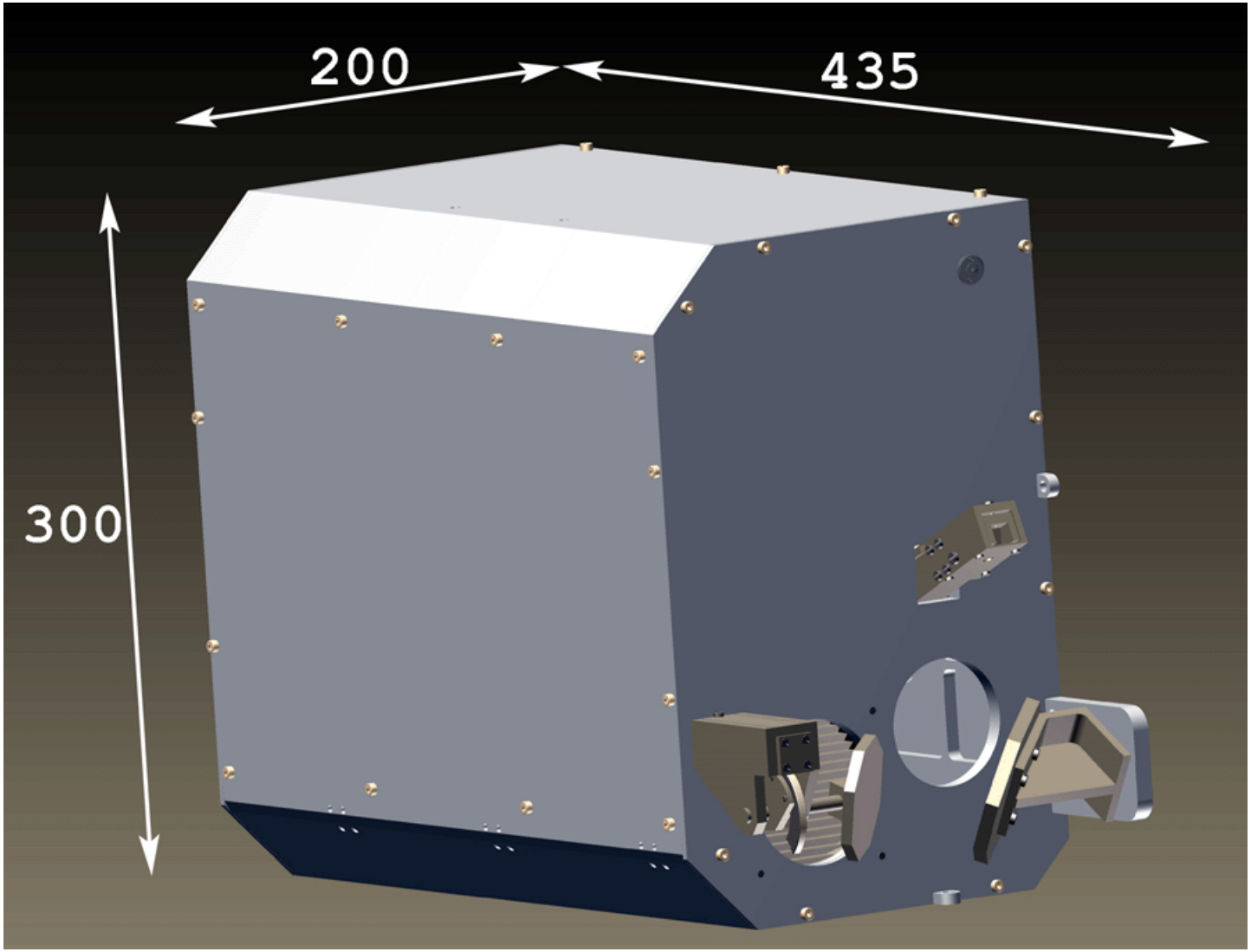
FAST (2018)

Fourier-spectrometers in ExoMars missions

MISSION	EXPERIMENT	STATUS
Trace Gases Orbiter, “ExoMars-2016” (2^h polar orbit)	TIRVIM/ACS: $0.2cm^{-1}$; 2-17μ; 12kg; 2”-aperture; single-direction scaner	Is being funded by Roscosmos
Landing Platform, “ExoMars-2018”	FAST: $0.05cm^{-1}$; 2-17μ; 4kg; 1”-aperture; bi-directional scaner	Got the top grade at contest, the funding is pending

TIRVIM/ACS (ExoMars-2016)

Instrument overview



Main scientific objectives

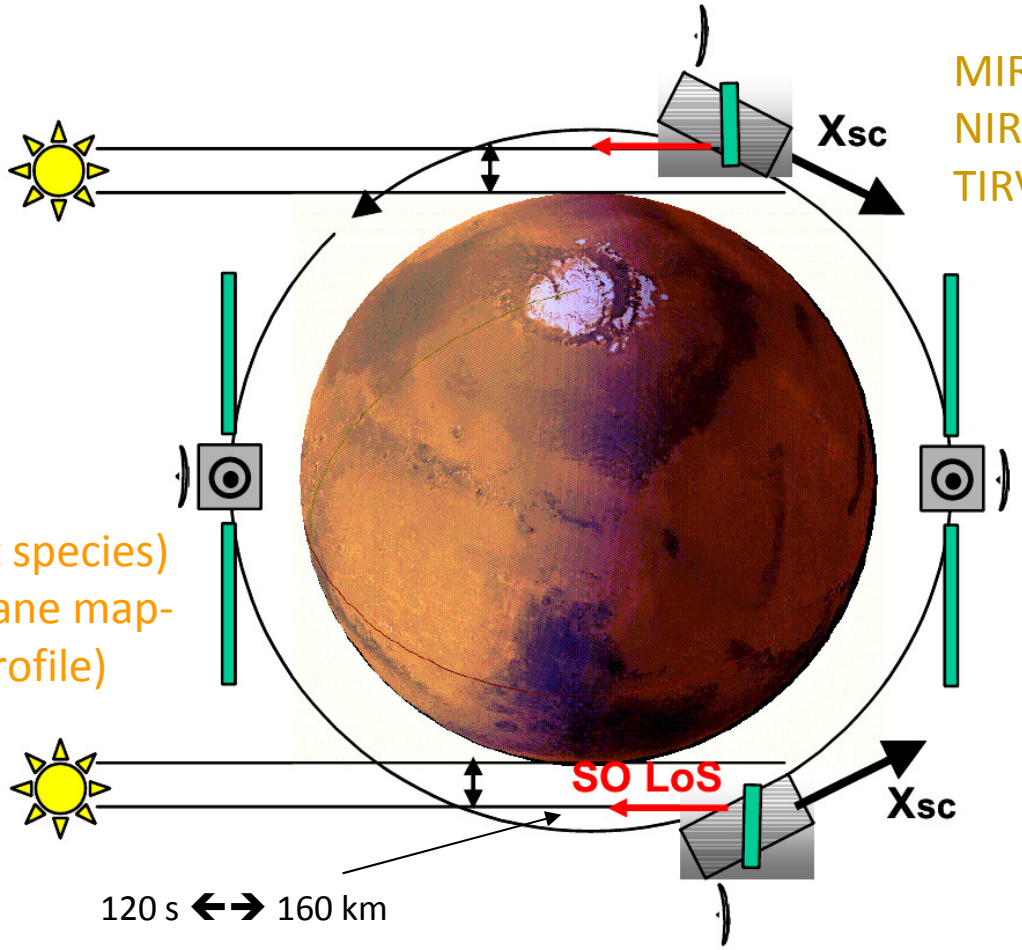
OBJECTIVE	MESUREMENT MODES & PARAMETERS
Methane & other minor atmosphere constituents	Sun occultations, 2-17um, 0.2cm^{-1} 1) PV-MCT detector @65K, 1 IFG: 2sec, S/N~10^{3} or (redundant channel): 2) Pyro-detector @RT, 1 IFG: 30sec, S/N~3x10^{2}
Methane, if any, mapping at day-side	Nadir, 2-4um, 0.2cm^{-1} PV-PbCdSe detector @200K, 1 IFG: 10sec, S/N~3x10^{2}
Vertical thermal profile of the atmosphere, both day-side & night- side	Nadir, CO_2 band at 15um, 1.6cm^{-1} PV-MCT detector @65K, 1 IFG: 4sec, S/N~3x10^{2}

On-board FFT and scissor mode apply to all modes

Experiment Operation Plan

TGO operational orbit T ~ 2 hr orbital period

➔ 12 orbits per day, 12 sunrises and 12 sunsets – 24 occultation's per day



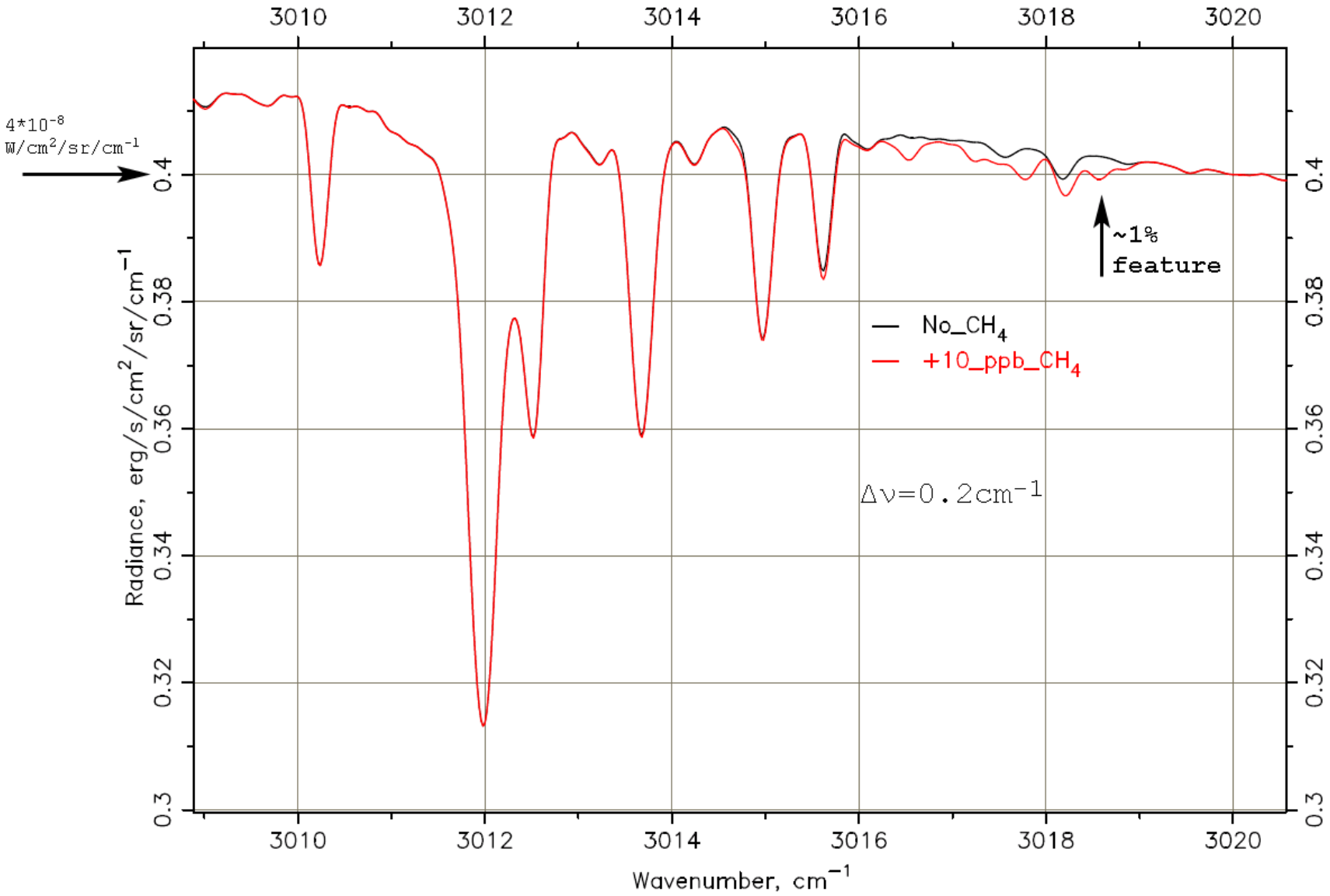
MIR (minor species)
NIR (abundant species)
TIRVIM (minor species)

NIR (nightglows)
TIRVIM (thermal profile)

NIR (abundant species)
TIRVIM (methane map-
ing, thermal profile)

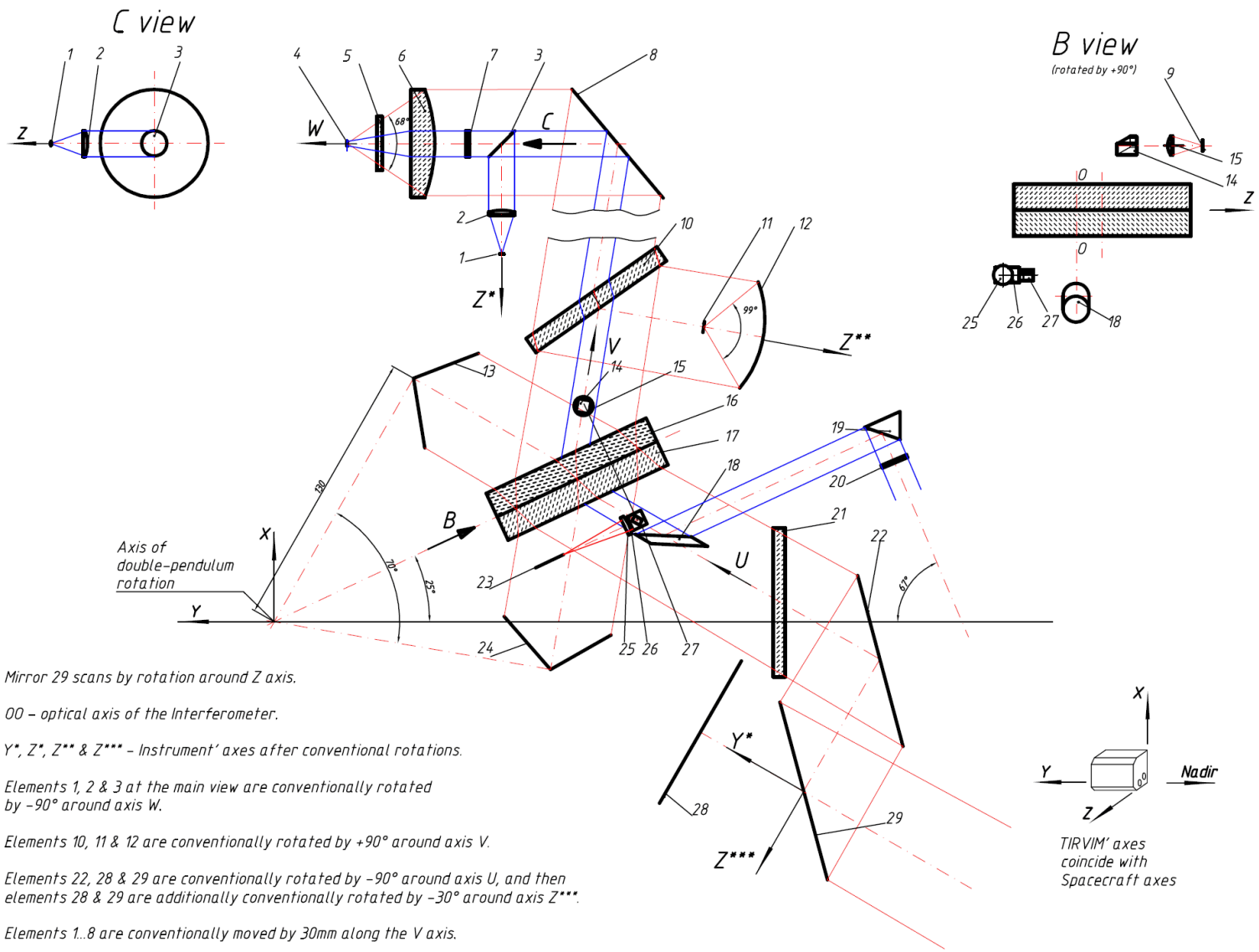
TIRVIM/ACS (ExoMars-2016)

CH_4 simulated spectra (nadir)



TIRVIM/ACS (ExoMars-2016)

Optical scheme



1 Pyro-detector
2 Pyro-detector' lens (ZnSe)
3 Flip mirror (flat)
4 PV-MCT detector (@65K)
5 ARC-Ge window (2.5mm thick)
6 Aspheric ZnSe lens (Ø50)
7 Diverging ZnSe lens (Ø12 R=-150)
8 Fixed flat mirror (CA: 50x66)
9 Reference Channel (RC) detector
10 Dichroic plate
11 PV-PbCdSe detector (@200K)
12 Parabolic mirror (Ø50 R=50)
13 Retro-reflector (CA=Ø51)
14 RC-detector mirroring prism
15 RC-detector lens
16 Compensator (ZnSe Ø88x12)
17 Beam-splitter (ZnSe Ø88x12)
18 Flat mirror(Sun periscope outlet)
19 Sun-inlet mirroring prism
20 Sun-inlet filter & field stop
21 Nadir-inlet window (TBD)
22 Fixed flat mirror (CA: 55x78)
23 RC-emitter fiber optic
24 Retro-reflector (CA=Ø51)
25 RC-emitter collimating lens
26 RC-emitter mirroring-prism-big
27 RC-emitter mirroring-prism-small
28 Calibration Black-Body
29 Scanning flat mirror (CA: 58x84)

Mirror 29 scans by rotation around Z axis.

OO – optical axis of the Interferometer.

Y, Z*, Z** & Z*** – Instrument' axes after conventional rotations.*

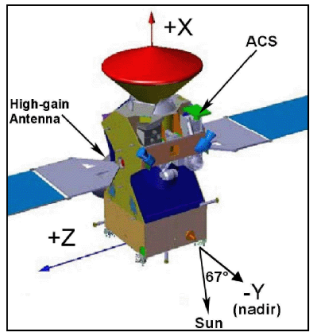
Elements 1, 2 & 3 at the main view are conventionally rotated by -90° around axis W.

Elements 10, 11 & 12 are conventionally rotated by +90° around axis V.

*Elements 22, 28 & 29 are conventionally rotated by -90° around axis U, and then elements 28 & 29 are additionally conventionally rotated by -30° around axis Z***.*

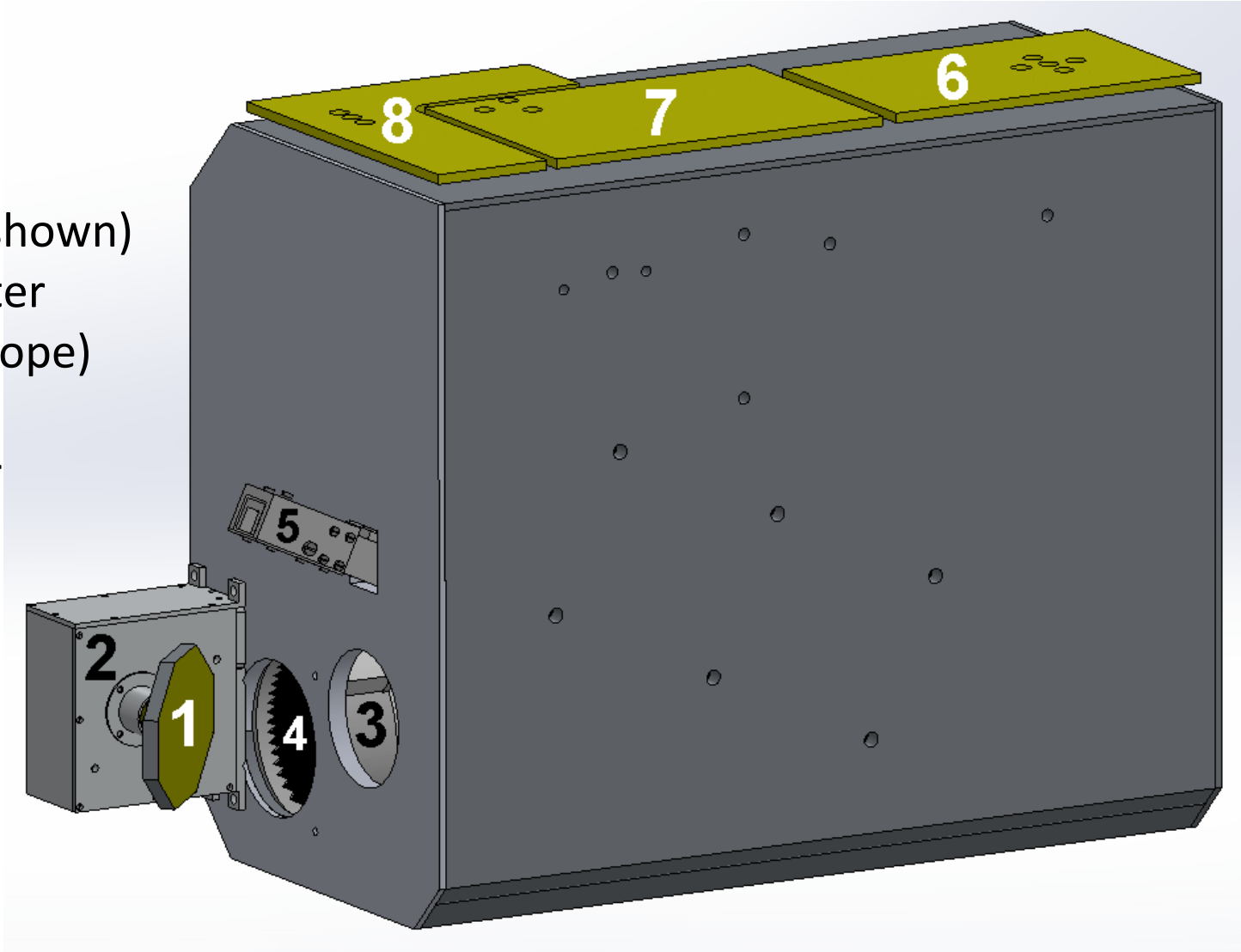
Elements 1...8 are conventionally moved by 30mm along the V axis.

TIRVIM' axes coincide with Spacecraft axes



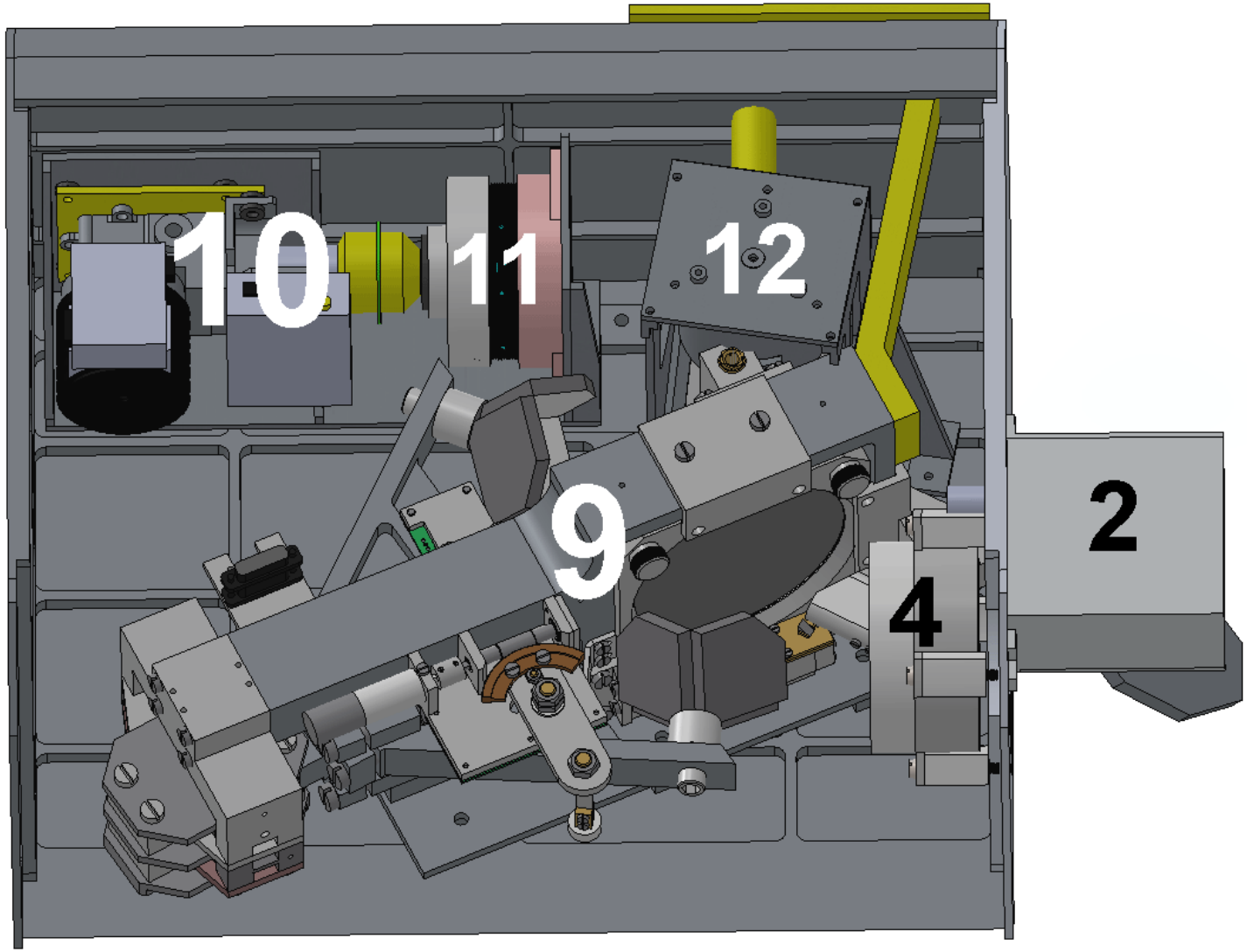
Instrument overview continued

1 – Scanning mirror
2 – Scaner module
3 – Optical inlet
(fixed mirror not shown)
4 – Blackbody emitter
5 – Sun inlet (periscope)
6 – Stirling radiator
7 – PbCdSe radiator
8 – Interferometer radiator

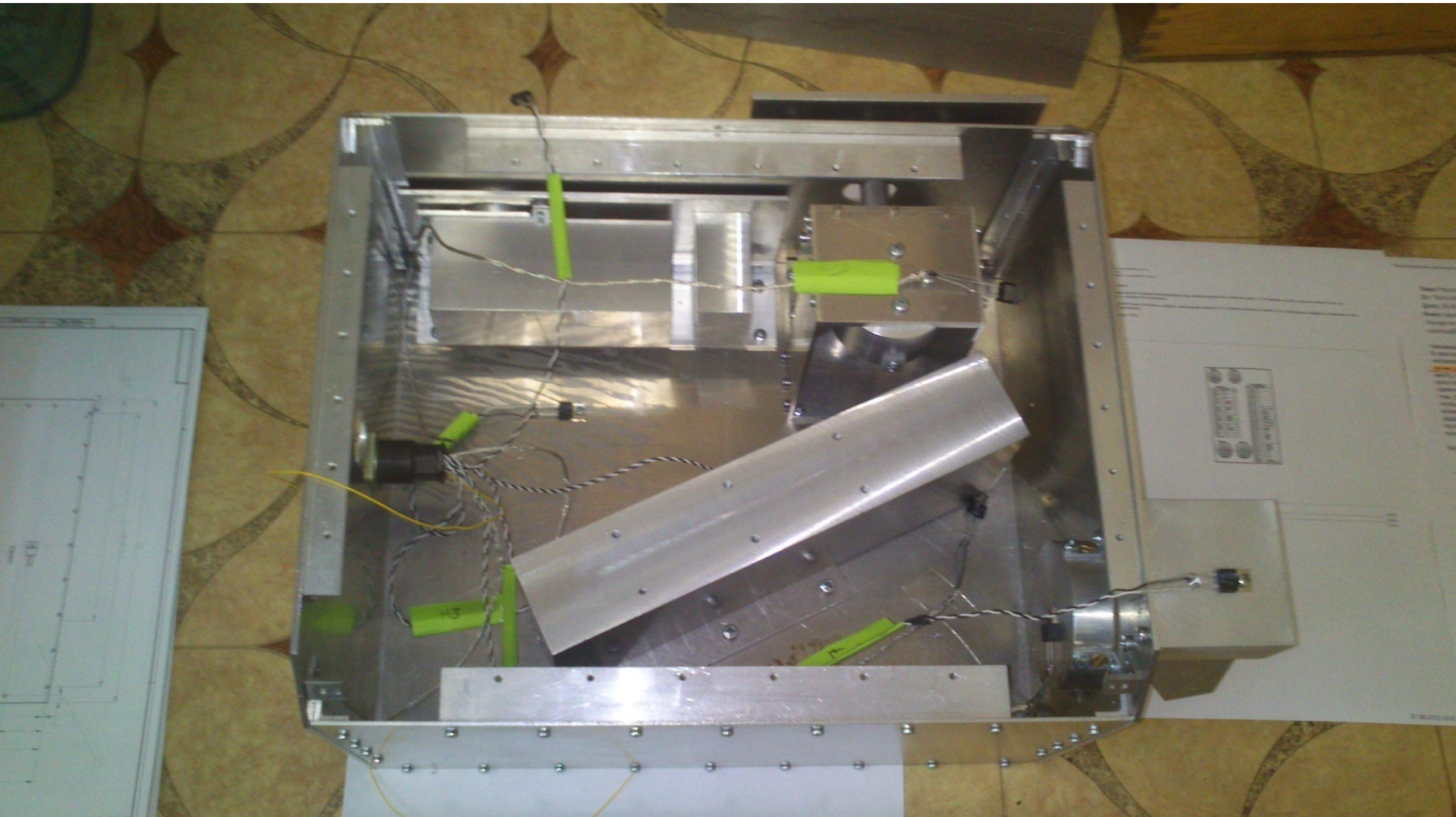


Instrument overview continued

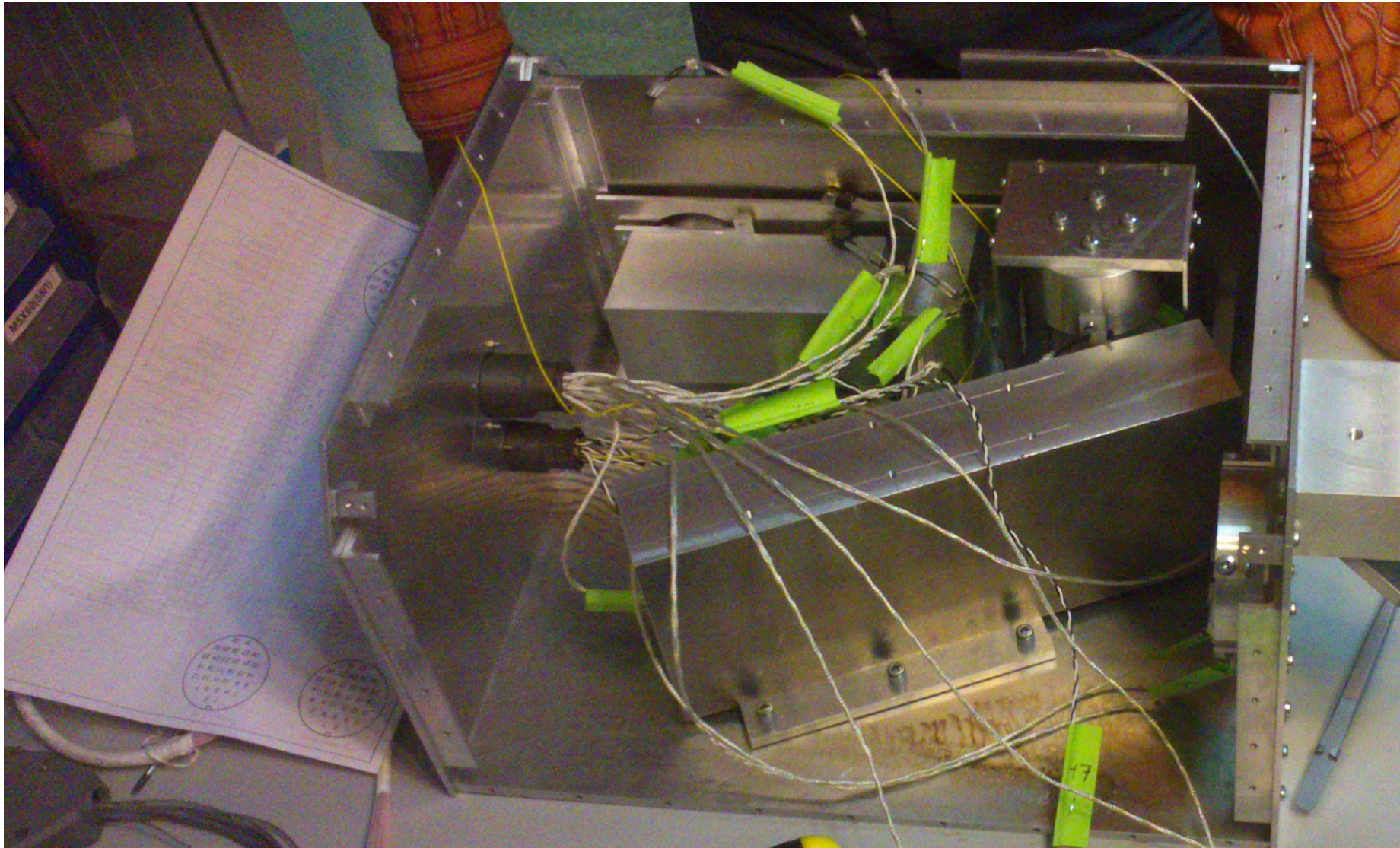
2 – Scaner module
4 – Blackbody unit
9 – Interferometer
10 – Stirling cooler
11 – ZnSe aspheric lens unit
12 – Dichroic & parabolic mirror unit

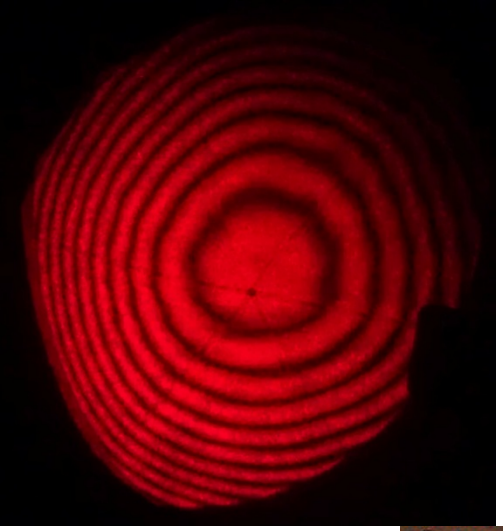


HW: Thermal Model



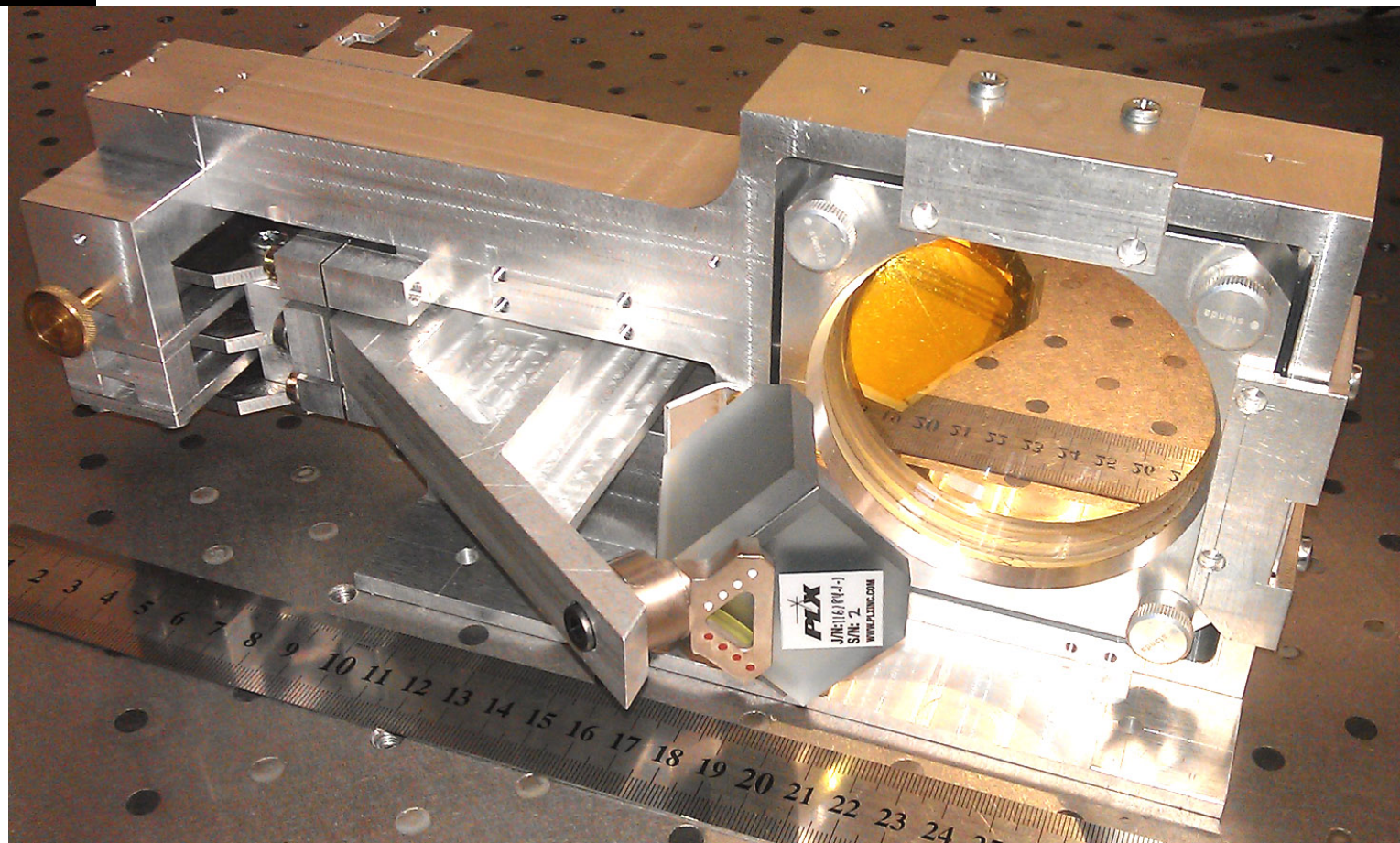
HW: Thermal Model



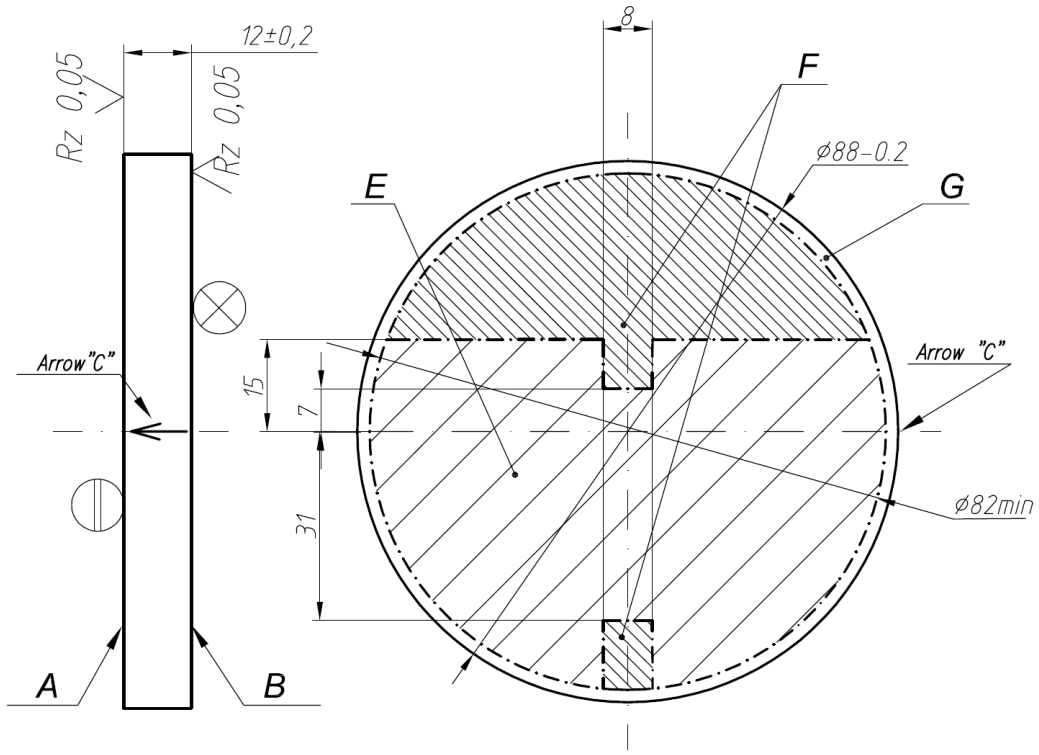


TIRVIM/ACS (ExoMars-2016)

HW: Interferometer



TIRVIM/ACS (ExoMars-2016)

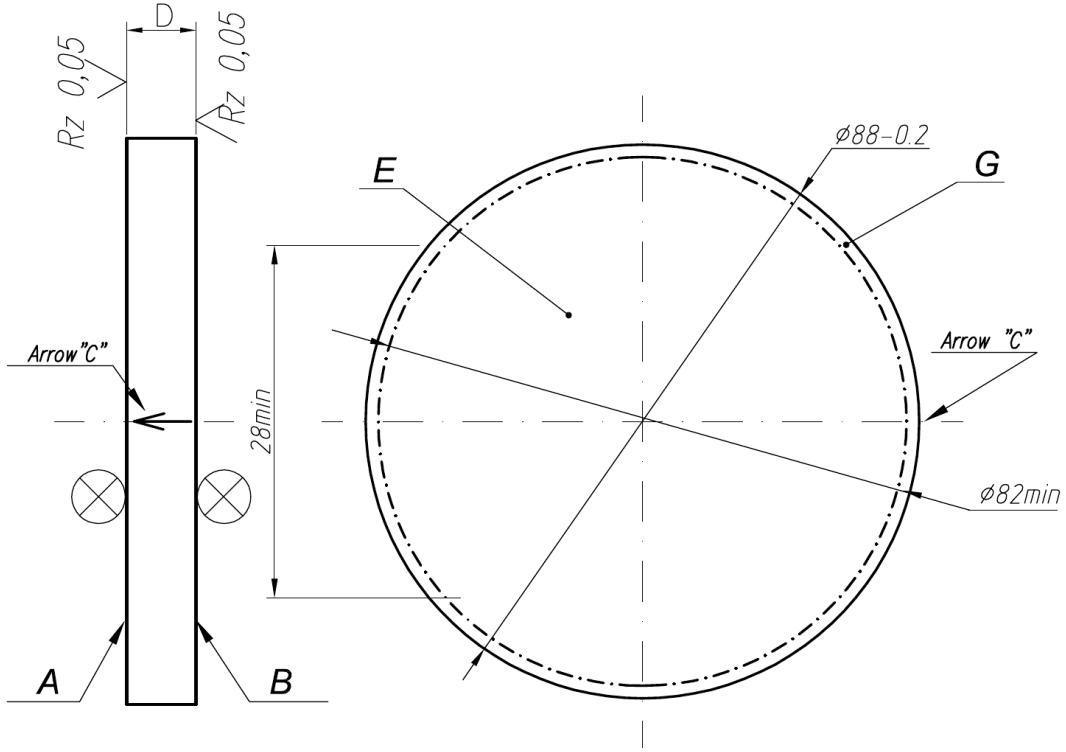


BeamSplitter

(preliminary drawing)

1. ALPHA (angle between planes A & B) = 3+-1 arcminutes
2. Zones E & F may overlap by 0.5mm max
3. Planarity of planes A & B in zones E & F: N=0.7, dN=0.3
4. Painted arrow "C" indicates the most thick place with max error +-2mm
5. ⊖ - BeamSplitting coating:
   in zone E: R=0.5+-0.05 for 3.3 & 15 micron;
   R=0.5+-0.1 for rest parts of ranges 3.1-3.5 & 14-16 micron;
   R=0.5+-0.2 in the rest parts of the region 2-17 micron.
   in zone F: R=0.5+-0.2 for 0.76 & 0.63 micron.
6. ⊗ - antireflective coating:
   R<0.02 for 3.1-3.5 & 14-16 micron;
   R<0.07 in the rest parts of the region 2-17 micron;
   R<0.1 for 0.76 & 0.63 micron.
7. Reflection must be measured at Angle of Incidence 35+-5degrees.
8. Zone G is a non-working zone.
9. Bevels at sharp edges: 0.5mm*45degrees.

TIRVIM/ACS (ExoMars-2016)

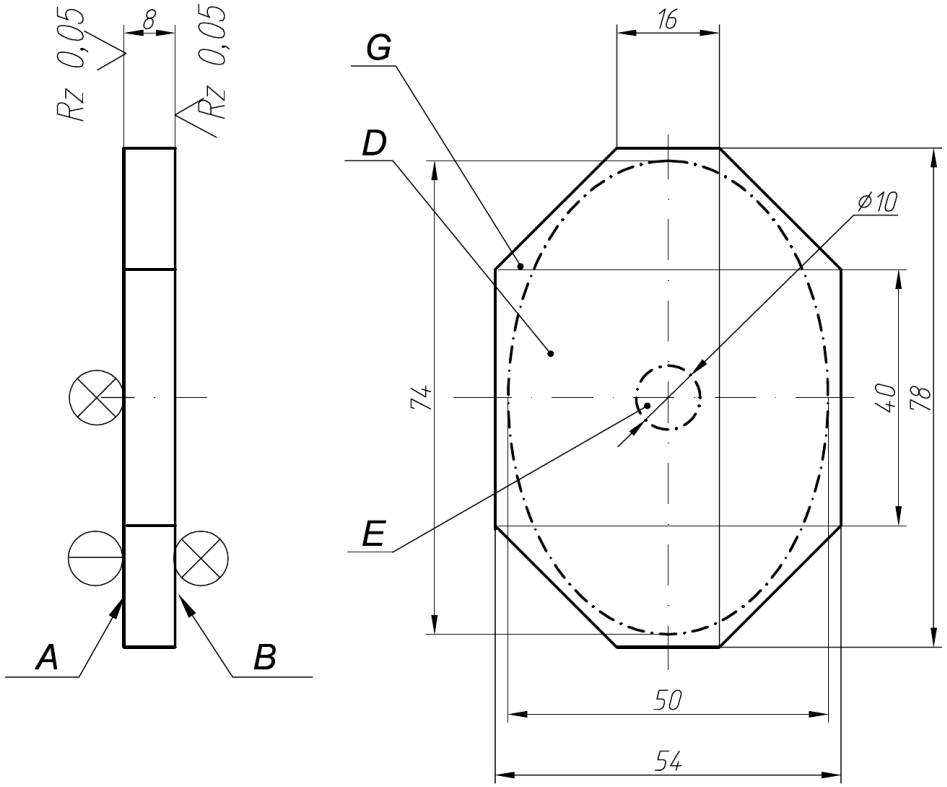


Compensator

(preliminary drawing)

1. The angle between planes A & B must be equal to that of Beamsplitter ("ALPHA") with accuracy +-5arcseconds
2. The Compensator thickness "D" must be equal to that of Beamsplitter with accuracy +-0.01mm
3. Planarity of planes A & B in zone E: N=0.7, dN=0.3
4. Painted arrow "C" indicates the most thick place with max error +-2mm
5. ⊗ - antireflective coating:
   R<0.02 for 3.1-3.5 & 14-16 micron;
   R<0.07 in the rest parts of the region 2-17 micron
   R<0.1 at 0.76 & .63 micron.
6. Reflection must be measured at Angle of Incidence 35+-5degrees.
7. Zone G is a non-working zone.
8. Bevels at sharp edges: 0.5mm*45degrees.

TIRVIM/ACS (ExoMars-2016)

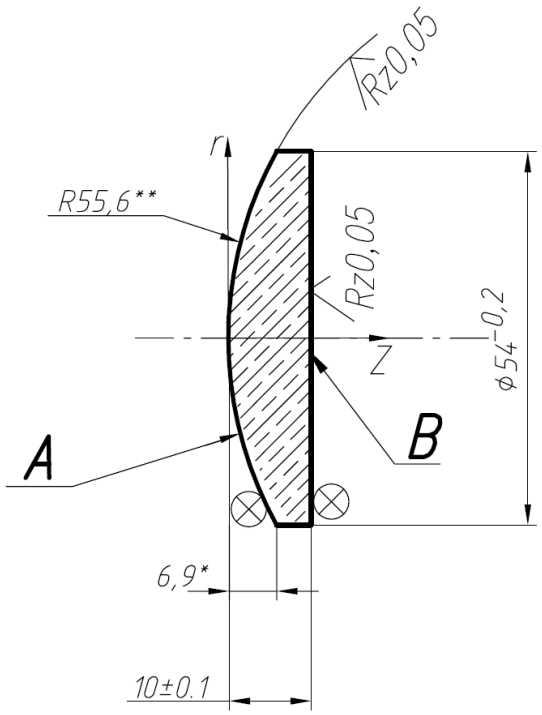


Dichroic

(preliminary drawing)

1. Angle between planes A & B: <5arcminutes.
2. Planarity of planes A & B in zones D & E: N=3, dN=0.5.
3. ⊖ – dichroic coating in zone D:
   at 3.3micron R>0.97, T is not important;
   in rest parts of range 3.1–3.5micron R>0.9, T is not important;
   in rest parts of range 2–4micron R>0.7, T is not important;
   at 15micron T>0.97, R is not important;
   in rest parts of range 14–16micron T>0.9, R is not important;
   in rest parts of range 5–17micron T>0.7, R is not important.
4. ⊗ – ARC in zone E of plane A and zones D & E of plane B:
   R<0.02 in range 14–16micron;
   R<0.1 in the rest parts of the region 2–17micron.
5. Reflection must be measured at Angle of Incidence 45+–5degrees.
6. Zone G is a non-working zone.
7. Bevels at sharp edges: 0.5mm*45degrees.

TIRVIM/ACS (ExoMars-2016)



Однородность	1
Двулучепрел.	1
Бессвильность	1А
Пузырность	1А
N	5
△ N	1
P_A	VI
$Z_F(\lambda=15\mu)$	42,8
øсв	50

Aspheric ZnSe lens

(preliminary drawing)

1. Рабочая область 2...17 мкм.
2. * – размер для справки.
3. Фаски на ребрах 0,5±0,2x45°.
4. ⊗ – Просветл, R<0,02 при λ = (14...16) мкм. R<0,07 в остальных.
5. Уравнение поверхности А (гипербола):

$$Z=\frac{Gr^2}{1+\sqrt{1+0,8G^2r^2}} \qquad G=0,02$$

6. ** – радиус исходной описанной сферы.

   (макс. разность Zсфер–Zгипер равна 0,24 мм при r=18 мм)

7. Z_F – координата фокуса по оси Z.

FAST –
Fourier for
Atmospheric
Species and
Temperature

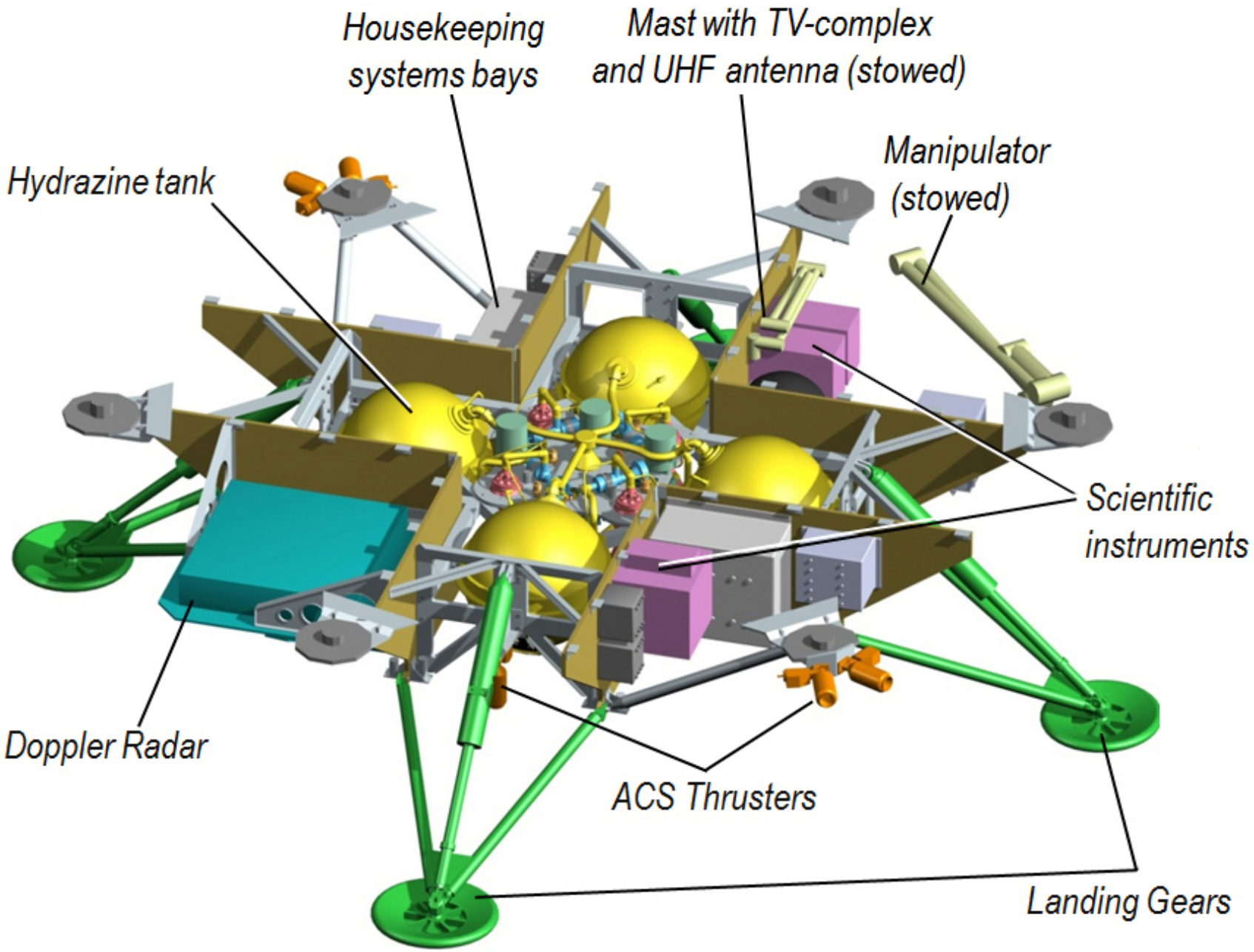
(0.05cm^{-1} !)

FAST has won the contest:

FAST (first place in the list):	76 points
Next after FAST in the list:	68 points
The last in the list :	30 points

Landing platform

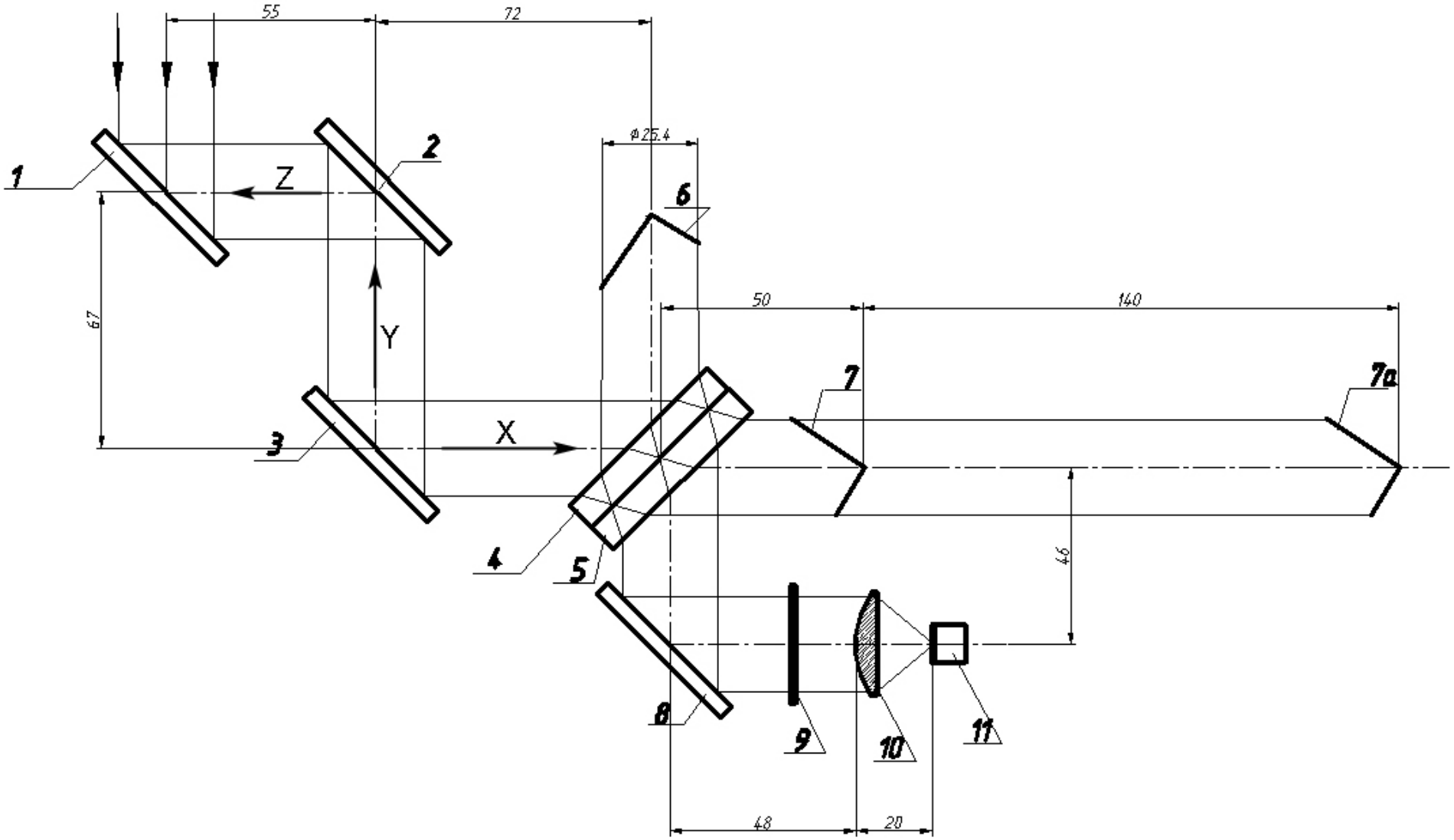
FAST (ExoMars-2018)



Main scientific objectives

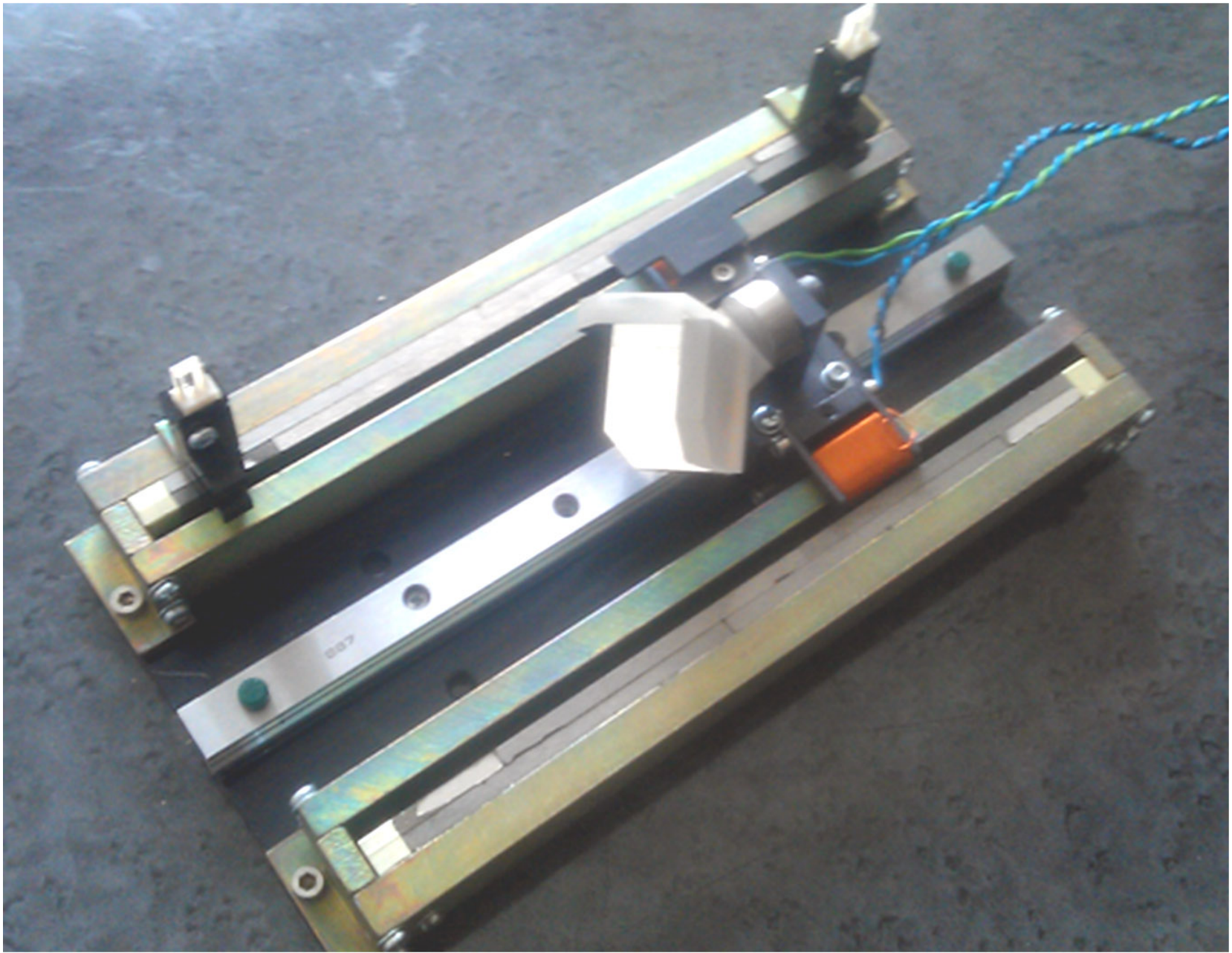
OBJECTIVE	MESUREMENT MODES & PARAMETERS
Methane & other minor atmosphere constituents	Sun tracking, 0.05cm^{-1} 1) 2-4um, PV-PbCdSe detector @200K, 1 IFG: 10sec or: 2) Pyro-detector @RT, 1 IFG: 30sec
Vertical thermal profile of the atmosphere, both day & night	Different air masses, CO_2 band at 15um, 1.6cm^{-1} Pyro-detector @RT, 1 IFG: 30sec, averaging
Mineral composition of the surroundings	1) 2-4um, PV-PbCdSe detector @200K, 1 IFG: 10sec or: 2) Pyro-detector @RT, 1 IFG: 30sec, averaging

Concept



Carriage unit prototype

FAST (ExoMars-2018)

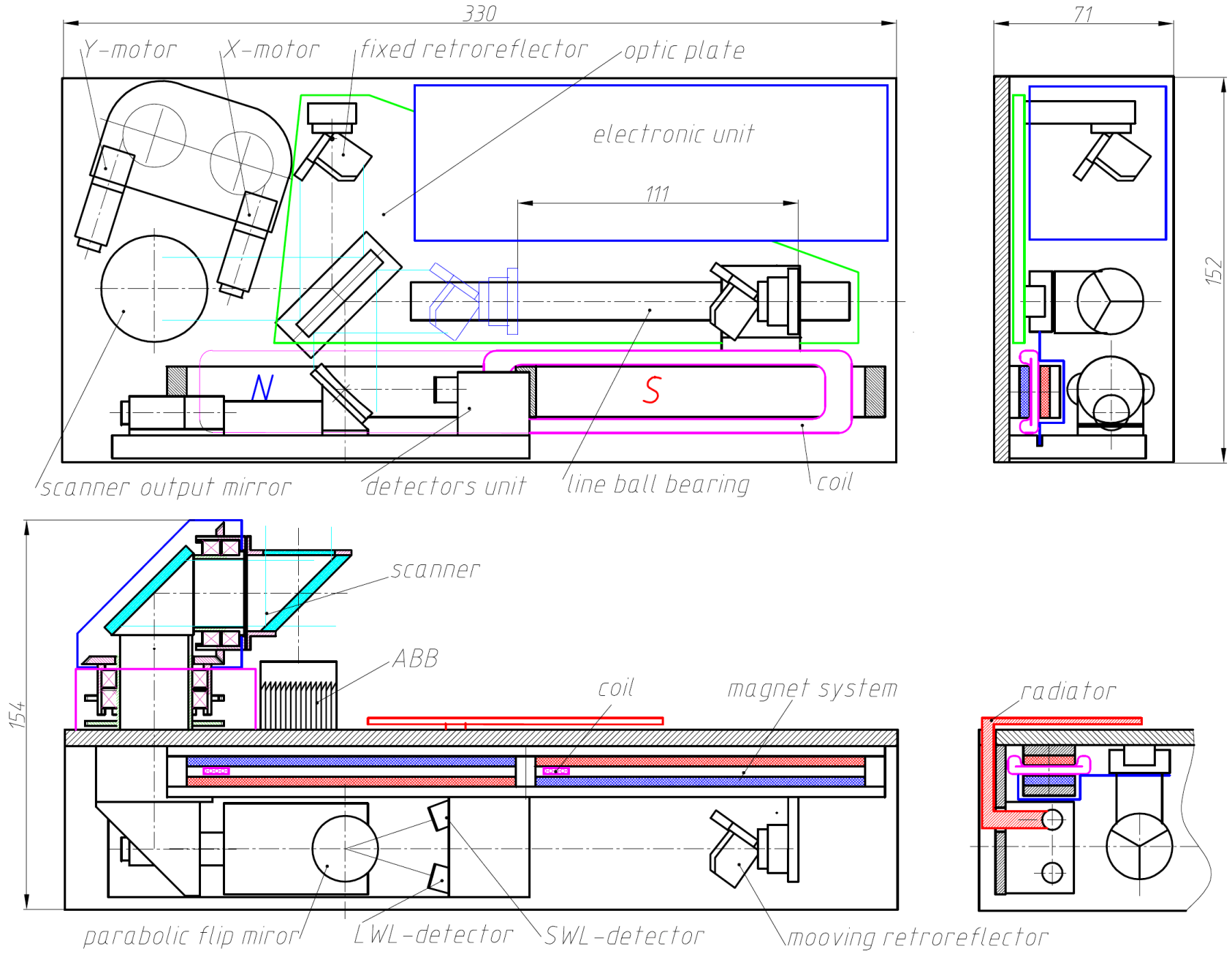


FAST (ExoMars-2018)

Size mockup

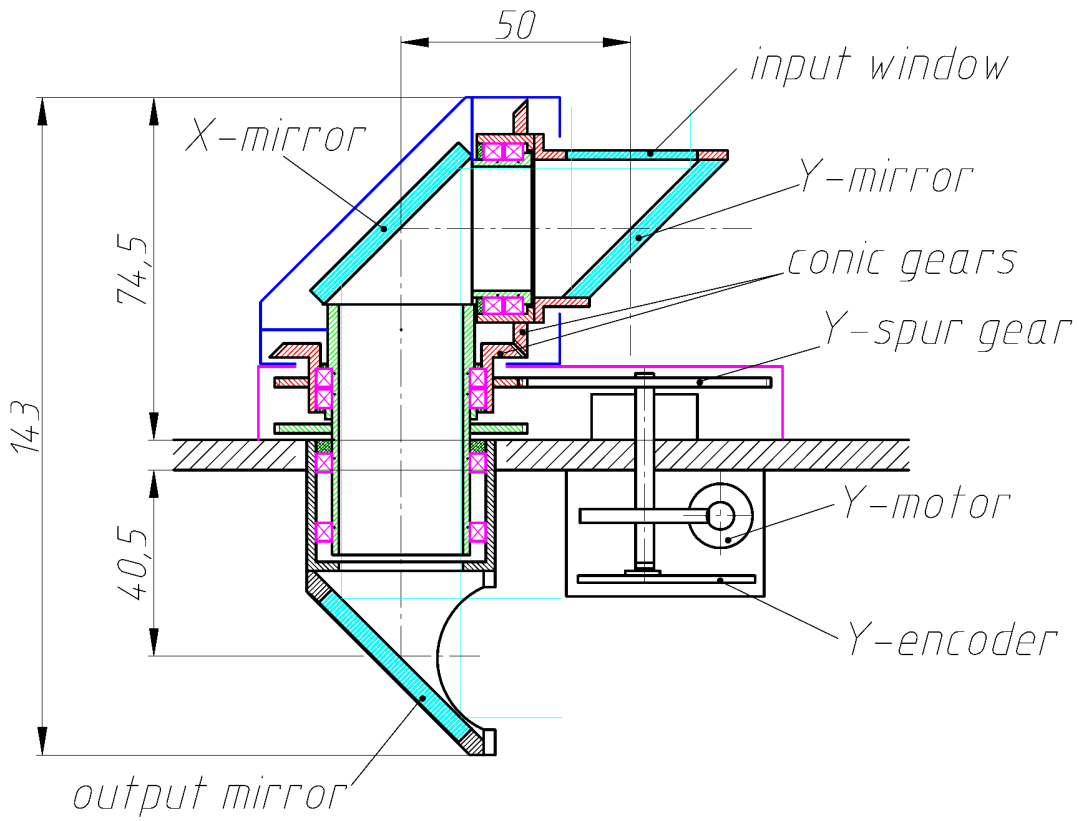
Layout

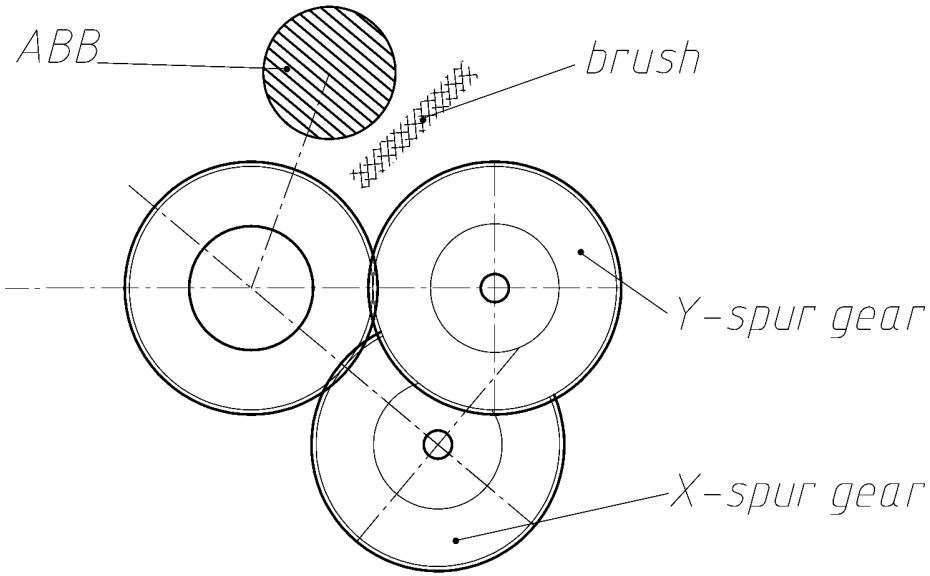
FAST (ExoMars-2018)



FAST (ExoMars-2018)

Scaner layout





Possible German inputs for FAST

Moving mirror system	Rail with carriage, motor and electronics,incl. PID system, providing the stable 11-cm movement
Key optical subsystems: design (together with IKI), manufacturing (procurement), tests, measurements, certification,…	• **Beamsplitter-Compensator unit (ZnSe)** • **Laser for reference channel** •**Au-coated metallic mirrors for Scaner** • … • Retro-reflectors (1” cube corners) • …
Manufacturing of mechanical components	According to drawings issued by IKI and ASTROFEIN,…
On-board BlackBody	Design, manufacturing, tests, certification,…
…?	