Small-sat Platforms and Formation Flying: an opportunity for the gamma ray telescope MAX

Focusing Telescopes in Nuclear Astrophysics

September 12-15 2005, Bonifacio

Small-sat Platforms and Formation Flying: an opportunity for the gamma ray telescope MAX

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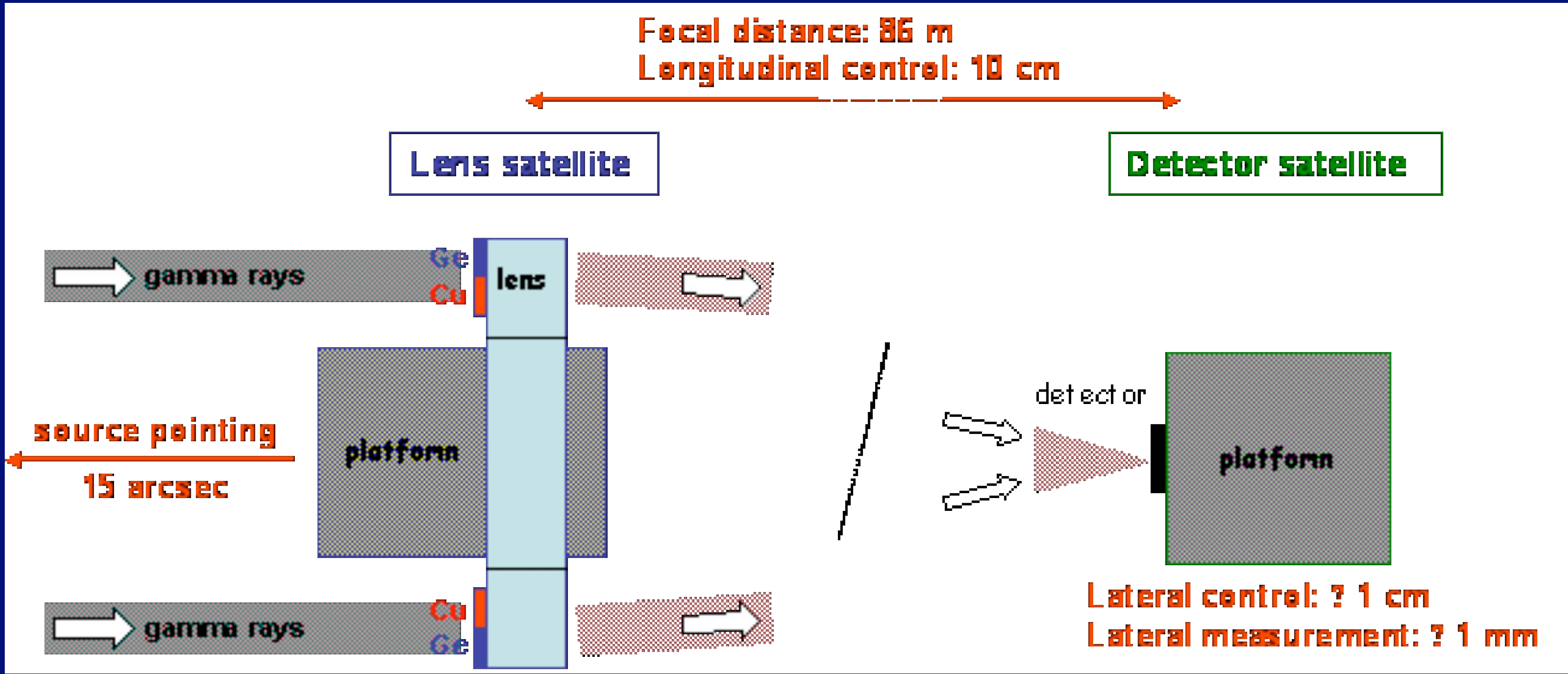
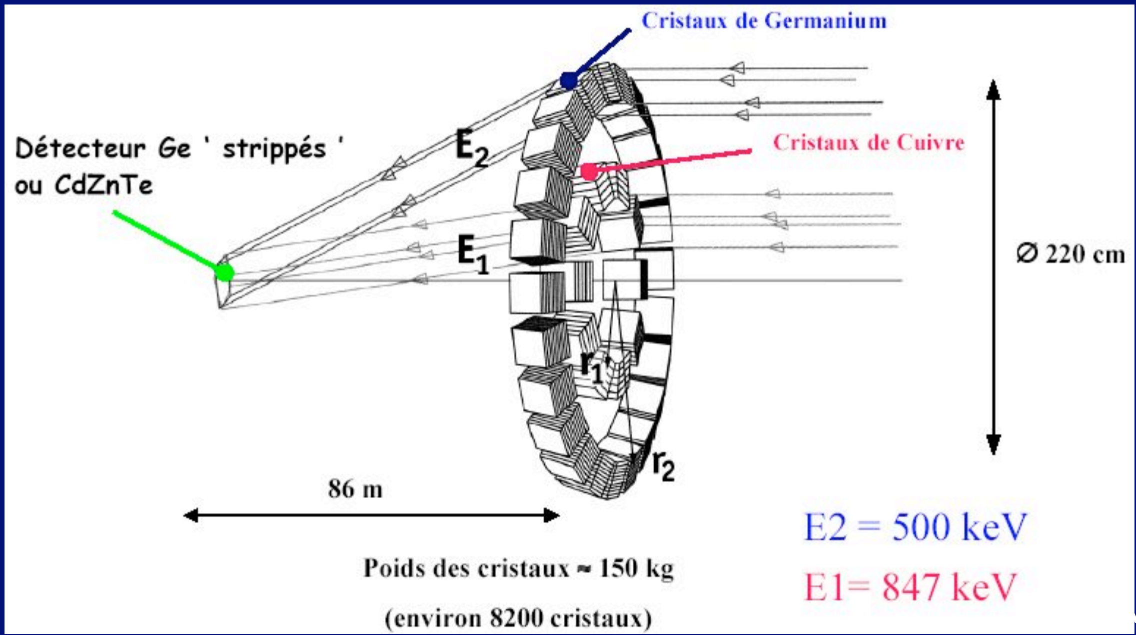
Innovative concepts and techniques for MAX

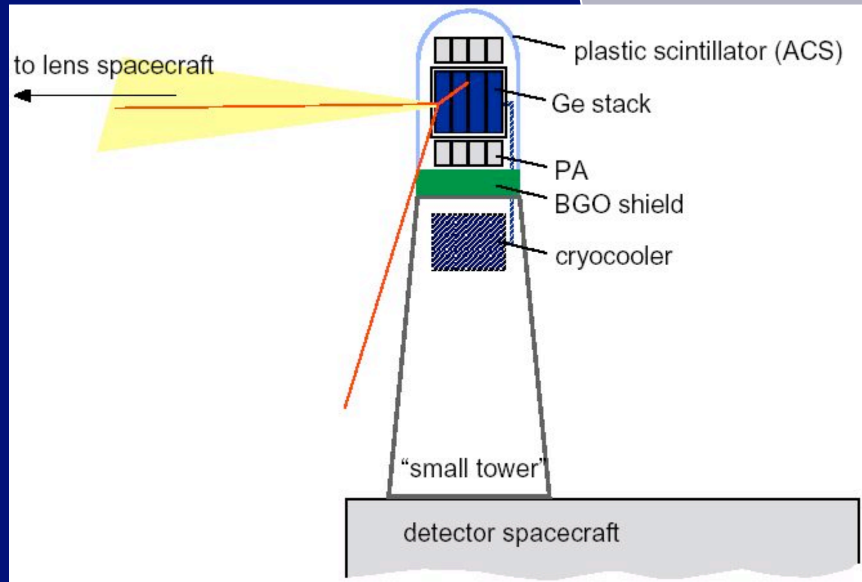
- MAX is new concept of gamma ray telescope with as prime objective the study of supernovae of type Ia.
- The concept of MAX is radically different from the traditional gamma ray telescopes: *gamma rays are focused from the large collecting area of a crystal diffraction lens on a very small detector volume*.
- The implementation of the MAX space mission consists in flying a lens-detector duo satellites in active Formation Flying geometry.
- The satellite platform is based on a new generation small-sat platform in the 200 kg range.
- Beyond its scientific objectives, MAX is good opportunity for demonstrating Formation Flying concepts and technologies in space.



Focal distance: 86 m
Longitudinal control: 10 cm
Lens satellite
Detector satellite
gamma rays
Ge
Cu
lens
source pointing
15 arcsec
platform
detector
platform
gamma rays
Cu
Ge
Lateral control: ? 1 cm
Lateral measurement: ? 1 mm



Cristaux de Germanium
Détecteur Ge ' strippés '
ou CdZnTe
E2
Cristaux de Cuivre
E1
Ø 220 cm
r1
r2
86 m
E2 = 500 keV
E1= 847 keV
Poids des cristaux ≈ 150 kg
(environ 8200 cristaux)



to lens spacecraft
plastic scintillator (ACS)
Ge stack
PA
BGO shield
cryocooler
"small tower"
detector spacecraft

Main challenges for MAX

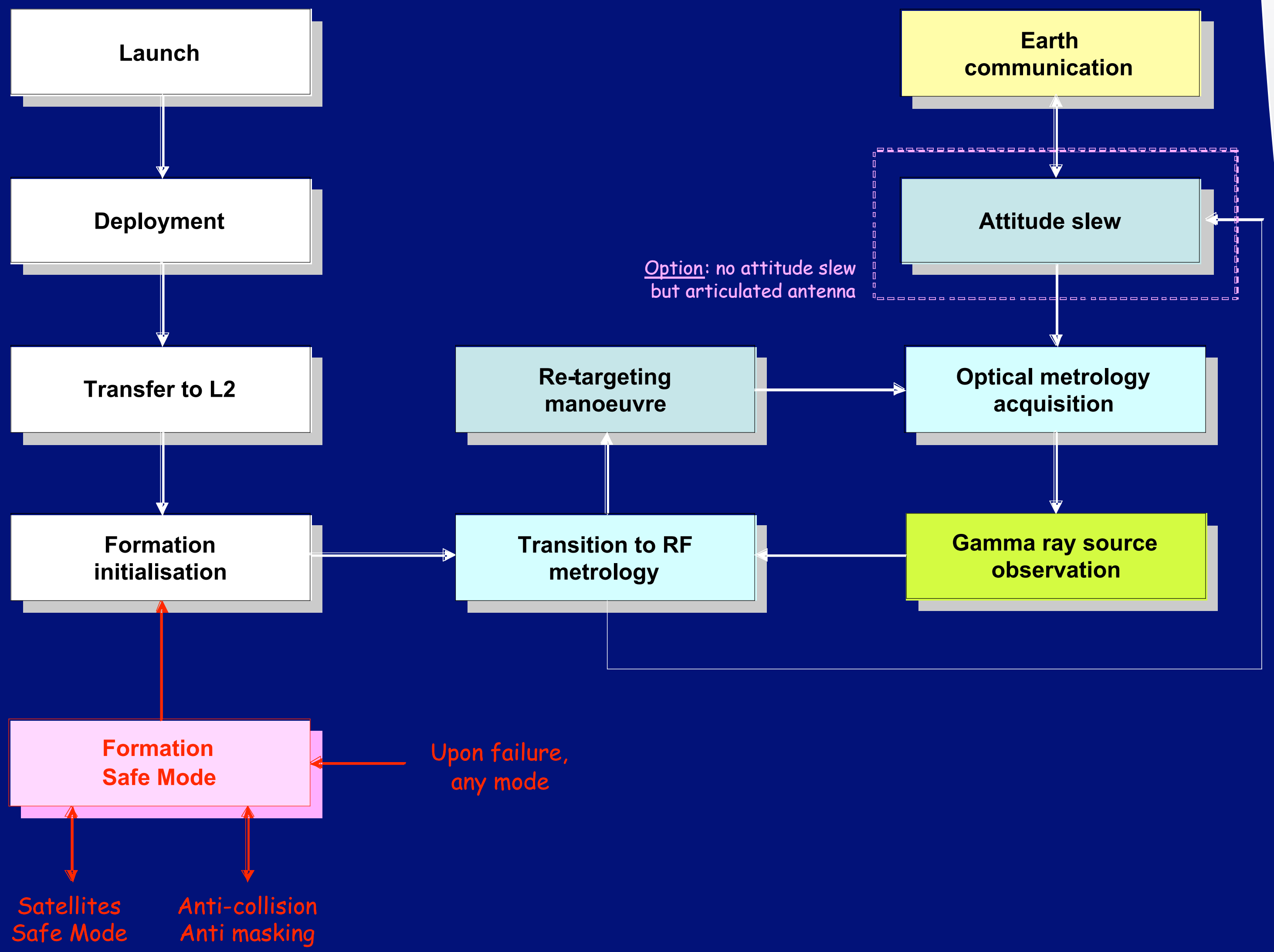
- Accommodation of a duo instrument lens + detector on 2 satellites in active Formation Flying (FF), with an accuracy in the mm range.
- Inertial pointing of the lens with 15 arcsec accuracy.
- Mechanical / thermal design and accommodation of a 150 kg lens with a torus shape (110 - 220 cm inner - outer diameters).
- Cooling of the detector to an operational temperature of 85 K.
- Adaptation of the 200 kg new generation small-sat platform to the mission needs.
- Launch envisaged in 2011: critical paths are the science payload and the Formation Flying package.

MAX mission overview

- Operational orbit: large Lissajous orbit around L2, free insertion.
- Launch in 2011 with Soyuz ST / Fregat from Kourou as baseline.

  Other launchers, cheaper (e.g. Rockot, Dnepr) are possible, but require a propulsive stage.
- 3-year mission duration, 50 sources to be observed, 15-day observation per source.
- Prime mission objective: science, with secured Formation Flying technology.
- Second objective: Formation Flying demonstration mission, with performances higher than those required by MAX science.
- The 2 satellites are separated just after Launch; they remain independent and are separately operated during the whole mission.

Mission phases



Space segment definition (1/2)

- The space segment is composed of 2 satellites, one acting as the lens, the other one as the detector.
- The satellites are inertially pointing to the same source.
- Any inertial direction can be observed. This direction is a priori unknown.
- The system is sized to continuously and safely observe the same source for 15 days.
- The Command/Control architecture is decentralised: both satellites are individually and similarly operated from the ground.

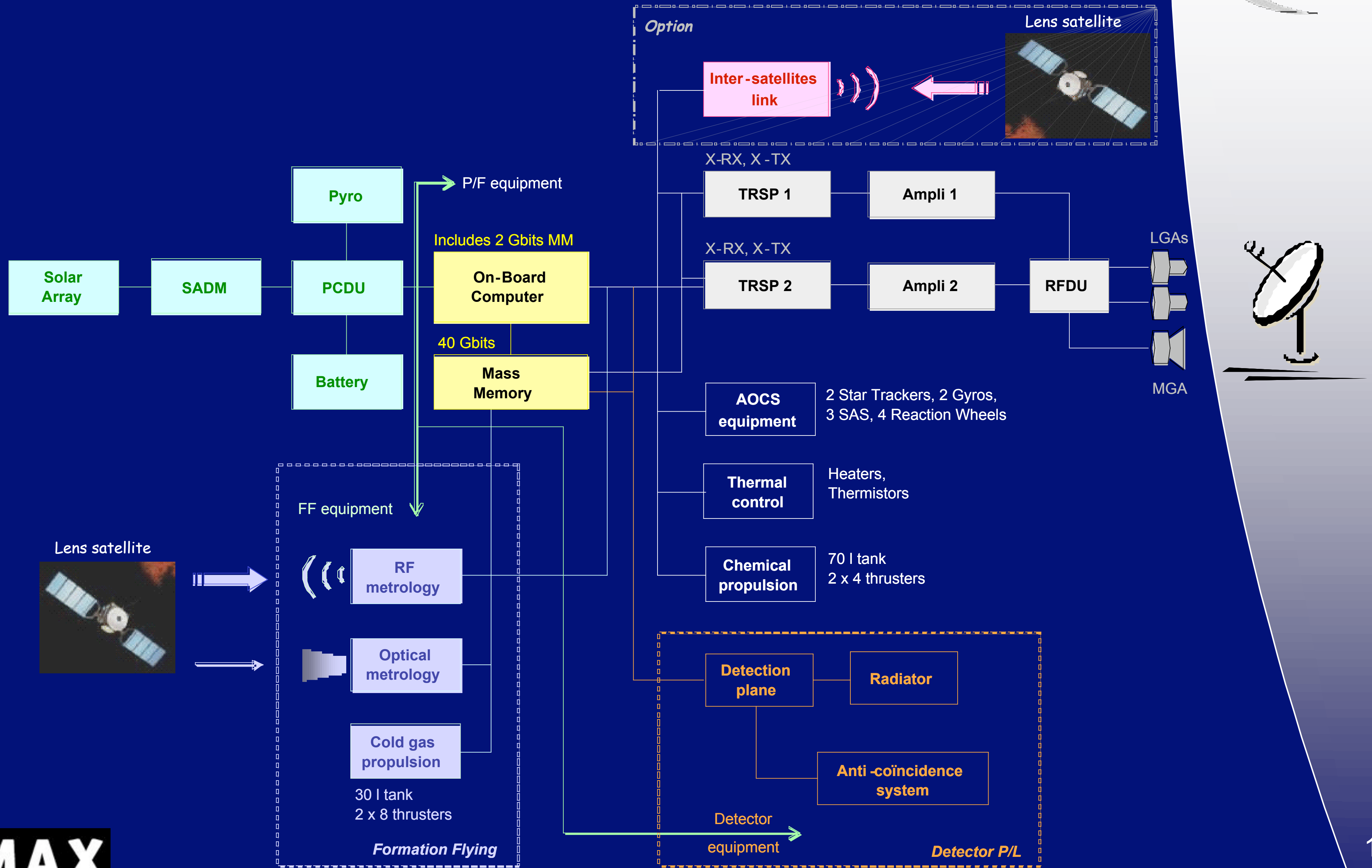
> - For distributed GNC and more robust formation FDIR, a bi-directional inter-satellites RF link can be added.
> - With this inter-satellites link, the Ground could operate the Formation through a single satellite, if preferred.
> - The hardware supporting this inter-satellite link is independent from the RF metrology for safety reason (e.g. S-band transponder with 2π sr omnidirectional antennas).

MAX

Space segment definition (2/2)

- Lens satellite:
  - Controlled in attitude with 15 arcsec absolute pointing: gyro-stellar estimation, control with reaction wheels,
  - Remains « free-flying »: no position control apart from standard station keeping,
  - SA Sun pointing and fixed during observation and communication,
  - Continuous down-load of HK TM through the LGA.
- Detector satellite:
  - Controlled in attitude using the same mode and equipment as the lens for simplicity of design, validation and operations,
  - 3D position relative to the lens sensed by the RF or optical metrology and controlled with cold gas thruters,
  - SA Sun pointing and fixed during observation and communication,
  - Continuous down-load of HK TM through the LGA.

Detector satellite functional architecture



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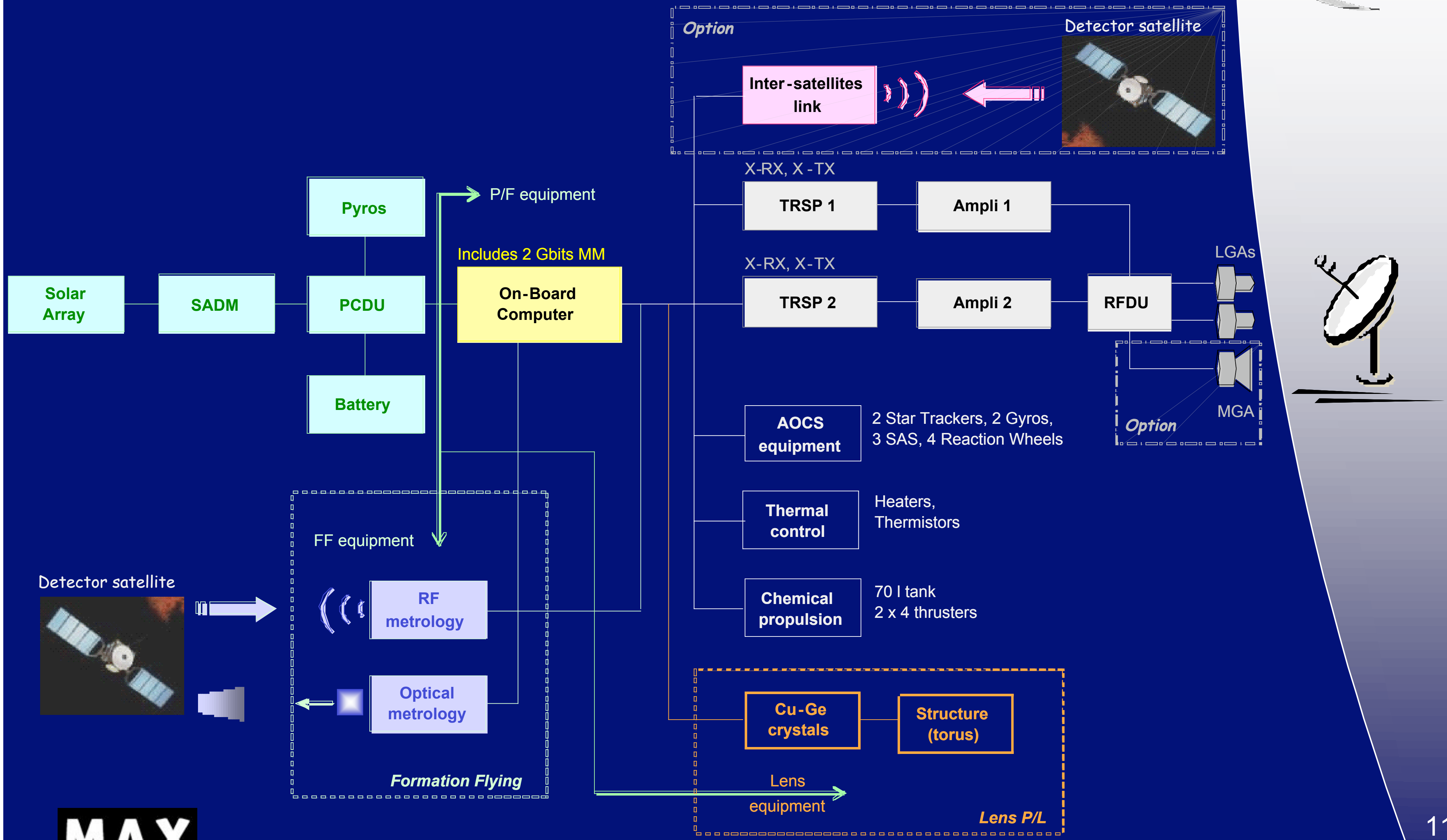
Lens satellite functional architecture



Platform

- MAX platform is based on a « new generation » platform product in the 200 kg range.
- Starting points for the platform design: Pleiades, Rocsat 2.
- The platform is adapted to account for the specificities of the MAX mission:
  - deep-space mission,
  - adaptation to the payload interfaces,
  - Formation Flying.
- The same platform design is proposed for the 2 satellites so as to:
  - minimise the development work: engineering, equipment procurement, spare philosophy, software, AIT bench,
  - secure the in-orbit operations: same space-to-ground interface, same flight procedures.

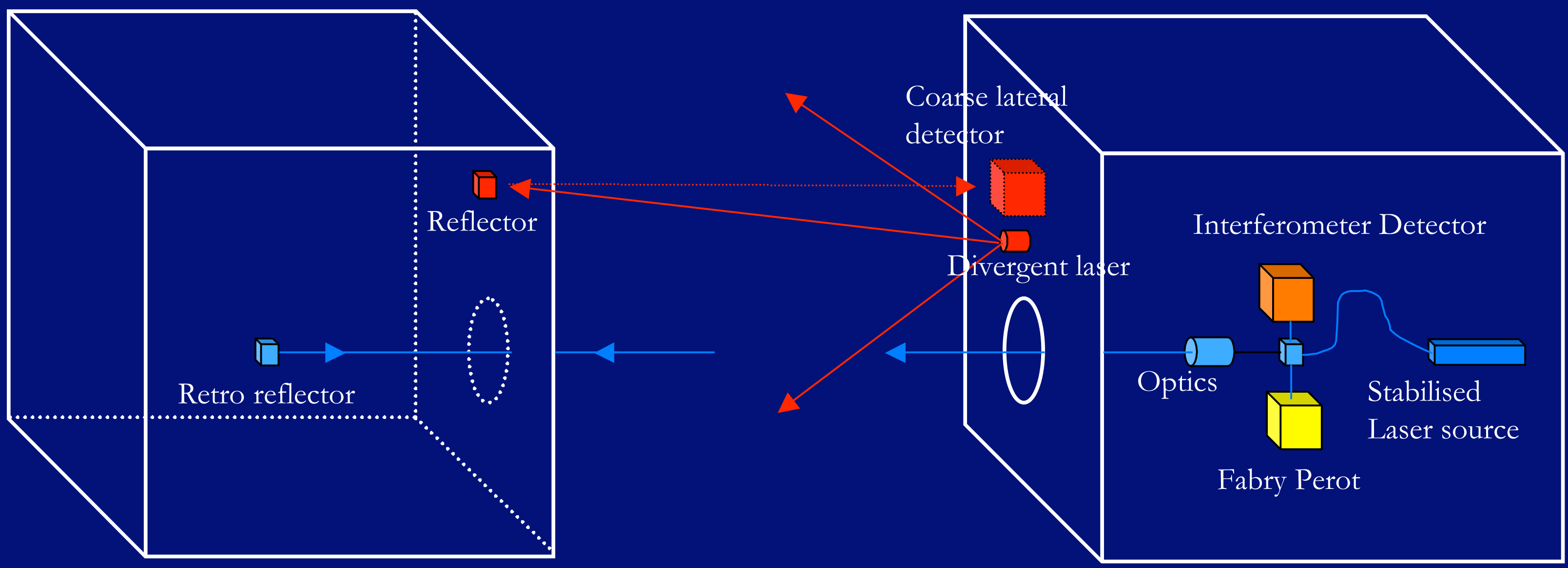
Formation Flying

- Units required for the Formation Flying are functionally decentralised in a dedicated Formation Flying Package (FFP).
- The FFP is different on the lens and detector satellites.

	Lens	Detector
RF metrology (formation deployment, initialisation & backup)	1 + 1 transceivers Emit/receive antennas 4π sr coverage	1 + 1 transceivers Emit/receive antennas 4π sr coverage
Optical metrology (science)	Reflecting corner cubes	Coarse lateral metrology Fine longitudinal metrology (demonstration)
Cold gas propulsion (science)	None	30 l cold gas tank (N_2, 300 bar) 8 + 8 thrusters

MAX

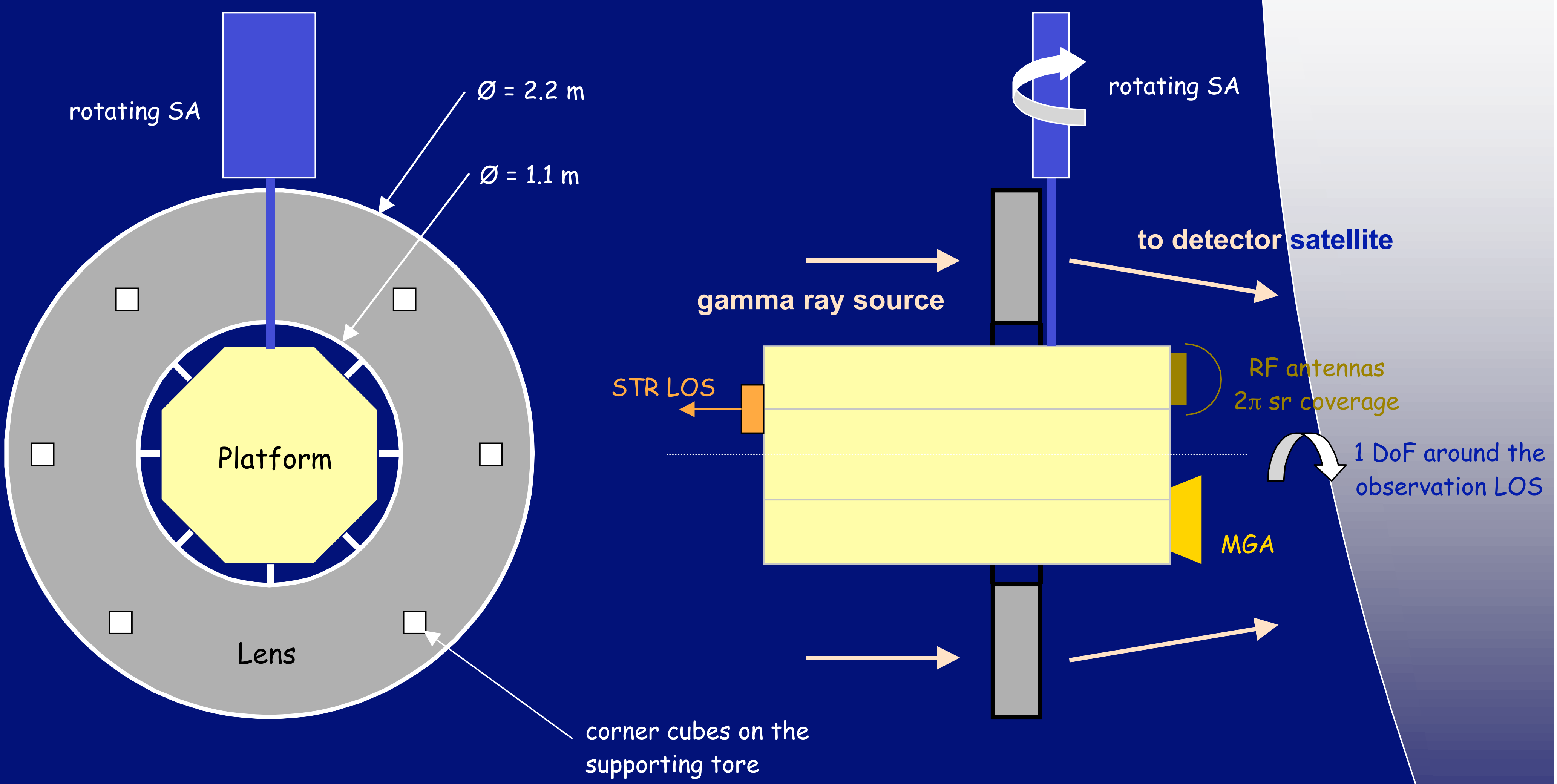
Coarse lateral & fine longitudinal optical metrology



	Operational range	Measurement accuracy
Lateral plane	1 km 0.25 deg half cone	0.1 to 1 mm
Longitudinal axis	1 km 0.25 deg half cone 1 mm/sec	0.01 mm

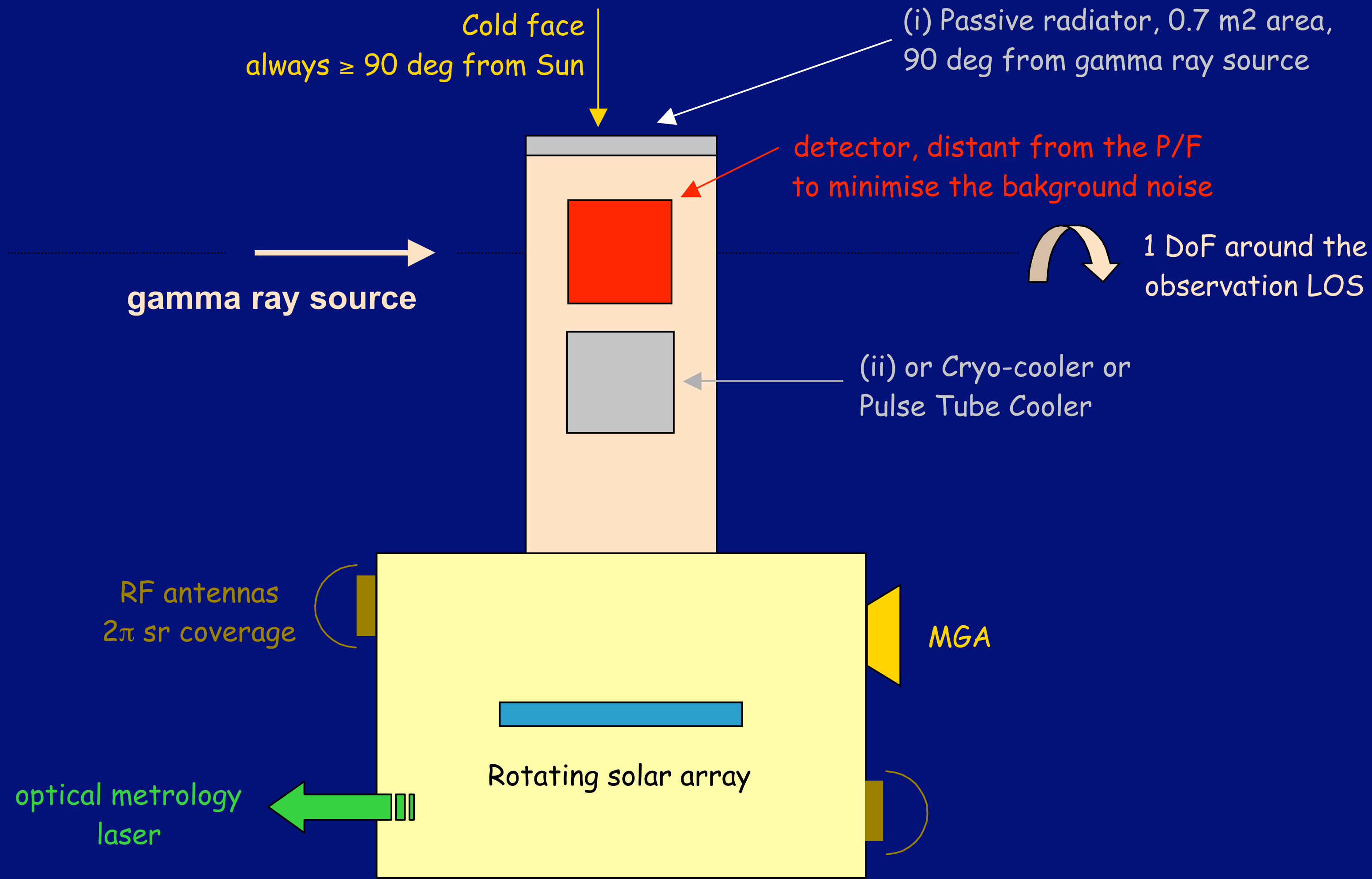
The proposed Fine Longitudinal Metrology is based on the HPOM (High Precision Optical Metrology) mockup, under development for ESA at EADS Astrium.

Lens functional configuration



MAX

Detector functional configuration



MAX

Programmatics

- Phase A: 12 months (year 2006).
- Phase B: 12 months. KO Jan 2007. Platform Suitability Review 9 months after KO, PDR 12 months after KO.
- Phase C/D: 36 months. CDR 18 months after PDR.
- AIT: 15 months for the Detector S/C, 12 months for the Lens S/C.
- 4-month margin.
- 2-month launch campaign.
- Launch: June 2011 (i.e Phase B KO + 54 months).
- Planning constraints:
  - need to start the development of the Optical metrology shortly after phase B KO,
  - definition and development of the science payload in parallel to the development of the Platform and Formation Flying units.
    - → Payload pre-development assumed to be initiated early enough.

Conclusions

- MAX is a good opportunity to associate Science and Formation Flying in a CNES programme.
- CESR and EADS Astrium propose an implementation of the MAX mission as a pair of satellites in active Formation Flying.
- Both satellites are operated independently and designed for a deep space mission.
- Both satellites are based on a new generation small-sat platform in the 200 kg range.
- The large experience gained at EADS Astrium through numerous ESA and CNES studies allows the definition of a Formation Flying package that fulfills the objectives of the MAX mission with margins.
- With a phase B Kick-Off in early 2007, the mission can be ready to be launched by mid-June 2011.