NEXT GENERATION GRAVITY MISSION (NGGM): STATO DELLA MISSIONE

Workshop di consultazione della comunità scientifico/applicativa sulla missione ESA NGGM/MAGIC

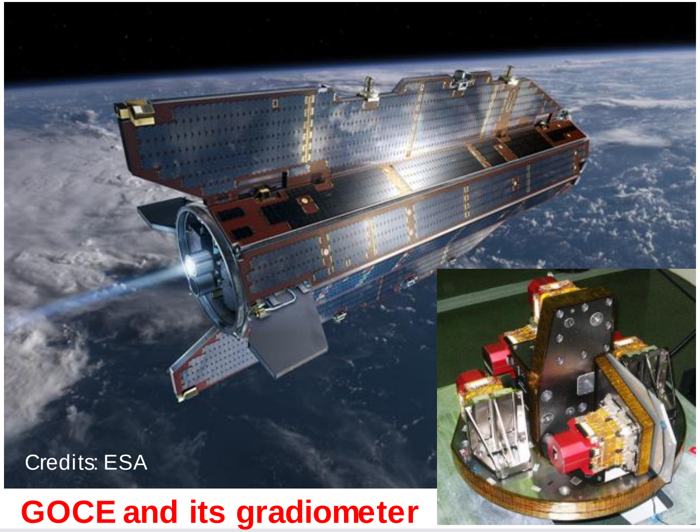
26 gennaio 2021

Date: 26/01/2021
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

BEFORE NGGM: GOCE, THE FIRST EUROPEAN GRAVITY MISSION

- March 17th 2009: launch of the Gravity and Ocean Circulation Explorer (GOCE).
- Objective: provide a global, high resolution map of Earth's gravity field and of its geoid.
- Payload: 3-axis gradiometer composed by 6 accelerometers, measuring gravity gradients.
- Orbit: sun-synchronous (i=96.5°), operational altitude from 259.5 km BOL to 229 km EOL.
- Spacecraft key feature: variable-thrust ion propulsion for drag-free control in flight direction

17 March 2009: GOCE liftoff from the Plesetsk Cosmodrome



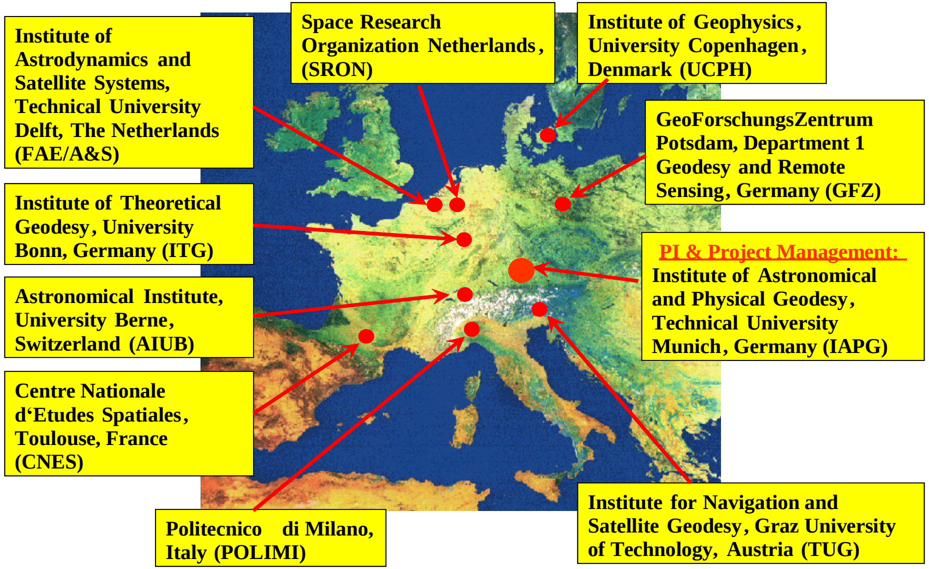
GOCE and its gradiometer

11 November 2013: GOCE reentry into Earth's atmosphere at the end of its mission

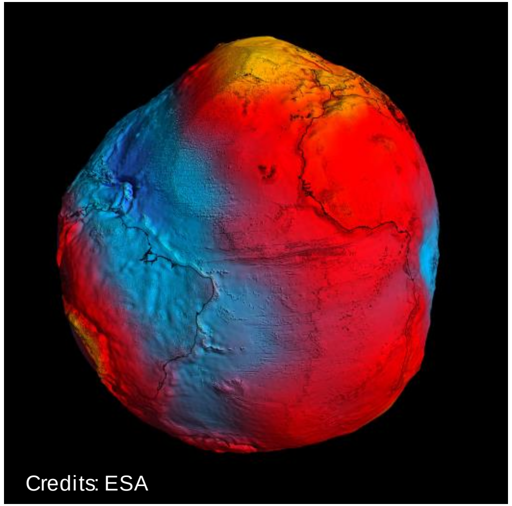
Date: 26/01/2021
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

BEFORE NGGM: GOCE, THE FIRST EUROPEAN GRAVITY MISSION

- Thales Alenia Space Italia has been the Prime Contractor for the implementation of GOCE
- The methods processing the GOCE measurements and obtaining the level-2 geodetic gravity products have been developed by the European GOCE Gravity Consortium (EGG-C) of 10 Institutes distributed over 7 European countries. Italy was among them.



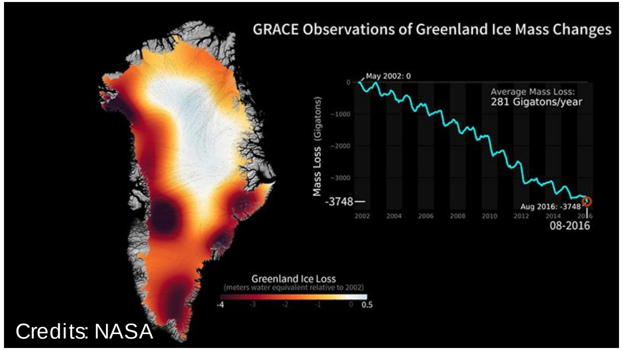
European GOCE Gravity Consortium

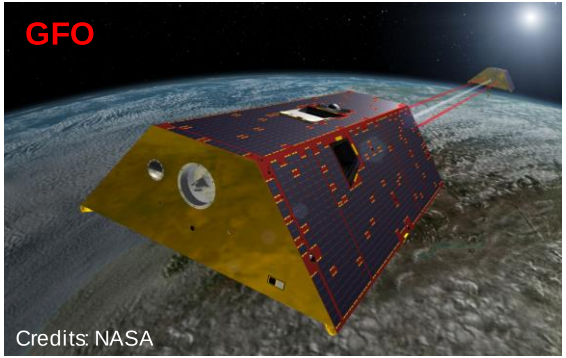


GOCE produced the Earth gravity map with mean global accuracy of 2.4 cm on geoid heights and 0.7 mGal on gravity anomalies, at 100 km spatial resolution

BEFORE NGGM: GRACE, GRACE-FOLLOW ON

- Launched on 17 March 2002 on a 500 km polar orbit, the GRACE twin satellites (NASA-DLR joined mission) introduced the satellite-satellite tracking technique (SST) based on a K-band ranging system (~1 μm resolution) for measuring Earth's gravity field.
- Between 2002 and 2017 GRACE data enabled to detect both long-term and seasonal changes in the gravity field (generated by geophysical phenomena involving large mass displacements) at spatial scales as short as 300 km and monthly temporal resolution.
- Launched on 22 May 2018, GRACE-Follow On (GFO) ensured the continuity of the GRACE mission and performed the first on-orbit demonstration of a laser interferometer for satellite-satellite tracking (GFO primary payload is still the K-band ranging).

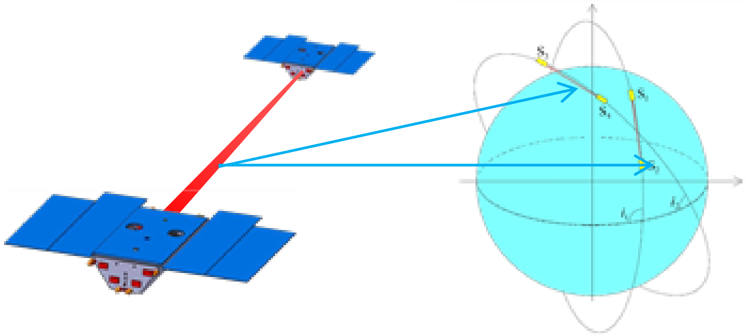


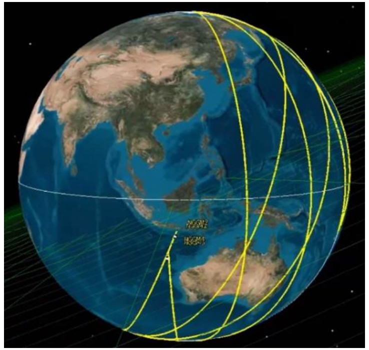


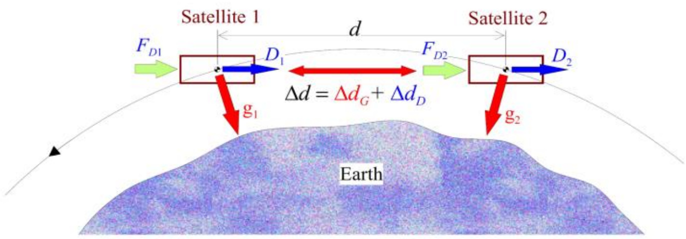
Date: 26/01/2021
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

NEXT GENERATION GRAVITY MISSION: OBJECTIVE AND ARCHITECTURE

- NGGM objective is the long-term monitoring of the temporal variations of Earth's gravity field at high resolution in time (down to 3 days) and space (100 km), providing continuity and improvement of the Earth mass change monitoring (and of the associated geophysical phenomena) service with respect to the predecessor missions.
- Mission key features to achieve this objective:
  - "Bender-type" constellation constituted by two satellite pairs, one in polar and one in ~70° orbit.
  - Orbit altitude control to ensure constant, homogenous sampling of the Earth surface every 5-7 days.
  - Distance variation between two satellites measured by a laser interferometer with nm resolution.
  - Drag accelerations of each satellite measured by accelerometers with pm/s^2 resolution.







Date: 26/01/2021
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

PREPARING NGGM

- Since 2003 the European Space Agency has promoted studies to establish the scientific requirements, to identify the most appropriate measurement techniques, to start the associated technology developments, and to define the system scenarios for NGGM.
- Thales Alenia Space Italia has led or had been involved in most of these studies:

Title	Epoch	Prime / SubCos	Purpose and main achievements
Laser Doppler Interferometry Mission for Earth's Gravity Field	2004 - 2005	TASI INRIM, UniMi, PoliMi, UniPi	System and instrument concept study
Laser interferometry high precision tracking for LEO	2007-2009	TASI INRIM	Proof of concept of the measurement principle (retro-reflector concept) • Laser interferometer prototype • Angular/lateral metrology breadboard • Beam Steering Mechanism breadboard (CCN 1)
System support to laser interferometry tracking technology development for gravity field monitoring	2007-2010	TASI Turin Polytechnic	System concepts • Investigation on electric propulsion technology and first tests of mini-RIT on NanoBalance facility (CCN1, 2)
Assessment of a Next Generation Mission for Monitoring the Variations of Earth's Gravity	2009 - 2012	TASI ONERA, DEIMOS, GIS	System definition study • Extended Study of the "Pendulum" Option (CCN1)
Next Generation Gravity Mission: AOCS Solutions and Technologies	2012-2014	TASI Turin Polytechnic	Control design and algorithm study • 4-tier control design (formation/orbit control/drag-free control/attitude control)
Assessment of Satellite Constellations for Monitoring the Variations in Earth's Gravity Field	2013-2016	Munich University TASI consultant	Geophysical applications and anti-aliasing (Earth tides)
Consolidation of the System Concept For the Next Generation Gravity Mission	2015-2017	TASI STI	System study update • Trade-off of Transponder and retroreflector concepts
Development of the Lateral Angular Metrology for NGGM	2017-2019	TASI INRIM	Angular metrology breadboard
Gravitational Seismology	2018-2019	Università di Milano TASI, GIS	New application for the Next Generation Gravity Mission
Proof-of-concept test for retroreflector interferometer for NGGM	2019-ongoing	STI TASI, INRIM	Optical bench design and breadboard tests (retroreflector concept)

Date: 26/01/2021
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

NGGM PHASE A SYSTEM STUDY ORGANISATION

NASA

ESA

Phase A Industrial team 1

Team leader: Thales Alenia Space Italia

- Subcos/consultants for Phase A tasks
- Subcos for specific techno pre-developments

Team composition will maximise GOCE experience & heritage

Phase A Industrial team 2… N

ESA funded activates developed in parallel to Phase A Study

Activity Title	Status
Laser Tracking Instrument technology pre-development	Activity KO planned in Q1 2021
T5 technology pre-development	Activity KO planned in Q1 2021
Accelerometer technology pre-development	Activity KO planned in Q1 2021
FEEP Technology pre-development	Intended to start in Q2 2021
E2E Performance Scientific activities	Planned
Science studies	Planned

KEY MISSION & SYSTEM ISSUES TO BE ADDRESSED IN PHASE A

- Finalise high-level architecture trade-off's
  - Bender constellation, pendulum configuration, double pair at different orbital altitudes possibly with different performance
- Select laser interferometer scheme
  - Off-axis Retro-Reflector scheme (proposed by TAS I with INRIM) vs. Transponder concept (GFO solution).
- Select reference orbits within specified range (350 – 550 km, 70° and 89°)
  - Compatibility with on-board resources (propellant mass, power to supply the electric propulsion) and lifetime (4 to 7 years + 6 months commissioning).
- Select propulsion technology (electric, chemical, hybrid)
  - Tasked with orbit altitude & satellite formation control, drag compensation, satellite pointing, compatible with on-board resources and with the required technology readiness level.
- Establish technology development planning
  - All involved technologies (platform and payload) shall have TRL ≥ 4 at end of Phase A and TRL ≥ 5/6 at end of Phase B1 (2024).
- Establish design and development plan compatible with 2028-2029 launch.
- Support ESA in defining cooperation scenarios with NASA.