Clean Space

Guaranteeing the future of space activities by protecting the environment

Clean Space Team
30 October 2012

Introduction

- **Environmental concerns** are in the forefront of public attention:
  - new legislative demands such as REACh, RoHS but also LOS
  - green technologies provide competitive advantage

- Space Industry is also **under pressure**:
  - risk of supply chain disruptions (direct or indirect),
  - interest and request from their customers, operator clients, employees and stakeholders (e.g. Arianespace, comparisons ground/space solutions).

- Concerns on the **sustainability of the exploitation of space**:
  - Recently space debris related events have often made news headlines worldwide (ROSAT, Ariane 4 tank, ISS evacuations…)

- With the Clean Space initiative, ESA will give a **pro-active answer to the environmental challenges both on Earth and in space, including its own operations as well as operations performed by European space industry**.

Action is necessary to turn a threat into an opportunity

Overview of Clean Space

Clean Technologies for space are defined by ESA as those which contribute to the reduction of the environmental impact of space programmes, taking into consideration the overall life-cycle and the management of residual waste and pollution resulting from space activities, both in the Earth eco-sphere and in space.

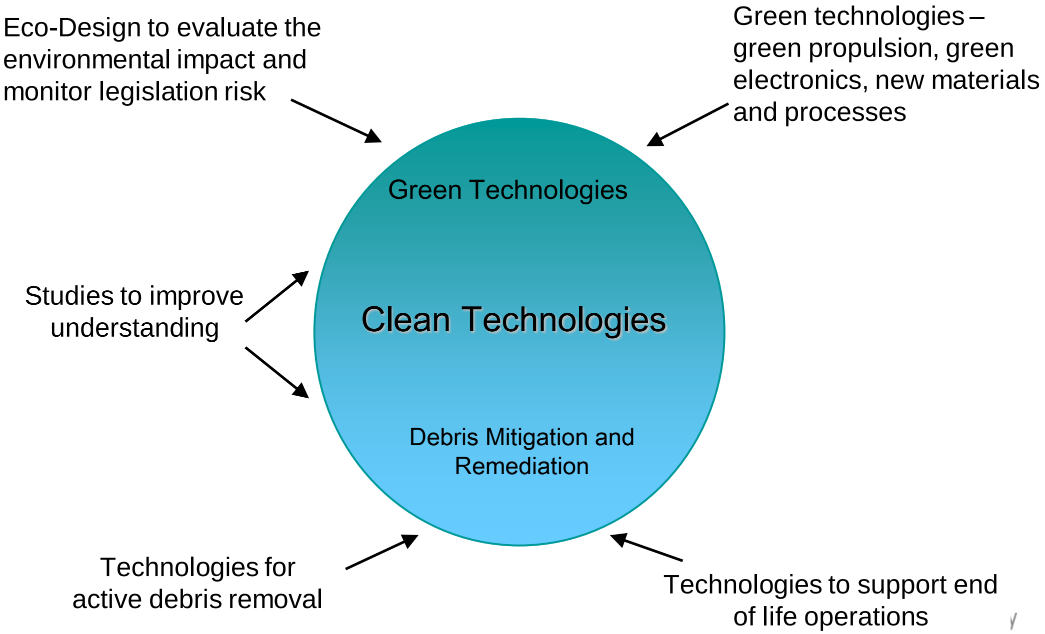
Four Branches:

1 – Eco-Design

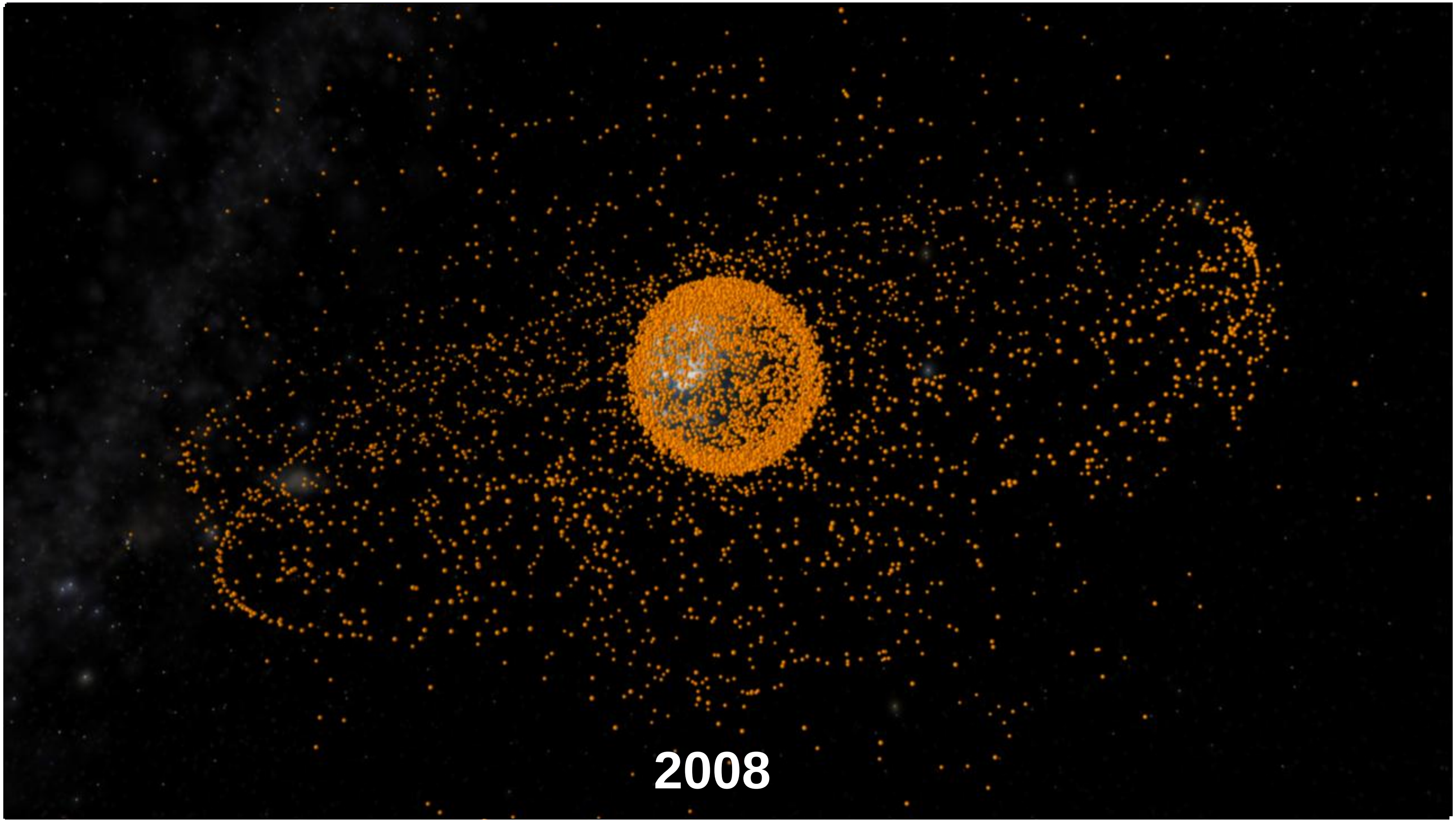
2 - Green Technologies

3 – Space Debris Mitigation

4 – Space Debris Remediation



Distribution of Known Objects



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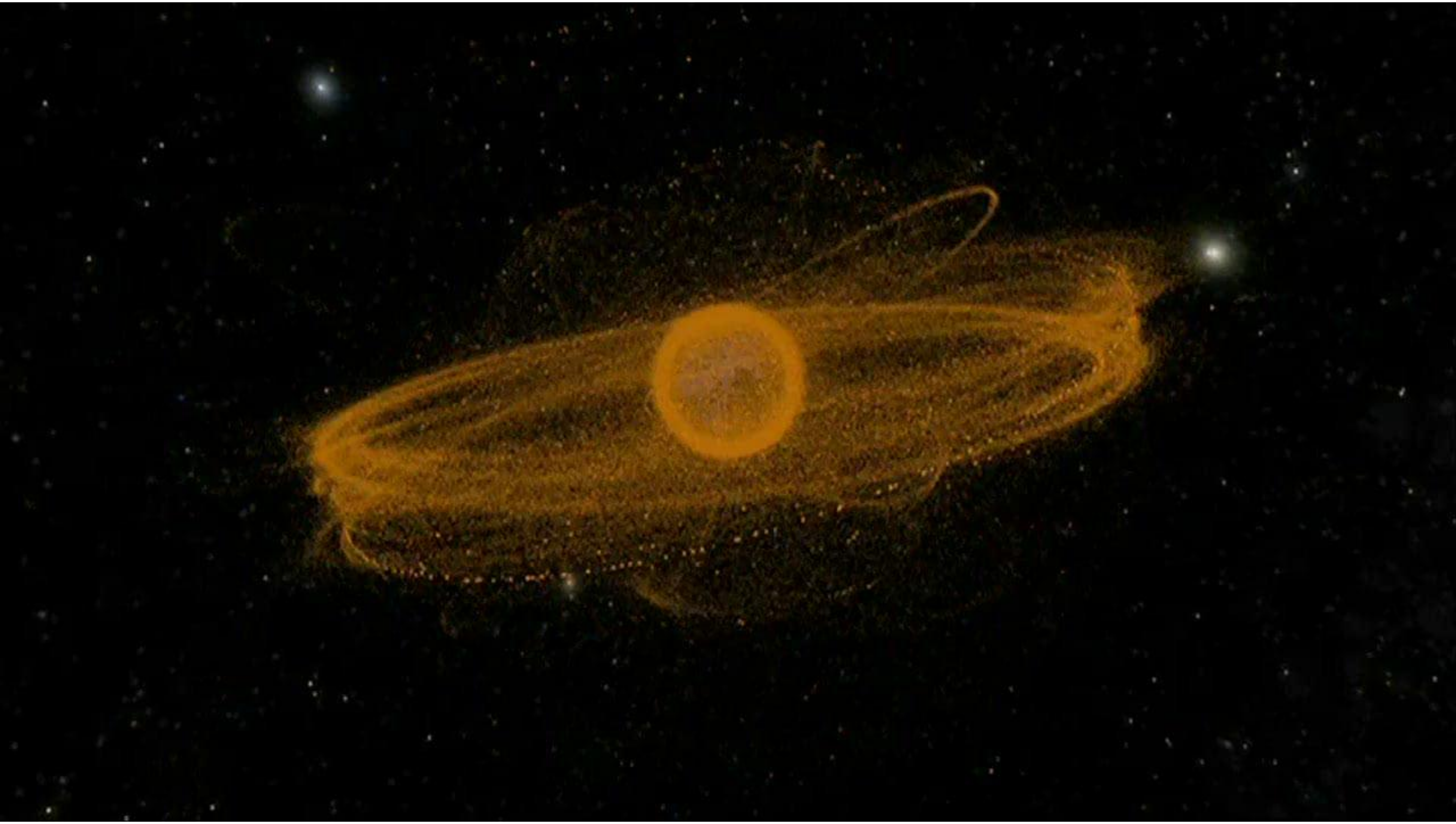
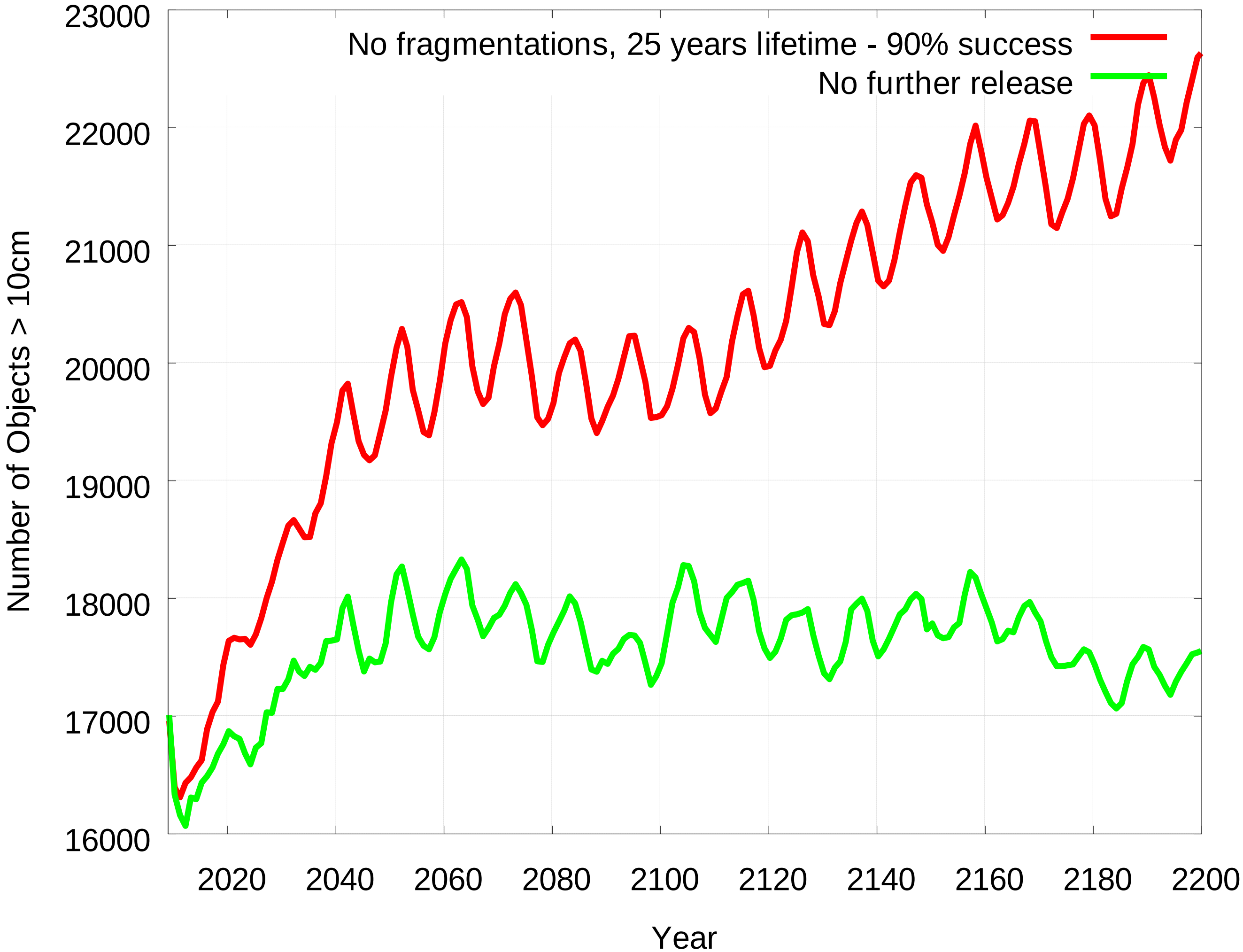
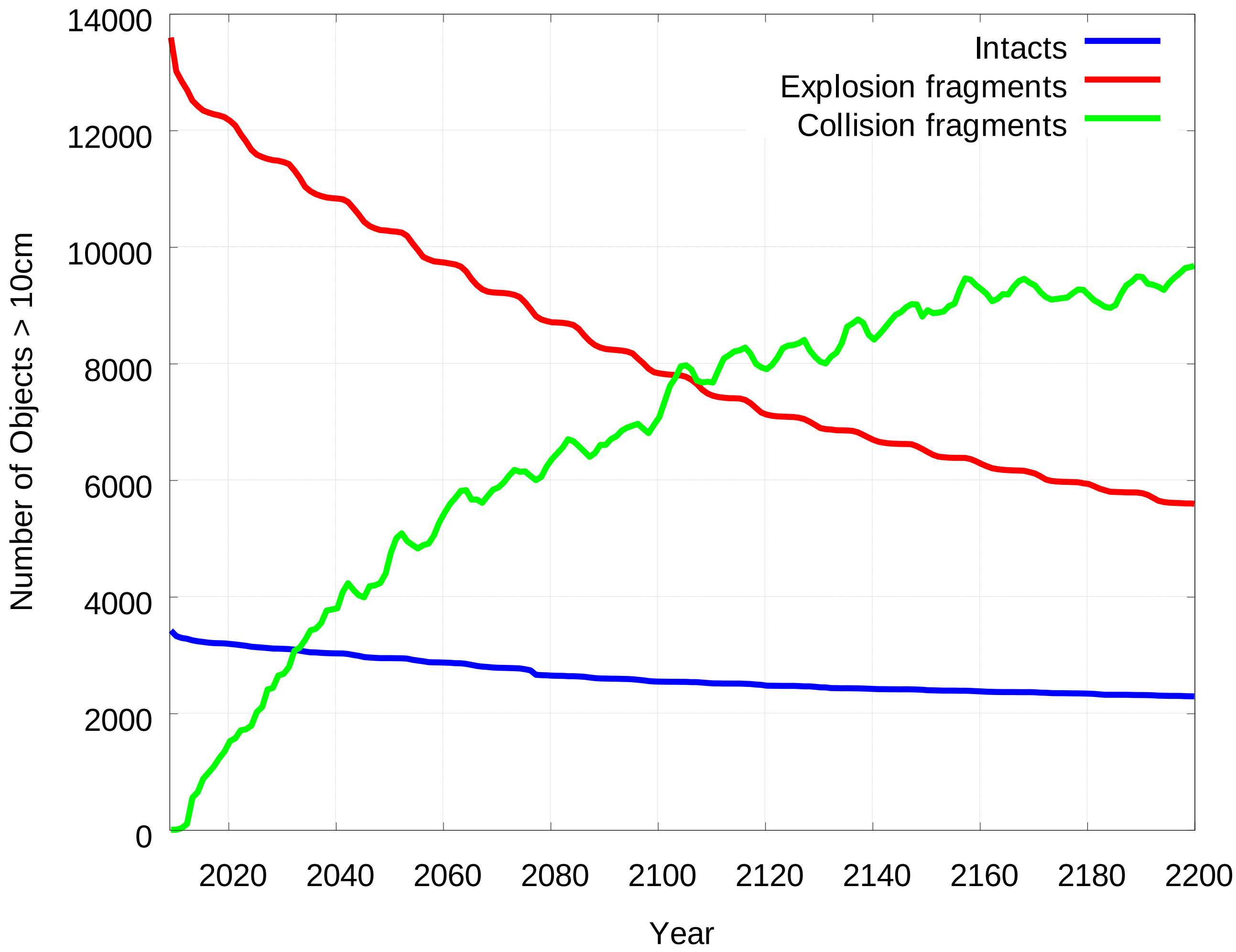
Objects > 1cm



DELTA results: Future evolution of the environment



No further release scenario



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Limiting the number of intact objects

3 Options:

- ***Lifetime Limitation:*** 25 years lifetime limitation → constant number of objects added to intacts → (launches/year x object lifetime)

Lifetime (years)	Satellites (8 years of mission)	Rocket bodies	Total
5	468	180	648
15	828	540	1368
25	1188	900	2088

- ***Launch Rate Reduction:*** Limit launches into LEO (currently: 72 intacts per year) →No legal means
- ***Active Debris Removal:*** Removal of intact objects (defunct satellites and rocket bodies) →Only acceptable if lifetime limitation requirement is fulfilled

Space debris mitigation and remediation

1. ADR can be more efficient then launch rate and lifetime reduction, because the targets can be selected (optimised)
2. It is important to understand in which timeframe the environment shall be stabilised
3. Ideally, only one type of removal vehicle is used (requires targets to have similar characteristics)
4. On average, 50 objects need to be removed to prevent one collision
5. This can be optimised by selecting density hot-spots (in high altitudes)
6. Criteria for removal should be (a combination of):
    a. Collision probability [cross-section, population density]
    b. Altitude of the target orbit [lifetime of fragments]
    c. Mass of the target
7. Delays in starting ADR activities make ADR less effective

Branch 3 – Space debris mitigation

Objective:

Develop technologies for the systematic compliance of ESA missions (S/C and launchers) with debris mitigation requirements, covering re-entry or parking in graveyard orbits, passivation.

Risk Mitigation

Compliance with mitigation requirements

- ESA adopted European Code of Conduct for Space Debris Mitigation and derived ESA "Requirements on Space Debris Mitigation" as of 2008.
- Compliance with the debris mitigation requirements has a high impact on missions design and raises feasibility issues.

Degrade space debris environment

- Need to keep in-orbit lifetime of the missions within 25 years after the end of mission in order to reduce risk of in orbit collision.
- The S/C must be completely passivated shortly after the end-of-mission.

On-ground casualty

- Large S/C and launchers upper stages have a higher risk of causing on-ground casualties if the re-entry happens in an uncontrolled way.
- This risk must be addressed already in the preliminary design phase.

Branch 3 – Space Debris Mitigation

What will Clean Space do?

Technological options for main technical challenges:

- **Passive de-orbiting devises** to decrease in-orbit lifetime particularly for small S/C, especially those without propulsion system.

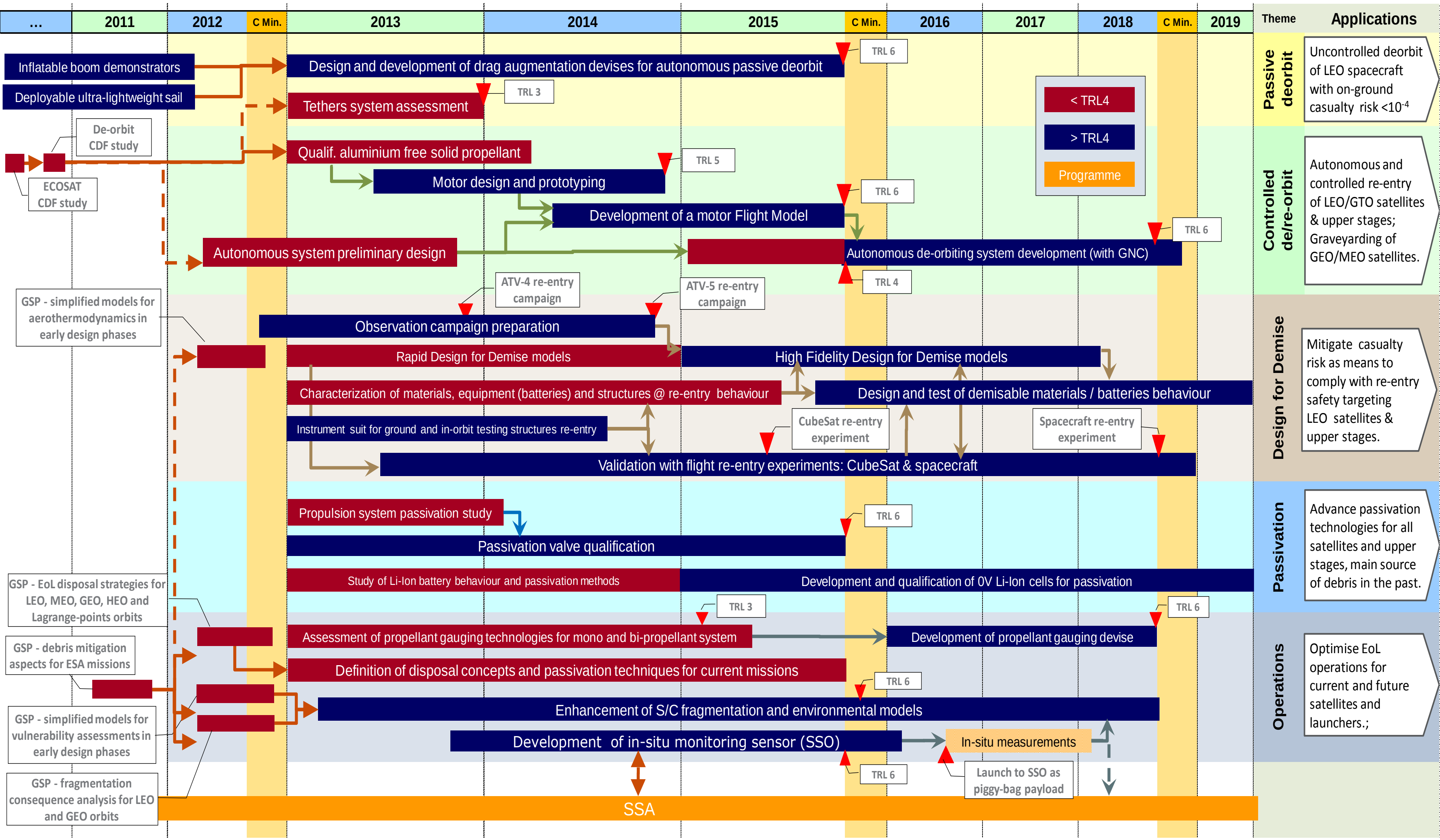
- **Active de-(re)orbit devices** to promote the immediate re-entry or graveyarding of satellites after the end of operations with limited impact on the design.

- **Design for Demise** to ensure break-up during during the atmospheric re-entry meeting requirements of on-ground casualty risk below 10^{-4} , very problematic for medium and large LEO satellites and upper stages.

- **Passivation of power and propulsion systems**, advanced passivation methods for current and future missions shall be identified and implemented

- **Operations,** to improve disposal concepts and passivation concepts, propellant gauging techniques, and environmental models & in-situ measurements

Clean Space roadmaps – Branch 3



Branch 4 – Space debris remediation

Objective:

Develop technologies for space debris rendezvous, capture and re-entry. Adopting a system approach, technology developments will be focused around a mission enabling the controlled de-orbit of heavy object. This will place European industry in the forefront position on anticipated future markets.

Risk Mitigation

Sustainability of space exploitation

- Simulations by NASA and ESA show that the number of debris keep growing even if no further objects are launched
- The current environment is already impacting the operations in SSO, Envisat performed 12 CAM in 10 years of operations, 3 of which in 2011.

In-orbit collisions

- Risk of a in-orbit collision is increasing in time. Operational satellite (Iridium) was destroyed by collision with debris (Cosmos).
- Risk of a ESA satellite going through a catastrophic collision in the next 50 years varies from ~7.5% to ~11%.

International awareness

- World-wide actions to limit the proliferation of space debris by active debris removal (5 objects per year)

e.Deorbit CDF System Study

1. The mission is to perform **active space debris removal**
   a. Uncooperative target (large satellite or upper stage) with heavy mass
   b. In 800-1000 km (near) polar region

1. Produce a preliminary system design for the most promising option(s), identify the required technology roadmap, and investigate its (their) applicability to other ESA missions

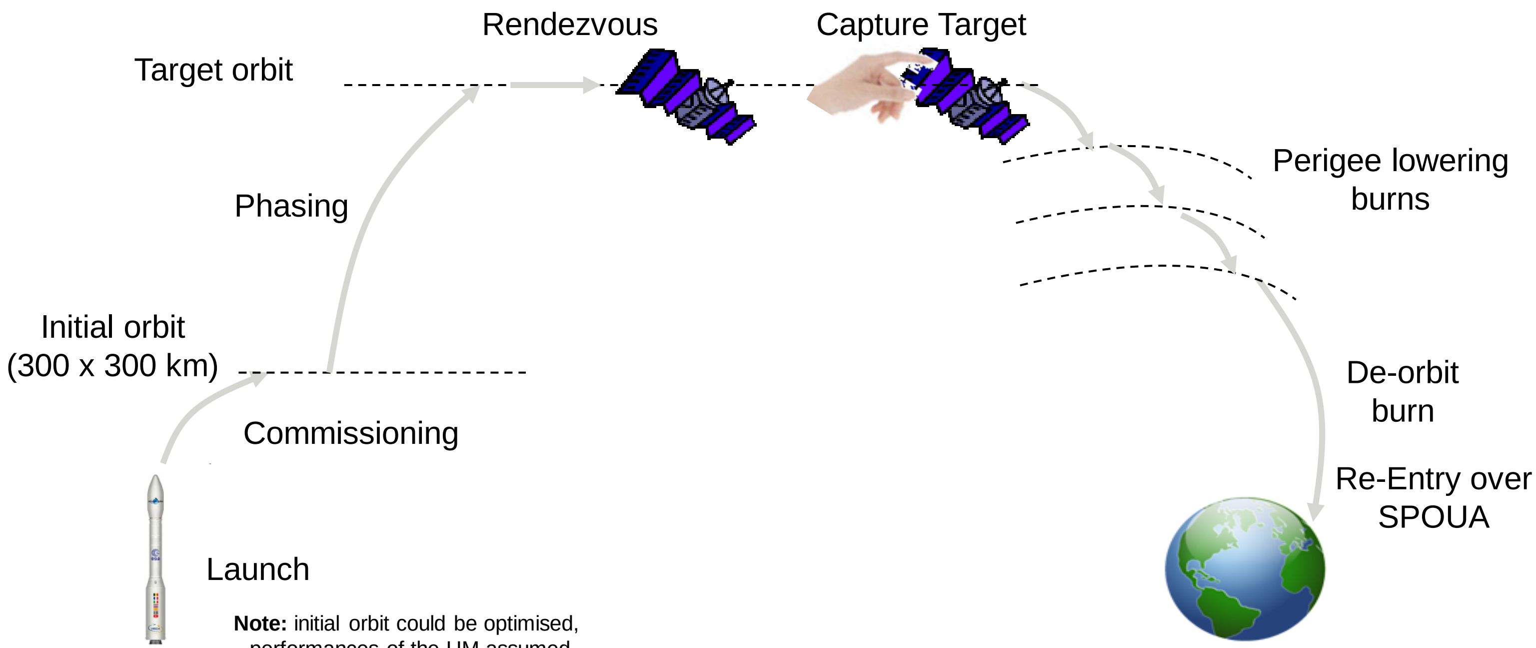
2. Main tasks:
   a. Assess the feasibility of a mission for the controlled de-orbiting and re-entry of a large target in SSO, using technologies analysed in previous CDF studies (e.g. tentacles, robotic arm, net)
   b. System level conceptual design of the spacecraft with the participation of all discipline specialists
   c. Trade-off different mission scenarios
   d. Assess programmatics, risk and cost aspects of the various alternatives
   e. Consolidate the Technology road maps in line with the programmatic aspects of the mission
   f. Evaluate the applicability of the technologies to different categories of satellites and debris remediation mission

The e.Deorbit CDF System Study

1. The e.Deorbit pre-assessment study was performed in ESA’s Concurrent Design Facility (CDF), using bi-weekly ‘design sessions’
    a. The CDF is a state-of-the-art facility equipped with a network of computers, multimedia devices and software tools, which allows a team of experts from several disciplines to apply the concurrent engineering method to the design of future space missions (www.esa.int/cdf)

2. Interdisciplinary team
    a. Study manager
    b. Team leader
    c. System Engineers
    d. Debris expert
    e. Engineers for mechanical and electrical sub-systems, including C
    f. Engineers for cost, risk, safety and programmatics
    g. Representatives for Human spaceflight (VAC) and Earth Observations
    h. Representatives for CNES, ASI and DLR

Mission timeline



Note: initial orbit could be optimised, performances of the UM assumed

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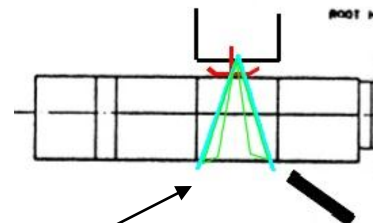
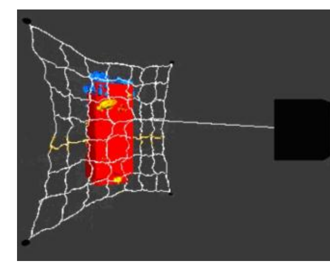
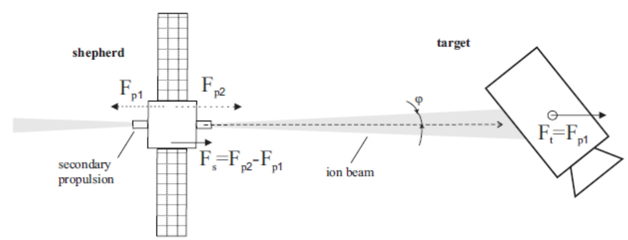
System options

1. Orbit:
    a. Re-orbit to >2000 km
    b. De-orbit to <600 km
    c. Controlled re-entry
2. Propulsion
    a. Chemical (CP)
    b. Electrical (EP)
3. Capture techniques
    a. Robotic arm
    b. Tentacles
    c. Net
    d. Ion-beam shephard







eDeorbit CDF Study: Conclusions

1. Two options were designed showing feasible first assessments
    a. Both are similar in mass & dimensions and appear suitable for a VEGA launch
    b. Net option shows fewer severe risk items, is less sensitive to target shape, 6-7% cheaper and 6 months less development time
2. Open points tentacles:
    a. Further analysis of the rendezvous and mating operations for the option using only the tentacles
        – Need for extra LIDAR, Tentacles closing parameters
    b. Good models of the target and sensor models are required, namely for the points being used for relative navigation in the close range (SAR antenna)
    c. Need for ground in the loop for the capture operations has to be re-assessed
    d. Structural integrity of the target holding points should be further analysed
3. Open points net:
    a. Plume impingement and chemical reactions with the tether material.
    b. ATD analysis for optimisation of the thrusters configuration of both the multi and single-burn designs (number of thrusters, tilting angle, TPS required)
    c. Tether cutting scenario, behaviour of the tether after cutting, interaction with following capture
    d. Optimisation of the tether control and tensioning ΔV can have an important impact on the propellant mass
    e. Detailed analysis and definition of the operation concept for the de-orbit phase and tether dynamics damping
    f. For single-burn option, out-gassing of the TPS after orbit raise burn should be assessed (even though it is a shorter burn)

Branch 4 - Space Debris Remediation (Active Debris Removal)

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What will Clean Space do?

Mature ADR technologies:

- Adapt and upgrade existing **sensor suit** to perform rendezvous with un-cooperative target
- Evaluate **capture mechanisms**: Net, Tentacles, Robotic Arm , etc.

  and promote technology maturation (e.g. net, tentacles)
- **Control of stack after capture**, push or pulling approaches must be studied and developed
- **Verification & Validation** framework

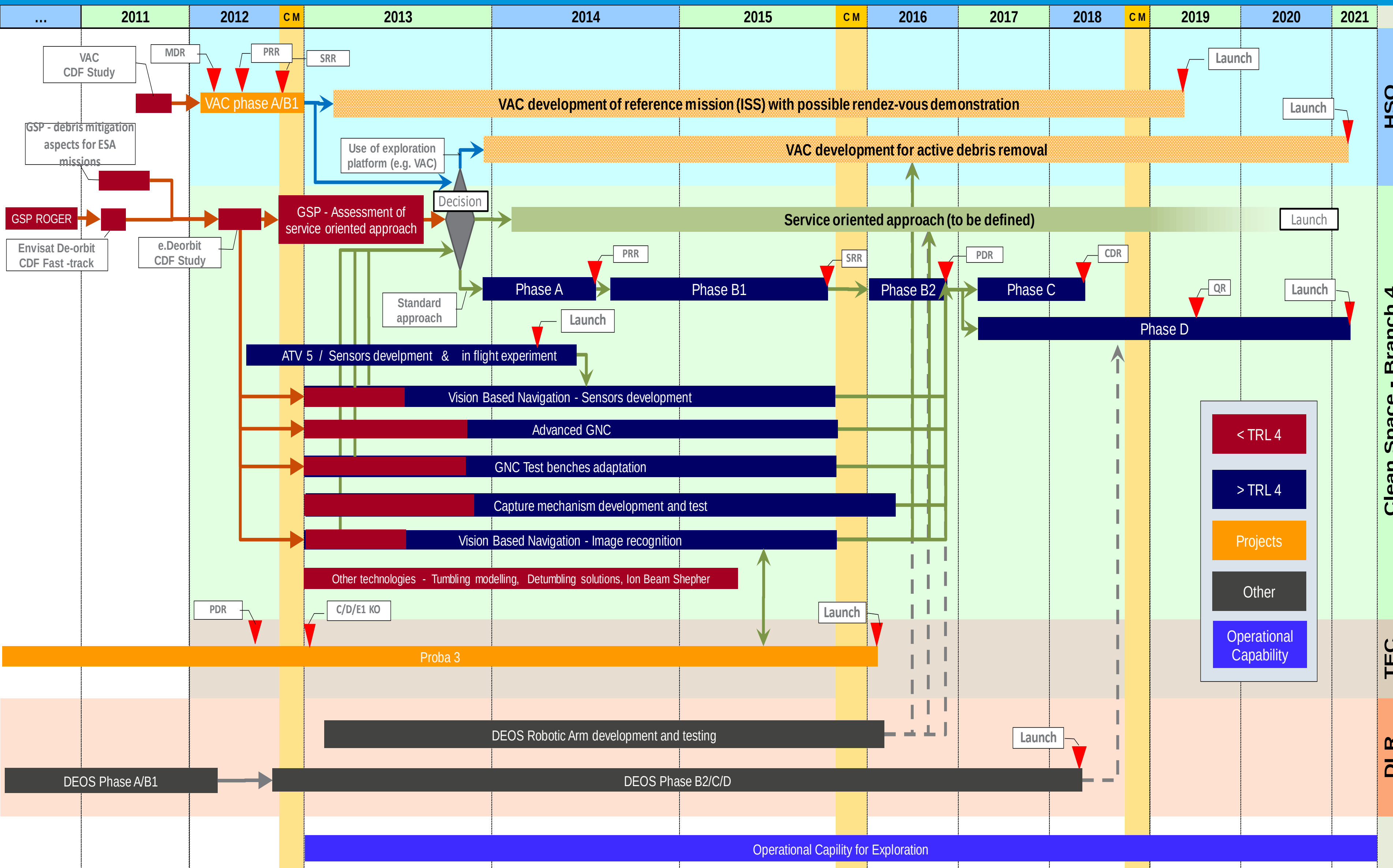
System approach targeting an ESA S/C controlled re-entry:

- **Phase A and B1** mission design before next CM

Study alternative approaches for other targets:

- Stabilisation of tumbling targets
- Ion Bean Shepherd

Clean Space Branch 4 Roadmap



Conclusions

Clean Space is the ESA initiative to "Guaranteeing the future of space activities by protecting the environment".

Clean Space is part of DG proposal as a cross-cutting initiative within the "Advancing Technology Programmes" Proposal for the C-M 2012.

It contains technology activities, in particular covering debris mitigation and remediation aspects.

The main goal is to provide space missions with technologies which will ease the implementation on End-of-Life regulations and would pave the way to a active debris removal mission.

Thank you

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Extra slides

Combination of Methods

There are different ways to come back to a population of not more than 2500 intacts (pure arithmetic – no simulation):

	Success of lifetime limitation	Lifetime limitation (years)	Number of launches in LEO	Years to reach threshold	ADR need (objects/year)
Reference case:	100%	25	36	100	19.4
Lifetime compliance:	90%	25	36	100	20.5
Lifetime reduction:	100%	10	36	100	11.3
Launch rate:	100%	25	18	100	11.2
	100%	25	54	100	27.6
By when is stability to be achieved?	100%	25	36	200	7.2

Realistic Case:	90%	25	36	200	9.1

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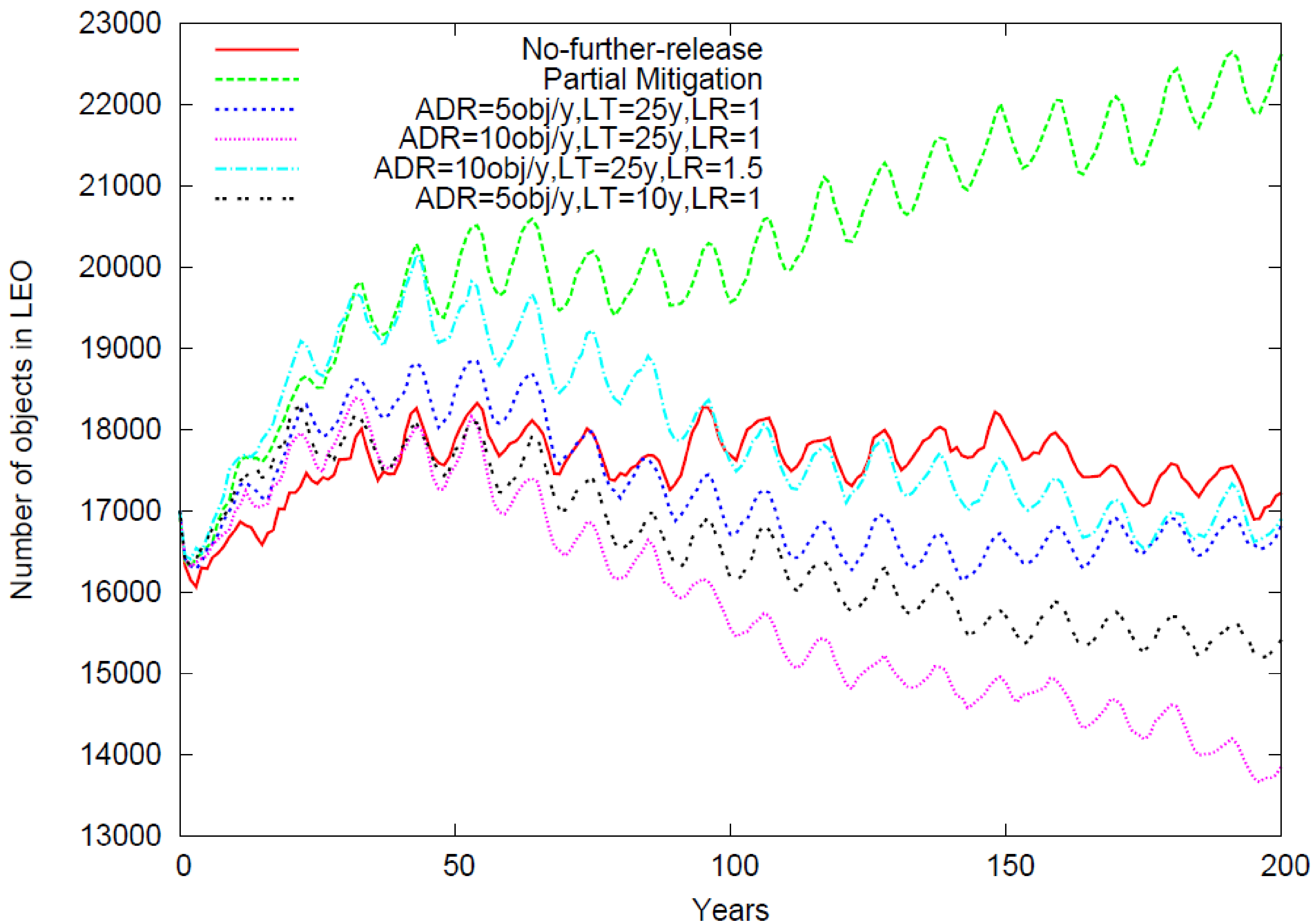
Simulation results of selected cases

Removal order: by object mass

LT: Lifetime limitation to 10 or 25 years with 90% success of de-orbiting and re-orbiting measures

LR: Launch Rate scaled by 1 or 1.5 of the current rate



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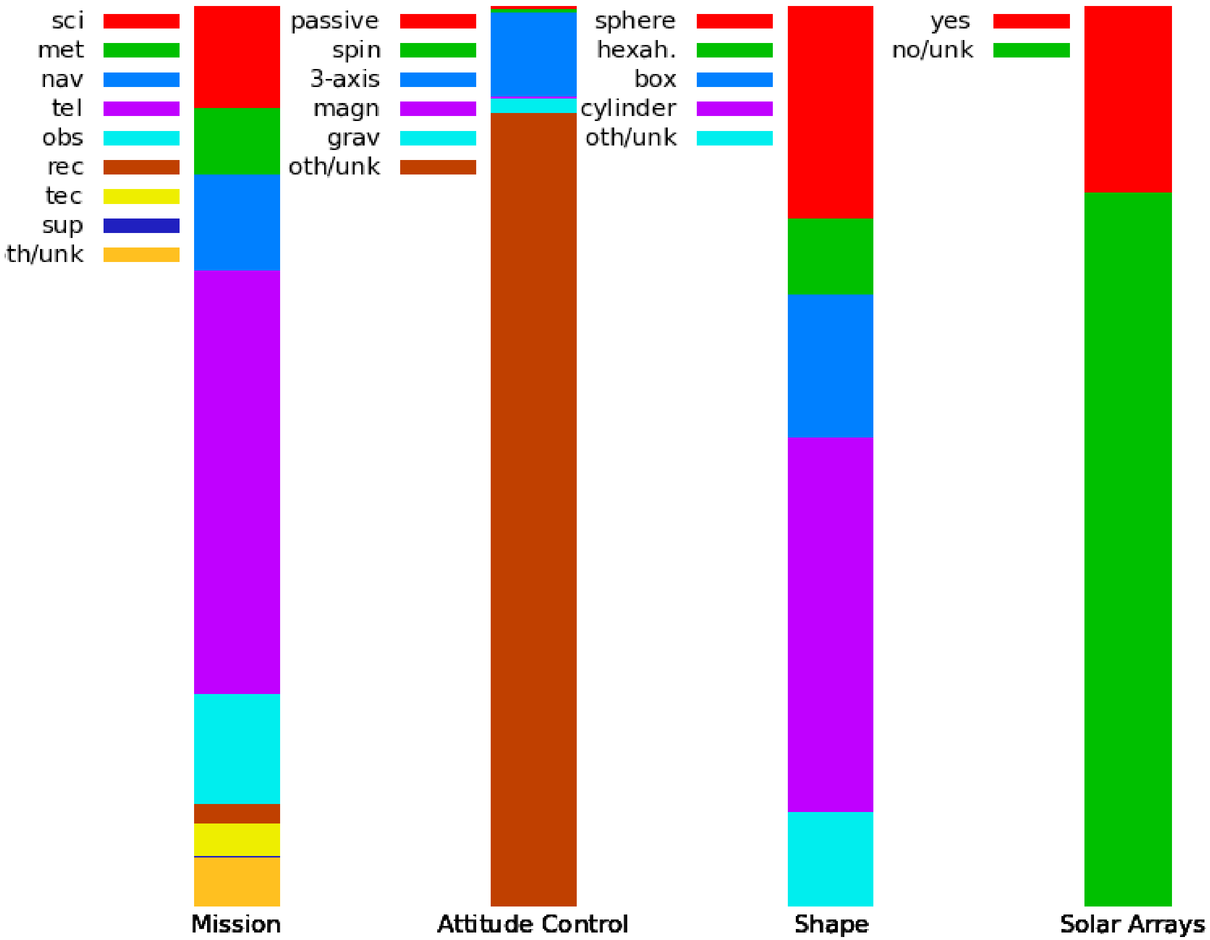
Selection of removal targets

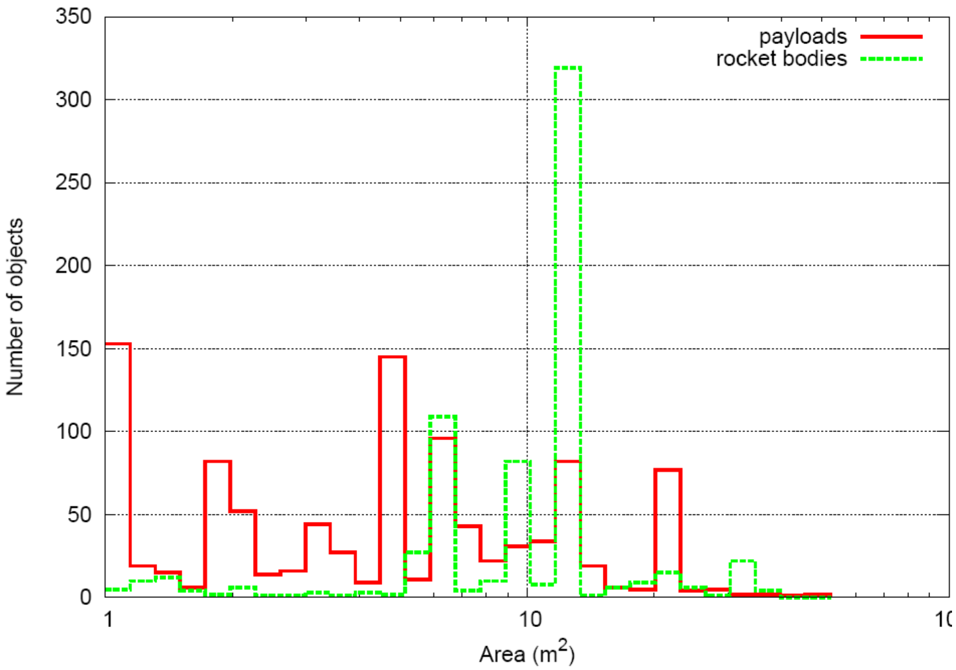
17,000 objects > 10 cm intersect LEO (May 2009), out of which 3,500 “intacts”

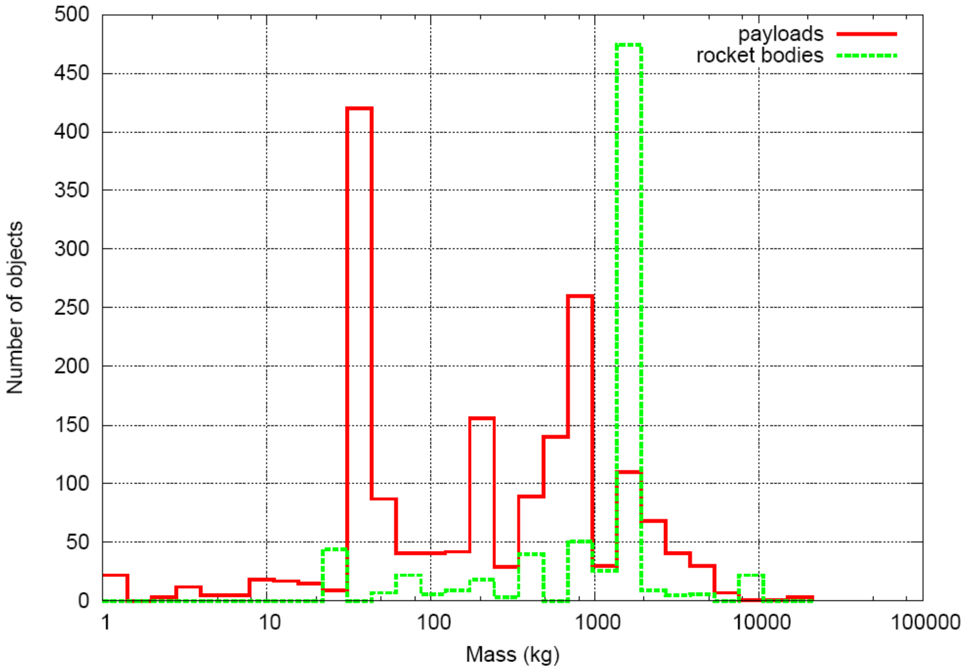


Object characteristics

Larger area → higher collision probability

Larger mass → higher fragment number





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Effectiveness of removal strategies

- No-further-release scenario (starting in 2006) for 200 years

	Removal by mass	Removal by area	Removal in (1000km, 82°)	Removal in (800km, 99°)	Removal in (850km, 71°)
# objects available (removed)	1000	1000	288	142	45
# objects reduced per object removed	5.3	5.3	7.8	9.1	36.3
# collisions reduced per object removed	0.008	0.008	0.018	0.023	0.024
# population growth %	-25.8	-26.1	-0.64	7.25	4.43

Mass and area are coupled and equally important

Large masses, higher altitude

Impact of delays in the start of the activity

1. No-further-release scenario, 290 objects in 1000km-82° in 58 years, Removal order by mass
    a. Start in 2006, 2020, 2040, 2060 and 2080 with 5 objects removed per year