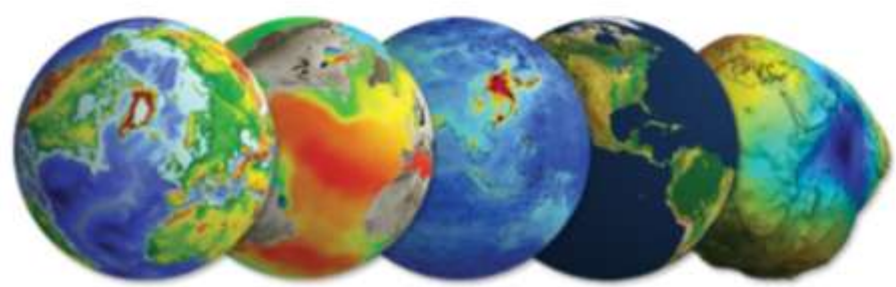
CEOI Emerging Technologies Workshop

30th April / 1st May, 2014

Amanda Regan
Future Missions Division
Earth Observation Directorate
European Space Agency
ESA/ESTEC
amanda.regan@esa.int



Contents

The ESA Earth Observation 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 (EOEP)

The Earth Observation Envelope Programme (EOEP) is the key to implementing the Living Planet Strategy.

It represents a stable planning environment for new technologies and associated missions to be prepared.

EOEP comprises two main components:

a) The *Earth Explorer Component*

This component is science driven.

It comprises the definition, development, launch and operations of Earth Explorer missions (platform, payload and ground segment).

b) The *Development and Exploitation Component*

The Development and Exploitation component includes all preparatory activities for future missions. It addresses both science-themed Earth Explorer candidates and operational Earth Watch missions.

The Earth Observation Envelope Programme

- The EOEP is run as an optional ESA programme (optional = ESA member states decide whether to contribute or not)
  a. Operates on a 4 - 5 year cycle

- The EOEP-3 ran from 2008 and 2012
- The EOEP-4 runs from 2013 – 2016
- The EOEP-5 will run from ~2017 – 2020/1

- It provides a long-term, rolling environment for the planning of new activities, exploitation of results, contingency response and continuity of missions.

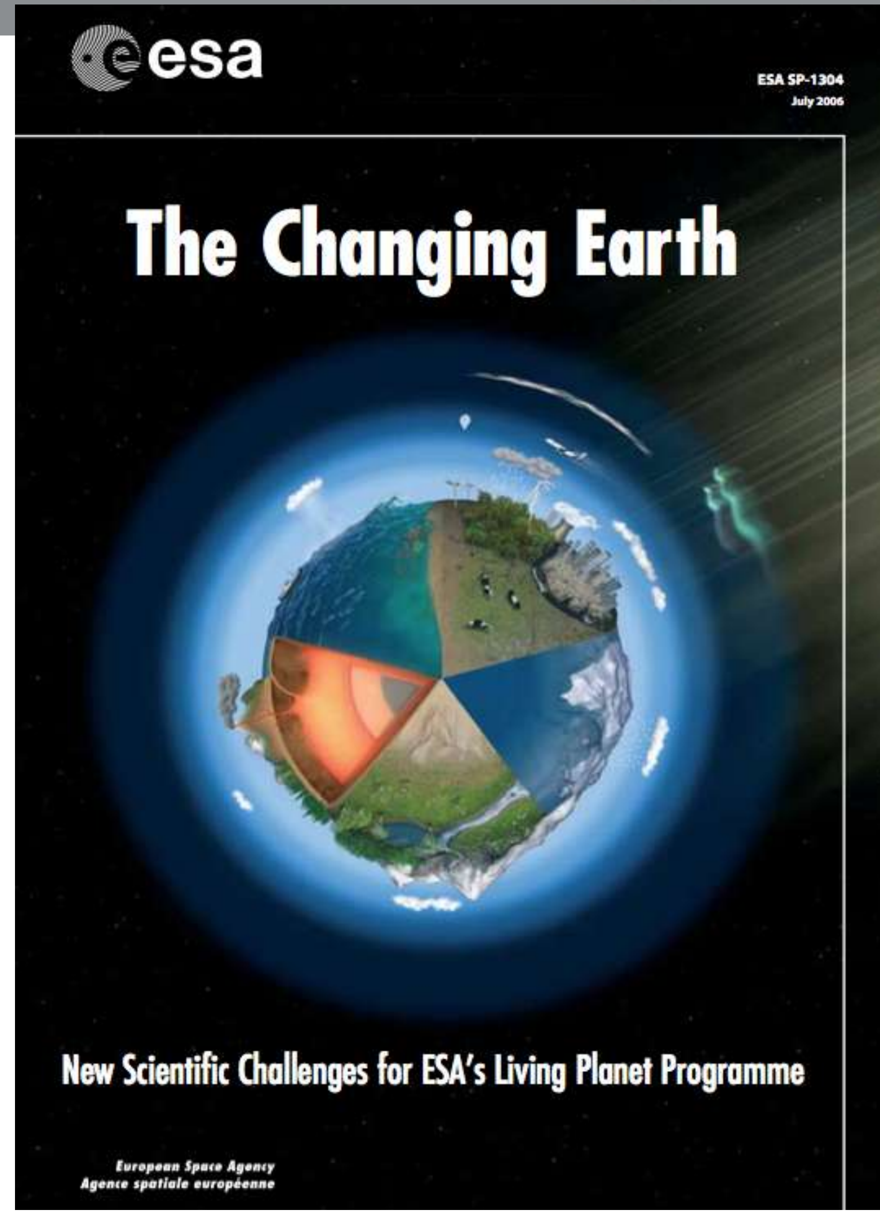
- Next Ministerial Meeting December 2014

ESA Earth Observation Science Strategy

- Identifies the primary scientific challenges across five Earth system elements
  - Land
  - Ocean
  - Cryosphere
  - Atmosphere
  - Solid Earth

http://esamultimedia.esa.int/docs/SP-1304.pdf

- These challenges were defined following a wide consultation with the Earth science community and updated inputs were given at the Living Planet Symposium in 2013
- The updates will be published as an annex to to the science strategy in Autumn 2014.



ESA Earth Observation Missions

Living Planet

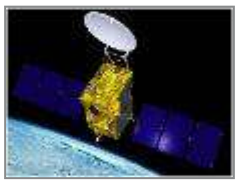
Earth Explorer

Research driven

Core Missions

GOCE
17/03/09

ADM-Aeolus
2016



EarthCARE
2017

Biomass
2020

Opportunity Missions

CryoSat-2
08/04/10

SMOS
02/11/09

Swarm
22/11/13

CarbonSat
FLEX

EE8
2021/2

Continuity of Missions

ERS-2
1995 – 2011

Envisat
2002 - 2012

Earth Watch

Operational Service driven

Operational Meteorology

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

Copernicus

- Sentinel 1
- Sentinel 2
- Sentinel 3
- Sentinel 4 (MTG)
- Sentinel 5 precursor
- Sentinel 5 (MetOp-SG)

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esa

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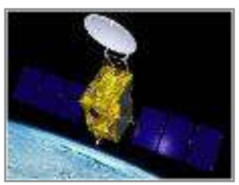

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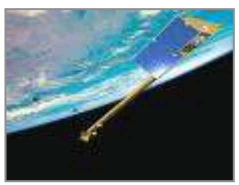

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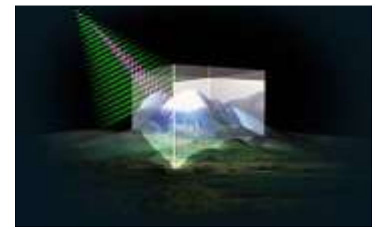
The Earth Observation Envelope Programme (EOEP) is the key to implementing the Living Planet Strategy. It is a stable planning environment where all new missions and technologies are prepared.

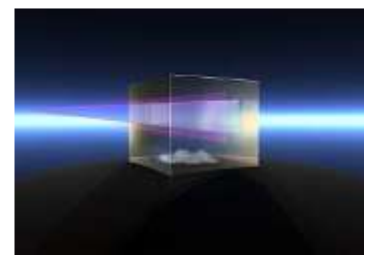
Earth Explorer 7 Core Mission Selection

- **Status: Biomass was selected** following a user consultation meeting in 2013. Planned launch is 2020
- 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

ace Agency

Earth Explorer 8 Opportunity Mission Candidate Status

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

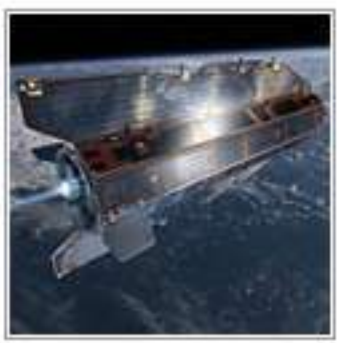
- **FLEX:** to provide global maps of vegetation fluorescence, which can be converted into an indicator of photosynthetic activity -> to improve our understanding of how much carbon is stored in plants and their role in the carbon and water cycles
- Designed to fly with Sentinel-3 (synergy with optical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

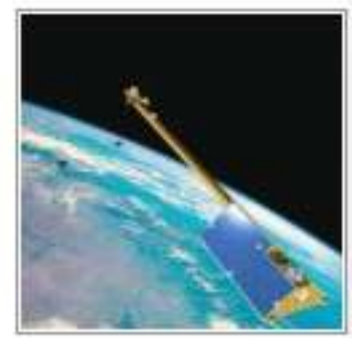
- **CarbonSat:** to quantify and monitor the distribution of carbon dioxide and methane -> for a better understanding of the sources and sinks of these two gases and how they are linked to climate change.

Future Earth Explorer Calls EE9

- <u>Earth Explorer EE9:</u>
- Call will be initiated around end 2014 / beginning 2015

  (Implementation Phase B/C/D to start around 2018)

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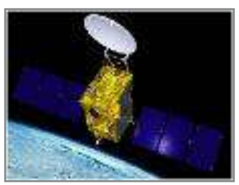

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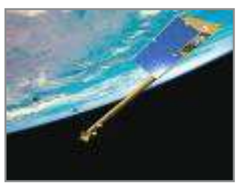

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Missions outside EOEP
but preparatory work
is within EOEP

The European Earth Observation Programme - Copernicus

- Previously know as Global Monitoring Environment and Security (GMES)

- Joint initiative of EU and ESA

- The Sentinel satellite series represent the dedicated (long term) space segment of Copernicus, supported by:
  - ➢ contributing missions from ESA member states
  - ➢ ground (in-situ) observation capabilities

- to address a large number of information services and applications

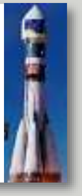
Copernicus
The European Earth Observation Programme

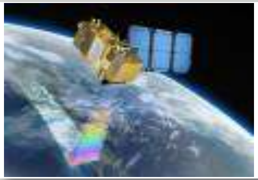
Copernicus dedicated missions: Sentinels

Unit A / Unit B

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

03-04-14 / 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

2015 / 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 / 2016

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

2020

(Payload on MTG)

Sentinel 5 – Low-orbit atmospheric
Atmospheric composition monitoring
(S5 Precursor launch in 2015, x 1 satellite – follow ground track of Suomi-NPP)

2020

(Payload on Metop-SG)

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

Copernicus
The European Earth Observation Programme

Sentinel–1: C-band SAR Mission

Applications:

- monitoring sea ice zones & the arctic environment
- surveillance of marine environment
- monitoring land surface motion risks
- monitoring of land surfaces: forest, water and soil, agriculture
- mapping in support of humanitarian aid in crisis situations

Mission and Instrument

- C-band Synthetic Aperture Radar
  - 4 nominal modes
    - ➢ Strip map (80 km swath, 5 m x 5 m res. (range x azimuth
    - ➢ Interferometric wide swath (250 km swath, 5 m x 20 m res.) with burst synchronisation for interferometry
    - ➢ Extra wide swath (400 km swath, 20x40 m res.)
    - ➢ Wave (5X5 m res, leap-frog sampled images of 20x20 km at 100 km along orbit)
- Near Polar Sun-Synchronous at 693 km mean altitude (18:00 LTAN)
- 12 day repeat cycle with 2 satellites
- 7 years design life time, consumables for 12 years

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Applications:

- monitoring sea ice zones & the arctic environment
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- mapping in support o

Sentinel-1A launched successfully on Thursday 3rd April, 2014

Mission

- C-band

th, 5 m x 5 m res. (range

  - ➢ Interferometric wide swath (250 km swath, 5 m x 20 m res.) with burst synchronisation for interferometry
  - ➢ Extra wide swath (400 km swath, 20x40 m res.)
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Sentinel–2: Multispectral Imager Mission

Applications:

- generic land cover maps
- risk mapping and fast images for disaster relief
- generation of leaf coverage, leaf chlorophyll content and leaf water content

Mission and Instrument

- Push broom filter based multi-spectral imager with 13 spectral bands (VNIR & SWIR)
- Spatial resolution: 10, 20 and 60 m
- Swath: 290 km
- 5 days repeat cycle (cloud free) with 2 satellites
- Sun synchronous orbit at 786 km mean altitude
- LTDN: 10:30 am
- 7 years design life time, consumables for 12 years

Sentinel–3: Ocean & Global Land Mission

Applications:
- Sea/land colour data and surface temperature
- sea surface and land ice topography
- coastal zones, inland water and sea ice topography
- vegetation products

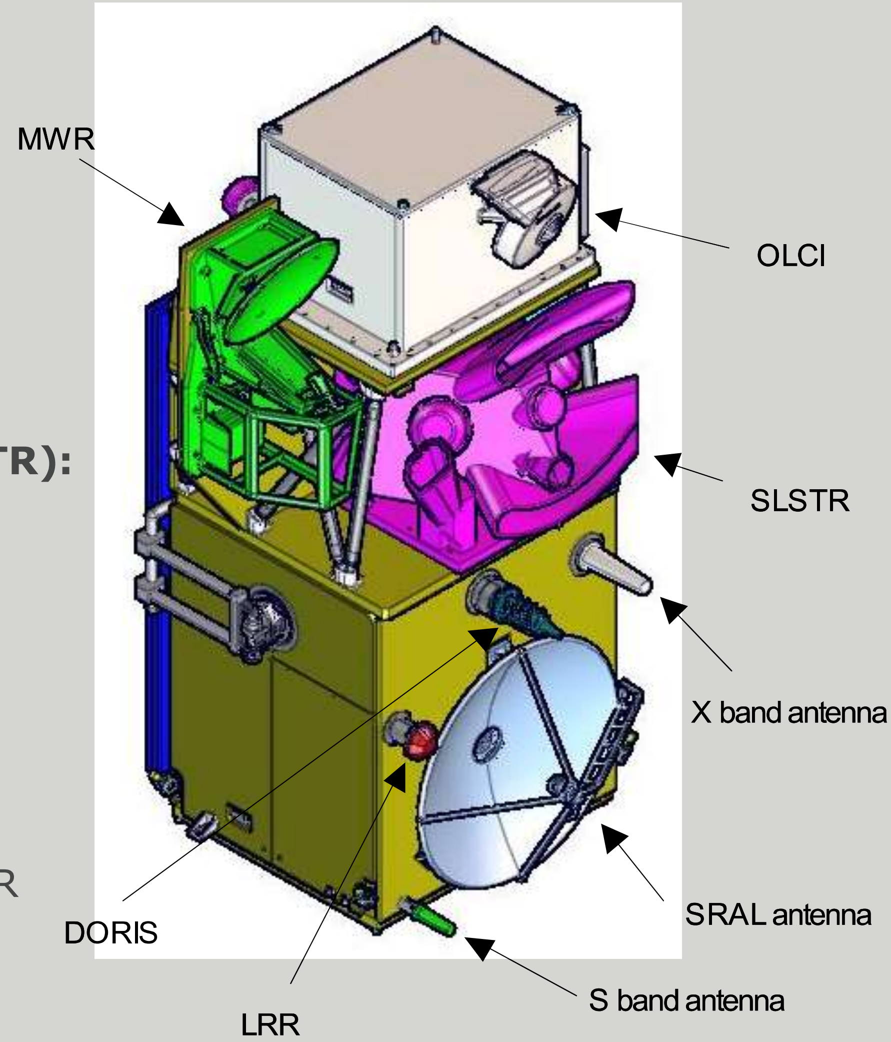
Mission and Instrument
- Multi-instrument platform
  - Ocean and Land Colour Instrument (OLCI)
  - Sea & Land Surface Temperature Radiometer (SLSTR)
  - Dual frequency Radar Altimetry Suite (RA)
- 27 day repeat cycle with 2 satellites
- Sun synchronous orbit at 814 km mean altitude over geoid
- LTDN: 10:00 am
- 7 years design life time, consumables for 12 years

Sentinel–3: Ocean & Global Land Mission

- **Ocean and Land Colour Instrument (OLCI):**
  - 21 bands in [400, 1020] nm comprising:
    - 5 cameras for a total swath of 1270 km
    - 8 bands (in VIS) for open ocean (low res),
    - 15 bands (in VIS) for coastal zones (high res).
  - Spatial sampling: 300 m @ SSP
  - Radiometric accuracy: absolute: 2 %, relative: 0.1%

- **Sea and Land Surface Temperature Radiometer (SLSTR):**
  - 9 spectral bands [0.55, 12] um;
  - Resolution: 0.5 km (VIS, SWIR), 1 km (MWIR, TIR);
  - TIR NEDT: 0.05 K
  - Swath: 180-rpm dual-view scan, nadir (1420 km) & backwards (750 km)

- **Radar Altimetry suite (RA)**
  - 3-cm accurate SRAL Ku/C altimeter with LRM and SAR measurement modes, supported by MWR and POD (with LRR, GPS, DORIS)



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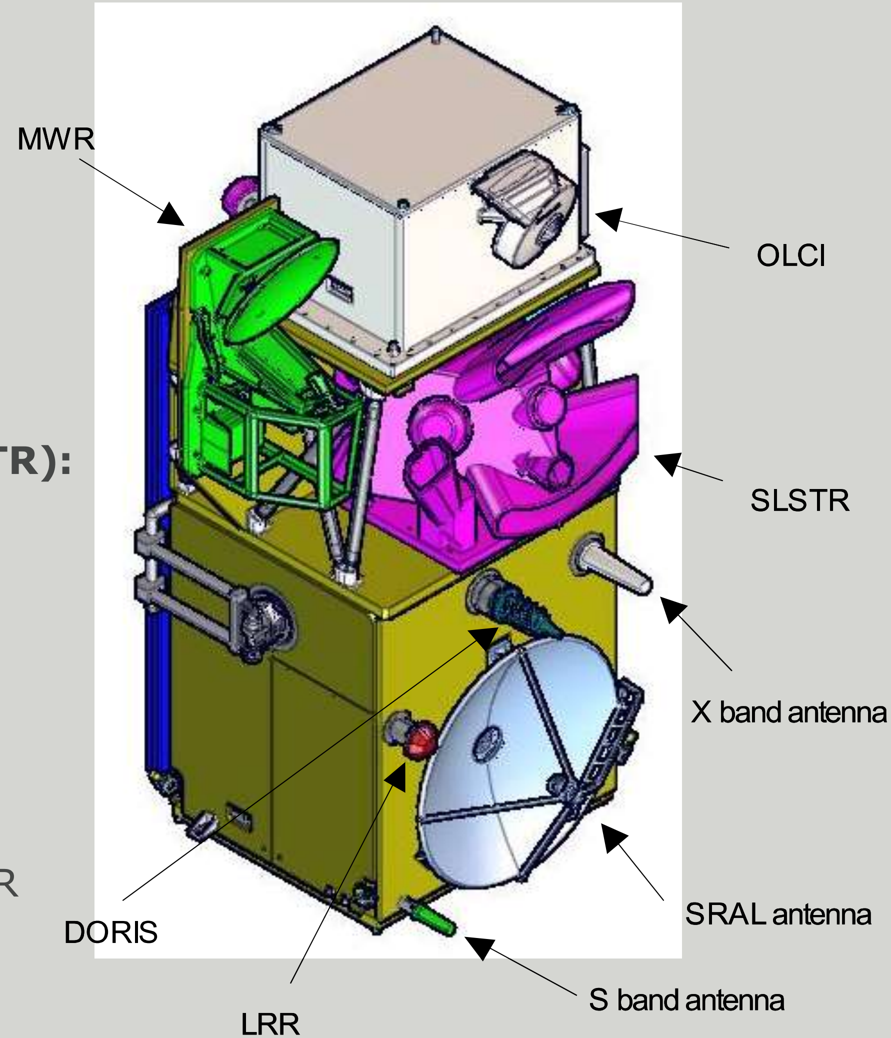


Sentinel–4: GEO Atmospheric Mission

Applications:

- monitoring changes in the atmospheric composition (e.g. ozone, NO_2, SO_2, BrO, CHOCHO, formaldehyde and aerosol) at high temporal resolution
- tropospheric variability

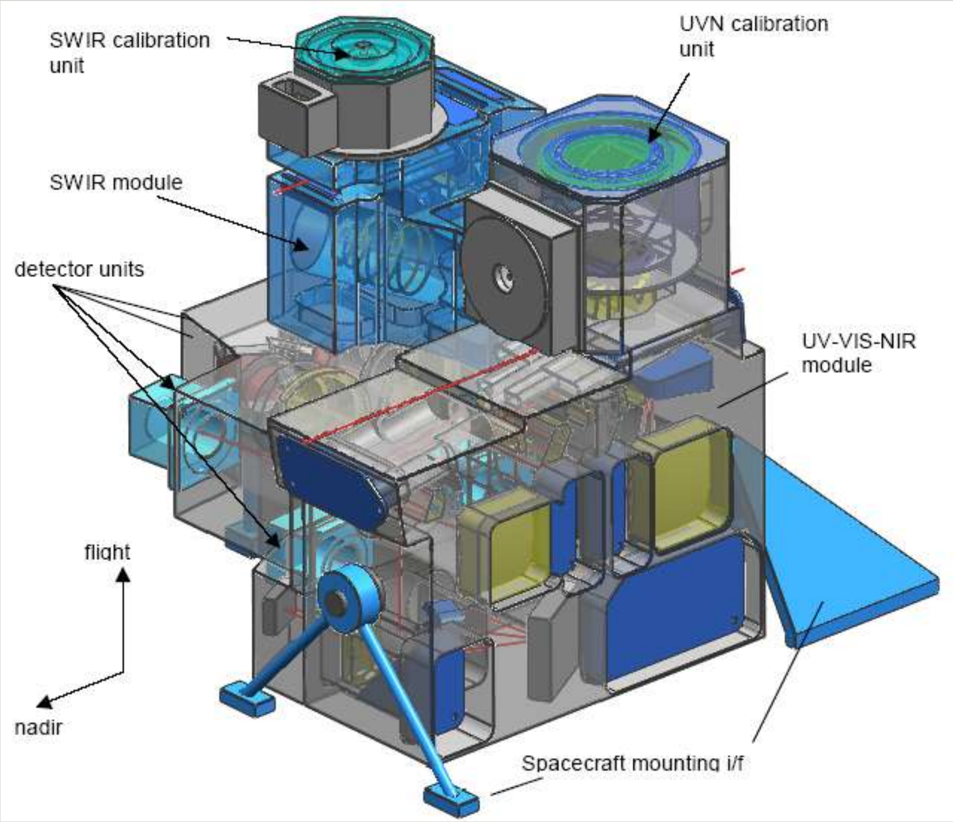
Mission and System

- Narrow field spectrometer UV (305-400 nm), visible (400-500 nm) and near-IR (750-775 nm)
- Spatial sampling 5-50 km and spectral resolution between 0.05 nm and 1 nm (depending on band
- Geostationary orbit, at 0° longitude
- **Embarked as a payload on MTG-S and operated by EUMETSAT**

Sentinel–5: LEO Atmospheric Mission

Applications:

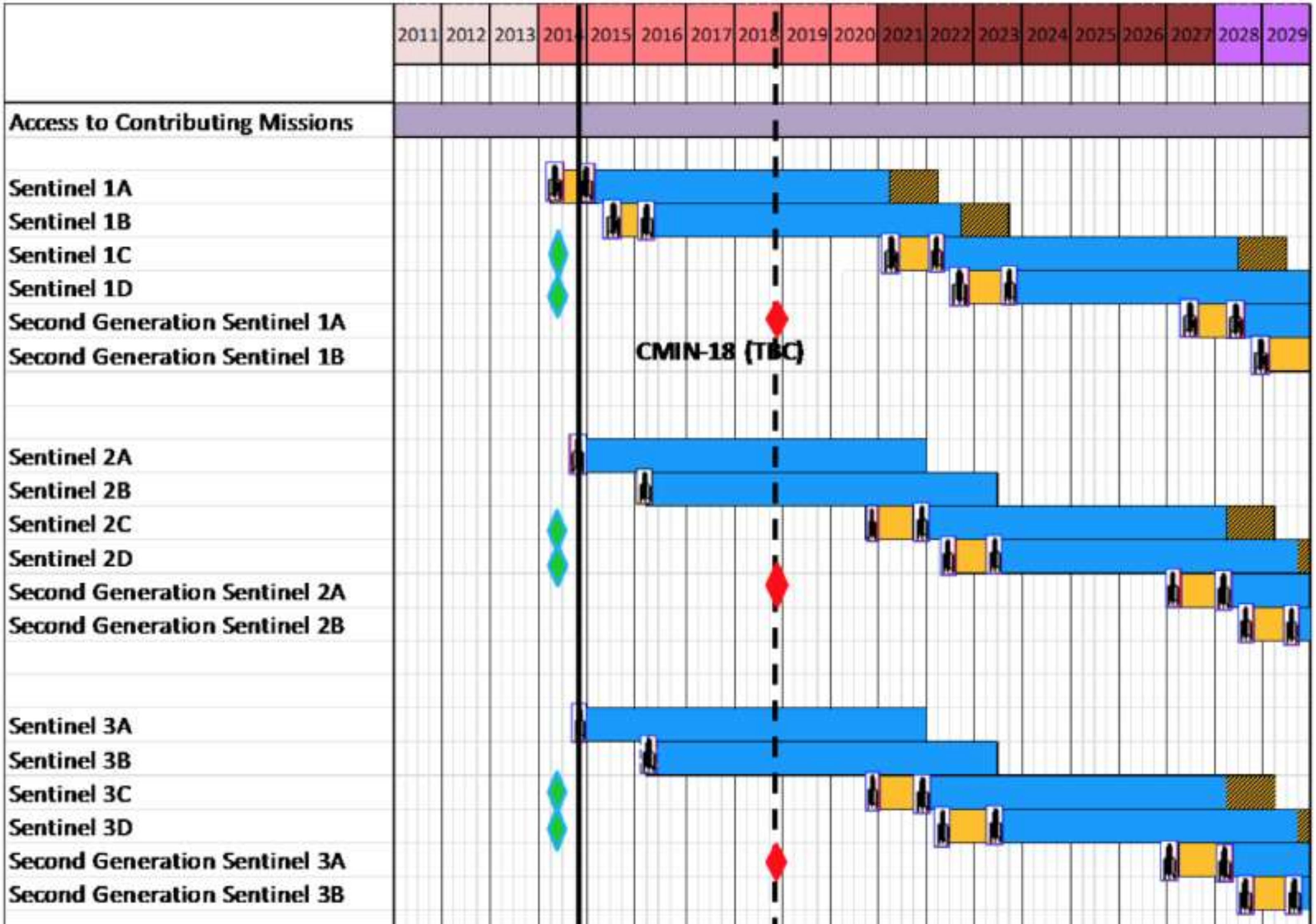
- monitoring changes in the atmospheric composition (e.g. ozone, NO_2, SO_2, BrO, formaldehyde and aerosol) at high temporal (daily) resolution
- tropospheric variability



Mission and System

- Push broom grating 5 channels spectrometer
    - UV (270-495 nm)
    - Visible (400-500 & 710-750 nm),
    - NIR (710-775 nm)
    - SWIR (2314-2382 nm)
- Spectral resolution between 0.25 nm and 1.1 nm
- Low Earth orbit (reference altitude of about 824 km)
- **Embarked as a payload on Metop-SG and operated by EUMETSAT**

Copernicus Space Segment Planning



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-I

Flexible Combined Imager,
Lightning Imager, IR sounder

2021

MTG-S (including Sentinel-4 as a payload)

GEO Meteosat series

LEO Metop series

2006 **Metop-A**

2012 **-B**

2017 **-C**

2020 **Metop SG-A**

~ 2021+ **-B**

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

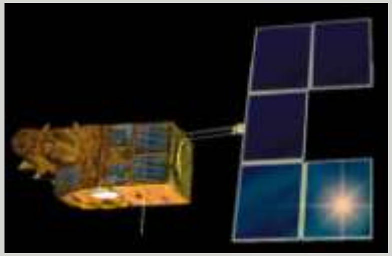
LTDN: 9.30 am, 817 km

Several instruments on each platform. Improved instrument Performance. Includes Sentinel-5 as a payload)

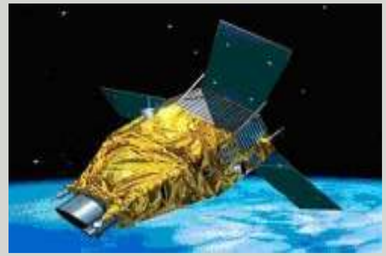
European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). ESA is the R & D agency for EUMETSAT missions

Potential Contributing Missions to Copernicus

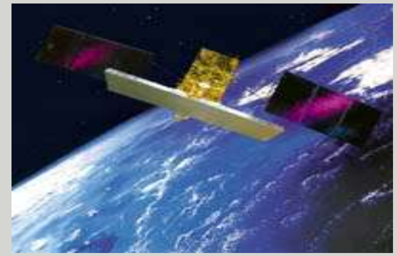
Jason



SPOT

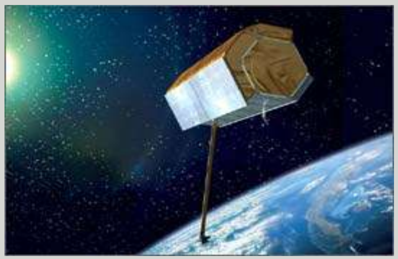


Pléiades

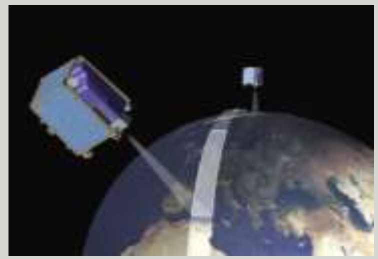


Cosmo-Skymed

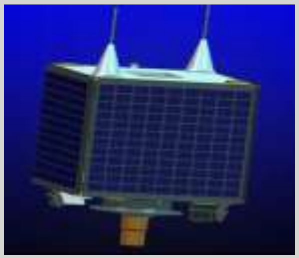
Radarsat



Terrasar–X



RapidEye



DMCs

METOP

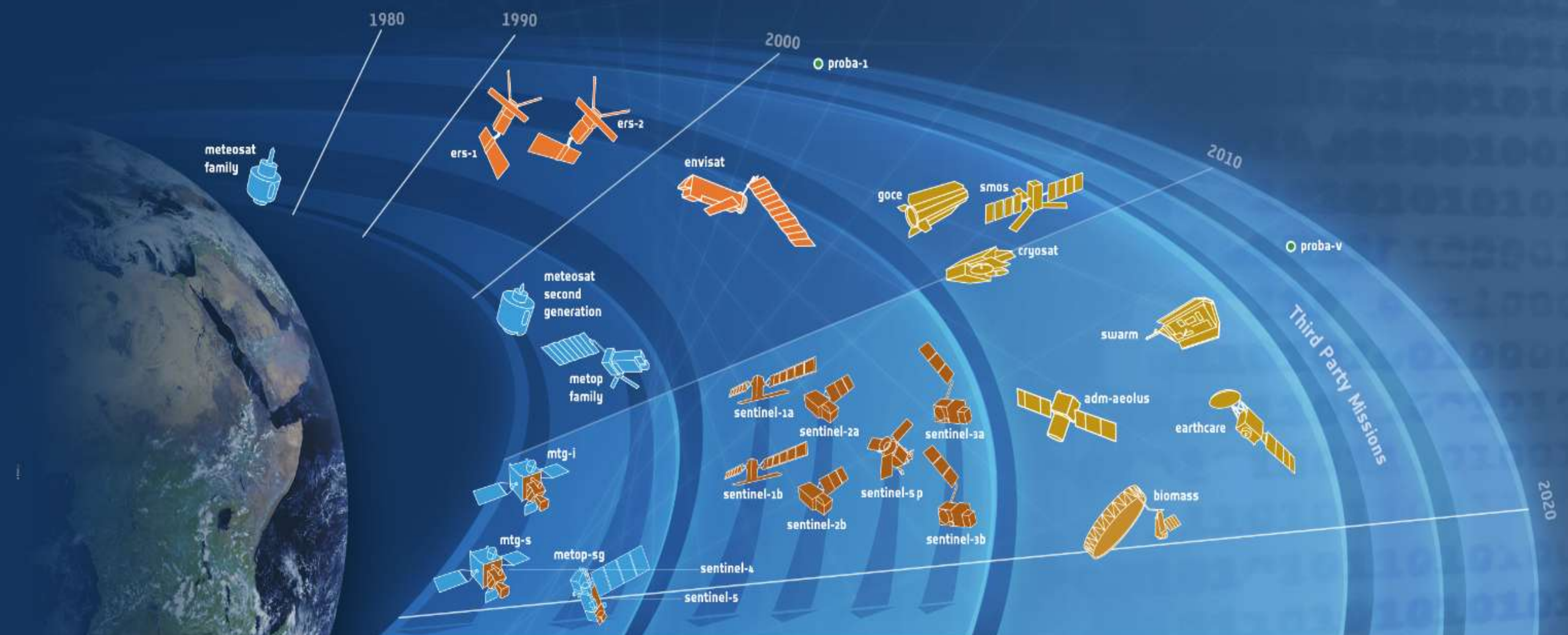
MSG

- ESA missions
- National missions from ESA member states and Canada.
- Eumetsat operated missions
- European & International Third Party Missions

(list not exhaustive – it will evolve based on service requirements)

+ Seosat, Tandem-X, Enmap, Venµs, Altika, etc.

→ THE ESA EARTH OBSERVATION PROGRAMME



Meteorological Missions driven mainly by Weather forecasting and Climate monitoring needs. These missions developed in partnership with EUMETSAT include the Meteorological Operational satellite programme (MetOp), forming the space segment of EUMETSAT's Polar System (EPS), and the new generation of Geostationary Meteosat satellites (MSG & MTG satellites).

Copernicus Sentinel Missions driven by Users needs to contribute to the European **Global Monitoring of Environment & Security** (GMES) initiative. These satellite missions developed in partnership with the EU include C-band imaging radar (Sentinel-1), high-resolution optical (Sentinel-2), optical and infrared radiometer (Sentinel-3) and atmospheric composition monitoring capability (Sentinel-4 & Sentinel-5 on board Met missions MTG and EPS-SG respectively).

Earth Explorer Missions driven by Scientific needs to advance our understanding of how the ocean, atmosphere, hydrosphere, cryosphere and Earth's interior operate and interact as part of an interconnected system. These **Research** missions, exploiting Europe's excellence in technological innovation, pave the way towards new development of future EO applications.

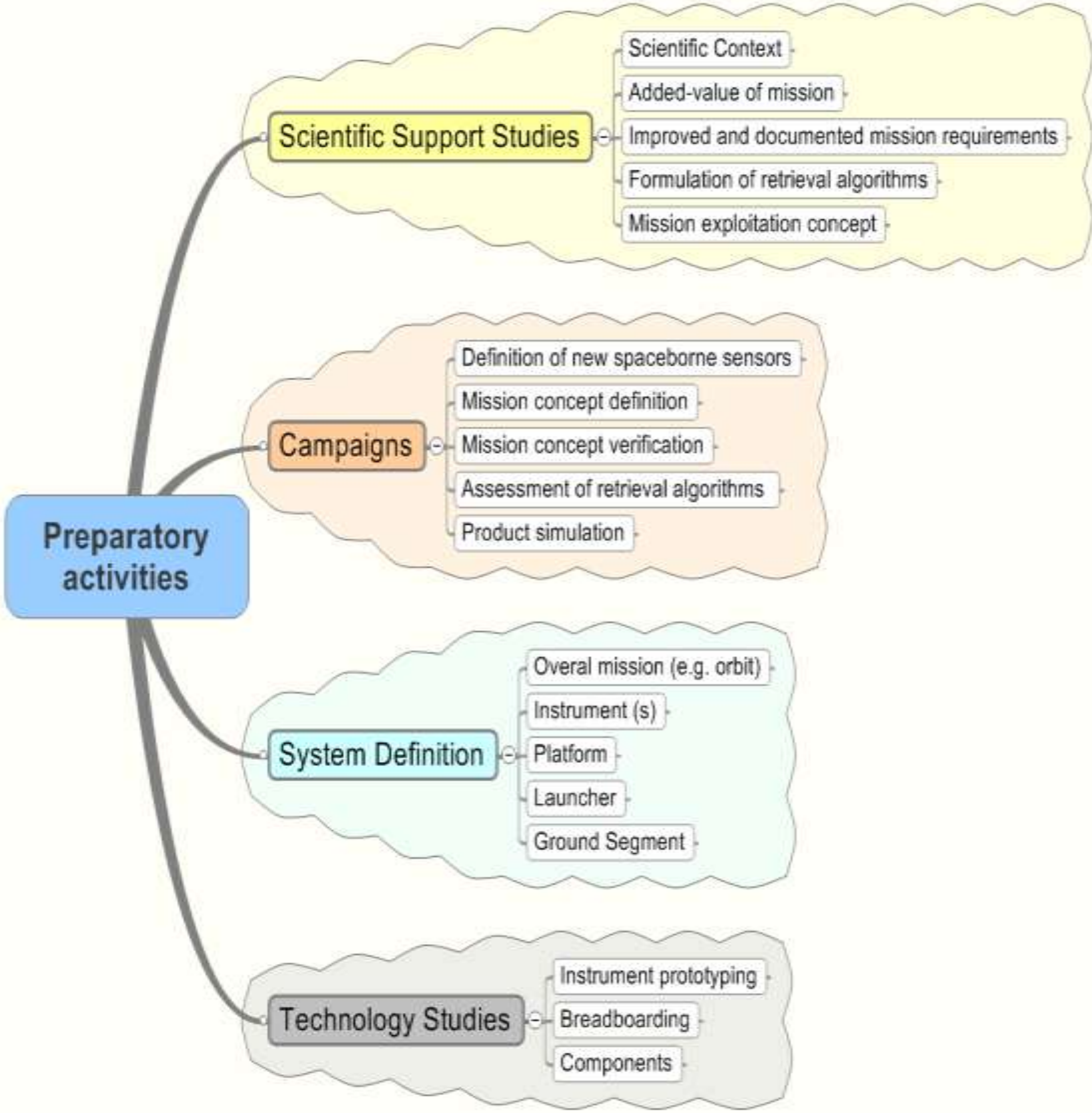
Missions With Partners

EOP Operated Missions

Contents

1. The Living Planet Programme
    - Earth Observation Envelope Programme (EOEP)
    - Overview of Missions in relation to the EOEP
    - Earth Explorers: EE7, EE8, EE9
    - Copernicus
2. **ESA EO Preparatory Activities**
    - Earth Explorers
        - Core Missions
        - Opportunity Missions
3. ESA Technology
    - ESA Technology Programmes
    - End to End Technology Process
    - ESA EO Future Mission Planning
    - Examples of Technology Challenges: Ocean, Land and Atmosphere
    - Identified Mission Areas
    - Example Road Map Activities – 26GHz Downlink
4. 1st International EO Convoy and Constellation Workshop
    - Key Messages

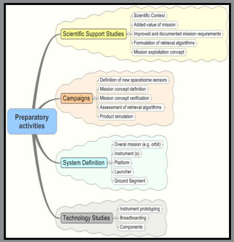
Funding for Earth Observation Preparatory Activities



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 Core Mission Phase A (now in Phase B)

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)

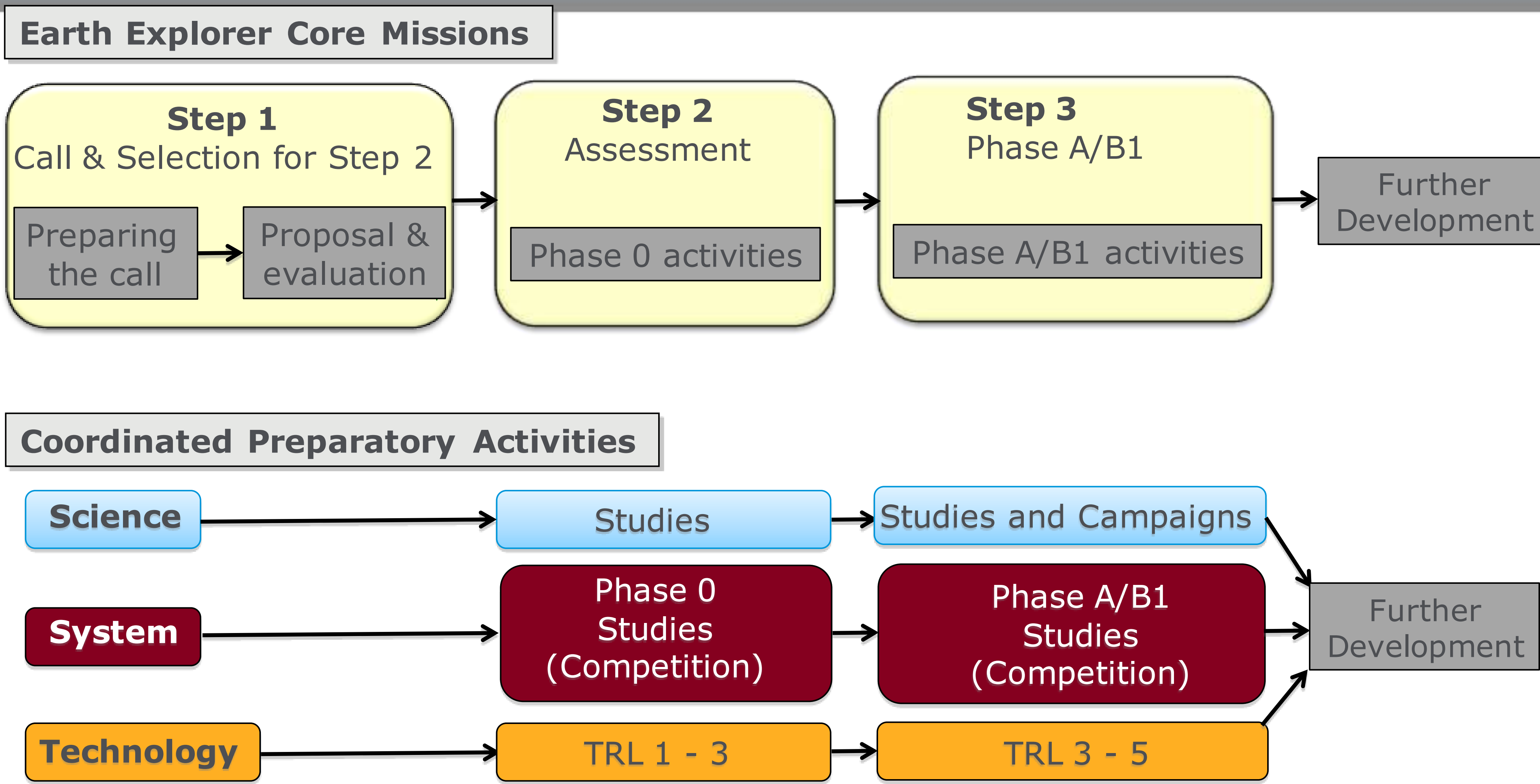
End-to-end Performance Evaluation and System Support

- 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)

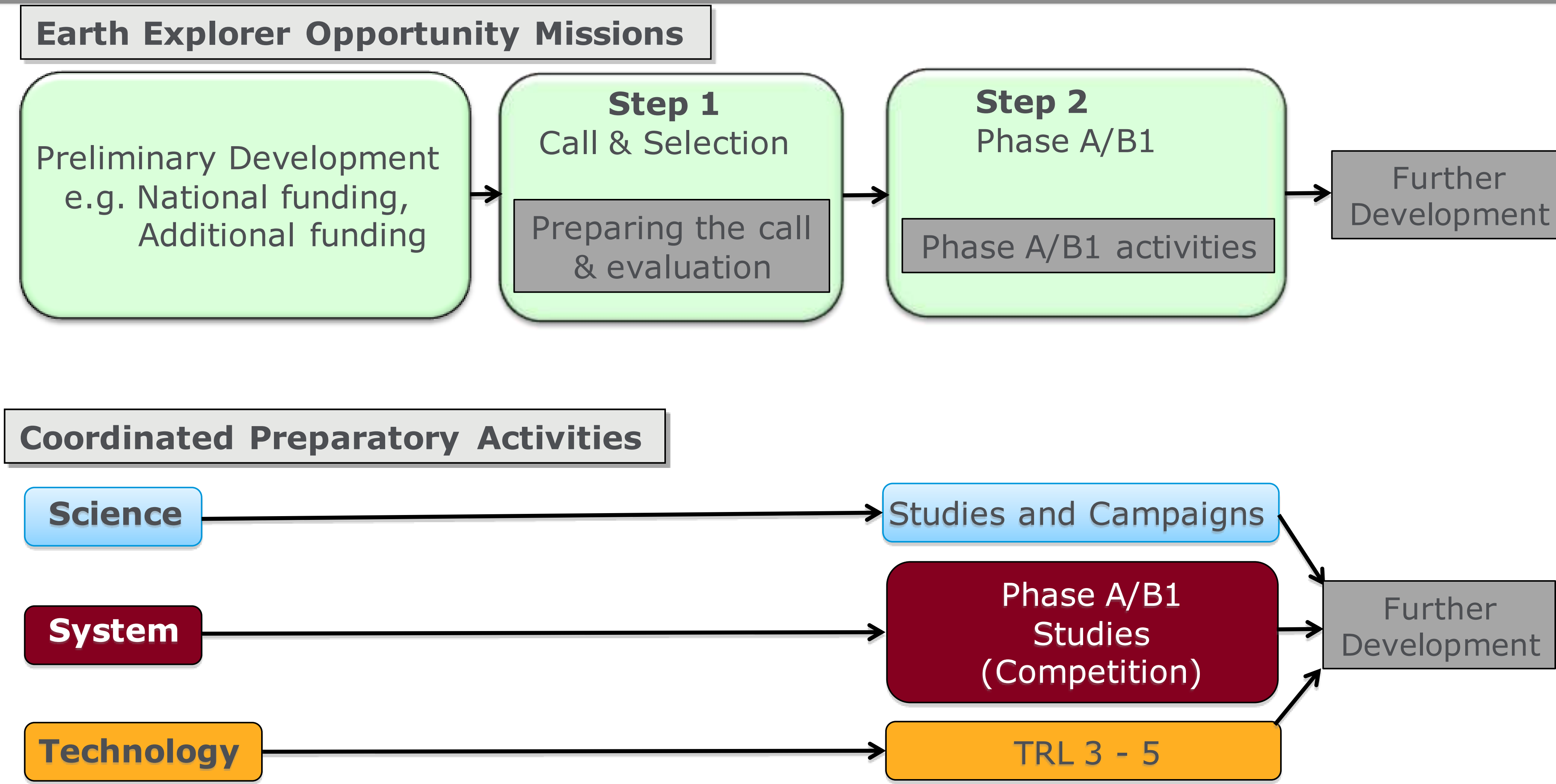
= EOPA
= IPD
= TRP / GSTP
= GSP

European Space Agency

Coordinated Preparatory Activities: EE Core Missions



Coordinated Preparatory Activities: EE Opportunity Missions



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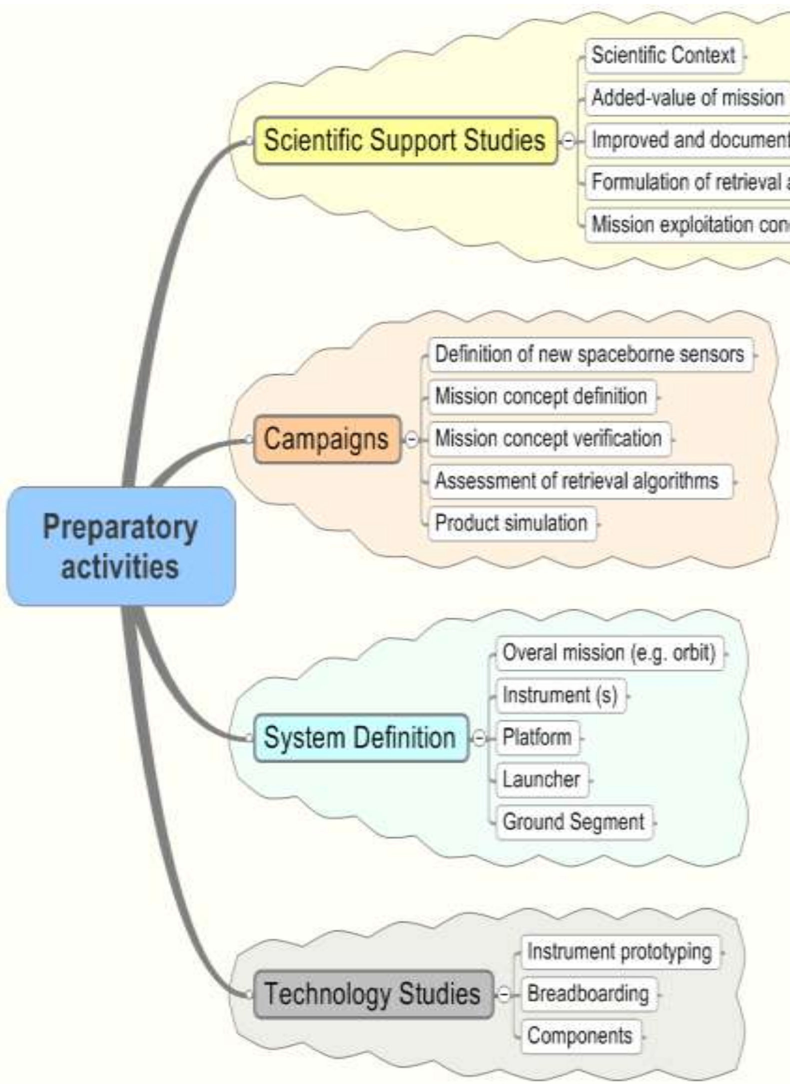
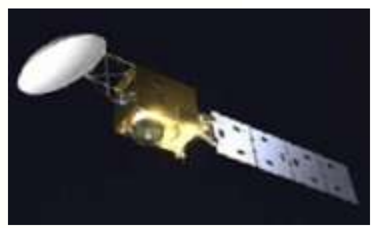
        - Opportunity Missions
3. **ESA Technology**
    - ESA Technology Programmes
    - End to End Technology Process
    - ESA EO Future Mission Planning
    - Examples of Technology Challenges: Ocean, Land and Atmosphere
    - Identified Mission Areas
    - Example Road Map Activities – 26GHz Downlink
4. 1st International EO Convoy and Constellation Workshop
    - Key Messages

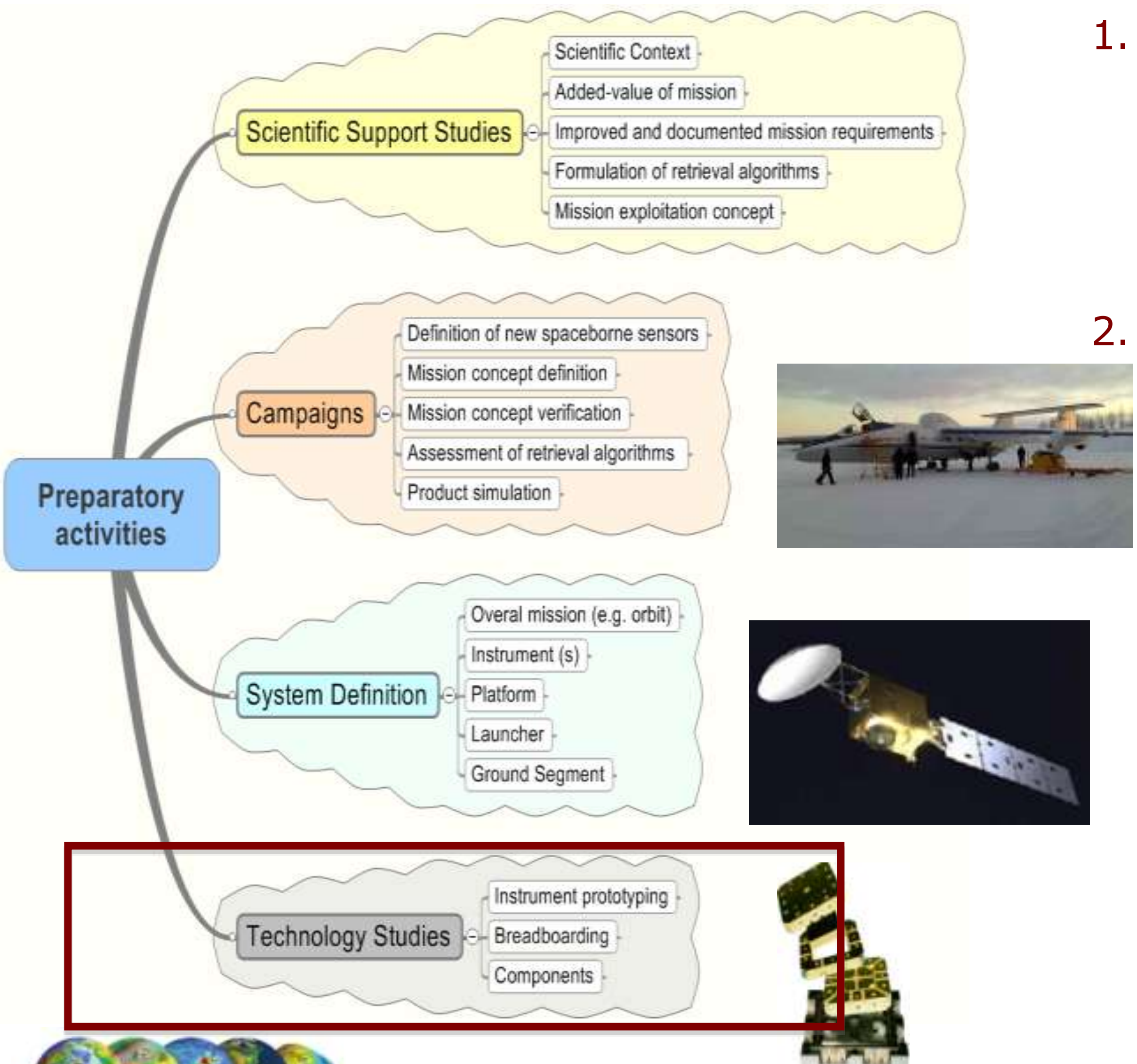
Overview of Earth Observation Preparatory Activities





1. EOEP preparatory activities include all necessary activities to define and evaluate future EO space borne missions (Earth Explorer, Copernicus, 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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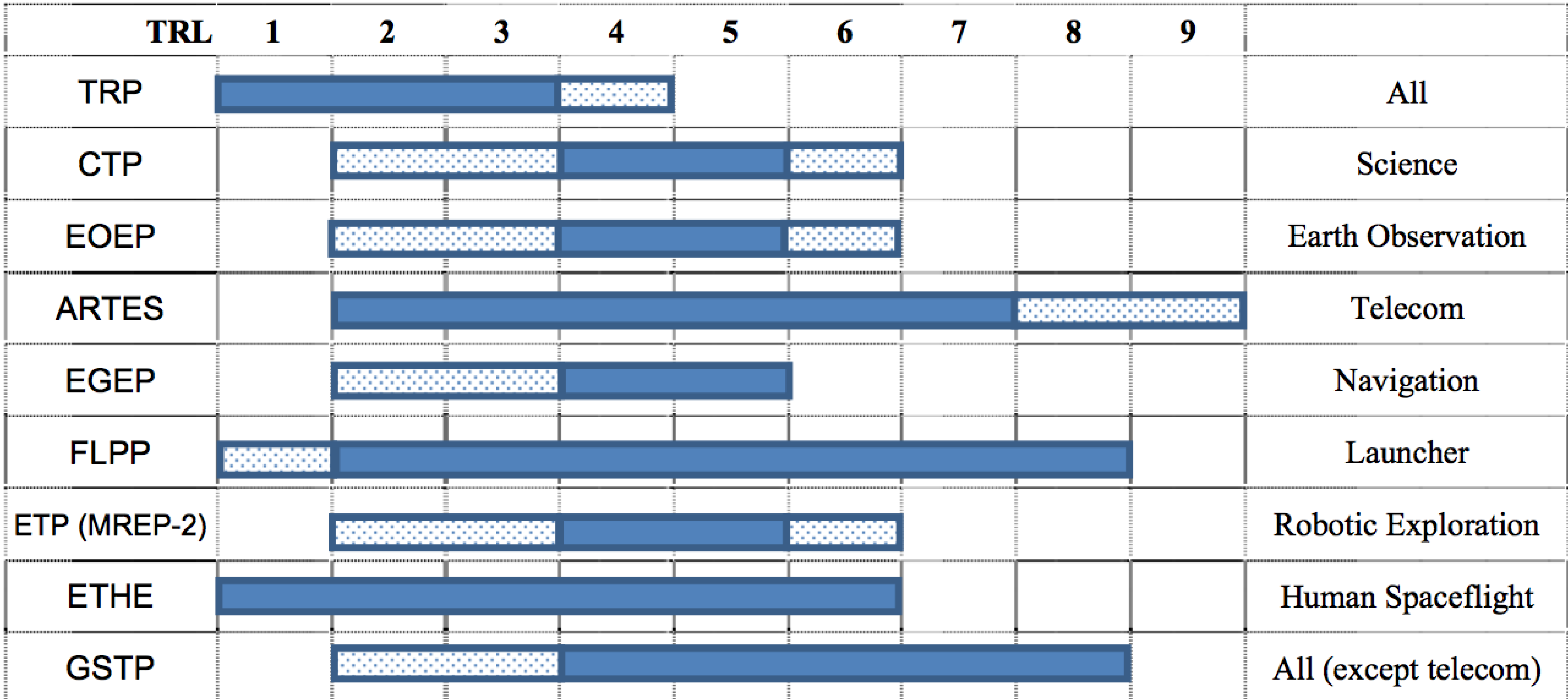
ESA Technology Programmes vs. Technology Readiness Level



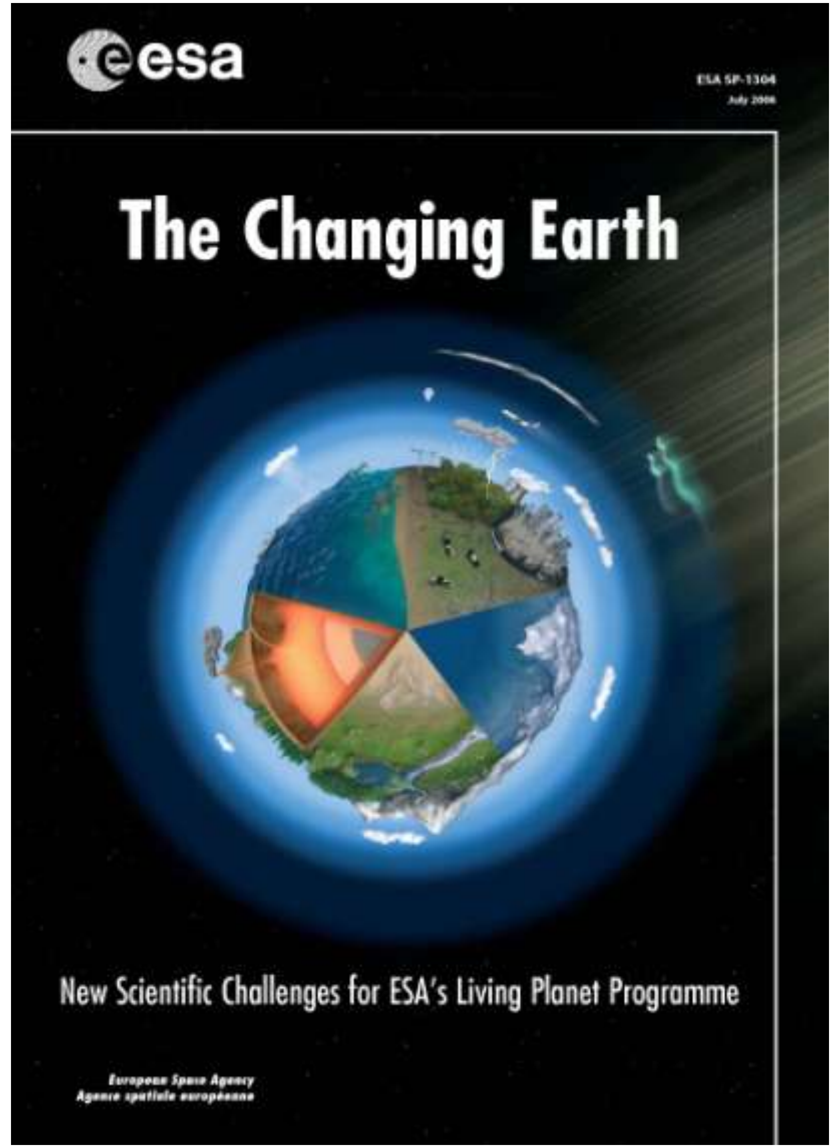
Technology Driven by Science

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.



ESA End to End Technology Process

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

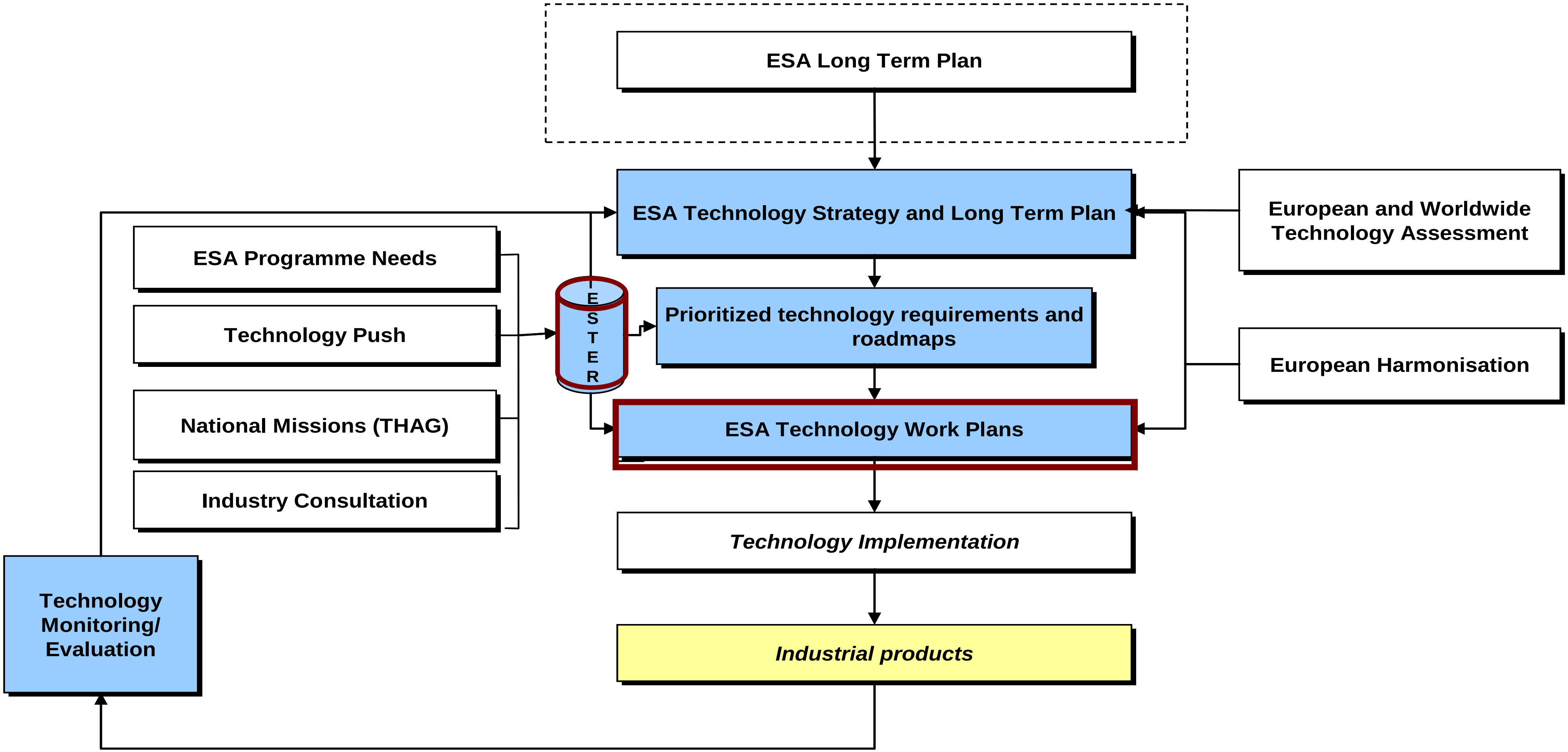
ESA's technology programmes:

- at corporate level : TRP (up to TRL 3), GSTP (from TRL 4)
- 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 End to End Technology Process

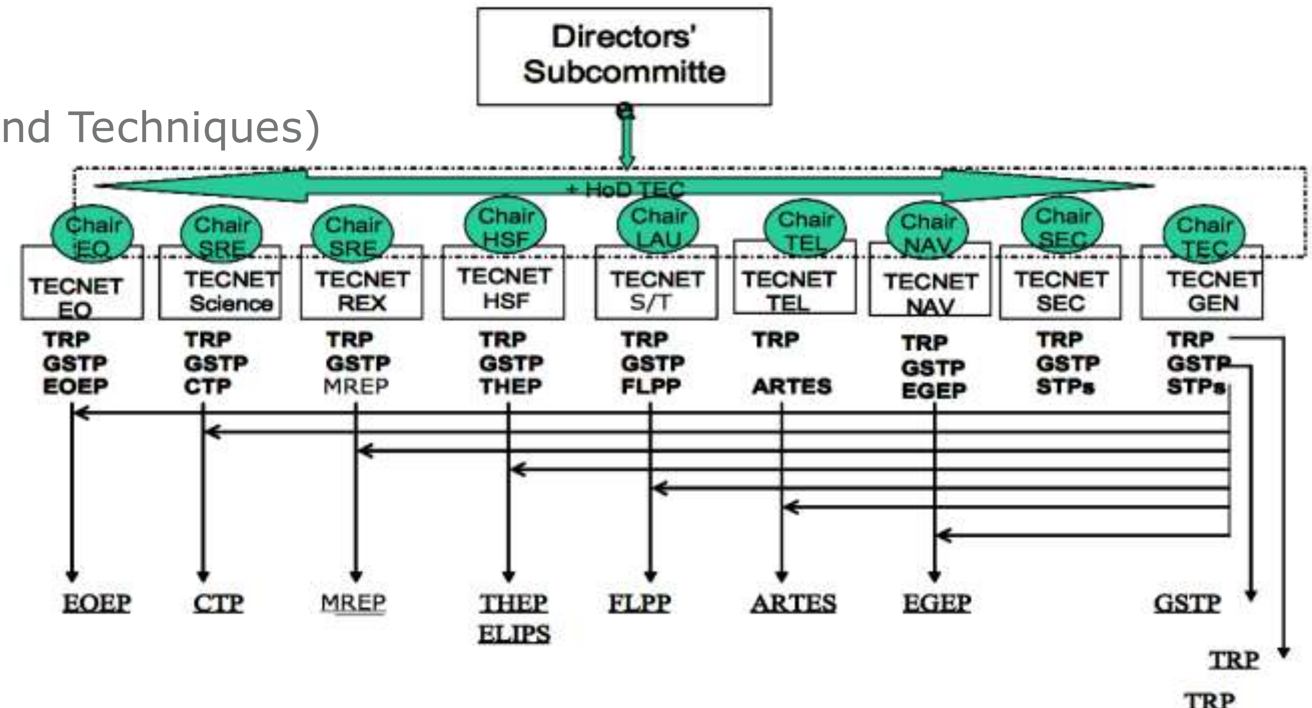


- Under the supervision of a dedicated Director' Sub-Committee on Technology
- ESTER: European Space Technology Requirements Database
- THAG: Technology Harmonisation Advisory Group

ESA End to End Technology Service Domains

- The process comprises in a top-down (users) approach complemented by a bottom-up development approach (technical experts).
- Organised by Service Domains across ESA.
- Working groups are set up for each service domain and all working groups together form the Technology Network (TECNET)

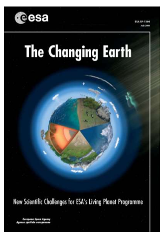
- SD1 (Earth Observation),
- SD2 (Space Science),
- SD3 (Human Spaceflight and Human Exploration)
- SD4 (Space Transportation)
- SD5 (Telecommunication)
- SD6 (Navigation)
- SD7 (Generic Technologies and Techniques)
- SD9 (Robotic Exploration)



ESA EO Future Mission Planning

- In 2010 Earth Observation technology challenges and plans are identified and these are used as input for work plans. This is a technology vision document.
- Technology challenges were identified across Ocean, Land, Atmosphere, Cryosphere and Solid Earth science domains (see examples in the next six slides)
- To focus efforts 13 potential mission areas and 4 topics on more generic needs (structures, thermal control, data handling, communications, ground segment) were defined.

Science

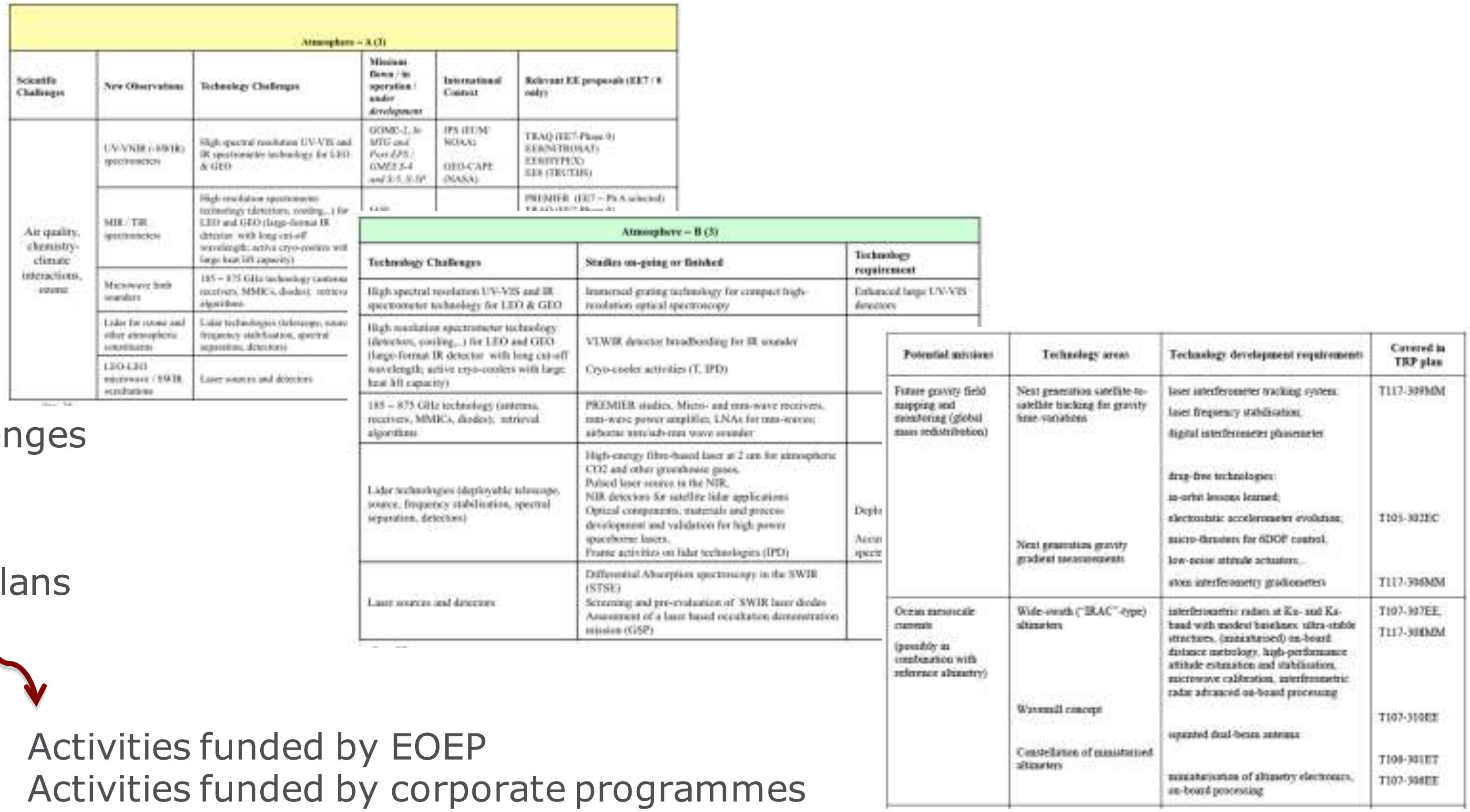


New observations

EO Technology Challenges

Workplans

Activities funded by EOEP
Activities funded by corporate programmes



Examples of Ocean Domain Technology Challenges

esa

	Scientific Challenges	New Observation	Tech. Challenges
Ocean General Circulation	Mesoscale circulation Western Boundary currents	Global abs sea-level Altimetry ref to HR Geoid High spatial/temporal Resolution altimetry Gravity variations combinations of scatterometers and altimeters GNSS reflectometry	Wide swath altimeters Ultra stable interferometric Baseline, precise altitude Estimation, calibration Onboard processing Constellation of low cost Altimeters HR Scatterometry GNSSR performance demo.
Currents	Spatial patterns for surface currents. Absolute magnitudes & dynamics	Along track SAR Interferometry SAR Doppler processing	Antenna tech. OB processing Scan-On Receive and other tech for wide swath.
Coastal Winds	HR coastal winds	HR scatterometry, wide Swath SAR derived winds	High sensitivity SAR systems HR Scatterometry, retrieval algorithms
Ocean bottom pressure	Barotropic vs. Baroclinic Circ. components	HR meas., gravity variations	Laser interferometer, drag Free tech. HR altimetry

Examples of Ocean Domain Technology Challenges

	Scientific Challenges	**New Observation**	**Tech. Challenges**
CO2 Flux	Open sea Coastal biogeochemistry In case 2 waters Air-sea interactions Heat/gas flux Momentum flux	Enhanced ocean colour data Hyperspectral data co-located with Scaterommetry and SST Wind stress, wind vector Temperature, sea-state info	High spectral resolution spectrometer UV and IR bands for corrections In Case 2 waters Scatterometry, SST, diurnal sampling
Ocean Colour	Coastal water derivations	Coastal observations from GEO	Image navigation and registration, GEO AOCS, large aperture telescope
Salinity	Spatial distribution, Coastal shelf, river plume	High sensitivity L-band radiometry in cold water	Ultra-stable radiometer receiver technology, improved spatial And radiometric resolution, internal calibration.
Waves	Ocean surface waves	Leap frog wave mode, radar Radar altimetry SAR	Global coverage
Global Ocean wind	Dual polarisation scatterometers, combined wind/current scatterometers, Altimeters, polarimetric microwave radiometer	Dual polarisation scatterometers, combined wind / current scaterommeters, Altimeters, polarimetric microwave radiometers	Highly stable, dual polarisation Antenna, on-board polarimetric Correlator and calibration subsystem

Examples of Atmospheric Domain Technology Challenges

Scientific Challenges	New Observation	Tech. Challenges
Carbon Cycle	Improved CO2 and CH4 Monitoring	High resolution spectrometers, Lidar technologies
Clouds	Synergy of lidar and radar observations, Sub-mm wave radiometry from LEO and GEO	Lidar technologies Antenna technology components
Aerosols	Multispectral, multiangular Polarimetric data for asimulation	Optical components of polarimetric imager
Precipitation	Observations in Ku/Ka band GEO microwave observations	Antenna technology, high power Mm-wave components
Water vapour	Lidar observations, LEO-LEO Occultation	DIAL, Laser sources and detector Technology
Wind	All weather wind profiles	Enhanced (lifetime, resolution) Operational versions of existing sensors, mm-wave Doppler radar
Thunderstorm activity	Lightening imager	APS detectors with on-chip processing large filters
Mesosphere	Temperature, winds, gravity waves	Limb sounding, lidar, SWIR occulations
Thermosphere	Wind and air density	Accelerometers

Examples of Atmospheric Domain Technology Challenges

Scientific Challenges	New Observation	Tech. Challenges
Air Quality, Chemistry Climate Interactions, Ozone	UV-VNIR (-SWIR) spectrometers	High spectral resolution UV-VIS and IR spectrometer technology for LEO and GEO
	MIR / TIR Spectrometers	High resolution spectrometer technology (detectors, cooling, …) for LEO and GEO (large format IR detector with long cut off wavelength, active cryo-coolers
	Microwave limb sounders	185 – 875 GHz technology (antenna receivers, MMICs, doides, retrival algorithms
	Lidars for ozone and other atmospheric constituents	Lidar technologies (telescope, source, frequency stabilisation, spectral sepration, detectors
	LEO-LEO microwave / SWIR occultation	Laser sources and detectors

Examples of Land Domain Technology Challenges

	Scientific Challenges	New Observation	Tech. Challenges
Carbon	Terrestrial (biomass, vegetation)	Addressed on next slide	
	Ocean	Addressed in Ocean section	
	Atmosphere	Addressed in Atmosphere section	
Water	Snow accumulation and water equivalence	Addressed in Cryosphere section (not shown in this presentation)	
	Rivers and reservoirs	Ka-band interferometer	Antenna technology, stable baseline, attitude control
	Underground water	Gravity field temporal variations	Laser interferometry for LEO-LEO tracking, drag free technologies
	Precipitation	Addressed in Atmosphere section	
	Water vapour	Addressed in Atmosphere section	
	Soil moisture	C- and L-band radiometers C-band SAR	Antenna technology, components, wide swath

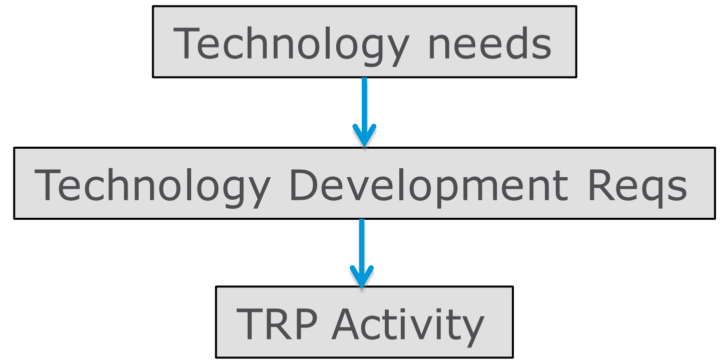
Examples of Land Domain Technology Challenges

	Scientific Challenges	New Observation	Tech. Challenges
Vegetation	Biomass	P-Band and L-band InSAR, SAR tomography, TanDEM SAR At L-band, POLInSAR	Antenna technology (large deployable, planar, reflector types, testing, control, P-band calibration technology, wide swath
		Fluorescence spectrometry TIR Radiometry	VHR spectrometers, detectors, retrievals
	Structure	Canopy lidar, SAR tomography Multi-angle hyperspectral imager	Lidar technologies, SAR tomography capabilities
	Status	Hyperspectral VNS imager, multichannel TIR radiometer	Detector developments e.g. uncooled microbolometers etc

Note: The vision document identifying technology challenges was written in 2010, missions such as Biomass were selected later.

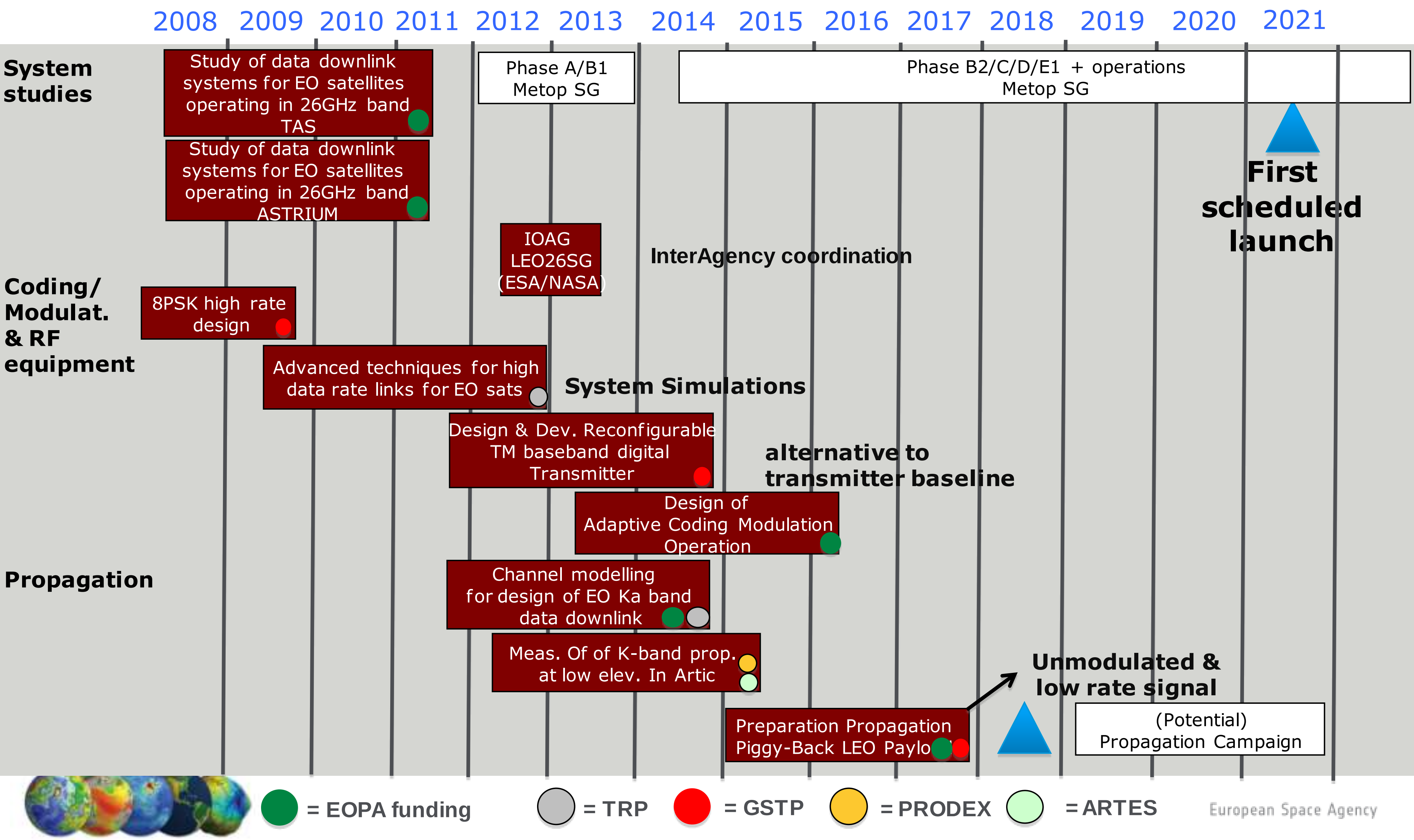
Identified Vision for Future Mission Areas

To try to prioritise and focus efforts for planning purposes 13 mission areas were identified (in no particular order):

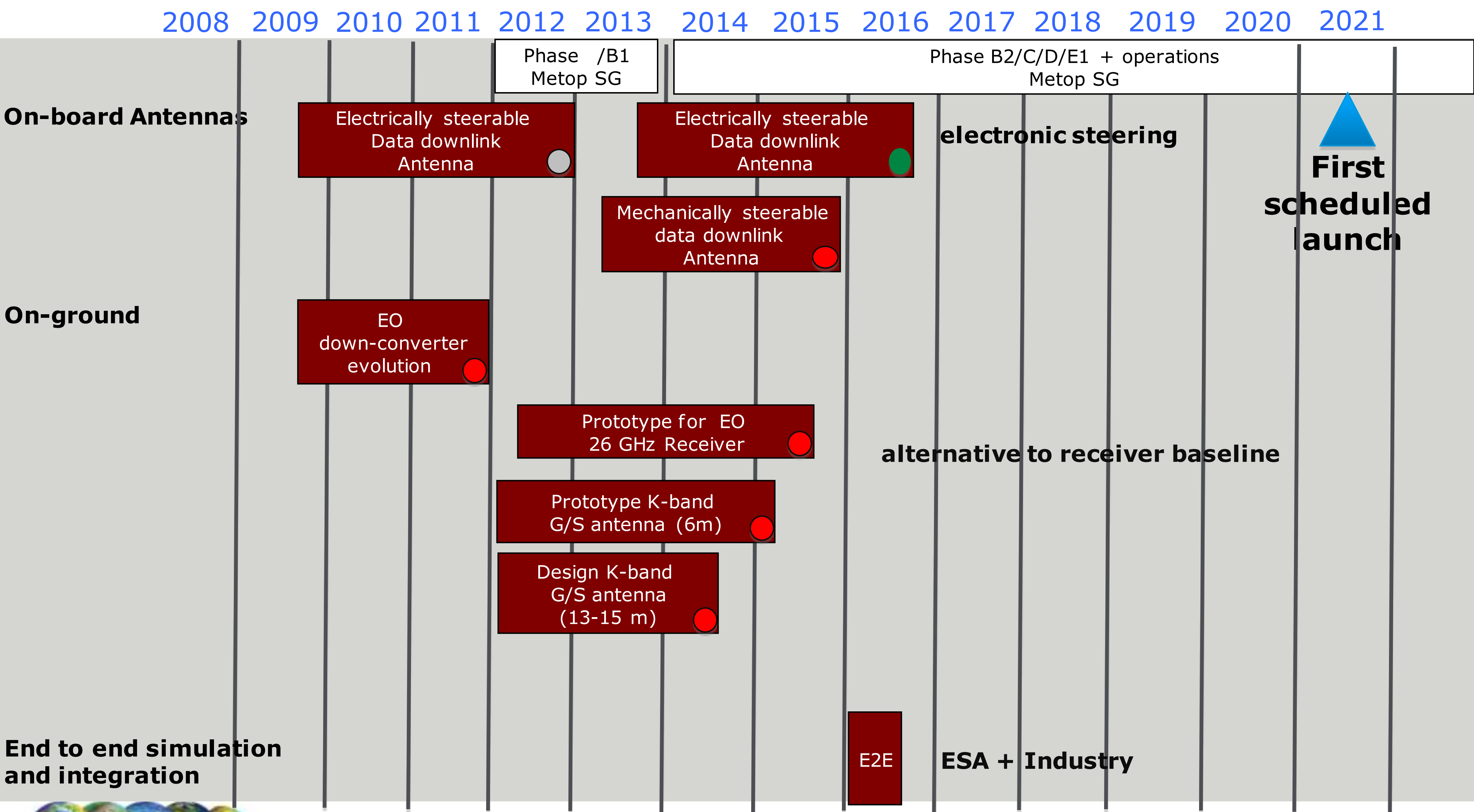


1. Future gravity field mapping and monitoring
2. Ocean mesoscale currents
3. In-land waters
4. Air-sea interactions
5. Ice sheet (sounding) and glaciers
6. Atmospheric processes and air quality
7. High resolution thermal infrared
8. High resolution from GEO (coastal monitoring and ocean colour)
9. High 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

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



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



= EOPA funding = TRP = GSTP = PRODEX

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    - Key Messages

→ 1st INTERNATIONAL EARTH OBSERVATION CONVOY AND CONSTELLATION CONCEPTS WORKSHOP

Science and Application Opportunities from Novel Multi-Satellite Approaches

eo convoy

support to science element

9–11 October 2013 | ESA-ESTEC | The Netherlands

Workshop Structure

Session 1: Key Science & Implementation Accomplishments from Existing Constellations

Session 2: Future Landscape 2020 and Beyond

Session 3: ESA Convoy Missions and Candidate Missions

Session 4: Technological Challenges

Session 5: ESA EO Convoy Studies – Latest Results

Session 6 : Future Concepts

Session 7 : Programmatic Challenges

Workshop Key Messages 1 of 4

1) Future Constellation Science and Measurements

Key Message 1.1 : Focus on **cross cutting science** with focus on the interfaces & interactions e.g. Land / Ocean, Cryosphere / Atmosphere

Key Message 1.2 : Exploit **complementary measurements** including active / passive measurements and LEO & GEO observations.

Key Message 1.3 : **Long term sustainable data is needed** to understand the complexities of the Earth System.

Key Message 1.4 : **Higher resolution measurements** is needed (spatial and temporal to capture complex, dynamic phenomena

Workshop Key Messages 2 of 4

2) Future Constellation Design

Key Message 2.1 : **Measurement synergy** is critical. Missions can no longer be designed in isolation

Key Message 2.2 : **Long term anchor satellites** are needed for future constellations. e.g. Sentinels

Key Message 2.3 : **Copernicus Sentinels** should be considered as a constellational infrastructure

Key Message 2.4 : **International Cooperation** is essential

Workshop Key Messages 3 of 4

3) Constellation Lessons Learned

Key Message 3.1: **Effective management at constellation level and agency support** is critical

Key Message 3.2 : **Cooperative sensing requires a paradigm shift** e.g. Missions cannot be considered in isolation

Key Message 3.3 : **Flexible manoeuvre capabilities** are desirable for spacecraft flying together e.g. retro-firing and **detailed characterisation** is needed e.g. propellant, spacecraft modes and manoeuvres

Key Message 3.4 : **Constellation agreements, policies and codes of practice** are critical. This includes: e.g. communication, coordination, data policy for all mission phases

Workshop Key Messages 4 of 4

4) Highlighted Convoy Concepts

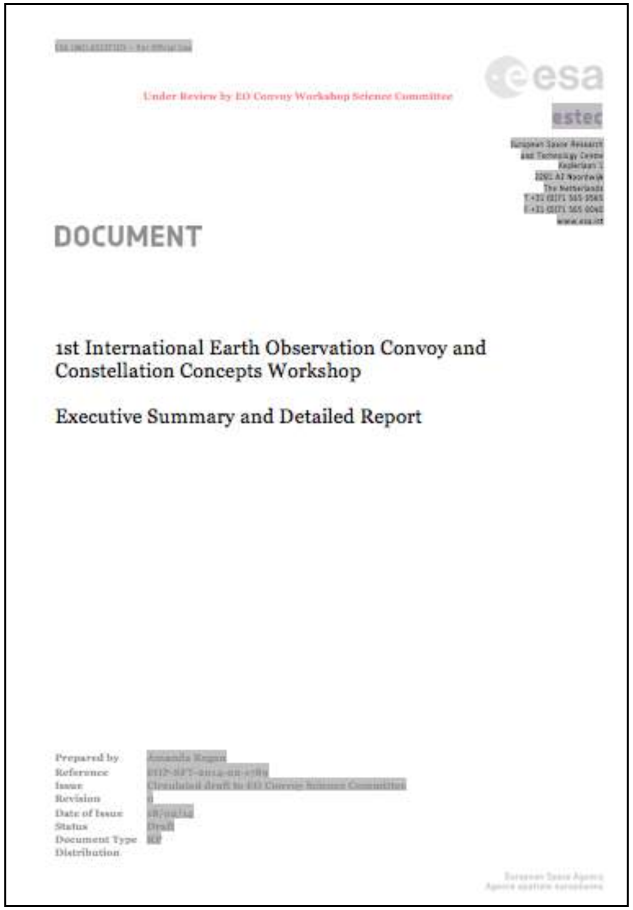
Key Message 4.1 **: Laser and radar combinations** provide complementary measurements for cross cutting science

Key Message 4.2 : **Long term medium to high resolution thermal infrared measurements** (< 60 m to < 250 m). Both MIR/TIR needed for some applications and a co-registered visible imager for context. Flying a TIR imager with Sentinel-2 was highlighted.

Key Message 4.3 **: LEO and GEO concepts flying together** Coordinated GEO and LEO observations to capture dynamic processes on different scales

Workshop Report

Workshop Report and Executive Summary have been distributed to the Science Committee for comments. Executive Summary is on website.


Under Review by EO Convoy Workshop Science Committee

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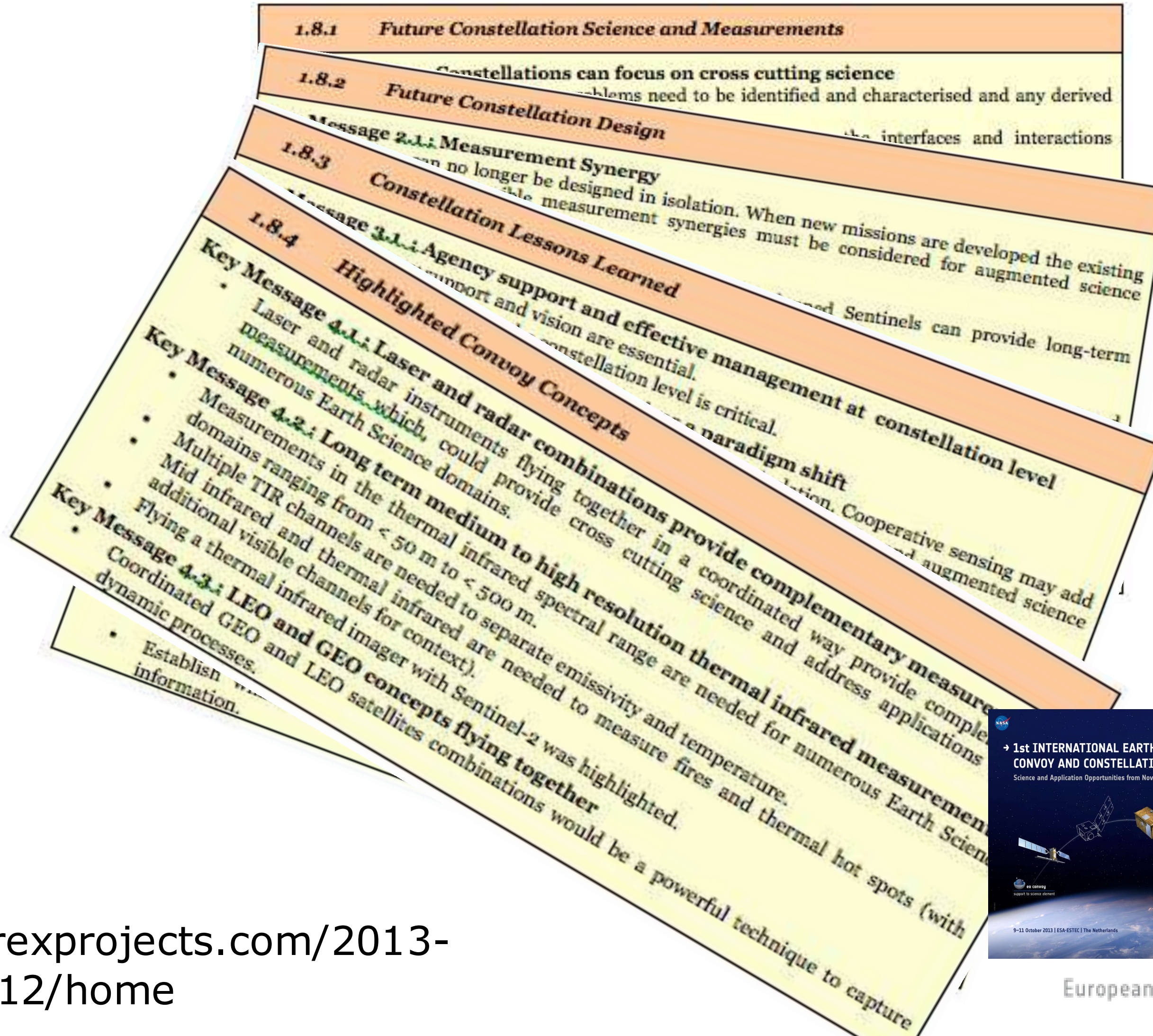
DOCUMENT

1st International Earth Observation Convoy and Constellation Concepts Workshop

Executive Summary and Detailed Report



http://congrexprojects.com/2013-events/13m12/home

THANK YOU