Sustainable activities in space:
Space debris problematic in a nutshell

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OUTLINE

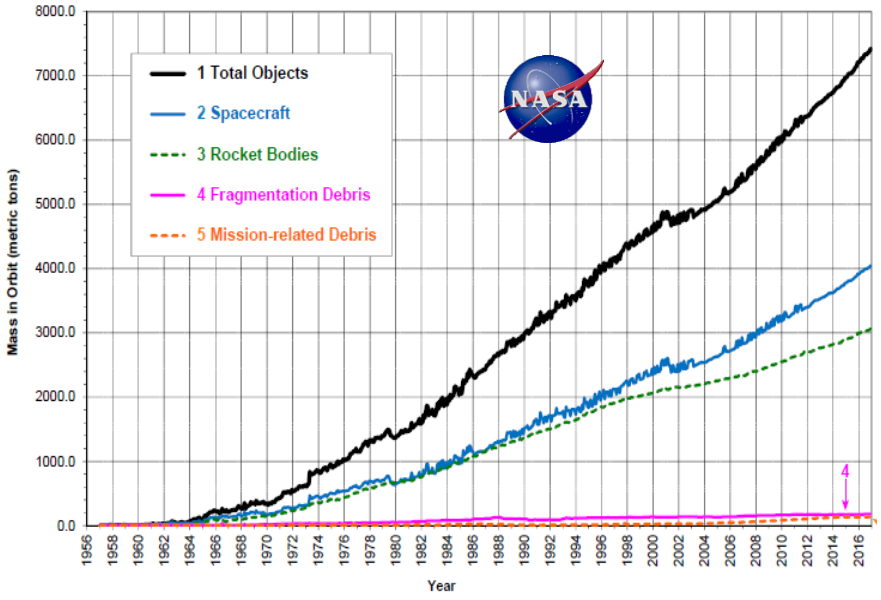
- Evolution of the orbital population
- Casualty risk at reentry
- Collision risk in orbit
- Required actions
- Open problem: JCA
- Conclusion

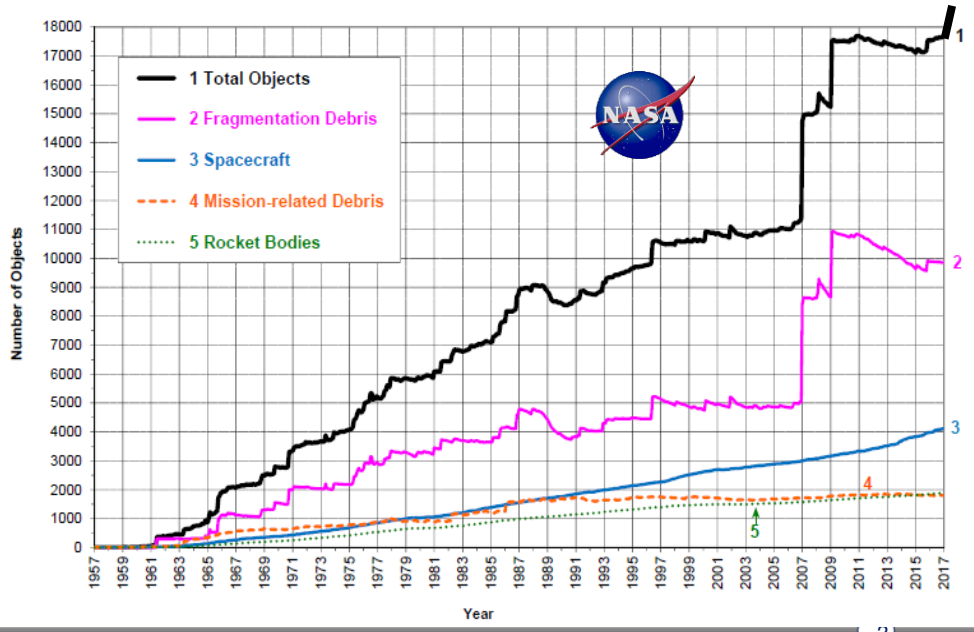
Evolution of the orbital population:

1. Ever increasing

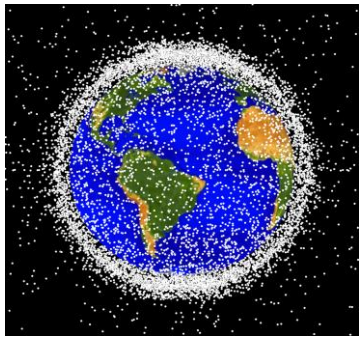
Since 1957, number and mass of space objects raise continuously:

- Despite reduction of launch rate compared to 60-80's
- Despite decades of debris mitigation rules





Evolution of the orbital population:



2. Roughly 23,000 objects larger than 10 cm in space:

Difficult to determine:

- 29,200 large objects according to # ESA MASTER 2009

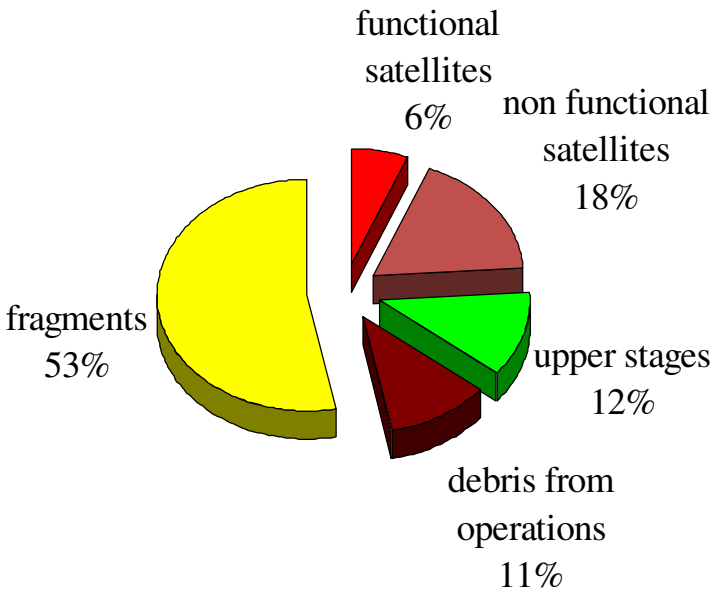
- 18,636 catalogued objects (June 2017)
- 744,000 debris larger than 1 cm #
- 167 million debris larger than 1 mm #

✞ **But space is very wide and infinitely empty!**

- ↳ At a given time, only 20 large objects above Italy
- ↳ In the worst zone, 1 object per 10 M.km^3

- Roughly 1300 active satellites (6 %):

- 450 in GEO
- 700 in LEO
- 150 elsewhere



Casualty risk at reentry:

Random reentry of large objects may generate a casualty risk on ground:

In average:

- Two catalogued objects reenter randomly every day
- One large intact object (upper stage or satellite) reenter randomly every week
- 10 to 40% mass survives reentry and hit the surface of Earth

No way to predict potential impact point:

- Best precision in prediction today ≅ 20% of remaining orbital time

Collision risk in orbit:

Four major families of collisions depending on size and maneuverability:

1. Collision between a catalogued object and an active satellite:

- Potential maneuver of the satellite to avoid collision
- Need very good Space Surveillance and Tracking feeding operational teams

2. Collision between a non catalogued object and an active satellite:

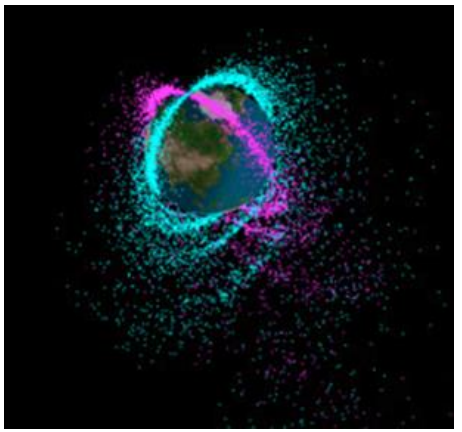
- If the debris is small enough (≤ 1 cm), potential shielding
- If the debris is significant (≥ 5 mm), loss of function or complete loss of satellite

3. Collision between two non catalogued objects:

- No avoidance possible today
- Moderate regeneration of debris following collision

4. Collision between two large intact derelict objects, catalogued but non maneuverable:

- No avoidance possible today
- Massive regeneration of debris following collision



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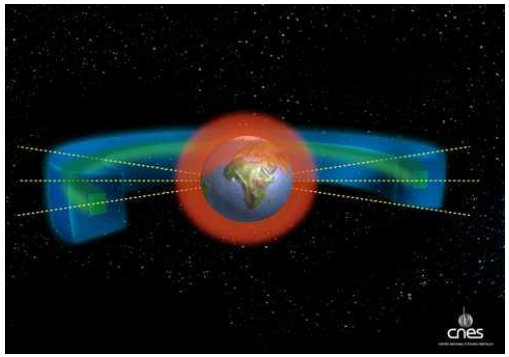
Required actions:

Highest level priority: comply with mitigation rules:

1. Short term:

- Minimization of operational debris; no voluntary break-ups,
- Systematic passivation to prevent accidental break-ups,
- Two protected zones (LEO, GEO): 25 years rule.



2. Long term

- Systematic deorbitation or escape.

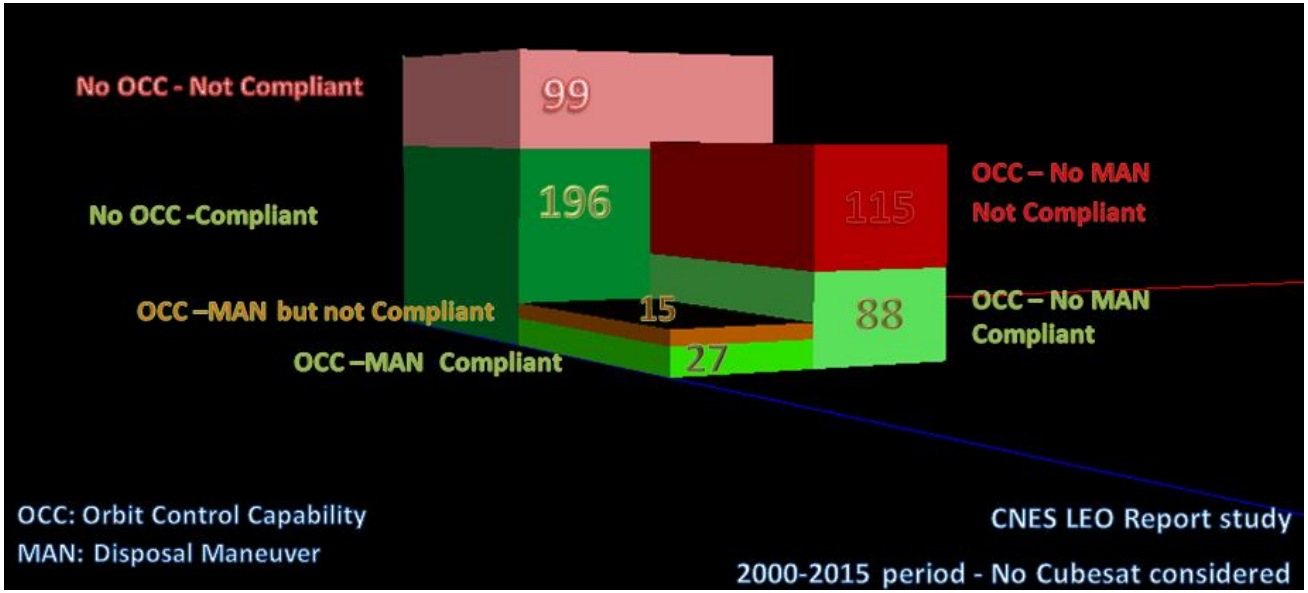
Very wide number of reference documents:

- National standards (NASA 1995, JAXA 1997, CNES 1999)
- IADC Guidelines (2002),
- UN Guidelines (2007),
- European Code of Conduct (approved ASI-BNSC-CNES-DLR-ESA 2004),
- ISO 24113 standard and second tier standards (2011),
- French Space Law LOS (approved 2008, into force since Dec.2010).

Current compliance level is still low:

Rules are poorly followed in LEO:

Globally ≅ 65% des LEO space objects comply with the requirements, but only 20% of the objects higher than 650 km altitude



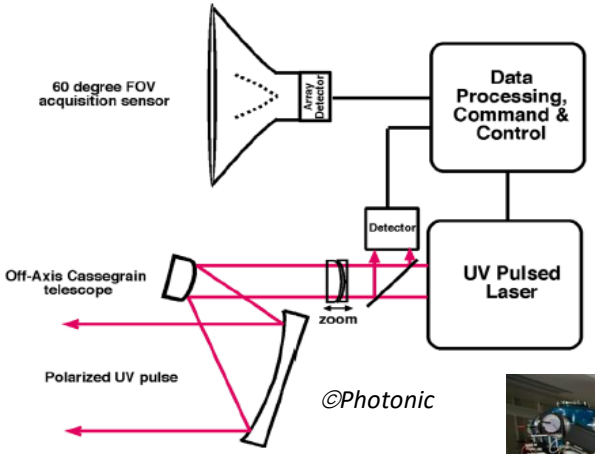
Compliance to mitigation rules may turn out not to be sufficient if no drastic improvement is considered in a short time

Required actions:

Different solutions depending on size and altitude:

1. Small debris sweeping in LEO:

- Most promising solutions are based on lasers



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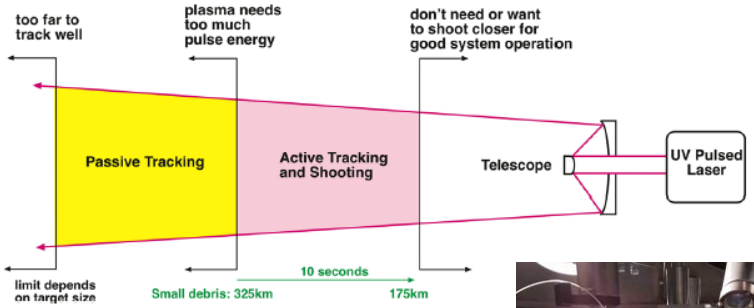

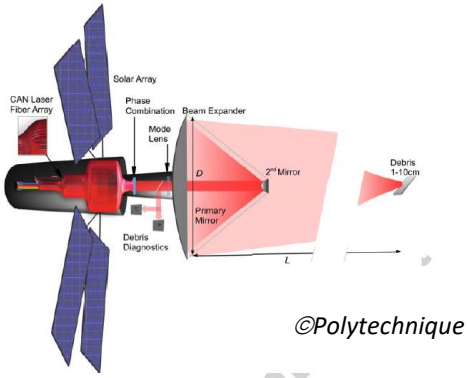

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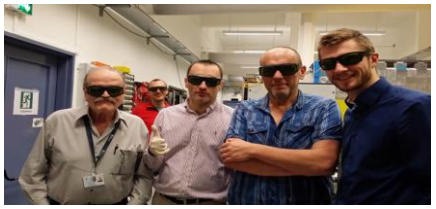

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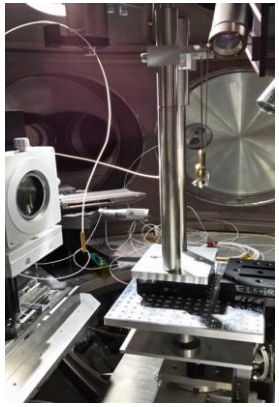

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Required actions:

Different solutions depending on size and altitude:

2. GEO reorbiting:

- Space Tug mission
- Electrostatic leash (GLIDER)
- Ion Beam Shepherd
- Laser reorbiting

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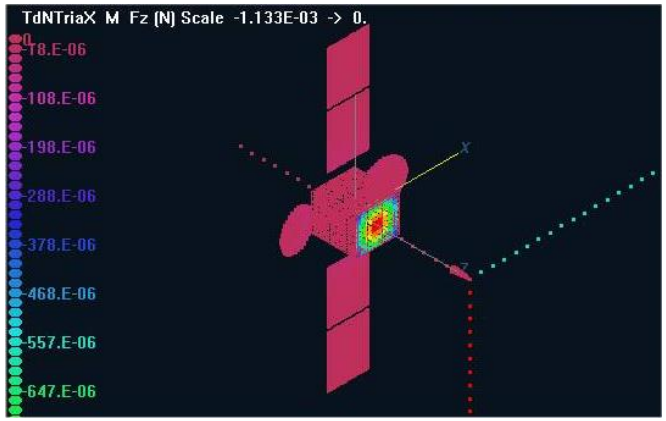

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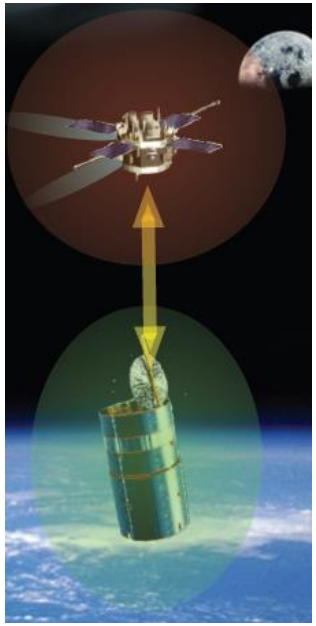

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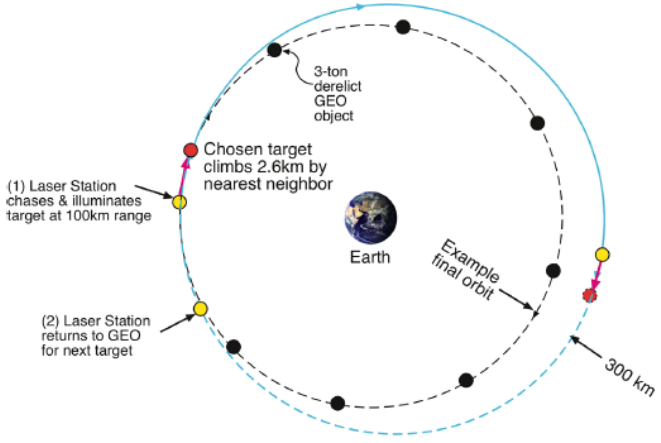

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Required actions:

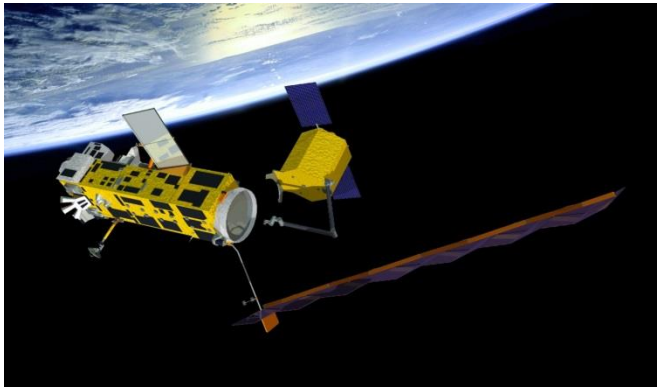
Different solutions depending on size and altitude:

3. Active Debris Removal (ADR) in LEO

- Space Tug mission
- Numerous variants, passive or active, with or without prior stabilization of Debris, with or without controlled reentry (robotic arm, harpoon, net, grapple, EDT, drag sail, airbag,…): **no best solution so far**

↳ Global efficiency is questionable: 35-50 retrievals are necessary to avoid one collision

↳ Financing of operations is questionable; potentially for large constellations



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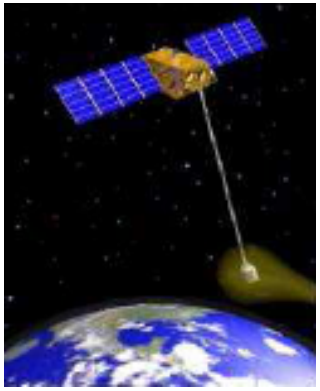

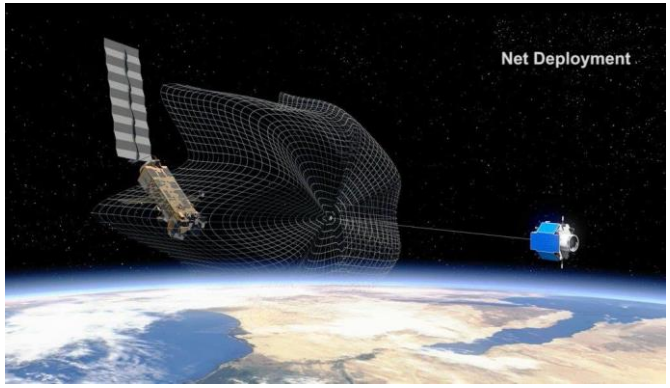

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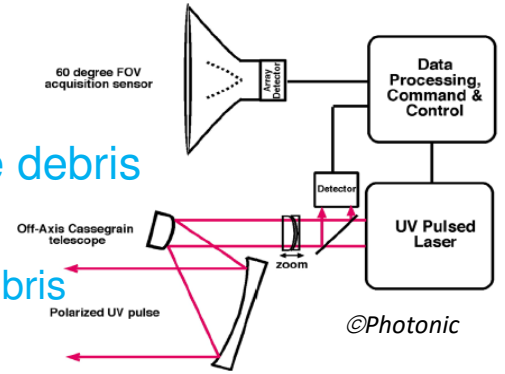
Required actions:

Different solutions depending on size and altitude:

4. Just-in-time Collision Avoidance (JCA) in LEO

- Tactical action to avoid a predicted collision
- Nudging: slight modification of the trajectory of one of the debris
- Some promising solutions today
  - Artificial atmosphere (gas and/or particles) in front of the debris
  - Laser



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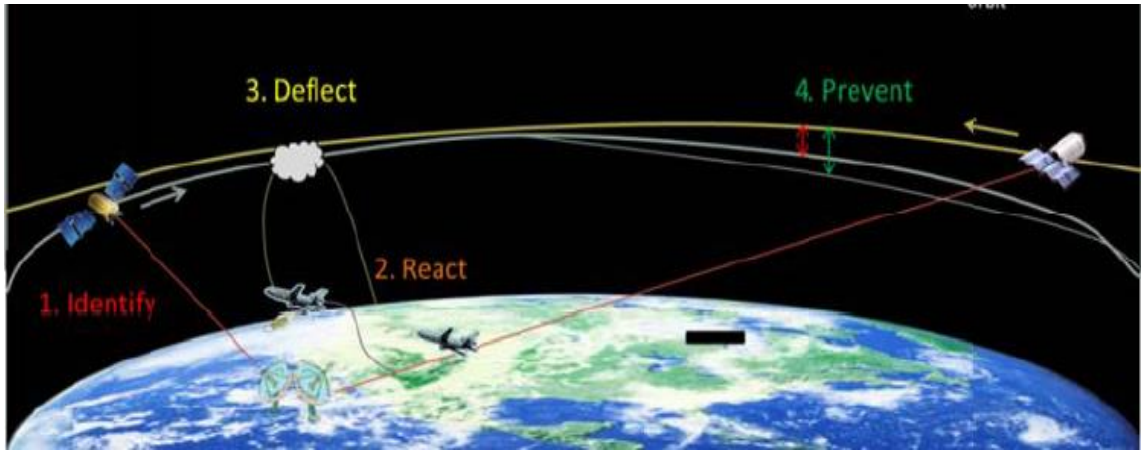

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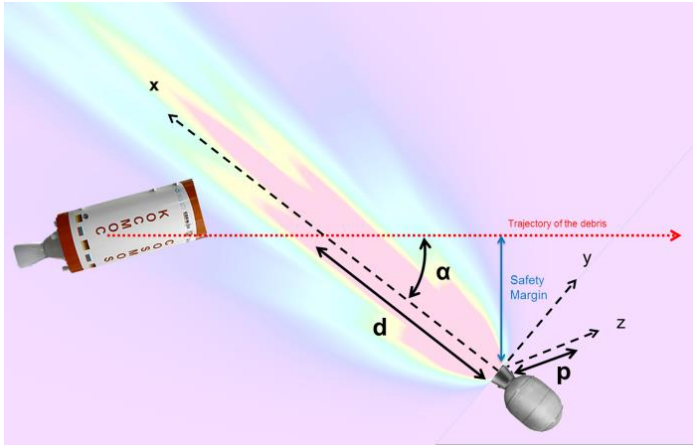

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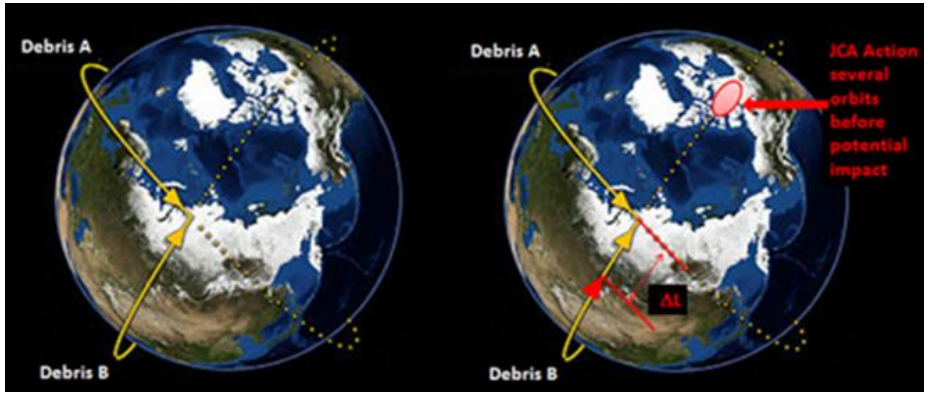
Open problem – JCA needs you!

An urgent problem, simple to express, needs a solution:

How to impart a $\Delta V \geq 5$ mm/s to a large derelict object?

- Enough to deflect trajectory by 1 km if applied 24 hours prior to collision
- No need for a good precision of ΔV in module nor direction
- Shall not generate potential problems to other space objects
- Shall be operational relatively rapidly
- Shall be affordable both in development and in operations
- Think out of the box: numerous domains of physics can be used…



Conclusion

Numerous points of concern:

Open problems calling for innovative activities in every domain

Thank you for your attention

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To know more:

IAA Situation Report on Space Debris – 2016

Downloadable from IAA website: http://iaaweb.org/content/view/487/655/