Gaia Mission Summary

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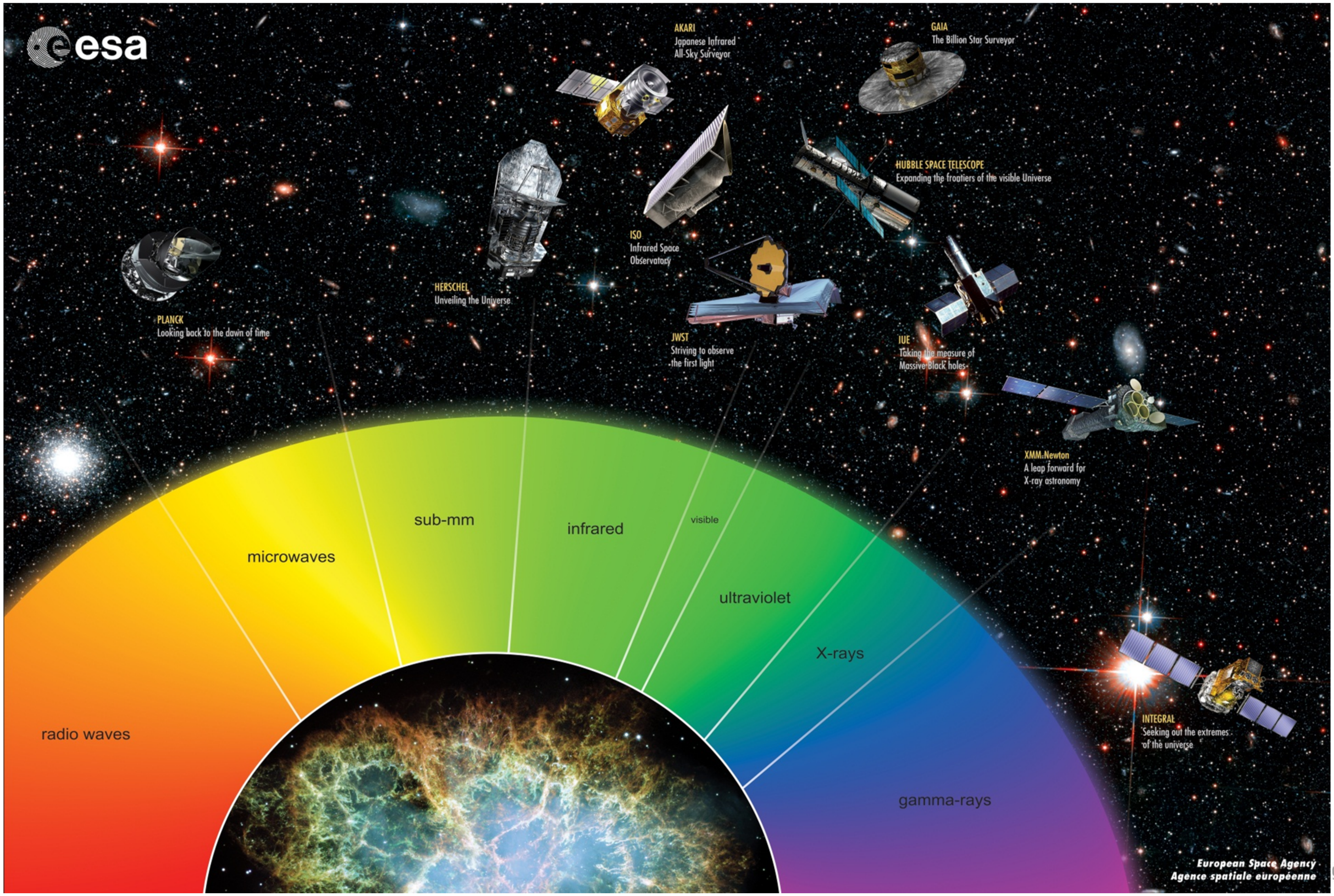
May 2013

Gaia is a cornerstone of the ESA science programme



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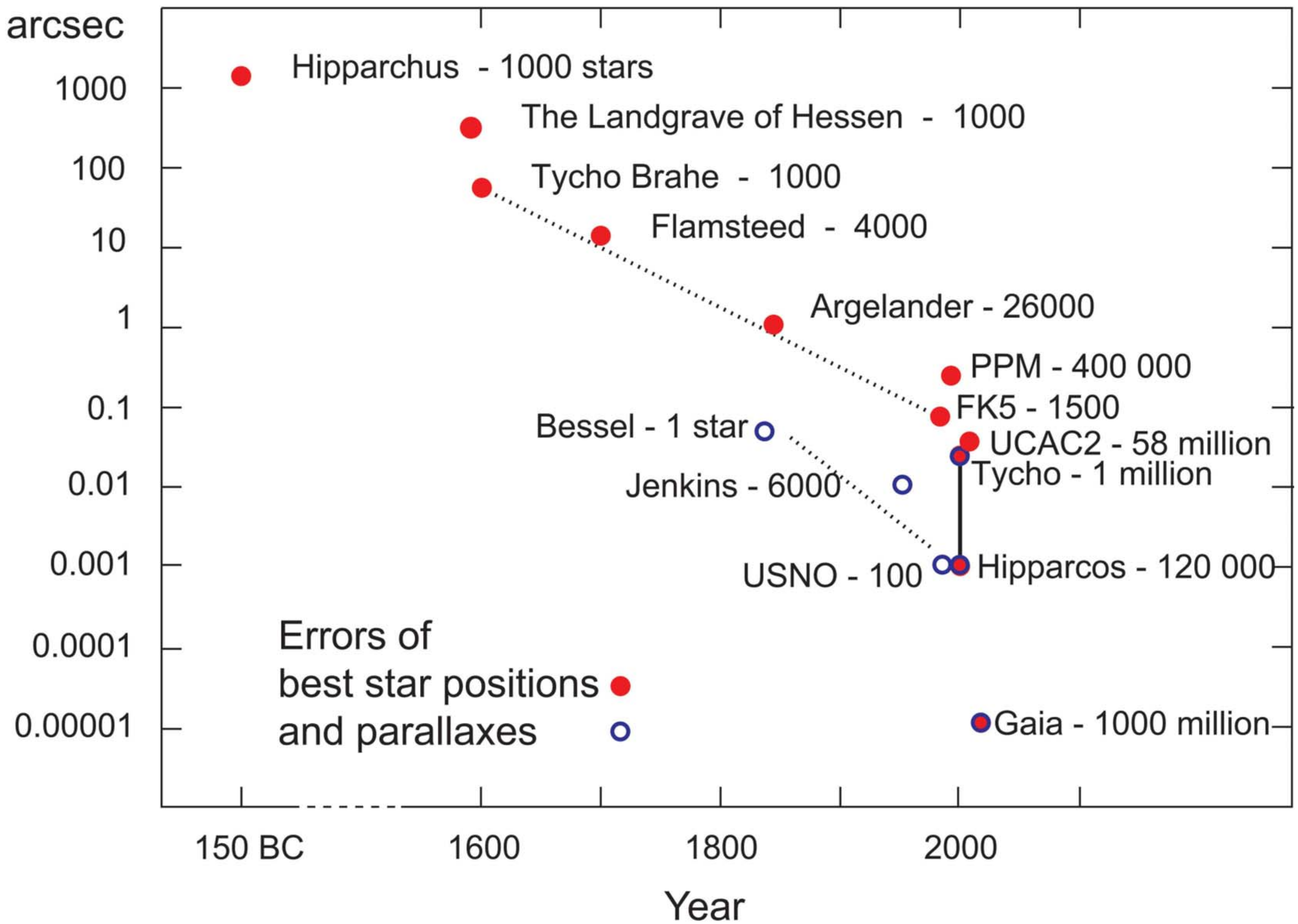
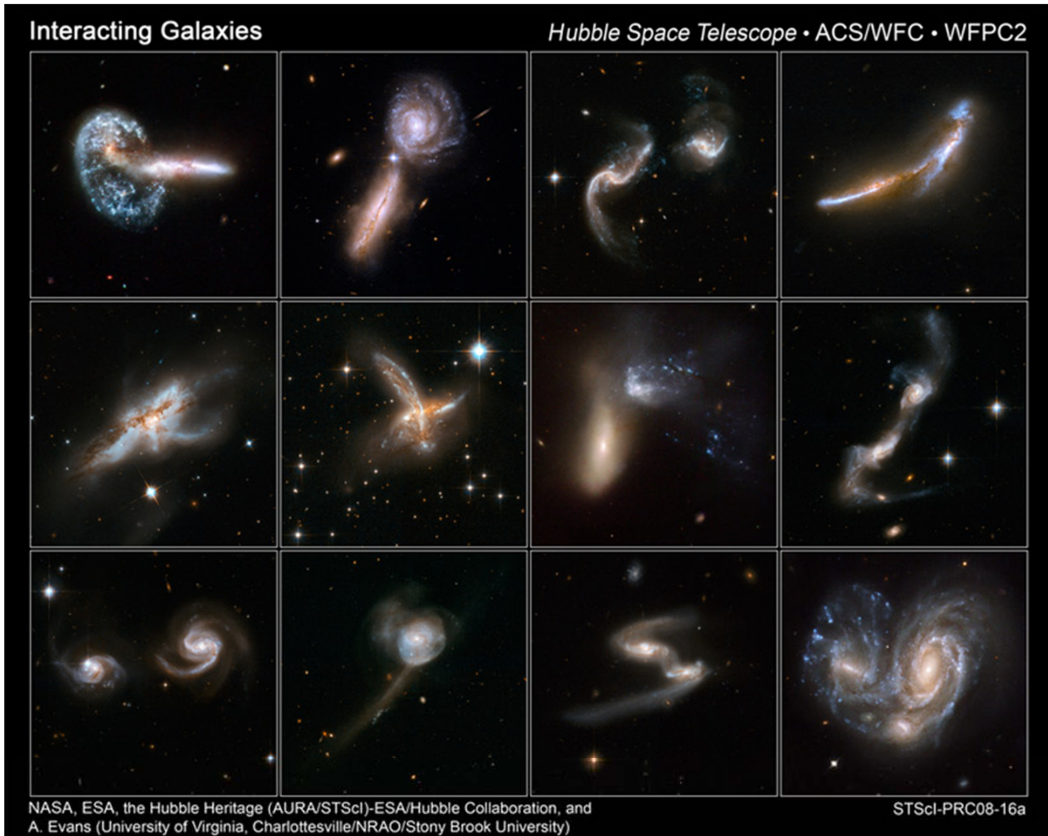
Evolution of astrometric accuracy

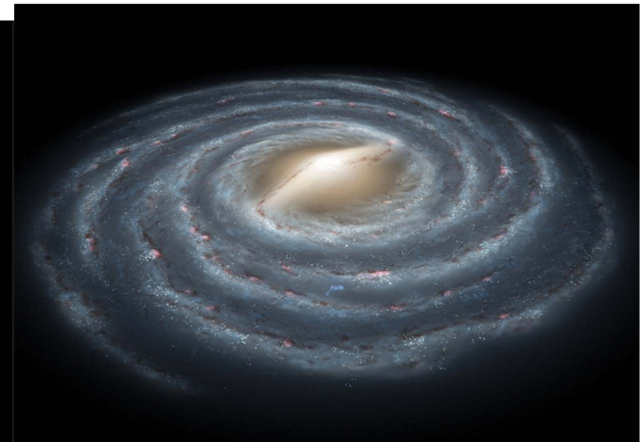


Gaia mission objectives

- To create the largest and most precise 3D chart of our Galaxy by providing positional and velocity measurements for about one billion stars

  - Astrometry and Photometry for at least one billion stars (1% of the stars in the Milky Way)
  - Spectroscopy for about 150 million stars
  - One billion objects observed on the average 70 times over 5 years mission is 40 million stars a day (400 million measurements a day)
  - Order of magnitudes improvement w.r.t. Hipparcos

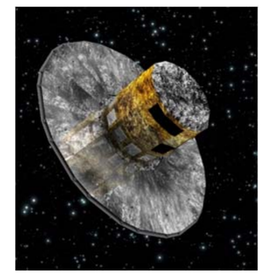

Interacting Galaxies
Hubble Space Telescope • ACS/WFC • WFPC2
NASA, ESA, the Hubble Heritage (AURA/STScI)-ESA/Hubble Collaboration, and
A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)
STScI-PRC08-16a




Sa
Sb
Sc
E7
S0
SBa
SBb
SBc

From Hipparcos to Gaia

	Hipparcos	GAIA
Magnitude limit	12	20 mag
Completeness	7.3 – 9.0	~20 mag
Bright limit	~0	~3-7 mag
Number of objects	120 000	26 million to V = 15 250 million to V = 18 1000 million to V = 20
Effective distance limit	1 kpc	1 Mpc
Quasars	None	$\sim 5 \times 10^5$
Galaxies	None	10^6 - 10^7
Accuracy	~1 milliarcsec	7 μarcsec at V = 10 12-25 μarcsec at V = 15 200-300 μarcsec at V = 20
Broad band	2-colour (B and V)	5-colour to V = 20
Medium band	None	11-colour to V = 20
Radial velocity	None	1-10 km/s to V = 16-17
Observing programme	Pre-selected	Complete and unbiased



Gaia science performances

	Band	EOM Performance [mmag]	Specification
B1V - V=15	C1M410	5	< 10
	C1M549	5	< 8
	C1M965	8	< 20
G2V - V=15	C1M410	6	< 10
	C1M549	5	< 8
	C1M965	6	< 10
M6V - V=15	C1M410	16	< 20
	C1M549	5	< 8
	C1M965	4	< 10

End of mission photometry performances

	V mag	EOM Performance [µas]	Specification
B1V	< 10.0	8.3	< 7
	15.0	26.2	< 25
	20.0	326.3	< 300
G2V	< 10.0	8.5	< 7
	15.0	24.2	< 24
	20.0	290.2	< 300
M6V	< 10.0	10.4	< 7
	15.0	9.2	< 12
	20.0	96.6	< 100

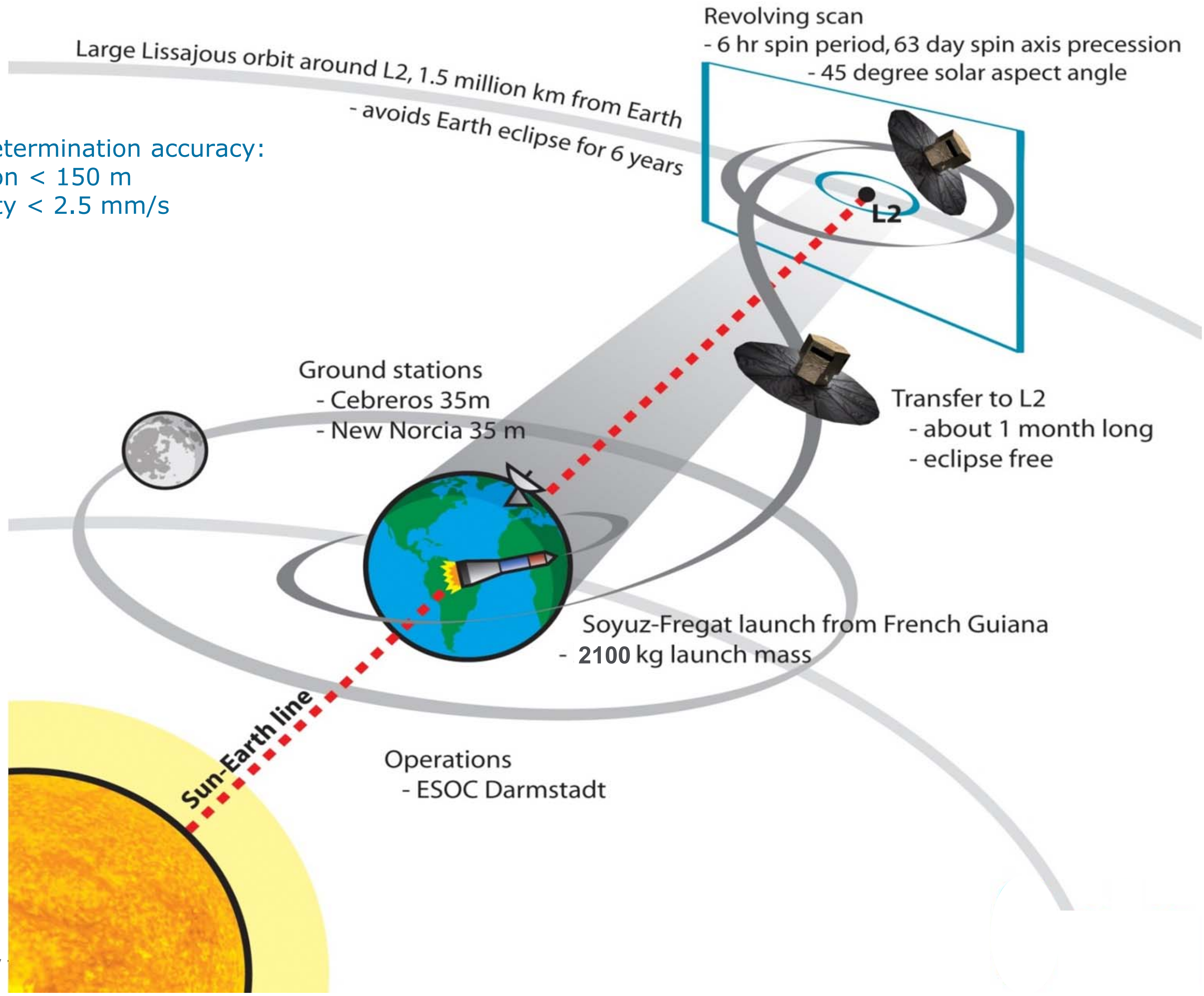
End of mission astrometry performances

	V mag	EOM Performance [km/sec]	Specification
B1V	7.0	0.6	< 1
	12.0	8.5	< 15
G2V	13.0	0.6	< 1
	16.5	12.8	< 15
K1IIIMP	13.5	0.6	< 1
	17.0	13.3	< 15

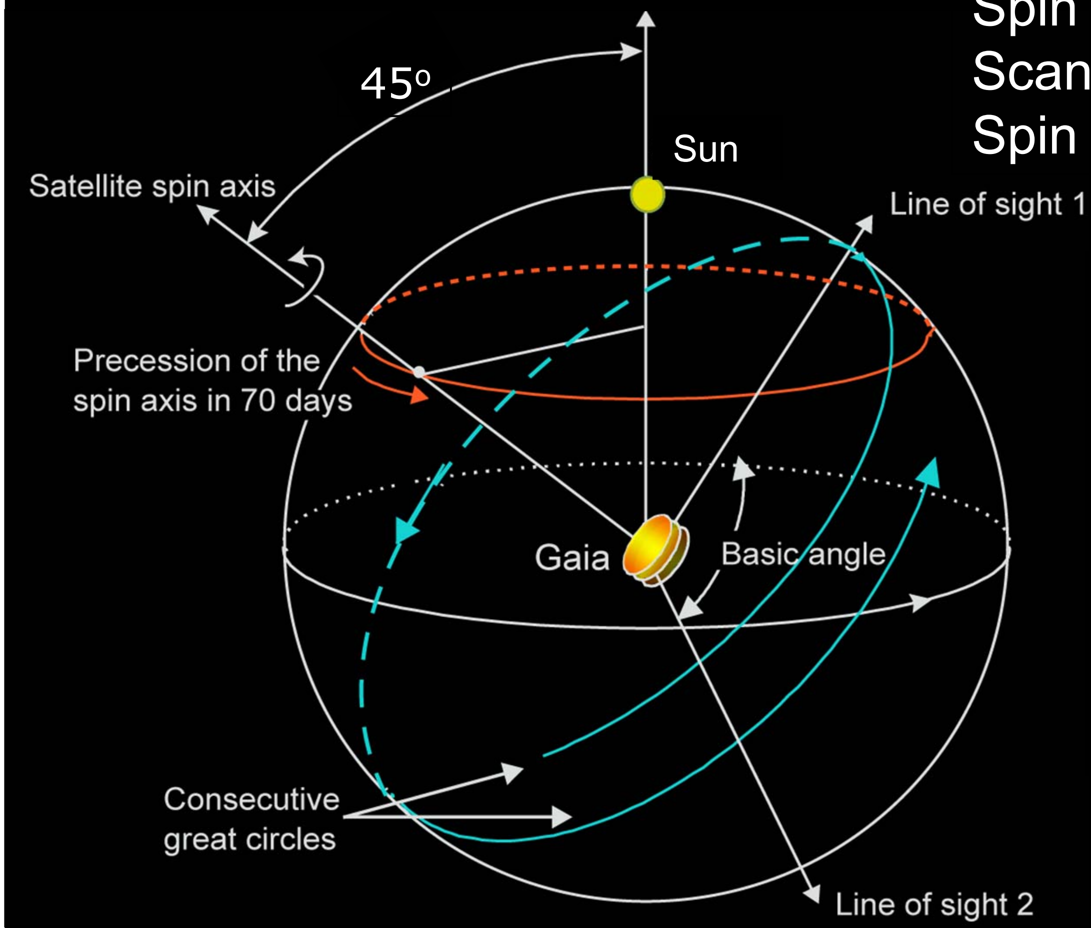
End of mission radial velocity spectrometry performances

Launch and operations

Orbit determination accuracy:
- position < 150 m
- velocity < 2.5 mm/s



Sky-Scanning Principle

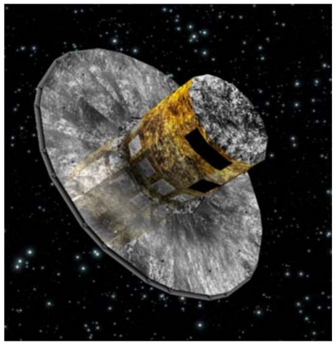


Spin axis	45° to Sun
Scan rate:	60 arcsec s^{-1}
Spin period:	6 hours

This revolving scanning:

- ❑ keeps the viewing directions at a constant angle to the sun (thermal)
- ❑ provides a fairly uniform coverage of the sky
- ❑ allows the details of the star motion to be identified

Elements of the Gaia program



Satellite

Launcher

Cebreros

New Norcia

Mission Operation Centre (MOC)

ESOC

Science Operation Centre (SOC)

ESAC

Data Processing & Analysis Centre

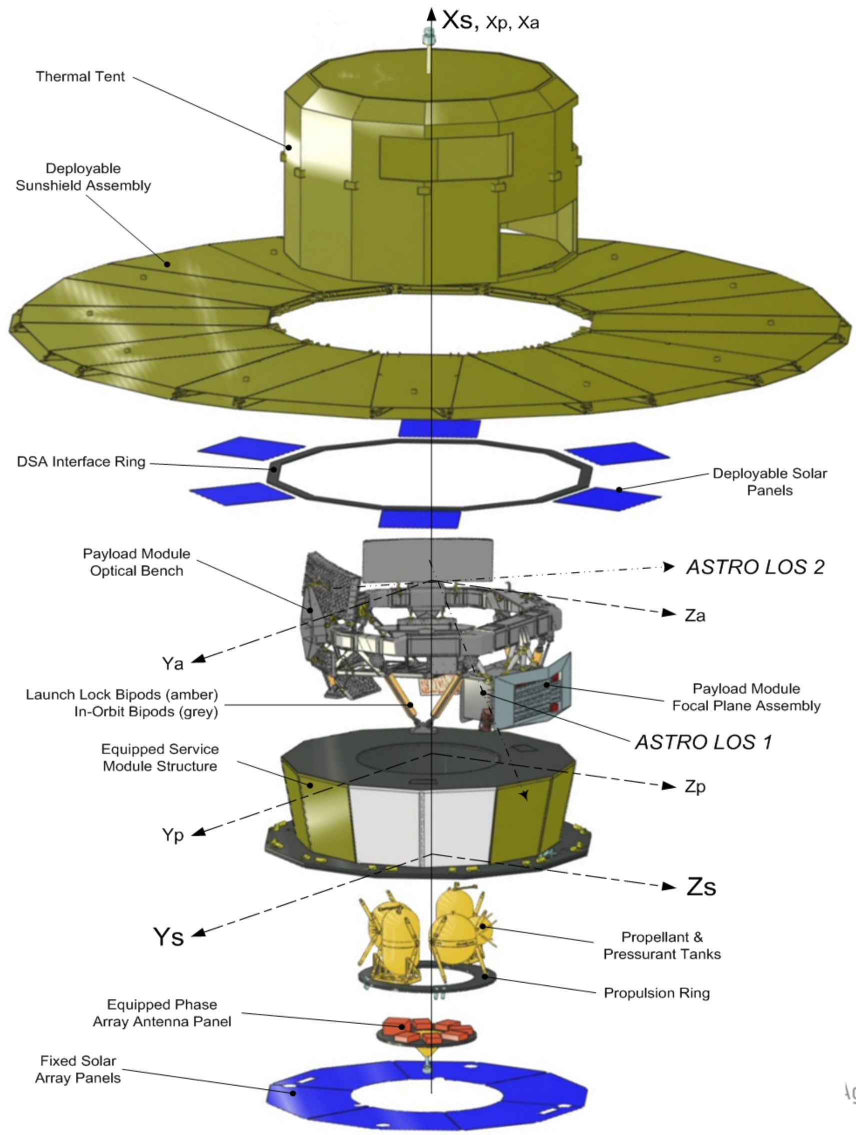
DPAC

Short program history

- Gaia SPC approval, Oct 2000
- Dec 2002, start of definition
- Definition Phase A/B1
- July 1st 2005, ITT to industry
- March 1st 2006, kick-off Phase B2/C/D
- Phase B2
- July 7th 2006, SRR
- June 29th 2007, PDR
- Phase C/D
- Oct 15th 2010, CDR
- Apr 13th 2011, Mission CDR
- July 2013, FAR
- Sept 19th , 2013, Launch
- Commissioning
- Jan 2014, IOC
- Nominal operations (5 y)
- Extended operations (1 y)
- Jan 2020, End of Mission

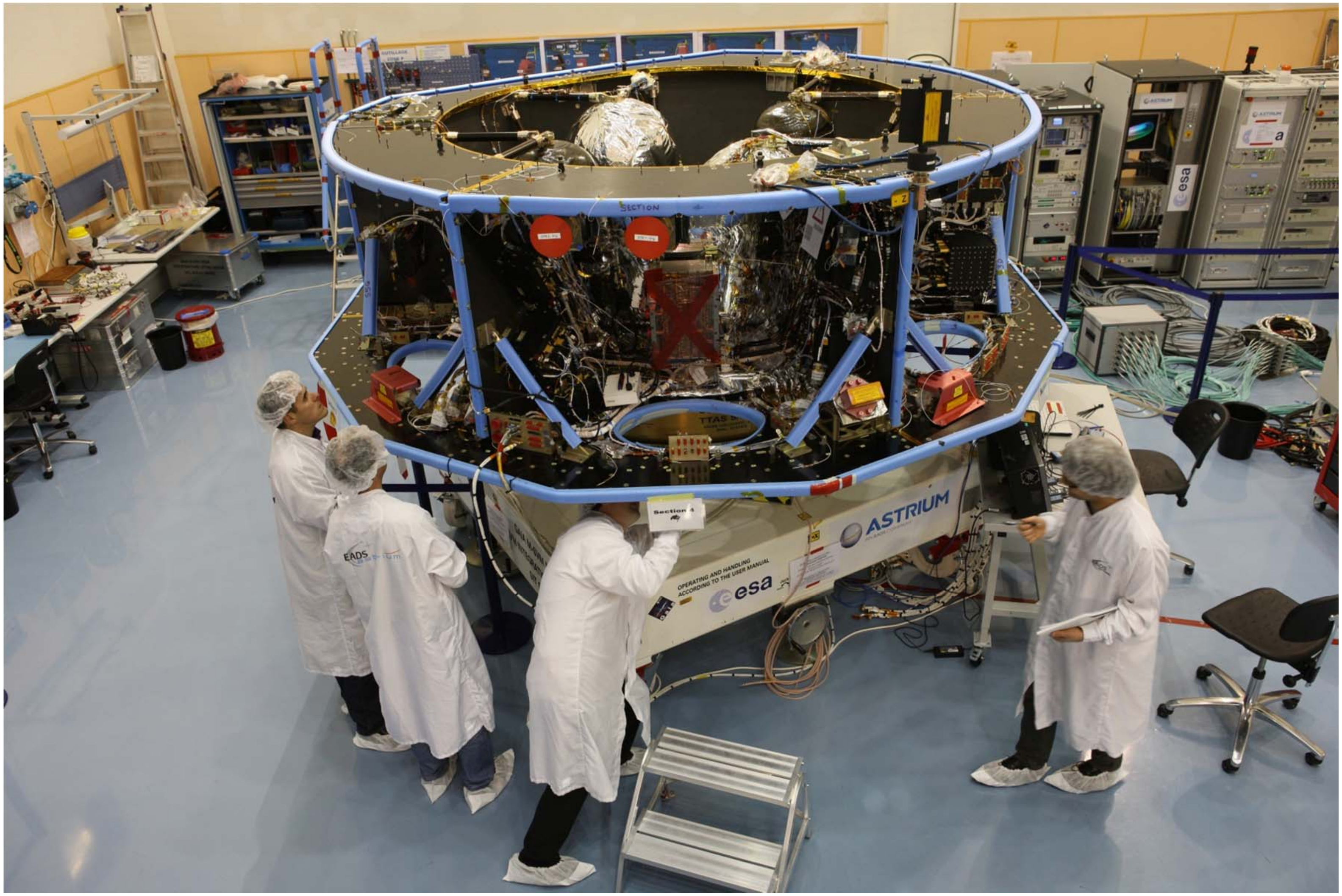
Overview of the spacecraft

- Mass
  - S/C wet launch mass 2030 kg
  - Bi-propellant fuel 335 kg
  - Cold gas fuel 60 kg
- Power
  - 1.9 kW
- Data management
  - Data rate up to 7.5 Mbps
  - Data storage 1 Terabit
  - Atomic clock 1 s drift in 250000 y
- Optical payload
  - Two telescopes
  - Entrance pupil 1.45 x 0.5 m^2
  - Focal length 35 m
  - Field of View 1.58 x 0.69 deg
  - Focal plane size 1 Gpixels

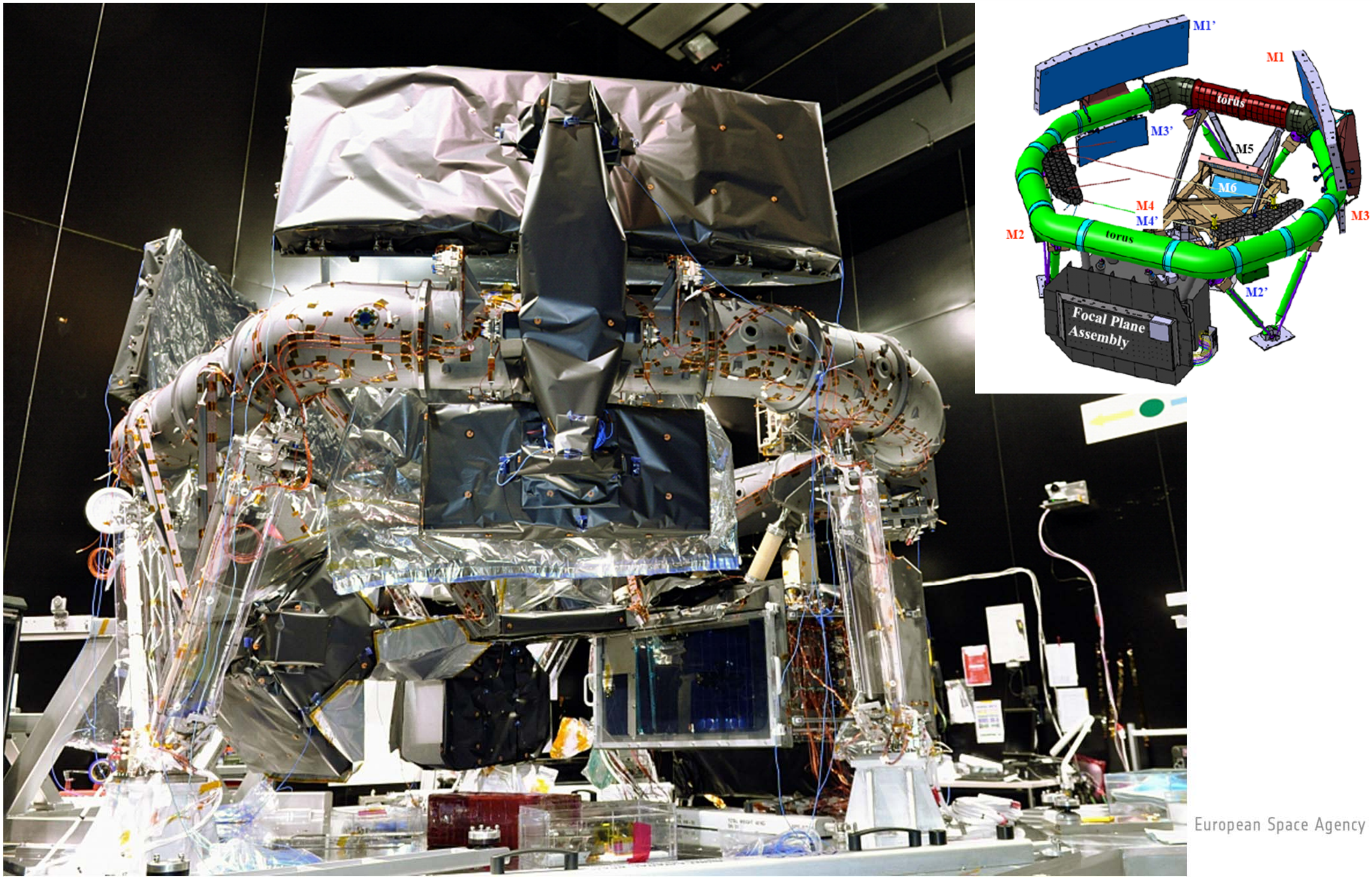


Gaia Spacecraft

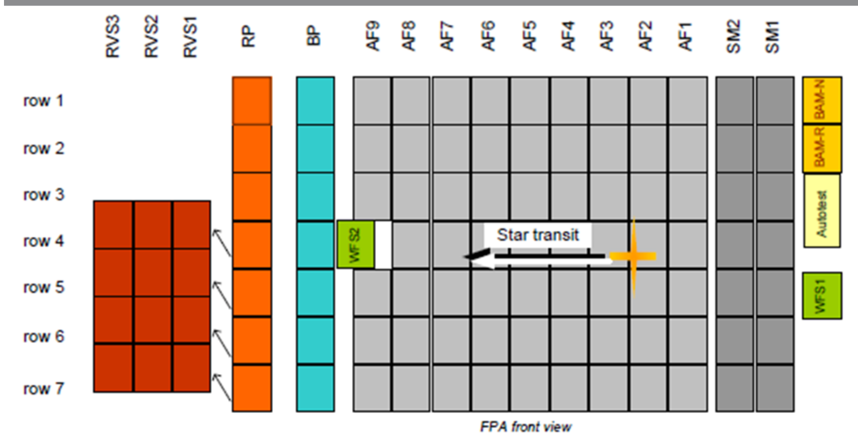
Gaia Service Module (SVM)

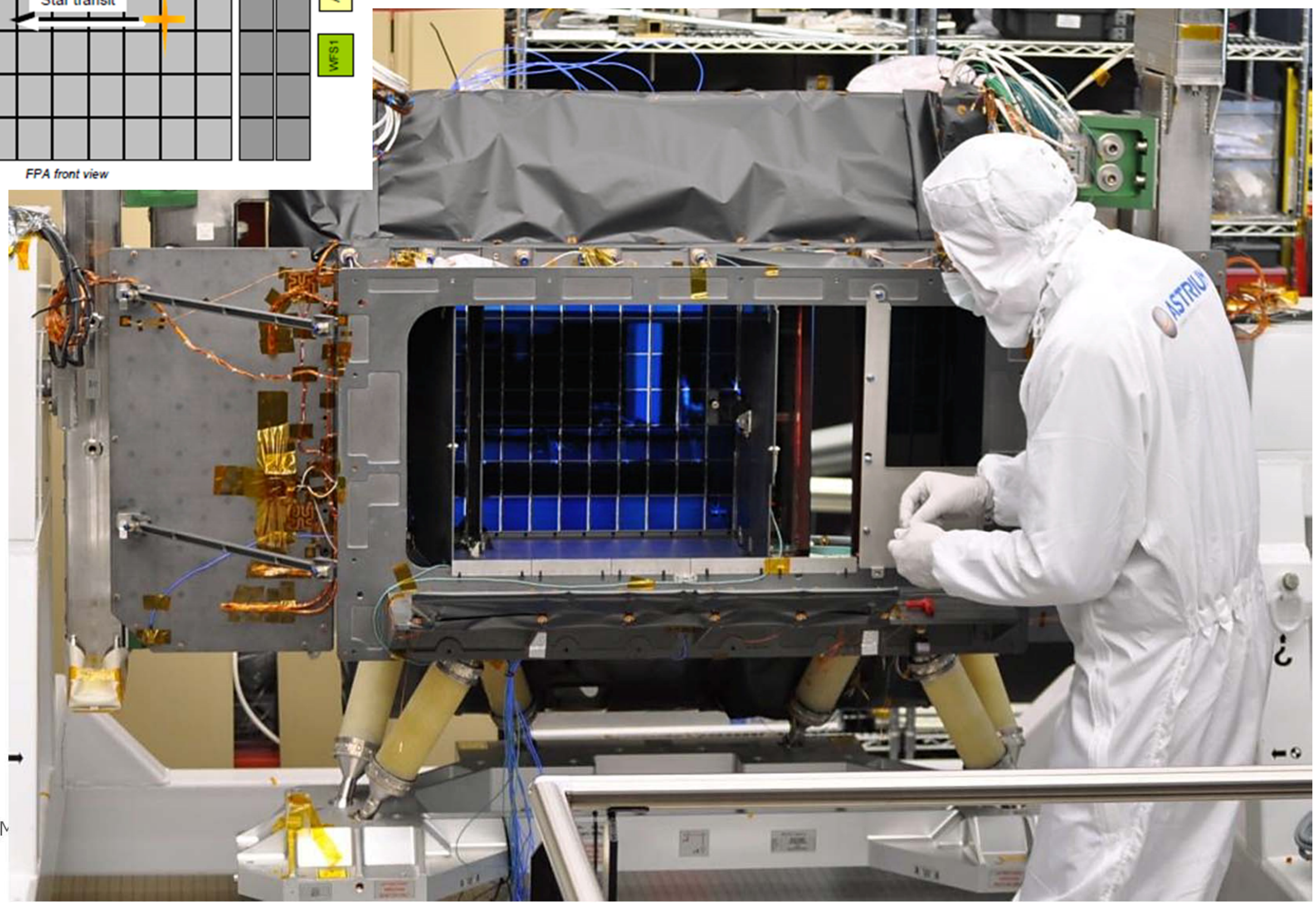


Gaia Payload Module (PLM)



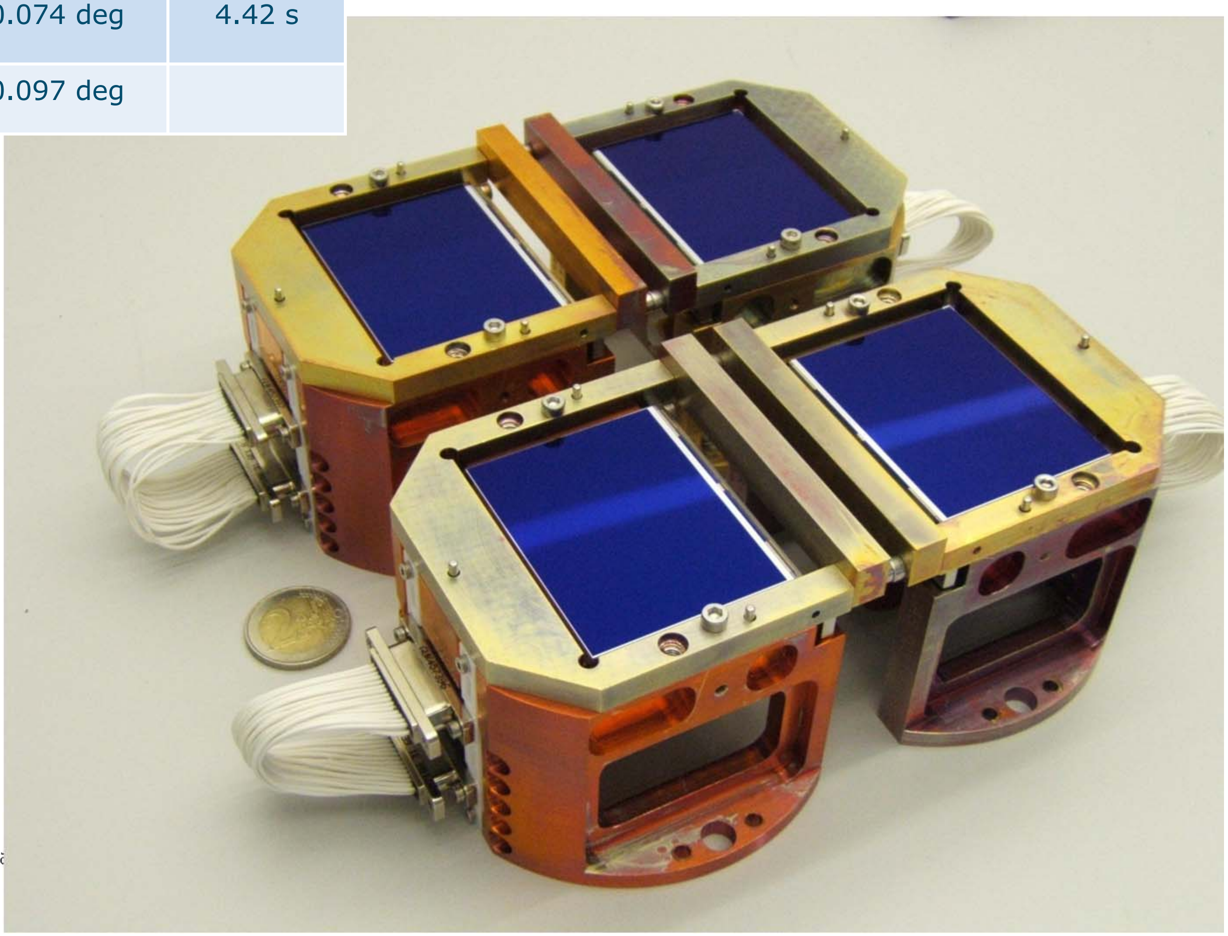
Focal Plane Assembly (FPA)



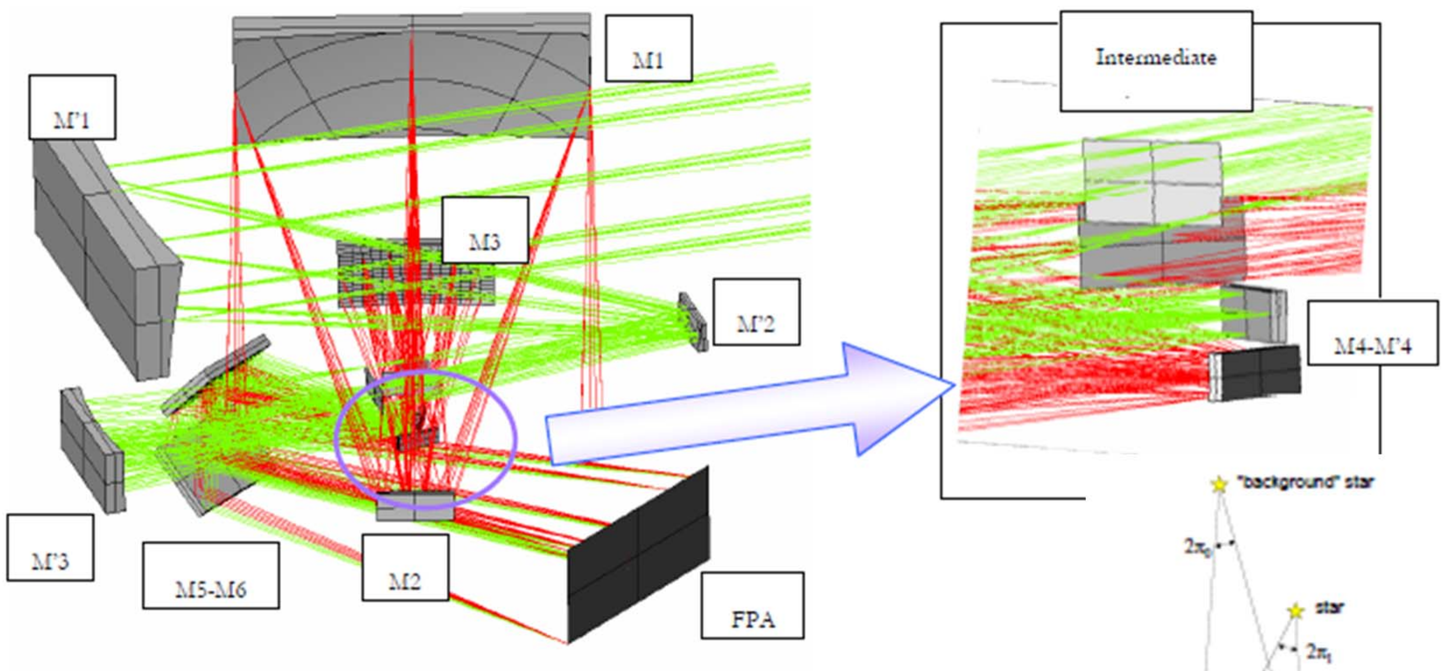


The core of the detection: CCD

CCD dimensions				
CCD pixel	1 pixel AL	10 μm	0.059 arcsec	0.982 ms
	1 pixel AC	30 μm	0.177 arcsec	
CCD matrix	4500 pixels AL	45 mm	0.074 deg	4.42 s
	1966 pixels AC	59 mm	0.097 deg	



Two viewing directions



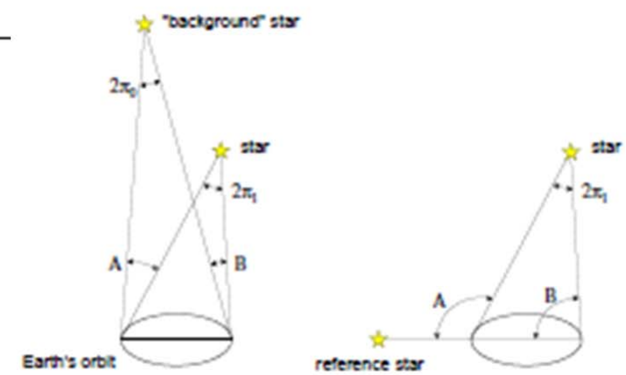
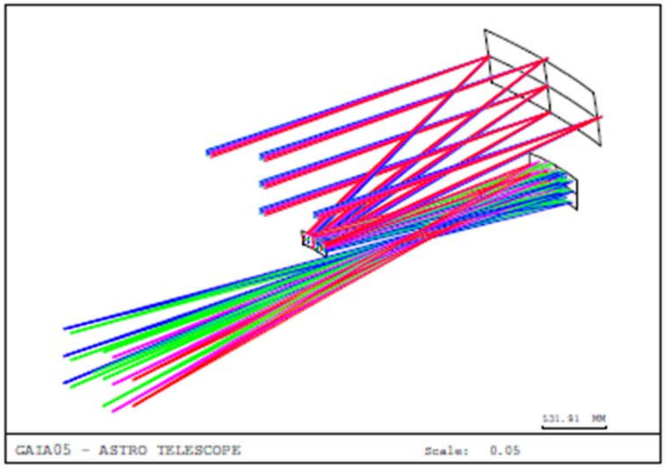
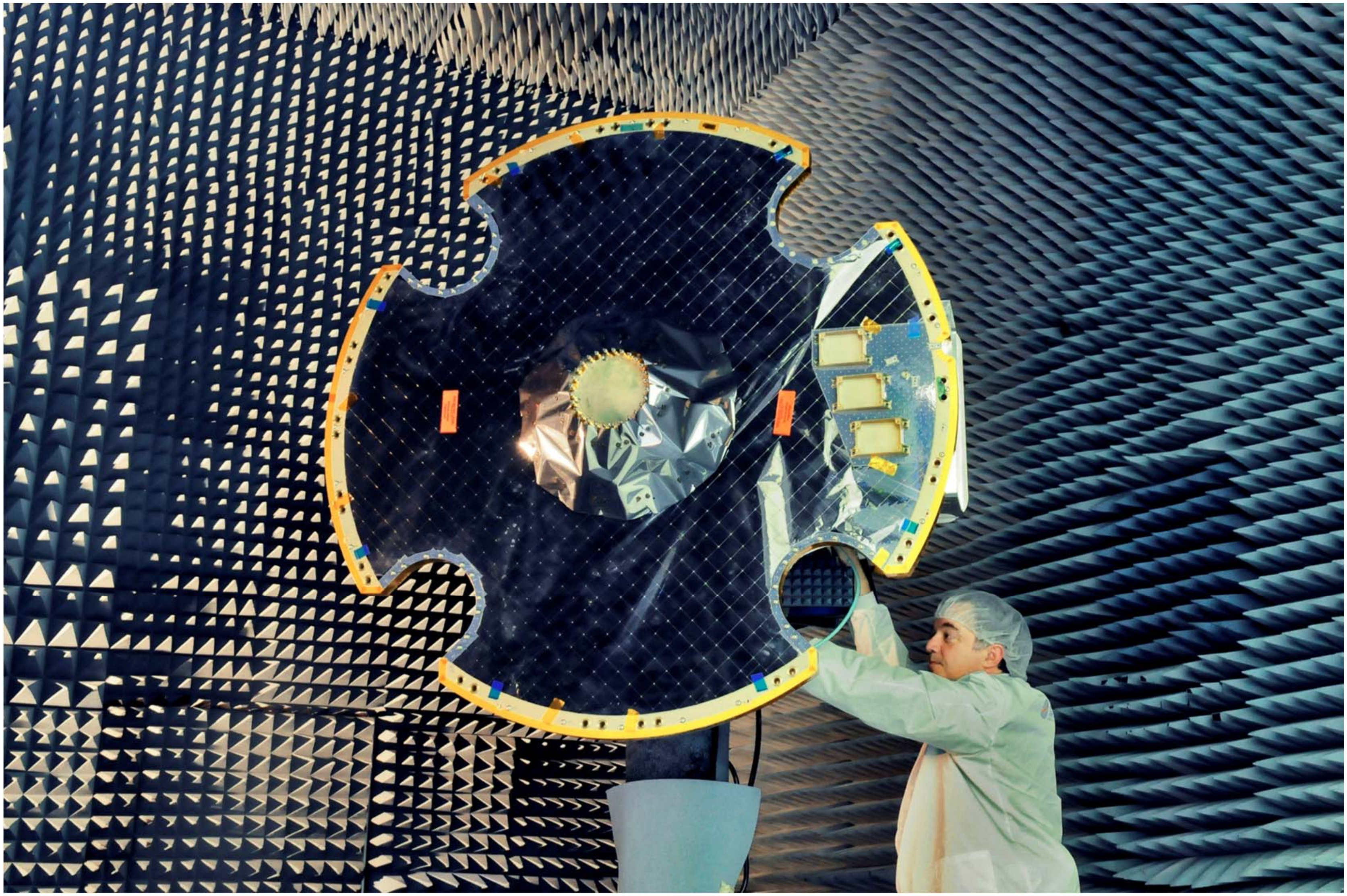


Figure 4. Illustrating the principle of absolute parallax measurement: in the left diagram, the measurement of the (small) angles A, B only allows to determine the relative parallax $\pi_1 - \pi_0 = (A - B)/2$. By contrast, measuring the large angles in the right diagram allows to obtain the absolute parallax $\pi_1 = (A - B)/2$ independent of the distance to the reference star.

Telescopes and mirrors



Phased Array Antenna (PAA)



Agency

Gaia Deployable Sun Shield (DSA)

Soyuz Launcher and Launch site

- Gaia will be carried into space by a Soyuz-STB launch vehicle with a Fregat MT upper stage

- Launch site is the CSG in French Guiana

Data Processing / Reduction

If we had simply dumped all the CCD data to ground (every pixel) we would end up with ~ 73000 TB after 5.5 years mission!

The immense volume of data created by Gaia:

(50GB/Day = 100 TB (65 TB Astro + Photometer, 35 TB RVS)

and their complex relationships make the data processing requirements amongst the most challenging even by the standards of computational power in the next decade.

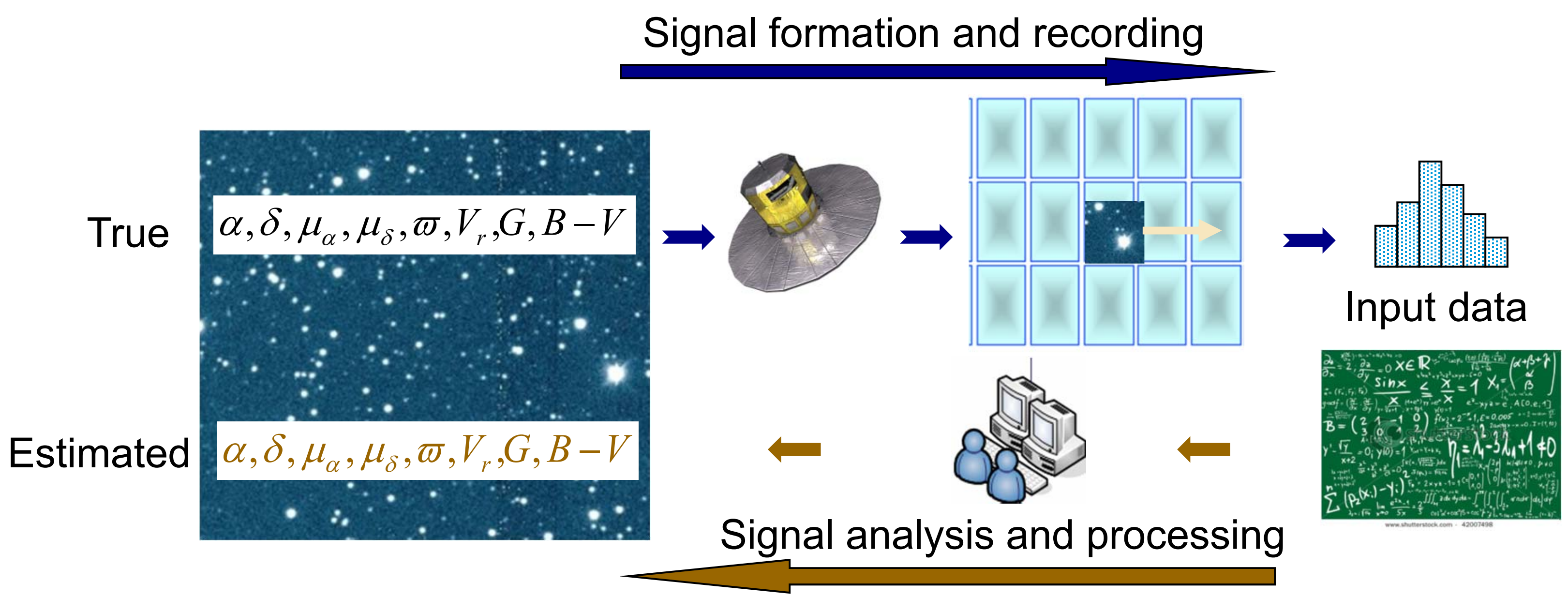
The required numerical processing (core processing) is of the order of 10^{21} floating-point operations.

To meet this challenge, the Gaia Data Processing and Analysis Consortium (DPAC) organises nearly 450 scientists and software engineers in nine Coordination Units (CU), 25 countries, currently designing and implementing a software system (distributed over several processing centres) for analysing the data when it starts arriving in 2013, and simulating telemetry data before launch.

A huge ground data processing effort

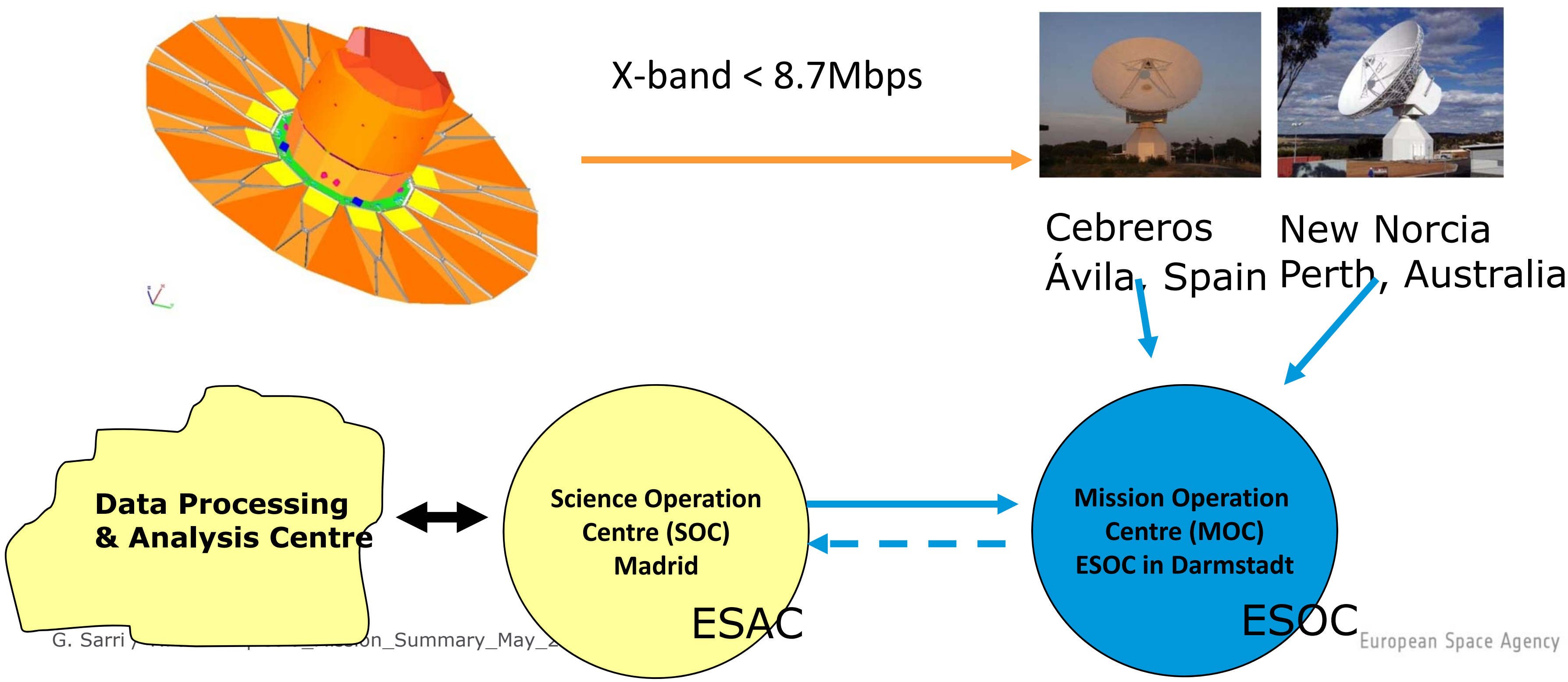
- Data volume
  - compressed telemetry: 250 Tbit
  - raw data: 100 TByte
  - processed data and archives: 0.5-1 PByte

- Computational size
  - 1.5 x 10^{21} FLOP
  - 10 TFLOP/s --> 2 years CPU

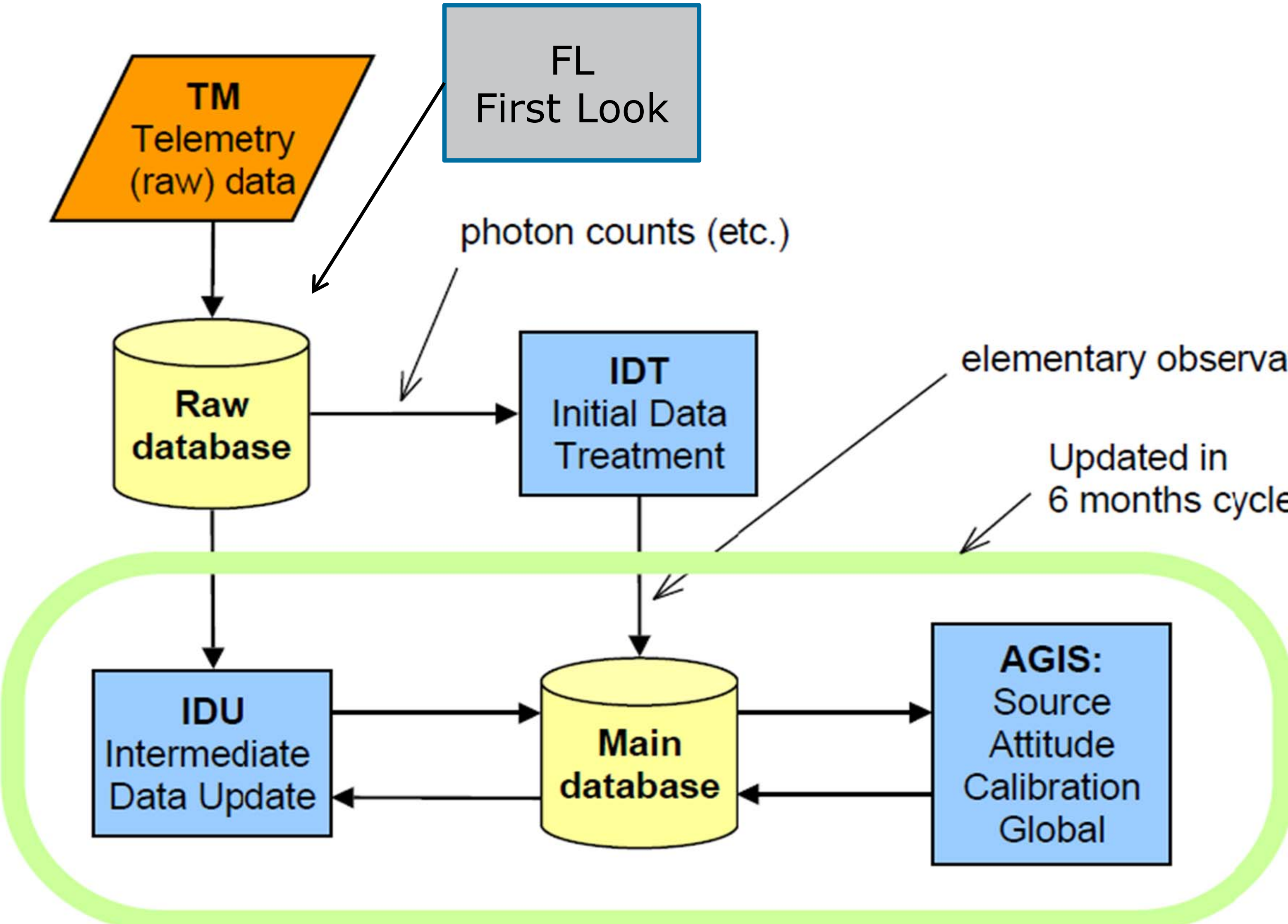


Gaia Mission Components

- Space segment : The satellite
- Operation ground segment: ground stations and Mission Operation Centre (MOC)
- Science ground segment: Science Operation Centre (SOC) and Data Processing (DPAC)

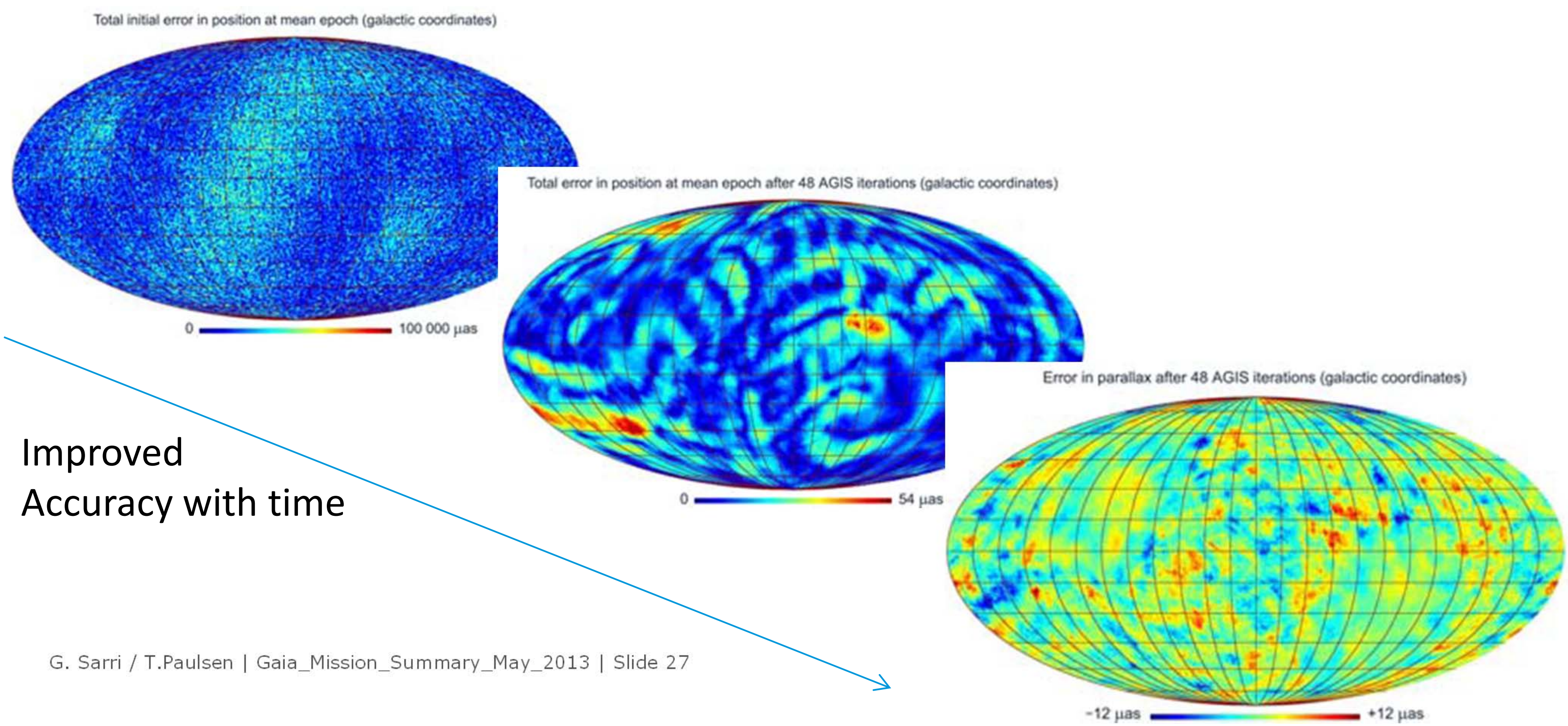


Data Processing Task

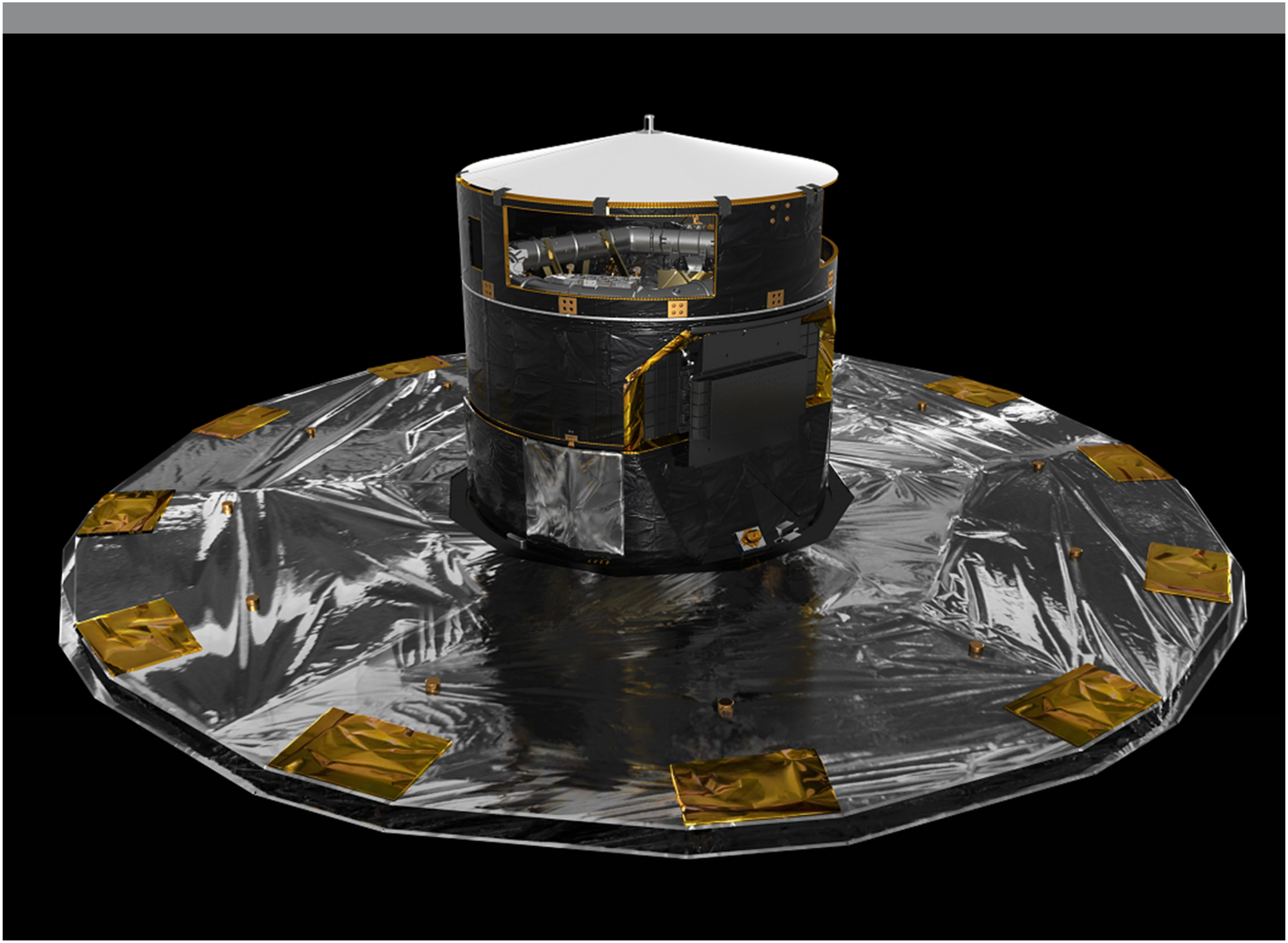


AGIS Iterations

The sky charts show results from recent AGIS runs using simulated data for 10^6 stars.
Initial errors of up to 0.1 arcsec (left) were brought down to the 10 µas level after 48 AGIS iterations (centre and right).
The remaining error patterns show eigenvectors of the iteration matrix and will largely disappear with further iterations. This property can be used to improve the convergence rate of AGIS.



Improved
Accuracy with time



Final Products

- Determining the positions, distances, and annual proper motions of >1 billion stars with an accuracy of about 20 µas (microarcsecond) at 15 mag, and 200 µas at 20 mag
- Determining the radial velocity measurements with expected detection of tens of thousands of extra-solar planetary systems
- Capacity to discover Apohele asteroids with orbits that lie between Earth and the Sun, a region that is difficult for Earth-based telescopes to monitor since this region is only in the sky during or near the daytime.
- Detection of up to 500 000 distant quasars
- More accurate tests of Albert Einstein's general relativity theory
- Data-distribution policy:
  - final catalogue ~2021
  - intermediate catalogues currently under definition
  - science-alerts data released immediately
  - no proprietary data rights