CleanSat Workshop
Evolution of LEO Platforms

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Agenda

- Introduction: AIRBUS DS experience on debris mitigation topics
- Overview of existing Airbus DS LEO platforms
- Issues in achieving compliance with the SDM requirements
- Brief overview of future platforms/tendencies in LEO
- Identified issues from looking at upcoming legislation
- Technology for performance or competitiveness
- Drivers for technology development.
- Conclusion

Introduction: AIRBUS DS experience on SDM requirements

Involvement in SDM requirements definition (since 2009):

- Participation to ISO/ECSS-U Working Groups
- Participation to the review of French Technical Regulations

Lead or participation to different studies relative to debris mitigation (since 2013):

- ESA studies:
  - CleanSat – Definition of specifications for future LEO platforms compliant with SDM requirements
  - Design for demise (D4D) techniques
  - System impacts of Propulsion passivation
  - Spacecraft Power System Passivation (SPSP)

- CNES studies:
  - SRL (Satellite Respectueux de la LOS – Satellite respectful of the French Space Act)

Space laws and their main new requirements

Space laws (ESA policy and French LOS and) are now clearly applicable

- ESA policy (IPOL 2014) fully applicable for programs with SRR after 28/03/2014
- LOS (Loi sur les Operations Spatiales) fully applicable for launches after 01/01/2021
- Practical applicable rules are under definition by ESA and CNES
  - New ESA handbook under finalization in the new "ESA safety office"
  - CNES "Guide des Bonnes Pratiques" (current issue = V4.0, still under evolution)

Main new satellite impacts

1. <u>Free LEO operational region</u>
- Re-entry in less than 25 years : typically 700 x 550 km disposal orbit (50m/sec), feasible with classical 4x1N
- Re-orbit over 2000km : not practically interesting except if operational orbit is over 1500km

2. <u>Avoid debris creation during the 25 years disposal phase</u>
- Fluidic and electric passivation needed to avoid any dangerous remaining energy in tanks and batteries

3. <u>Limit the risk of human casualty during re-entry</u> :
- Uncontrolled re-entry : feasible for satellites with low casualty risk ($<10^{-4}$)
- Controlled re-entry : required for large satellites
  - Requires a very large ΔV (around 150m/s) and a strong last impulse ⇨ a few 10N thrust level at least
  - Additional engine could be mandatory

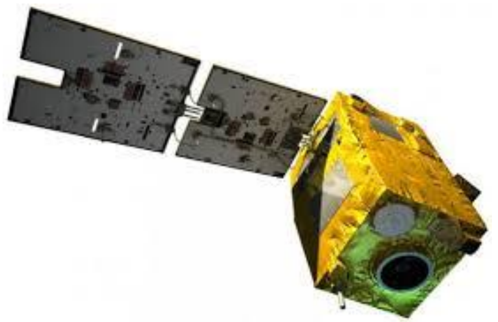
Overview of existing Airbus DS LEO platforms (1/3)

AIRBUS DS is currently commercialising and developing 4 different LEO platforms:

- AstroBus Extra Small (Myriade)
- AstroBus Small (Myriade Evolution)
- AstroBus Medium
- AstroBus Large

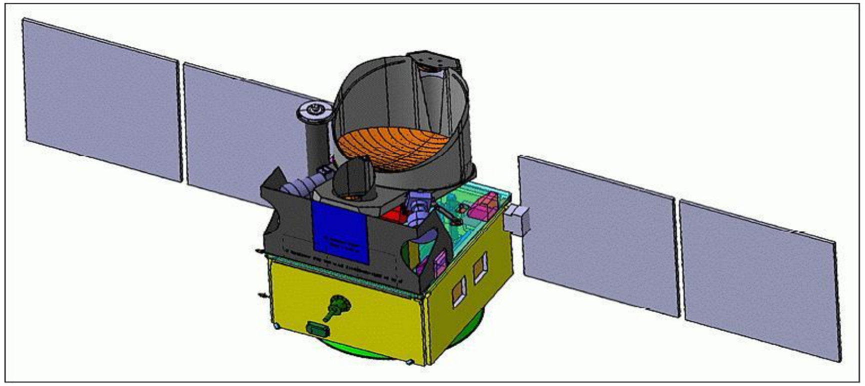
Satellite class	Mass	Existing Airbus DS platforms
Class S	<150 kg	AstroBus XS
	150 to 500 kg	AstroBus S
Class M	500 to 1000 kg	AstroBus M
	1000 to 1500 kg	AstroBus L
Class L	> 1500 kg	No generic platform

Overview of existing Airbus DS LEO platforms (2/3)



AstroBus XS (Vnredsat-1)

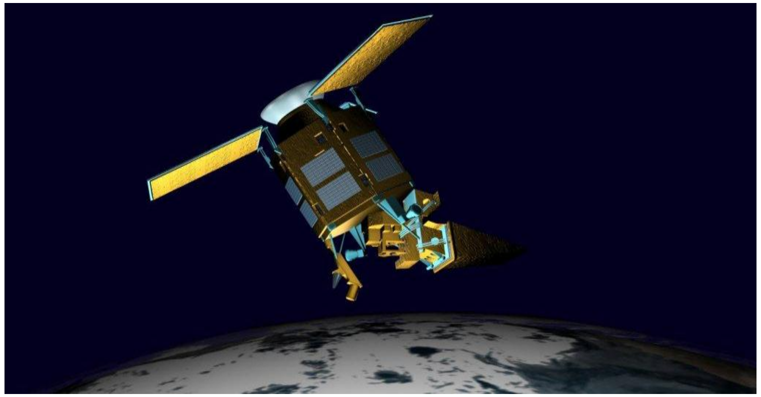
Characteristics	
Mission design lifetime	5 years
Bus dry mass	83kg
Payload maximum mass	50kg
Payload peak power	100W
Orbit average payload power	50W
Types of orbits available	SSO 500-800km



AstroBus S (Merlin)

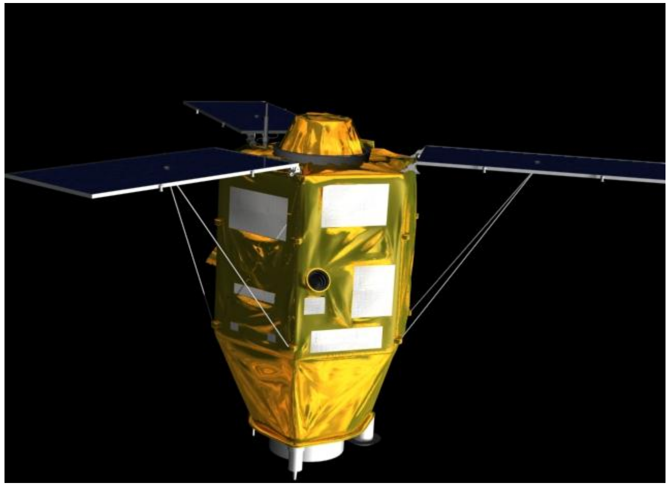
Characteristics	
Mission design lifetime	7 years
Bus dry mass	260kg
Payload maximum mass	200kg
Payload peak power	200W
Orbit average payload power	100W
Types of orbits available	SSO 500-800km

Overview of existing Airbus DS LEO platforms (3/3)



AstroBus M (Sentinel 5 Precursor)

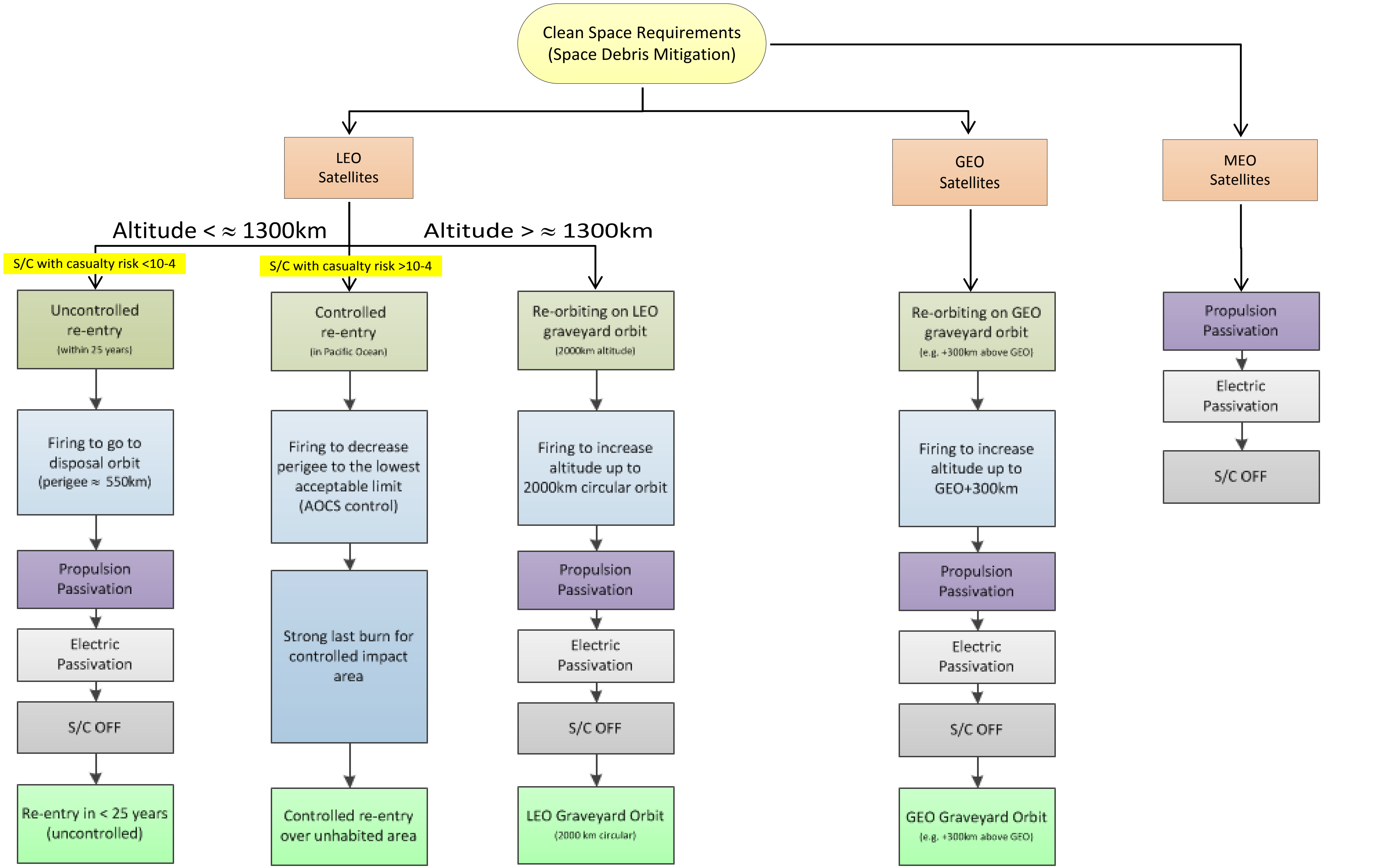
Characteristics	
Mission design lifetime	7 years-10 years
Bus dry mass	560kg
Payload maximum mass	200kg-250kg
Payload peak power	400W
Orbit average payload power	200W
Types of orbits available	SSO 500 - 800km



AstroBus L (Pleiades)

Characteristics	
Mission design lifetime	7 years-10 years
Bus dry mass	800kg
Payload maximum mass	500kg
Payload peak power	500W
Orbit average payload power	250W
Types of orbits available	SSO 500-800km

Issues in achieving compliance with the SDM requirements (1/2)
Impact on EOL operations



Issues in achieving compliance with the SDM requirements (2/2) Compliance status of existing Airbus DS platforms to SDM requirements

- **25-year rule:** *Usually compliant (depends on operational orbit altitude)*
- **Debris release**: *All platforms are compliant*
- **Accidental break-up**: *All platforms are compliant*
- **Probability of disposal manoeuvres:** *All platforms are compliant*
- **Casualty risk :** *Compliance dependent on platform size and considered payload*
  - Satellites below 500 kg: no casualty risk issue
  - Satellites between 500-1500 kg: compliance to casualty risk is strongly dependent on the considered payload
    - No major issue with radar payloads
    - Some optical payloads items are critical (optical glasses, ceramic parts)
  - Satellites above 1500 kg: non-compliance to the casualty risk requirement
- **Satellite passivation:** *Partial compliance*
  - No device on-board (up to now) to ensure full fluidic or electrical passivation
  - Specific operations to deplete propellant tanks and to prevent batteries from charging at the end of the operational mission

Identified issues from looking at upcoming legislation

Among long terms impacts of legislation (in connection with debris mitigation):

- REACH issue (regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals):
  - Entered into force on 1st June 2007
  - "*The main aims of REACH are to ensure a high level of protection of human health and the environment from the risks that can be posed by chemicals …*"

- Toxicity issue:
  - French Space Act: "*Systems shall be designed in such a way that the elements that reach ground will not have an impact on public health or environment (Technical Regulation, Article 45-2)*".

➔Both will have a potential impact on the selection of on board materials:

- Either forbidden materials (e.g. propellant)
- Or limited amount of some materials (e.g. lead)

Brief overview of future platforms/tendencies in LEO (1/4)

The design of future LEO platforms is driven by the following elements:

- Debris mitigation constraints
- Mission duration increase (7-10 years)
- Increase of payload operation duty cycle
- Obsolescence issues
- Satellite market segmentation
- Launcher characteristics evolution

Brief overview of future platforms/tendencies in LEO (2/4)

Constraints induced by SDM requirements (1/3):

	Class S satellites		Class M satellites	Class L satellites
	< 150 kg	150 to 500 kg	500 to 1500 kg	> 1500 kg
Controlled re-entry	No	No	Optional (payload dependent)	Yes
Demiseability	No	Yes	Yes/No	No
Fluidic passivation	Yes (TBC)	Yes (TBC)	Yes/No	No
Electrical passivation	Yes (TBC)	Yes (TBC)	Yes/No	No

Fluidic passivation covers several aspects:

Dedicated passivation devices (e.g. pyros or valves) which can save time in terms of operations but with additional costs and safety issues,

Or

Dedicated operations to deplete the propellant. This kind of strategy may be sufficient in the case the propellant tanks have no membrane.

Brief overview of future platforms/tendencies in LEO (3/4)

Constraints induced by SDM requirements (2/3):

	Class S satellites		Class M satellites	Class L satellites
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Fluidic passivation	Yes (TBC)	Yes (TBC)	Yes/No	No
Electrical passivation	Yes (TBC)	Yes (TBC)	Yes/No	No

Controlled re-entry and demiseability are exclusive requirements:
In case of controlled re-entry no need to ensure satellite demiseability
(no added value in terms of casualty risk reduction and extra development costs and mass)

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Brief overview of future platforms/tendencies in LEO (4/4)

Constraints induced by SDM requirements (3/3):

	Class S satellites		Class M satellites	Class L satellites
	< 150 kg	150 to 500 kg	500 to 1500 kg	> 1500 kg
Controlled re-entry	No	No	Optional (payload dependent)	Yes
Demiseability	No	Yes	Yes/No	No
Fluidic passivation	Yes (TBC)	Yes (TBC)	Yes/No	No
Electrical passivation	Yes (TBC)	Yes (TBC)	Yes/No	No

Controlled re-entry and passivation are exclusive requirements.
In case of controlled re-entry no need to ensure satellite passivation,
(the satellite will leave the protected LEO zone in a very short period of time)

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Identified issues from looking at obsolescence and other topics

Equipment and component expected obsolescence:

- Need to upgrade equipment (e.g. AstroBus-M Power Control and Distribution Unit)

Launcher evolutions (notably the Vega C evolution for single and multiple launches)

- Impact on satellite maximum mass (and dimensions)

Mission duration increase (7-10 years)

- Need to improve equipment reliability and/or to add redundancies

Increase of payload operation duty cycle

- Need to consider the introduction of a solar array drive mechanism

Note: At a first glance the above constraints do not interact much with debris mitigation constraints

Technology for performance or competitiveness improvements

Source of performance improvement for future platforms = use of green propellant:

- Increased ISP with respect to hydrazine (+10%)
- Higher density than hydrazine

Improved thrust level per kg

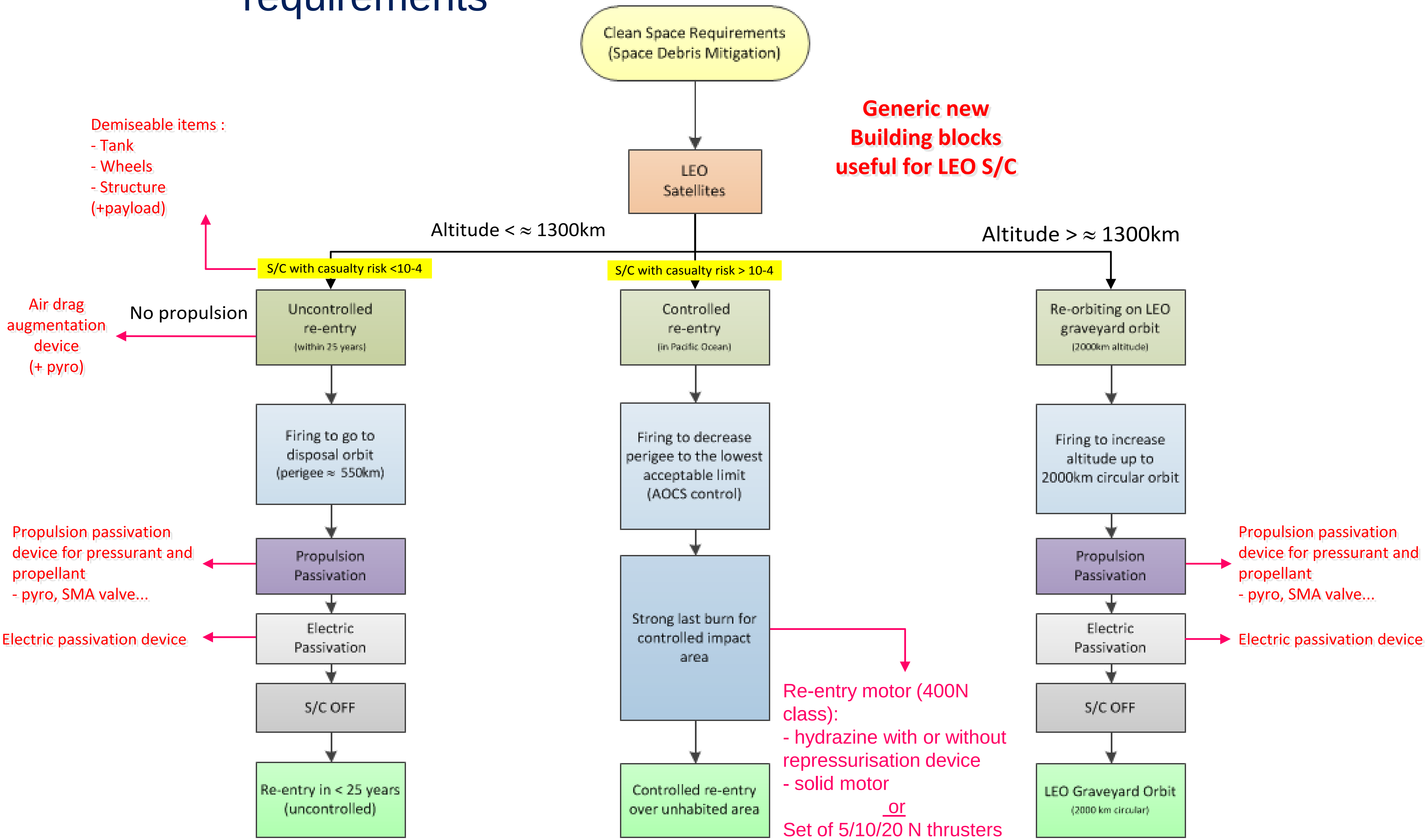
<u>Potential drawback</u>: Higher temperatures at propulsion level (impact on thruster design and on demiseability)

Drivers for technology development

Debris mitigation constraints are the main drivers for technology developments.

- Passivation (fluidic/electrical)
  - Introduction of passivation devices:
    - 100% safe during nominal mission (10 years)
    - Sufficiently reliable (>0.9?) for EOL operations
- Demiseability (platform and payload level)
- Controlled re-entry
- 25-years rule

Potential “building blocks” derived from SDM requirements requirements



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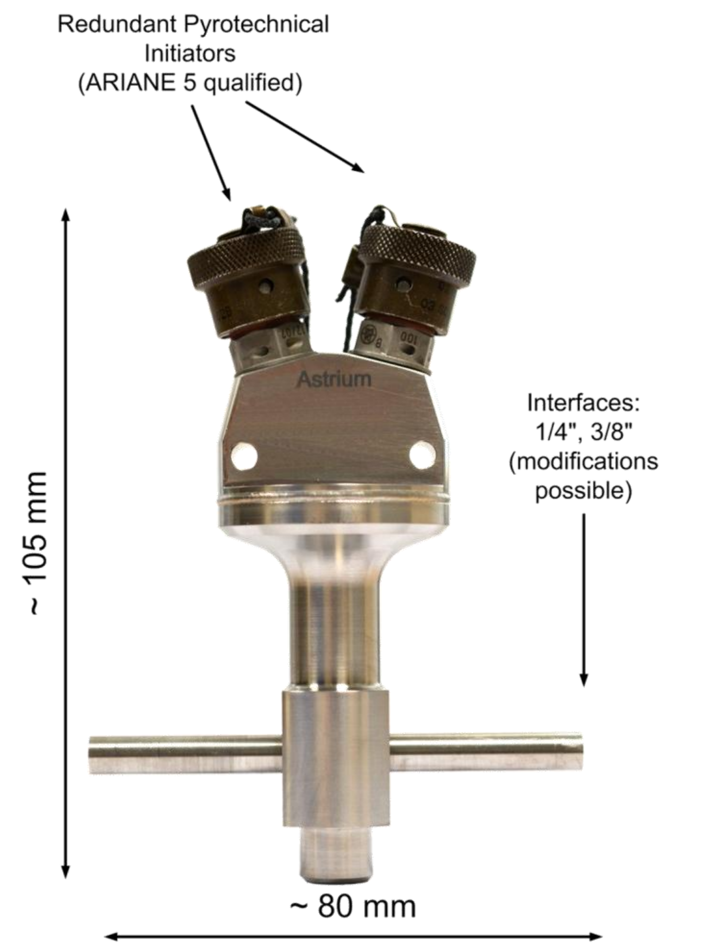
Space Debris Mitigation Passivation – Solutions

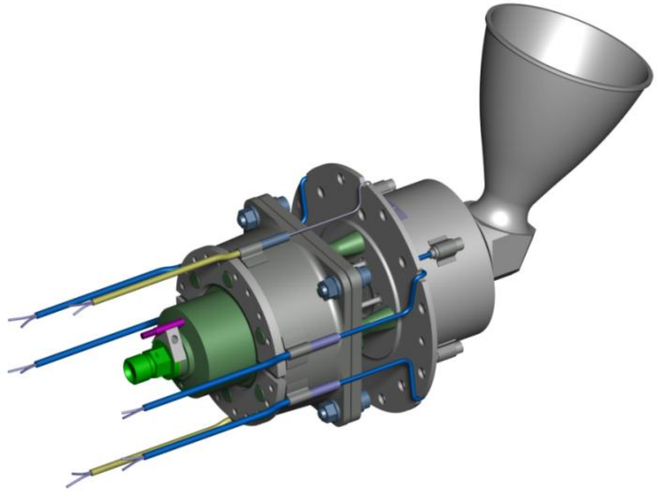


Pyrovalve life time extension
(> 23 years) activities within GSP
Ready for flight in 24 months

SMA based passivation non-pyro valve
Ready for Qualification

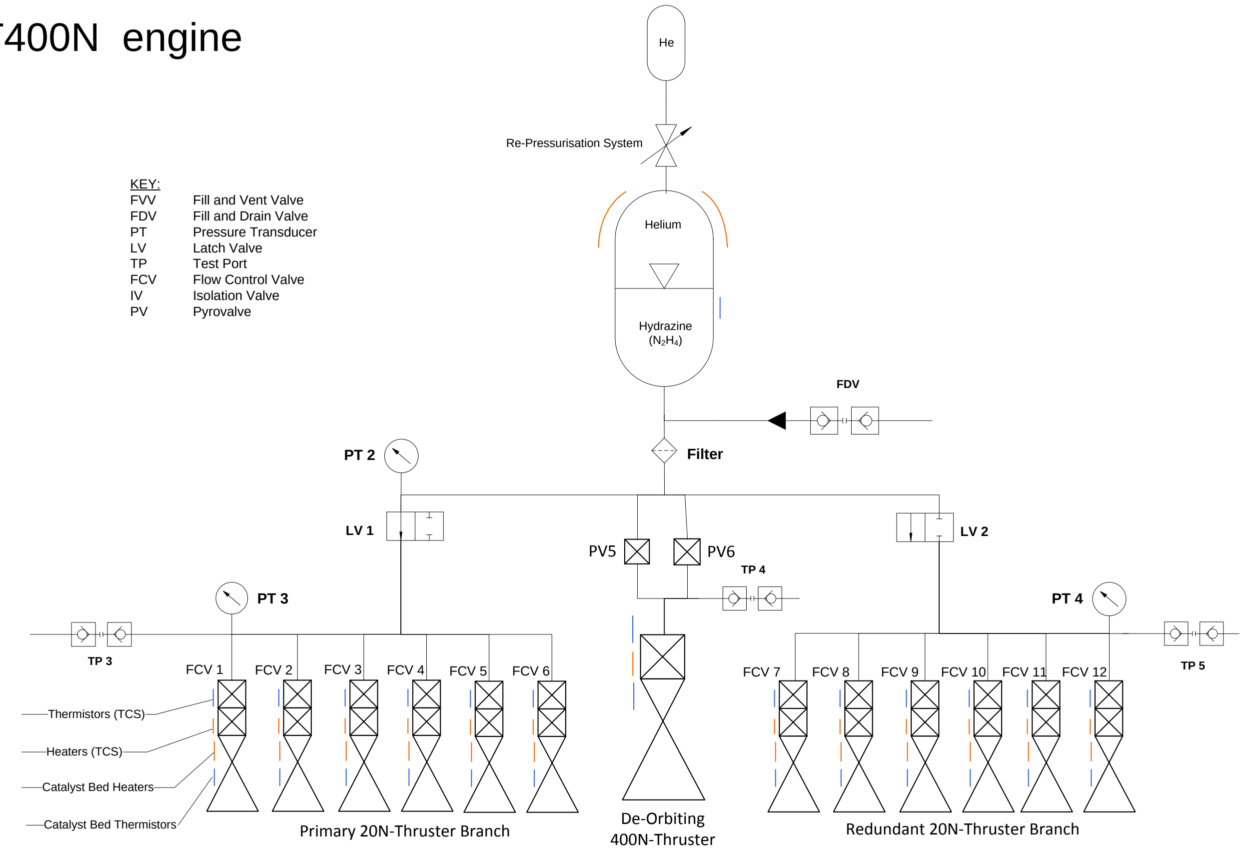
SMA actuators

Space Debris Mitigation
Controlled re-entry – Solution for MetOp-SG



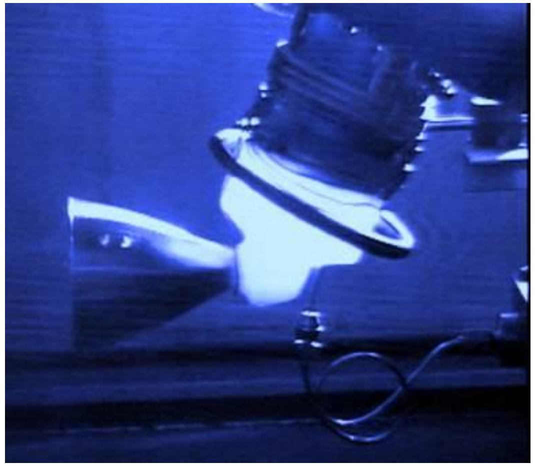
Controlled re-entry aims to remove a satellite from its LEO orbit and to dump it into the Pacific Ocean by multiple firing manoeuvres.

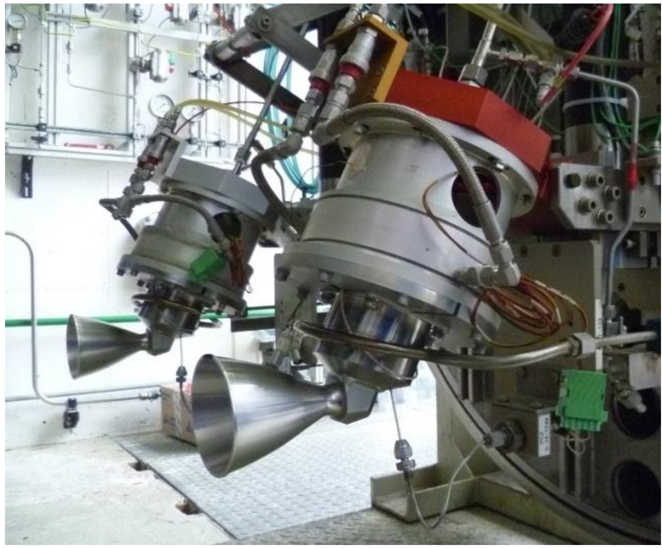
- For MetOp-SG a Monopropellant System with main engine for de-orbiting from LEO is considered
- Further development and adaption of the CHT400N engine
- Main system elements are:
  - Tank Assembly (TA)
  - Re-Pressurisation System (RPS)
  - Propellant Isolation Assembly (PIA)
  - 20N Thruster Assemblies (THA)
  - De-Orbit Engine CHT400N
  - Fluidics



Space Debris Mitigation
Controlled re-entry – Solution for MetOp-SG

- Major achievement: Long Storage Confidence Test successfully passed
- An 18-year old thruster has been re-activated and successfully tested
- The capability of the CHT400N to behave within the nominal range after 11 years of storage has been successfully demonstrated:
  - The FCV performance data (leak and electrical) after 11 years of storage are well in family to nominal FCV data
  - Thruster hot fire performance (ISP; thrust; chamber temperature) are in the expected range of test tolerance; no sign of degradation was observed
- A strong confidence of CHT400 suitability for MetOp-SG Mission has been established





Conclusion
What and when?

Preliminary list of « building blocks » has been identified

➔ Proposal to be discussed during the workshop and to be refined during the weeks to come (CleanSat study)

Building blocks development schedule is a key issue:

- First LEO missions to be fully impacted by debris mitigations rules will be launched in 2020-2021

➔Building blocks should be available somewhere in 2018

Any questions?

Thank you for your attention