The Preparatory Activities for ESA’s Earth Observation Programmes

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1. Mission preparatory activities
   • what they cover and how
2. Technology preparation
   • some achievements
3. Recent contributions from Italian EO community
4. Preparatory activities in EOEP-4
5. Examples of mission concepts for future studies
6. Conclusions
What do preparatory activities cover?

EOEP (Earth Observation Envelope Programme) has the task of preparing all ESA EO missions until start of implementation, under 3 lines:

1 - Earth Observation Preparatory Activities, EOPA:
- establishment of scientific objectives, including scientific studies
- derivation of mission and system requirements
- instrument, satellite system and mission feasibility or concept studies
- initiation, harmonised with other programmes, of critical technology developments
- identification of cooperation possibilities and related preparatory studies
- architecture and concept studies for new missions and end-to-end systems
- supporting scientific and campaign activities

2 - Earth Watch Definition, EWD:
- all aspects of preparation of Earth Watch type programmes
- studies involving Partners (institutions, Member States, and industry) prepared to contribute to the mission

EW type missions rely upon partners (EC, EUMETSAT, industry), established user communities or their representatives for their definition

3 - Instrument Pre-Development, IPD:
- design and manufacturing of early breadboard or downscaled version, representative of technologies, assembly and verification of full instrument
Overview of preparatory activities in EOEP

1. All the activities required to define and evaluate future missions (Earth Explorers, (pre-) operational missions, new concepts,..)

2. Driving elements include:
   - ESA’s Living Planet scientific challenges, currently as per summary in “The Changing Earth”, ESA SP-1304
   - associated observation, mission and technology requirements
   - mission preparation through Phase 0 (pre-feasibility) and Phase AB1 (feasib.)
   - foster new ideas, cooperation opportunities and prepare technologies, also for European independence and competitiveness
   - ESAC guidance, user communities / industry feedbacks
Earth Explorers: the process in practice for a Core mission... (I)

Core Missions – Phase 0

- Call for Ideas
  - Peer Scientific Evaluation Technical/Prog. Evaluation
  - ESAC Recommendation
  - PB-EO Selection

- Call for MAG
  - MAG nomination
  - MRD preparation
  - Science support / RfA

- Phase 0 System studies Procurement Proposal
  - AC/IPC
  - Phase 0 System ITT preparation
  - Proposals Evaluation
  - Phase 0 System Studies (2x) KO

- Science Support Activities – ITT’s preparation
- Technology Support Activities – ITT’s preparation
- System Support Activities – ITT’s preparation

Report for Assessment

User Consultation Meeting - ESAC Recommendation

Funding sources:
- EOPA; IPD
- TRP(GSTP); GSP

out of EOEP framework
Earth Explorers: the process in practice for a Core mission... (II)

Core Missions – Phase A/B1 (EE7)

Call for MAG → MAG nomination → MRD consolidation → Science support / RfS

Phase A System studies Procurement Proposal → Phase A System ITT preparation

Science Support Activities ITT’s preparation

Technology Support Activities ITT’s preparation

System Support Activities ITT’s preparation

End-To-End Mission Performance ITT’s preparation

PB-EO Selection

User Consultation Meeting - ESAC Recommendation → PB-EO Selection

2x Phase B1 (selected mission) → Phase B2/C/D/E1 Procurement Proposal

AC/IPC → Start B2/C/D/E1
What does it mean in practice?
An example of EE Core Phase A

**Example: BIOMASS (candidate EE7 mission)**

**System (4 M)**
- BIOMASS Phase A System Study (x2), addressing:
  - Space segment: payload, platform
  - Mission analysis and operations
  - Launcher
  - Ground segment
  - Critical technologies
  - Programatics

**Science (1.1 M) and Campaigns (1 M)**
- Development of algorithms for forest biomass retrieval
- Study of ionospheric disturbance mitigation schemes
- Assessment of the BIOMASS retrieval error on flux
- P-Band SAR wave interaction and information retrieval
- Analysis of BIOMASS secondary objectives
- TropiSAR campaign
- TropiScat campaign
- BioSAR 3 campaign

**Technology (3.5 M)**
- Large P-Band SAR antennas critical breadboard (x2)
- Very Large P-Band Antennas performance verification methodology & Facilities
- P-Band HPA technology assessment
- P-Band Reflector antenna Feed elements
- SSPA breadboard (incl. circulator/switch, power divider and calibration coupler) (x2)
- Study of P-Band transponder with ionospheric correction capabilities (x2)

**End-to-end Performance Evaluation and System Support (1.3 M)**
- BIOMASS End-to-End Mission Performance Simulator
- OpenSF end-to-end simulator framework infrastructure
- Modern attitude control of EO satellites with large flexible elements (x2)

> 20 activities for one candidate mission!
Approach to preparatory activities: key features

1. **End-to-end approach** with all aspects covered: science, space and ground segments, launcher, processing, end-to-end mission performance (science-engineering simulators), programmatic (cost, development plans)

2. **Array of coordinated activities**, with parallel contracts for **competition** and **alternative solutions**

3. Optimal use of other funding sources than EOEP, interacting with relevant processes (e.g. TRP 3-years planning, GSP Calls, GSTP,...)

4. EOEP provides **flexibility** to cover all types of activities, adding new ones as issues arise (e.g. campaigns to clarify assumptions on sensing physics)

For operational missions: similar complexity as for EE but no competition among missions

For meteorological missions:

- user community and relevant interfaces managed by EUMETSAT

For GMES missions:

- GMES architecture and Sentinel studies, driven by enhanced continuity through new observational concepts
- identification of new mission needs and concepts, e.g. Sentinel-5p and Jason-CS
Preparatory activities for other missions

• In addition to missions identified through Calls for Earth Explorers or in coordination with e.g. EUMETSAT, EOEP addresses new concepts emerging from the community (scientists, industries, data users)

• These often mature into: new EE proposals, concepts adopted in operational missions, national or multi-lateral projects benefitting of system/techno work,..

• Some success cases (outside EE lines):
  • series of super/hyper-spectral mission studies, instrumental to define case and critical aspects for Sentinel-2 (initially not in GMES baseline);
  • ocean EW studies supporting definition of Sentinel-3;..

• ESAC recommendations for non-selected but scientifically valuable missions
Preparing the EO missions of ESA... (1)
Preparing the EO missions of ESA... (2)

..a subset of the many mission concepts prepared to
deliver science and applications
provide long-term perspective
serve as international reference
improve industry competitiveness

Preparing the EO missions of ESA... (2)
Examples of activities anticipated in EOEP-4

Studies on commended but not selected EE candidate missions:

- EE 8 candidates with commendations (listing only those with Lead Proposer in Italy):
  - FORUM: Study on the benefits of a FORUM type mission (wavelength coverage, radiometric performance)
  - GEOSAT: Feasibility and performance study of a geo-synchronous SAR mission
  - GLACIES: Antarctic campaign using POLARIS to evaluate the measurement concept
  - ...

Similarly, studies are anticipated also for commended EE9 and EE10 candidates

Aim to build a portfolio of (mature) mission concepts for e.g. international cooperation
ESA’s EO strategy is used to define:

- scientific challenges
- new observation requirements
- technology challenges and
- technology requirements and activities

=> prioritised requirements used to define activity workplans, based on the scientific “drive” and other inputs, e.g. anticipated evolution of meteo programmes
Science Driving Technology (2)

Candidates Earth Explorer 7
- BIOMASS
- Core H2O
- Premier

Candidates Earth Explorer 8
- CarbonSat
- Flex

Technology to address scientific challenges

Update process
**Goal:** drive all technology programmes by requirements defined with and for the users (EO, telecom,..) aiming at:

1. Preparing the technologies for future projects in a timely manner
2. Stimulating technology innovation
3. Supporting European industry competiveness
4. Ensuring European non-dependance on critical technologies

ESA’s technology programmes:

- **at corporate level:** TRP (at present 15 % of TRP budget is for EO),
  
  **GSTP** (a la carte programme)

- **at EOEP level:** EOPA/EWD for early developments on instruments (TRL 1 - 3) and for EO platform technologies at TRL 1 – 5
  
  **IPD** for higher TRLs to mature key instrument subsystems or full BB for planned or candidate missions

  currently, in EOEP-3 > 7 Meuro/year
### Science goals

- New observations
- Technology challenges
- Activities in - EOEP - corporate programmes

### EO technology challenges and plans

<table>
<thead>
<tr>
<th>EO technology challenges and plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Optimising use of resources</td>
</tr>
<tr>
<td>- EOEP provides stable but flexible programme environment for EO R&amp;D activities</td>
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</tbody>
</table>

### Atmosphere – A (3)

<table>
<thead>
<tr>
<th>Scientific Challenges</th>
<th>New Observations</th>
<th>Technology Challenges</th>
<th>Missions flown / in operation / under development</th>
<th>International Context</th>
<th>Relevant EE proposals (EE7 / 8 only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV-VNIR (SWIR) spectrometers</td>
<td>High spectral resolution UV-VIS and IR spectrometer technology for LEO &amp; GEO</td>
<td>GOME-2, I, MTG and Post-EP2/ GMES S-4 and S-5, S-5P</td>
<td>IPS (EUM/NOAA)</td>
<td>TRAQ (EE7-Phase 0) EE0(NITROSAT) EE0(HYPEREX) EE8 (TRUESS)</td>
<td></td>
</tr>
<tr>
<td>MER / TIR spectrometers</td>
<td>High resolution spectrometer technology (detectors, cooling...) for LEO and GEO (large-format IR detector with long cut-off wavelength; active cryo-coolers with large heat lift capacity)</td>
<td>IASI, Post-EP2 IASI-NG</td>
<td>PREMIER (EE7 – Ph A selected) TRAQ (EE7-Phase 0) EE0(MAGEA) EE0(MARKTHA) EE8(TIREX)</td>
<td></td>
<td></td>
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<tr>
<td>Microwave limb sounders</td>
<td>185 ~ 875 GHz technology (antenna, receivers, MMICs, diodes); retrieval algorithms</td>
<td>ODIN</td>
<td>SMILES</td>
<td>PREMIER EE8(Ifland)</td>
<td></td>
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<tr>
<td>Lidar for ozone and other atmospheric constituents</td>
<td>Lidar technologies (telescope, source, frequency stabilisation, spectral separation, detectors)</td>
<td>Lidar on Calipso, Earth-Can</td>
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<tr>
<td>LEO-LEO microwave / SWIR occultations</td>
<td>Laser sources and detectors</td>
<td>MetOp GR</td>
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### Atmosphere – B (3)

<table>
<thead>
<tr>
<th>Technology Challenges</th>
<th>Studies on-going or finished</th>
<th>Technology requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>High spectral resolution UV-VIS and IR spectrometer technology for LEO &amp; GEO</td>
<td>Immersed grating technology for compact high-resolution optical spectroscopy</td>
<td>Enhanced large UV-VIS detectors</td>
</tr>
<tr>
<td>High resolution spectrometer technology (detectors, cooling...) for LEO and GEO (large-format IR detector with long cut-off wavelength; active cryo-coolers with large heat lift capacity)</td>
<td>VLWIR detector broadboding for IR sounder</td>
<td>Cryo-cooler activities (T, IPD)</td>
</tr>
</tbody>
</table>

### Potential missions

<table>
<thead>
<tr>
<th>Technology areas</th>
<th>Technology development requirements</th>
<th>Covered in TRP plan</th>
</tr>
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<tbody>
<tr>
<td>Future gravity field mapping and monitoring (global mass redistribution)</td>
<td>Next generation satellite-to-satellite tracking for gravity time-variations</td>
<td>T117-309MM</td>
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<tr>
<td>Next generation gravity gradient measurements</td>
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<td>T165-3026</td>
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<tr>
<td></td>
<td></td>
<td>T117-306MM</td>
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<tr>
<td>Ocean mesoscale currents (possibly in combination with reference altimetry) (STSEs)</td>
<td>Wide-swath (“TRAC”-type) altimeters</td>
<td>T107-307EE, T117-308MM</td>
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<td></td>
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<td>T107-310EE</td>
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<tr>
<td></td>
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<td>T106-301ET, T106-306EE</td>
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<tr>
<td></td>
<td>Wavemill concept</td>
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<td></td>
<td>Constellation of miniaturised altimeters</td>
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At **low TRL**: enabling technologies, early prototyping

At **high TRL**: representative breadboards, critical sub-systems

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**EO technology preparation**

(links to technology readiness levels, TRL)

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At **low TRL**: remote sensing principle interactions studies, observation concepts

At **high TRL**: end-to-end performance simulators (incl. validated retrieval algorithms), in-depth analyses of campaign data, impact studies

=> pursue increased coordination with national agencies for studies and campaigns
EOEP innovation achievements (1)
putting Europe at forefront of EO

- EOEP advances science and applications especially through the innovative sensing techniques of the Earth Explorers (EE), e.g.:
  - gravity gradiometry (GOCE)
  - interferometric SAR altimetry (CryoSat)
  - synthetic-aperture radiometry (SMOS)
  - ultraviolet Doppler wind lidar (ADM-Aeolus)
  - magnetometry with sensing constellation (Swarm),.. 

- Additional innovations, improving or even adding entirely new mission capabilities, emerge during preparatory work – some examples:
  - in GOCE, active drag compensation by ion propulsion, 3D gradiometry (i.p.o. 2D), precision GNSS (independent from US), ultra-stable thermal control,..
  - in SMOS, new calibration means, high-speed optical data links,..
  - in Swarm, reducing number of satellites without science loss,..
  - in CryoSat, SAR altimetry for improved precision, solid-state altimeter,..

- Enabled by close cooperation of scientific and technical teams

⇒ more science return, more European competitiveness
Combined EOEP/TRP resources advance:

- optical instrumentation, e.g.:
  - monolithic immersed gratings enabling very compact imaging spectrometers for atmospheric chemistry and vegetation observations
  - long-life high-power laser diodes for all kinds of lidar missions (Doppler wind, differential absorption, high spectral resolution)
  - large heat-lift low-vibration coolers to cool focal planes down to 40 K
  - capacitance-stabilised High Spectral Resolution Etalon
Innovation Achievements (3)
putting Europe at forefront of EO

- Combined EOEP/TRP resources advance:
  - microwave instrumentation, e.g.:
    - mm- and sub-mm wave components and quasi-optic devices enabling high-performance radiometers and sounders operating up to ~1 THz
    - wide range of high-performance microwave components and antennas required to enhance the performance of (operational) active and passive microwave sensors
    - Klystron sources outputting signals with power of hundreds of watt at up to 100 GHz, adopted for e.g. atmospheric radar missions
Combined EOEP/TRP resources advance:

- platform technologies, e.g.
  - technologies for higher performance receivers with new GPS / Galileo signals
  - transmission systems for multi-gigabit/second data downlinks
  - multi-head star-trackers and advanced estimation algorithms for precise gyro-less pointing with high operational robustness
  - control momentum gyroscopes for rapid attitude maneuvers (agility)
  - new modulatable electrical thrusters, incl. mini-RIT and FEEP arrays
  - mass memories with multi-terabit capacity, low mass and power
  - ...

GNSS processing chips, enabling radio occultation on MetOp and precise orbit determination on GOCE, Swarm, EarthCARE, Sentinel 1/2/3, Radarsat, COSMO,..

multi-head star tracker for gyro-less AOCS (Seosat, Sentinel-3,..)

FEEP array for ultra-fine orbit and attitude control (ongoing R&D for e.g. next-generation gravity mission)
Innovation is intrinsic to EOEP and benefits all missions, including operational ones, implies large effort of technology preparation and coordination (in ESA, with Member States,..) to support all EO

R&D in preparatory phases benefit (also) other projects proposed at later EE Calls, or as EW projects, or pursued by Member States; two examples:

- ESA-developed accelerometers for gravity gradiometry, enabled CHAMP and GRACE missions, before GOCE

- Short-wave infrared detector, developed in frame of LSPIM / SPECTRA, enabled APEX (airborne), Sentinel-2, PRISMA, Sentinel-5p, HYPER-X,..
Lessons learned lead ESA to:

- improve scientific and technological readiness of candidate missions
- systematic parallel phase A/B1 work for candidate missions
- prepare instrument and/or small missions of opportunity (EEx)
- closer interactions with Member States for mission/technology preparations and for planning transitions EE - precursor missions - EW

Activities in same EOEP lines (+ STSE line for science gap analyses):

- update of the “Changing Earth” challenges of ESA’s EO programmes in 2013, followed by **Call for Mission Ideas for Earth Explorer 9** (core) early 2014
  - Phase 0 of four EE9 concepts, downselection, Phase AB1 of two EE9 missions
- **Call for Mission Proposals for Earth Explorer 10** (opportunity) in 2015/16
  - selection of two missions for Phase AB1 studies
- investigate flight opportunities for **instrument or small mission, EEx**, as e.g. cooperation with international partners
Further EOEP-4 activities on:

- next-generation of GMES Sentinels (under EWD, initial steps)

- commended but not selected EE candidate missions, in particular: science and mission requirements, campaigns

- build up a portfolio of sensor and mission concepts (hence both science and technical studies) useful also for cooperative efforts (international, with national Agencies)

- mission exploratory studies and studies supporting long-term international cooperations, e.g. joint ESA-NASA effort on constellations for future mass transport monitoring system via gravity monitoring or for monitoring by multiple SARs
Examples of recent Italian contributions to science and mission studies (excl. EE system studies)

As Prime:

- Algorithms for snow and land ice retrieval using SAR data (IFAC CNR)
- CoReH2O end-to-end mission performance simulator (ARESYS)
- PREMIER - analysis of campaign data (IFAC CNR)
- Assessment of Vegetation Photosynthesis through Observations of Solar Induced Fluorescence from space (Univ. Bologna)
- Assessment of a laser based occultation demonstration mission to monitor chemical species (TAS-I)
- End-to-End System for Volcanic Ash Plume Monitoring and Prediction (CGS)

+ in many other activities, Italian institutes are involved as sub-contractors
Examples of recent Italian contributions to EO technology developments

As Prime:

- MetOp-SG Scan Mechanism Breadboard for Imaging Microwave Radiometers (TAS-I)
- System support to laser interferometry tracking technology (TAS-I)
- Study of data downlink system in K-band for EO (TAS-I)
- Modern attitude control of EO satellites with flexible appendages (TAS-I)
- Ku-band antenna feed breadboarding (TAS-I)
- Innovative planar highly directive antenna based on artificial surfaces (IDS)
- Study into Ka-band SAR instrumentation and mission concept (TAS-I)
- Advanced Techniques for High Data Rate inks for EO satellites (TAS-I)
- Large Aperture Telescope Technology (CGS)
- Next-generation Gravity Mission AOCS solutions and technologies (TAS-I)

+ in many other activities, Italian companies and institutes are involved as sub-contractors
Examples of future mission concepts
[from current EO technology challenges and plans; no priority order, not exhaustive]

- High-resolution (3D) land and ocean monitoring
- Future gravity field mapping and monitoring
- Ocean mesoscale currents
- In-land waters
- Air-sea interactions
- Ice sheet (sounding) and glaciers
- Atmospheric processes and air quality
- High resolution thermal infrared
- High resolution from GEO (coastal monitoring and ocean colour)
- High resolution soil moisture and ocean salinity
- GMES/Security: maritime surveillance
- GMES evolution: next generation high resolution wide-swath SAR imagery
- GMES evolution: next generation high resolution land optical
- ...
Examples of future mission concepts
[from current EO technology challenges and plans; no priority order, not exhaustive]

- **High-resolution (3D) land and ocean monitoring**
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- ...
Example: Ka-band interferometric SAR (1)

Ka-Band (35 GHz) SAR for 3D imaging with single-pass interferometry and very high resolution

Applications in:

Civil Security:
- digital elevation models (DEM)
- urban development
- cartography
- disaster management
- earthquakes, flooding
- reconnaissance and surveillance
- humanitarian crises, peace keeping
- ground vehicle moving target detection
- ship detection and identification
- coastal defence to identify changes of coastlines and topography by heavy storms/high waves

Environmental Monitoring:
- snow coverage
- ocean currents
- sea ice and glacier monitoring and tracking
- surface tracking
- iceberg classification and trajectory prediction
- subsidence
- height measurement over vegetation in support of biomass estimate
- rainfall estimate and prediction
- in-land waters discharge monitoring

Ka-band interactions and data applications addressed in on-going activities and forthcoming ad-hoc studies
Ka-band interferometric SAR (2)

- preliminary theoretical demonstration of feasibility (theoretical and via airborne campaign)
- bistatic concept through reflector antennas with distributed TX amplification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Orbit Height</td>
<td>500-800 Km</td>
</tr>
<tr>
<td>Frequency</td>
<td>35.75 GHz</td>
</tr>
<tr>
<td>Tx Bandwidth</td>
<td>&lt; 500 MHz</td>
</tr>
<tr>
<td>HR: Range and Azimuth Resolution</td>
<td>1 m x 1 m</td>
</tr>
<tr>
<td>HR: Swath-width</td>
<td>&gt; 16 Km</td>
</tr>
<tr>
<td>MR: Range and Azimuth Resolution</td>
<td>To be maximized</td>
</tr>
<tr>
<td>MR: Swath-width</td>
<td>&gt; 100 Km</td>
</tr>
<tr>
<td>Height Accuracy (12m x 12m Spatial Resolution after multi-look)</td>
<td>2 m</td>
</tr>
<tr>
<td>Access Range</td>
<td>25÷45 deg</td>
</tr>
<tr>
<td>Polarization</td>
<td>Single /Dual / Quad</td>
</tr>
<tr>
<td>NESZ</td>
<td>-15 dB</td>
</tr>
<tr>
<td>PTAR/DTAR</td>
<td>-25 dB</td>
</tr>
<tr>
<td>Cross-Polar Isolation</td>
<td>-25 dB</td>
</tr>
</tbody>
</table>
Ka-band interferometric SAR (3)

*airborne campaign (over Piemanson, FR)*
### Examples of future mission concepts

[from current EO technology challenges and plans; no priority order, not exhaustive]

- **High-resolution (3D) land and ocean monitoring**
- **Future gravity field mapping and monitoring**
  - Ocean mesoscale currents
  - In-land waters
  - Air-sea interactions
- **Ice sheet (sounding) and glaciers**
- **Atmospheric processes and air quality**
- **High resolution thermal infrared**
- **High resolution from GEO (coastal monitoring and ocean colour)**
- **High resolution soil moisture and ocean salinity**
- **GMES/Security: maritime surveillance**
- **GMES evolution: next generation high resolution wide-swath SAR imagery**
- **GMES evolution: next generation high resolution land optical**
- ...

Future gravity field mapping and monitoring

Two-satellites ranging by laser interferometry to nm precision

Cross-plane gradiometer for (non)-gravitational effects
Activity roadmap for Gravity Mapping and Monitoring

- **2003**: Enabling observation techniques for future solid Earth missions.
- **2005**: Laser Doppler Interferometry Mission for determination of the Earth gravity field.
- **2007**: System support to Laser interferometry Tracking technology Development for Gravity field measurement.
- **2011**: Assessment of Next Generation Gravity Mission to Monitor the variations of the Earth Gravity Field.
- **2013**: Science Assessment of Constellations for Monitoring the Variations in Earth’s Gravity Field.

**2007**: Miniaturised grided ion engine bread boarding and testing for future Earth Observation missions.

**2011**: Science Impact Study.

**2013**: High stability laser with fibre amplifier for interferometric Earth gravity measurements + Laser stabilisation unit for interferometric Earth Gravity measurements.

**Legend**:
- **EOPA**
- **TRP / GSTP**
- **GSP**
# Technologies for Future Gravity Field Mapping and Monitoring Activities

## Potential Mission: Future Gravity Field Mapping and Monitoring

### Technology Area: Next Gen. sat to sat tracking for gravity time variations

**Technology Development Requirements**

- Laser interferometer tracking system
- Laser Frequency stabilization
- Digital interferometer phasemeter

**Target**

- T117-309MM: Laser Stabilisation Unit for Interferometric Earth Gravity Measurement
  - TRL: 4
- T105-302EC: NGGM: AOCS solutions & technologies
  - TRL: 3

### Technology Area: Next generation gravity gradient measurement

**Technology Development Requirements**

- Drag free technologies
- In-orbit lessons learnt
- Electrostatic accelerometer evolution
- Microthrusters for 6DOF control
- Low noise attitude actuators
- Atom interferometry gradiometry

**Target**

- T117-306MM: Compact vacuum chamber for an Earth gravity gradiometer based on laser cooled atom interferometry (critical component)
  - TRL: 3
Examples of future mission concepts
[from current EO technology challenges and plans; no priority order, not exhaustive]

- High-resolution (3D) land and ocean monitoring
- Future gravity field mapping and monitoring
- **Ocean mesoscale currents**
- In-land waters
- Air-sea interactions
- Ice sheet (sounding) and glaciers
- Atmospheric processes and air quality
- High resolution thermal infrared
- High resolution from GEO (coastal monitoring and ocean colour)
- High resolution soil moisture and ocean salinity
- GMES/Security: SAR imagery for land change detection and topography
- GMES/Security: maritime surveillance
- GMES evolution: next generation high resolution wide-swath SAR imagery
- GMES evolution: next generation high resolution land optical
- ...
Wavemill radar mission concept

- Radar instrument concept using hybrid (along- and across-track) interferometry for direct measurement of 2D ocean surface currents and topography mapping in a single pass.
- Additional applications include inland waters and ice: lake height, river flow rate, ice freeboard,..
- Feasibility studies indicate high potential with accuracies < 10 cm/s and 5° for dual swaths of 100 km to either side of the sub-satellite track.
- Basis: wide swath interferometric (SAR) radar.
  - At K_u band with 100 MHz bandwidth, PRF = 2.7 kHz.
  - Antenna configuration ensures separation of antennas in both across- and along-track directions.
- Successful demonstration campaign over Liverpool Bay.
Wavemill Operation

Sub-Satellite Track

Flight Direction

Orbit Height ~550 km

$3 \text{ km}$

$280 \text{ km}$

$90 \text{ km}, 200 \text{ km}$
Wavemill Operation

Sub-Satellite Track

Flight Direction

Orbit Height ~550 km

$ t_o $
Sub-Satellite Track

Flight Direction

Orbit Height ~550 km

80 km, 100 km, 280 km, 3 km
Wavemill Operation

Flight Direction

Sub-Satellite Track

Orbit Height ~550 km

280 km

80 km, 200 km, 3 km

ASI Meeting | Roma | 18-19 October 2012 | Page 43 | ESA Unclassified – For Official Use
Wavemill Operation

Flight Direction

Sub-Satellite Track

Orbit Height ~550 km

280 km

80 km, 200 km

3 km

280 km
Wavemill Operation

Flight Direction

Sub-Satellite Track

Orbit Height ~550 km

90 km, 100 km, 280 km, 3 km
Wavemill Operation

Flight Direction

Sub-Satellite Track

Orbit Height ~550 km

280 km

80 km, 100 km

280 km

3 km
Wavemill Operation

Flight Direction

Sub-Satellite Track

Orbit Height ~550 km

280 km

3 km

80 km 100 km
Wavemill Operation

Flight Direction

Sub-Satellite Track

Orbit Height ~550 km

- 280 km
- 3 km
- 80 km - 200 km
- 280 km
Sub-Satellite Track

Flight Direction

Orbit Height ~550 km

280 km

3 km

Wavemill Operation

90 km 100 km
Overview of Wavemill related activities

Feasibility Study
- Scientific requirements for ocean currents
- Preliminary instrument & s/c designs

PoC Campaign
- Adaptation of airborne interferometric SAR
- Campaign over region with ground truth
- Process hybrid and co-time data
- Extract surface currents
- Compare and validate
- Science workshop

Science Study
- Configurable instr. model
- Sea surface state model
- Processing

Simulator
- Science requirements
- Review ATI
- Scientific products validation
- Scatterometry (windspeed from amplitude)
- Additional Products e.g. sea-ice, inland water and rivers
- Synergies with other instruments

CDF?

System Study

Antenna B/B

OBP B/B

All activities below in TRP plan 2011-13

2010
2011
2013

European Space Agency
TRP planning for Future Ocean Mesoscale Current Measurement

**Technology Area: Wavemill**

**Technology Development Requirements**

- Squinted dual-beam antenna

**T107-310EE:** Wavemill antenna concept & critical breadboarding

**Target TRL: 3**

**Technology Area: Constellation of miniaturised altimeters**

**Technology Development Requirements**

- Altimetry electronics & O/B processing miniaturisation

**T106-301ET:** Miniaturised altimeter study

**Target TRL: 2**

**T107-306EE:** Compact Ku/Ka-band altimetric antenna for LEO constellation

**Target TRL: 2**

**Potential Mission: Ocean mesoscale currents**

**Technology Area: Wide swath altimeters**

**Technology Development Requirements**

- Interferometric SAR Ku/Ka-band
  - Ultra stable structure
  - Mini on board distance metrology
  - High performance attitude estimation and stabilization
  - Microwave calibration
  - On-board processing

**T107-307EE:** Interferometric antennas at Ku/Ka for wide swath altimetry (postponed)

**Target TRL: 3**

**T117-308MM:** Compact optical attitude transfer system

**Target TRL: 3**
Conclusions

• EO mission and technology preparations play a crucial role to achieve scientific and technical excellence of European missions and to enhance the competitiveness of the EO community (industrial and scientific)

• Their main objectives were met, as shown e.g. by the in-orbit mission track record, though several lessons had to be learned e.g. on technology maturity aspects

• EOEP flexibility can be used to somewhat alleviate resource limitations; more resources would secure more robust early preparation of missions, in particular to match science and technology readiness levels

• Systematically advancing early concepts and EO technologies, allowing time-critical developments, will support the ambitions of the EO community

• The Italian EO community is a leading player and will benefit of increased efforts and Agency-level coordination in early preparation of science and applications (its industrial component being already in a leading role, as confirmed by the EOEP georeturn)