D-ORBIT

NEW SPACE SOLUTIONS

LARGE CONSTELLATIONS END-OF-LIFE ISSUES AND POTENTIAL SOLUTIONS

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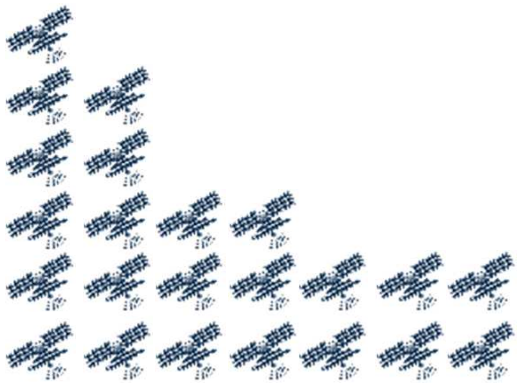
LARGE CONSTELLATIONS: OPPORTUNITY OR THREAT

Projected Commercial Constellations of smallsats

- ExactEarth → up to 15 sats
- OrbComm → 54 sats
- GlobalStar → 96 sats
- Skybox Imaging → up to 180 sats
- OneWeb → up to 900+ sats
- SpaceX / Google → up to 4000 sats
- …



CubeSat Phenomenon

2005 - 2014

393 sats < 50kg

227 sats > 50 kg

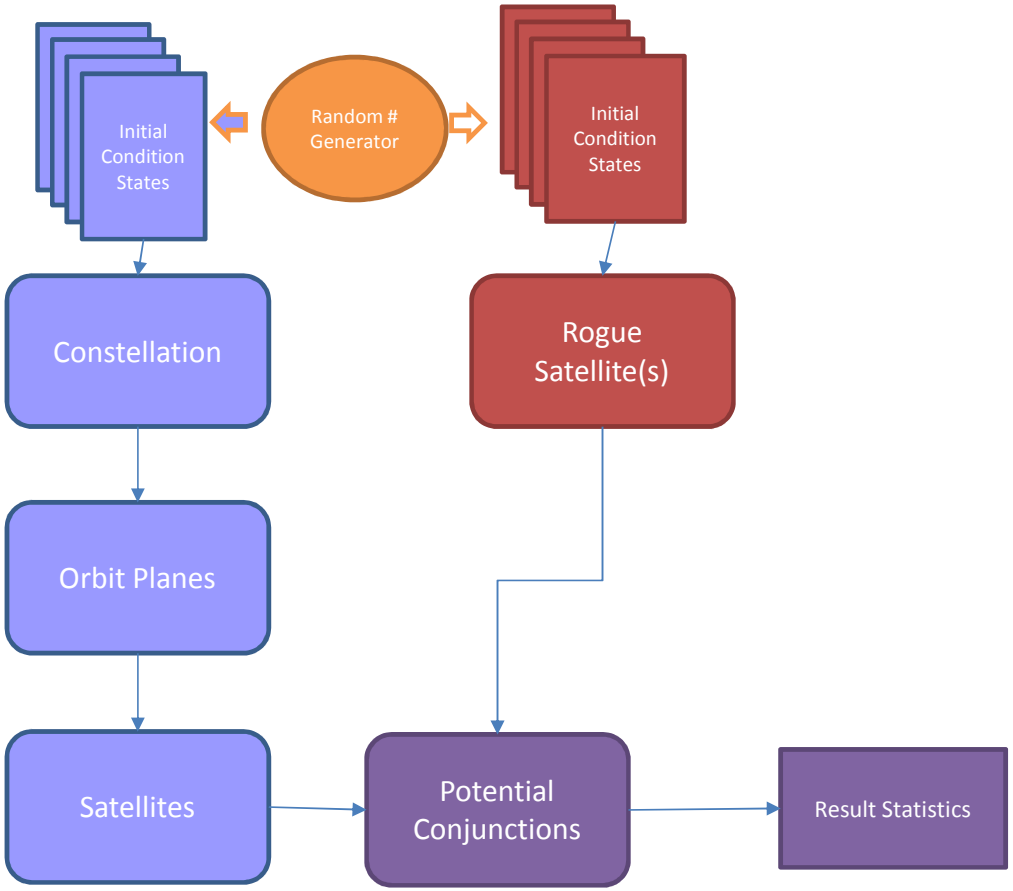
- **Planetlab: 100 nanosats per year**
- **Spire: 50 nanosats per year**

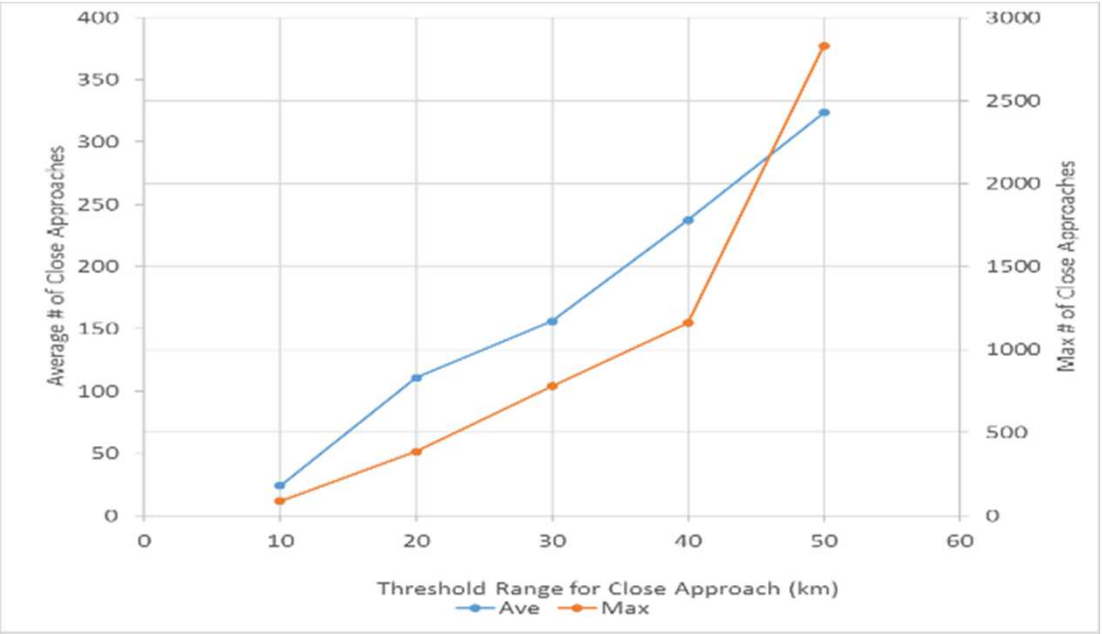
Sources: Euroconsult, the Web

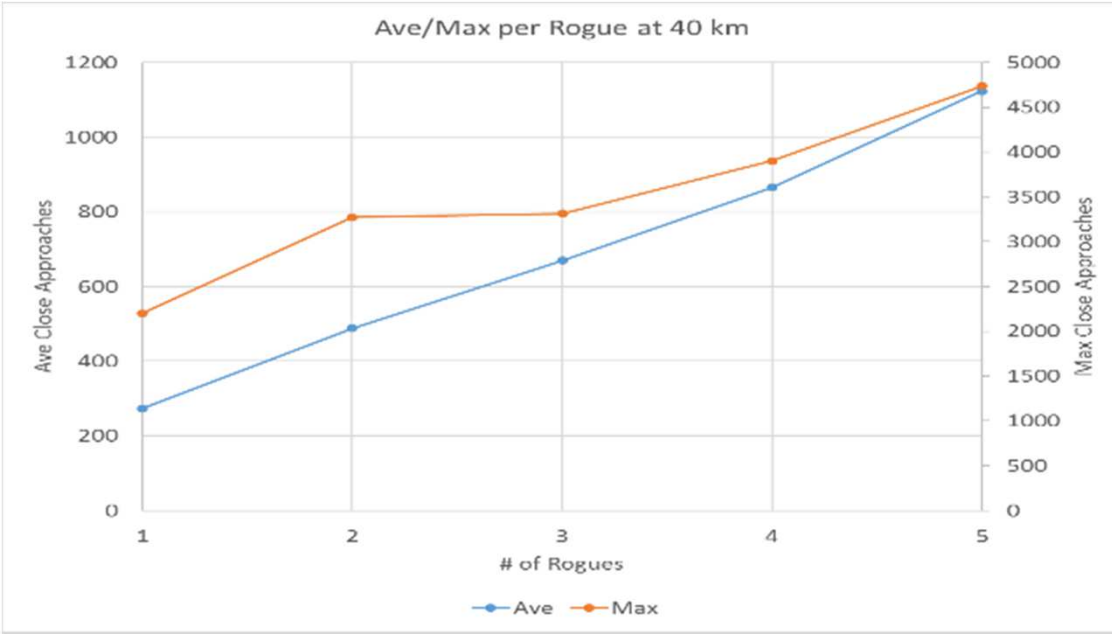
POTENTIAL CONJUNCTIONS WITHIN THE CONSTELLATION

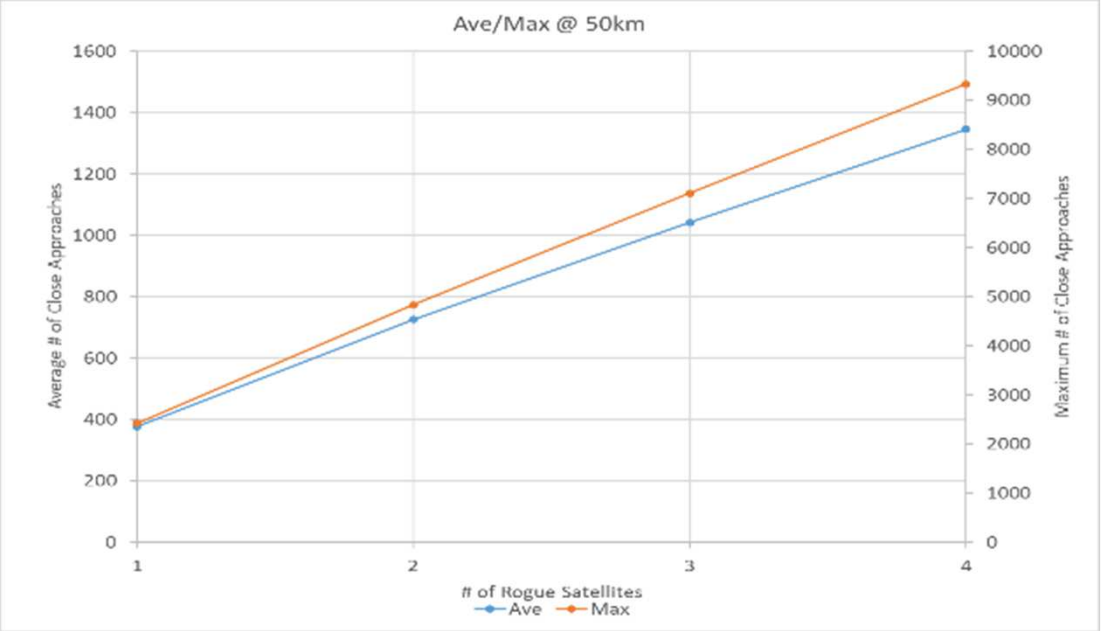
Failed satellites threatens alive satellites

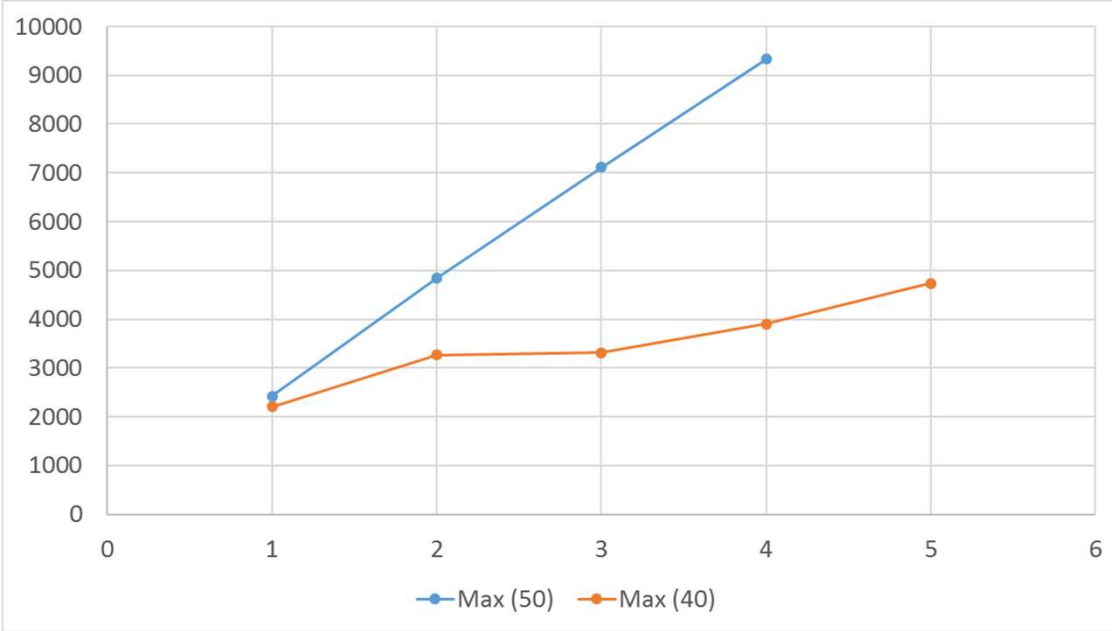
- Use Orekit Astrodynamic library and Java to write an analysis simulation to model the nominal constellation and one or more uncontrolled/drifting satellites.
- Use Monte Carlo variation to model the drifted state of the rogue satellites.
- Compute the # of close approaches between rogue satellites and operational satellites and collect statistics.



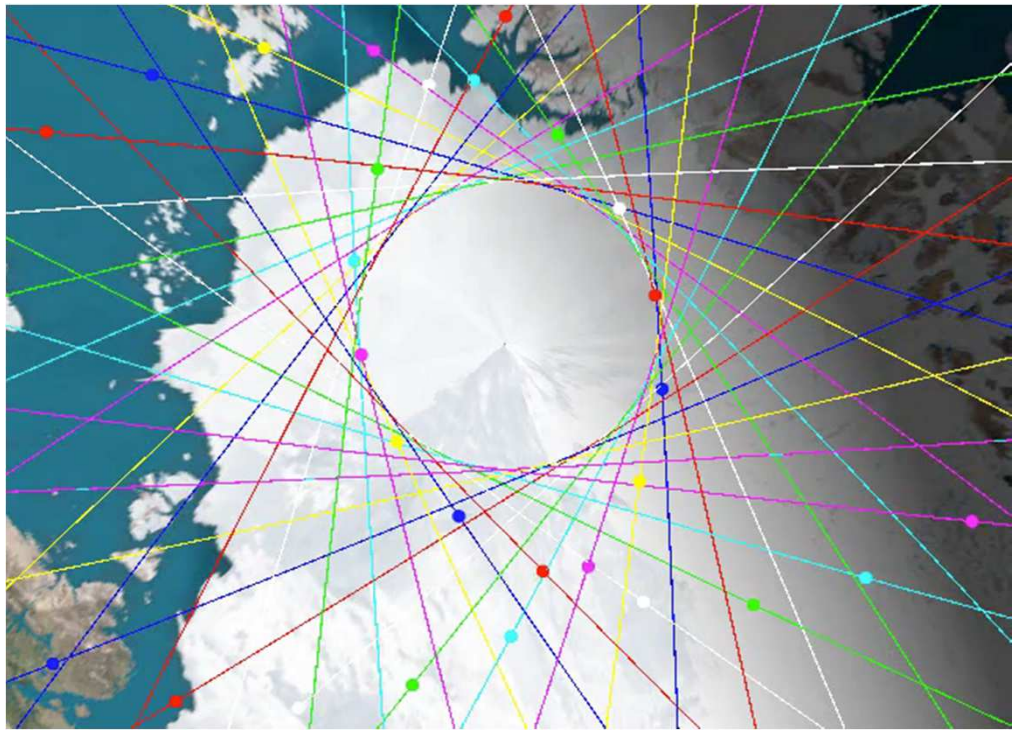

Average # of Close Approaches
Max # of Close Approaches
Threshold Range for Close Approach (km)
Ave
Max


Ave/Max per Rogue at 40 km
Ave Close Approaches
Max Close Approaches
# of Rogues
Ave
Max

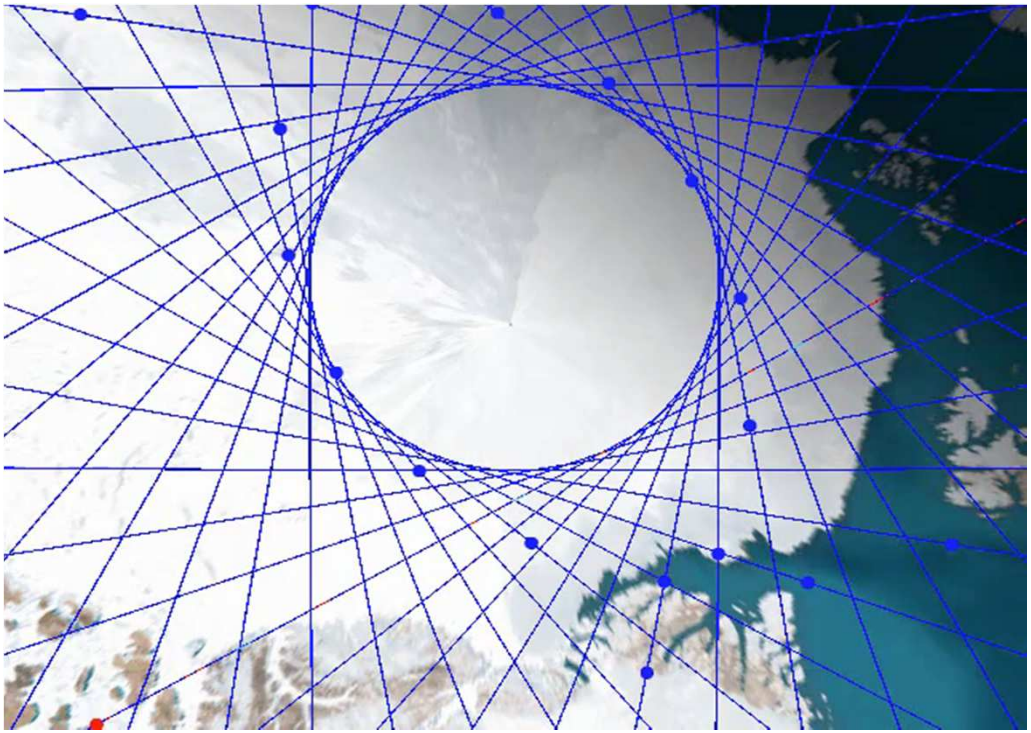

Ave/Max @ 50km
Average # of Close Approaches
Maximum # of Close Approaches
# of Rogue Satellites
Ave
Max


Max (50)
Max (40)

ALL PLANES (AND SATELLITES) CROSS AT THE POLES



IDEAL CASE: all the satellite are controlled and functional



STUDY CASE 3: 3 defunct satellites in the constellation drifting

SUMMARY OF RESULTS

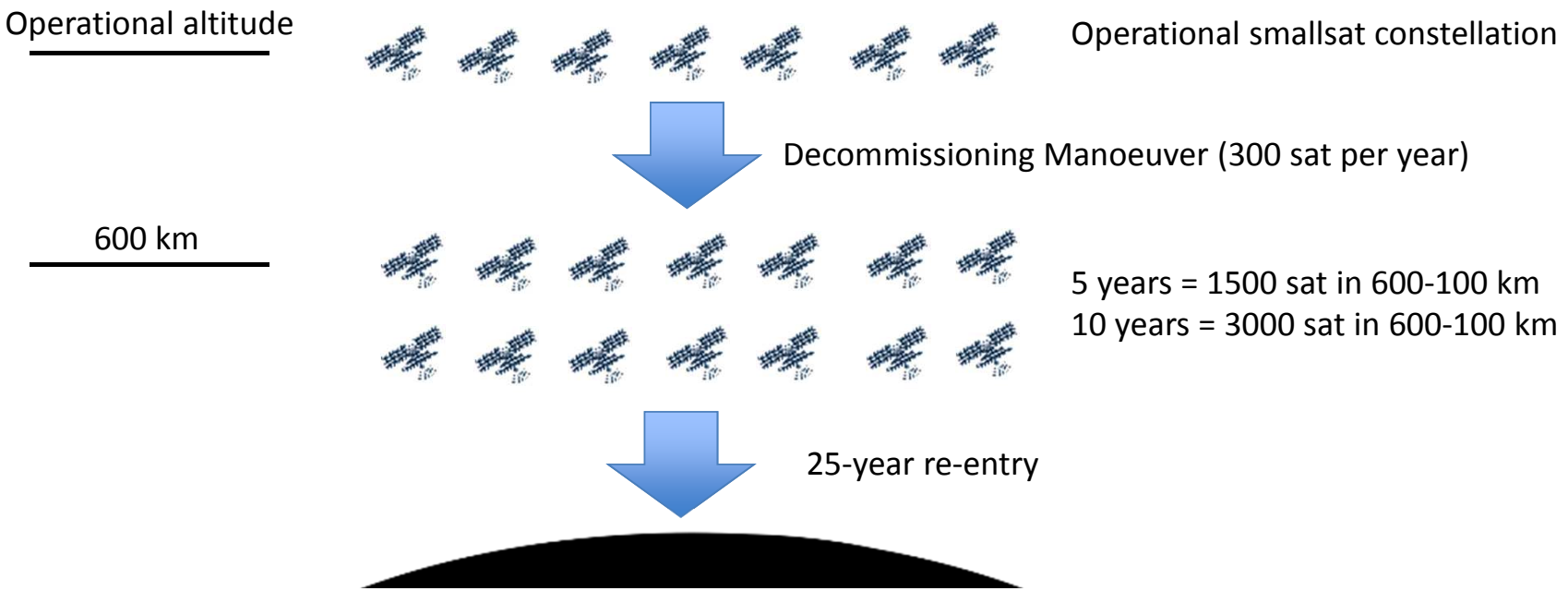
- More than 100 Close Approaches (CA) of less than 1 km occur for each defunct satellite in 90 days and the number will grow with increasing time
- Even with careful management of the constellation, up to 10 % of the satellites will not be successfully deorbited.
- The CAs occur at or near the poles and involve intersections between planes
- Even though it could be measured the position of a satellite to an accuracy of a few meters with careful post processing of collected data, the accuracy for predicted position is much less (SOCRATES predicted a CA of 584 m for Iridium 33 and Cosmos 2251 on Feb 10, 2009: they collided at the predicted time of CA).
- Any time a CA of 1 km or less is predicted, very careful measurements must be performed to evaluate the requirement and plan for a maneuver of the operational satellite. This may be hours or days in advance of the CA.
- At 7.25 km/s, the CA occur in an intersection time of ~0.0001 s.

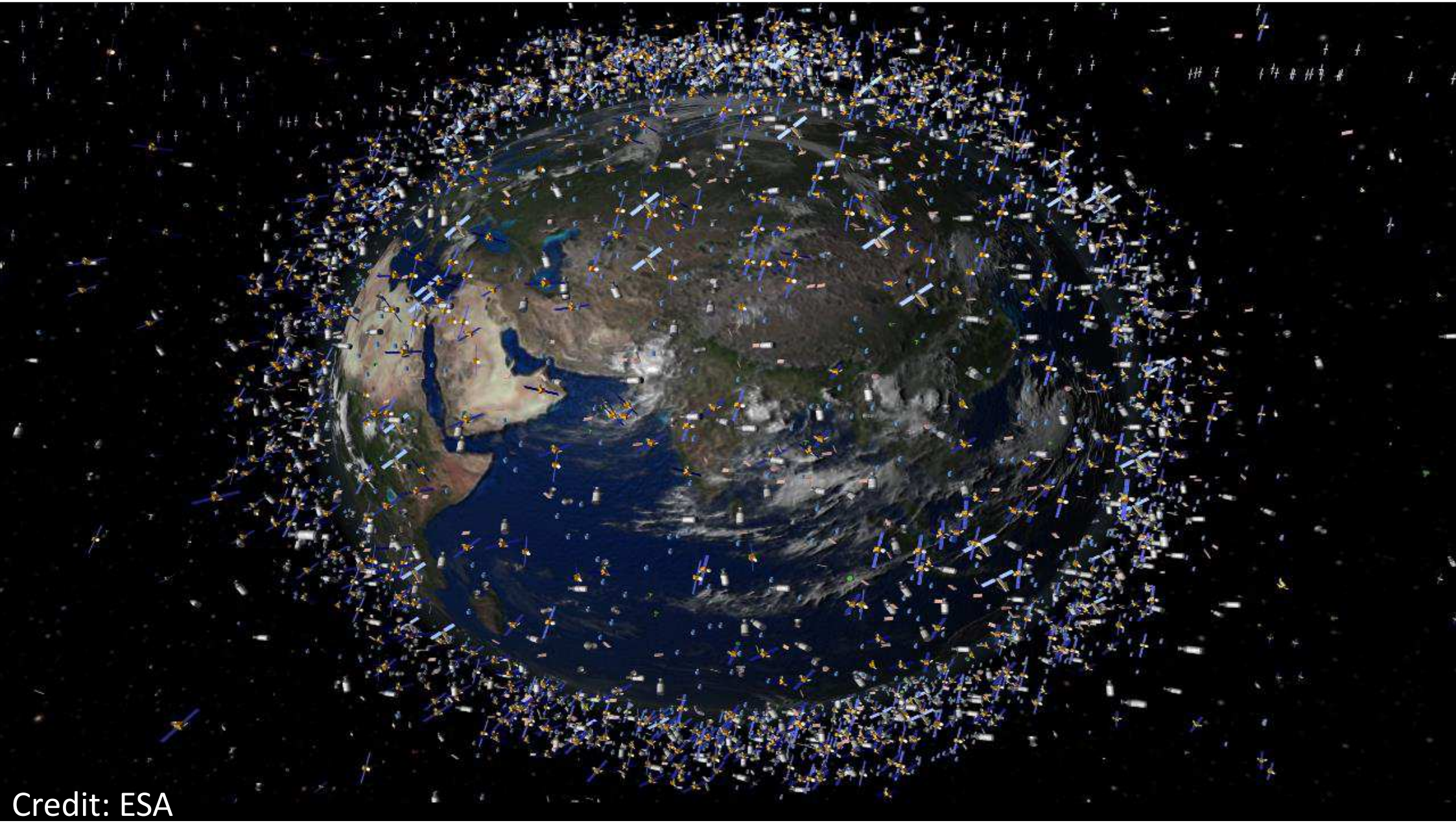
Decommissioning or orbit clearance at end-of-life is required

Constellation Uncontrolled Re-Entry Issues

Example Scenario:

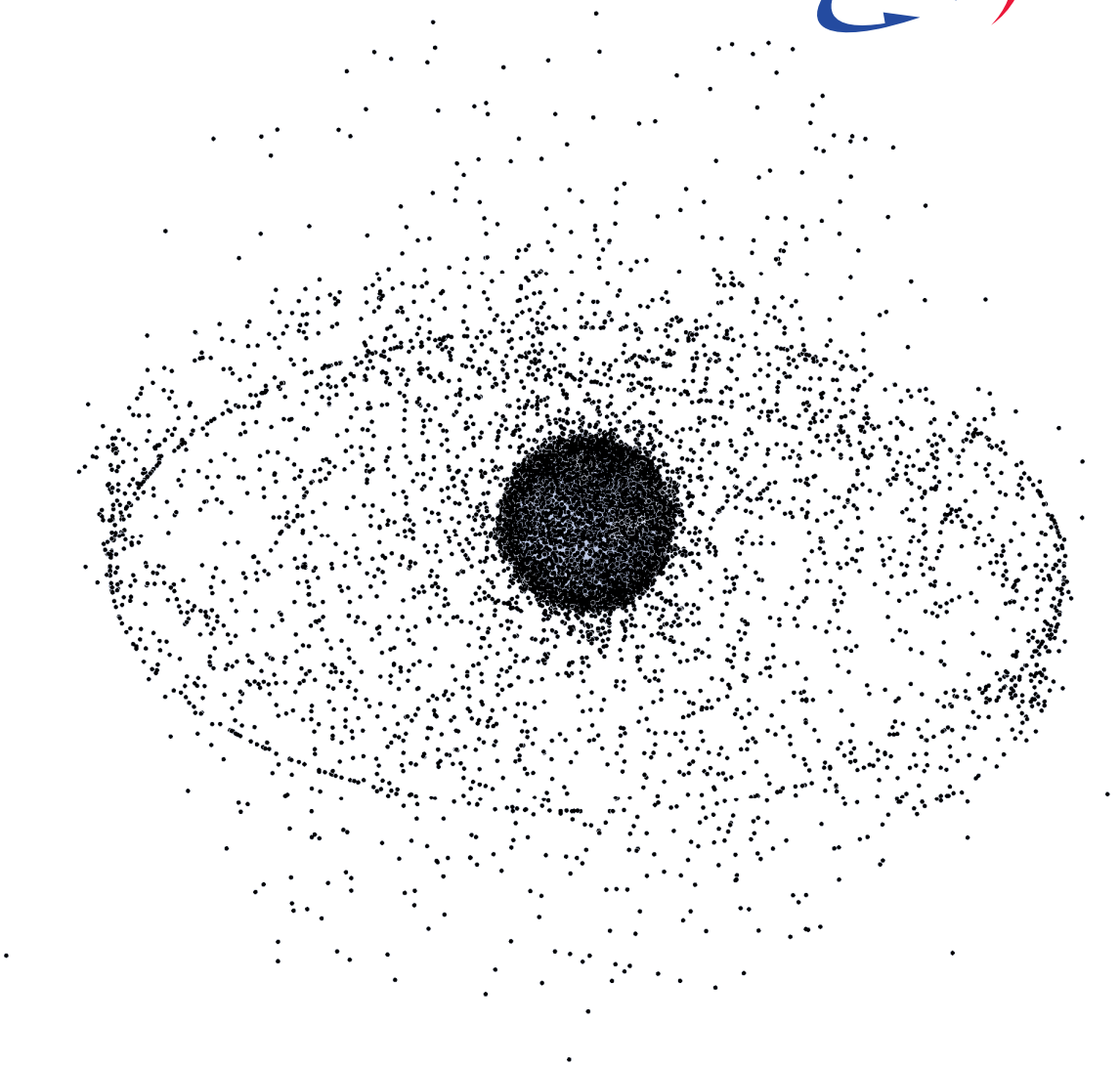
LEO Smallsat constellation ➔ 650 satellites
Launch capability ➔ 300 sats per year
Operational life ➔ 5 years
Decommissioning Strategy ➔ business-as-usual 25-year re-entry




Credit: ESA

IMPACT ON COMMERCIAL USE OF SPACE

- **FUEL** lost does not generates revenues
- **END-OF-LIFE** is costly
- **DEAD SATELLITES** threaten the business
- **LARGE CONSTELLATIONS** looking for solutions
- **REGULATIONS** worldwide force satellite decommissioning



SATS CATEGORIES and EOL SOLUTIONS

	PASSIVATION			EOL MANOEUVRE						CASUALTY RISK
	Pw & El	**Venting**	**N/A**	**Tethers**	**Inflatable**	**Sails**	**El. Prop.**	**Solid Prop.**	**Liquid Prop.**	**$<10^{-4}$**
Cubesats	YES	NO	Direct R-E	Yes if < 25y	Yes if < 25y	Yes if < 25y	Yes if < 25y	YES (LOS)	N/A	Inherently compliant
Mini-/Small Sats no propulsion	YES	NO	Direct R-E	Yes if < 25y	Yes if < 25y	Yes if < 25y	Yes if < 25y	YES (LOS)	N/A	If > 10^{-4} design for demise or controlled R-E
Mini-/Small Sats with propulsion	YES	YES	Direct R-E	Yes if < 25y	Yes if < 25y	Yes if < 25y	Yes if < 25y	YES (LOS)	YES (LOS)	If > 10^{-4} design for demise or controlled R-E
Medium Sats	YES	YES	Direct R-E	Yes if < 25y	Yes if < 25y	Yes if < 25y	Yes if < 25y	YES (LOS)	YES (LOS)	If > 10^{-4} design for demise or controlled R-E
Large Sats	NO	NO	Direct R-E	NO	NO	NO	NO	YES	YES	Inherently compliant
MEO/GEO Sats	YES	YES	Never	NO	NO	NO	YES	YES	YES	N/A

LOS: French "Loi des Operations Spatiales"

NEWSPACE OPERATORS: MONEY BETTER THAN RISK

WHAT DO THEY CARE MOST:

- Lifetime of their satellites, especially cubesats
- Reduce the time to operation after deployment in orbit
- Decommissioning is a plus, and only if cheap

NEWSPACE OPERATORS: MONEY BETTER THAN RISK

WHAT WE ARE MISSING:

- Adoption of effective end-of-life strategy at EOL
- EXAMPLE from institutional programs:

  STOP WAIVERS!

OUR SOLUTIONS

ORBIT CLEARANCE
small satellite constellations

Application: Decommissioning of constellation platforms with mass in the realm of 150 Kg at 1200km

Configurations	Emergency – full configuration
D3 Mass	5 kg
Power consumption during host satellite operations	10 W during BIT
Power consumption (decommissioning phase)	35 W Independent from host satellite
Power Interface	24/28 V or custom
Data Interface	MIL-STD-1553 / CAN / SpaceWire or custom
Specific Impulse	273 s
Temperature Range	-20 / +50 degC

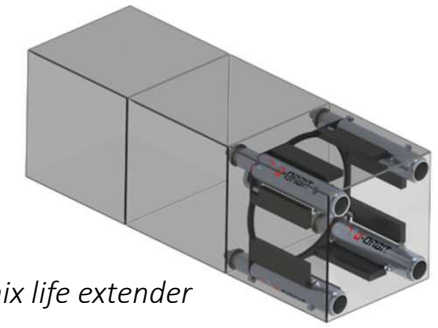
Fail-Safe Architecture

- Single-point-of-failure free both for reliability and safety
- Critical software B-class
- Safety Standard MIL-STD-1576

NEWSPACE MARKET PRODUCTS:
CUBESATS AND LIFE-ENHANCING SYSTEMS

FENIX Life extension system for cubesat:

- Up to 60% more lifetime for nanosatellites
- Reduce by 90% the time to operation after deployment in orbit
- Fast collision avoidance or disposal capabilities
- Only 4% of the volume allocation

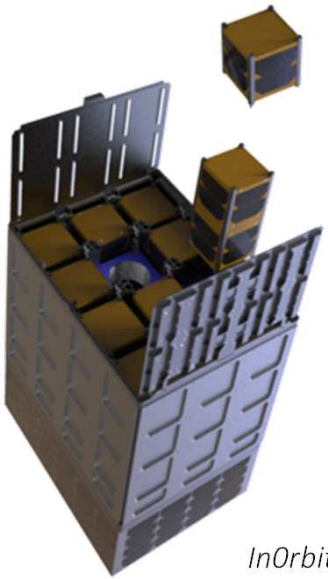


Fenix life extender

BEFORE ADR: V.I.P. SERVICES FOR SMALL SATELLITE

In0rbit One smallsats deployer platform:

- Self-decommissioning platform
- Precise and low cost delivery of a single satellite into orbit
- **Shortest zero-to-operations time**
- Prevent early failure



In0rbit One

CONCLUSION

- Not removing a defunct satellite could hamper the future exploitation of very strategic orbits
- In **LARGE CONSTELLATIONS** a defunct satellite drift toward the other satellites, forcing them to use fuel for collision avoidance manoeuvers
- **LARGE CONSTELLATIONS** require decommissioning strategy
- **REGULATIONS** are changing: more and more concern on small sats

BETTER SPACE BUSINESS

WHILE PREVENTING MAJOR CRITICAL EVENTS IN SPACE?

POSSIBLE TODAY.

D-ORBIT

NEW SPACE SOLUTIONS

www.d-orbit.space

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Certified B Corporation

ISO 9100 and ISO 9001 CERTIFIED
CMMI LV3 in progress

Future cost of the “25-year” rule

Because of the 25-year rule, in the coming year:

- Monitoring effort and costs will increase;
- Number of collision avoidance manœuvres will increase, together with related costs in terms of fuel consumption and and service down-time.
- Risk to create a cloud of re-entering satellites, jeopardizing future launches and space operations.
- Increasing collission probability, together with insurance costs and other indirect costs (e.g. political costs).

FOR HOW LONG THE 25-YEAR RULE WILL STILL BE APPLICABLE?