ESA's Studies of Next Generation Gravity Mission Concepts

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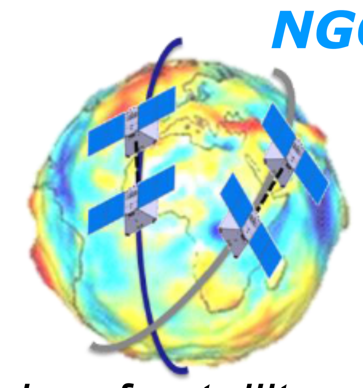
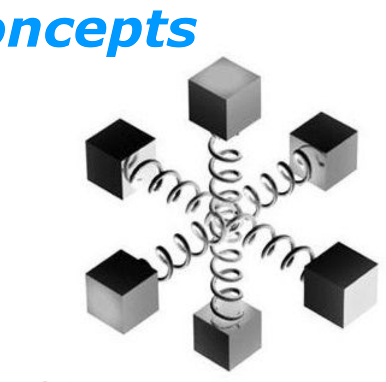
Introduction

The ESA initiatives started in 2003 with a study on observation techniques and continued through several studies focusing on the **satellite system**, technology development for **propulsion** and **distance metrology**, preferred **mission concepts**, the **attitude and orbit control system**, as well as the optimization of the **satellite constellation**. More recently, several studies related to **new sensor concepts based on cold atom interferometry** were initiated, mainly focusing on technology development for different instrument configurations.

NGGM Concepts



Pairs of satellites
Inter-satellite ranging

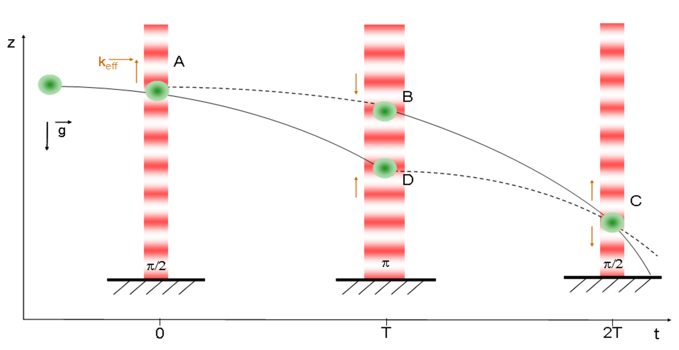


Single satellite
Gravity gradiometry

CAI Mission/Instrument Concepts

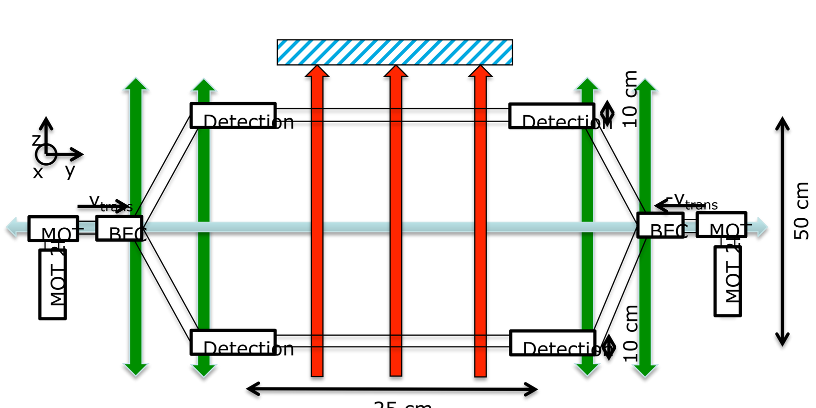
Cold Atom Interferometry (CAI) is based on measuring the motion of a cold atom cloud with high precision using a stabilized laser. The laser frequency stabilization is ensured using an atomic transition as a reference.

The phase (position) of the laser is imprinted on the atoms each transition. Control of the transfer from one state to another acts like a beam splitter for π/2 pulses where half of the atom population is transferred or a mirror for π pulses where all atoms are transferred.

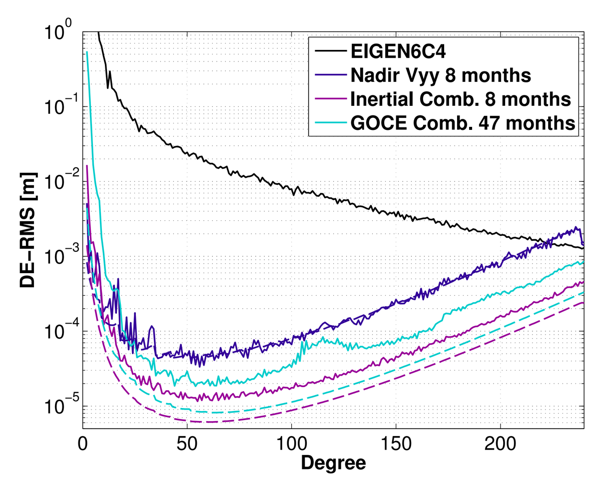


Instrument concepts realizing a CAI gravity gradiometer and a CAI accelerometer are investigated in the following studies:

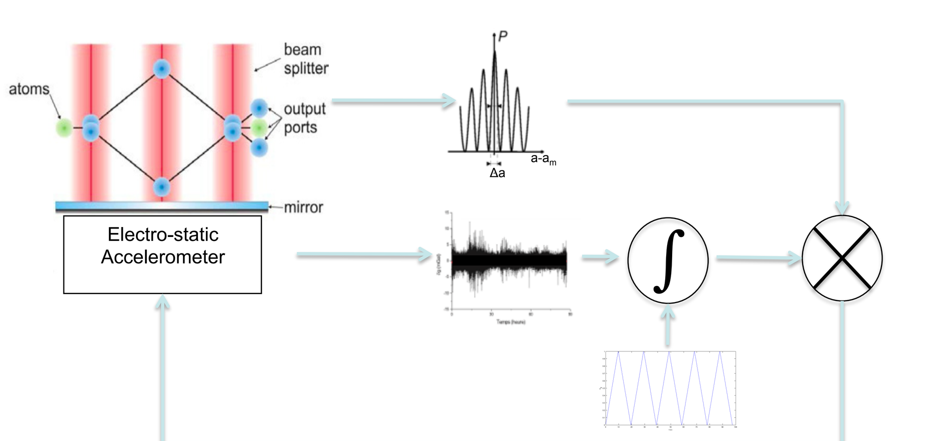
- *Study of a CAI Gravity Gradiometer Sensor and Mission Concepts*

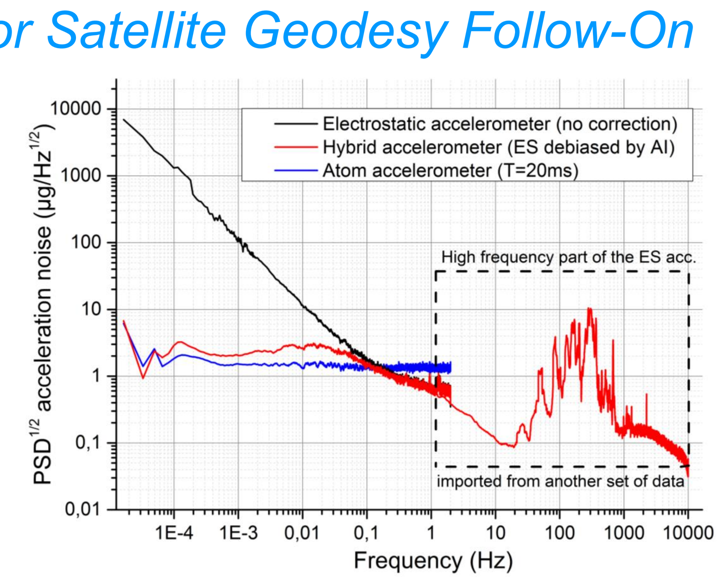


Flat instrument noise PSD of 3.5 mE/sqrt(Hz)

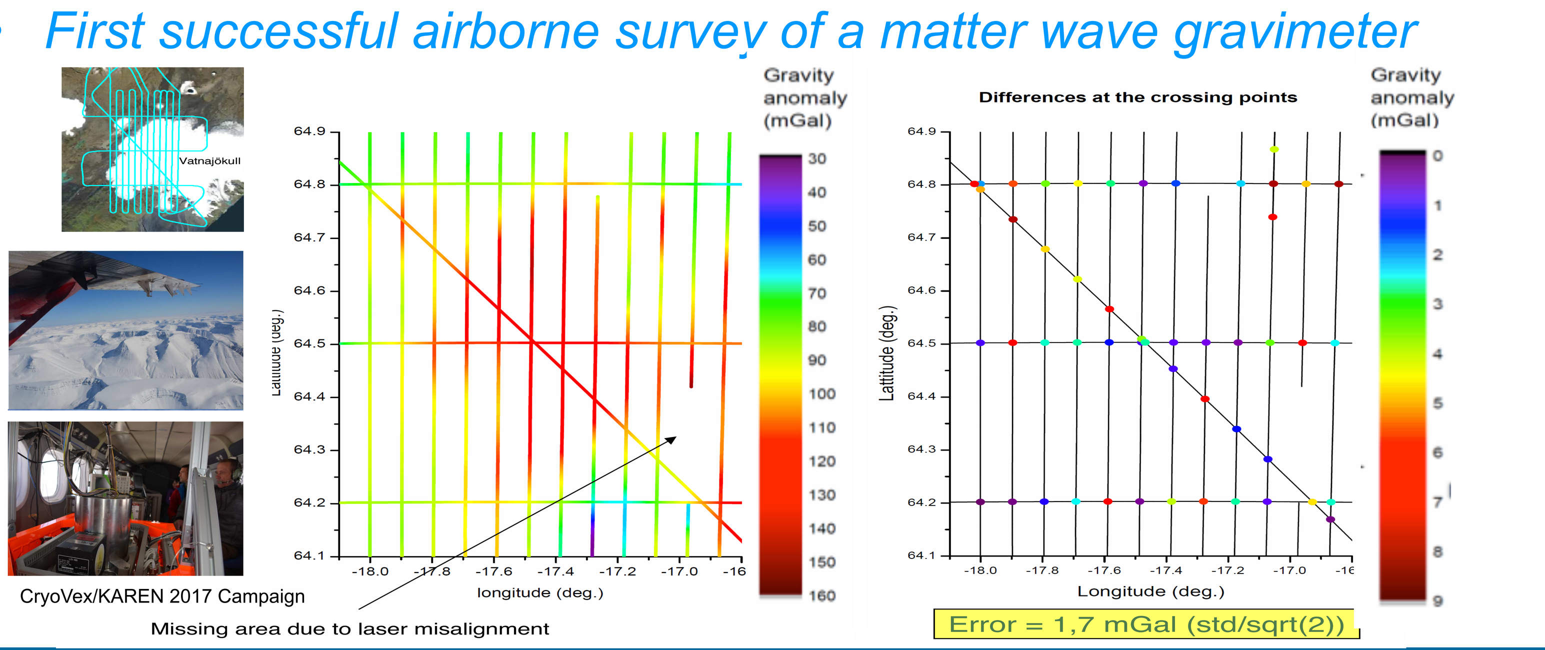


- *Hybrid Atom Electrostatic System for Satellite Geodesy Follow-On*





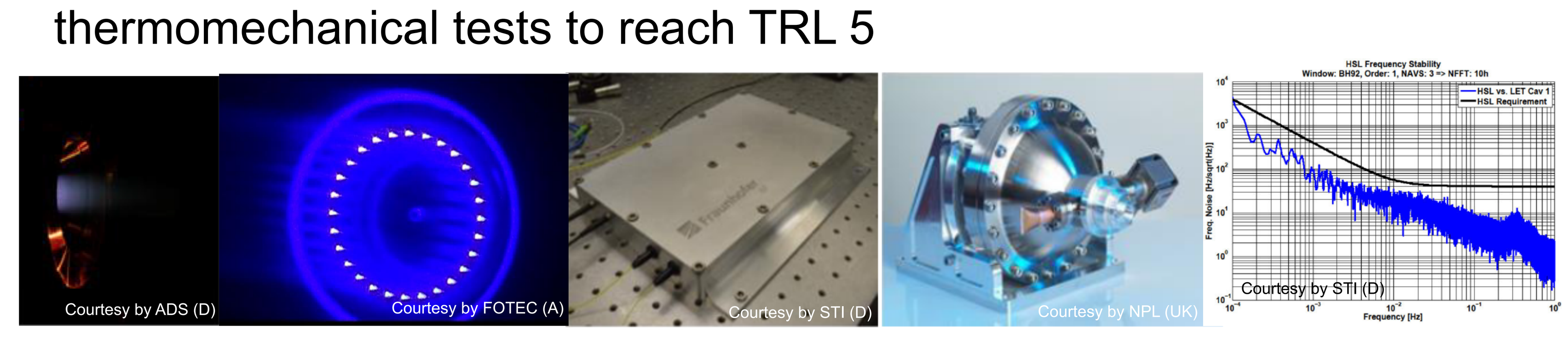
- *First successful airborne survey of a matter wave gravimeter*



Technology Developments

ESA has started and is still running several studies in support of NGGM concepts. The variation of the distance from one satellite center of mass to the other has to be measured with very high precision by a **distance metrology**. In order to retrieve the gravity signal from the laser metrology measurements, the non-gravitational forces need to be measured by **accelerometers**, which requires some level of **drag compensation** due to the limited dynamic range. As a consequence, the satellites need loops for controlling the **attitude** and the **loose formation**, where each of these loops will have its bandwidth, and they work in a hierarchical structure, interacting in complex ways. To ensure a mature TRL for all the satellites subsystems, several complementary studies were initiated:

- *Next Generation Gravity Mission: AOCS Solutions and Technologies*: AOCS & FF control, AOCS modes tested on the E2E MST simulator
- *Miniaturized Gridded Ion Engine (GIE) sub-system and coupling test*: thrust range from 50 μN to 2.5 mN (ongoing qualif. @ TRL 5)
- *Consolidation of the micro-PIM Field Emission Thruster design for NGGM*
- *High-Stability Laser with Fibre Amplifier and Laser Stabilisation Unit for Interferometric Earth Gravity Measurements*: EBB undergoing thermomechanical tests to reach TRL 5

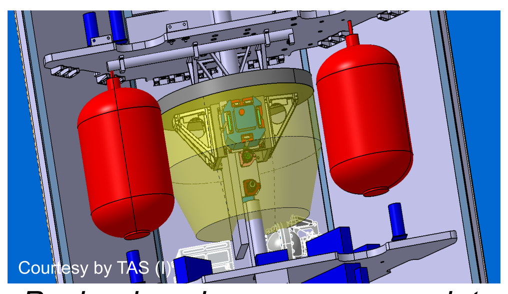


RIT-μX (left); Indium mN-FEEP; fibre amplifier, cavity (inside vacuum chamber) - all fibre coupled (center); PSD of measured laser frequency noise (right).

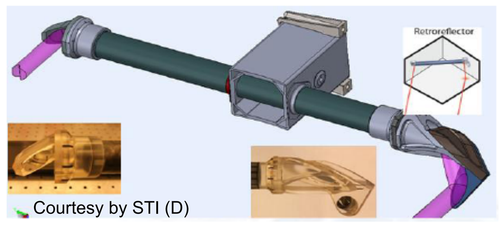
The study *Consolidation of the system concept for the Next Generation Gravity Mission (NGGM)* aims at

- preliminary conceptual design of the mission and system elements
- consolidation of system architecture and its elements with an emphasis on the laser ranging system
- definition of development approach and schedule, ROM cost estimates
- analysis of critical technologies and the definition of required development activities

Further consolidation of the system design on all the above aspects is on-going at pre-Phase A level



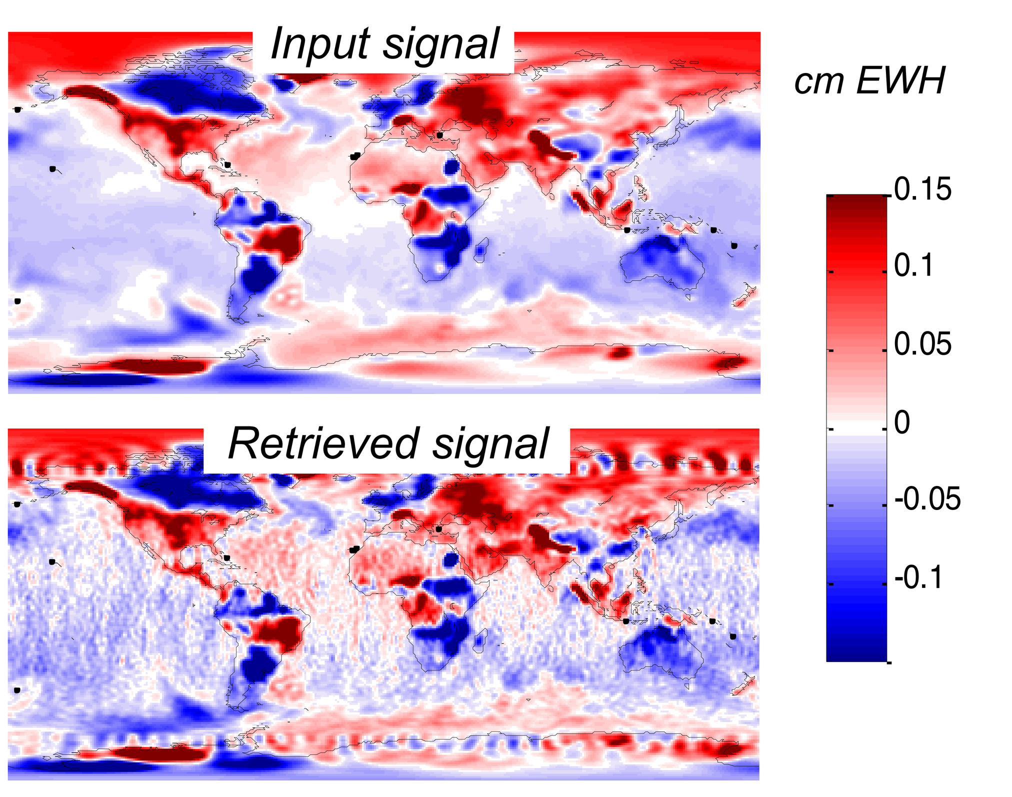
Payload enclosure accommodated in Iridium-Next P/F



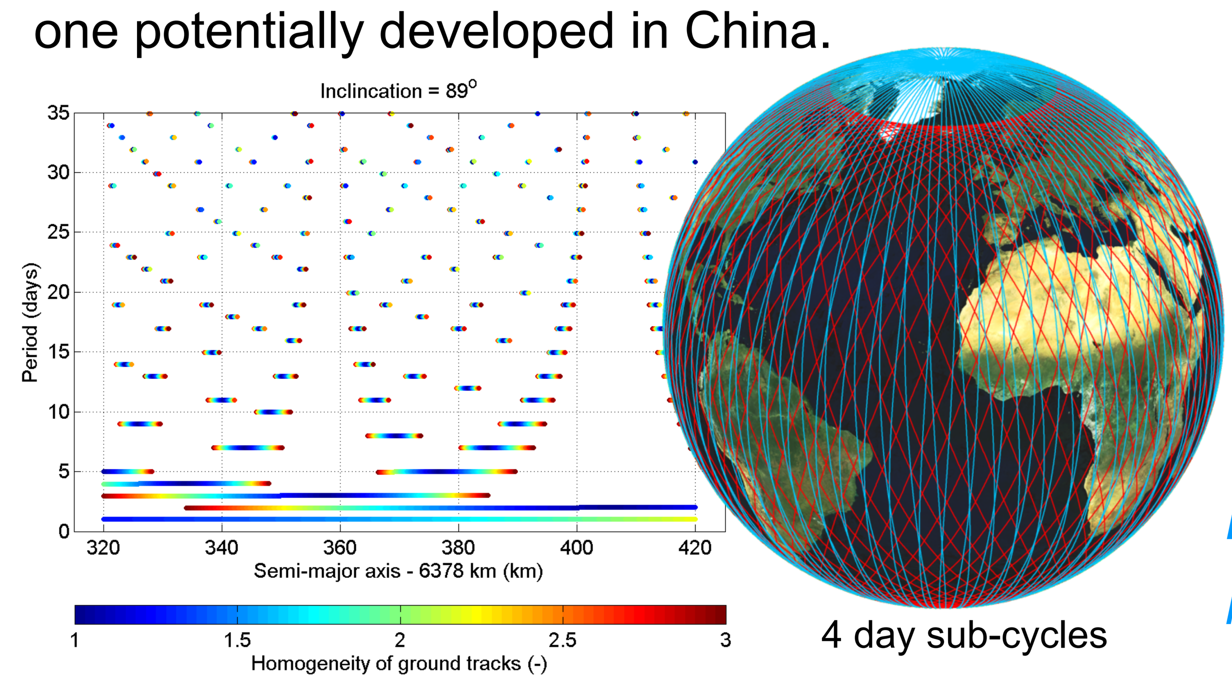
GRACE-FO's LRI CAD model: for NGGM beam spacing < 150 mm

Science Studies

The *Assessment of Satellite Constellations* study focused on the identification of optimal satellite constellations and the development of a method for the **reduction of aliasing** due to the undersampling of fast atmospheric and oceanic mass transport.

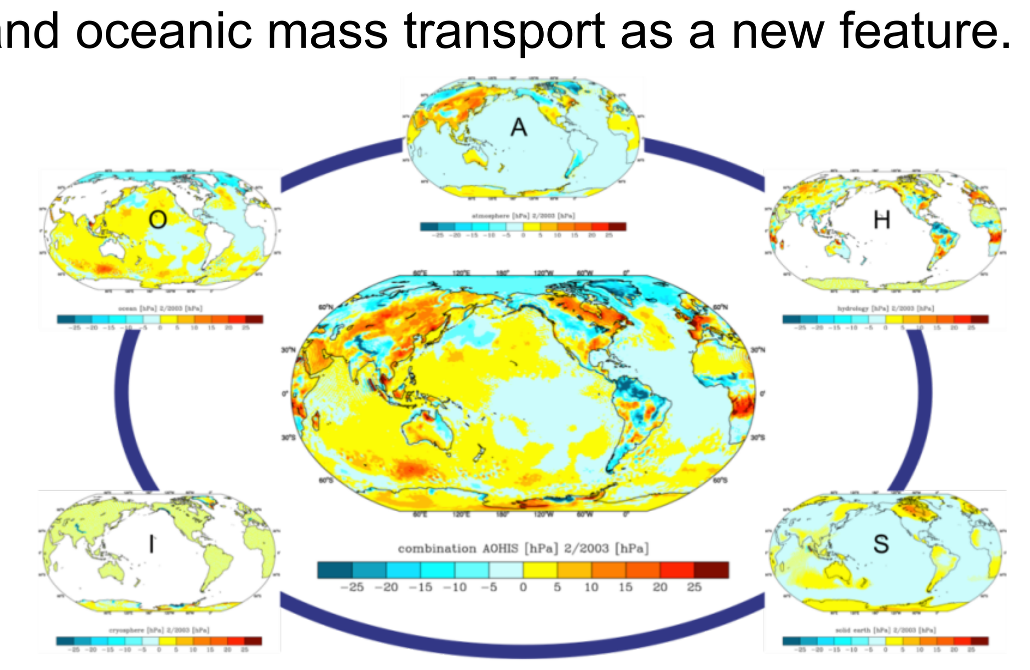


The *Additional Constellation Analysis* study investigated the scenario of **drifting ground tracks with fixed interleaving** of polar and inclined satellite pair. The needs of **near real-time** and **hydrological services** in view of NGGM were addressed. In the extension, the study team will *cooperate with Chinese colleagues* to investigate a constellation of three satellite pairs, one potentially developed in China.



4 day sub-cycles

The constellation studies use ESA's *New Earth System Model* that includes the signal due to atmospheric, oceanic, hydrologic, cryospheric and solid earth mass transport, and also provides **realistic error time series** for rapid atmospheric and oceanic mass transport as a new feature.



ESM data and documentation:

https://isdc.gfz-potsdam.de/esmdata/esaesm/