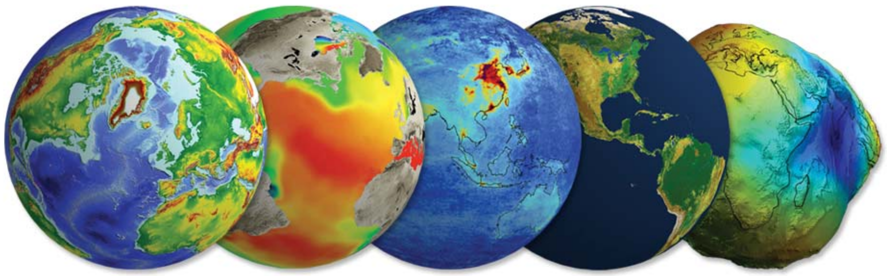
EOEP REVIEW SEMINAR

Development of Earth Explorer Missions

15 -16 June 2011



Contents

The Earth Explorers - 3 satellites in orbit

GOCE launch
17 March 2009

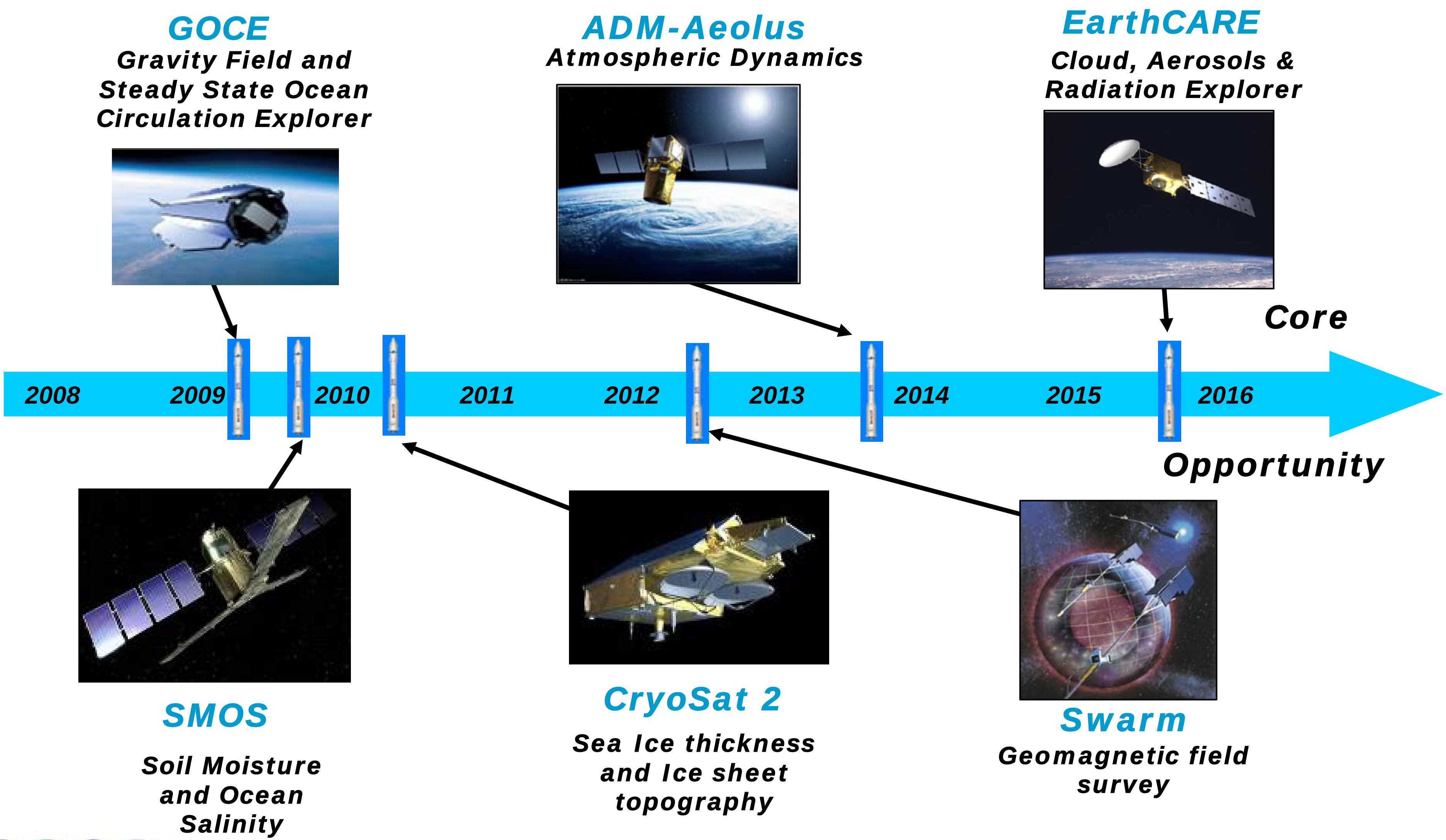
SMOS launch
2 Nov 2009

Cryosat-2 launch
8 April 2010

The Earth Explorers

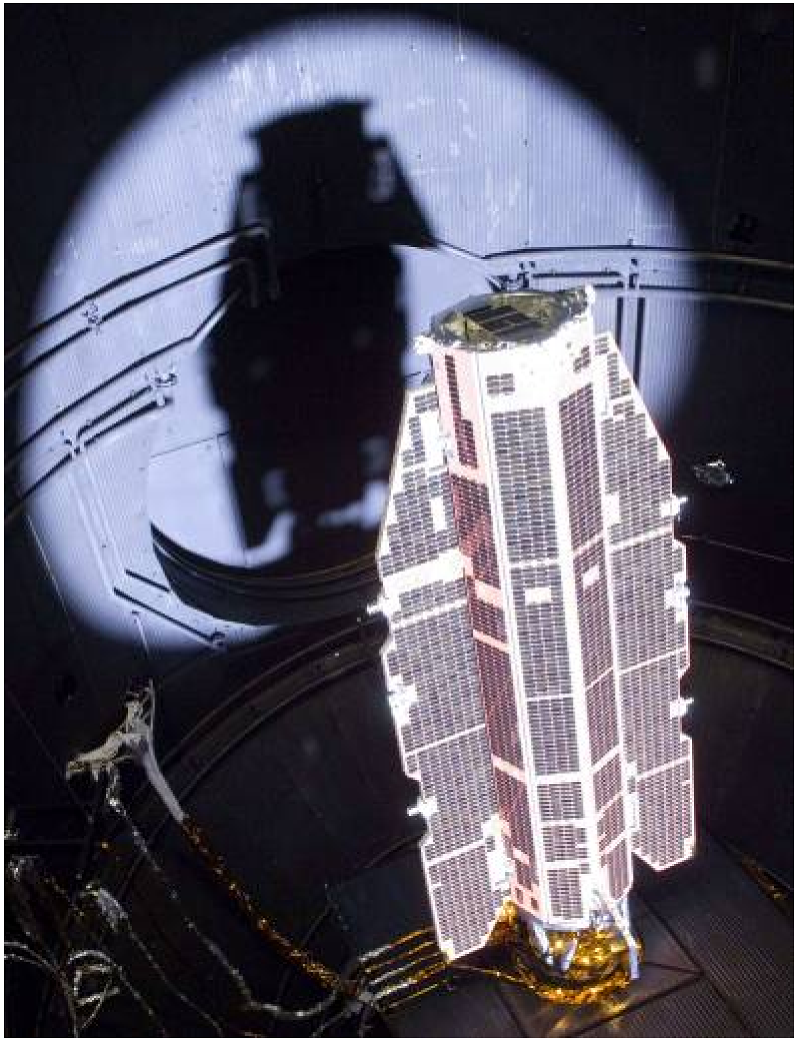
- EOEP-3 has seen the completion and launch of three Earth Explorers (four including CryoSat-1), namely GOCE, SMOS and CryoSat 2 and the further development of Swarm, ADM/Aeolus and EarthCARE
- We had three successful launches in 14 months, two from Plesetsk and one from Baikonur
- All launched satellites fulfil their requirements in spite of technologically challenging nature of Explorer Programme
- GOCE has already completed its nominal mission and its operations have been extended, SMOS and CryoSat 2 are in their nominal mission phases
- Next launch will be in the summer of next year for the three Swarm satellites
- ADM/Aeolus and EarthCARE launches are planned before end 2013 and 2015, respectively.

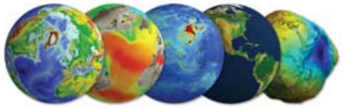
The Earth Explorers Family



GOCE - Gravity field and steady-state Ocean Circulation Explorer

- First Earth Explorer Core Mission approved by the 77th PB-EO, Nov. 1999
- Phase B kick-off Dec. 2000
- FAR April 2008
- Launch 17 March 2009
- Launcher related problems introduced 1 year delay between FAR and launch
- Nominal mission accomplished in February 2011
- Mission extension till Dec. 2012 approved by 137th PB-EO, Nov. 2010

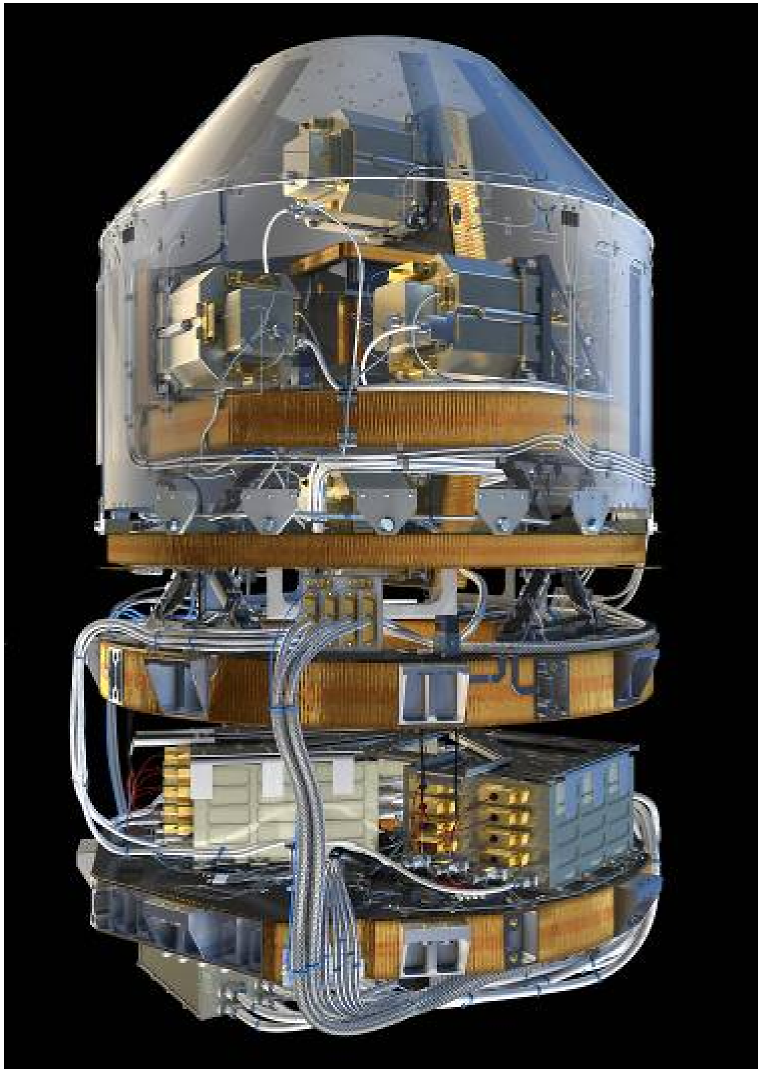


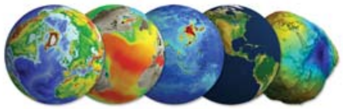


GOCE - Gravity field and steady-state Ocean Circulation Explorer

GOCE development has represented a major technological challenge:

- First space borne 3 D gradiometer instrument
- Ultra-sensitive gradiometer accelerometers
- Ultra-stable carbon/carbon gradiometer structure
- 12 channel GPS receiver with geodetic quality
- Drag free attitude control system
- Ion propulsion with accurately modulated thrust amplitude
- No moving parts and no thermo/mechanical induced disturbances
- Very low orbit altitude (~ 250 Km)





GOCE - Gravity field and steady-state Ocean Circulation Explorer

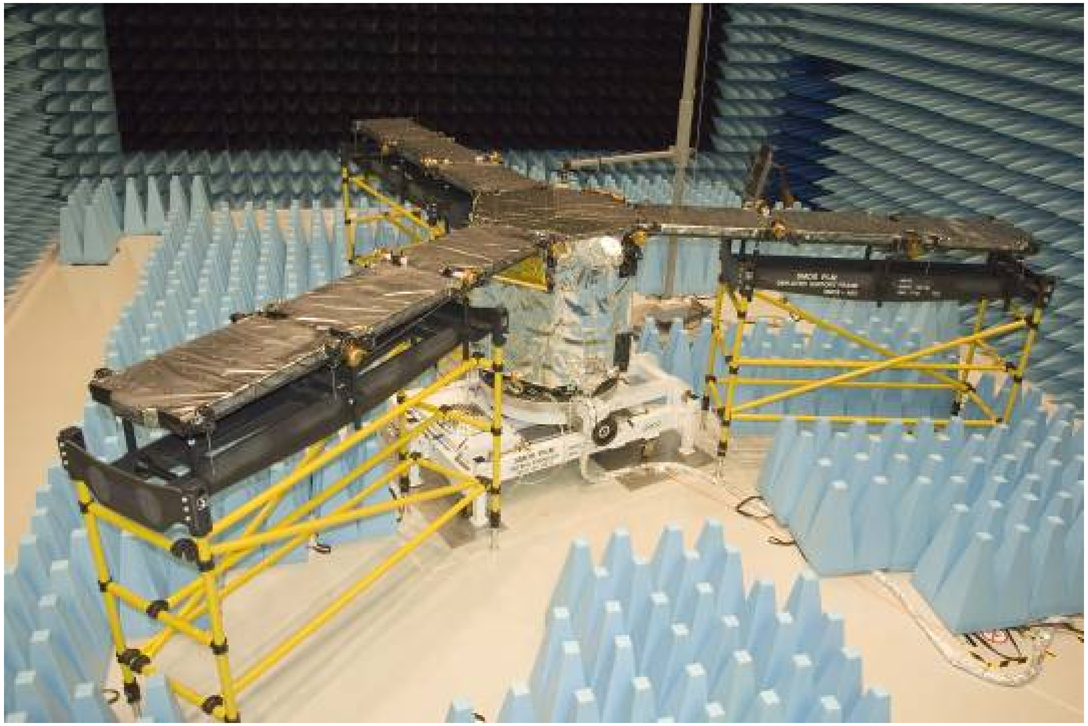
- Phase B was completed in 1.5 years and Phase C/D in 6 years
- GOCE development took 3.5 years longer than estimated at mission selection
- GOCE is the first Earth Explorer (EE) which has already completed its nominal operational phase and we can look back at the main features of its development to get a better understanding of the challenges inherent to an EE development (see dedicated slides later in presentation).

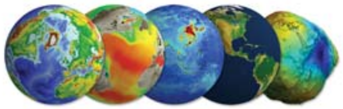
SMOS - Soil Moisture and Ocean Salinity Mission

- Second Earth Explorer Opportunity Mission
- Approved by the 97th PB-EO, Sept 2003
- Phase B kick-off January 2003
- Phase C/D kickoff August 2004
- FAR May 2009
- Launch 2 November 2009
- Launcher related problems introduced a launch delay of about of 1 year
- Phase B completed in 1.5 years
- Phase C/D in less than 5 years

SMOS - Soil Moisture and Ocean Salinity Mission

- Proteus platform provided by CNES in international collaboration
- MIRAS, a fundamentally new 2d interferometric passive microwave radiometer, its individual LICEF receivers, optical harness and DICOS correlator represent the new SMOS technologies
- Good preparatory activities carried out on payload technology and system definition prior to start of Phase B (i.e. 3 years of Phase A) have paved the way for the rather smooth development of the space segment



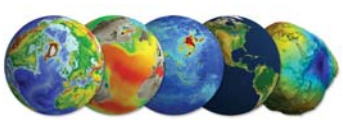


CryoSat 1

- First Earth Explorer Opportunity Mission approved by the 75th PB-EO, May 1999
- Phase B kick-off Aug. 2000
- Phase C/D kick-off July 2001
- FAR June 2005
- Launch failed on 8 October 2005

CryoSat 2

- Thanks to EOEP inherent flexibility it was possible to have the approval to rebuild CryoSat in about 4 months
  - Money for operations of Cryosat-1 could be immediately taken to procure long-lead items
  - Assessment of areas where change was needed was performed
    - Introduction of full redundancy in payload (SIRAL)
    - New S-band transponder (old transponder out of production)
    - New version of DORIS
    - PDGS update
  - Reconfirmation of Scientific priority of CryoSat mission, by science - community led to the decision to go ahead with CryoSat-2
- EOEP-3 was approved in Nov 2005 including Cryosat-2, no additional funds however were allocated
- CryoSat 2 was approved by the 113th PB-EO, 23-24 Feb 2006



CryoSat - Cryosphere Satellite Mission

- Phase C/D kickoff March 2006 (no Phase B)
- FAR November 2009
- launch 8 April 2010
- 9 months launch delay due launcher availability.

- Switch from Rockot to Dnepr was decided because price negotiations with Eurokot did not converge

Swarm - Earth Magnetic Field and Environment Mission

- Third Earth Explorer Opportunity Mission approved by the 100th PB-EO, May 2004

- Phase B kick-off December 2005
- C/D kickoff February 2007
- FAR planned for January 2012
- Launch planned July 2012

- Phase B was completed in 1 year
- Phase C/D planned to be completed in 5 years
- Launcher availability introduces a launch delay of 1/2 year.

Swarm - Earth Magnetic Field and Environment Mission

esa

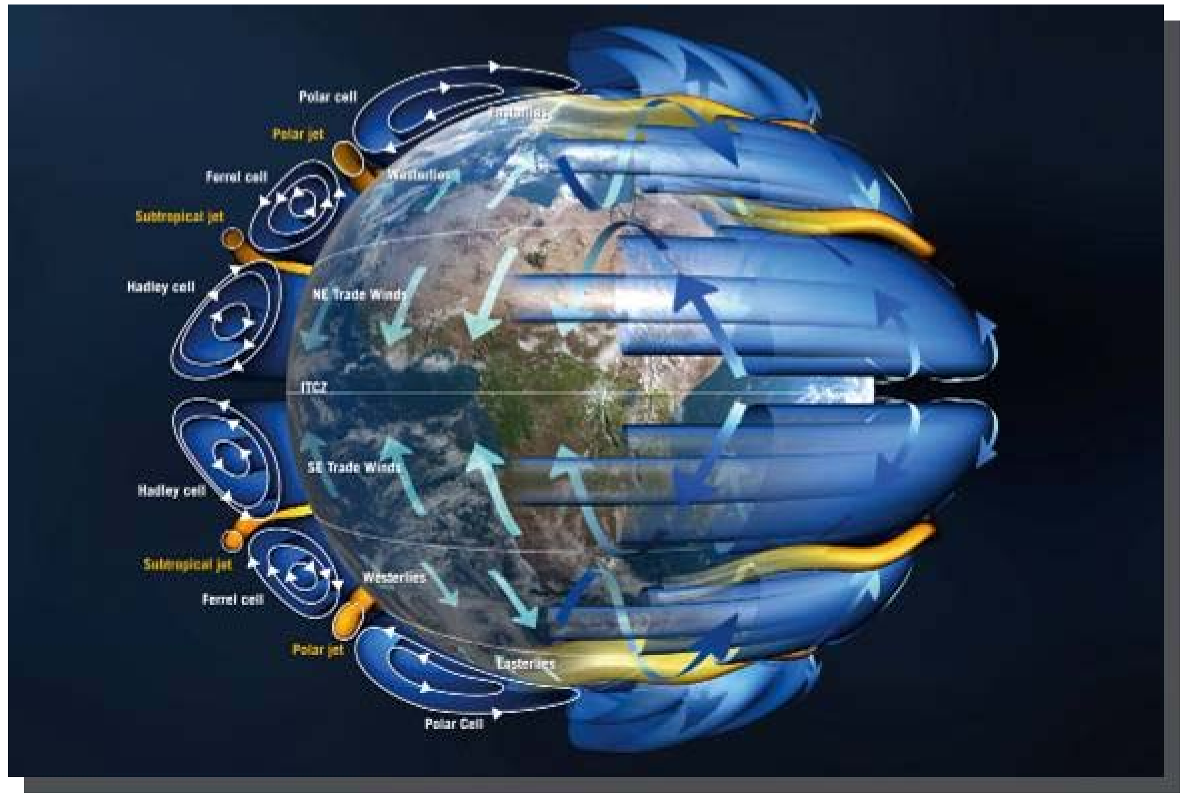
- Originally scheduled for first Vega (Verta) flight
- Vega unable to guarantee triple satellite launch
- Swarm development challenges:
  - first EO constellation, requiring uniform quality data from 3 satellites
  - first ESA EO mission with combination of Absolute Scalar Magnetometer; Vector Field Magnetometer; and Electrical Field Instrument
  - CFI instruments (ASM and EFI)

SWARM status

- Manufacturing of all 3 satellites has been completed
- Environmental testing is proceeding in a staggered approach with the completion of the TB/TV test of the Satellite 1 in November last year and the ongoing environmental test campaign on Satellite 2
- Payload:
  - VFM (Vector Field Magnetometer): Two models delivered and successfully tested
  - ASM (Absolute Scalar Magnetometer): all models delivered and successfully tested
  - EFI (Electrical Field Instrument: communication problem between EFI and On-Board Computer being worked on, 2 models delivered, will have to be refurbished
  - ACC (accelerometer): one unit delivered and successfully tested. Major success for the Czech company VZLU
  - GPSR, STR, LR all models delivered and successfully tested

- Satellite Qualification Review is completed.
- Successful first test to command satellite and its instruments (without EFI) from ESOC
- Nominal progress of ground segment & launcher dispenser developments

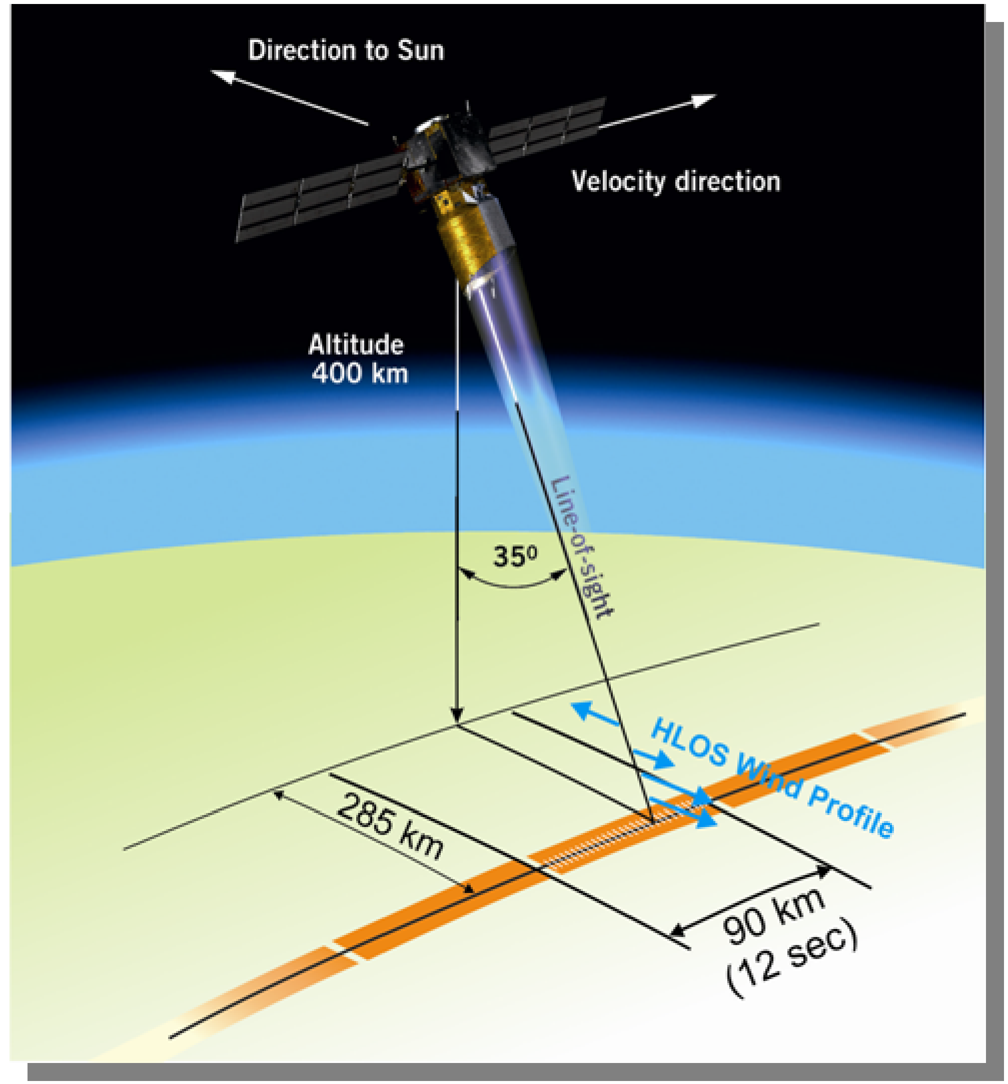
- Second Earth Explorer Core Mission approved by the 77th PB-EO, Nov. 1999
- Phase B kick-off July 2002
- FAR planned July 2013
- Launch planned Nov. 2013



ADM-Aeolus – Atmospheric Dynamics Mission

ADM-Aeolus specific aspects:

- Fundamentally new Doppler Wind Lidar with UV laser transmitter (ALADIN).
- Discovery of Lidar and UV Laser critical issues during development responsible for 10 year duration of Phase C/D.
- No a-priori experience with complete breadboard - many Laser related issues discovered and solved for the first time, e.g. LID margins, micron-stability of optics, LIC mitigation.
- Laser Expert Review advice taken on board - reconfiguration of instrument baseline to account for “Independent Laser Experts Report”



ADM / Aeolus - Summary of Status

Satellite: all subsystems are ready for satellite FM integration except for the Aladin Instrument and one panel of the platform where the In-Situ Cleaning System will be installed, satellite platform in storage since March 2010.

Aladin Instrument: all items are ready for instrument FM integration except for the Transmit Laser Assembly (TxA), the Transmit & Receive Optics (TRO) and the Instrument Electronics.

Ground Segment: Phase 1 of the Ground Segment Overall Verification has been completed including formal deliveries of level 1b and 2 ground processors and the end-to-end simulator for burst mode. Upgrade of ground processors supporting continuous mode as well as scientific impact studies are in progress.

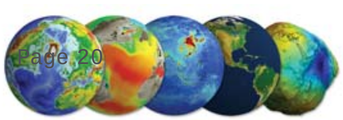
Launcher: Interface compatibility confirmed and contractual agreements in place for a baseline launch with VEGA (Verta2) and for a back-up opportunity on Rockot.

ADM/Aeolus - Items under Development

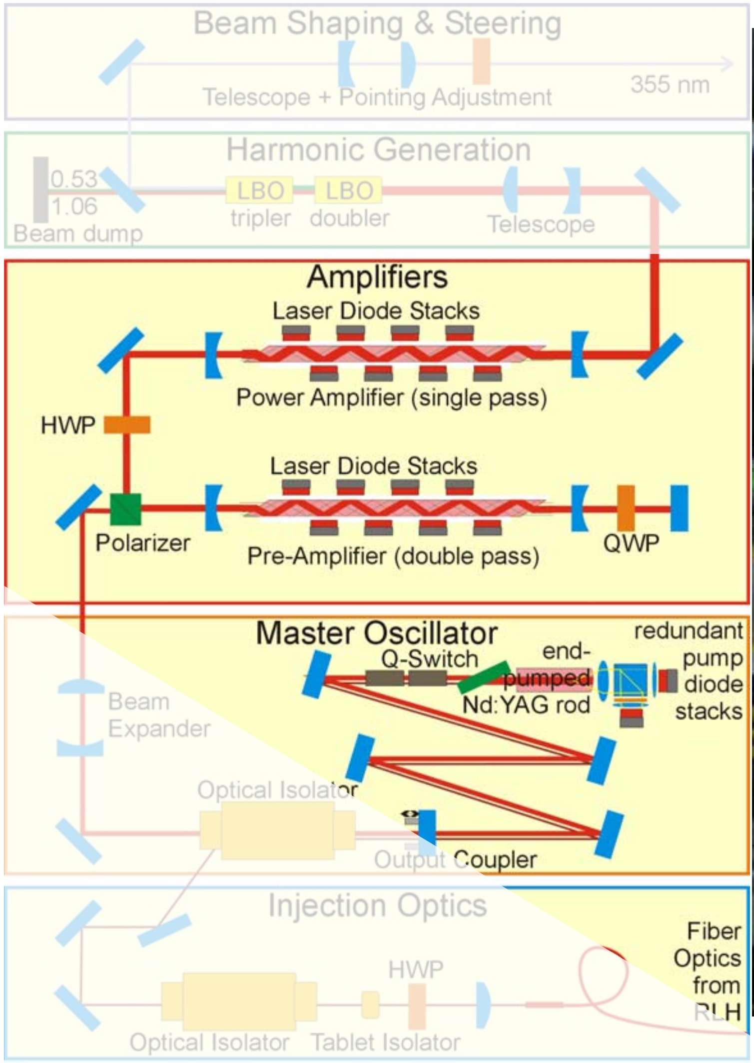
Transmit Laser Assembly: due to various deficiencies in the laser transmitter, the UV laser output performances could not be confirmed with adequate margins for end of life conditions; therefore, a number of corrective activities have been started to regain the required margins.

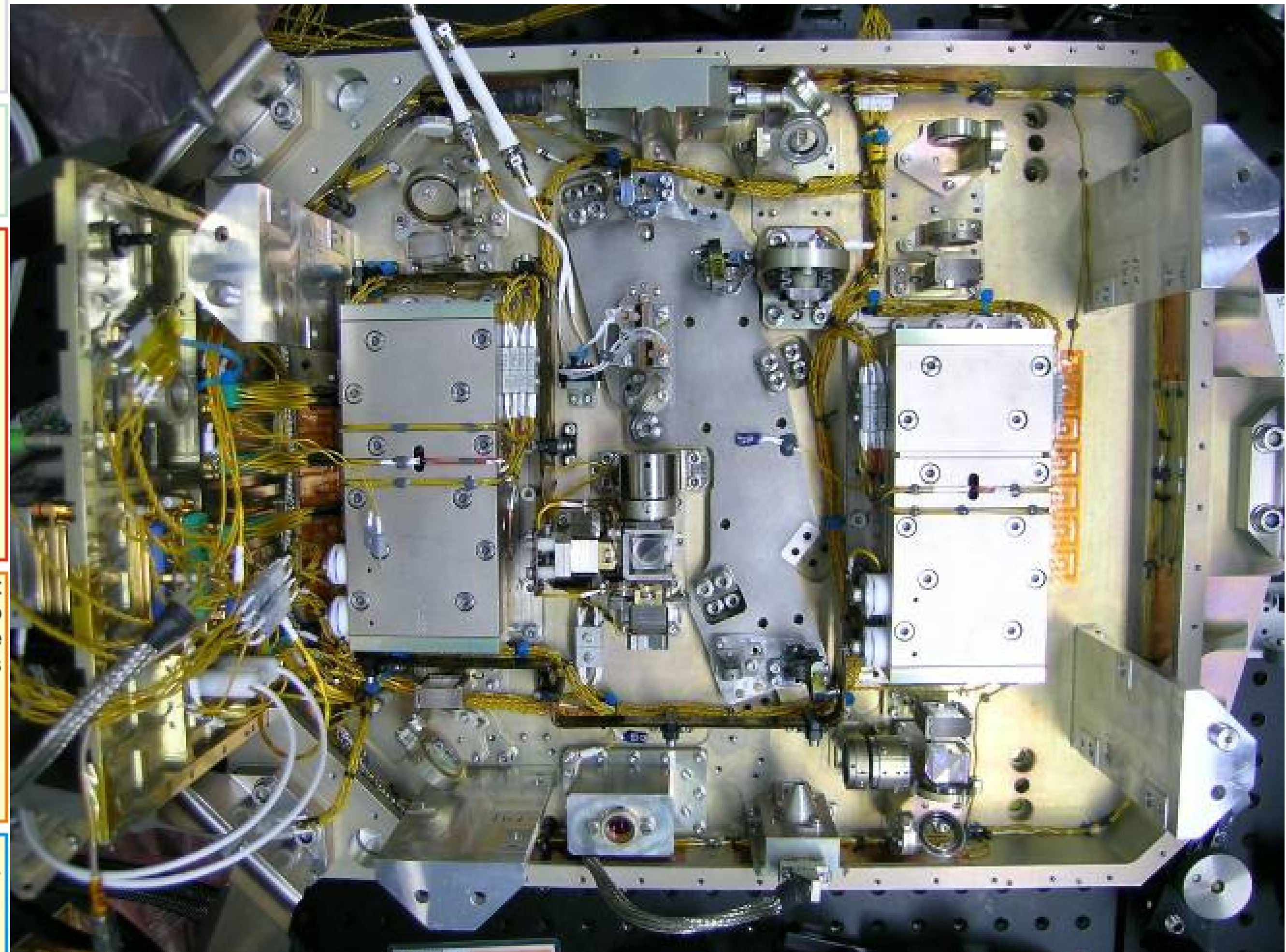
They can be summarised as:

- Introduction of the In- Situ Cleaning System to prevent Laser Induced Contamination
- Change the operational mode of the Aladin Instrument from burst mode, i.e. the laser is pulsed at 100 Hz for 7 second with a repetition time of 28 seconds, into continuous mode whereby the laser is pulsed continuously but at 50 Hz
- Modification of the attachments of pump unit amplifiers to the optical bench in order to stabilize the built in stresses in this over-constrained interface
- Introduction of a reproducible procedure to mount and remount the cold plate (water cooled GSE or heat pipe cooled FM) to the upper optical bench by using a special screw tensioning tool.
- Characterization and adjustment of the setting of the pump unit amplifiers in continuous mode operation such to enable the output beam quality to be matched with the harmonic stage requirements
- Redesign the harmonic stage which converts the IR laser beam into a UV beam, to obtain significantly higher conversion efficiency from currently <30% to typically 40%

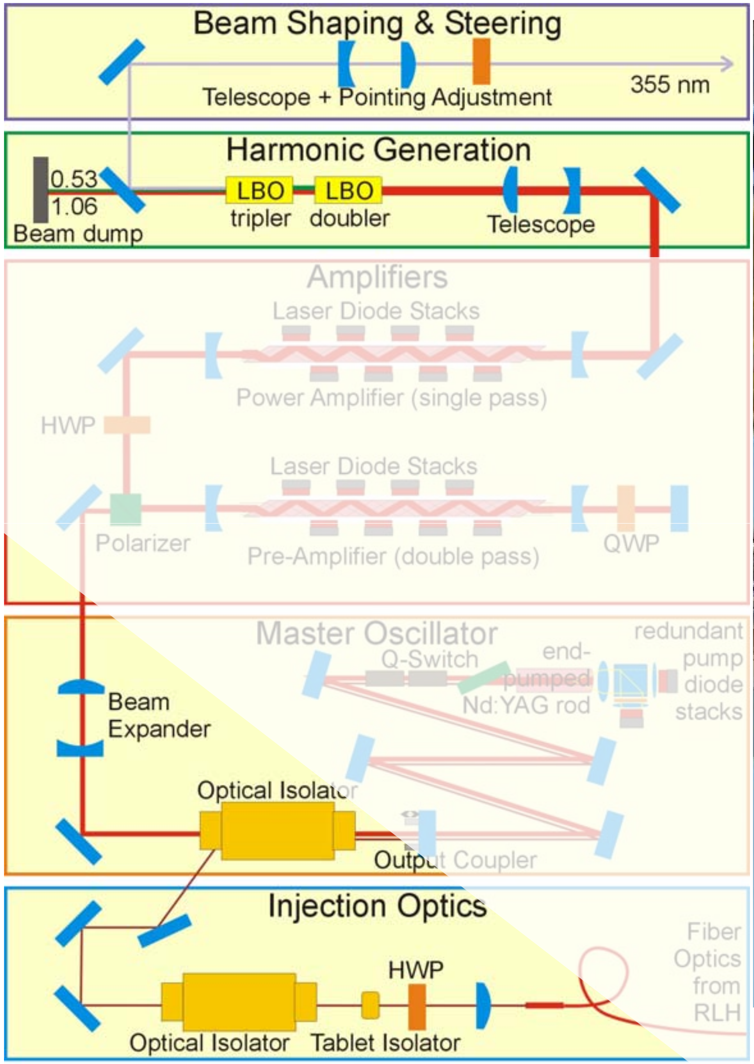


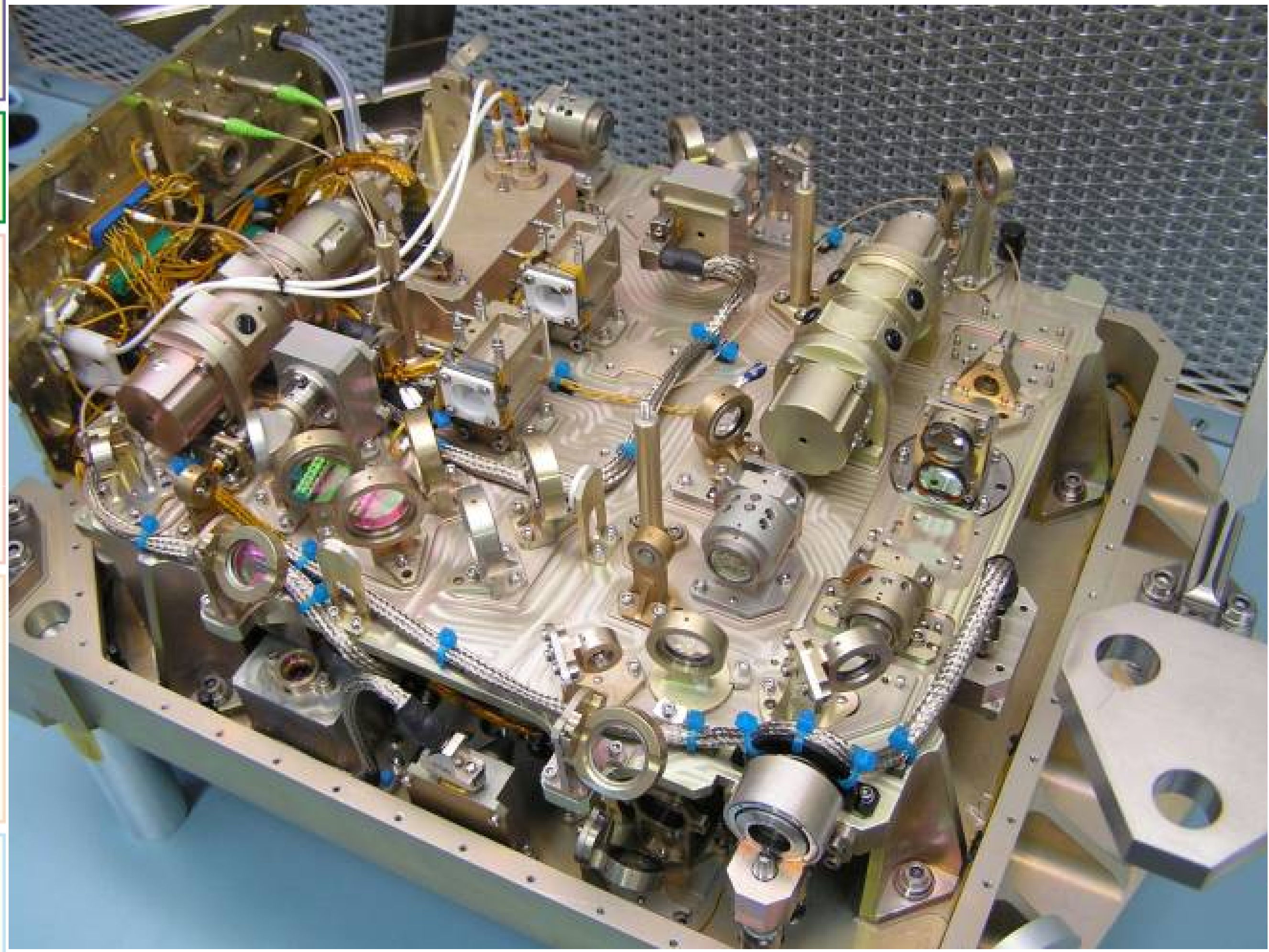
ADM / Aeolus - Upper Optical Bench





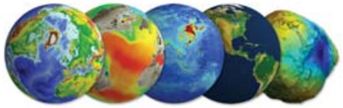
ADM / Aeolus - Lower Optical Bench





EarthCARE - Earth, Clouds, Aerosol and Radiation Explorer

- Third Earth Explorer Core Mission approved by the 103rd PB-EO, Nov. 2004
- Phase B kick-off February 2008
- FAR planned October 2015
- Launch planned end November 2015



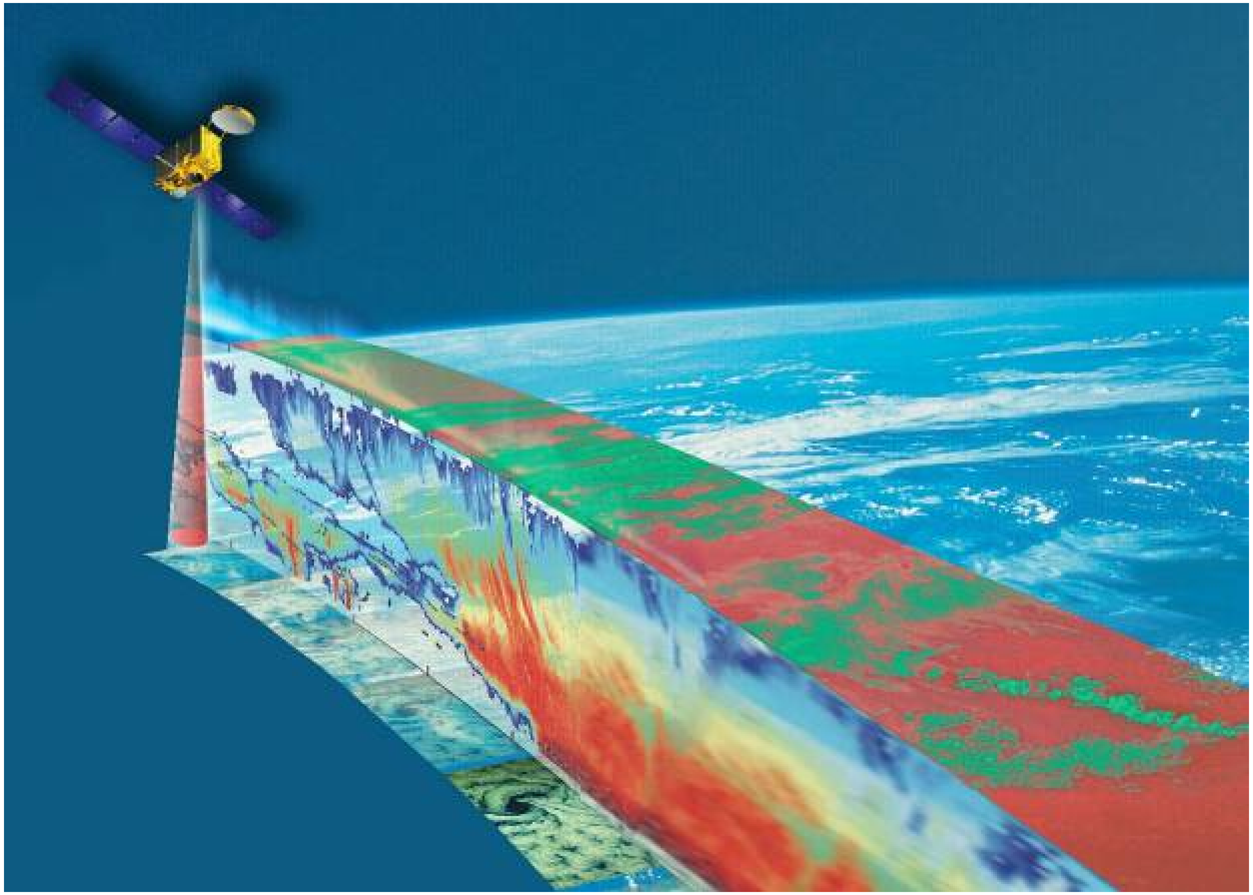
EarthCARE Mission

EarthCARE addresses:

- The impact of clouds and aerosols on radiation. Better understanding is needed to narrow down uncertainties in these components of climate system

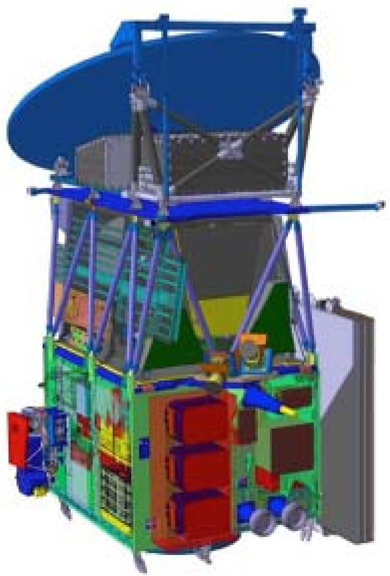
Key elements for selection:

- Synergetic approach using Doppler Cloud-Radar, Lidar, Multi-Spectral Imager, BroadBand Radiometer
- Joint European-Japanese science mission proposal

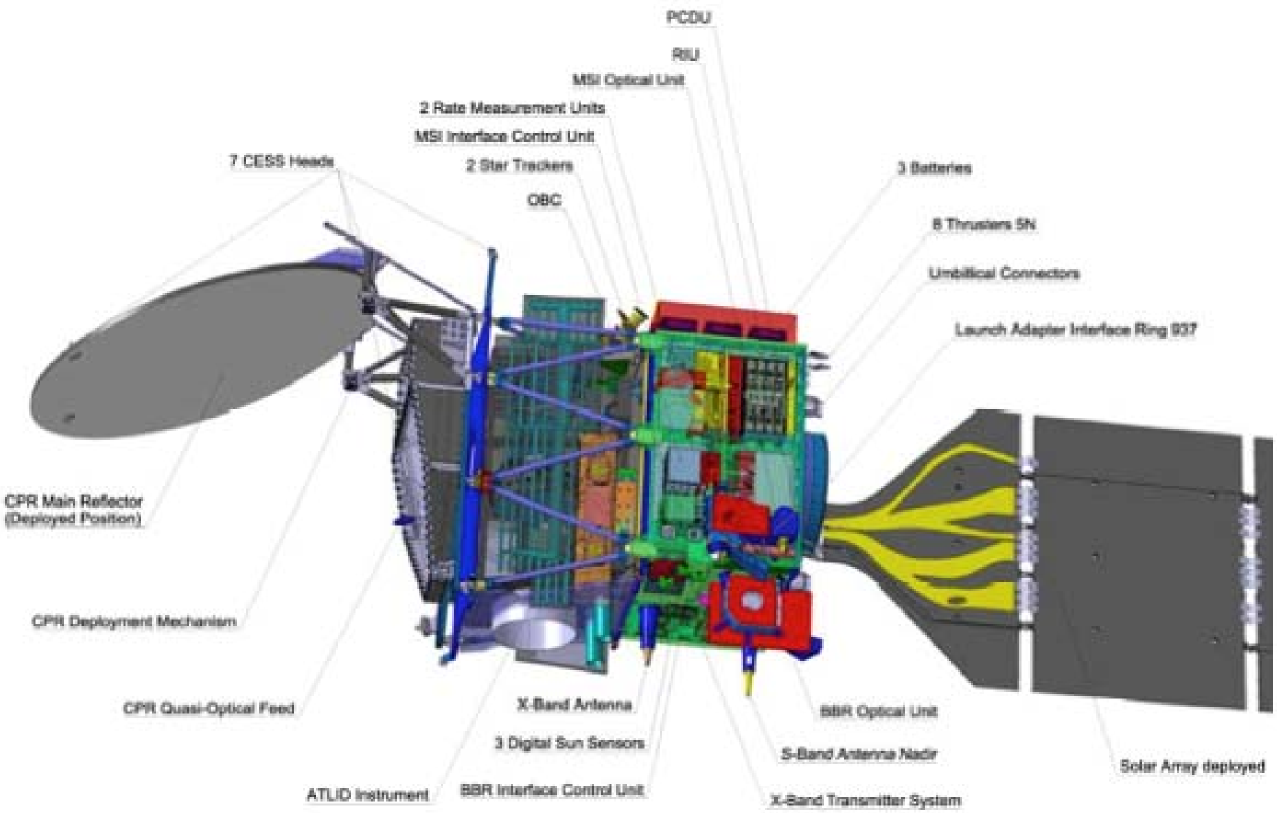


EarthCARE Main Project Milestones

- Industrial Phase A finished end-2003
- Presented to User's Consultancy Meeting in Frascati, April 2004
- Ranked as first priority Core EE by ESAC in April 2004
- Selected a 3rd Core Explorer Mission in November 2004 as per ESA/PB-EO(2004)110
- Phase A extension and Instrument pre-development until end-2006
- Phase B, C/D, E1 ITT in Feb-2007
- Phase B kick-off in February 2008
- System Requirements Review initiated in December 2008
- PDR initiated in Sep. 2009 but issue of LIC for ATLID instrumer led to reconfiguration from mono-static to bi-static concept: PDR2 in May 2010 & ATLID PDR Close-out in December 2010.
- Mission Independent Assessment in Period December 2010 to February 2011 confirmed mission objectives and payload complement.
- Presently preparing for full Phase C/D transition: CDR planned second half 2012.

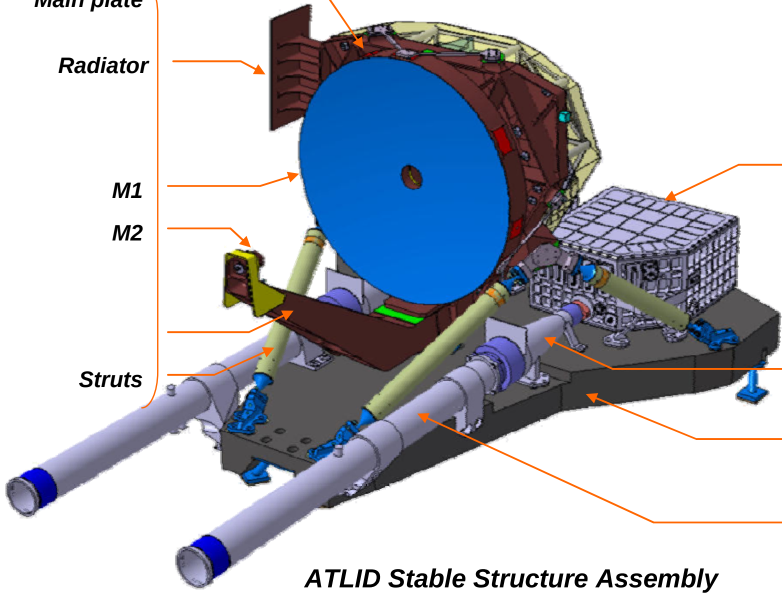


EarthCARE Spacecraft Overview

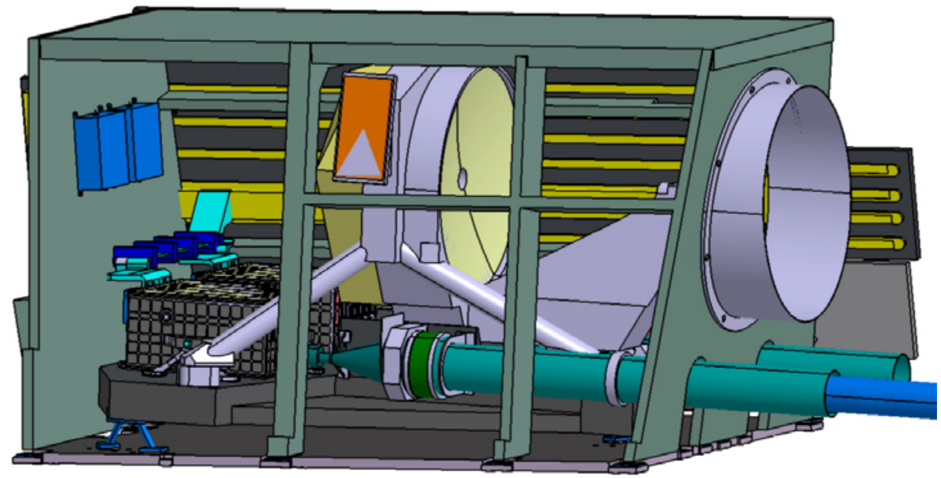


Mass : 2250 kg
Power : 1625 W

ATLID overview



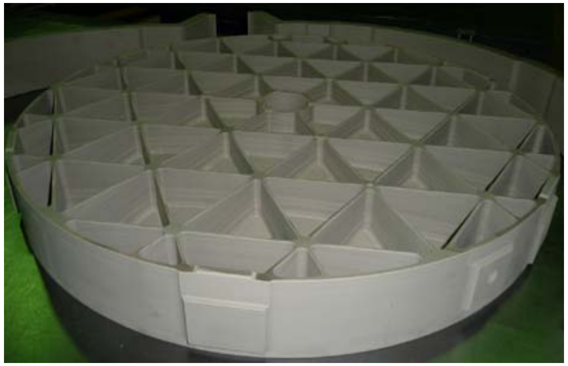
ATLID Stable Structure Assembly (SSA) and equipments

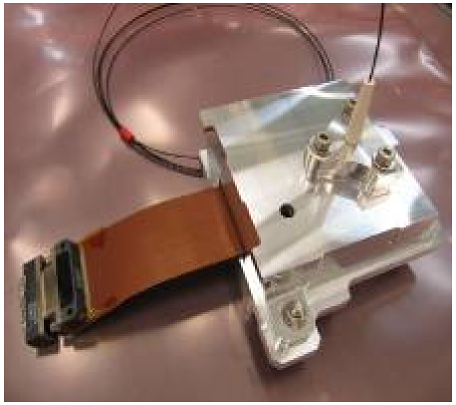


Mass : 479kg
Power : 554W
Data rate : 660kb/s

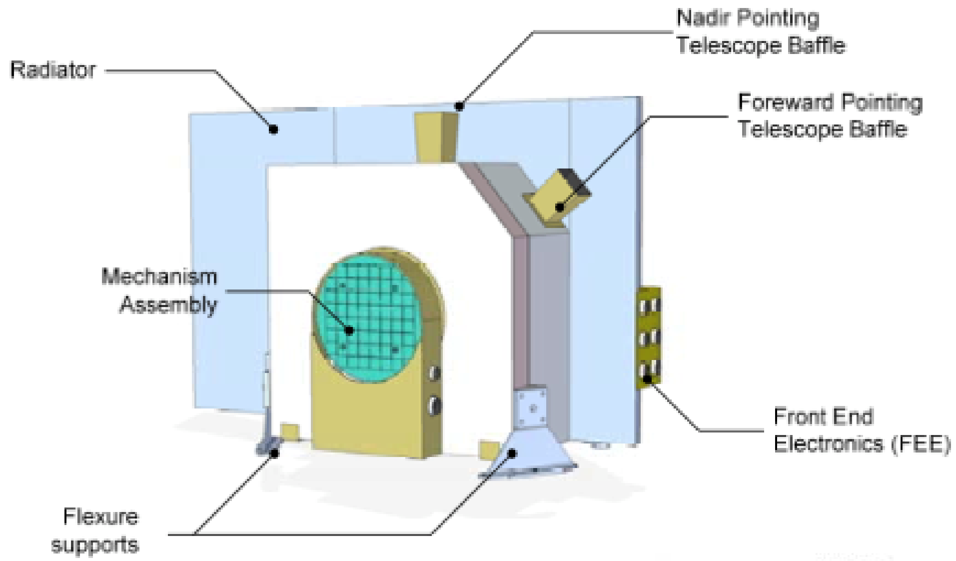
ATLID Development Status

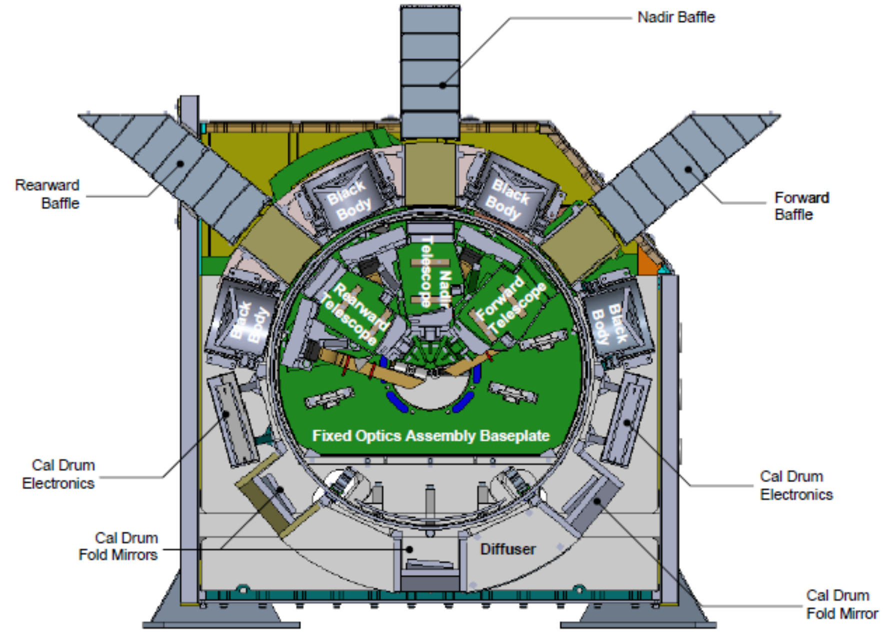
- Telescope primary mirror manufactured
- Detector : Breadboard tests in progress
- Detector-Fibre Assembly: Breadboard tests successfully completed
- Laser Cooling system : Breadboard tests in progress.
- Fibre coupler assembly: PDR successfully completed
- Instrument Control Unit : PDR close to be completed
- Instrument Detection Electronics, Etalons: subcontractors work initiated
- Other units (BEX, CAS, BSM, Structures): subcontractors selection in progress.

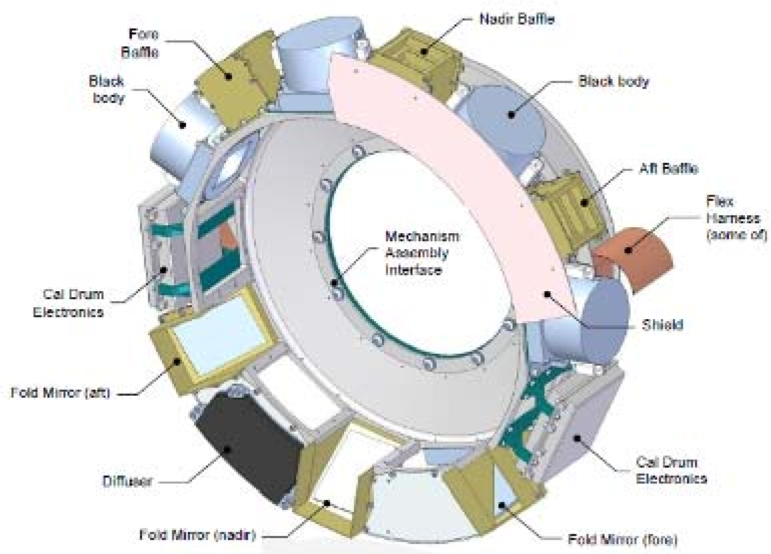




Broad Band Radiometer (BBR) overview



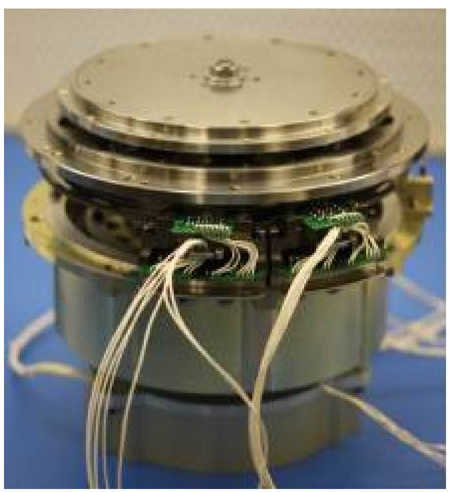


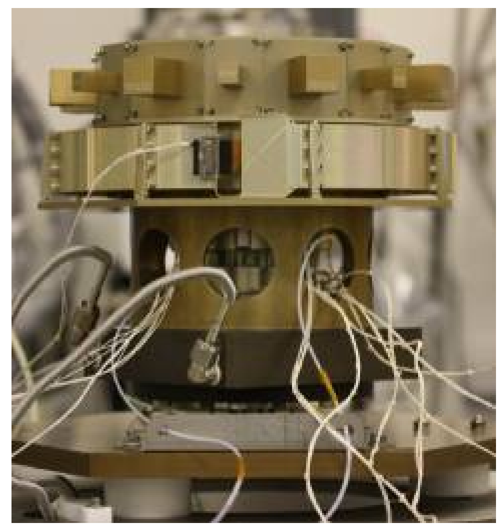


Mass : 46.6 kg
Power : 41 W
Data rate : 138 kb/s

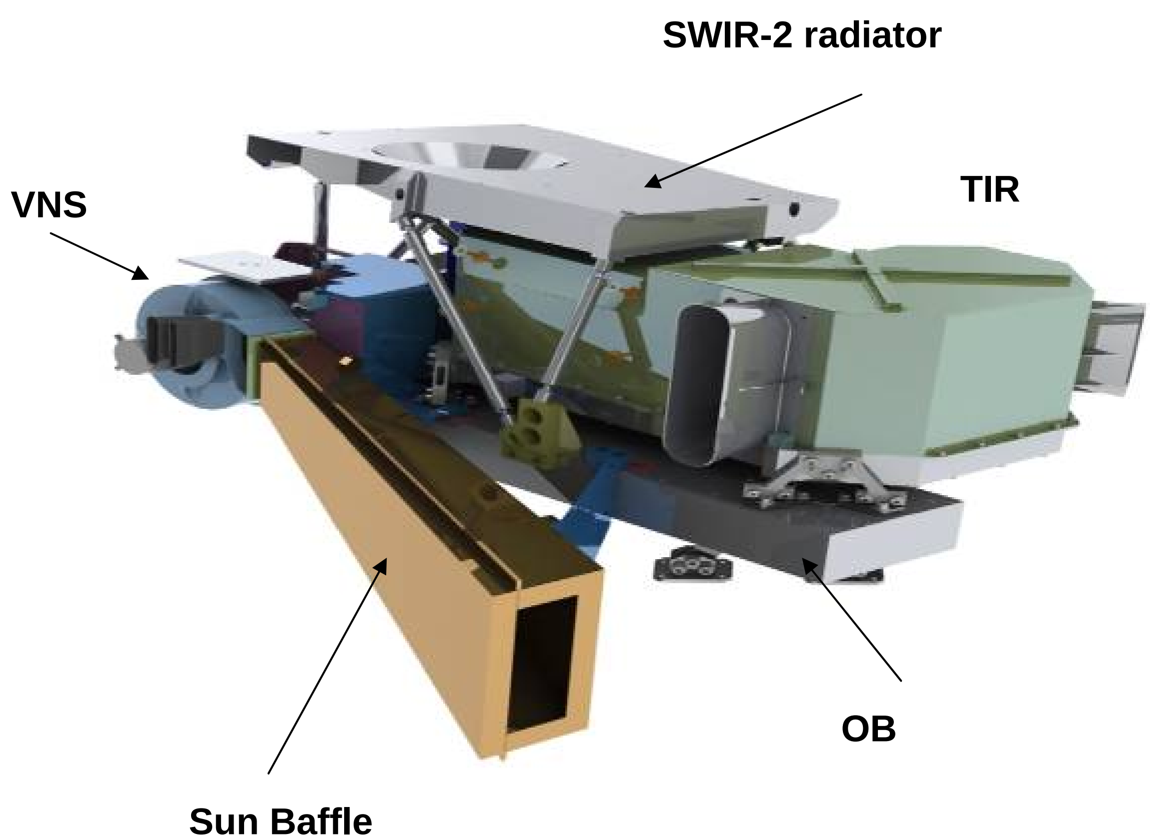
BBR Development Status

- Optics Unit Electronics CDR held 12-Nov-2010
- Mechanism Assembly CDR held 23-Nov-2010
- Optics Unit Structure / Thermal / Optics CDR held 24-Nov-2010
- Dummy drums (flight like) in use as part of mechanism Life Test Model
- Telescope CDR was held in March 2010
- Telescope mirrors (3 FM & 2 FS) delivered
- Detector µbolometer: manufacturing of FM detectors in progress
- Mechanism Life Test Model is ongoing





Multi - Spectral Imager (MSI) overview

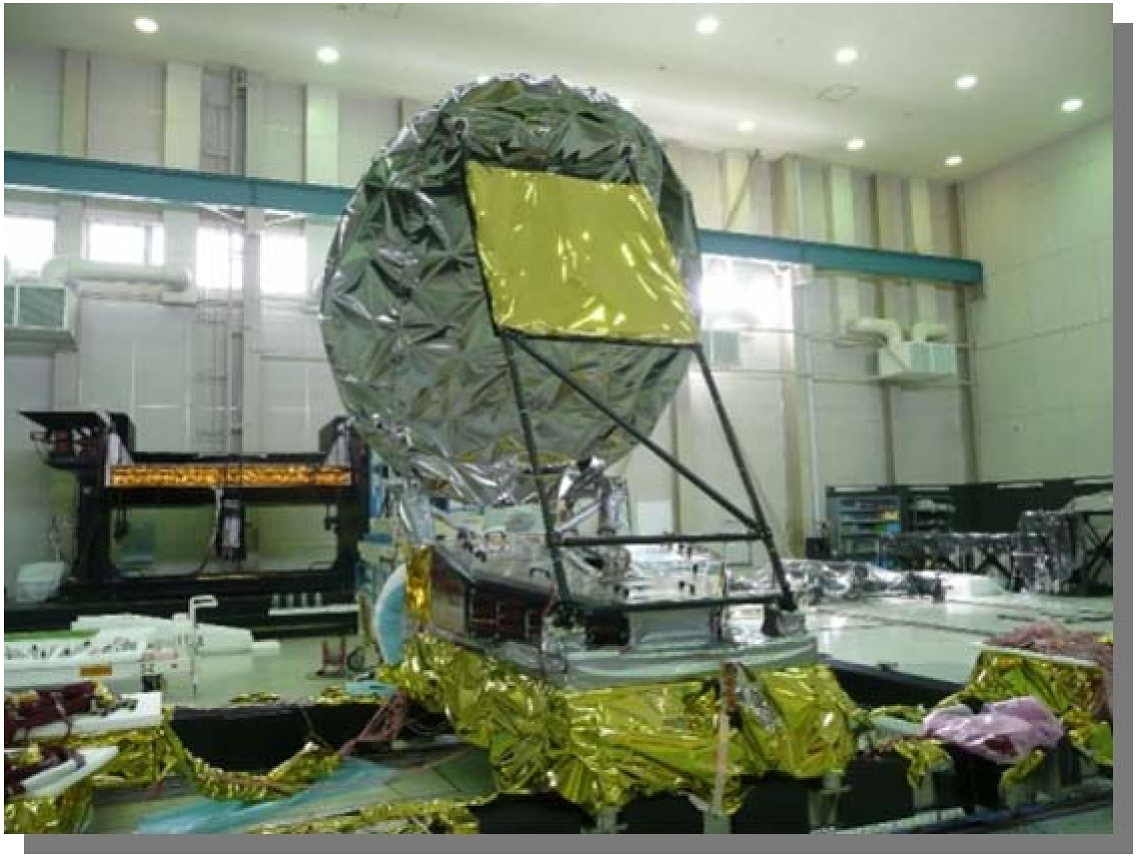


Mass : 57 kg
Power : 65 W
Data rate : 569 kb/s

MSI Development Status

- Instrument Control Unit, PDR completed in April 2011.
- Structural Model completed and tested with no major issues identified.
- Detectors for the Engineering Confidence Model to be delivered in May 2011.
- Engineering Confidence Model (ECM) manufacturing released, to be completed beginning of 2012.
- CDR planned for mid 2012.
- Flight Model to be delivered in June 2013

Cloud Profiling Radar (CPR) overview



Mass : 270 kg
Power : 370 W
Data rate : 272 kb/s

CPR EM outside the TV / TB test facility at the Tsukuba Space Centre

CPR SM/EM Development status

Test item	Status	Remarks
SM Deployment Test	Completed	2010/09
SM Mass Properties Test	Completed	2010/10
SM Sine Vibration Test	Failed	2010/10
SM Rework and Repair	ongoing	
SM Re-run Vibration	Planned	2011 - summer
SM Pyro Shock Test	Planned	2011 – summer
SM Delivery to ESA	Planned	2011 – Q3/Q4
EM Antenna Pattern Measurement (1)	Completed	2010/5~8, with test feed attached
EM Mass Property Test	Completed	2010/10
EM Initial Deployment – Pyro Shock Test	Completed	2010/11
EM Acoustic Test	Completed	2010/11
EM Interruption of Vibration Test (failure SM)		2010/11
EM installation of Quasi Optical Filter/Antenna	ongoing	
EM Antenna Pattern Measurement	Planned	2011 - summer
EM Mechanical Rework and Vibration test	Planned	after SM re-test
EM Final Deployment Test	Planned	Planned for 2011 – Q4
EM Electric Unit Integration & Performance Test	Planned	Planned for 2011 – Q4
EM EMC/EMI Test	Planned	Planned for 2011 – Q4

Part II

Generic principles and processes in work with industry

- ITT preparation for Phases B2/C/D/E1 after mission selection
- We request committing and credible proposals which already identify industrial Core Team
- Selection of industrial Prime Contractor and Core Team via open competition
    - Varying structure of core industrial consortia reflects size and complexity of missions
        - GOCE: system prime, platform and payload subcontractors
        - SMOS: system + payload prime, platform subcontractor
        - Cryosat: system + platform prime, payload subcontractor
- Selection of remainder of industrial consortium via “best practices” procedures during phase B2 / early Phase C/D
- Industrial procurement process and implementation of Phases B2/C/D is done according to well established ECSS standards and ISO9001 certified procedures.
- Regular milestone Project Reviews allow monitoring of compliance of system with mission requirements throughout implementation phase

Industrial structure of Earth Explorers

Project	Prime contractor	Number of subcontractors
GOCE	TAS-I	45
CryoSat	AST-G	36
SMOS	CASA	55
Swarm	AST-G	53
ADM/Aeolus	AST-UK	80
EarthCARE	AST-G	60

Scientific Advice during EE Development

- Mission Advisory Group (MAG) established to advise Implementation Teams (Space & Ground Segment) during Ph. B/C/D
- Scientist as MAG Chair (following EOEP-2 Review recommendation) - ESA Mission Scientist as Executive Officer/MAG convenor
- Direct feedback between MAG and Implementation Teams at MAG meetings and via the ESA Mission Scientist – Project team link
- MAG is engaged to resolve implementation issues: evaluating trade-off options, consequences of technological changes, and in risk mitigation
    - EarthCARE: ATLID performance evaluation of Green vs. UV
- MAG advice taken on specification of supporting campaigns and studies
    - Aeolus A2D airborne lidar campaign
- Assessment of potential science return risks via pre-launch study of failure cases and mitigation strategies
- Ph. E1 reconfiguration of Advisory Group to better respond to needs during Commissioning Phase Calibration and Validation

Mission Requirements Maintenance

- Mission Scientist responsible for preparing a consolidated Mission Requirements Document (MRD) in conjunction with the MAG for start of Ph. B2
- QMS/ISO 9001 process of mission requirements maintenance by Mission Scientist (strict configuration control of MRD)
- MRD Requirements baseline frozen at start of development phase
- The MRD is the single, top level document from which the implementation of the space segment and ground segment (i.e. level 1 and level 2 data processing) is deduced
- The System Requirement Documents (SRD) for the space segment and ground segment implementation translate the mission requirements into technical requirements that are made applicable to industry (via development contracts)
- Project Team (Space and Ground Segment) are responsible for the SRD and traceability to MRD via the Mission Scientist and Advisory Group
- Compliance of the system with SRD, and corresponding compliance of the performance with MRD checked through formal Project reviews

Safeguarding Mission Requirements

- Extensive use of End-to-End (E2E) simulators to safeguard science objectives and mission requirements, by evaluating performance impacts of any system changes
- Mission Requirements safeguarded for CryoSat, SMOS and Swarm
- Minor mission requirements adjustment during GOCE development (due to FEEP removal and final gradio performance)
- Mission Requirements adjustments during development of ADM-Aeolus and EarthCARE are thoroughly evaluated (see EarthCARE IA Report)

Missions Implementation: Science Perspective

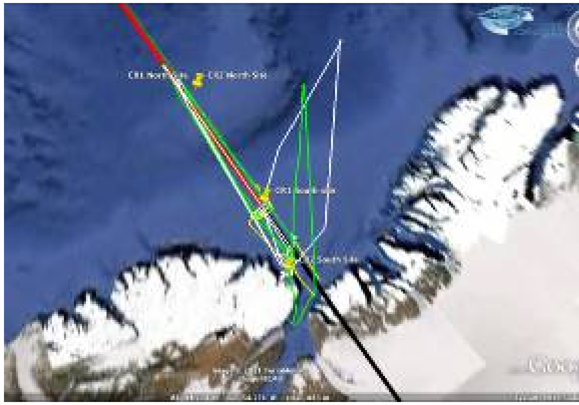
- Strived to continuously improve algorithms and final data product quality during development phase
- Supporting studies & campaigns initiated on basis of MAG advice benefited specification of modes of operation and used to improve retrieval methods
- Harnessing European expertise in scientific data processing – via distributed scientific data processing concept
- Impact Studies to prepare for optimal data use
- Frequent International User Workshops to report development status and to solicit scientific feedback/advice/recommendations

→ GOCE, SMOS, CryoSat-2 successfully commissioned – each met L1b performance specifications and data quality criteria applied at commissioning review

International Cooperation

- EOEP development activities have included some in-kind contributions:
  - SMOS – recurrent Proteus platform & Flight ops (CNES)
  - CryoSat - DORIS (CNES)
  - EarthCARE - CPR (JAXA)
  - Swarm – ASM (CNES)

- MAGs for EE missions (in development and candidates) each have a U.S scientific representative
- Participation of non-European experts to tiger team investigations (e.g. Aeolus)
- Cooperation agreement recently established with NASA
  - Extensive cooperation during ESA CryoVEx Validation Campaign, between NASA IceBridge and ESA airborne activities, and field teams
  - Planning of further areas of potential cooperation
- Cooperation agreement in process of formulation with ISRO



CryoVEx/IceBridge NASA DC-8 flight activities over Alert field site

Launchers situation for Earth Explorers

- Cryosat-1, GOCE and SMOS mission have used the Rockot Launcher, whereas CryoSat-2 was launched by Dnepr
- Prices of small Russian launchers have sharply increased in the past years (i.e. Rockot price doubled since the CryoSat-1 contract in 2002)
- Price of VEGA is substantially higher than current prices of small Russian launchers
- Future launches:
  - SWARM: Rockot
  - ADM/Aeolus: VEGA (Verta-2)
  - EarthCare: Soyuz
  - One Rockot is secured as generic backup
- Explorer class missions typically target small launchers and, in accordance to the European launcher policy, have to comply with the VEGA mass and volume limits

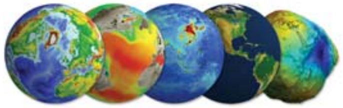
Specifics of implementing an Explorer Mission - example GOCE

- Earth Explorer satellites by nature explore uncharted territory both in science and technology
- Usually the payload is the most critical element which drives the overall project schedule (exception GOCE with complex payload – platform link)
- Even with proper technology preparation before mission selection, technological challenges will likely arise during qualification of fundamentally new hardware
  - Lesson learnt from UV laser application is to breadboard and test instruments to highest integration and operational level possible (e.g. in vacuum)
  - “mini-series” production issues (e.g the 6 accelerometers on GOCE) are difficult to mitigate before Phase C/D and will always pose schedule risks to Explorer type missions
- The following slides are intended to illustrate these challenges using the GOCE development programme as an example (i.e. could be any of the missions)

GOCE Phase B

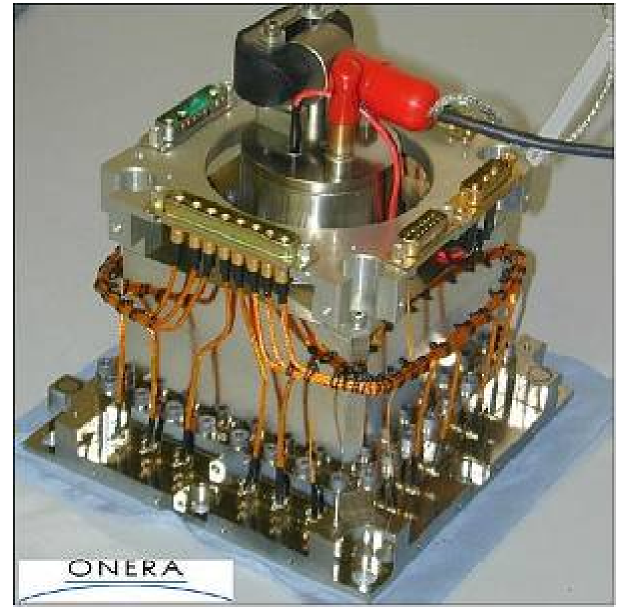
- Phase B schedule: Dec. 2000- April 2002
  1 year → 1.5 years
- Starting delayed of about 2.5 months wrt. initial planning due to IPC request of having a Contract Proposal Addendum submitted before giving its full authorisation to proceed
- Build up of industrial consortium from initial Core Team (TAS-I, ASG, TAS-F, ONERA) to final consortium of 45 companies in 13 European countries via Best Practices (e.g. preparation of more than 43 ITT packages, evaluation 85 proposals, negotiations, etc) could not be compressed beyond reasonable limits

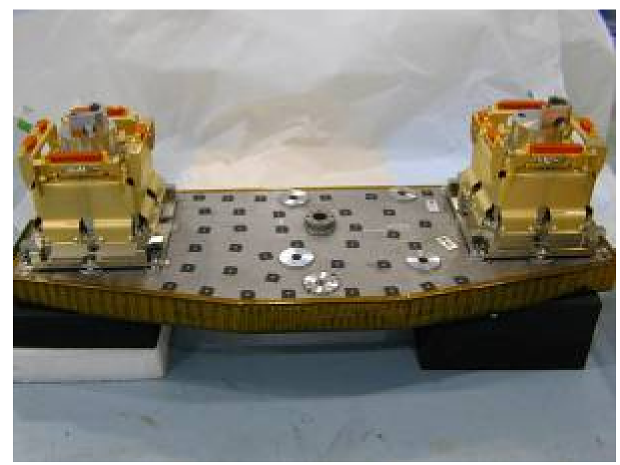
- Major efforts had to be spent during System PDR preparation in critical areas such as Gradiometer, Micro-Propulsion, Drag Free Attitude Control and Micro-disturbances.



GOCE Phase B – main criticalities at end of phase

- Micro-propulsion thrusters capable to fulfill the extremely demanding GOCE requirements.
- Selection of Field Emission Electric Propulsion (FEEP) thruster supplier not possible at the end of Phase B because of lack of technology maturity. Two companies kept in competition with the task to demonstrate feasibility and a minimum of lifetime by breadboard testing
- Capability of accelerometers to withstand the vibration launch environment (five times heavier proof mass than the one of GRACE accelerometers)
- Gradiometer electronics development due to the very challenging low noise requirements
- Gradiometer schedule as driving constituent of the overall critical path





GOCE Phase C / D

- Phase C/D: May 2002 - April 2008 3.5 years ←→ 6 years

Technology problems:

- One year after C/D start (i.e in mid 2003), due to failure of lifetime testing of FEEP thrusters, it was decided to disembark the MPA and to expand the use of the existing magnetic-torquers for compensation of air-drag disturbance torques. In addition, a simplified cold gas system had to be introduced to support the in-orbit calibration phase of the gradiometer.
- A new Gradiometer calibration method had to be elaborated and validated through an extensive simulation campaign

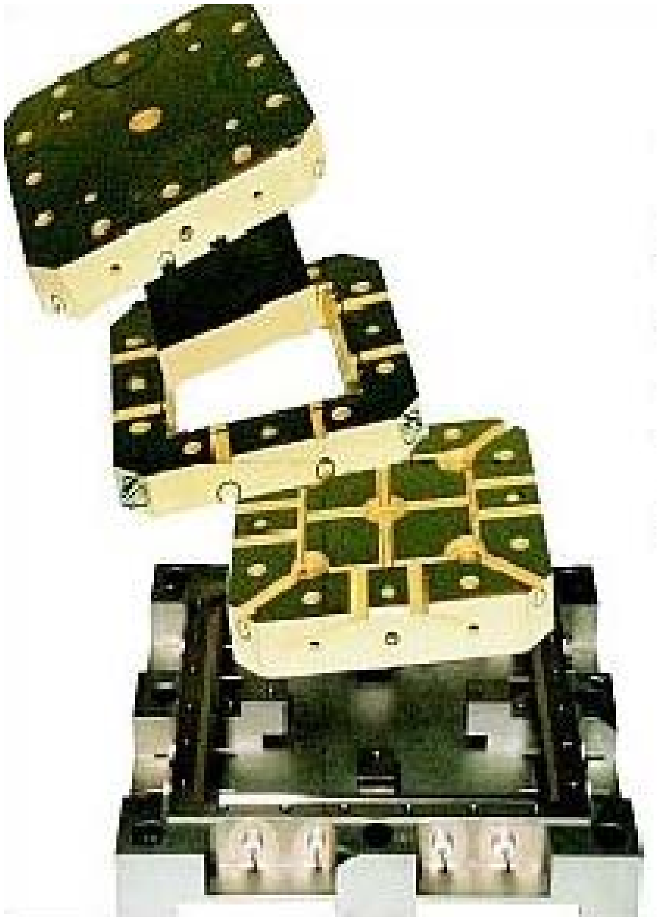
GOCE Phase C / D

Technology problems (cont):

- Inspection of the first accelerometer sensor head which had been submitted to mechanical testing revealed an unacceptable transfer of material between one stop and the proof mass.

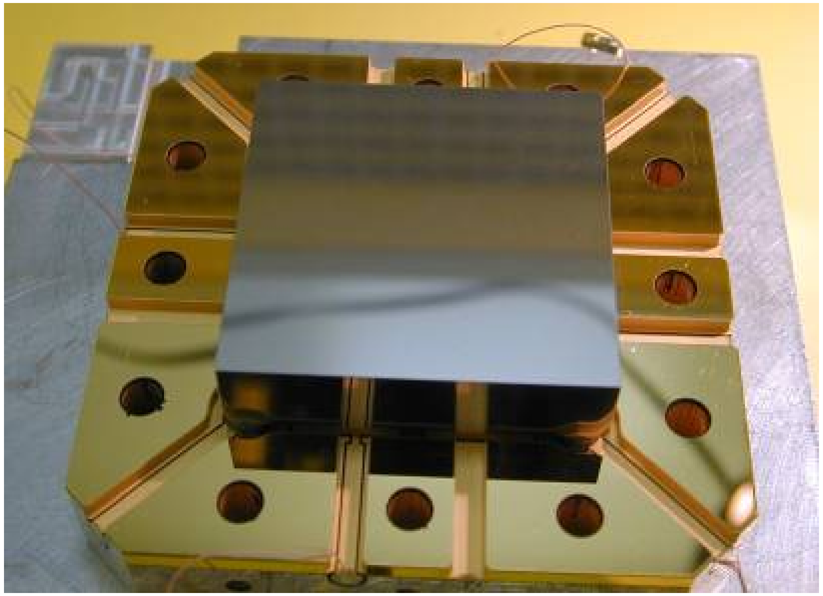
- Shape of the stops had to be modified and tribological tests aimed at finding best stop material and coating had to be initiated

- In the solar generator area , problems were encountered by the substrate supplier during testing of samples used to validate manufacturing process



GOCE Phase C/D

Several equipment failures were experienced during Phase C/D



In the Gradiometer:

- Mechanical endurance testing of first Accelerometer Sensor Head (ASH) equipped with newly shaped stops was interrupted because of the breakage of the Ultra Low Expansion (ULE) titanium silicate glass parts of the ASH core.
- Stiffness anomaly was present on several ASH flight models integrated at ONERA due to the presence of particles caused by contamination during integration and/or by the impacts of the proof mass against the stops during vibration testing.

GOCE Phase C / D

- Several failures occurred of the gold wire that connects the proof mass to the ground reference

- Due to above problems almost each of the six ASHs had to be re-opened at least once and sometimes two or three times. As a consequence, the last ASH was completed in mid 2007 and the last gold wire failure occurred in 2008 when the satellite was in ESTEC and the Gradiometer Core had to be re-opened to replace the failed ASH with a spare one.

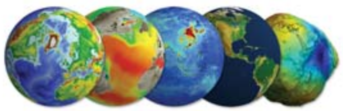
GOCE Phase C/D

Several equipment failures were experienced during Phase C/D in the Platform:

- Various GOCE units were affected by the ESA alert on Actel Field Programmable Gate ArraysTransponder (i.e. Command and Data Management Unit, Gradiometer Thermal Control Electronic Unit, Gradiometer Accelerometer Interface Electronic Unit and Gradiometer Front End Electronic Unit). Risk mitigation actions had to be pursued on a case-by-case basis.

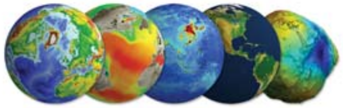
- In the area of the solar array, a delamination of the substrate occurred during the thermal vacuum testing of a qualification wing panel.

- A failure occurred also during final acceptance testing of the FM Ion Propulsion Control Unit.



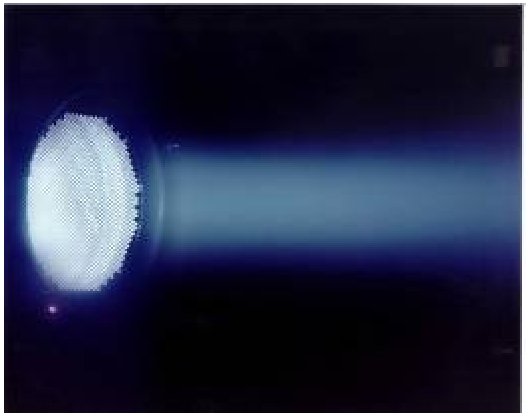
GOCE Phase C/D

- A severe set-back was encountered in July 2006 due to an over-voltage incident on the Platform PFM. An anomaly in the Electrical Ground Support Equipment (EGSE) triggered a chain of events which led to an over-voltage incident on the Platform PFM causing the failure of one power converter of the Command and Data Monitoring Unit (CDMU) PFM and stress on many electronic components of the Power Conditioning and Distribution Unit (PCDU) PFM. Both units were dismounted and returned to the respective manufacturers for replacement of affected components (several hundreds in the PCDU)
- Non-compliant leak rate was found on 4 thruster control valves used for the cold gas calibration system. The decision has been taken to dismount and clean all of them (nine in total).



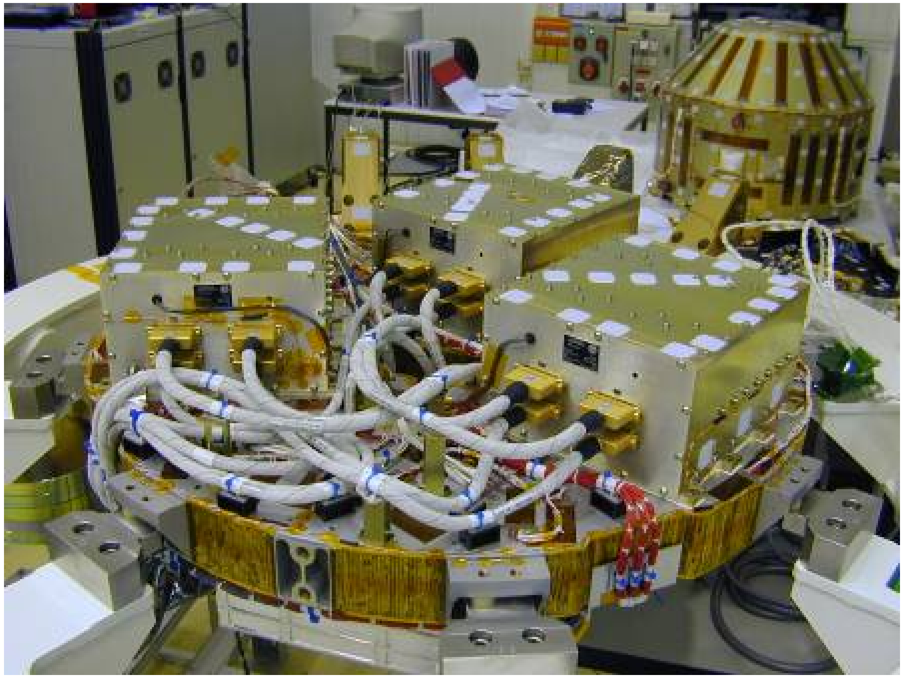
GOCE Phase C / D

- With regard to the Ion Propulsion Assembly (IPA), anomalies were detected during final acceptance testing of the overall IPA FM when firing the thrusters close to their maximum thrust level. A solution was found by inserting filters between the thrusters and the related power supplies.
- One of the two Satellite–to-Satellite Tracking Instruments (SSTI) was dismounted after satellite TB/TV testing and returned for investigations to the manufacturer. During the investigations, the unit suffered a mishandling. As a consequence, the mil-bus controller chip had to be replaced.
- The anomaly was detected during the last part of the satellite functional testing when the telemetry function of the Command and Data Management Unit (CDMU) had occasionally suffered spurious errors.



GOCE Phase C/D

Schedule recovery actions:



- To mitigate the consequences of the delay incurred in the production of the FM ASHs. The FM gradiometer electronic testing activities were decoupled from the FM gradiometer core which contains the FM ASHs by making a maximum usage of the existing Structural Thermal Model (STM) of the gradiometer core during the FM satellite level test campaign. In this way, the integration of the FM gradiometer core could be be accommodated as late as possible (i.e. after FM satellite environmental test campaign).
- Since 2006 satellite PFM integration and testing activities were performed, in double shifts, six days a week, in Thales Alenia Space (TAS-I) in Turin.

GOCE Phase E1

Phase E1 April 2008 – June 2009

0.5 years --> ~ 1

Launcher related problems introduced 1 year delay between FAR and launch:

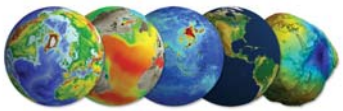
- Due to a failure of the Breeze upper stage on Proton, the Russian State Commission did put on hold all activities related to the Breeze programme, including Rockot launches. As a consequence, GOCE launch was shifted first from end May 2008 to 10 Sep. 2008.
- The Satellite arrived safely in Plesetsk on 31 July 2008. However, due to technical problems on the launcher side, the launch did not take place on 10 Sept. 2008 but rather on the 17th of March 2009.

GOCE Salient points

- GOCE development had to overcome significant challenges which, in spite of the constant attention given to schedule, have proven the initial estimate of 5 years for the Phase B/C/D/E1 planning to be rather optimistic.

- What distinguishes GOCE is the number of fundamentally new, critical technologies and the complexity of some of its equipment.

- Lesson learned: tech risk reduction of paramount importance prior to start of development phase and more realistic initial schedule and financial budget allocations have to be accounted for this type of satellites.

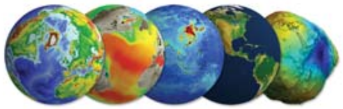


Earth Explorers balancing affordability and innovation

- Albeit the technical complexities of first 3 Explorers their final costs are within reasonable bounds (as concluded by Cost and Calendar Review - ESA/C/WG-M(2008)24).
- As a concept, Core Missions are at the limit of technological feasibility and deploy fundamentally new technologies; while Opportunity Missions apply existing technologies in a novel way. Both with the aim to achieve breakthrough science.
- Novelty of Opportunity Missions:
  - CryoSat: addition of SAR-In processing to conventional altimetry
  - SMOS: novel 2D synthetic aperture interferometric antenna to achieve broad swath to advance on previous Skylab L-band real aperture radiometry
  - Swarm: multi-satellite constellation approach to time varying magnetometry beyond single satellite approach (Oersted, Champ)

Earth Explorers balancing affordability and innovation

- Novel, breakthrough mission concepts typical for Core Explorer Missions (gradiometry, UV lasers) require substantial technology pre-development
- They also require more time and funds during Phase C/D because even with adequate preparation, technological difficulties are more likely to arise during qualification and production of fundamentally new flight hardware.
- For innovative missions, a strict design-to-cost approach leads to a greater likelihood of de-scoping performance requirements during the development phase.
- On the other hand mission calls, which from the outset impose cost cap, realistically lead to concepts characterized by a high level of technological maturity but less innovative science.
- ***Consequently, the essence of EOEP is for the Earth Explorer Missions to have a balance between achievability, affordability and innovation, within schedule constraints.***
- ***A fully funded EOEP is needed in order to ensure frequent launch opportunities for new Earth Explorer Missions***



Conclusions

- Development of first 3 Explorers has mastered extremely challenging new instrument technologies
- Diligent efforts have been made to uphold mission requirements throughout development – via interaction with MAG
- EE satellites work successfully and according to system specifications, and performance at L1b data products have been verified through successful commissioning Cal/Val activities
- EE missions prepare the ground for applications with operational use
- EE provide continuity of mission opportunities to the European science community and to European industry
- The nature of the EE at the forefront of science and technology allows European industry to advance in new technologies and gain an advantage edge for their commercial business.

THANK YOU