The Gaia mission

Status of satellite development

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All the space you need

EADS astrium

System

All the space you need

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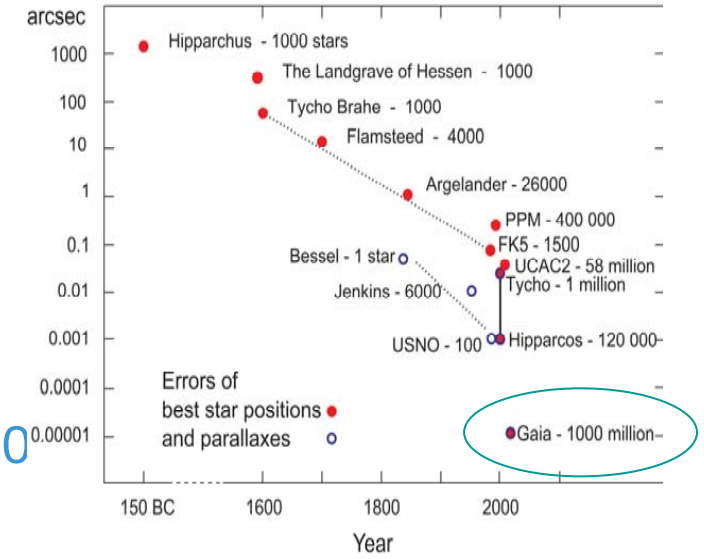
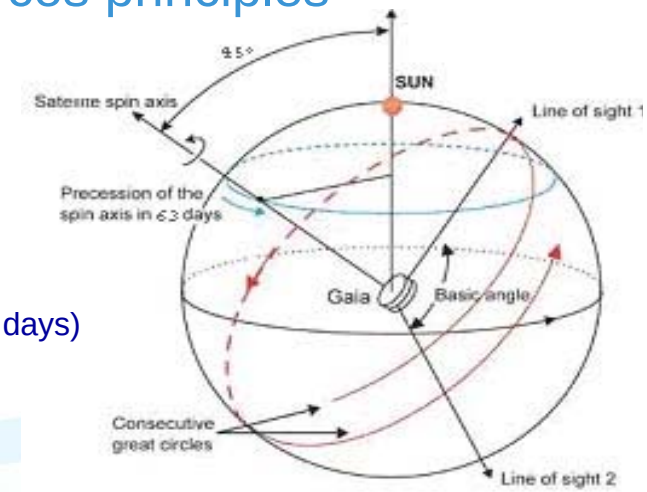
Gaia science objectives

- The mission covers 3 fields
  - *Astrometry* : star position and motions: 7 to 25 µas (V<15)
  - *Photometry* : spectral measurements [330– 1000 nm] and chromaticity correction
  - *Spectroscopy* : radial velocity: 1 km/s and fine spectral measurement [847 - 874 nm]
- Catalogue of 1 billion stars, up to mag 20



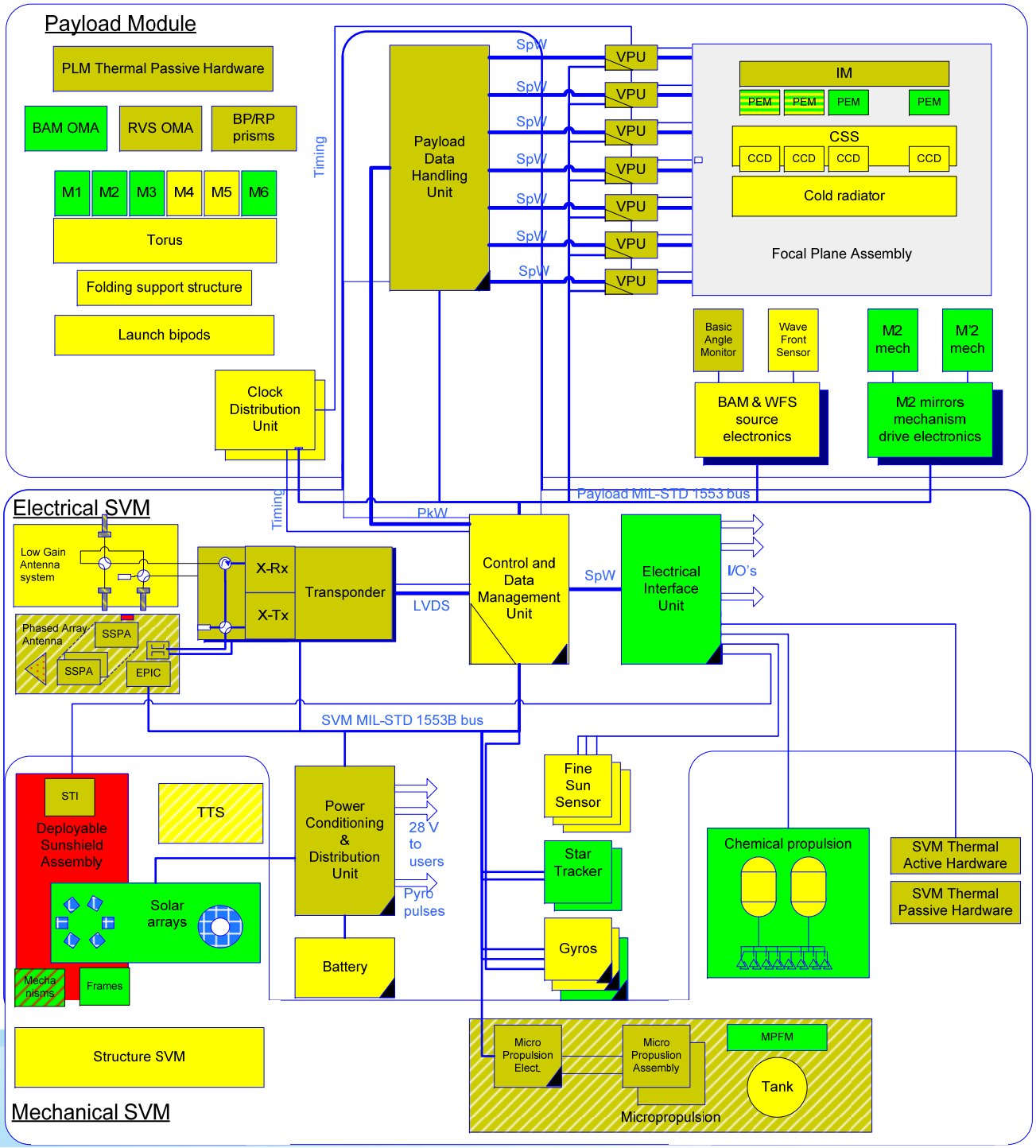
- The Astro measurement is based on Hipparcos principles
  - 2 observing directions
    - separated by the Basic Angle 106.5 deg
    - with a stringent stability of < 7 µas (35 pico radians)
  - the continuous scan of the sky
    - great circles are observed in 6 hours
    - a slow precession guarantees the full sky coverage (period of ~63 days)
  - repeated observations
    - 80 observations (transits) per star
    - 9 CCD acquisitions per transit in the focal plane



Industrial organization

Core team	Satellite Prime (Astrium)		
	E-SVM (Astrium-UK)	M-SVM (Astrium-G)	PLM (Astrium-F)
Austria		Thermal HW - RUAG	Thermal HW - RUAG
Belgium			Mirrors 2,4,5- Amos
Finland	Elec. Interface Unit - Patria		
France	Gyro - Astrium		FPA, RVS OMA - Astrium SiC parts - Boostec M1 mirrors - Sagem
Germany		S/C mech. & thermal analyses - astrium	Thermal analyses - Astrium M3 mirrors – Zeiss
Italy	Power (PCDU) - Galileo TRSP, Micro Prop. – TAS		Interconnexion Module – TAS Photometer - Galileo
The Netherlands	Fine Sun Sensor - TNO		BAM OMA, WFS - TNO
Norway			Opt. Sources & Electron. – KDA
Spain	Phased Array Antenna - CASA	Structure, Harness – CASA Deployable Sunshield - Sener	Proximity Electronics – Crisa M2 mechanism – Sener Atomic Clock (CDU) - TAS
Sweden	CDMU - RUAG		
Switzerland	PDHU - Syderal	Thermal Tent - RUAG	Bipods & Release Mech. - RUAG
UK	Central Software - Astrium Chemical Propulsion - Astrium		Video Processing Unit – Astrium CCD – e2v

Spacecraft equipment design status



PDR passed

CDR on going

CDR passed

MRR on going

MRR passed

Delivery

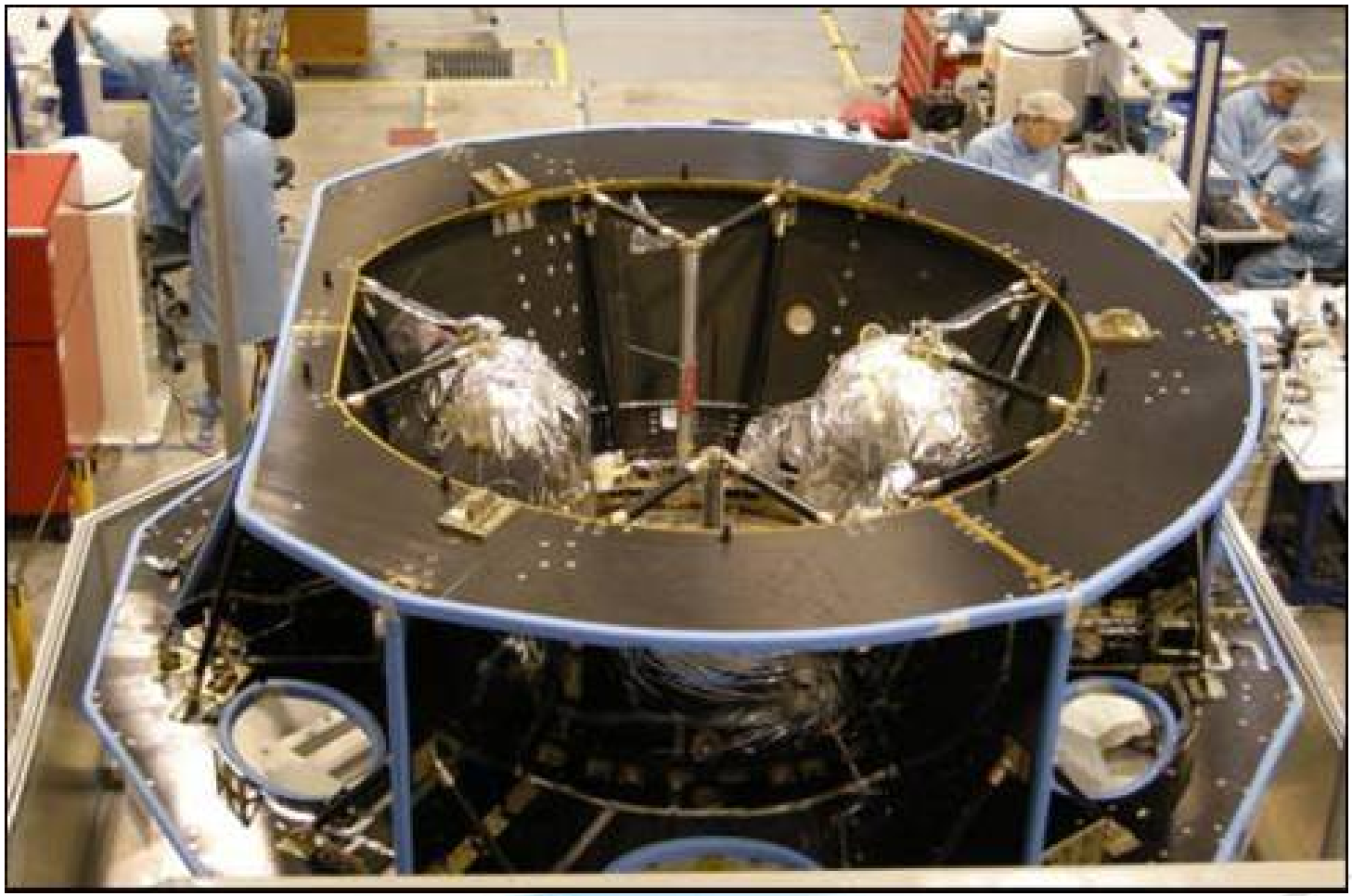
Spacecraft overview

- Spacecraft design is frozen
  - CDR of modules passed (E-SVM, M-SVM, PLM, SW)
  - Late change of motorisation concept for the sunshield decided last month
- Spacecraft budgets are within specifications, with exception of
  - Mass budget, with a margin slightly lower than specified for CDR
    - 3.5% margin (70 kg) wrt Soyuz-Fregat performance
  - Basic angle stability budget to be confirmed for CDR, with:
    - 5 µas for 7 µas specified for random contribution
    - 5 - 10 µas for 4 µas specified for systematic contribution
- Impacts of radiation on science performance now assessed
  - Contained through combination of pre-calibration and post-processing activities
  - Major concern of PDR in 2007, now addressed through CDR 2010
- S/C CDR data package delivered to ESA by end of June

Spacecraft development status

- S/C integration will start in Toulouse this summer
  - SVM structure equipped with propulsion systems to be sent from Stevenage
    - Pressurisation tests successfully passed in Westcott facility in May this year
  - Complete central software available & validated for start of S/C AIT
  - PLM torus is now mounted on its flight bipods
- Functional and performance validation on going
  - Pre-validation of the full detection chain achieved on the FPA EM end of last year
  - S/C functional validation on going on AVionics Model (flat-sat) in Stevenage
    - Integrated Subsystem tests (on going), Integrated System test (Started)
  - AOCS performance validated through simulation campaigns
    - Chemical Propulsion modes completed
    - Micro-propulsion modes (supporting science) on going

Structure with propulsion systems



AVionic Model in Stevenage

Data management & communication

Attitude & Orbit Control

Payload Units

Central Data Mngt Unit

Gyro

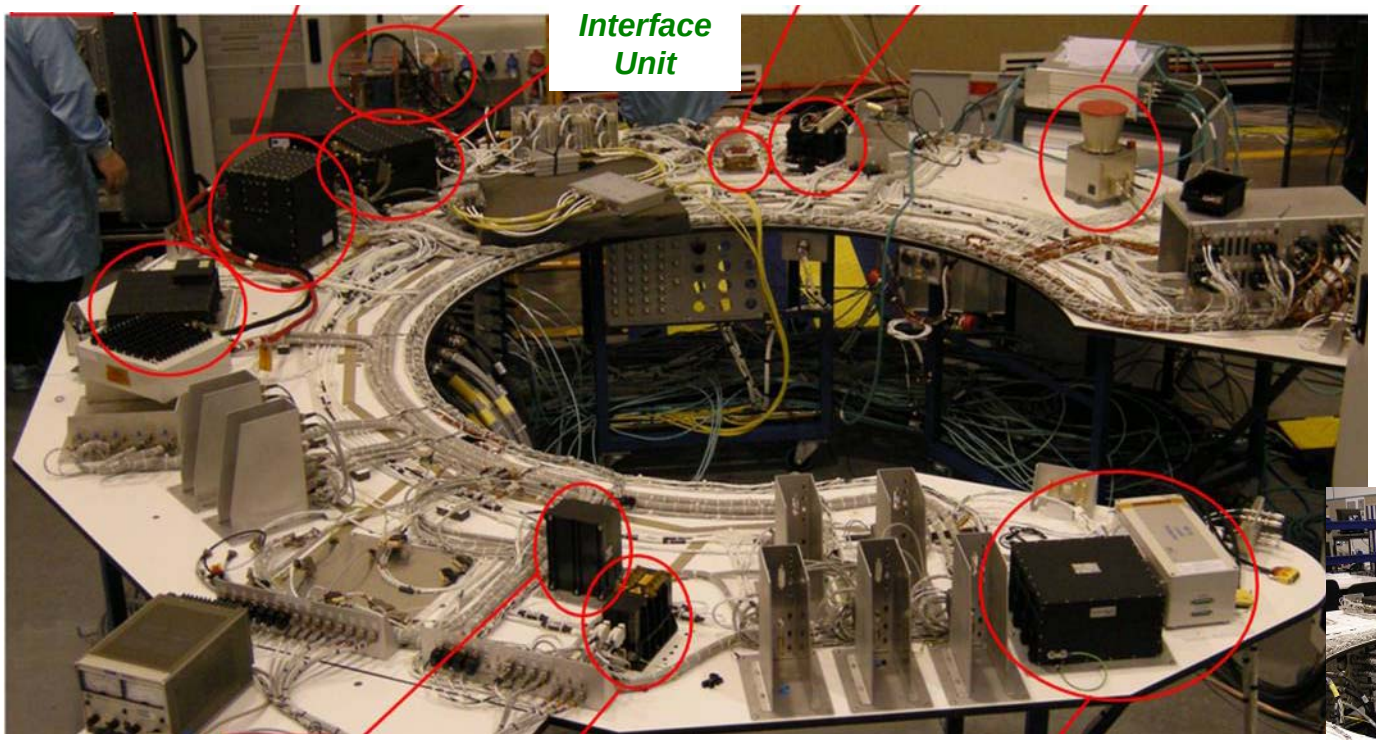
Fine Sun Sensor

Transponder

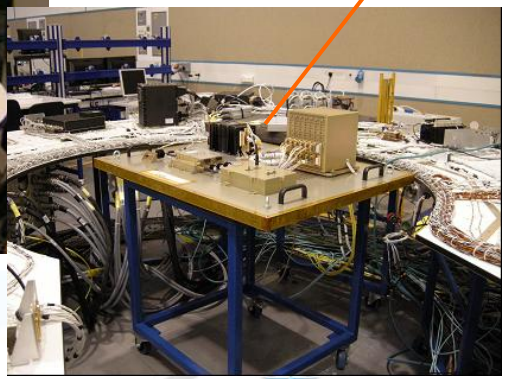
Star Tracker

Atomic Clock

Interface Unit



Phased Array X-band Antenna



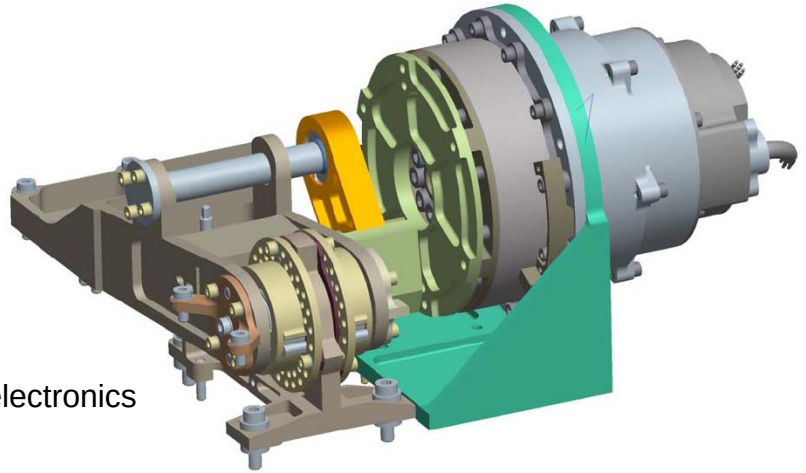
M2 Mechanism Drive Electronics

BAM & WFS Optical Sources & Electronics

Micro-Propulsion Electronics

Deployable Sunshield Assembly

- Major design change recently introduced
- Qualification of passive deployment system failed in cold vacuum condition
  - Insufficient control torque provided by regulator (motorisation / braking)
  - Not possible to strengthen failed item within geometrical constraints
  - Decision to switch to an electrical motorisation taken by end May 2010
  - New design based on existing elements
    - Actuator recurring from GMES Sentinel 1
    - Specific four lever arm linkage system
    - Drive electronic derived from PLM MDE
  - First tests demonstrates adequate torques
  - Full redounded system baselined
    - Two actuators selected
    - Each actuator is driven by an internally redounded electronics
  - DSA CDR to be held in the coming days.



Four bar linkage system with actuator and master hinge assembly

❑ Payload Module

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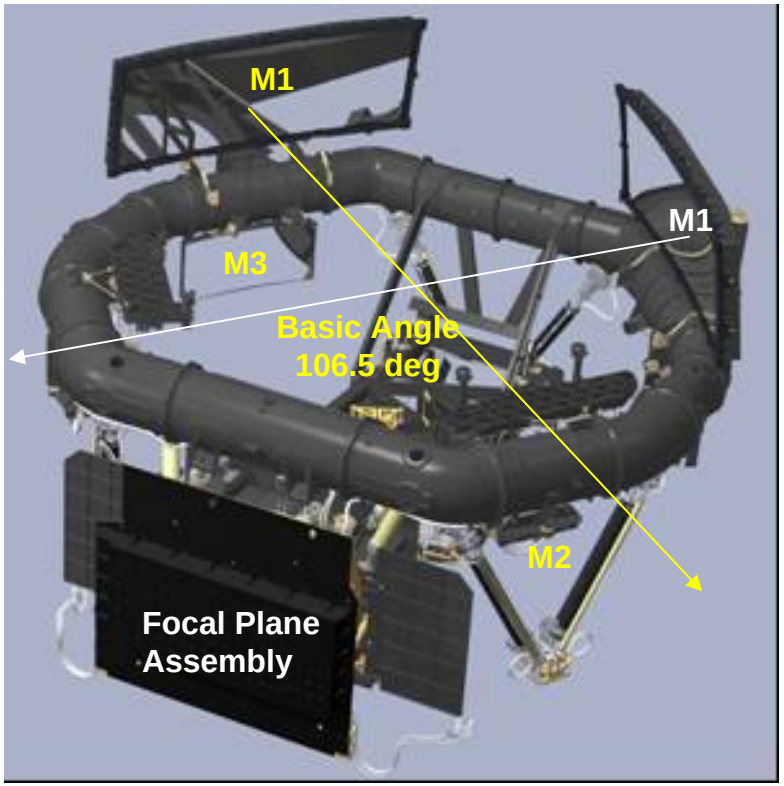
Payload instruments (1 payload, 3 science objectives, 5 instruments)

Astrometry

performed with 2 TMA telescopes at 106.5 deg and a common focal plane

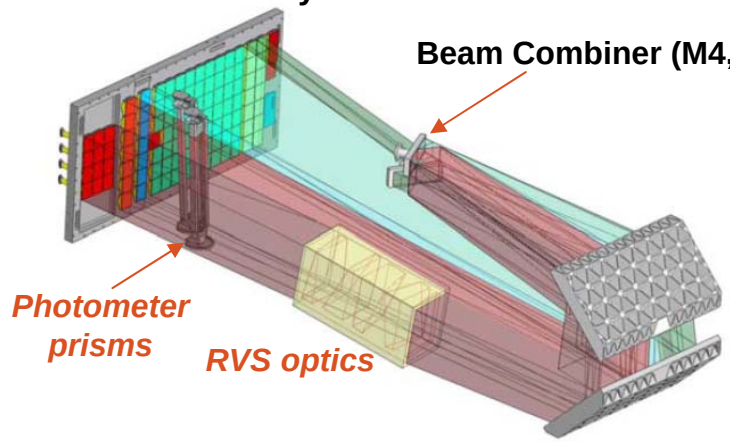


Gaia Payload Module

Radial Velocity Spectrometer & Photometers

share the same focal plane than Astro

3 fields (Astro, Photometers & RVS) in Focal Plane Assembly



Folding optics (M5, M6)

Metrology

✓ **WFS** for initial alignment after launch

✓ **Basic Angle Monitoring** by interferometry through the complete optical path of telescopes

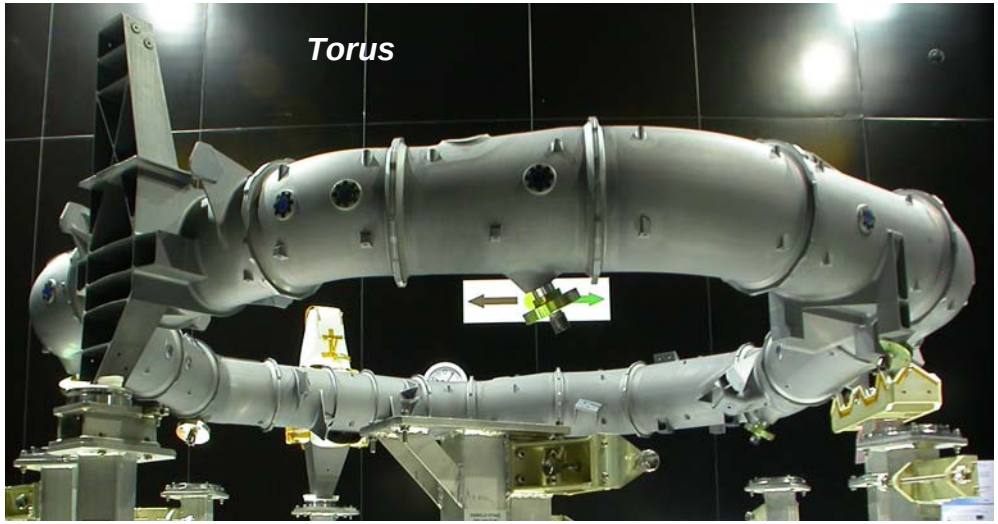
M2 Mechanism: 5 axes refocusing

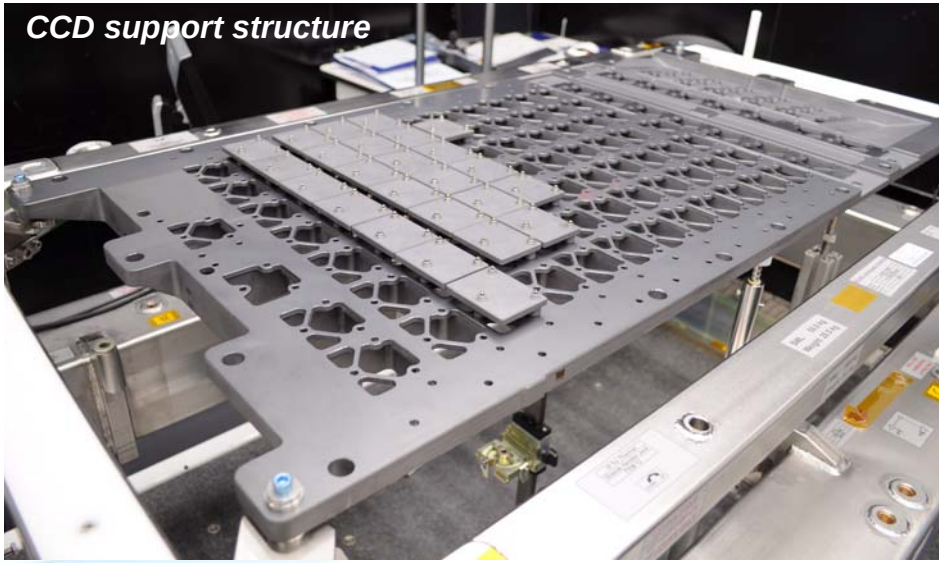
SiC structures

- Optical bench: torus 3m diam., 200 kg
  - Complex 3D geometry
    17 segments machined within ~20 µm
  - Brazing succeeded in July 2009
- Focal Plane Assembly structures
  - 1m light-weighted CCD support structure
  - Cold Radiator for structural, thermal, radiation functions: the biggest monolithic part
  - Bolted interfaces polished to less than 2µm to minimize integration stresses
- Mirror blanks: 17 mirrors
  - SiC CVD performed on the optical surface
  - SiC enables stiff, polishable & lighter mirrors
  - Good stability (high conductivity, low thermal expansion)

  => 1.5 m large M1 mirrors with only 40 kg each

=> Silicon Carbide has made Gaia feasible with the mass constraint of Soyuz launcher





Silicon Carbide mirrors – Technology & status

- Light-weighted blanks (Boostec-Fr)
  - SiC is pressed, machined sintered & ground
- SiC chemical vacuum deposit (Schunk-G)
  - Reduction of the scattering of sintered SiC
  - Some hundreds of µm thick
- Polishing (Amos-B, Sagem-Fr & Zeiss-G)
  - Computer Controlled Polishing & Ion Beam Figuring used wrt the hardness of SiC CVD
  - Final roughness in the nm range
  - WFE in the range of 20 nm rms
- Silver coating (Sagem & Zeiss)
  - Both coatings have been successfully qualified
- 17 mirrors in development
  - 5 mirrors for PLM structural model:
    - 2 M4, M5-a, 2 AC-flat delivered. M5-b ready.
    - M2-a, M3-a in final phase
  - M1-a & b foreseen in Summer


M3 blank

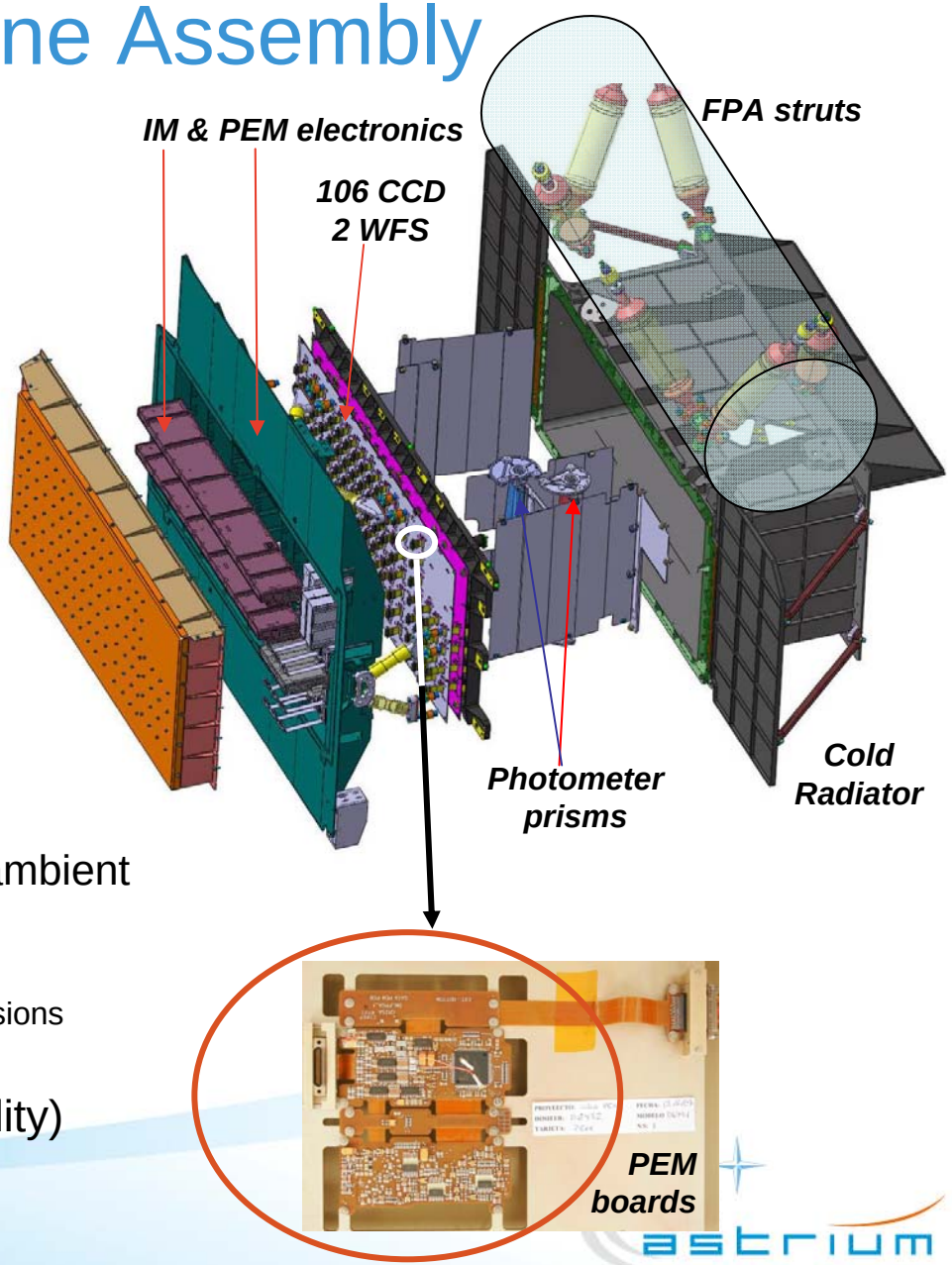

M1 demonstrator

2 Three Mirror Anastigmat telescopes

- *Aperture:1.46 x 0.51 m, focal length:35 m*
- *M1, M2 are 8th order aspherical surfaces*
  M1 off-axis of 0.9 m, light-weighted structure
- *M3 is defined by 2D polynomia*
- *Wave Front Errors of 20 nm*

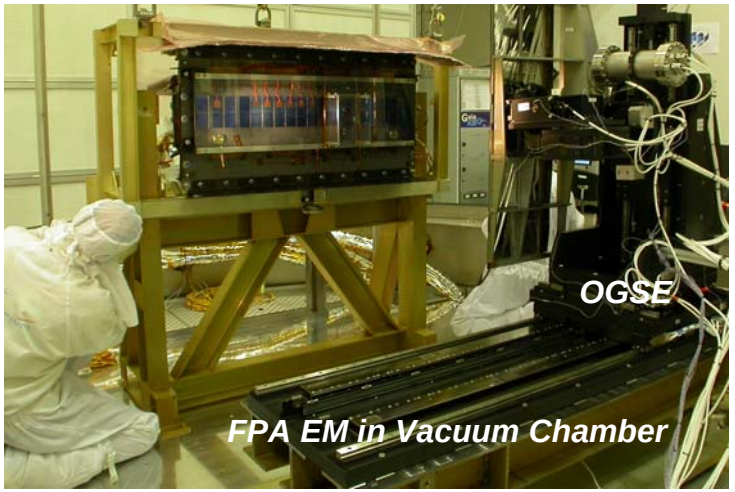
A very large Focal Plane Assembly

- Large & compact assembly
  - 180 kg, 340 W
  - Focal plane lay-out
    - 7 CCD rows of 106 CCD
    - Blue & red Photometer prisms
    - 2 Wave Front Sensors
    - Protection to radiations (Cold Radiator)
  - FPA & PLM proximity electronics
    - 106 Proximity Electronics Modules
    - 7 Interconnexion Modules
    - Refocusing mechanism electronics
    - Optical Sources & Electronics (OSE) for WFS & BAM
- 2 step thermal decoupling
  - CCD at -110°C from electronics at ambient
    - Warm / cold FPA : GFRP bipods
    - 2 thermal shields between CCD & PEM
    - Cold Radiator in PLM cavity + ext. extensions
    - External PEM & IM radiators
  - Optical bench from FPA (for stability)
    - Cold FPA / torus: GFRP FPA struts

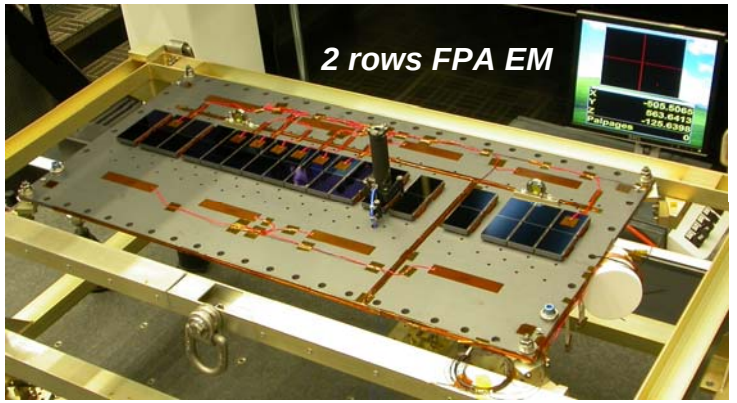


Development status for FPA

- Successful FPA Engineering Model tests Structural Model tests in Sept.2010
- CCD (e2v-UK)
  - Broadband CCD delivered (AF, BAM & WFS): 80
  - Blue enhanced CCD delivered (BP): 7/7
  - Red enhanced CCD in production (RP & RVS): 16/19
- PEM (Crisa-Sp)
  - Qualification passed. FM production: 22 /106
- PEM/CCD coupling (MSSL-UK): 8 couples tested
- IM (TAS-I): Qualification delayed. On-going production
- WFS (TNO-NL): the 2 FM are delivered
- Blue & Red Photometers (Selex Galileo-I)
  - On-going Structural Model program. FM production started. BP prism produced
- M2M Drive Electronics (Sener-Sp): on-going qualification
- Optical Sources & Electronics (Kongsberg-N) for BAM & WFS: FM delivered

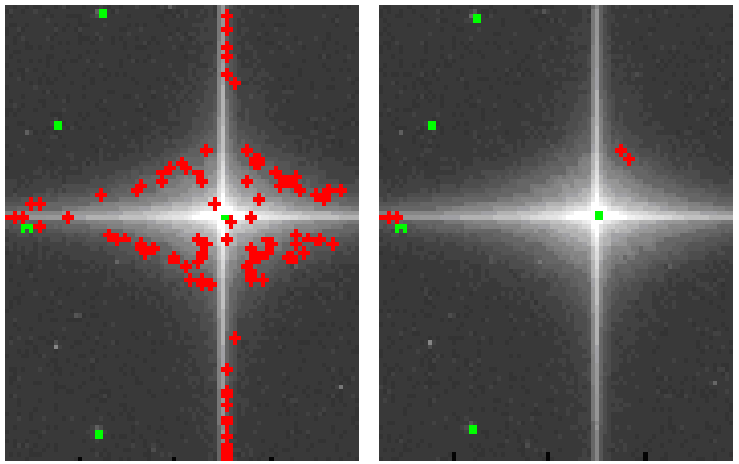


FPA EM in Vacuum Chamber



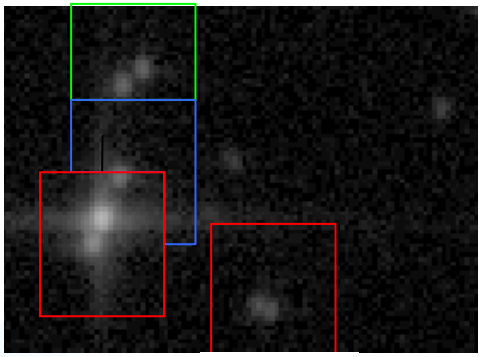
Real time video processing - VPU

- 7 VPU process the samples of each CCD row
  - HW-SW design: companion & processor boards
  - 630 MHz processor
- Complex sampling strategy
  - Monitors the CCD binning & modes (HR/LR)
  - Selects the gate, sampling & window per field, … monitors conflicts & priorities
  - Manages up to 3.10^6 stars/deg² in Astro
- Video Algorithms validation
  - Validation performed wrt science requirements
- VPU development
  - CDR successfully passed
  - SW Qualification Review successful
  - Successful test on EQM, but
    - Failure on processor board
    - Design locally changed
    - Mechanical qualification to be repeated
    - Life test performed
  - PFM/FM production authorized



Bright star detection…with rejection of ripples

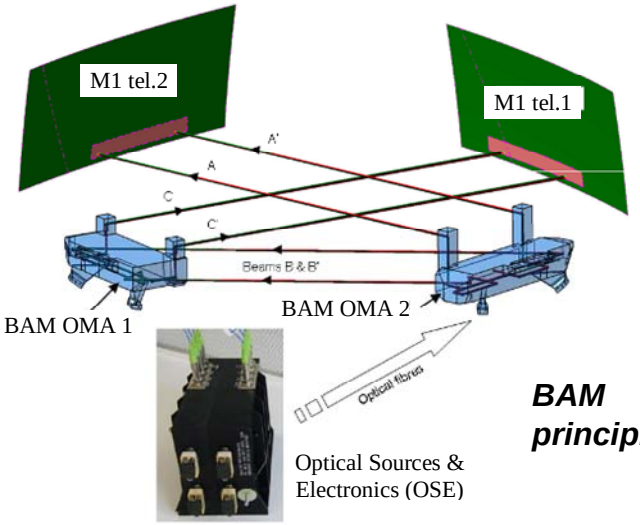
VPU EQM



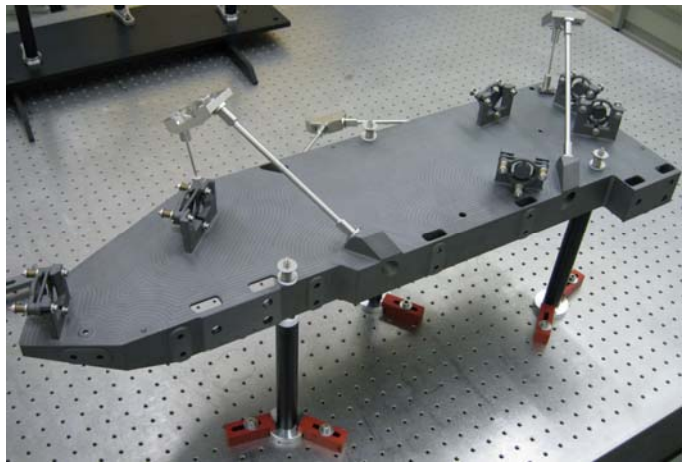
Allocation of windows with overlap in AF

Basic Angle Monitoring

- Interferometry principle
  - OSE unit generates a laser signal at 852 nm
  - BAM OMA derive 2 beams toward each telescope
  - Detection of fringes on BAM CCD
- Monitoring of BA within 0.5 µarcsec / 5 min
  - Detection accuracy of ~10^{-5} pixel per 5 min
  - OPD of 1.3 picometer
- Full silicon carbide assemblies
  - Monolithic bars & mirror brackets
  - Decoupling from PLM torus
- Stable optics assemblies (TNO-NL)
  - 22 mirrors, 3 beam splitters,
  - Collimator with optical fibber & off-axis SiC mirror
- BAM OMA development
  - All optical components have been breadboarded Stability of mirrors not tested yet in shock (1µrad)
  - Structural Model (bar #1) is now completed, ready for vibration tests, then reused for flight
  - Flight bars: integration starts now, leading to a full performance and environmental qualification



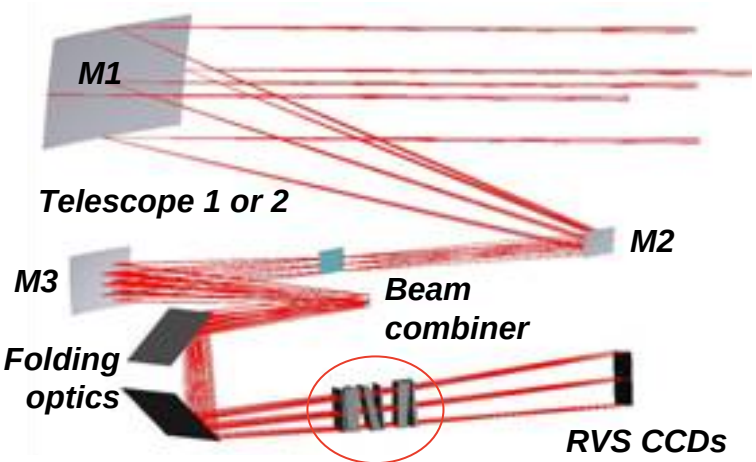
BAM principle

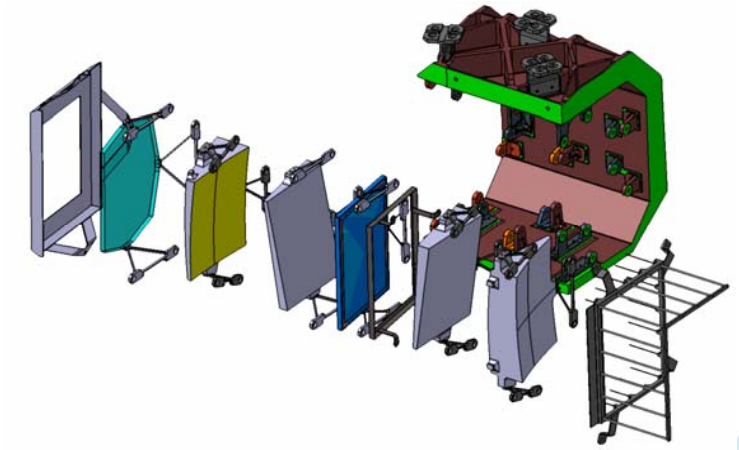


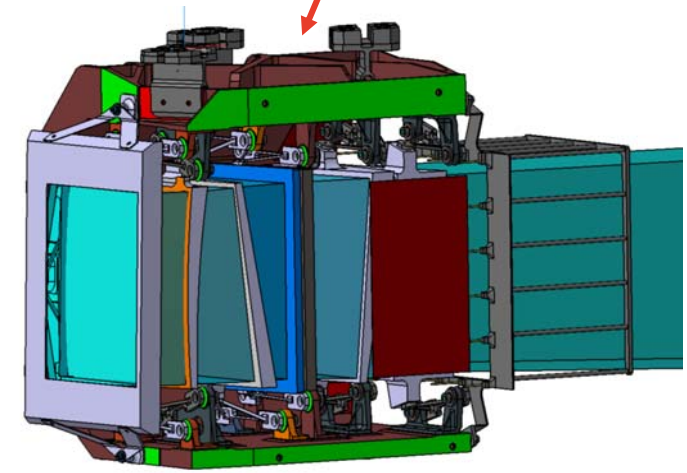
BAM bar with iso-static mounts

Radial Velocity Spectrometer – Design

- RVS principle
  - Correction of telescopes aberrations: λ/13
  - Narrow band pass filter [847 - 874 nm]
  - Spectra are imaged on 12 red CCD of FPA
    HR (bright stars): 1260 pixels ; LR : 3 AL pixel binning
- Acquisition up to mag 17 *(K1IIIMP)*
- Radial Velocity:1 km/s for star of mag 13 *(G2V)*
- Mean spectral resolving power > 10 500





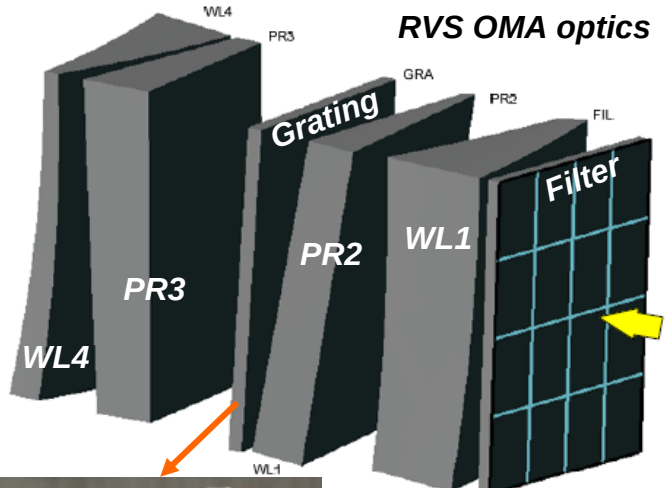


RVS Opto-Mechanical Assembly

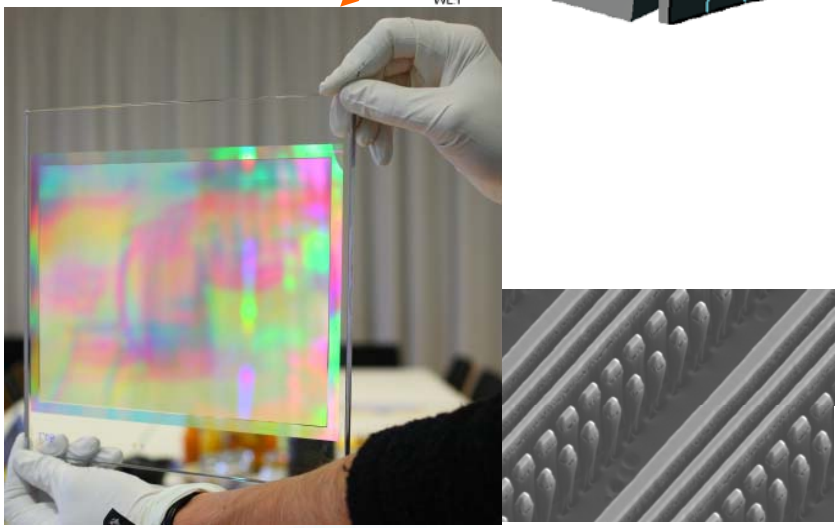
RVS Opto-Mechanical Assembly

- Silica optics for 130K environment (Galileo-I)
  - 6 optical elements mounted with invar bipods
  - 2 wedged lenses (Fery prisms) & 2 prisms
  - Narrow band filter with stringent uniformity
  - Innovative large size binary effective medium grating 3.15 µm periodic substructure of 1.8 µm depth

    Transmission > 77%
- Stable C-shape SiC structure
  - Accessibility for optics integration
- Mass of 27 kg, 400 x 423 x 225 mm3



RVS OMA optics

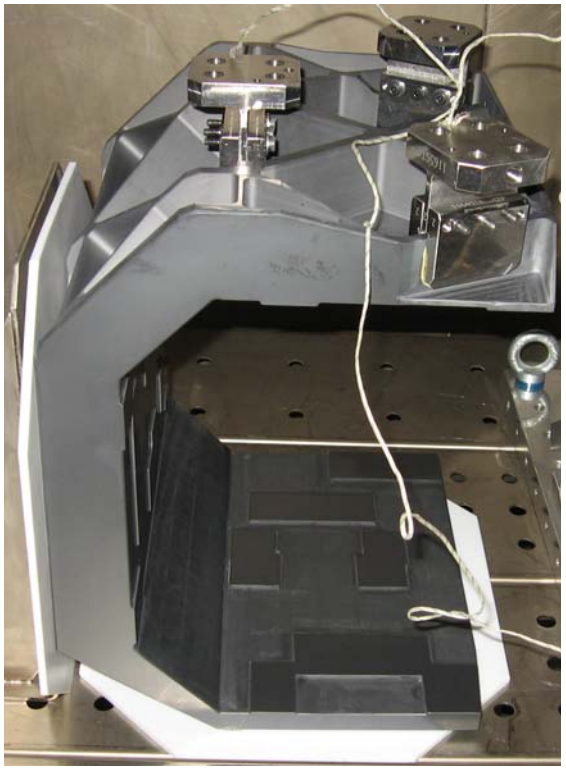


RVS grating demonstrator

RVS OMA – Development

- RVS OMA development (Astrium)
  - Design has been validated in 2009 (CDR)
  - Integration started for delivery by beg. 2011
- Prisms (Selex Galileo-I)
  - Full size breadboarding
  - 3 flight prisms are polished

RVS wedge lens breadboard



RVS SiC structure

- Grating (IOF-G)
  - Demonstrator was successful
  - FM grating has been manufactured, on-going qualification
- Filter (Barr-US): starts after Red Photometer
- SiC structure (Boostec-Fr)
  - Manufactured, proof tested & delivered