Space Science Talks – Herschel/Planck

Technology at the Edge of Feasibility

Technology at the Edge of feasibility

The Herschel Cryogenic cooling system

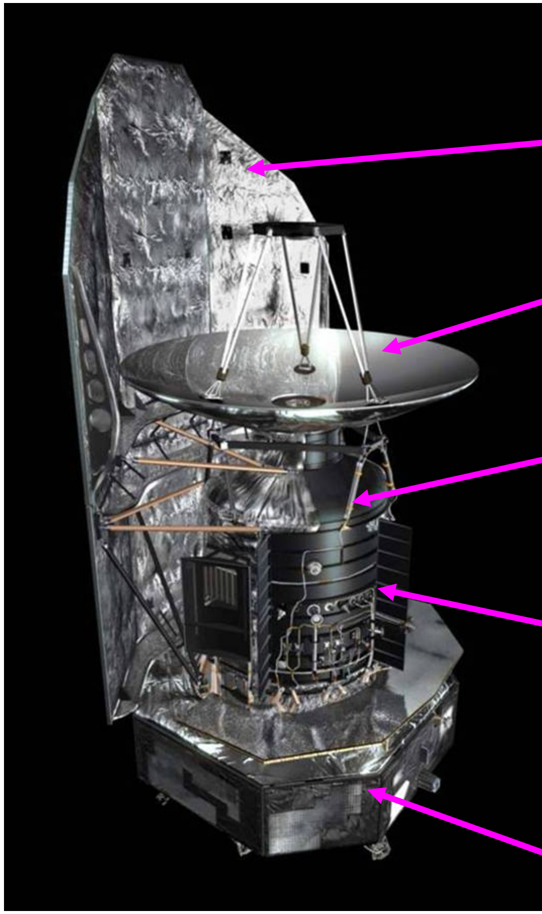
Highly accurate and thermally stable Cassegrain Telescope – Largest ever flown)

The Planck Cooling System – Room temperature SVM /20K/4K/1.6/ 100mk

Highly accurate thermally stable aplanatic dual offset ellipsoidal telescope

The Herschel Spacecraft

7.2 m



Sunshield and solar array

3.5 m SiC Telescope (80 K)

Instruments inside Cryostat (15 –300mK)

He II Cryostat (~2460 l) (1.7 K)

Service Module (300 K)

S/C units and Instrument electronics

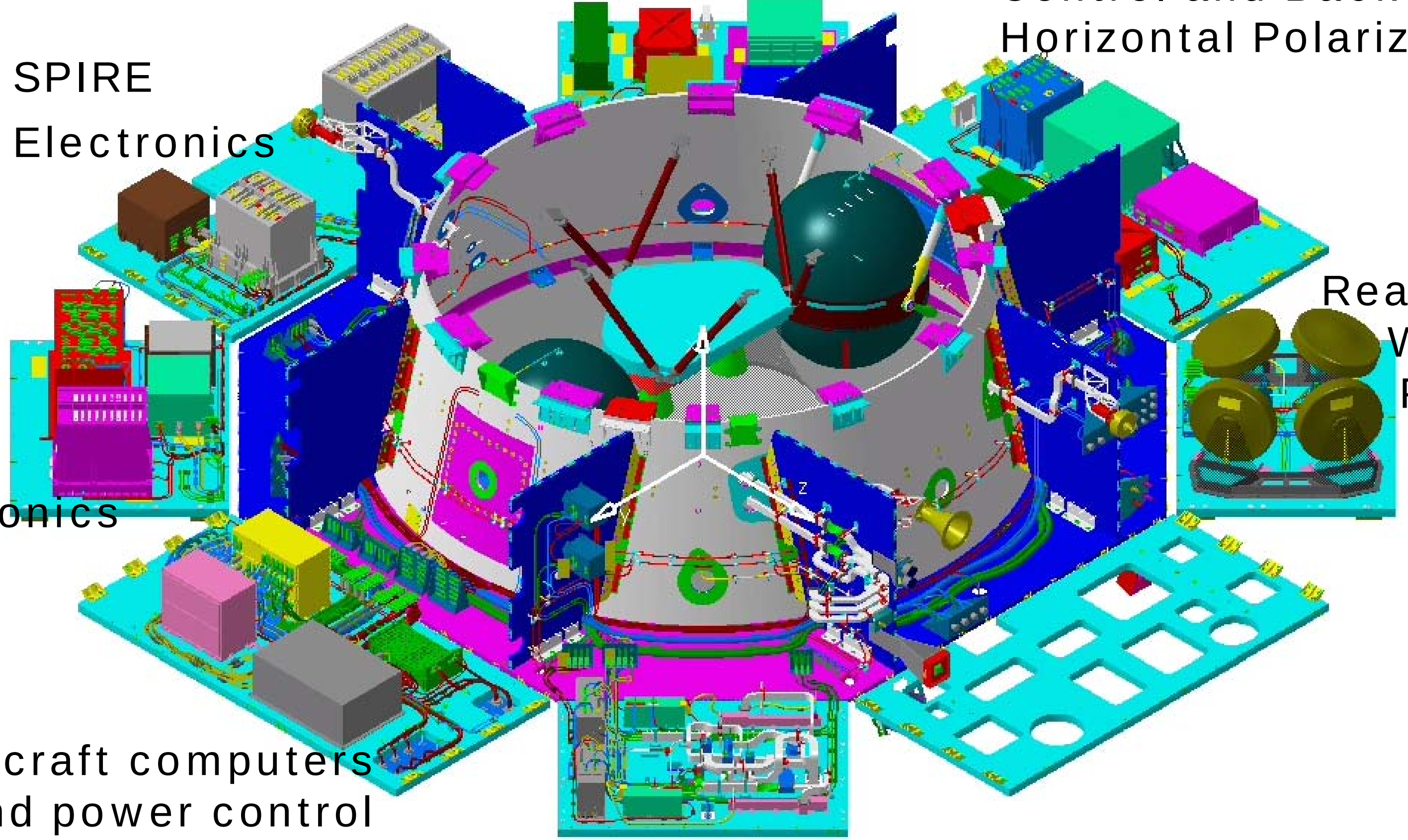
3000kg **1500W**

The Herschel Cooling System - Cryostat

HIFI Electronics
and Backend
Vertical Polarization

HIFI Local Oscillator
Control and Backe[redacted]
Horizontal Polariza[redacted]

SPIRE
Electronics



Rea[redacted]
W[redacted]
F[redacted]

PACS
Electronics

Spacecraft computers
and power control

Level 2

Spacecraft RF Functions

Not sure if this should be detailed

Herschel Telescope-Configuration Design & Key Requirements

- **Herschel Telescope design specs: Cassegrain, 3.5m M1, Pupil on M2**
- **Focal length = 28.5 m (+/- 150 mm), f/no = 8.68 (+/- 0.02), Transmission 0.975**
- **Operational temperature 70K, WFE = 6 microns RMS full field @ λ=80 microns**

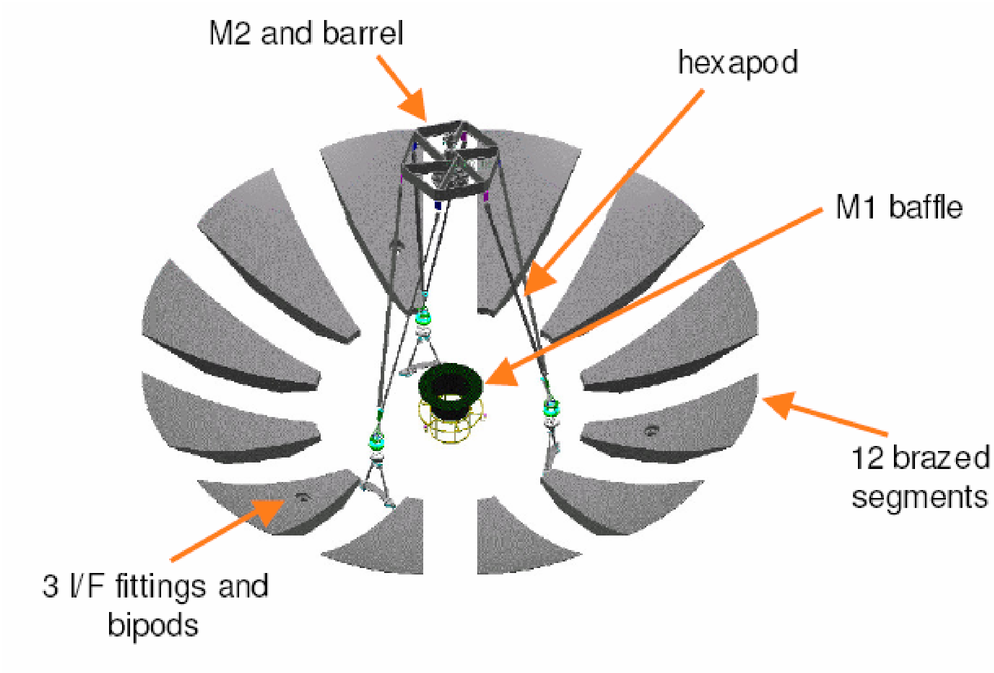


Figure 2-3: Exploded view of the Telescope

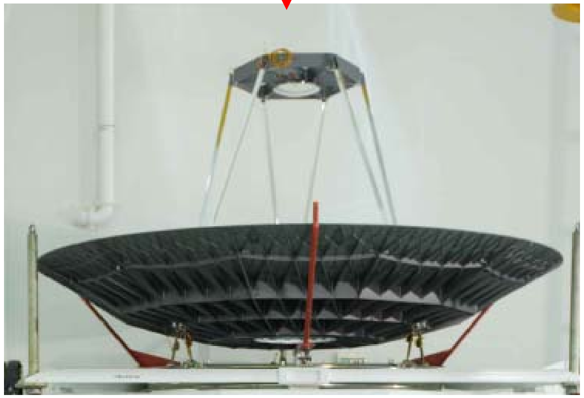
Primary reflector		
Radius of curvature	*3500 mm*	*± 2 mm (*)*
Conic constant	*-1*	
f-number	*f/ 0.5*	
(Free) diameter	*3500 mm*	*0, +2 mm(*)*
Secondary reflector		
Radius of curvature	*345.2 mm*	*± 0.4 mm(*)*
Conic constant	*-1.279*	*-*
Diameter	*308.1 mm*	*± 0.2 mm*
Image surface		
Radius of curvature	*- 165 mm*	*-*
Conic constant	*-1*	*-*
Diameter	*246 mm*	*-*

Manufacture sequence/technology

Silicon Carbide (SiC), chosen technology

- 3.5 m diameter largest SiC structure ever made
- Process flow M1:
  - Powder mixing => Hydrostatic pressing in moulds => "Green body" machining to shape => Segments sintering (ceramisization) => Assembly of segments => Brazing => Grinding of M1 to precise shape (diamond tools) => Polishing => Coating => Integration of M2 & Hexapod sub assembly => Alignment testing and qualification (under ambient and cryogenic conditions) => Delivery for integration onto spacecraft.

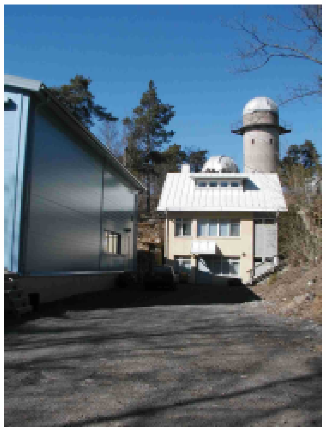
> From SiC "dust" to a cryogenic fully formed 3.5 m diameter Telescope !



Telescope Industrial facilities

EADS ASTRIUM

Finland



OPTEON polishing installations

BOOSTEC

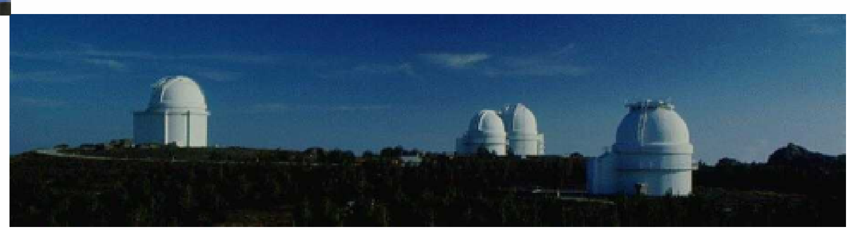
SiC facilities and ovens

France

CSL Focal XXL

WFE facilities

Belgium

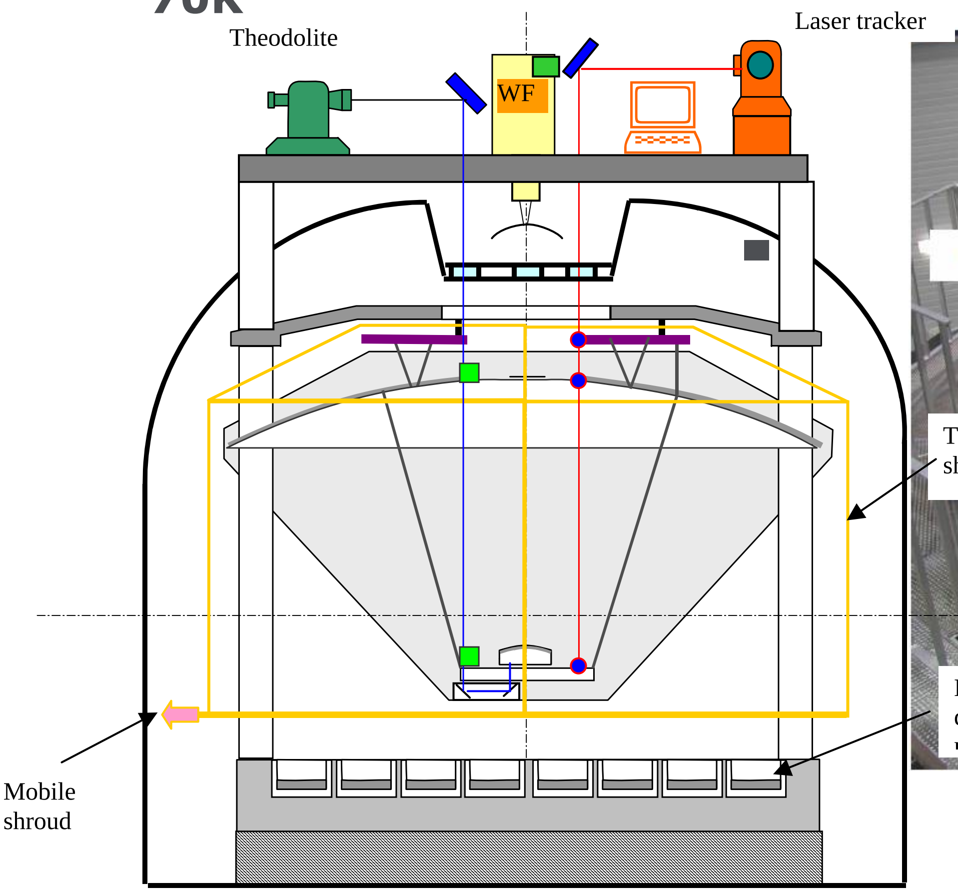


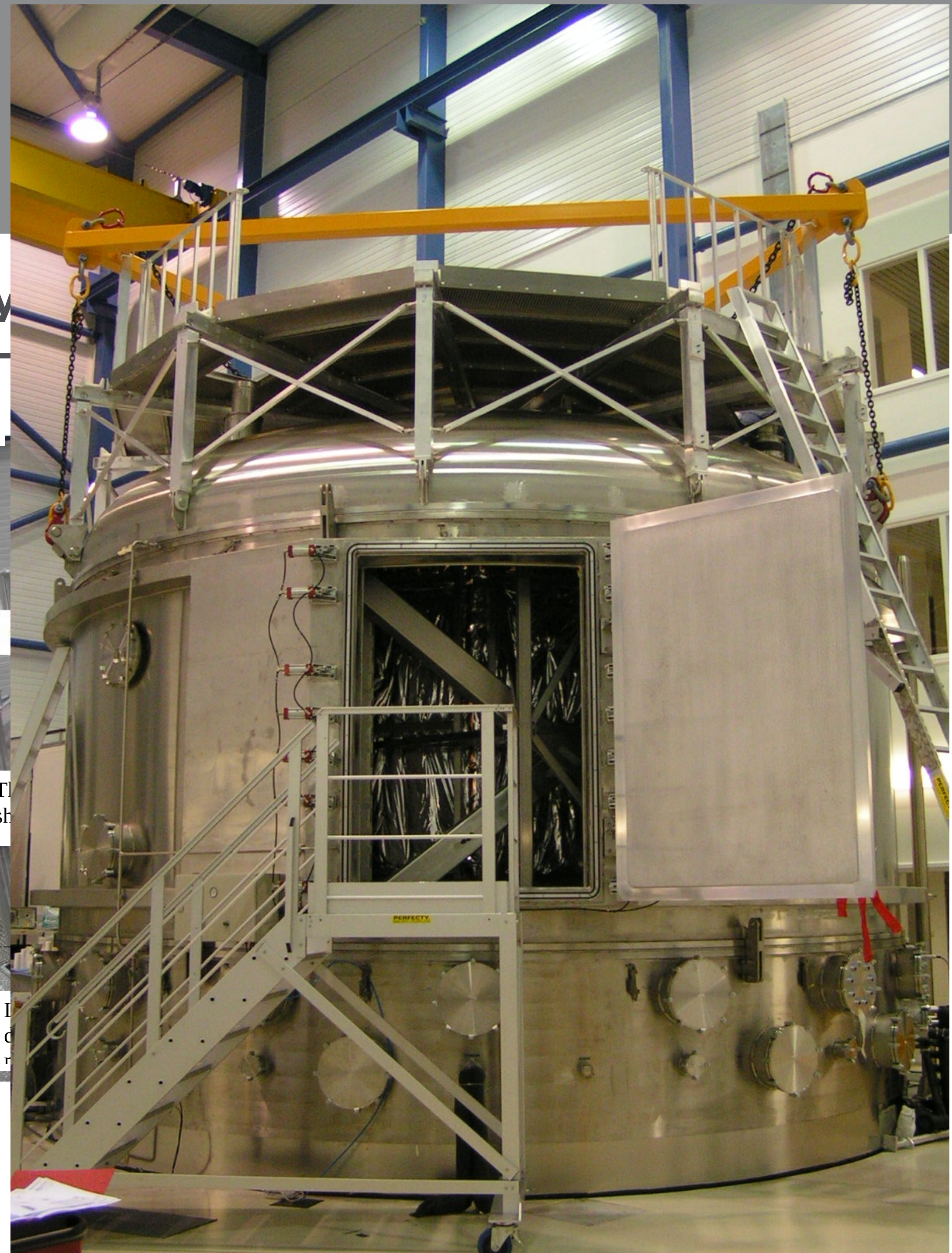
Spain

CALAR-ALTO coating chamber

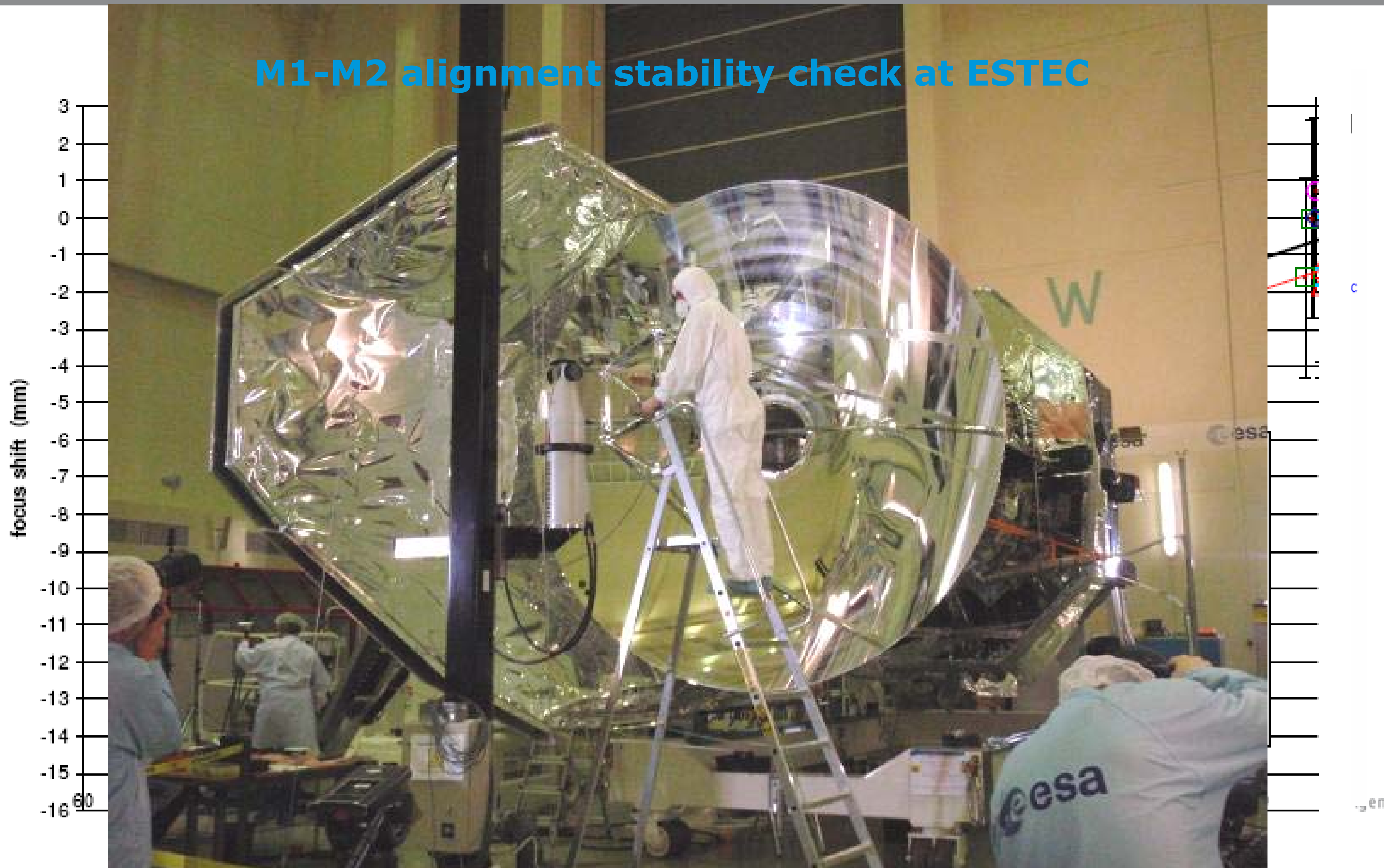
Cold testing at CSL

– **Herschel telescope test metrology sensor to measure optical end-to- 70K**



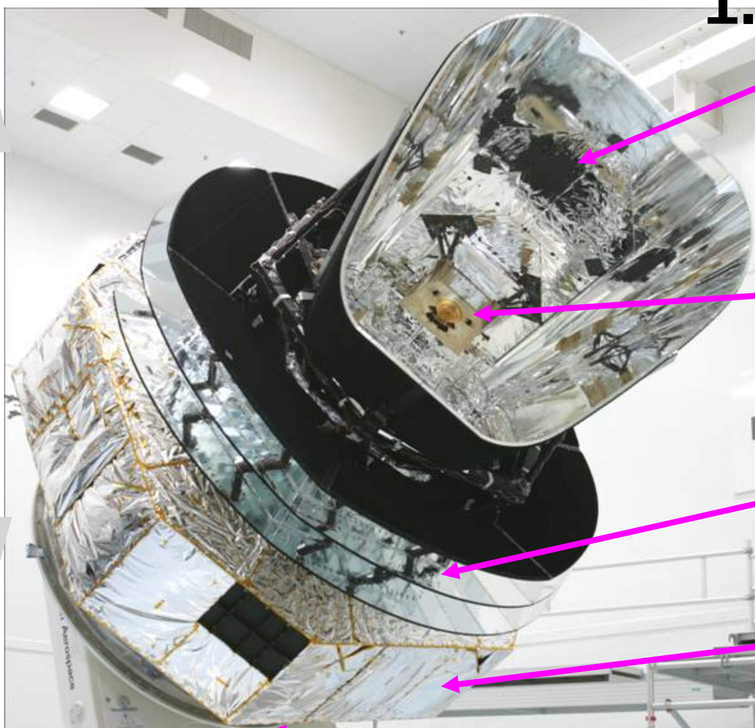


M1-M2 alignment stability check at ESTEC



Planck Satellite - Overview

esa



4.1 m

1.5 m Telescope (30 – 60 K)

Telescope Baffle

Instruments (20 –300mK)

V-Groove shields (150 - 60 K)

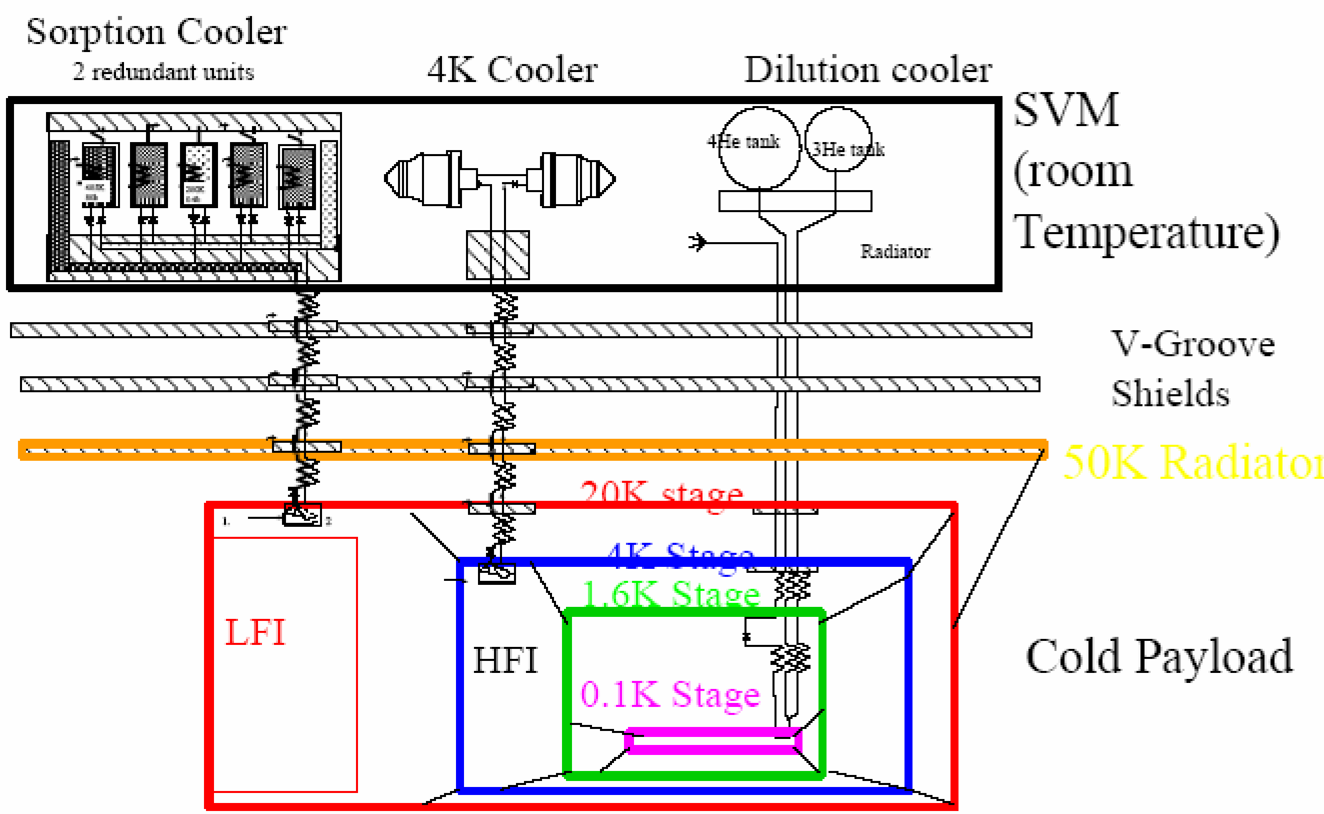
Service Module (300 K)

S/C units and Instrument electronics

Solar Array

1500kg 1800W

The Planck Cryochain



Planck Focal Plane Unit HFI

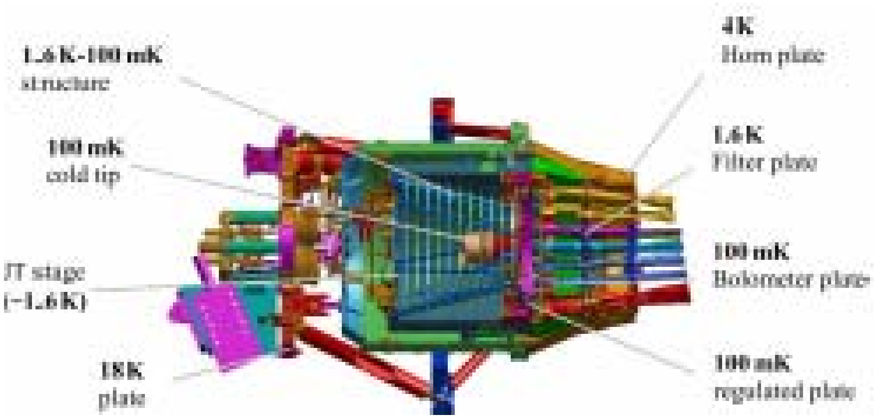
HFI Outer shell and horns at 4K

Filters at 4K/1.6K/100mk

Detectors bolometers at 100 mK

36 horns at 100,143,217,353
545, 857 GHz

European Space Agency



Planck Focal Plane Unit - LFI

LFI box and detectors (LNA’s) at 20K

11 horns – 30GHz, 44 GHz, 70 GHz

LFI waveguides carry signals from
Radiometer chains to back end unit

Passive Radiator System – V grooves

VG1 170 K

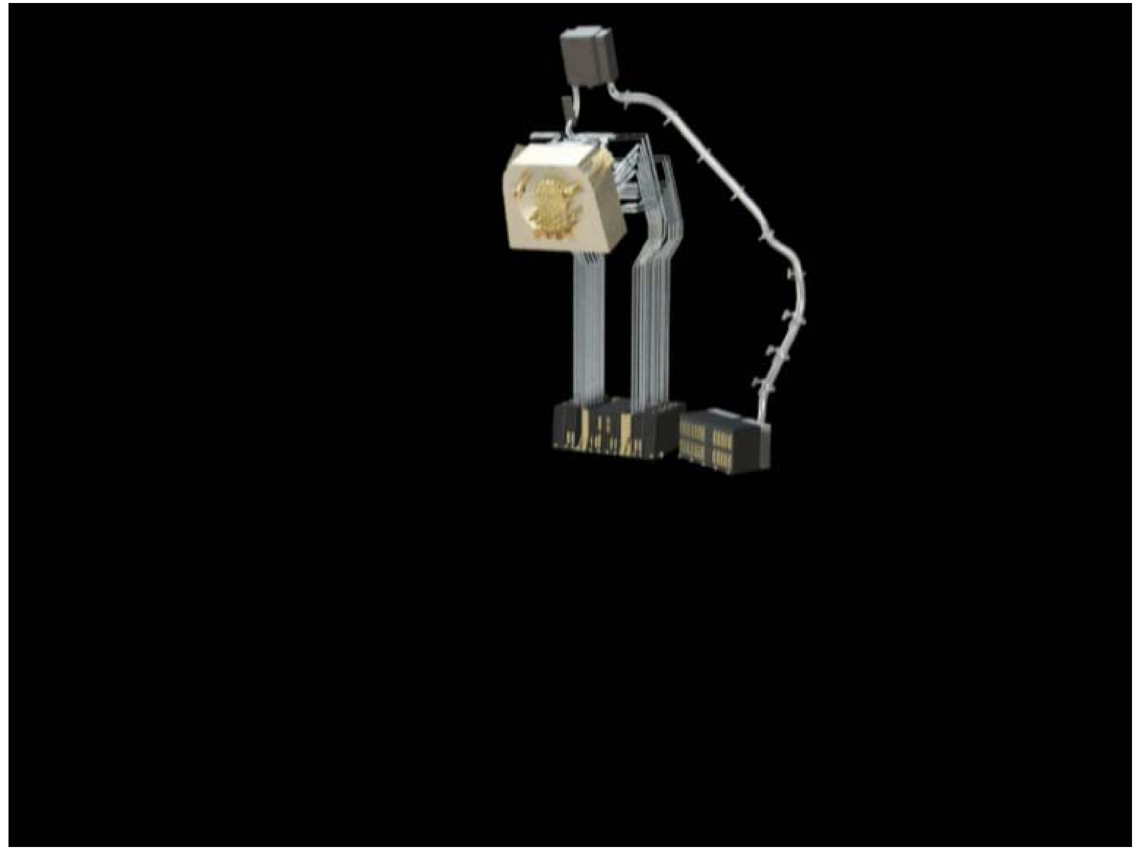
VG2 120 K

VG3 60K

Performance better than Spec.

Thermalization on/ pre –cooling

- LFI waveguides
- All coolers



20 K Hydrogen Sorption Cooler

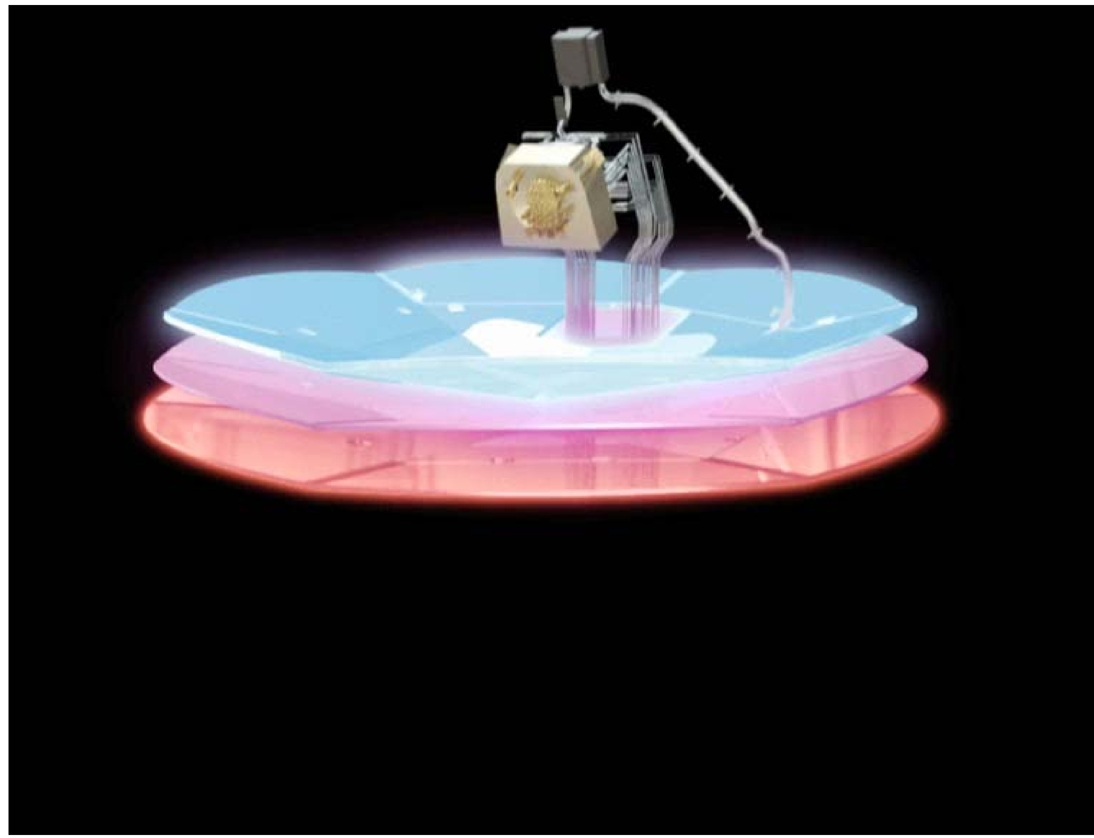
Closed system

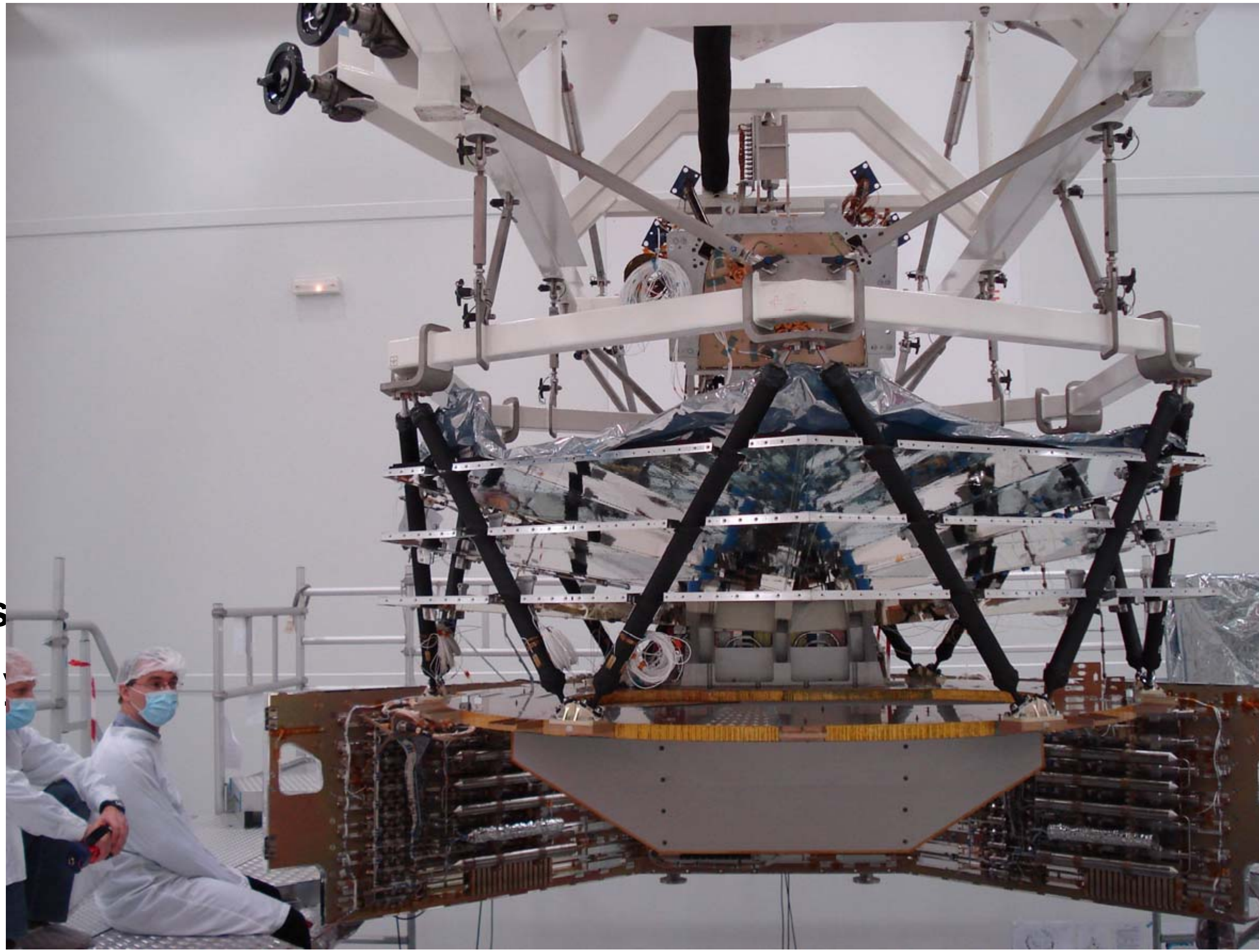
Gas Pre-cooling
•Pipes - bi-directional heat exchanger
•Thermalized on all three V-grooves

Joule-Thomson expander provides
liquid H

Pre-cooling for HFI 18 K
Cooling for LFI < 20 K

1 watt cooling power





Cooler

Compres

Assembl

FM1

ressor

nbly

4K He^4 Cooler Mechanical cooler

Closed System- Back to Back compressors

Gas Pre-cooling

- Pipes thermalized on VG 3
- 18K Sorption Cooler

Pre-cooling for Dilution cooler

Picture to come

Cooling for LFI Black body loads

Cooling Power around 15mW

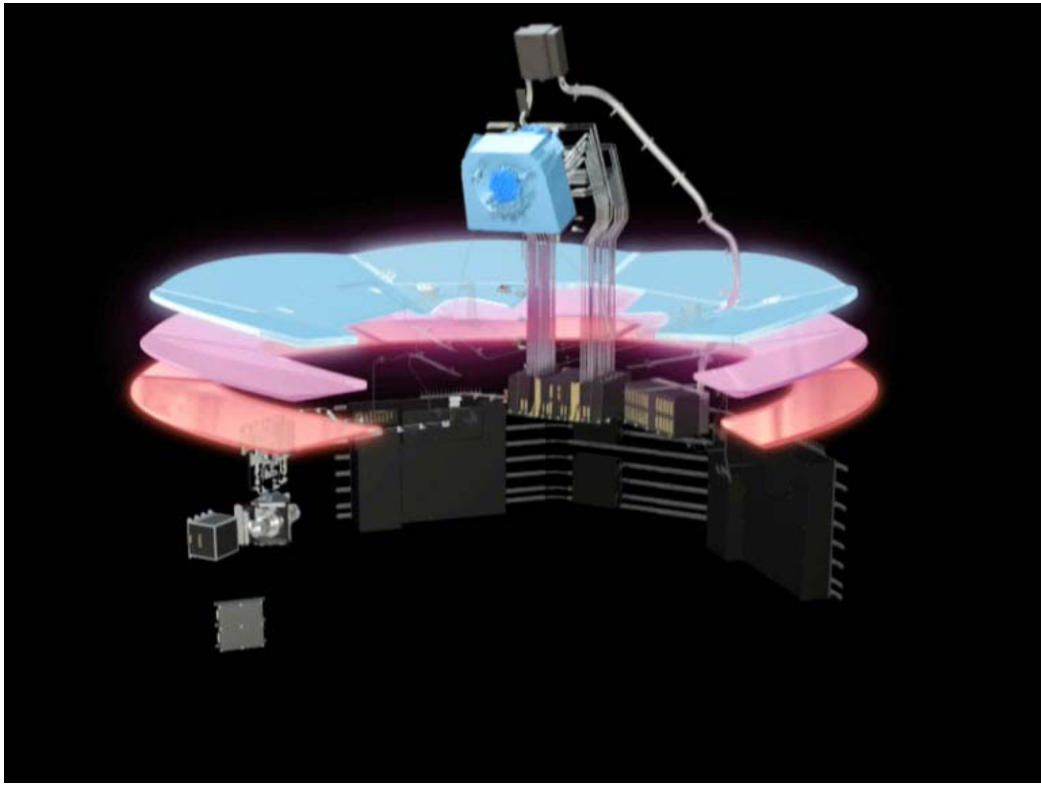
100 mK He^3 / H^4 Dilution Cooler

Gas precooling
•Pipes thermalized on all V-grooves
•4K cooler

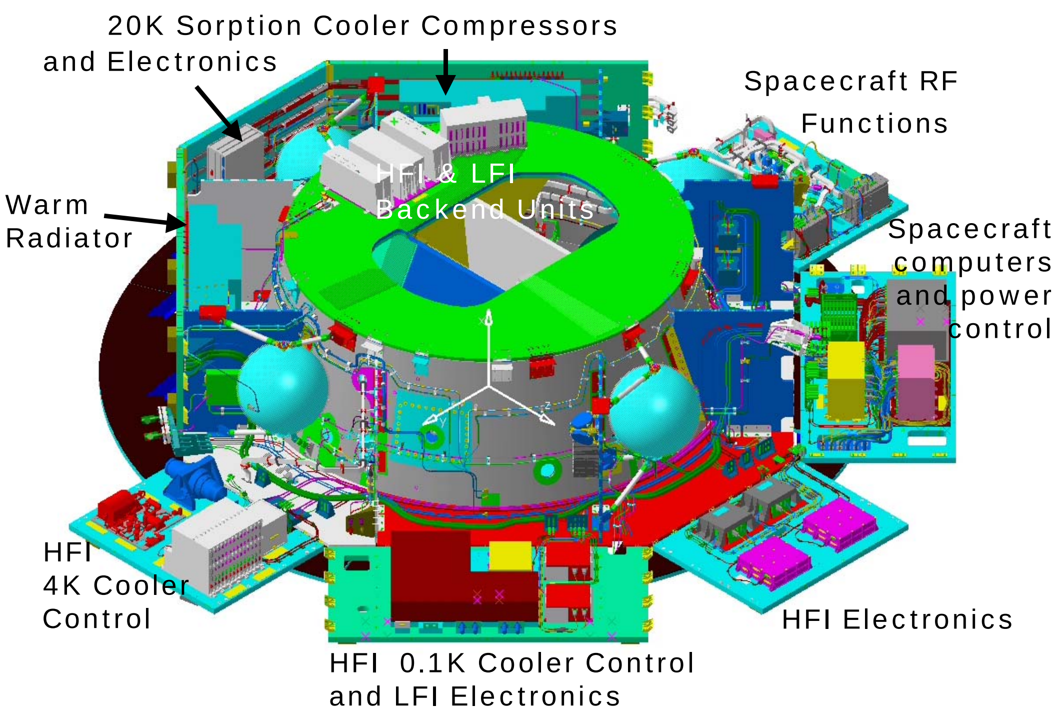
He^3 tank and 3 He^4 Tanks
Dilution results in 100mk on cold end

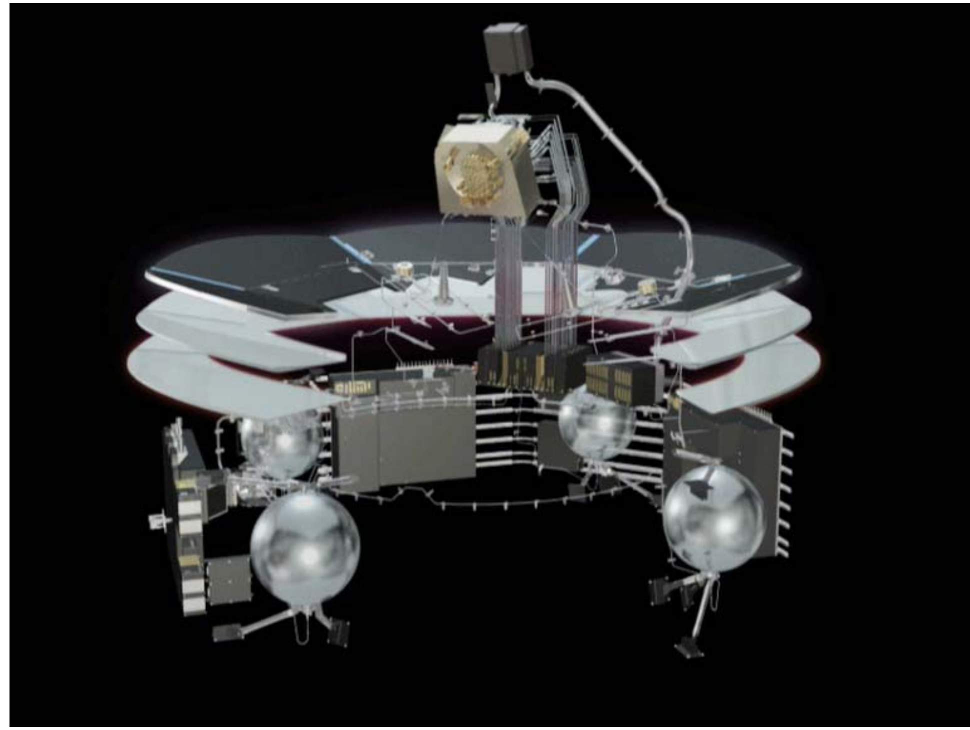
Cooling power around 200 uW at 100mK

Gas mixture vented to Space

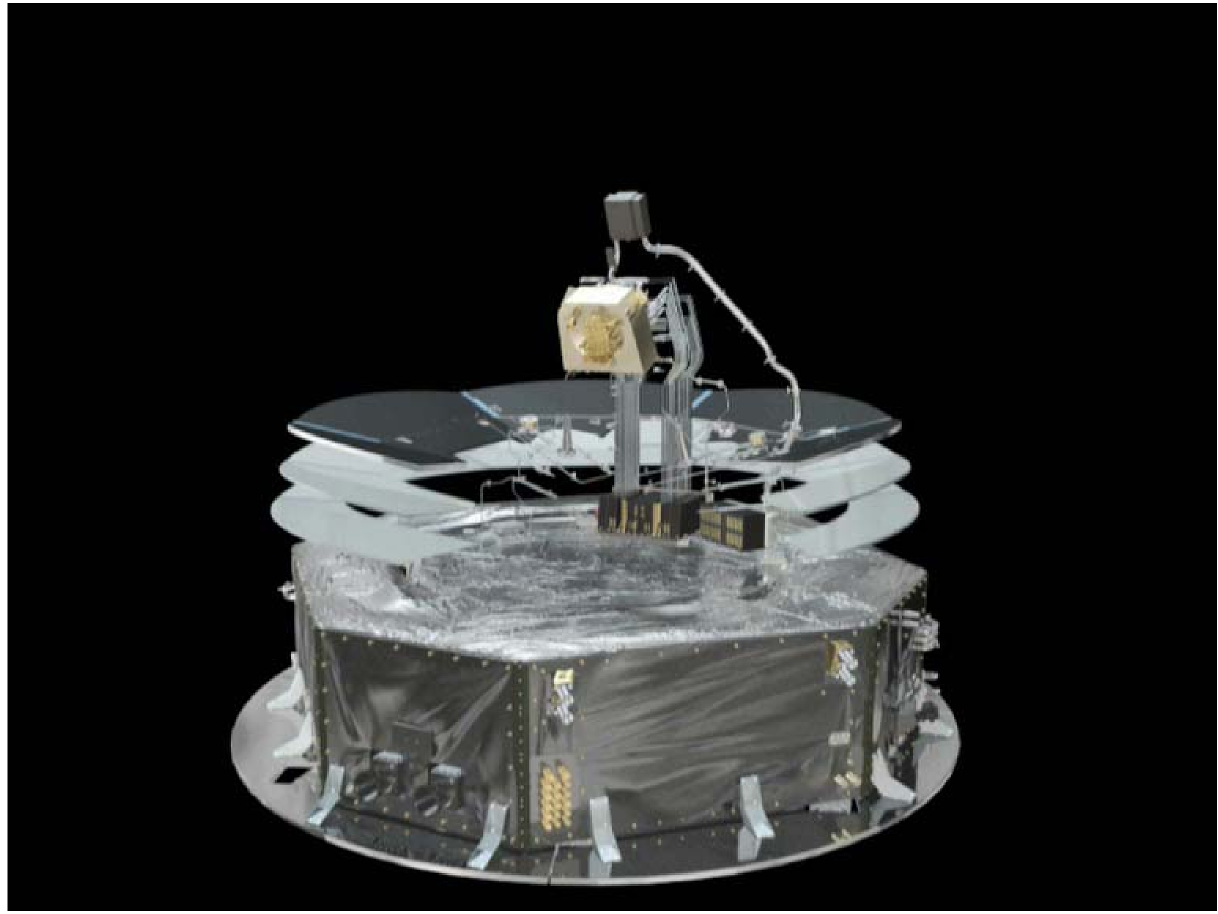


SVM

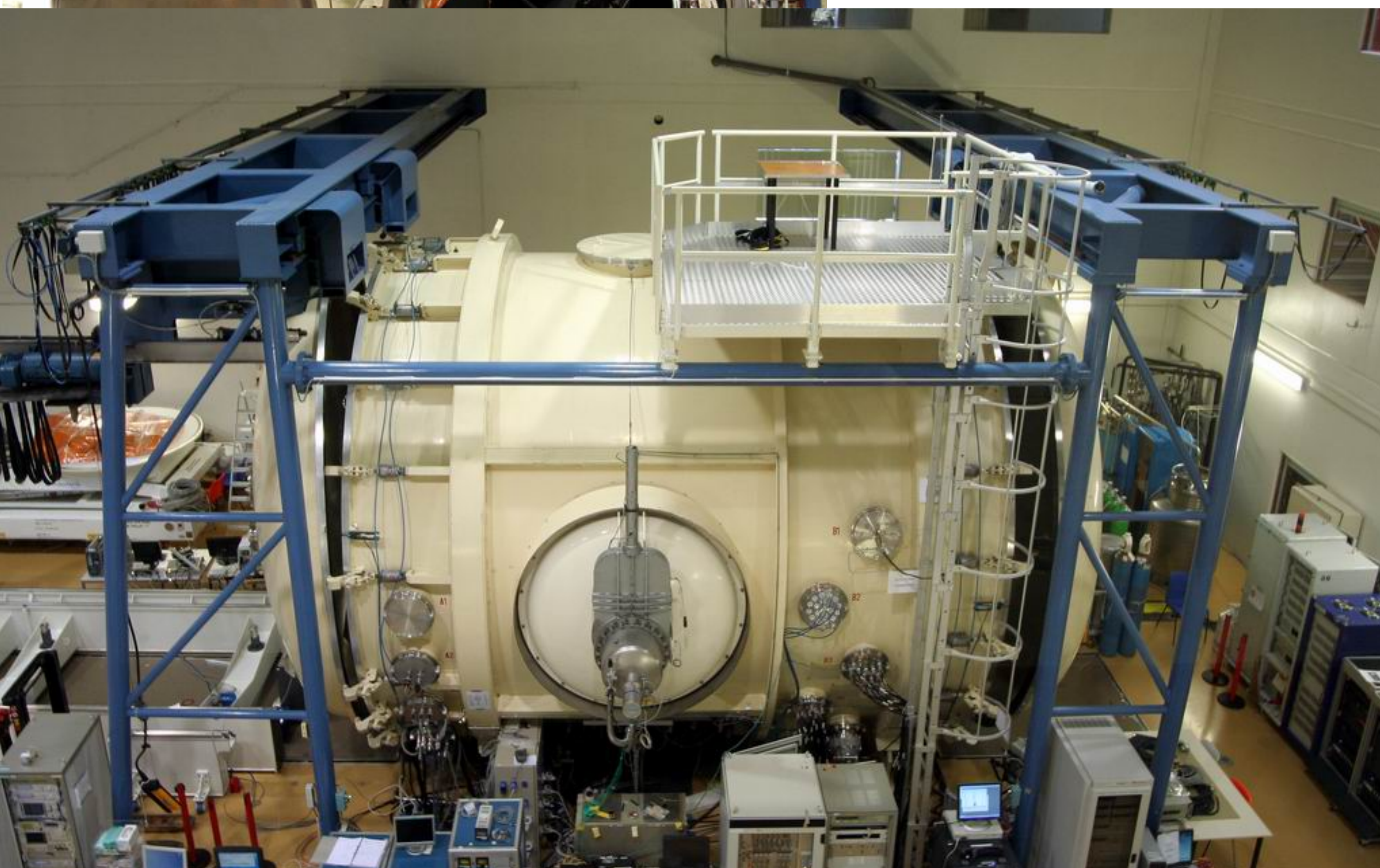

20K Sorption Cooler Compressors
and Electronics
Spacecraft RF
Functions
Warm
Radiator
HFI & LFI
Backend Units
Spacecraft
computers
and power
control
HFI
4K Cooler
Control
HFI Electronics
HFI 0.1K Cooler Control
and LFI Electronics



Telescope and Baffle Build-up



Planck Thermal Vacuum Test



The FOCAL 5 Test Chamber in Numbers

- **Pressure < 5E-06 mbar i.e. < 5 billion less than atmospheric pressure**
- **Liquid Nitrogen Cooled Shrouds at <173 deg C covering the SVM and GHe shrouds**
- **Helium gas cooler shrouds at <-253 deg C covering the PLM**
- **Liquide Helium Shield at <-268 deg C in front of Instrument Focal Plane**
- **Cold Space on earth !!**

The Thermal Test – Cold facts

Baffle: 41-44K

VG-3: 45-47.5K

VG-2: 92–93K

VG-1: 126–143K

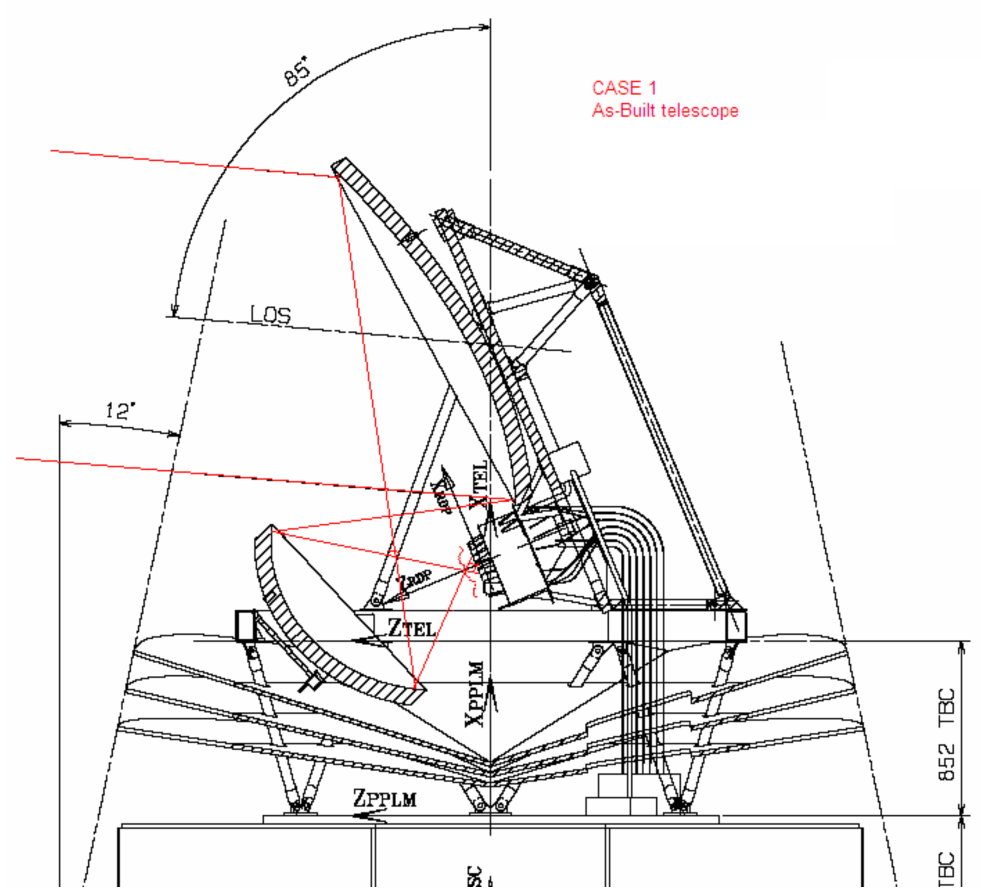
Coolers

Sorption 17.1K

4K cooler 4.5K

Dilution 93 mK

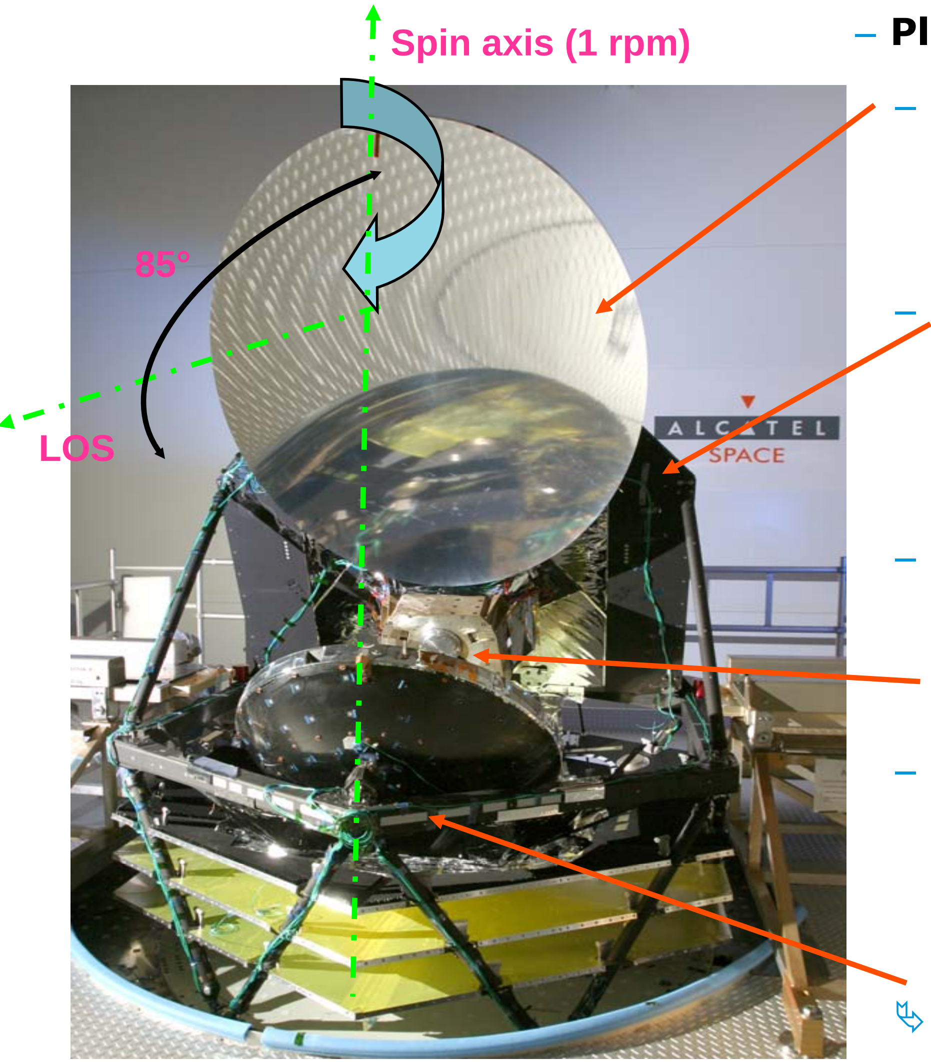
Planck Telescope Design and Configuration



Aperture	1.5m off-axis
Focal length	1600mm
Field of view	+ / -5°
Line of Sight	At 85° of Xtel

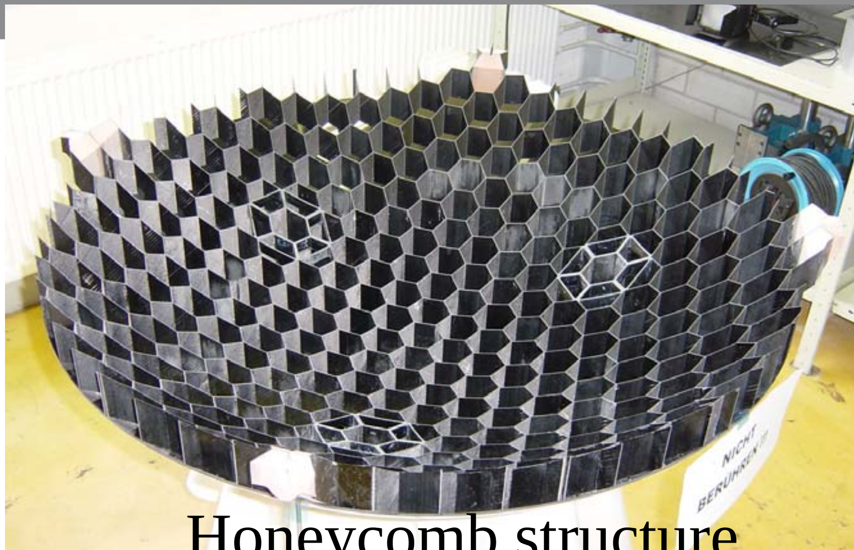
Off axis dual ellipsoid aplanatic design
Main drivers:
Low cross polar
Low off axis scan degradation
Unobscured aperture
Low straylight

Technology and Manufacture

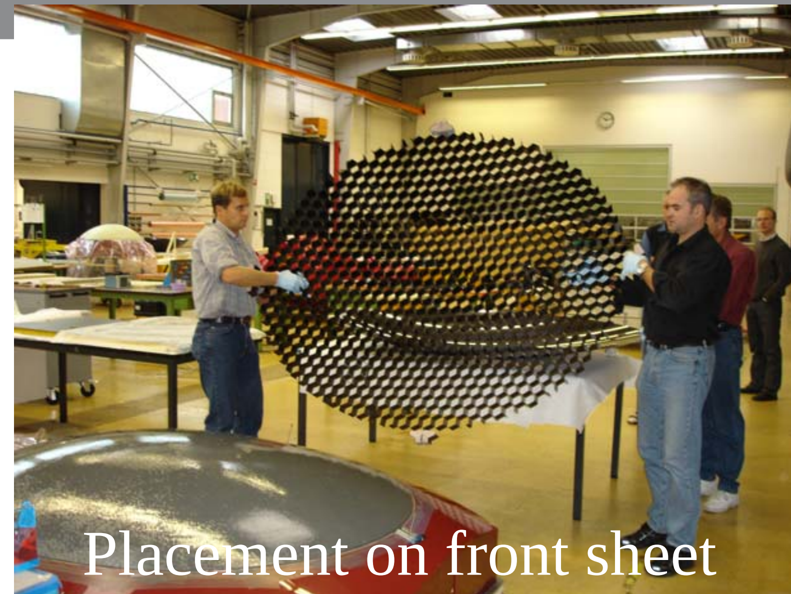


- Planck Telescope construction
  - CFRP Reflectors provided by ESA/DSRI (manufacturing by Astrium, Friedrichshaven)
  - Telescope structure – Glass-Fibre & CRFP by Oerlikon (Contraves) (CH)
  - Baffle CFRP by Oerlikon (Contraves) CH
  - FPU Instruments HFI & LFI (IAS, Paris & Laben Italy)
  - Cryo-structure/telescope Interface

Planck reflectors



Honeycomb structure

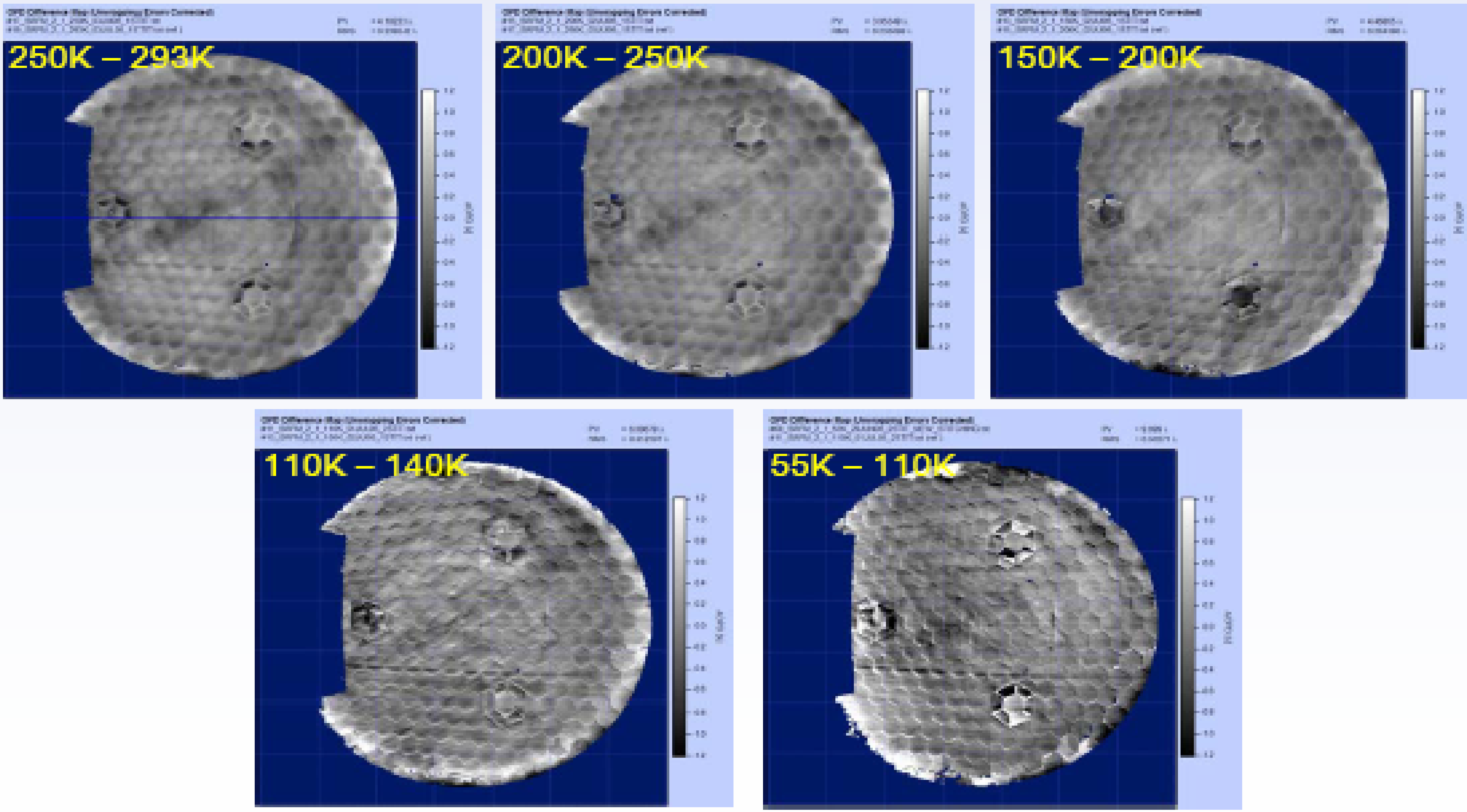


Placement on front sheet

Removed from mould

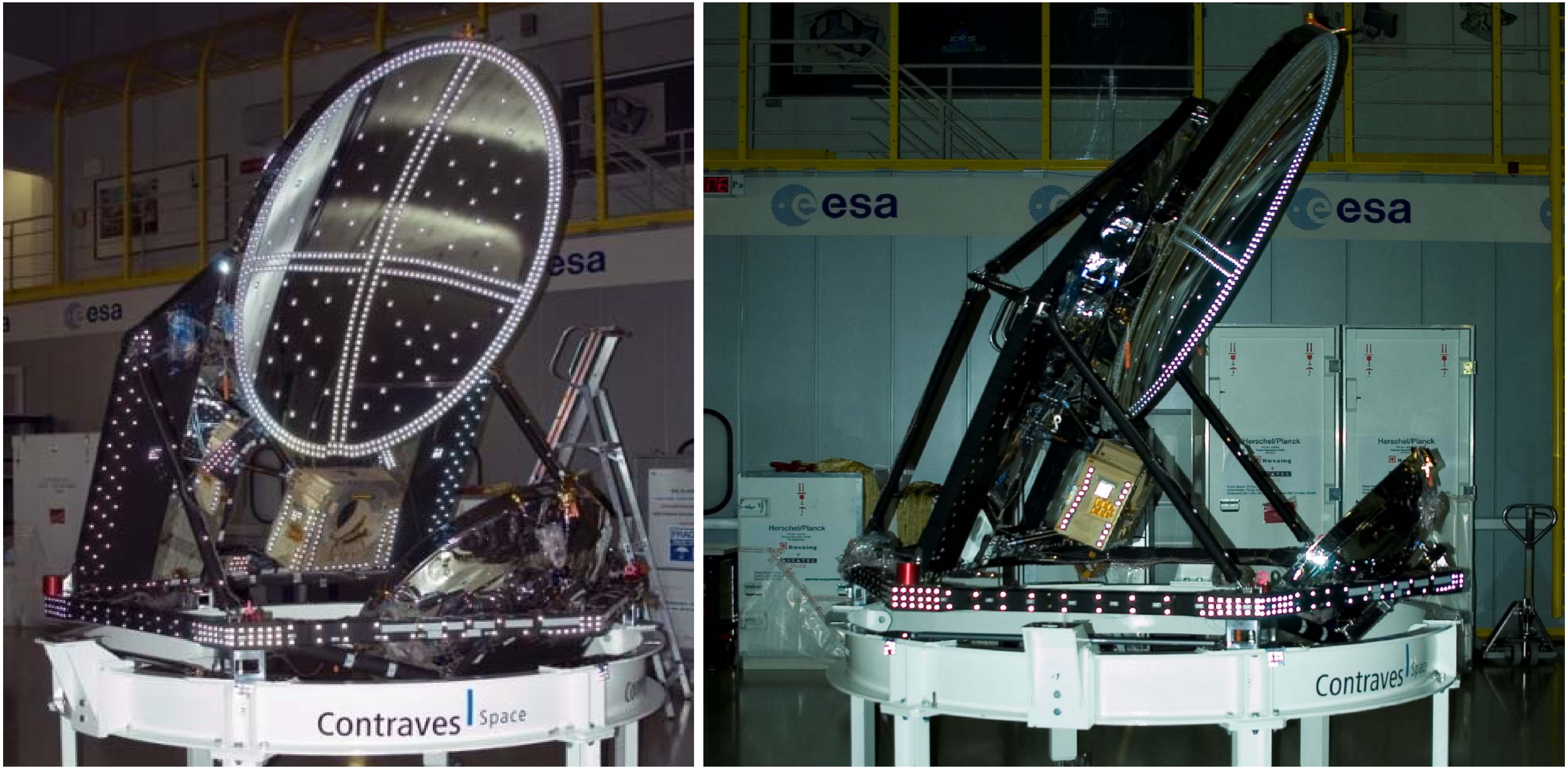
Coated

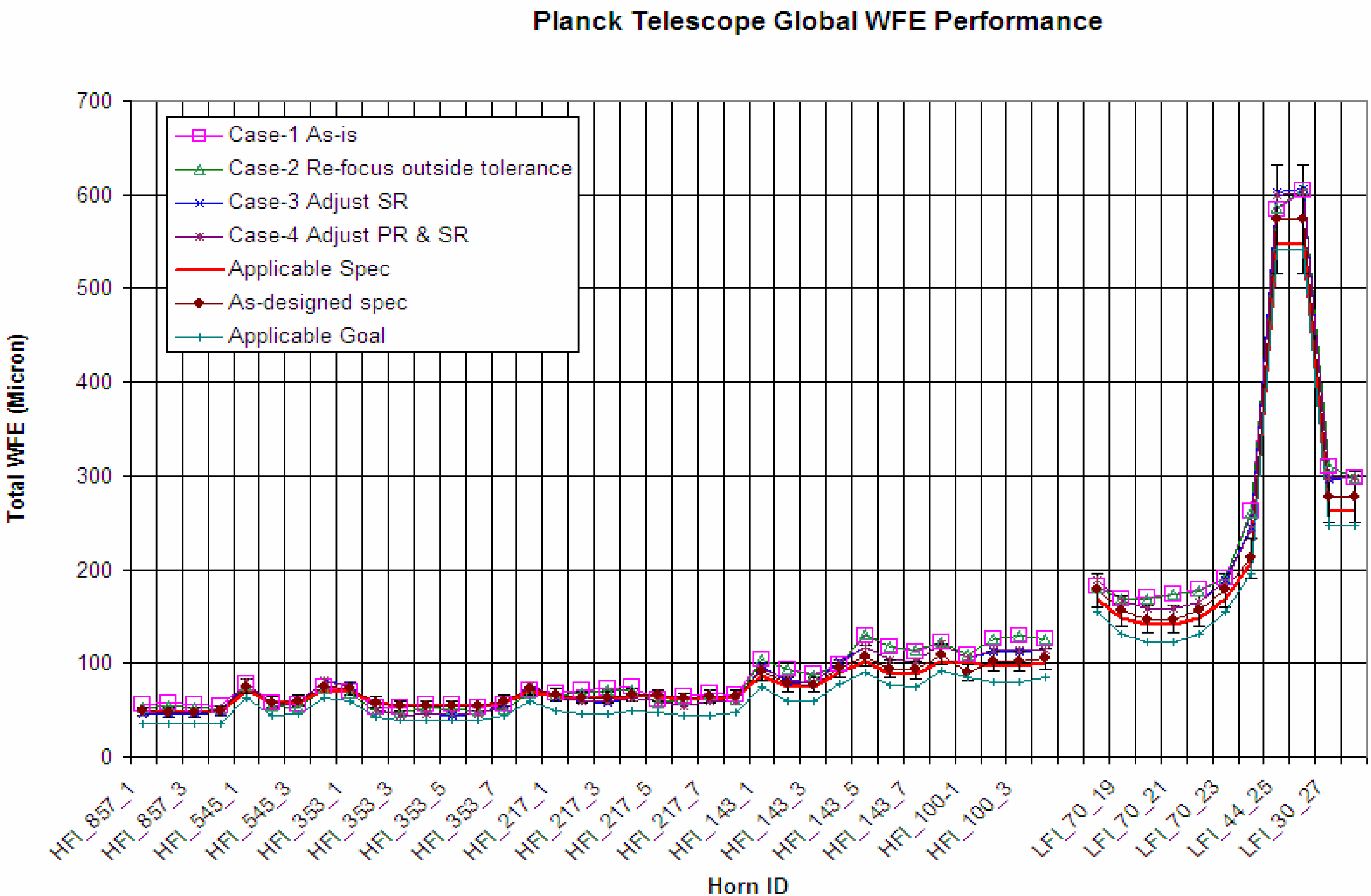
Planck Cryo-optical Reflector Testing



Videogrammetry – complementary metrology

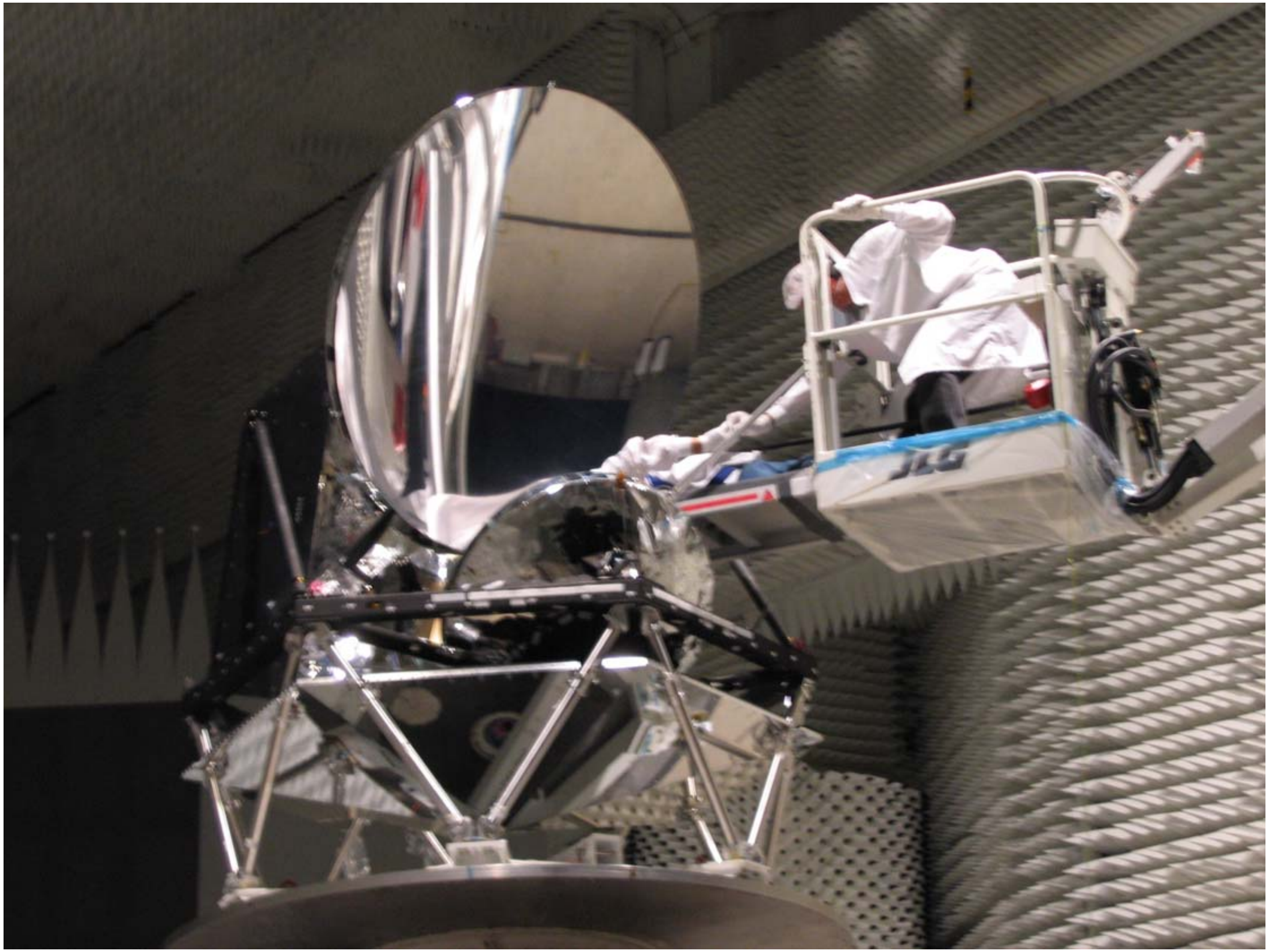
Flight Model telescope antenna equipped with retro-reflective spot targets for videogrammetry





Planck Telescope Global WFE Performance
Case-1 As-is
Case-2 Re-focus outside tolerance
Case-3 Adjust SR
Case-4 Adjust PR & SR
Applicable Spec
As-designed spec
Applicable Goal
Total WFE (Micron)
Horn ID
0
100
200
300
400
500
600
700
HFI_857_1
HFI_857_3
HFI_545_1
HFI_545_3
HFI_353_1
HFI_353_3
HFI_353_5
HFI_353_7
HFI_217_1
HFI_217_3
HFI_217_5
HFI_217_7
HFI_143_1
HFI_143_3
HFI_143_5
HFI_143_7
HFI_100-1
HFI_100_3
LFI_70_19
LFI_70_21
LFI_70_23
LFI_44_25
LFI_30_27

Planck RF Testing warm



1 or 2 More
Images to come
Picture + typical Mo
Animation