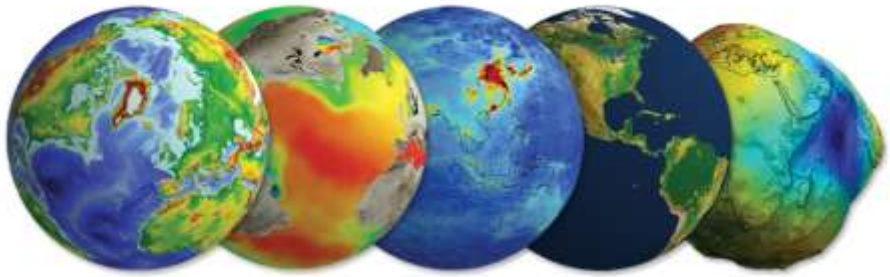
NCEO & CEOI Joint Conference
September 2012



Amanda Regan & Joerg Callies
Future Missions Division
Earth Observation Directorate
ESA/ESTEC

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1. **The Living Planet Programme**
   - Earth Observation Envelope Programme (EOEP)
   - Overview of Missions in relation to the EOEP
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     - EE9 and EE10
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   - Sentinel Convoy Studies
3. ESA Technology
   - ESA Technology Programmes
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   - TRP Plan 2011-13 and concept development overview
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The ESA E.O. Strategy – "Living Planet"

ESA's Living Planet Programme (LPP)
comprises two main components:

1. Science and Research element
including Earth Explorer missions
Aim: To better understand the Earth System

2. Earth Watch Element
including EUMETSAT and GMES Space component
Aim: To facilitate long term monitoring and the delivery of EO data for operational services

The Earth Observation Envelope Programme

The Earth Observation Envelope Programme (EOEP) is the key to implementing the Living Planet Strategy. It represents a stable planning environment within which new types of environmental sensing technologies and the missions that will fly them are prepared.

EOEP comprises two main components:

a) the *Earth Explorer Component*

This component comprises the definition, development, launch and operations of Earth Explorer missions (platform, payload and ground segment). Its purpose is to respond to the needs identified by the EO scientific community.

b) the *Development and Exploitation Component*

The Development and Exploitation component includes all preparatory activities for future missions, including Earth Observation Preparation Activities (EOPA), Earth Watch Definition (EWD) and Instrument Pre-Development (IPD), Support to Science Element (STSE), Data User Element (DUE) and Value Adding Element (VAE) It addresses both science-themed Earth Explorer candidates and operational Earth Watch missions**:**

- Preparatory activities for Earth Explorer and Earth Watch,
- Instrument Pre-Development for Earth Explorer and Earth Watch type missions
- Preparation of programme proposals for optional Earth Watch type programmes,
- Mission Exploitation/Market Development.
- Multi mission ground segment

The Earth Observation Envelope Programme

- The EOEP is run as an optional ESA programme which is run in four to five-year cycles
- The current EOEP-3 runs between 2008 and 2012
- It provides a long-term, rolling environment for the planning of new activities, exploitation of results, contingency response and continuity of missions.
- At present EOEP-4 is being prepared (2013-2016)
- Ministerial Council meeting in November 2012

ESA Earth Observation Missions

Living Planet

Earth Explorer

Research driven

Core Missions

GOCE
17/03/09

ADM-Aeolus
2013

EarthCARE
2013

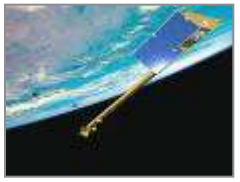
Biomass/ CoReH2O/ PREMIER

EE7

Opportunity Missions

CryoSat-2
08/04/10

SMOS
02/11/09



Swarm
2012

CarbonSat FLEX

EE8

Continuity of Missions

ERS-2
1995 – 2011

Envisat
2002 - present

Earth Watch

Operational Service driven

Operational Meteorology

- Meteosat
- MSG
- EPS (MetOp)
- MTG
- MetOp SG

GMES

- Sentinel 1
- Sentinel 2
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- Sentinel 5 precursor
- Sentinel 5 (MetOp-SG)

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Living Planet

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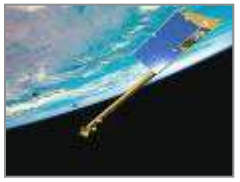

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Missions within EOEP

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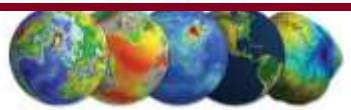

ESA Earth Observation Missions

Living Planet

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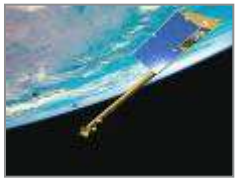

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Missions outside EOEP but preparatory work is within EOEP

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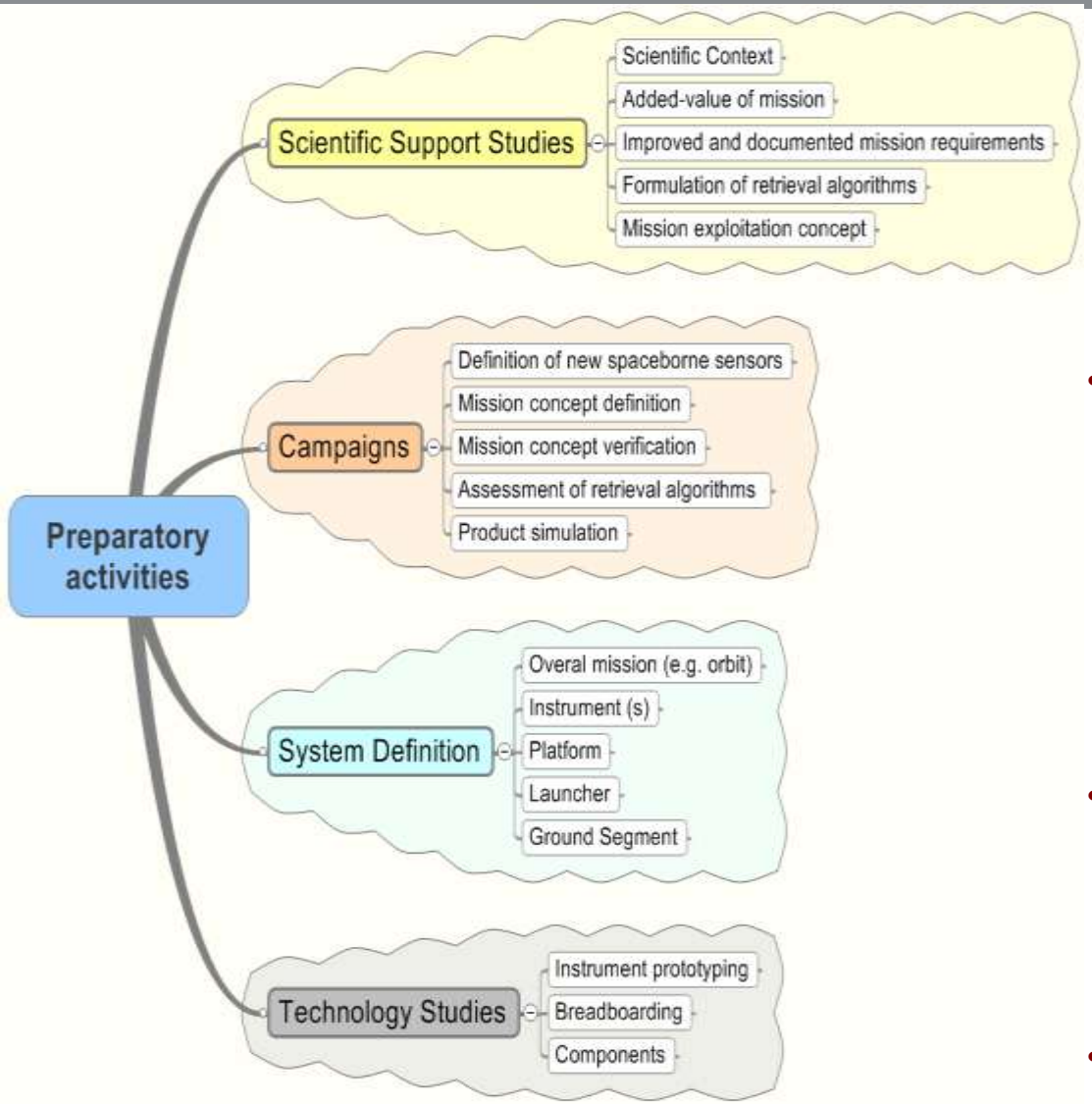
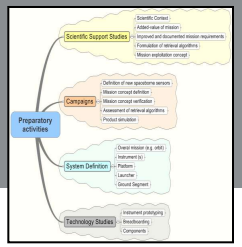
Funding for Earth Observation Preparatory Activities



Funding depends the nature of the activity as stated in the Living Planet strategy e.g. science / operational.

ESA Earth Observation available funding sources for preparatory activities

- **EOEP: e.g.**
  - Earth Observation Preparation Activities (EOPA)
  - Instrument Pre-Development (IPD)
  - Earth Watch Definition (EWD)
  - Support to Science Element (STSE)
- **ESA Technology Programmes e.g.**
  - Technology Research Programme (TRP)
  - General Support to Technology Programme (GSTP)
- **ESA General Studies Programme** (GSP)



EECM Phase A: what does it mean ?

Example: BIOMASS (candidate EE7 mission)

System

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

Technology

- Large P-Band SAR antennas critical breadboard (x2)
- Very Large P-Band Antennas performance verification methodology & Facilities
- P-Band HPA technology assessment
- Very large space antenna aperture – demo model
- P-Band Reflector antenna Feed elements
- P-band ice sounding radar demo development
- P-band passive sub-array development
- Very large space antenna aperature architecture trade-off (x2)
- SSPA breadboard (incl. circulator/switch, power divider and calibration coupler) (x2)
- Study of P-Band transponder with ionospheric correction capabilities (x2)

Science and Campaigns

- 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

e.g.

- TropiSAR campaign (completed)
- TropiScat campaign (on-going)
- BioSAR 2 campaign (completed)
- BioSAR 3 campaign (completed)

End-to-end Performance Evaluation and System Support

- BIOMASS End-to-End Mission Performance Simulator
- OpenSF end-to-end (E2E) simulator framework infrastructure
- Modern attitude control of EO satellites with large flexible elements (x2)

= EOPA
= IPD
= TRP / GSTP
= GSP

Coordinated Preparatory Activities

Earth Explorer Core Missions

Step 1
Call & Selection for Step 2

Preparing the call → Proposal & evaluation

Step 2
Assessment

Phase 0 activities

Step 3
Phase A/B1

Phase A/B1 activities

→ Further Development

Coordinated Preparatory Activities

Science → Studies → Studies and Campaigns

System → Phase 0 Studies (Competition) → Phase A/B1 Studies (Competition)

Technology → TRL 1 - 3 → TRL 3 - 5

→ Further Development

Coordinated Preparatory Activities

Earth Explorer Opportunity Missions

Preliminary Development
e.g. National funding,
Additional funding

→

Step 1
Call & Selection

Preparing the call & evaluation

→

Step 2
Phase A/B1

Phase A/B1 activities

→

Further Development

Coordinated Preparatory Activities

Science → Studies and Campaigns

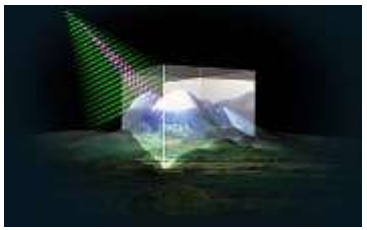
System → Phase A/B1 Studies (Competition)

Technology → TRL 3 - 5

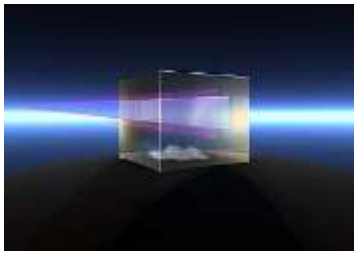
Studies and Campaigns, Phase A/B1 Studies (Competition), TRL 3 - 5 → Further Development

Earth Explorer 7 Core Mission Candidate Status

- **Status:** Phase A system studies are now complete.
  Phase A extension activities on-going. User consultation meeting scheduled for Q1 2013
  Reports for selection: http://www.esa.int/esaLP/LPfuturemis.html



- **BIOMASS:** single satellite carrying a P-band SAR **to provide continuous global interferometric and polarimetric radar observations of forested areas.**



- **CoReH2O / Snow mission:** single satellite with dual frequency (X, Ku), dual-polarisation SAR **to observe snow / ice at high spatial resolution**

- **PREMIER: 3D fields of atmospheric composition in upper troposphere and lower stratosphere with** an infrared limb-imaging spectrometer and a mm-wave limb-sounder. Designed to fly with Metop
- PREMIER → limb sounding view
- Metop → Nadir view

} observation of same volume

Earth Explorer 8 Opportunity Mission Candidate Status

- **Status:** x 2 Industrial Phase A/B1 studies underway for each mission candidate.

- **FLEX:** to provide global maps of vegetation fluorescence, which can be converted into an indicator of photosynthetic activity -> to improve our understanding of how much carbon is stored in plants and their role in the carbon and water cycles
- Designed to fly with Sentinel-3 (synergy with optical instruments)

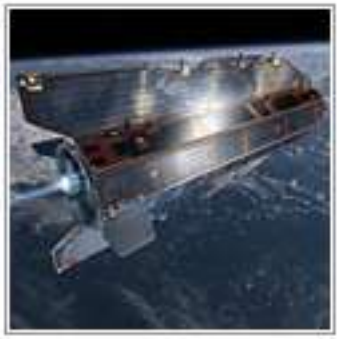
- **CarbonSat:** to quantify and monitor the distribution of carbon dioxide and methane -> for a better understanding of the sources and sinks of these two gases and how they are linked to climate change.

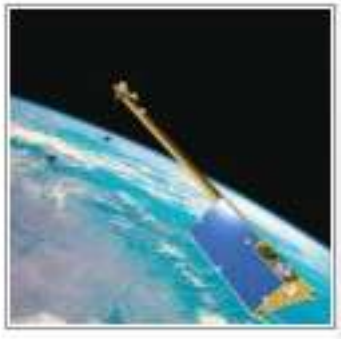
Future Earth Explorer Calls EE9, EE10 and EE-x

- EE9: Identified as an Earth Explorer Core Mission Call around 2014 (Phase 0)

- EE10: Identified as an Earth Explorer Opportunity Mission Call around 2015 (Phase A)

- EE-x: Identified as the development and commissioning of a self standing instrument, to be designed as a flight opportunity with international partners e.g. USA, China, India etc. Including opportunities offered by ESA Member States and other institutions.

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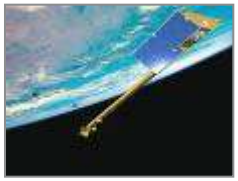

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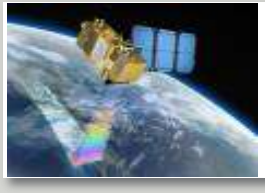
Missions outside EOEP but preparatory work is within EOEP

GMES dedicated missions: Sentinels

Sentinel 1 – C-band SAR imaging
All weather, day/night applications, interferometry
x 2 satellites, 693 km, SSO dawn-dusk orbit

2013 / 2015



Sentinel 2 – Multi-spectral imaging
Land applications: urban, forest, agriculture,..
Continuity of Landsat capabilities, SPOT etc
x 2 satellites, 786 km, SSO, LTDN 10:30 am

2014 / 2016

Sentinel 3 – Ocean and global land monitoring
Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry
x 2 satellites, 814 km, SSO, LTDN 10:00 am

2014 / 2017

Sentinel 4 – Geostationary atmospheric
Atmospheric composition monitoring, trans-boundary pollution

2017+

Sentinel 5 – Low-orbit atmospheric
Atmospheric composition monitoring
(S5 Precursor launch in 2014, x 1 satellite – follow ground track of Suomi-NPP)

2020+

Sentinel spacecraft lifetime = 7 years, with consumables for 12 years

EUMETSAT operated missions

For MTG two types of missions are proposed comprising six satellites focusing on Nowcasting and Numerical Weather Prediction (NWP):

- 4 x MTG-I (Imaging) missions
- 2 x MTG-S (Sounding) missions

1977 — **MOP**

MVIRI, 3 channels
Spinning satellite

2002 — **MSG**

SEVIRI, 12 channels,
GERB Spinning satellite

2017 — **MTG**

Flexible Combined Imager,
Lightning Imager, IR sounder

GEO Meteosat series

LEO Metop series

2006 — **Metop-A**

2012 — **-B**

2016 — **-C**

NOAA + EUMETSAT sensors
New sensors: ASCAT, GOME, GRAS

3 satellites **2020** — **Metop SG-A**

3 satellites **~ 2021+** — **-B**

Several instruments on each platform. Improved instrument performance

LTDN: 9.30 am, 817 km

EUMETSAT is the European Organization for the Exploitation of Meteorological Satellites. ESA is the R & D agency for EUMETSAT missions

Preparatory activities for operational missions

EOEP activities with similar complexity as for EE but no competition among missions

For meteorological missions:

- User community and relevant interfaces managed by EUMETSAT
- End-to-end mission definition and requirements under EUMETSAT responsibility

⇒ additional complexity in the consolidation of mission/system requirements and observation needs vs. engineering trades due to programmatic aspects, e.g. external instruments provision

The preparatory activities for GMES missions include:

- Definition of GMES architecture and definition of each Sentinel mission up to Phase A/B1
- Mission requirements from initial user requirements and GMES Service Element interactions with European Commission (iteration and validation)
- Identification of new mission needs, e.g. Sentinel-5p and Jason-CS

Convoy Studies

- Over the next few years, a number of new **long-term** operational EO satellite series will be launched by Europe.

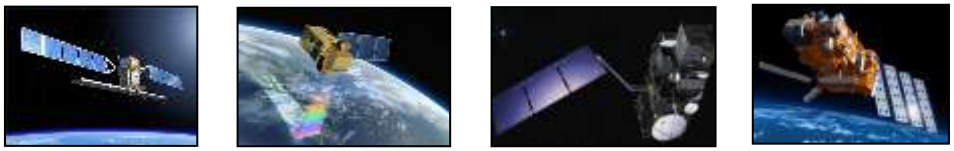
- This will provide a capacity for systematic, continuous and long-term Earth observation and monitoring

- This stable space borne operational capacity is **based on enhanced continuity** of the different satellite series.

- This capability represents an excellent platform to design **novel focused missions** which would fly with these operational missions:

  - Synergetic EO opportunities
  - New EO science objectives can be met
  - Unachievable with single satellite measurement

The Convoy Concept



Operational missions

Opportunities for synergetic EO

Additional missions

Convoy Studies funded by STSE

- Three activities have been defined and have been initiated following a “user driven” approach:

- Theme 1: Use of novel and additional observations for **Ocean & Ice** research & applications
  Team: Astrium, NERSC, Enveo and Polar Imaging Ltd
  Final Presentation in Q4 2012 at ESTEC.

- Theme 2: Use of novel and additional observations for **Land** research & applications
  Team: SSTL, University of Leicester, Astrium Ltd)
  Mid Term Review in Q4 2012

- Theme 3: Use of novel and additional observations for **Atmosphere** research & applications
  Team: Astrium, University of Leicester, KNMI
  Study Kicked off in Q3 2012

INTERNATIONAL MULTI SATELLITE FLYING “CONVOY” WORKSHOP
ESA-ESTEC
PROVISIONAL DATE : JUNE 2013

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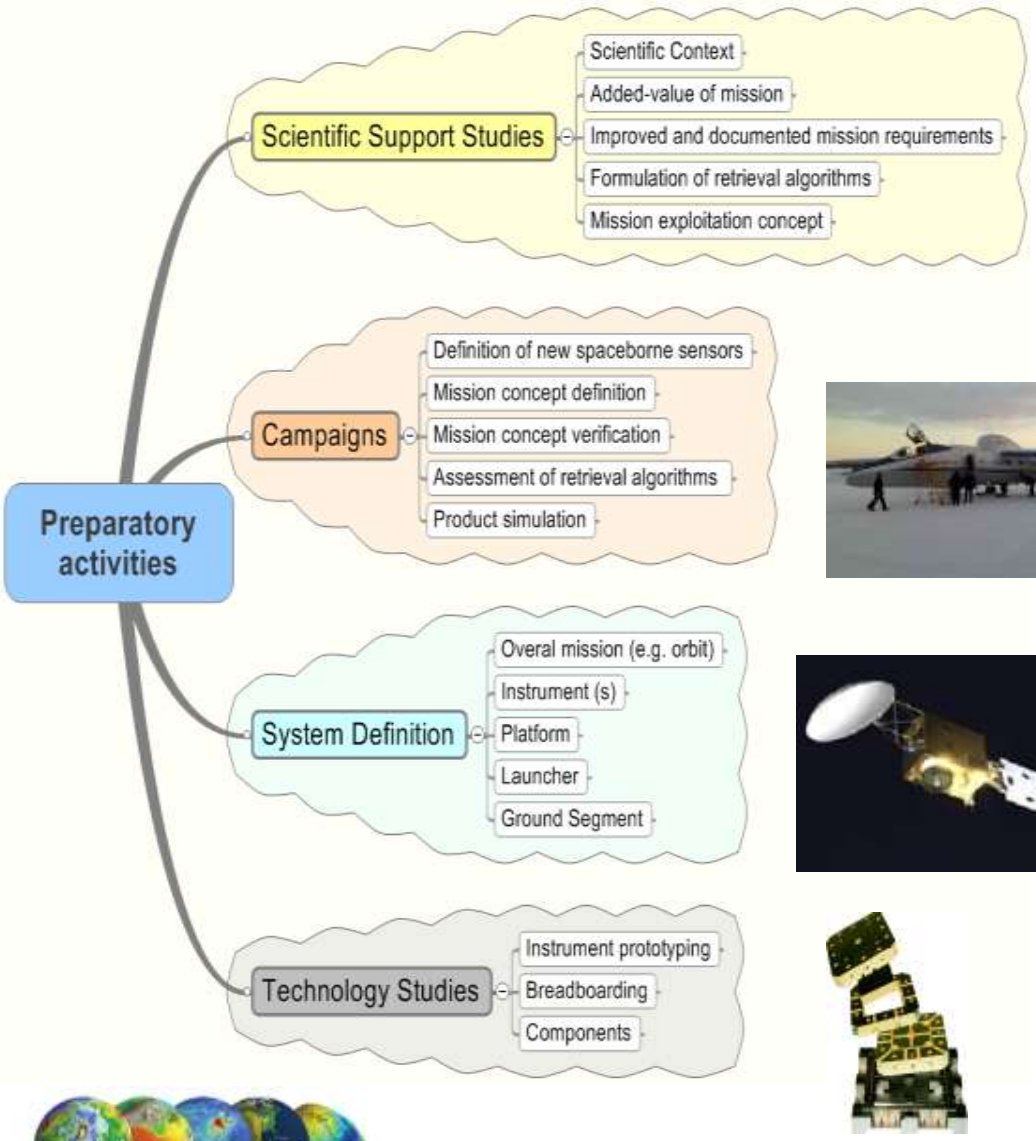
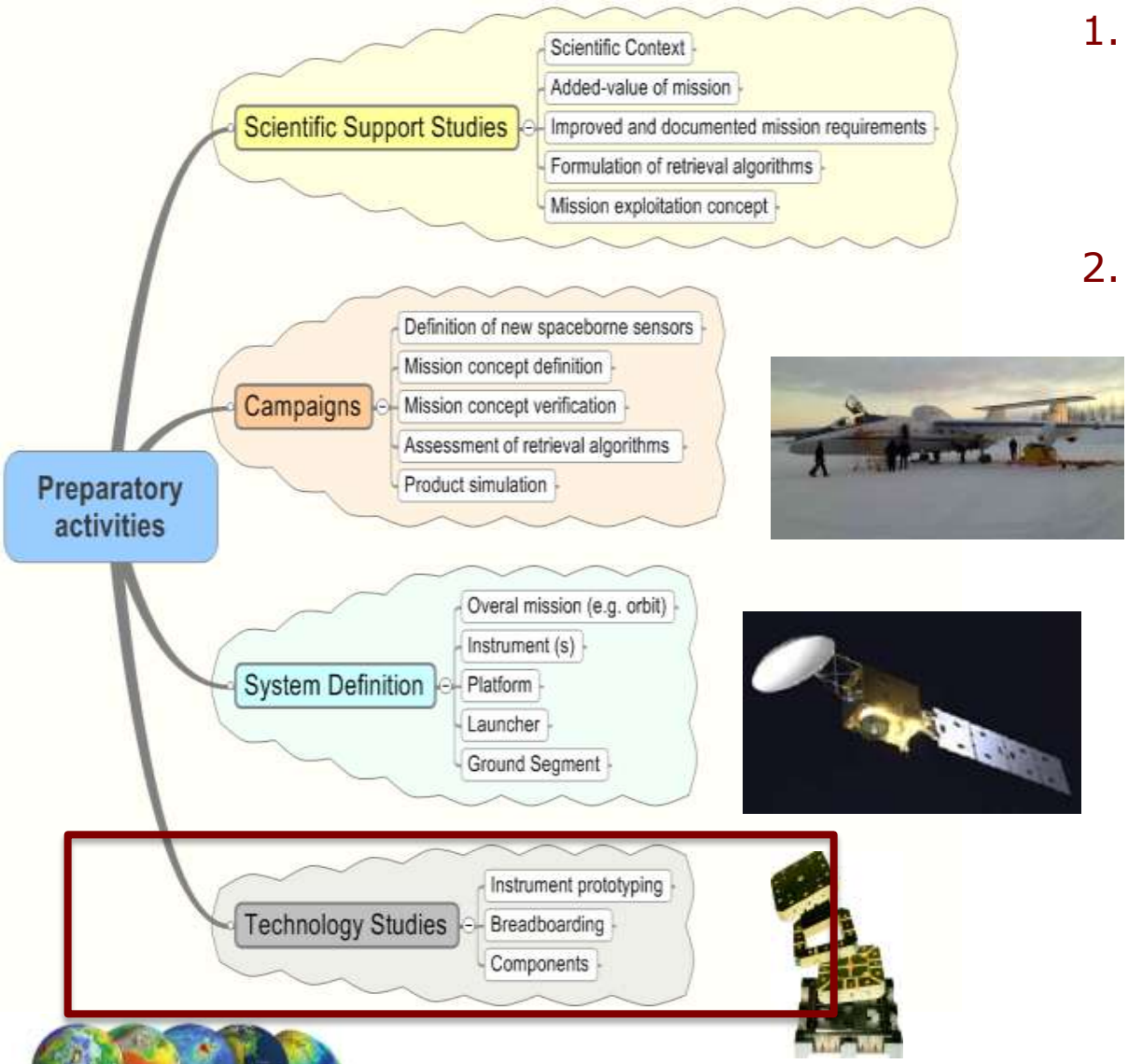
Overview of Earth Observation Preparatory Activities



1. EOEP preparatory activities include all necessary activities to define and evaluate future EO space borne missions (EE, GMES, meteorological,..)
2. Driving elements include:
   - Scientific challenges summarised in “The Changing Earth”, SP-1304
   - Associated observation, mission and technology requirements
   - Mission preparation through Phase-0 (Pre-feasibility) and Phase-A/B1 (Feasibility)
   - Foster new ideas, cooperation opportunities and prepare technologies, also for European independent capabilities
   - ESAC recommendations

Overview of Earth Observation Preparatory Activities



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ESA End to End Technology Process

EO technology activities are part of the ESA End-to-End Process

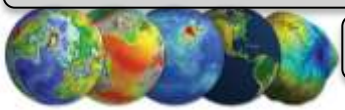
The goal is to drive all technology programmes by requirements defined with and for the users (EO, Science, Telecoms, etc) aiming at:

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

ESA's technology programmes:

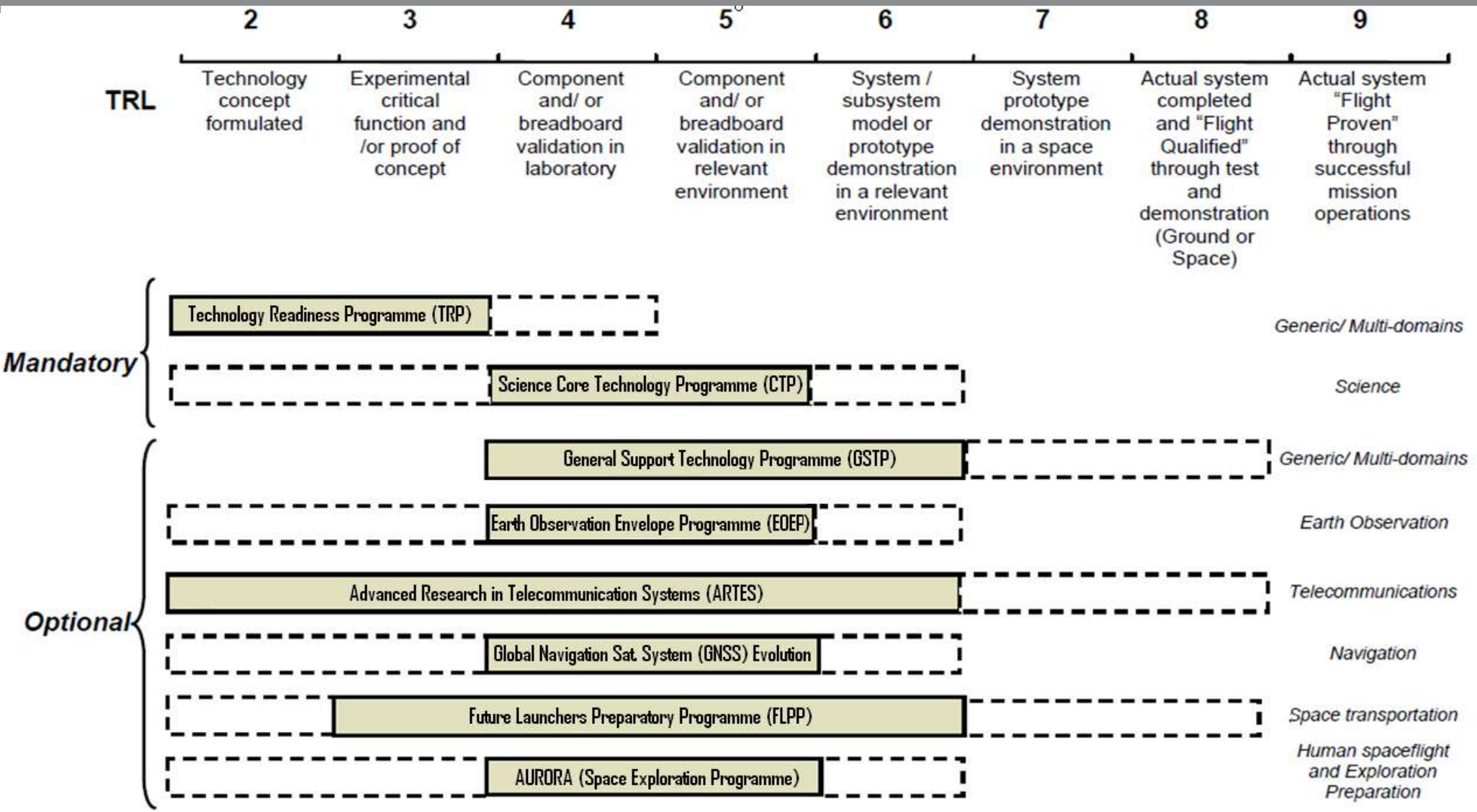
- at corporate level : TRP, GSTP (at present EO = 15% of TRP budget, TBD in future)
- at EOEP level : EOPA/EWD for early developments (TRL up to 3) and IPD for higher TRL to mature key instrument subsystems or full BB for candidate missions.
- Activities can be funded by the EOEP or by one of the technology programmes. It is possible e.g. where two parallel studies are identified that one activity can be funded by a technology programme e.g. TRP and and the second activity is funded by EOEP.

TRP = Technology Research Programme, GSTP = General Support Technology Programme,

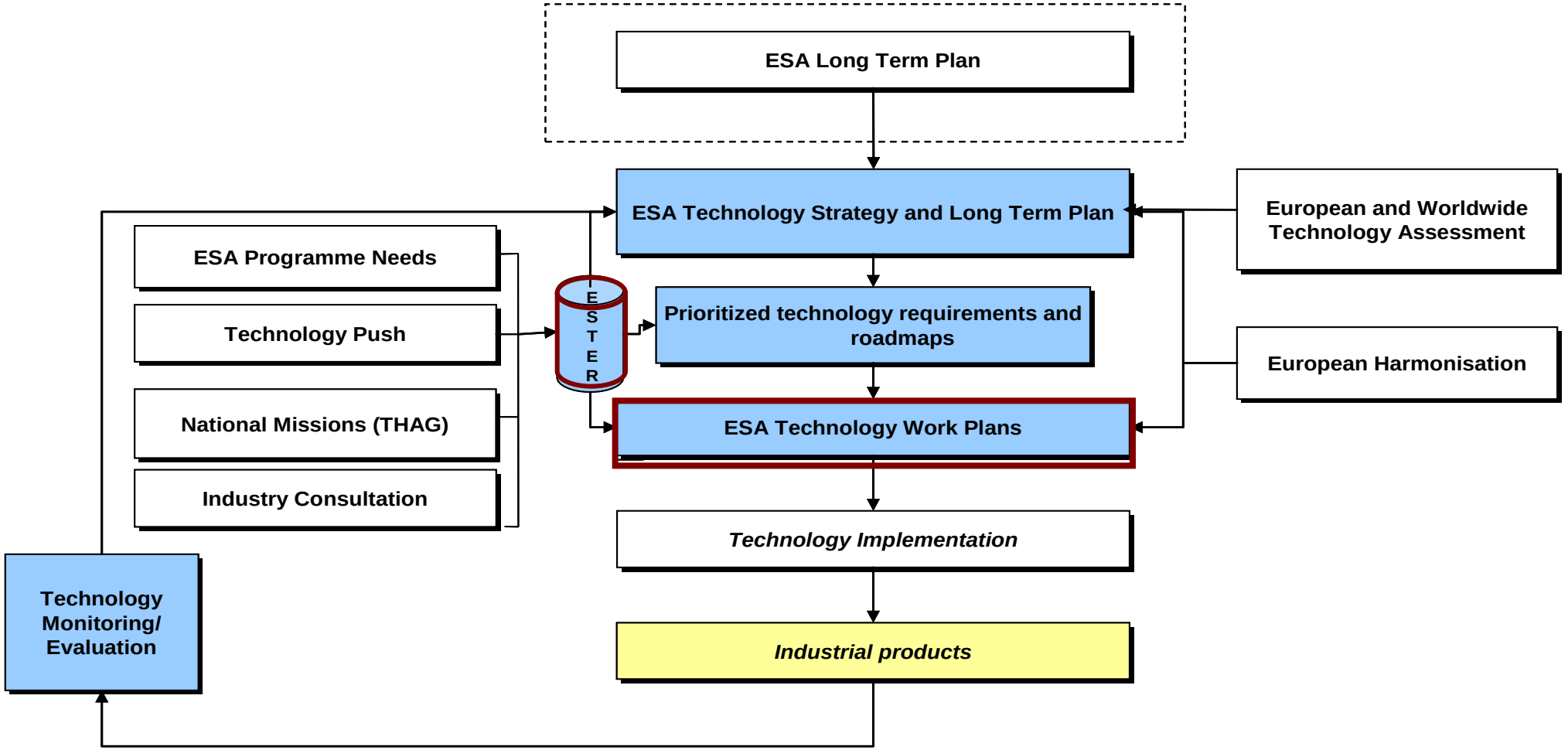


EOPA = EO Prep Activities, EWD = Earth Watch Def., IPD = Instrum Pre-Dev

ESA Technology Programmes vs. TRL



ESA End to End Technology Process



- Under the supervision of a dedicated Director' Sub-Committee on Technology
- ESTER: European Space Technology Requirements Database
- THAG: Technology Harmonisation Advisory Group

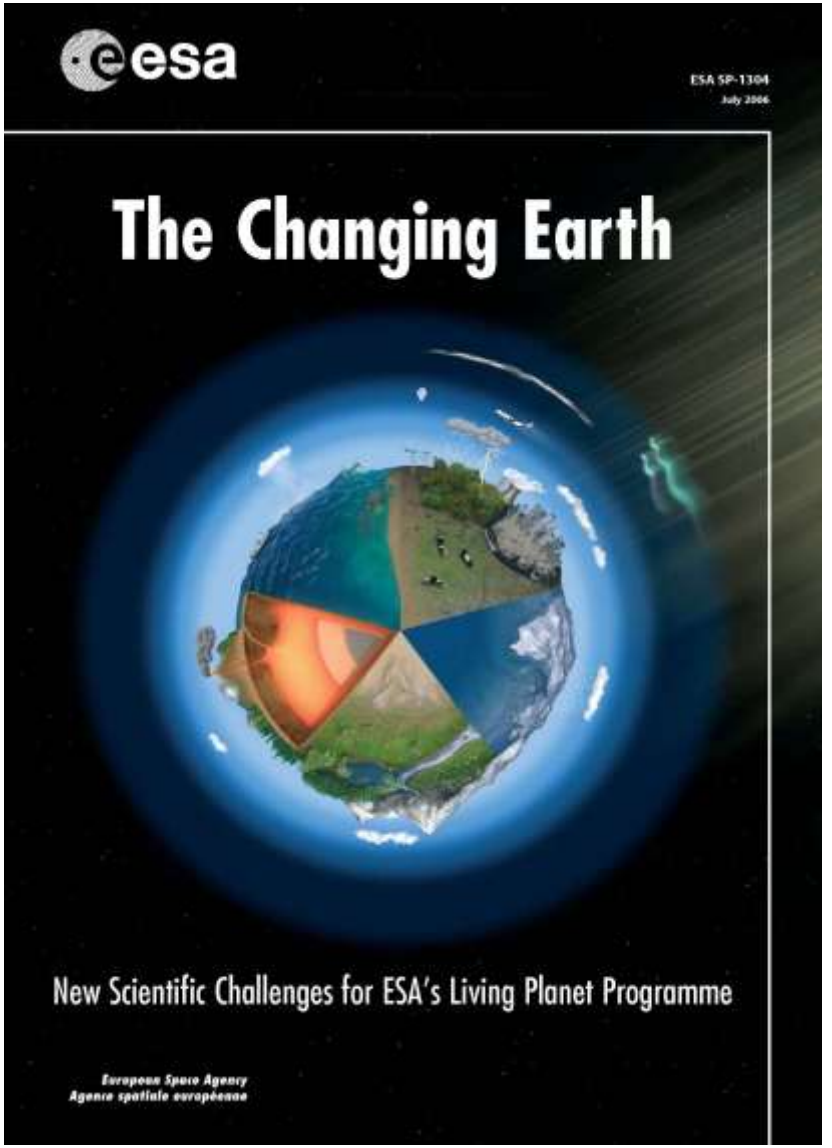
Technology Driven by Science

ESA's EO strategy is used to define:

- Scientific challenges
- New observation requirements
- Technology challenges and
- Technology requirements and activities

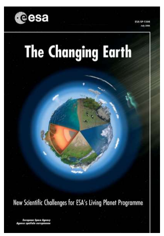
The prioritised requirements are used to define workplans, based on the scientific "drive" and from other inputs e.g. the likely evolution of the GMES programme.

EO is a vast field and despite streamlining through the process would require much higher resources to advance all technologies of interest.

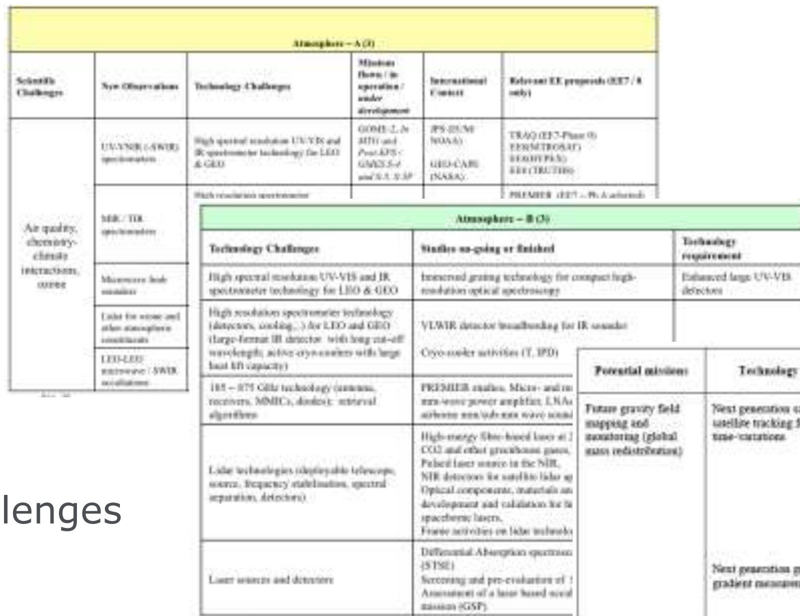


How are future activities defined?

- In 2010 Earth Observation technology challenges and plans were presented and iterated.
- These were then used as input for workplans.
- In the document 13 potential mission concepts and 4 topics on more generic needs (structures, thermal control, data handling, communications, ground segment) have been defined.



Science → New observations → EO Technology challenges → Workplans → Activities funded by EOEP / Activities funded by corporate programmes

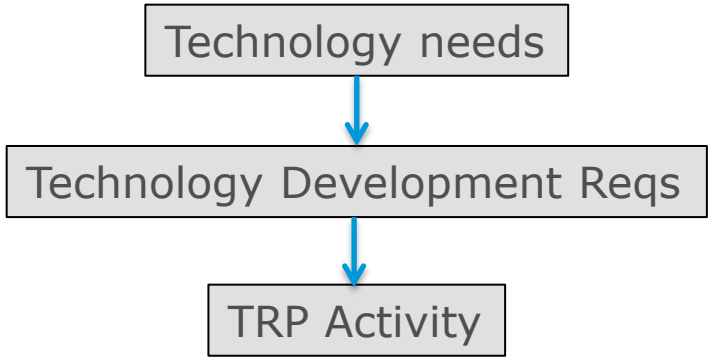


Potential missions	Technology areas	Technology development requirements	Covered in TRP plan
Future gravity field mapping and monitoring (global mass redistribution)	Next generation satellite-to-satellite tracking for gravity time-variations	laser interferometer tracking system; laser frequency stabilisation; digital interferometer phasemeter	T117-309MM
		drag-free technologies; in-orbit lessons learned; electrostatic accelerometer evolution; micro-thrusters for 6DOF control; low-noise attitude actuators;	T105-302EC
	Next generation gravity gradient measurements	atom interferometry gradiometers	T117-306MM
Ocean mesoscale currents (possibly in combination with reference altimetry)	Wide-swath ("IRAC"-type) altimeters	interferometric radars at Ku- and Ka-band with modest baselines: ultra-stable structures, (miniaturised) on-board distance metrology, high-performance attitude estimation and stabilisation, microwave calibration, interferometric radar advanced on-board processing	T107-307EE, T117-308MM
	Wavemill concept	squinted dual-beam antenna	T107-310EE
	Constellation of miniaturised altimeters	miniaturisation of altimetry electronics, on-board processing	T106-301ET, T107-306EE

- Optimising use of limited resources
- EOEP provides a stable and flexible environment for EO R&D activities.
- EOEP lines currently insufficient to advance all identified technology of interest

Potential Future Missions presented in the TRP plan (2011 – 2013)

1. Future gravity field mapping and monitoring
2. Ocean mesoscale currents
3. In-land waters
4. Air-sea interactions
5. Ice sheet (sounding) and glaciers
6. Atmospheric processes and air quality
7. High resolution thermal infrared
8. High resolution from GEO (coastal monitoring and ocean colour)
9. High resolution soil moisture and ocean salinity
10. SAR imagery for land change detection and topography
11. Maritime surveillance
12. Next generation high resolution wide swath SAR imagery
13. Next generation high resolution land optical



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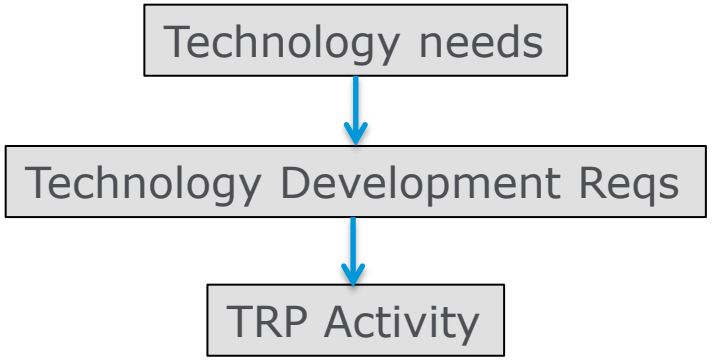

Example 1: TRP Planning for Future Ocean Mesoscale Current Measurement

Potential Mission: Ocean mesoscale currents

Technology Area: Wide swath altimeters
Wavemill
Constellation of miniaturised 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
- Squinted dual-beam antenna
- Altimetry electronics & O/B processing
  Miniaturiation

T107-307EE:
Interferometric antennas at Ku/Ka for wide swath altimetry (baseline 2.5 m)
Target TRL: 3

T117-308MM:
Compact optical attitude transfer system
Target TRL: 3

T107-310EE:
Wavemill antenna concept & critical breadboarding
Target TRL: 3

T106-301ET:
Miniaturised altimeter study
Target TRL: 2

T107-306EE:
Compact Ku/Ka-band altimetric antenna for LEO constellation
Target TRL: 2

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Potential Mission: Ocean mesoscale currents

Technology Area: Wide swath altimeters

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T107-307EE: Interferometric antennas at Ku/Ka for wide swath altimetry (baseline 2.5 m) — **Target TRL: 3**

T117-308MM: Compact optical attitude transfer system — **Target TRL: 3**

T107-310EE: Wavemill antenna concept & critical breadboarding — **Target TRL: 3**

T106-301ET: Miniaturised altimeter study — **Target TRL: 2**

T107-306EE: Compact Ku/Ka-band altimetric antenna for LEO constellation — **Target TRL: 2**

Example 1: Overview of Wavemill related activities

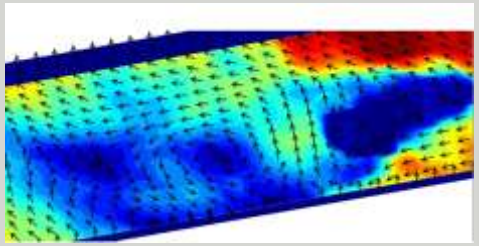
2010 2011 2012 2013 2014

Feasibility Study

- Scientific requiremts 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



Simulator

ESA Internal Funding

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

Wavemill Science Workshop Q1 2013

Product Assessment

- 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?? Funding TBD

System Study

Antenna B/B

OBP B/B

COATS

- Compact Optical Attitude Transfer System

All activities below are in TRP plan 2011-13

= EOPA = IPD = TRP = GSP

Potential Future Missions presented in the TRP plan (2011 – 2013)

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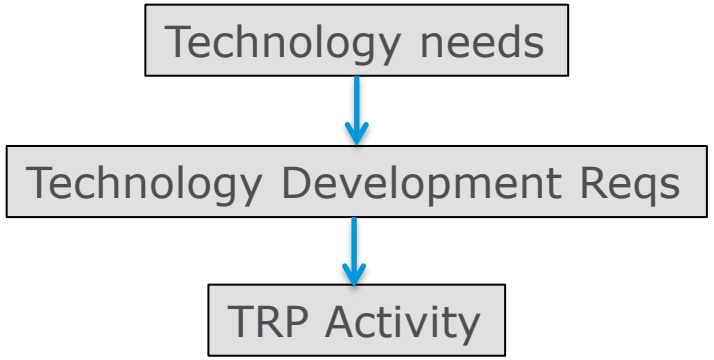

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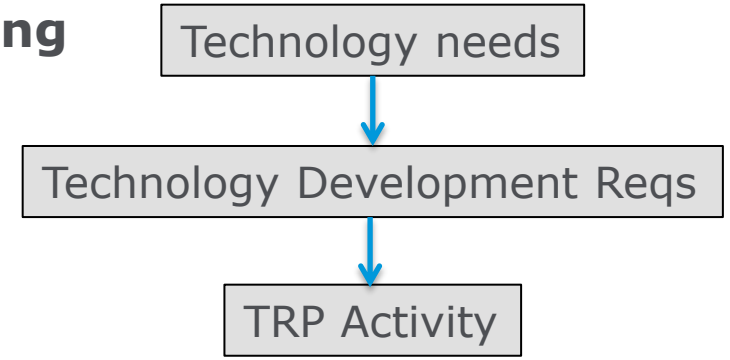


TRP Planning for Future Gravity Field Mapping and Monitoring Activities

Potential Mission: Future Gravity Field Mapping and Monitoring

Technology Area: Next Generation sat to sat tracking for gravity time variations
Next generation gravity gradient measurement

Technology Development Requirements

- Laser interferometer tracking system
- Laser Frequency stabilization
- Digital interferometer phasemeter
- Drag free technologies
- In-orbit lessons learnt
- Electrostatic accelerometer evolution
- Microthrusters for 6DOF control
- Low noise attitude actuators
- Atom interferometry gradiometry

T117-309MM:
Laser Stablilsation Unit for Interferometric Earth Gravity Measurement

Target TRL: 4

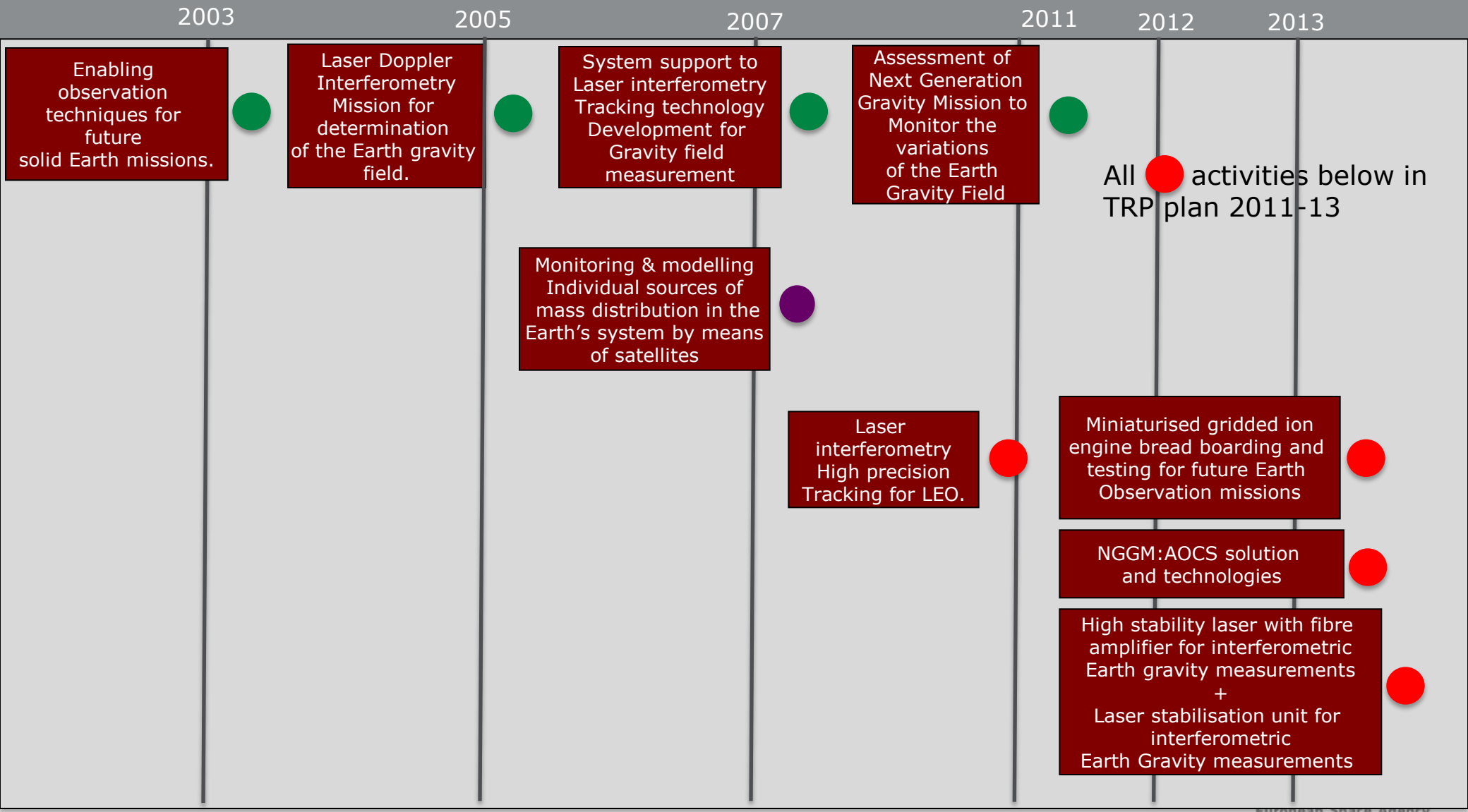
T105-302EC:
NGGM:AOCS solutions & technologies (identify critical h/w & s/w for feasibility and design drivers)

Target TRL: 3

117-306MM:
Compact vacuum chamber for an Earth gravity gradiometer based on laser cooled atom Interferometry

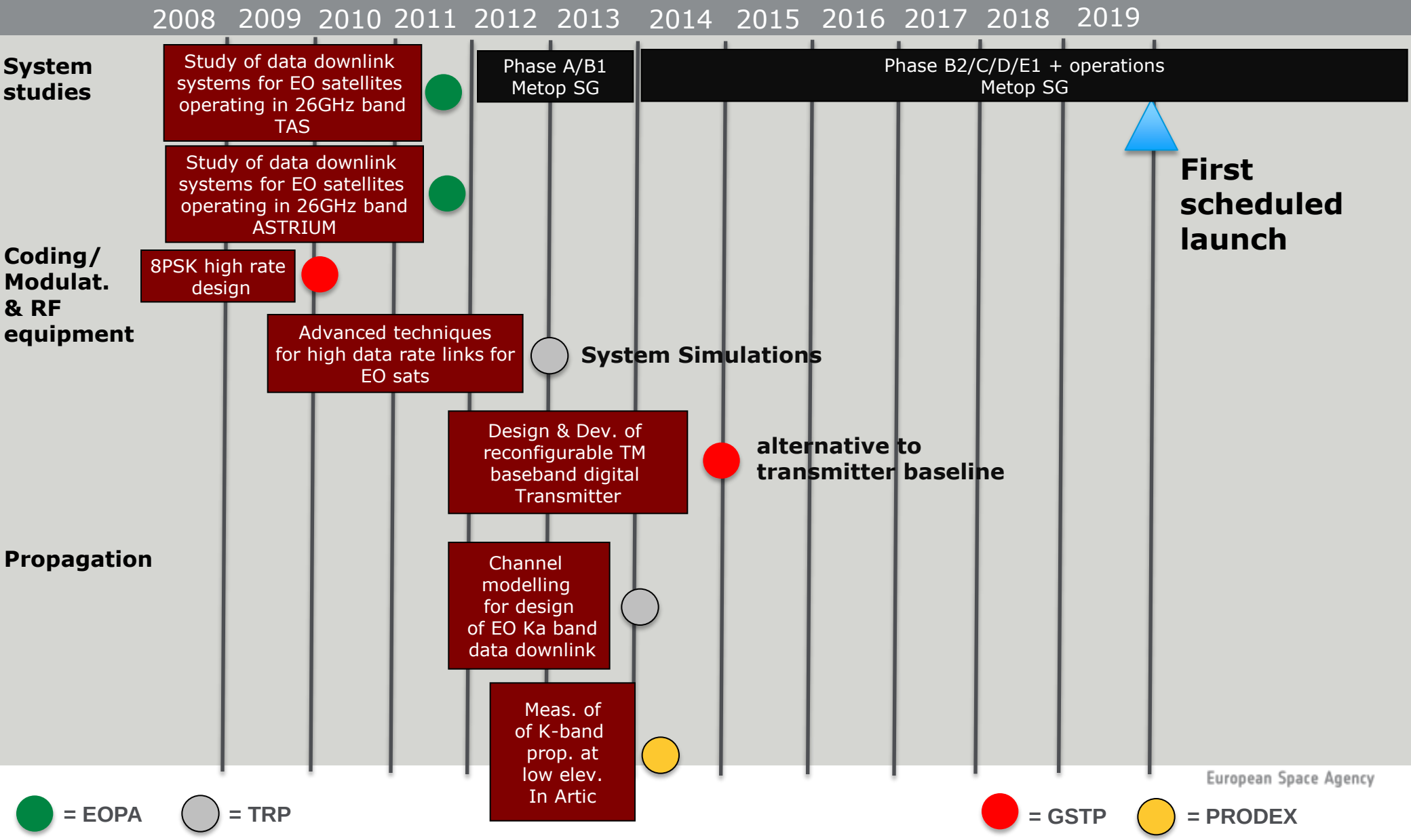
Target TRL: 3

Example 2: Overview of Gravity Mapping and Monitoring related activities



= EOPA = TRP / GSTP = GSP

Example 3: Overview of 26GHz Downlink Development Preparation to Implementation



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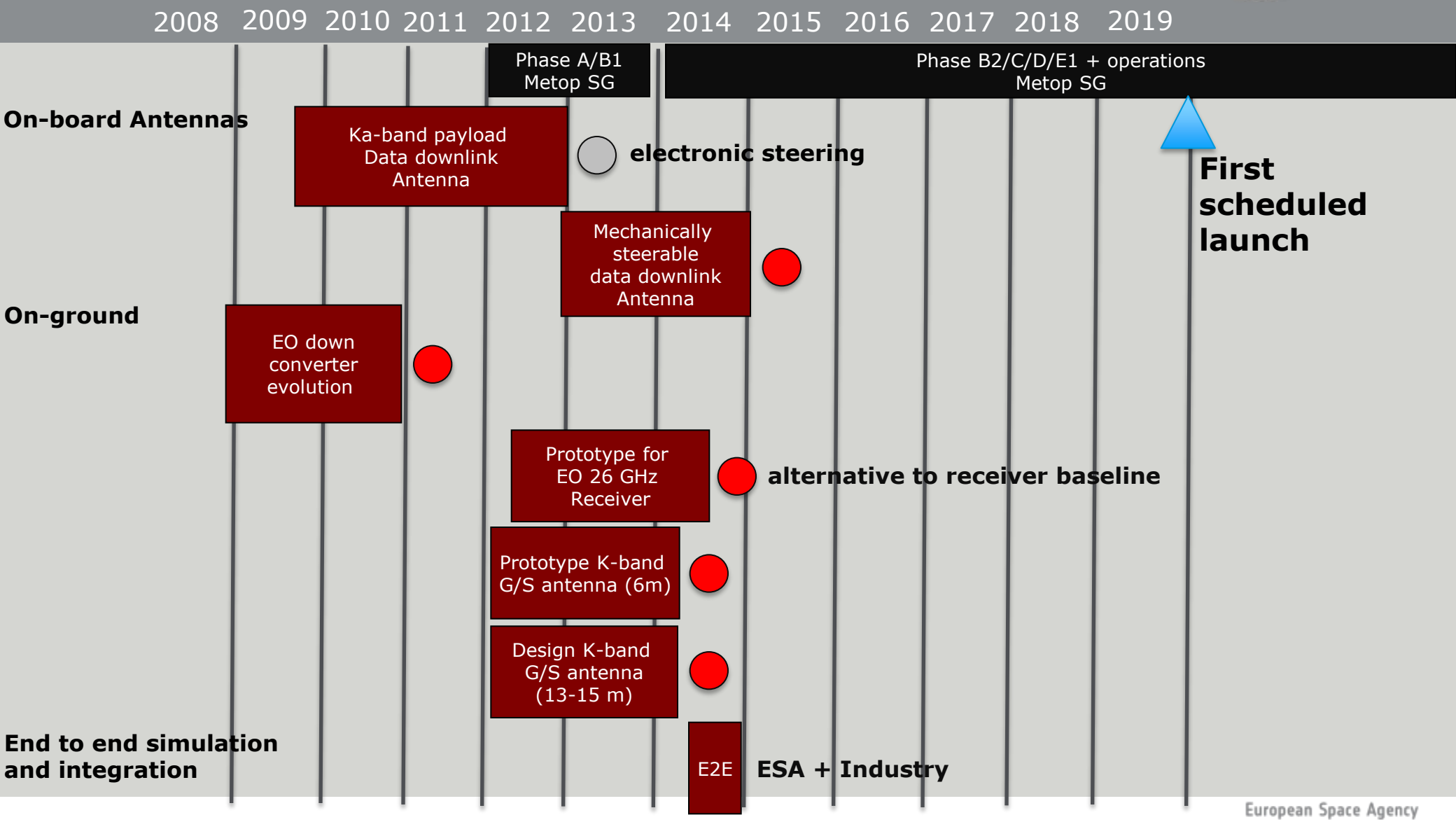


European Space Agency

= EOPA = TRP = GSTP = PRODEX

Status of Technology activities for EO missions in preparation

EE-7 candidates:

- BIOMASS, CoReH2O and PREMIER technology activities are well underway.

EE-8 candidates:

- Activities for FLEX and CarbonSat are on-going, in general, less technology support is expected to be necessary for the EE Opportunity missions, nonetheless breadboarding of critical elements is included in the Phase A/B1 studies.

MetOp SG:

- 60 activities (microwave, optical instruments, radio occultation and platform) are completed, on-going, or are being prepared.

Status of Technology activities for Commended EO missions

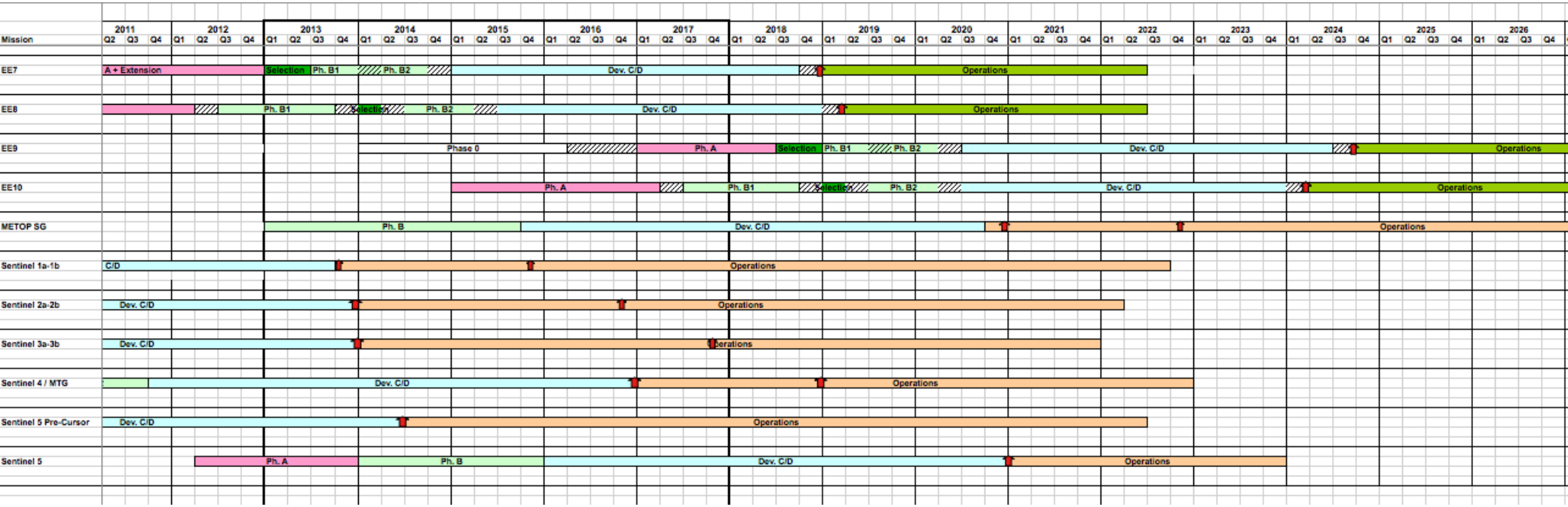
Commended EE-7 mission concepts: (A-SCOPE, TRAQ, GOMAS, CIWSIR, Space Waves, ACCURATE)

- Activities are close to completion, except for laser activities
- No follow-on activities planned

Commended EE-8 mission concepts: (Forum, ACCURATE, E.motion, EXCALIBUR, GEOSAT, GLACIES, SPeCL, TIREX, Truths)

- Activities will depend on availability of funds in EOEP-4
- Only occasional and minor efforts (under TRP/GSTP) could perhaps be accommodated at present.

Latest planning as of June 2012



Conclusions

1. Technology Support for EE missions and MetOp Second Generation is well underway.
2. Coordinated preparatory activities to ensure science, system and technological coherence.
3. Satellites being designed to fly together:
    a. PREMIER flying with Metop (EE7 mission candidate)
    b. FLEX flying with Sentinel 3 (EE8 mission candidate)
    c. Earth Observation Convoy studies: Ocean and Ice, Land and Atmosphere applications -> Workshop June 2013
4. EE7 and EE8 mission candidates are under way or planned – again limited by resources available.
5. For recommended (non-selected) EE8 mission concepts the support is limited (EOEP-3). EOEP-4 needs member state support at the Ministerial (2012) for these activities.

THANK YOU