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Sustainability of Orbital Operations: status of Space Pollution and proposed actions

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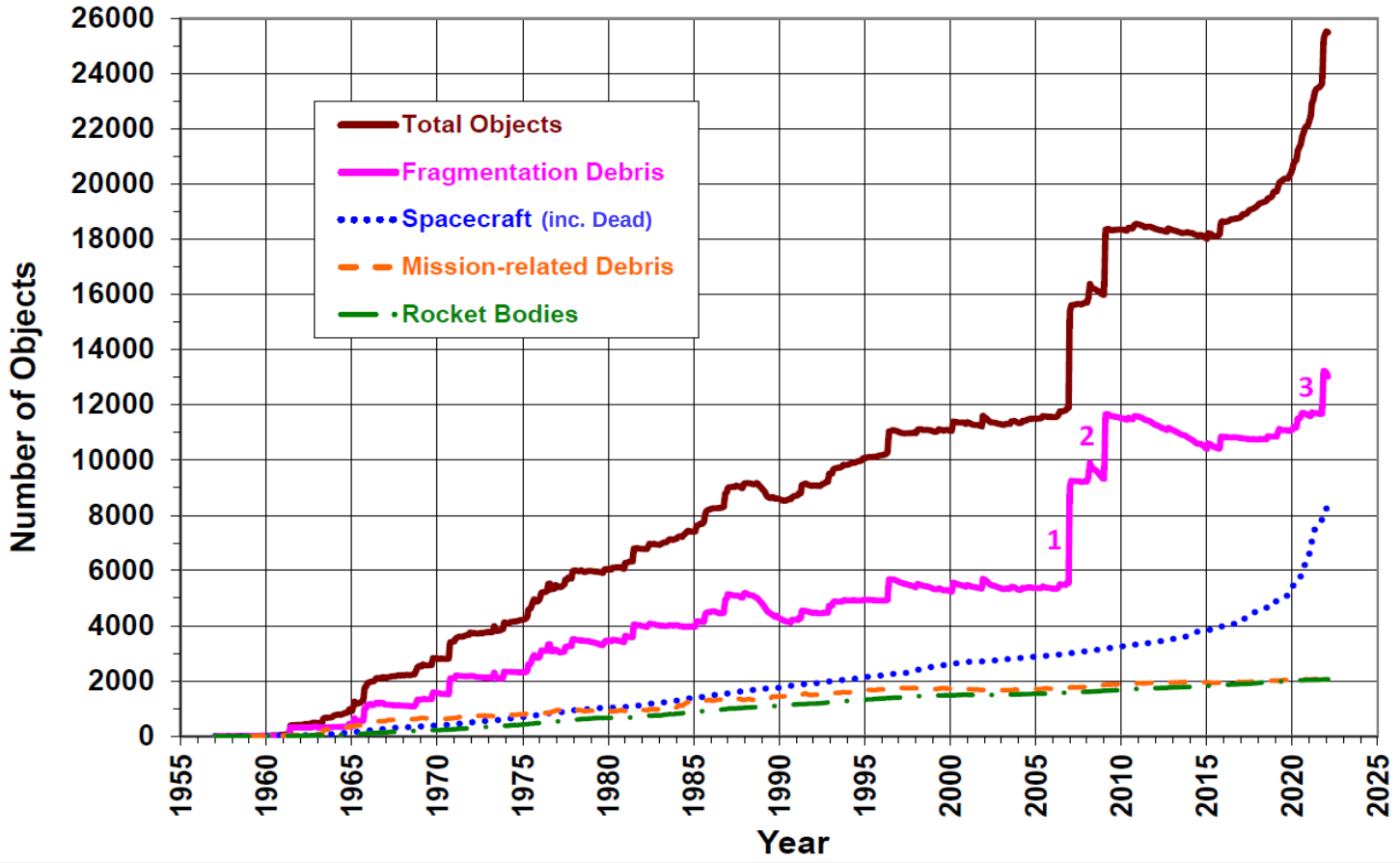
Content

- Current orbital population
- Kessler syndrome
- Critical LEO debris clusters
- Potential solutions
- Priorities
- Conclusions

Current orbital population

The number of cataloged objects has drastically increased these last years

- Number of debris has doubled in 15 years
- Number of active satellites: 999 on Jan. 4th, 2012 5,902 on June 30th, 2022



1 Feng Yun 1C ASAT
2 Iridium33 - K2251
3 K1804 ASAT

Current orbital population

Very scattered space objects sources

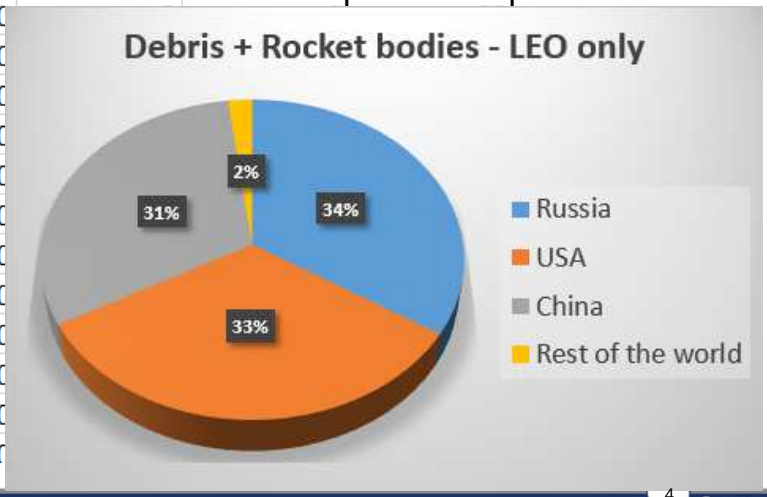
Beware: all satellites, including dead

↳ USA + Russia + China = 87% of orbital population. 95% of orbital debris. 97.5% of orbital debris in LEO

30.06.22	In Orbit				Decayed				Total
Country	Satellite	Rocket-Body	Debris	Total	Satellite	Rocket-Body	Debris	Total	per country
Total	8936	2290	14393	25619	3891	4047	19103	27041	52660
USA	4618	725	4479	9822	1447	736	4821	7004	16826
CIS (ex USSR)	1555	1048	5444	8047	2079	2895	11429	16403	24450
China	553	199	3741	4493	98	217	1264	1579	6072
France	82	166	353	601	11	82	667	760	1361
United Kingdom	480	1	0	481	15	0	5	20	501
Japan	205	62	47	314	72	69	275	416	730
India	108	40	73	221	13	25	448	486	707
ESA	96	7	52	155	12	7	22	41	196
Intelsat	91	0	1	92	1	0			
Globalstar	84	0	1	85	0	0			
Germany	86	0	1	87	17	0			
Canada	76	0	5	81	3	0			
Globalstar Orb	58	0	17	75	1	0			
SES	62	0	0	62	1	0			
Eutelsat	57	0	0	57	0	0			
Argentina	44	0	1	45	2	0			
Spain	42	0	0	42	4	0			
Italy	36	2	0	38	13	0			
Spain	32	0	0	32	3	0			
South Korea	26	1	0	27	5	0			

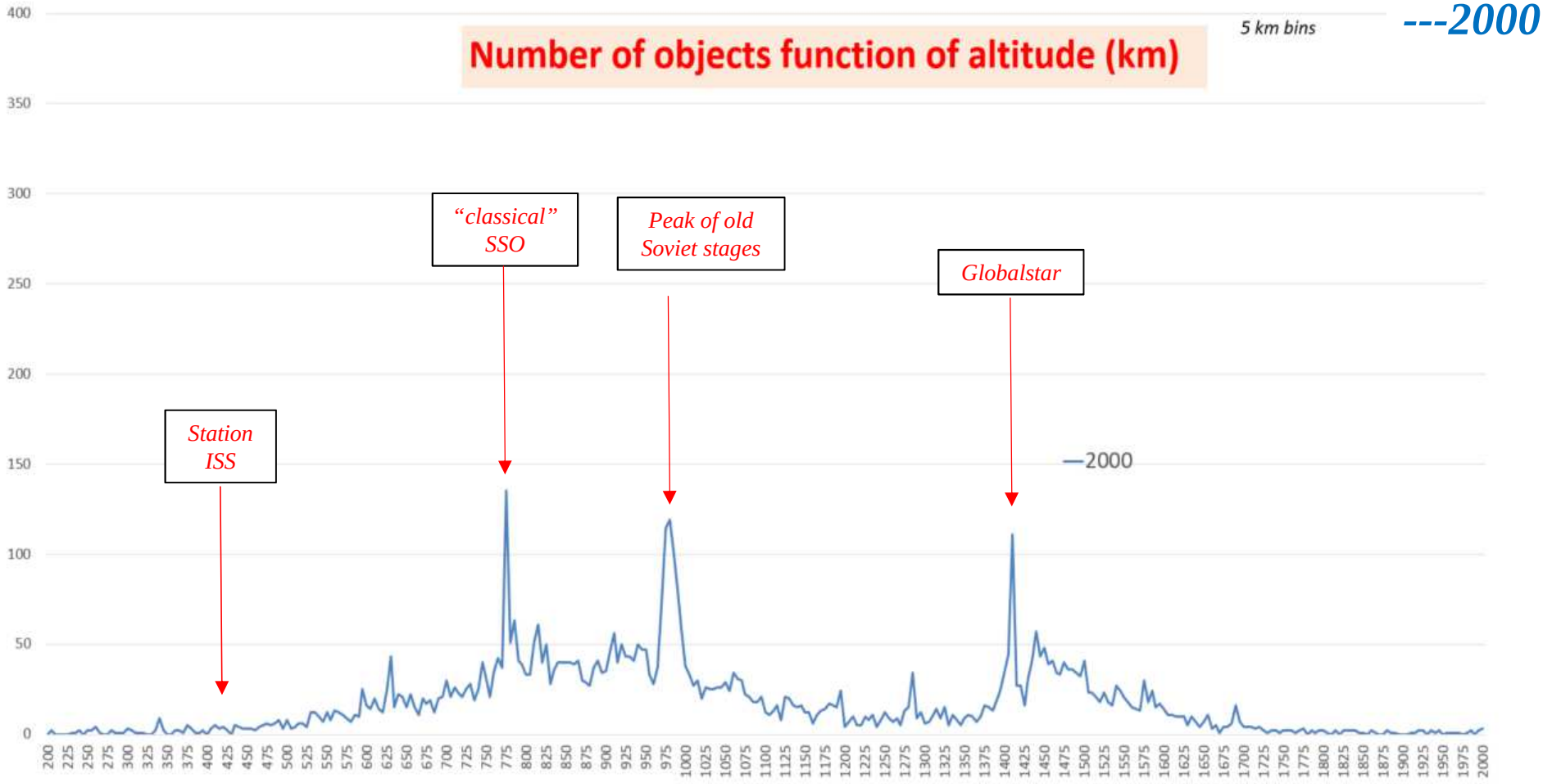
95%

87%



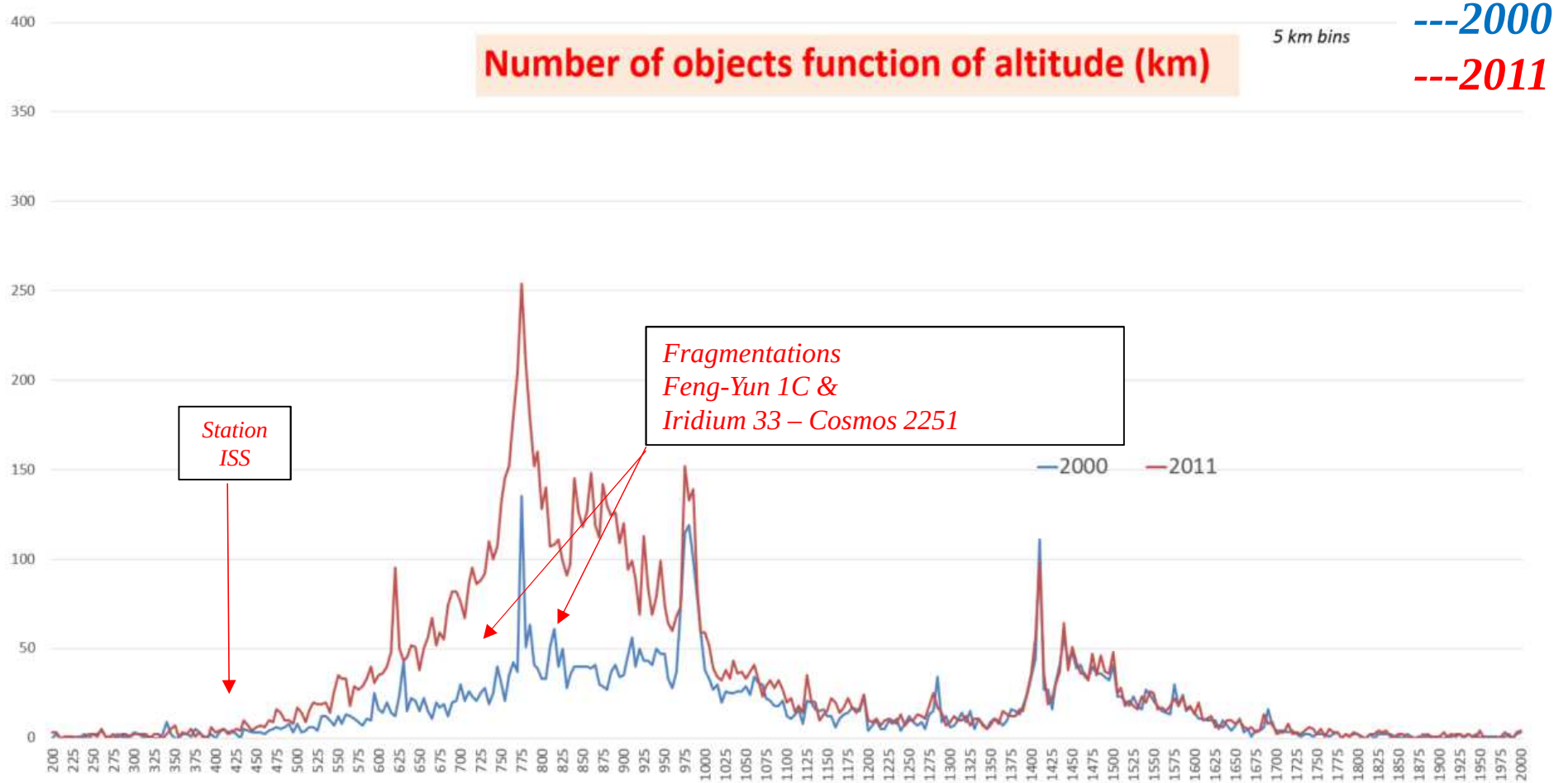
Current orbital population

2000



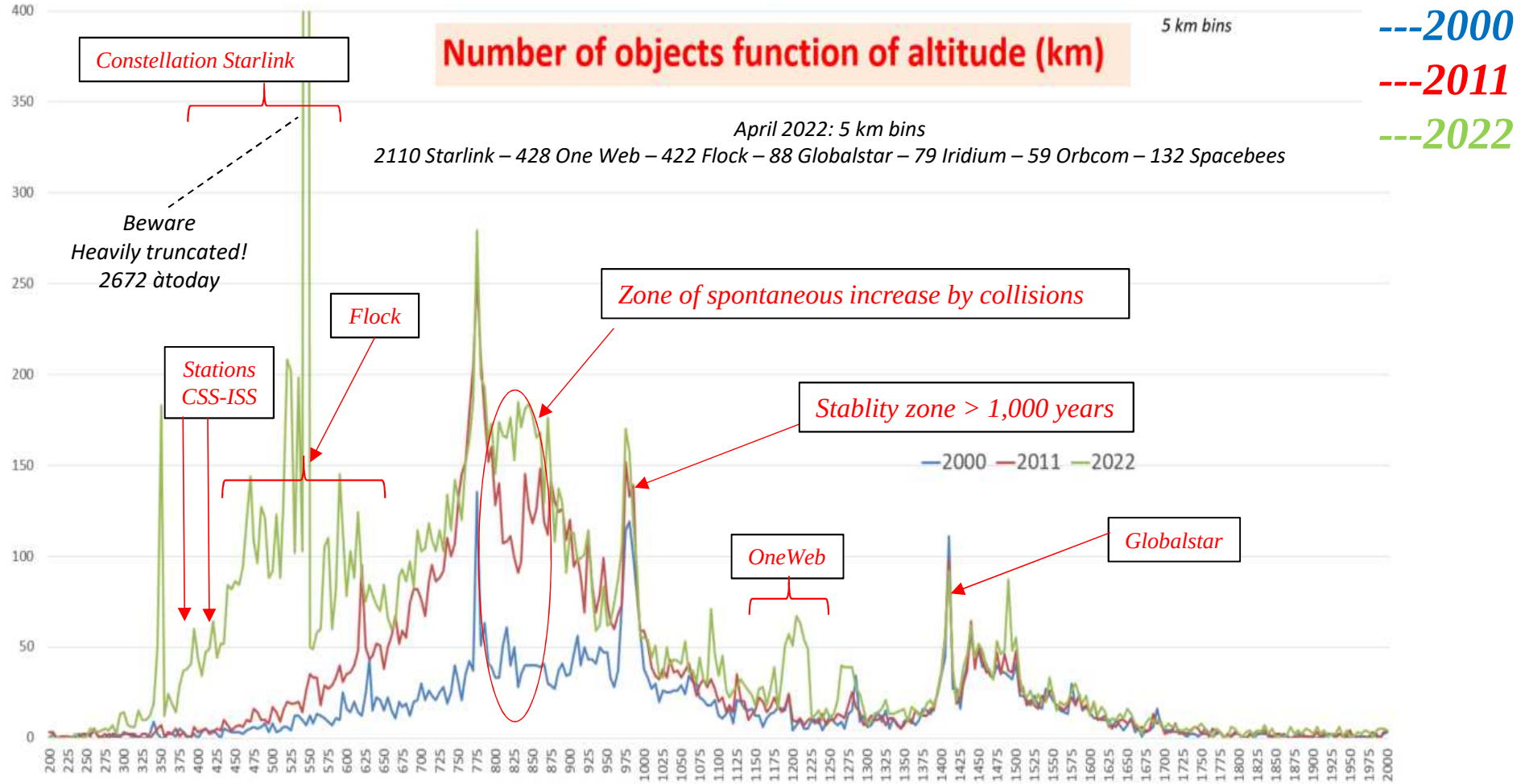
Current orbital population

2011



Current orbital population

2022

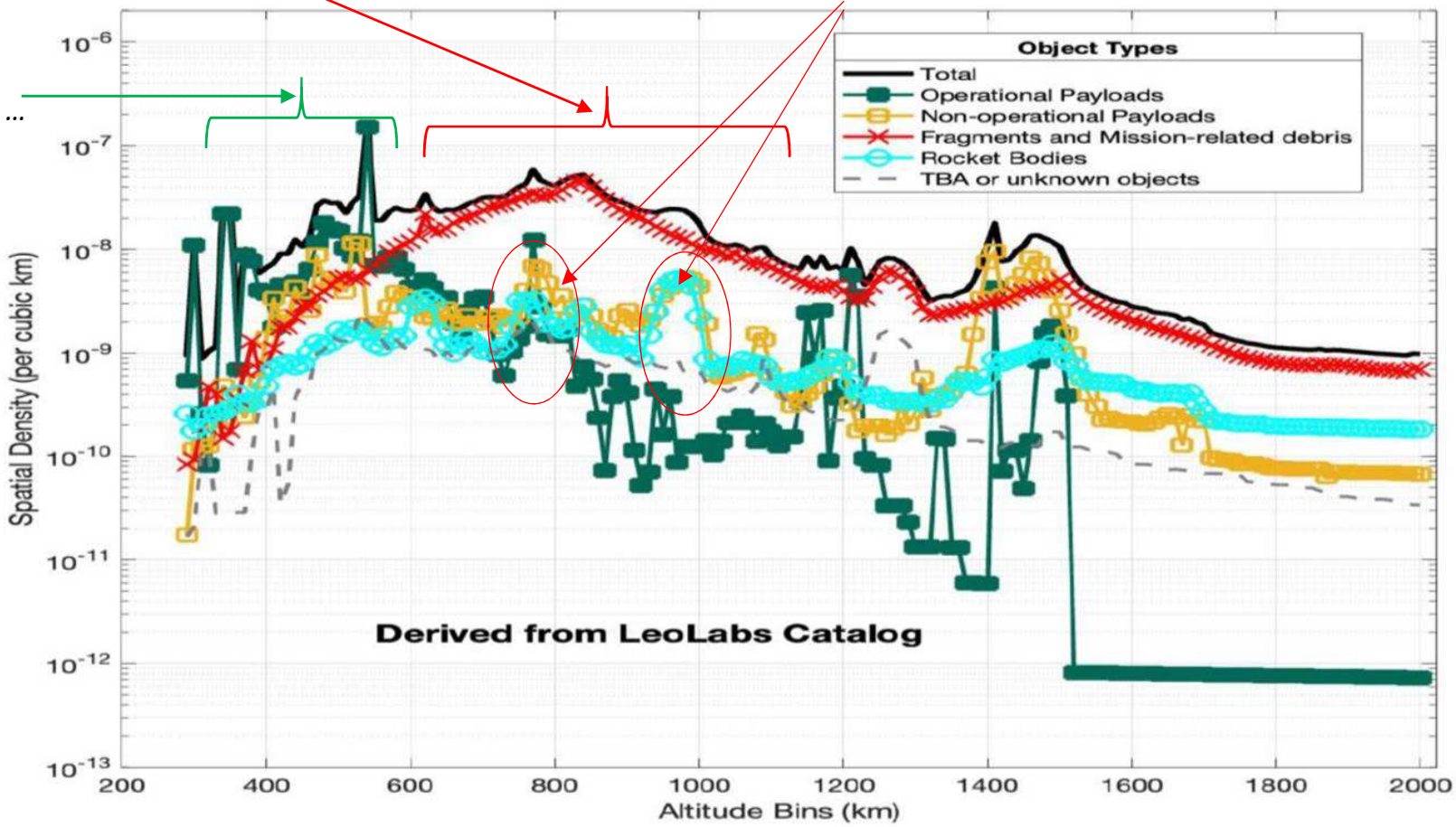


Current orbital population

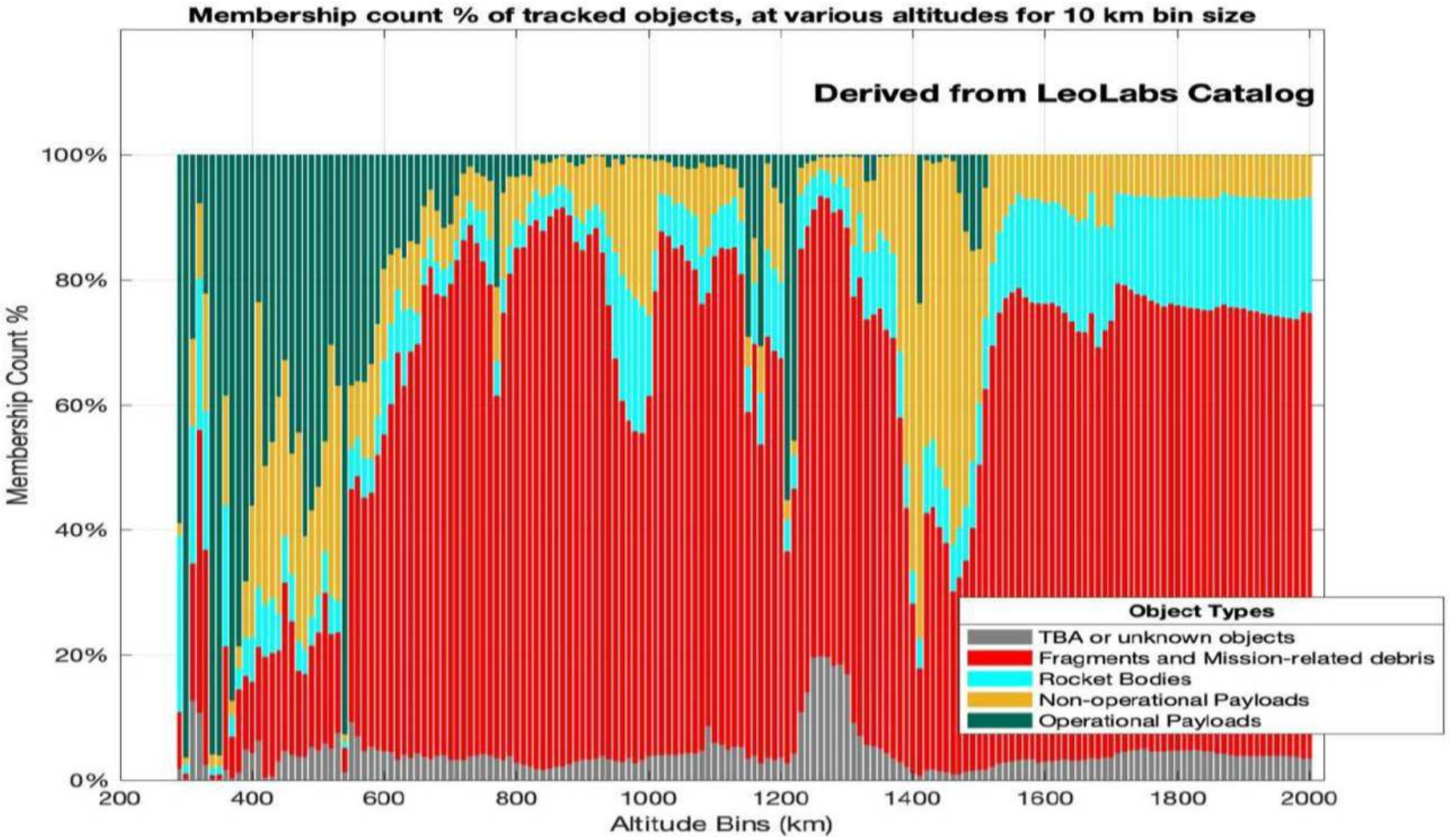
10-100-1,000 times more debris than active satellites

Critical clusters of large debris

Starlink, Planet, …



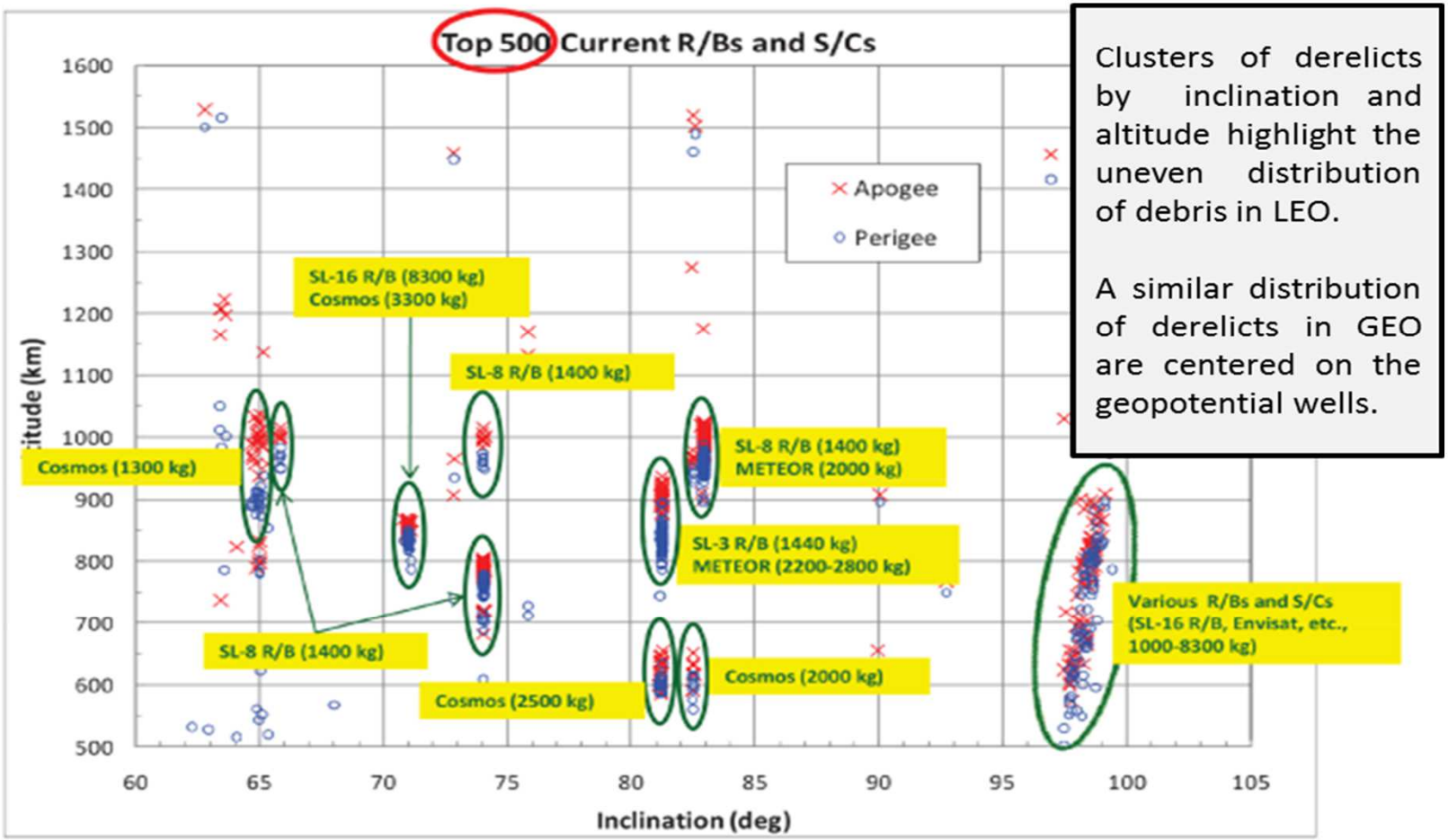
Current orbital population



Critical LEO debris clusters

Distribution of large debris in Low Earth Orbits

↳ Clusters in the Altitude-Inclination plane



Clusters of derelicts by inclination and altitude highlight the uneven distribution of debris in LEO.

A similar distribution of derelicts in GEO are centered on the geopotential wells.

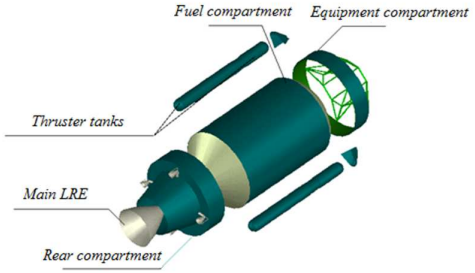
Critical LEO debris clusters

Some large clusters are particularly critical:

- 2 Zenit SL-16 second stages pass by less than 100 m from each other once per month
- 205 Cosmos-3M SL-8 upper stages en 3 Clusters
- According to our models, a front collision of two SL-16 would generate +18,000 new catalogued debris

Cluster	Cluster Member	Mass (kg)	Number	Apogee (km)	Perigee (km)	Inclination (deg)
C775	SL8 RB	1,434	44	793	733	74
	SL8 PL	850	44	802	742	74
C850	SL16 RB	8,300	18	860	814	71
	SL16 PL	3,250	18	868	823	71
C975	SL8 RB	1,434	144	1020	935	83
	SL8 PL	800	142	1024	934	83
	Other PL	1500	15	997	905	64
C1500	SL8 RB	1,434	17	1660	1330	74
	SL14 RB	1,407	24	1530	1363	83
	SL14 PL	2477	24	1507	1381	83
TOTAL		**~756k**	**490**			27

SL-16 Zenit Upper stage
Russian SpaceWeb Co.

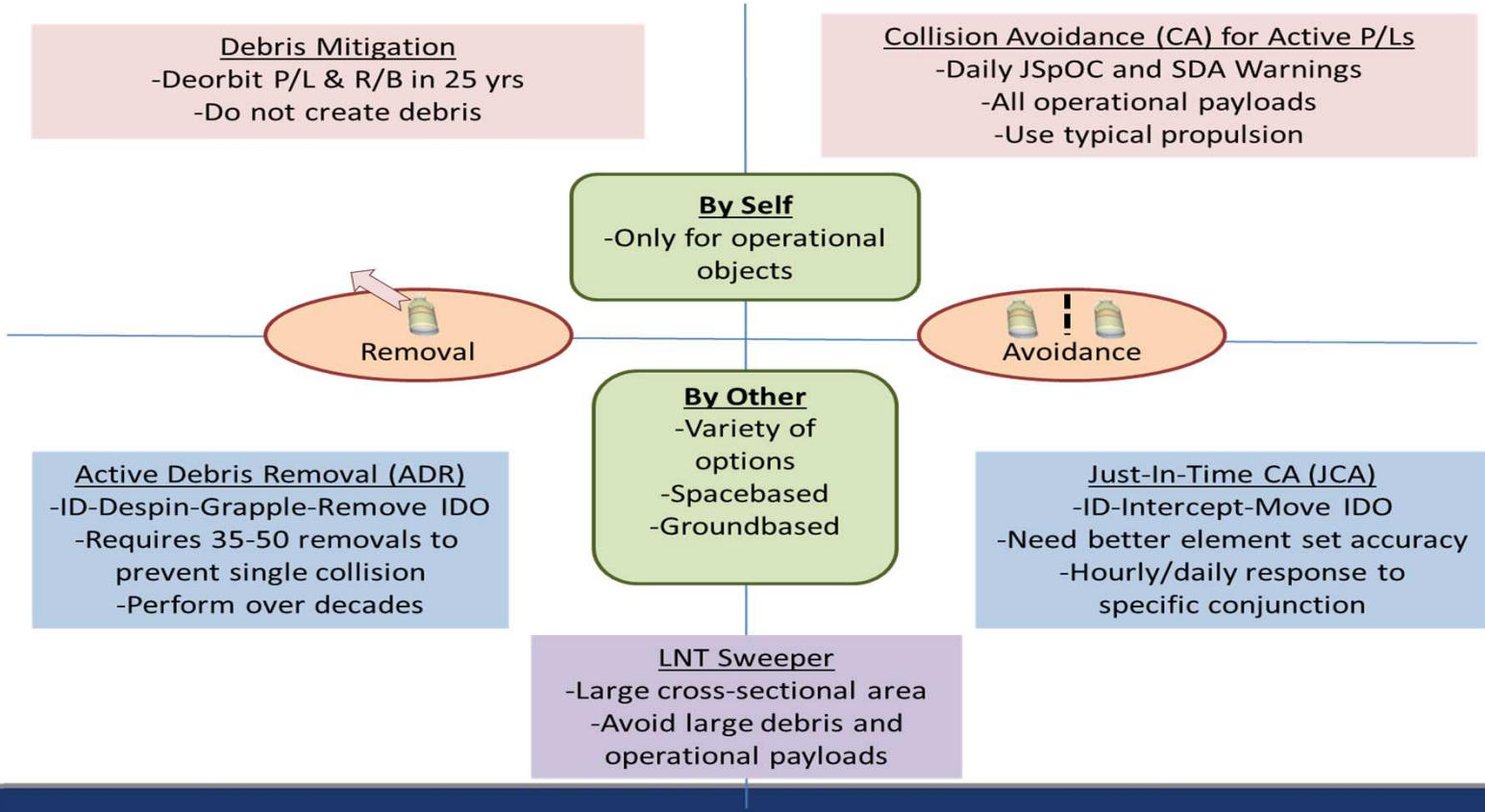


SL-8 Cosmos 3M Upper stage
V. Trushlyakov

Potential solutions

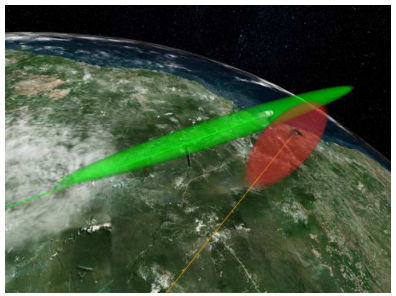
What can be done?

- Wait, simply applying current mitigation rules
- Avoid collision with maneuvering satellites
- Avoid collisions among large debris
- Retrieve most dangerous debris to avoid generation of smaller



Priorities

- **Wait, simply applying current mitigation rules** ⇨ Not sufficient. Not adapted to today – Diverging
  - Update the 25-year rule ⟶ 10, 5, 2, 1... ? Under discussion
  - Update the probability of success of Post Mission Disposal 90% ⟶ 95, 99%...? Under discussion
  - Check the effective application of rules



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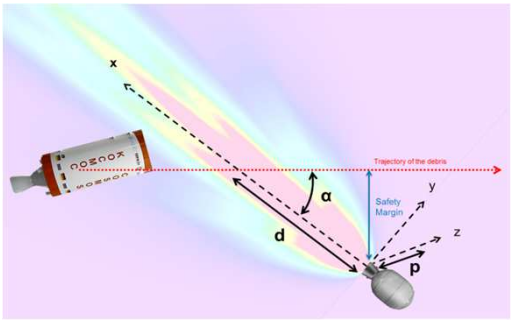
- **Avoid collision with maneuvering satellites** ⇨ Space Traffic Coordination – CNES COO, EU SST...
  - Fundamental, but not enough to ensure space operations sustainability

    ↳ 60+% of collisions are between non-maneuvering objects



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- **Avoid collisions among large debris** ⇨ « Just-in-time Collision Avoidance » JCA = Tactical
  - Theoretical solutions exist, but no Market, so hard to finance
  - Numerous associated problems, legal, insurance, dual use...

- **Retrieve most dangerous debris to avoid generation of smaller** ⇨ « Active Debris Removal » = Strategical
  - No major technical problem, but complex
  - Problem of financing: no credible business plan, except synergy with In-Orbit Servicing

© MDA

↳ **It is easy not to do anything**

Priorities

- **Deal with today's situation**
  - Consolidation of the international set of rules
    - **① It is necessary to share the current rules at international level**
    - **② It is fundamental to consolidate our actions at international level ECSS, IADC, ISO, COPUOS, IAA, IAF, IAASS**
  - Specificities of New-Space. A very high reactivity is mandatory
    - **③ It is fundamental to improve our the currents rules to cope with current situation**

- **Attenuate the effects of yesterday**
  - Kessler syndrome between 700 and 1,100 km altitude mainly linked to operations from the 70-90's
  - Necessity to go and retrieve the largest and most dangerous debris [1]
  - No serious action today, anywhere, at worldwide level
    - **④ It is fundamental to start at soon as possible Active Debris Removal operations**

- **Prepare tomorrow**
  - Establish all the new rues aimed at guaranteeing sustainability of space operations, despite large constellations
  - Drastic improvement of the collision avoidance process
    - **⑤ It is fundamental to coordinate at international level to share the same rules**
  - Improvement of the knowledge of orbital environment
    - **⑥ It is fundamental to improve detectability threshold and accuracy of orbital parameters**
  - Preserve the in-habitable zone
    - **⑦ It is fundamental to define a preserved zone for the inhabited space operations**

[1] *Identifying the 50 statistically-most-concerning derelict objects in LEO - Acta Astronautica 181 (2021) 282–291*

Conclusions

Several worries…

- **Low level of compliance to international rules** [1]
  - Globally 64% of LEO missions are compliant
    - But 17% of satellites higher than 600 km only
    - And 6% of large satellites (> 100kg) at > 600 km only!
  - Still numerous in-orbit fragmentations (1 per month in average)

© Spaceflight


© Starlink

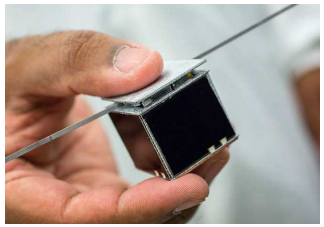
- **Very large number of Cubesats, or smaller**
  - 2,040 to date – 1,256 operational – 326 in 2021 – 500+ per year expected
  - No propulsion on board – no collision avoidance capacity
  - Hard to track – Reliability often low
  - Very frequently non compliant with the 25-year rule

© Planet

© One Web


36 Spacecraft per Launch

- **Large constellations of satellites**
  - Thousands of satellites expected in the coming years (New space: 100,000 by 2030 ?!)
  - Potentially critical even if they comply to rules
  - Continuous maneuvers in orbit
  - Reliability?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If there is a general, quick, worldwide awareness, followed by actions, everything will be fine...

[1] *IADC – WG2 – ESA & CNES*

Thank you for your attention

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