Space Debris Implementation Mitigation In Earth Observation Missions

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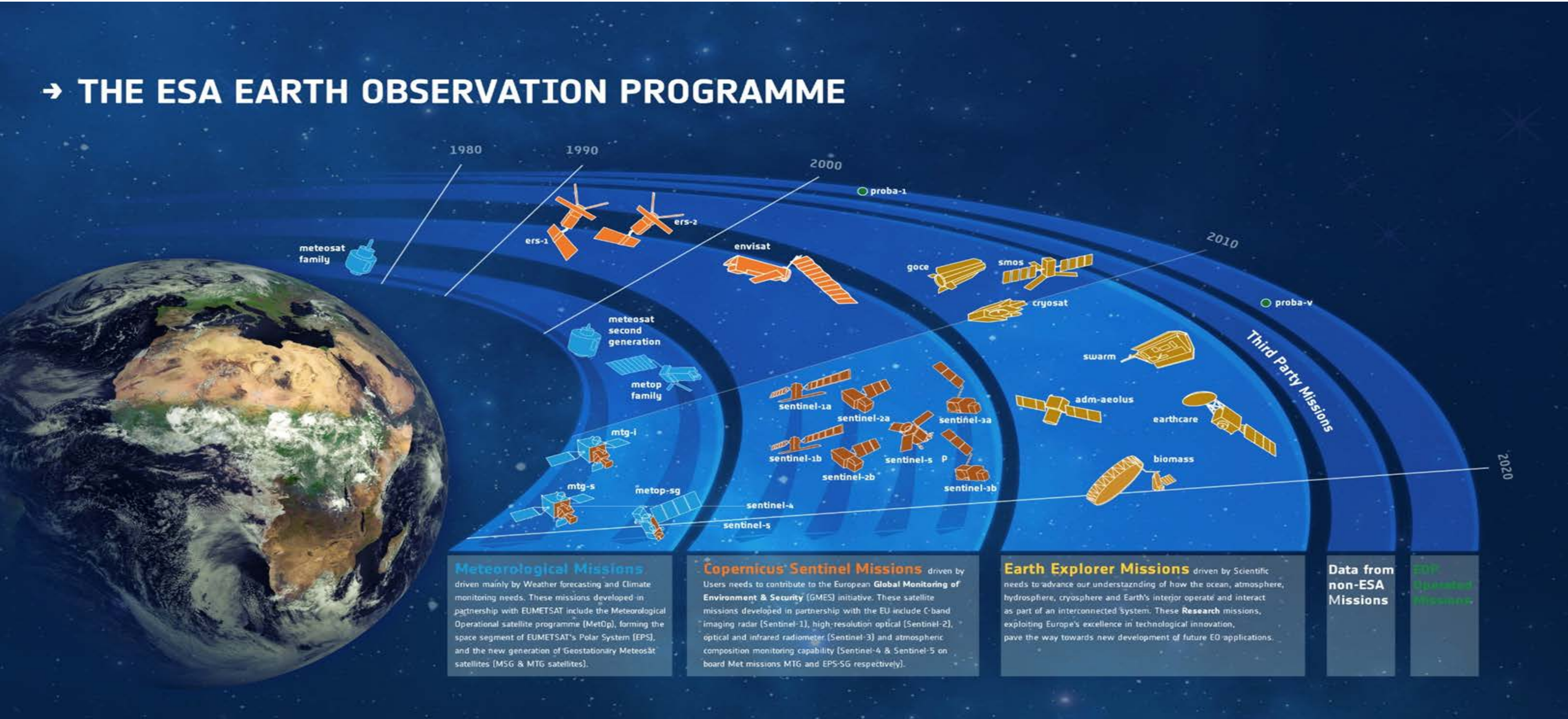
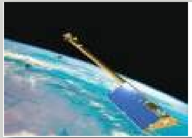
ESA Earth Observation Missions

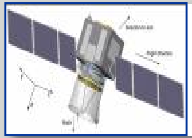


Earth Explorers Missions



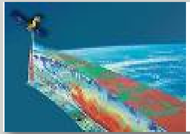
SWARM, constellation of 3 satellites
3D study of Earth magnetic field and environment
2013

3x0.5 tons
$< 10^{-4}$



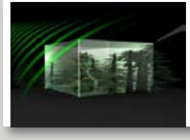
Aeolus
Lidar for wind measurements
2018

1.4 tons
$< 10^{-4}$



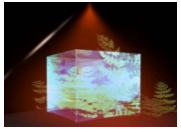
EarthCare
Lidar and Radar surface temperature, altimetry
2019

2 tons
$< 10^{-4}$



BIOMASS
P-Band radar for forests measurement
2020

1.2 tons
$< 10^{-4}$



FLEX
Measuring Fluorescence
2020+

0.8 tons
$< 10^{-4}$

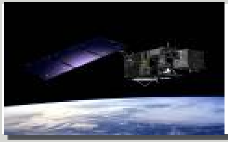
Sentinel Missions

Sentinel-1 (A/B/C/D) – SAR imaging
All weather, day/night applications, interferometry

2.2 tons
> 10^{-4}

Sentinel-2 (A/B/C/D) – Multi-spectral imaging
Land applications: urban, forest, agriculture,…
Continuity of Landsat, SPOT

1.2 tons
< 10^{-4}

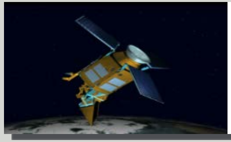


Sentinel-3 (A/B/C/D) – Ocean and land monitoring
Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry

1.2 tons
< 10^{-4}

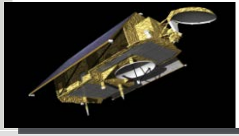
Sentinel-4 (A/B) – Geostationary atmospheric
Atmospheric composition monitoring, trans-boundary pollution

N/A



Sentinel-5 precursor – Low-orbit atmospheric
Sentinel-5 (A/B/C) – Low-orbit atmospheric
Atmospheric composition monitoring

0.9 tons (S5P)
< 10^{-4}



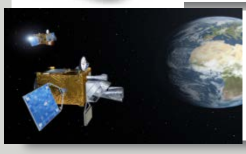
Sentinel-6 (A/B) – Low inclination Altimetry
Sea-level, wave height and marine wind speed

1.2 tons
< 10^{-4}

Meteorological missions

MSG-4
Meteorology from Geostationary orbit (imagery)
2015

N / A (GEO)



MTG-I
Meteorology from Geostationary orbit (imagery)
2018, 2022, 2025+,2030+

N / A (GEO)

MTG-S
Meteorology from Geostationary orbit (imagery)
2020, 2027

N / A (GEO)

MetOp-C
Meteorology from Low Earth Orbit (imagery, souding)
2018

4 tons
$> 10^{-4}$

MetOp-SG A
Meteorology from Low Earth Orbit (imagery, sounding)
2021, 2027, 2034

4 tons
$< 10^{-4}$

MetOp-SG-B
Meteorology from Low Earth Orbit (sounding)
2022, 2029, 2036

4 tons
$< 10^{-4}$

ESA EO Approach to Clean Space

Reference is the ESA/ADMIN/IPOL(2014)2 (28 March 2014)

Not applicable to most of the missions under development => still taken as goal by all ESA EO missions

Future EO missions:

- Controlled re-entry => beyond ~2.5 tons *(eg MetOp-SG)*
- Uncontrolled re-entry
  - With special demisable technologies => around 2 tons *(eg Sentinel-1C/-1D)*
  - With care about few driving elements, such as tank and batteries (below 1.2 tons)

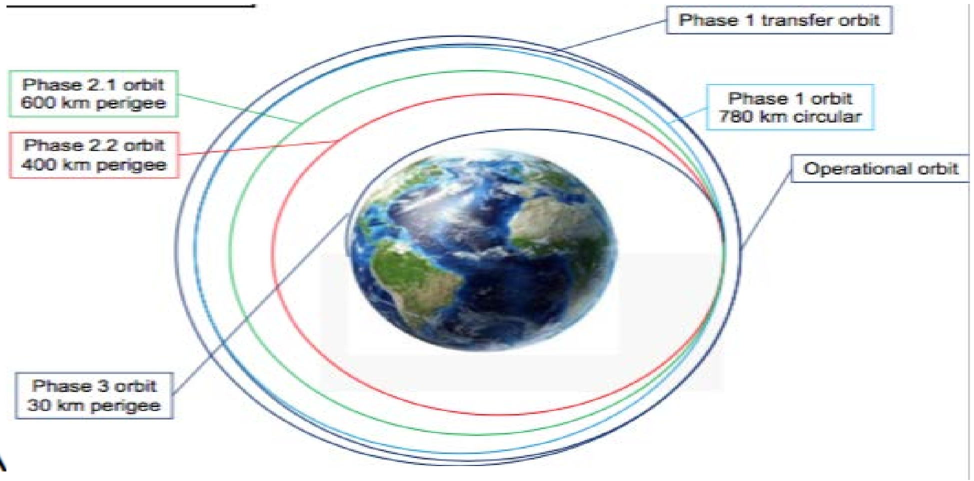
Work together with our colleagues from Clean Space and introduce requirements for demisable technologies in new projects.

MetOp-SG – Controlled Re-Entry

Controlled Re-Entry (CRE) is necessary to fulfill the Space Debris Mitigation requirements

- Uncontrolled re-entry would lead to casualty risk an order of magnitude above the requirement

	SAT A	SAT B	REQUIREMENT
CASUALTY RISK	7.9 10^{-4}	4.8 10^{-4}	10^{-4}



CRE principle

- Nominal scenario: LAE is used in 3 phases
  - Phase 1 for decreasing the orbit altitude to 780 km
  - Phase 2 for decreasing the perigee down to 400 km
  - Phase 3 for the final boost down to 30 km perigee
- A back-up scenario has been set-up in case of LA
  - The 2 branches of 20 N thrusters are used
  - Phase 2 is divided in series of smaller boosts down to 250 km perigee
  - Phase 3 perigee is set at 65 km

MetOp-SG – Controlled Re-Entry

Controlled Re-Entry (CRE) design & Operational aspects:

- It's the main purpose of the 400N thruster
  - The AOCS thrusters act as a back-up solution
- CRE requires a specific Thermal Control Mode
  - CRE leaves all unnecessary units out of non-operational range to save power on heating
- CRE requires a specific Operational Mode
  - Thrusters compensate for LAE perturbations
  - Thrusters only mode for back-up solution
  - Unnecessary units switch-off during CRE
  - Emergency Safe Mode (ESM) disabled during CRE
- Circa 70% of the Satellite fuel is for Controlled Re-Entry

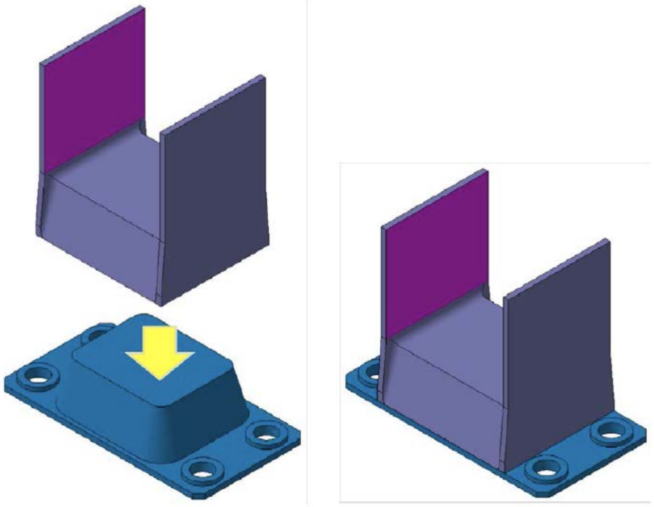
Copernicus Sentinel-1 A&B

- C-band SAR mission
- 2.2 tons S/C (~1 ton P/L)
- Two S/C – A & B models – launched in 2014 and 2016 respectively
- Casualty risk estimated:
    - 9.0 E-04 from DAS simulations
    - 7.2 E-04 from DRAMA simulations
    - 3.3-4.0 E-04 from SCARAB simulations
- SRR held before entry into force of the Admin (hence, casualty risk requirement not applicable)

Copernicus Sentinel-1 C&D

Design for Demise (D4D) techniques:

1. SAR antenna separation brackets:
   - 6 silver coated titanium brackets fixing the SAR antenna central panel to the S/C structure
   - the brackets are made of two parts soldered through a Sn/Bi solder alloy
   - predicted separation temperature is in the range 450K/177°C
   - detachment of the SAR antenna occurs at 80-110 Km altitude depending on the re-entry evolution
   - S/C demisability improves
   - activities on-going to develop and qualify the bracket design and associated manufacturing processes
2. improved design (layering) of the S/C balancing masses in Aluminum



=> Predicted casualty risk for S1 C&D S/C : 2 E-04 (SCARAB simulations)

Future ESA EO Missions

Potential missions to come (10 Sentinels and 2 Earth Explorers)

- Sentinel-1 NG
- Sentinel-2 NG
- Sentinel-3 NG Optical
- Sentinel-3 NG Topography
- Anthropogenic CO2 Mission
- Land Surface Temperature Mission
- HyperSpectral Mission
- Polar Ice Topography Mission
- L-band SAR Mission
- Passive Microwave Radiometer Mission
- Earth Explorer 9
- Earth Explorer 10

LEGENDA

~2 tons spacecraft

< 1.5 tons spacecraft

Let’s Talk about the Future

“The future is no longer like it used to be”

Herman Josef Abs

Director of Deutsche Bank (1938-1945) and Chairman from 1946 onwards

(Paul Valery as well)

The Way Forward

Constellations in LEO orbits will see an unprecedented growth in the next decade

Operational missions will have to periodically replenish a stable and growing satellite infrastructure

Operational lifetime of past missions dictated by the “projected” lifetime

Actual lifetime could be greatly extended if S/C could be actively removed when no longer operational

⇒ More efficient than equipping all S/C with controlled re-entry

⇒ Space capacity probably (almost) systematically available on future launchers

⇒ This requires a standard (for cooperative removal) :

⇒ to be defined and

⇒ be adopted