Hyper-Spectral and Copernicus Evolution

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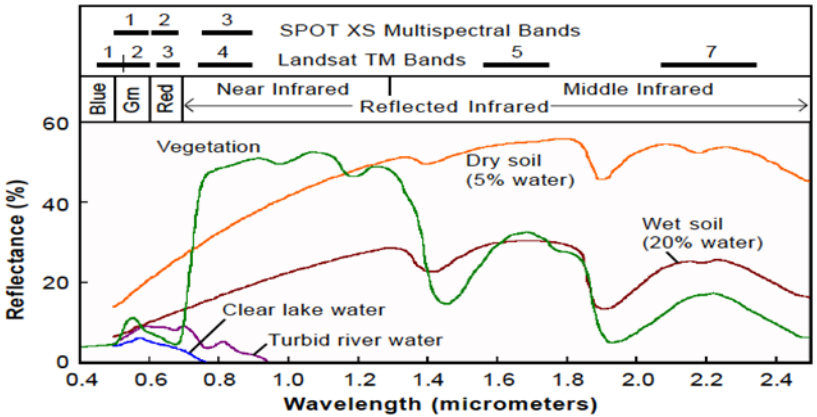
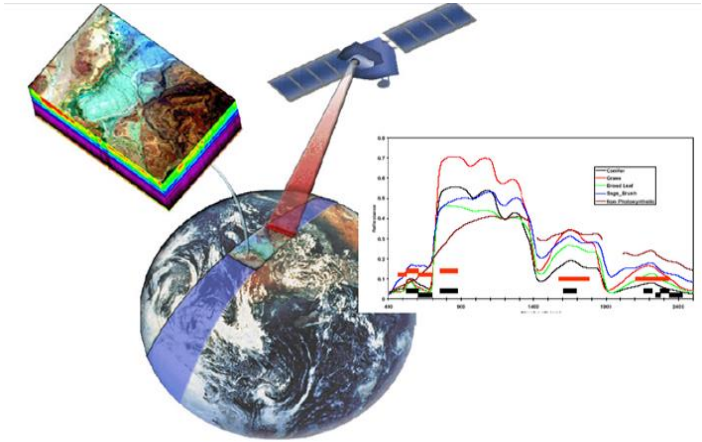
Hyperspectral land imaging in the visible to shortwave infrared (1)

- Full "spectral signatures" of observed scenes, enabling panoply of applications e.g. in:
  - monitoring of terrestrial ecosystems, resolving bio-physical, bio-chemical and geo-chemical variables in detail
  - detect, classify and monitor natural and man-made elements of land surfaces, from vegetation to soil to (raw) materials, and including waste, contaminated land, coastal/inland water quality,..





Hyperspectral land imaging in the visible to shortwave infrared (2)

- Technology of hyperspectral instruments is mature and flight proven. Two hyperspectral missions are operating in-orbit: Hyperion on EO-1 (NASA, since 2000) and CHRIS on PROBA-1 (ESA, since 2001). These demonstrators with one-year design lifetime are still operating.

- Although vastly successful (CHRIS data used by some 450 groups in 60 countries), these missions are only demonstrators, with limited spatial and temporal coverage and moderate radiometric performance, limiting their use for (pre-)operational applications

Hyperspectral land imaging in the visible to shortwave infrared (3)

- Vast experience with airborne hyperspectral sensors routinely used: APEX, CASI/SASI, HYPER… but spatial/temporal coverage is inherently limited
- Three hyper-spectral missions are under development, for launch soon - PRISMA (ASI, 2018), ENMAP (DLR, 2018), HISUI on ALOS-3 (JAXA, 2019) - expected to provide better radiometric performance than CHRIS and Hyperion. Shalom operational in early 2020ies.
- Mission & system studies conducted by ESA at end of the 90's, with a focus on the applications, definition of concepts and validation of the ground processing chain
- Study to consolidate land and coastal applications and needs for hyper-spectral data are on-going, to perform analyses of gaps and synergy with current Sentinels missions, so as to clarify the way for future operational applications and services at horizon 2025-2030

MFF 2021-2027: Content of the CSC

- Completion of the activities planned in the current MFF to deploy the C and D units of the Sentinels 1/2/3
- Evolution of Copernicus Space Component (CSC):
  - Second Generation (horizon 2028+): enhanced continuity of observations of current CSC, including new capabilities, to meet User Requirements (UR)
  - Shorter horizon (2022+) evolution, for additional capabilities in support of current emerging needs (Sentinel Expansion)
- Operations of the Sentinels
- Data Access and Data Procurement from Contributing Missions

Governance and Role of ESA

Assumption for next MFF : no changes with respect to the current Regulation, i.e.:

The Commission shall:

- Have overall responsibility for Copernicus and for the coordination of its components
- Manage the funds allocated and oversee the implementation of Copernicus
- Support the appropriate development of Copernicus services
- Formulate data policy

Via an agreement, ESA shall:

- Ensure the technical coordination of the CSC
- Define the overall system architecture for the CSC and its evolution
- Develop new dedicated missions and procure recurrent dedicated missions
- Operate the dedicated missions and coordinate a scheme for access to Contributing Missions services

CSC Evolution

- A structured dialogue with the Commission and the Member States on the CSC evolution is currently on-going
- The user requirements definition is an EU process. The requirements drive the type of missions and the associated costs.
- User requirements are expected in mid 2017. However:
  - The Commission has expressed its interim priority for the CSC expansion
  - The architecture of the SG-Sentinels has not a unique solution

Interim Conclusion

- **The following observation needs will be further investigated for environmental observations:**

- **Priority 1:**
  - **Greenhouse gas monitoring**, specifically on anthropogenic CO2 emissions, for which currently no satellite observations are available
- **Priority 2:**
  - **Monitoring the Polar regions**, specifically the arctic for sea ice and weather
  - **Monitoring Agriculture**, specifically on parameters, which potentially could be addressed through thermal infrared observations
- **Priority 3:**
  - Mining, biodiversity, soil moisture and other parameters, requiring observations in additional bands, currently not available

Reflections on future monitoring capabilities vs services

Copernicus Service	Current Capabilities					
	All-weather radar imaging	Optical Imaging (HR)	Optical Imaging (LR)	Spectro-Radiometry (LEO)	Spectro-Radiometry (GEO)	Altimetry high along-track res.
Atmospheric			•	•	•	
Climate	•	•	•	•	•	•
Emergency	•	•	•		•	•
Land	•	•	•			
Marine	•	•	•			•
Security	•	•				

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Atmospheric			•	•	•	
Climate	•	•	•	•	•	•
Emergency	•	•	•		•	•
Land	•	•	•			
Marine	•	•	•			•
Security	•	•				
Service Evolution						
Energy	o	o	o	o	o	o
Water / Hydro	o	o	o			o
Biodiversity		o	o			
Urban	o	o		o	o	
Arctic/Polar	o	o	o	o		o

**Note Operational Meteorology capabilities (MSG/MTG/MetOp/MetOp-SG) cover a broad spectrum of service needs

Reflections on future monitoring capabilities vs services

	Current Capabilities						Potential Capability Evolution						
Copernicus Service	All-weather radar imaging	Optical Imaging (HR)	Optical Imaging (LR)	Spectro-Radiometry (LEO)	Spectro-Radiometry (GEO)	Altimetry high along-track res.	CO2 / GHG Imaging Spectro-radiometry	Interferometric Altimetry	Thermal Imaging (TiR)	Hyperspectral (HR)	Enhanced Polar Imaging	L-band radiometry	Gravimetry (Mass distribution / transport)
Atmospheric			•	•	•		•						
Climate	•	•	•	•	•	•	•	•	•		•	•	•
Emergency	•	•	•		•	•		•	•	•		•	•
Land	•	•	•					•	•	•	•	•	•
Marine	•	•	•			•		•		•	•	•	•
Security	•	•							•	•	•		
Service Evolution													
Energy	o	o	o	o	o	o	•	•	•	•	•		•
Water / Hydro	o	o	o			o		•	•		•	•	•
Biodiversity		o	o							•	•		
Urban	o	o		o	o		•		•	•			
Arctic/Polar	o	o	o	o		o	•	•	•	•	•	•	•

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Reflections on future monitoring capabilities vs services

	Current Capabilities						Potential Capability Evolution							Future Capabilities					
Copernicus Service	All-weather radar imaging	Optical Imaging (HR)	Optical Imaging (LR)	Spectro-Radiometry (LEO)	Spectro-Radiometry (GEO)	Altimetry high along-track res.	CO2 / GHG Imaging Spectro-radiometry	Interferometric Altimetry	Thermal Imaging (TiR)	Hyperspectral (HR)	Enhanced Polar Imaging	L-band radiometry	Gravimetry (Mass distribution / transport)	High Elliptic Orbiting imager	Active Optical (Lidar)	Precipitation (rain, snow)	Companion (bistatic) SAR Imaging	long wavelength SAR (formation with current SAR)	Limb Imaging Spectrometry
Atmospheric			•	•	•		•							•	•	•			•
Climate	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•
Emergency	•	•	•		•	•		•	•	•		•	•			•	•	•	
Land	•	•	•					•	•	•	•	•	•	•	o	•	•	•	
Marine	•	•	•			•		•		•	•	•	•	•		•	•	•	
Security	•	•							•	•	•			•			•		
Service Evolution																			
Energy	o	o	o	o	o	o	•	•	•	•	•		•		•	•	•	•	
Water / Hydro	o	o	o			o		•	•		•	•	•	•		•	•	•	
Biodiversity		o	o							•	•			•	o				
Urban	o	o		o	o		•		•	•					o		•	•	
Arctic/Polar	o	o	o	o		o	•	•	•	•	•	•	•	•	•	o	•	•	•

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NB: plenty of 'low-hanging-fruits' to meet user needs with proper architecture / mission design

Sentinels Expansion

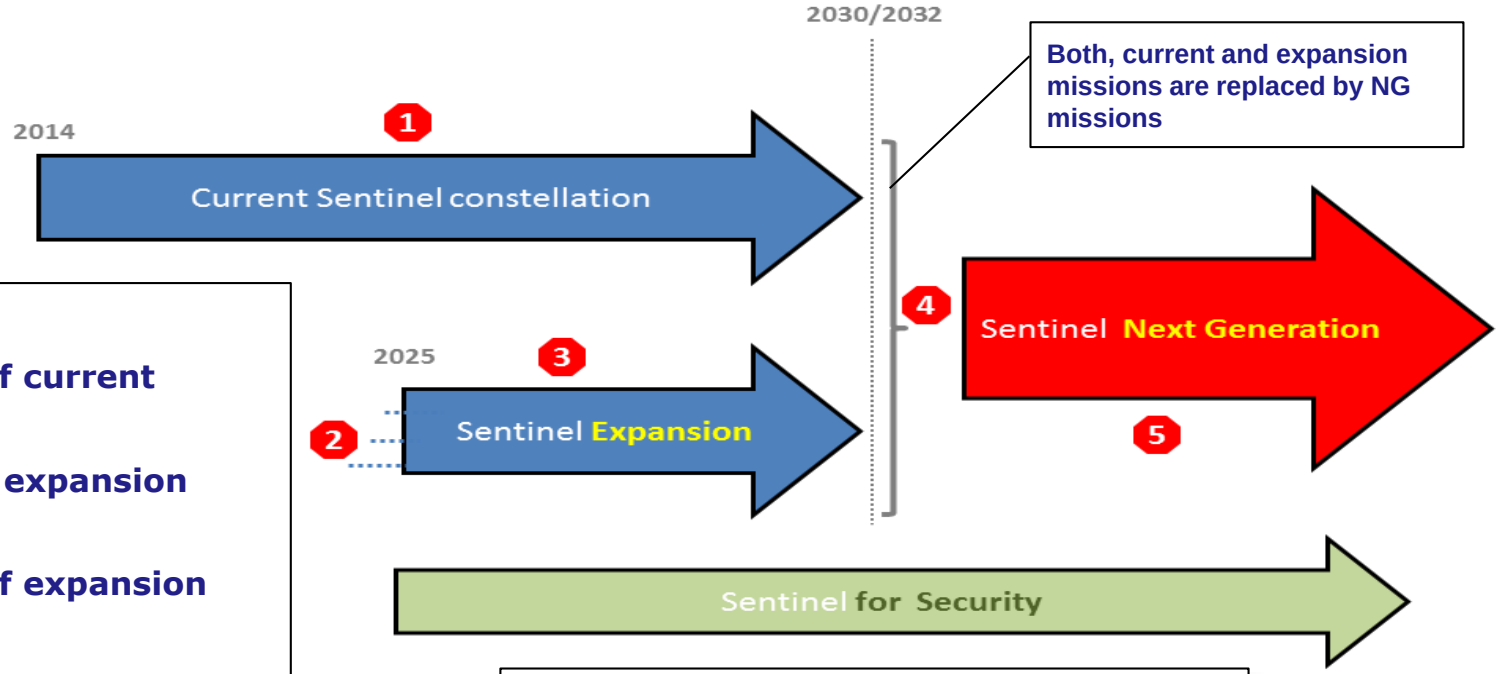
It is assumed that the following Sentinels could emerge as result of the users' consultation process and following a gap analysis :

- Sentinel-7: an anthropogenic CO2 monitoring mission
- Sentinel-8: a Thermal Infrared Imager (companion to Sentinel-2 C/D)
- Sentinel-9: declined into two components:
  - S-9 ICE: Enhanced Ice and Snow Continuity mission
  - S-9 HEO: Polar Weather Payload on a Highly Elliptical Orbit
- Sentinel-10: a Hyper-spectral mission

Space Component

European Commission

Evolution



Parameters:

1. **Life-time of current Sentinels**
2. **Number of expansion missions**
3. **Life-time of expansion missions**
4. **Number and scope of NG missions**
5. **Life-time of NG missions**

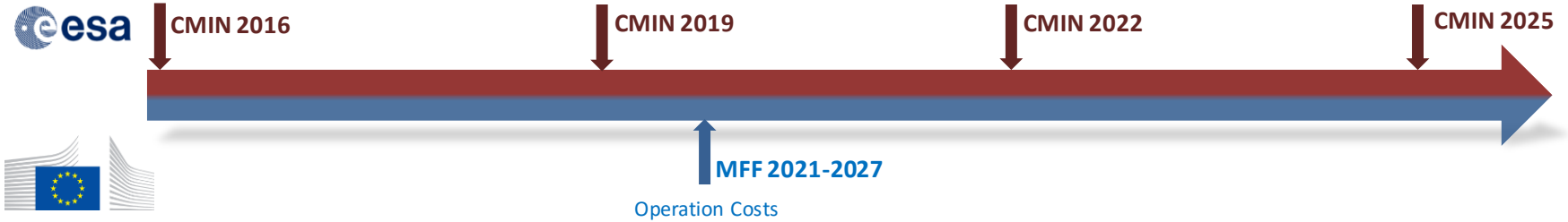
This approach will be reflected in the Copernicus Space Component (CSC) Long Term Scenario (LTS)

Assumed Funding Milestones

Initial Development for Sentinels' Expansion -
Phase 0/A studies
Mission concept study for Sentinels SG

Development of Sentinel Expansion
Main development for Sentinels SG

Development Completion for Sentinels SG



Operation Costs
Launcher Costs
Recurrent Costs
Data Access

Conclusions

- Times are becoming mature for an operational use of hyper-spectral technology
- Sentinel-10 is considered to support a number of applications in the domain of agriculture, food security, biodiversity, geology, culture heritage, forestry, ice type identification
- If the requirements are confirmed by the user communities, S-10 can bridge the gap where multi-spectral and hyper-spectral capabilities will complement each other
- Follow-on of Sentinel 10, if confirmed by architecture studies, may also be part of Sent-2 SG