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Latest Developments on Space Debris Modelling Activities at CNES

○Juan-Carlos Dolado-Perez (CNES)

The space debris modelling and risk assessment office of CNES is in charge, on the flight dynamics domain, of the activities linked with the analysis, the modelling, the development of tools and the R&D activities related to Space Surveillance and Tracking, space debris and the French Space Operations Act. The activities developed within the CNES space debris modelling and risk assessment office, are therefore structured around key technical domains, as the active and passive detection of space objects from ground or from space, the correlation and cataloguing of the objects orbiting the Earth, the short and long term propagation of the space objects, the computation of on-orbit collision risk in case of close approaches or on-ground casualty risk in the event of a re-entry as well as the evaluation of the long term evolution of the orbital environment.

The work that will be presented will be focused on this very last key technical activity, this is the long term evolution of the orbital environment. The presentation will provide a focus of the most recent work done by CNES on this topic, as the analysis evaluating the decoupled effect of the background and of the future space activity on the long term evolution of the orbital population. A focus will be also given to the last CNES efforts to develop a space object criticality index allowing to identify the missions posing the biggest threat to the orbital environment. Finally, these latest developments will be presented on the perspective of a new framework being developed by CNES with the aim to have a global view of the state of the orbital environment at every moment.

Biography

Juan-Carlos Dolado-Perez

Juan-Carlos Dolado-Perez is the head of the space debris modelling and risk assessment office at the “Centre National d’Etudes Spatiales” (French Space Agency). Since 2008 he has worked at the system engineering and orbital dynamics sub directorate, where his main research topics concerns the long and middle term re-entry prediction, the long term evolution of the space debris population, the on orbit collision risk assessment, the orbit determination from radar and optical measurements and the uncertainty characterization and propagation.
He is a member of the Inter Agencies Space Debris Committee (IADC)’s French Delegation and of the International Academic of Astronautics (IAA). Juan-Carlos owns a B.S. in Aerospace Engineering from the Madrid’s Polytechnic University and a MSc. in Aerospace Engineering from the Institut Supérieur de l’Aéronautique et de l’Espace (ISAE).

LATEST DEVELOPMENTS ON SPACE DEBRIS MODELLING ACTIVITIES AT CNES

9TH JAXA SPACE DEBRIS WORKSHOP

24th to 26th February 2021
Virtual

Juan Carlos Dolado Perez.

Head of the Space Debris Modelling and Risk Assessment Office

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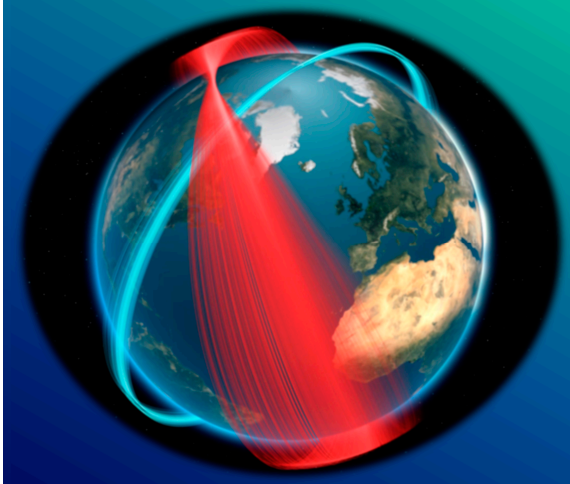
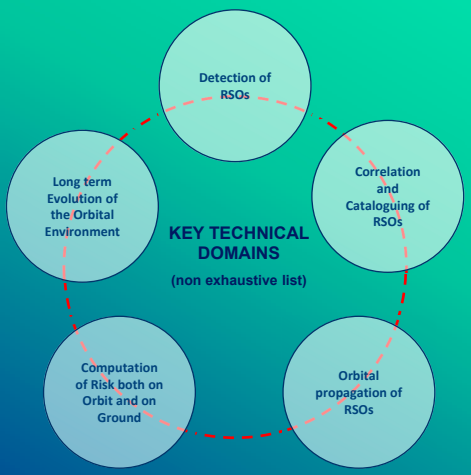
INTRODUCTION





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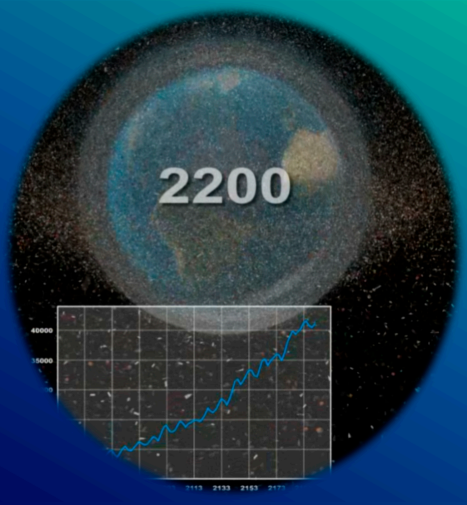
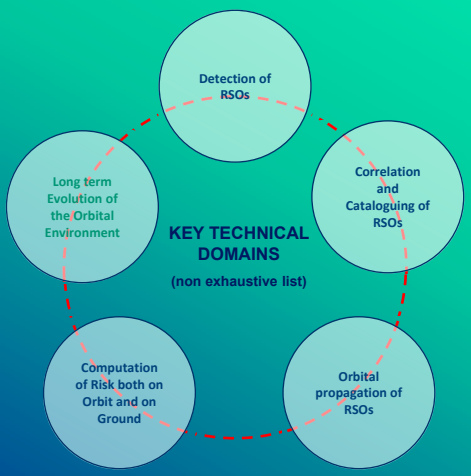
INTRODUCTION





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2 LONG TERM EVOLUTION OF THE ORBITAL ENVIRONMENT

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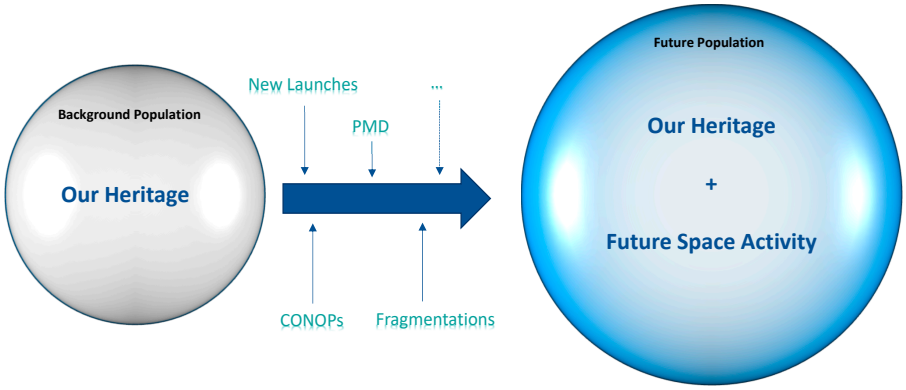
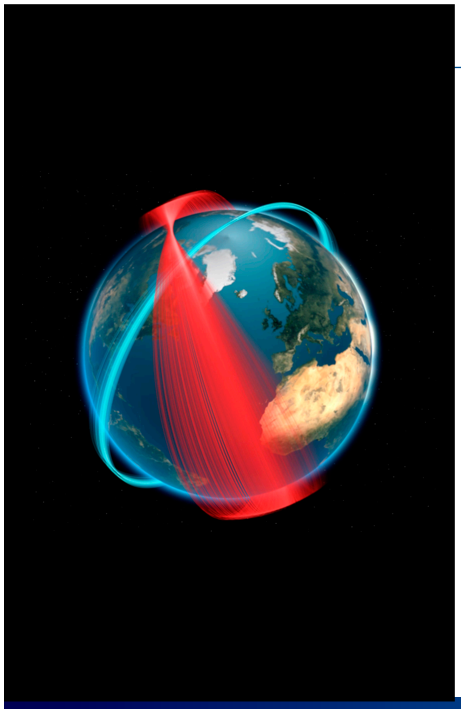
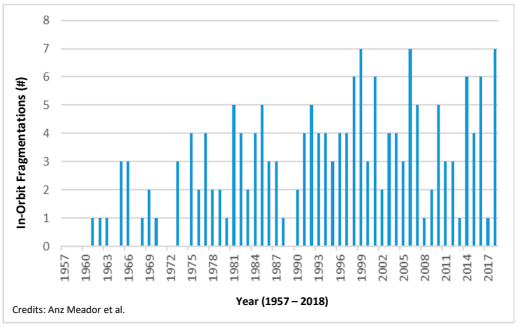
Future Population

What's more important, our Heritage or How do we use space?





Our Heritage

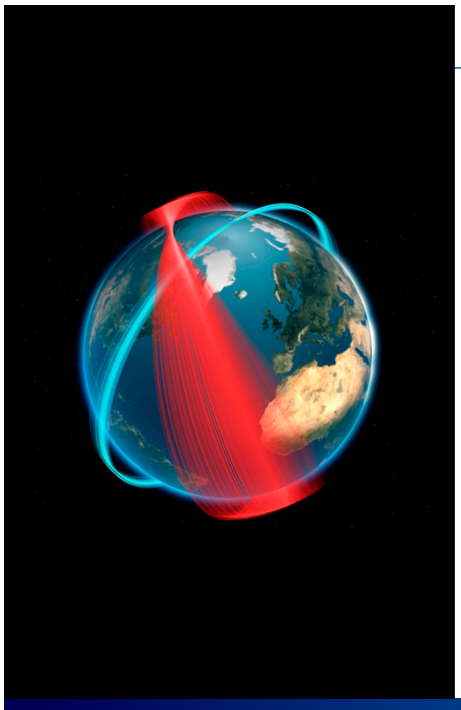


More than 5000 Launches since 1957

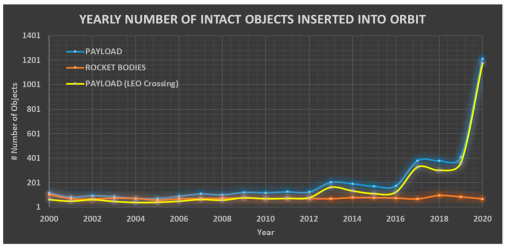
First orbital fragmentation in 1961

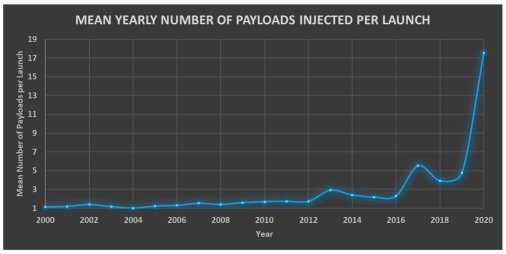
Fragmentation occurs regularly since

Non-deliberated Fragmentations is the main source of debris generation since 1957



How do we use Space → New Space is Old





Radical Change on the way the Space is used (missions, actors, …)

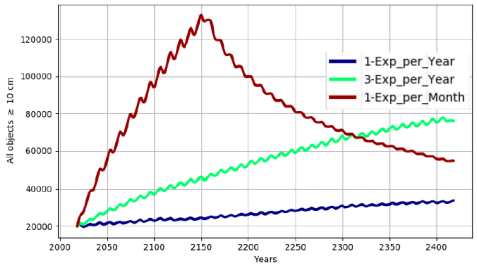
3 OUR HERITAGE

HOW IT IMPACT US?

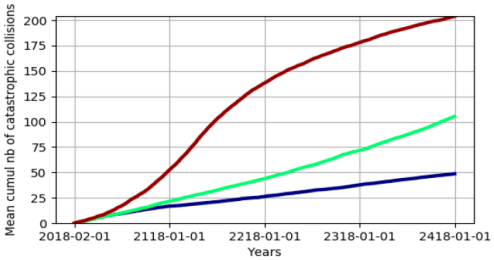
OUR HERITAGE

How our heritage Impact us?

Effective LEO population (>10cm) as a function of the explosion rate



Number of Catastrophic collisions as a function of the explosion rate



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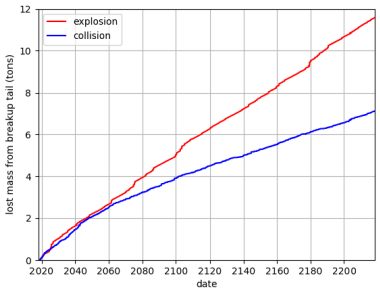
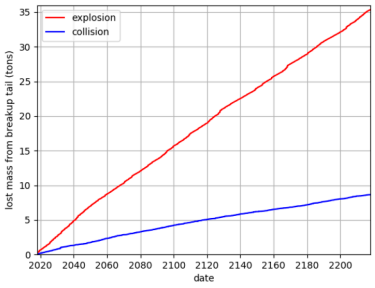
OUR HERITAGE

How our heritage Impact us?

Mass Lost “Effect” induced by minimal size threshold (>10cm) for 1 explosion / year



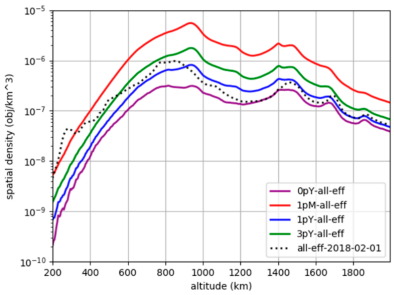
Mass Lost “Effect” induced by minimal size threshold (>10cm) for 3 explosion / year



Need to consider smaller objects (>1cm), to evaluate long term population trends

OUR HERITAGE

How our heritage Impact us?



Mean Spatial Density Increase for LEO population (>1cm) after 100 years of simulation

- In the **absence of new explosions**, the spatial density decreases at all altitudes regimes
- In the event of **1 Exp/year**, spatial density increases above 900 Km and decreases below due to drag
- In the event of **3 Exp/year**, spatial density increases above ~500 Km and decreases below (**x 2 - x3 increase at 900 Km**)
- In the event of **1 Exp/Month**, spatial density increases above 300 Km (**x 8 – x 9 increase at 900 Km**)

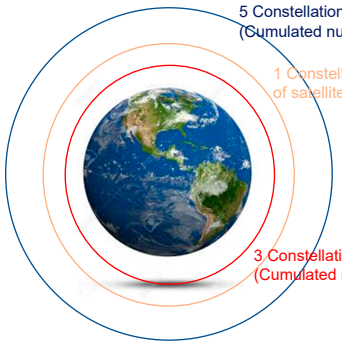
Need to consider smaller objects (>1cm), to evaluate long term population trends

4 FUTURE POPULATION

WHAT IF WE COULD BENEFIT FROM A “FRESH” START?

FUTURE POPULATION

What if we could benefit from a « fresh » start (i.e. no past space activity) ?



“2012 type Space Activity”
(Launch cycles representatives of past activity, non including small satellites launches) with linear increase (50% increase after 50 years)

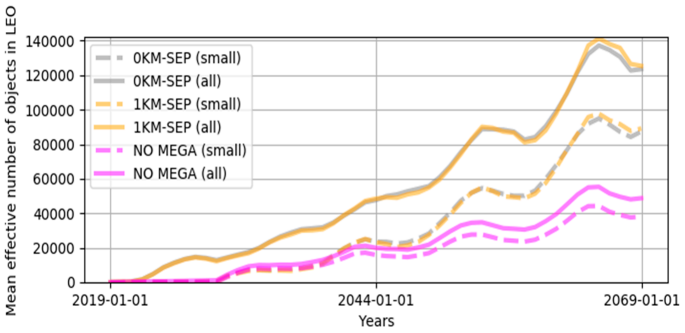
90% Post Mission Disposal Success Rate (25 years Rule)

100% CAM Success Rate during Operational Lifetime

1 / 1000 probability of unintentional Fragmentation

FUTURE POPULATION

What if we could benefit from a « fresh » start (i.e. no past space activity) ?



All scenarios result in a very important increase of the population, most of all due to small satellites and constellations

5

FUTURE POPULATION

HAVE ALL THE OBJECTS THE SAME POTENTIAL TO CHANGE THE ORBITAL ENVIRONMENT?

FUTURE POPULATION

Need to Evaluate the Criticality of Space Objects to the Environment

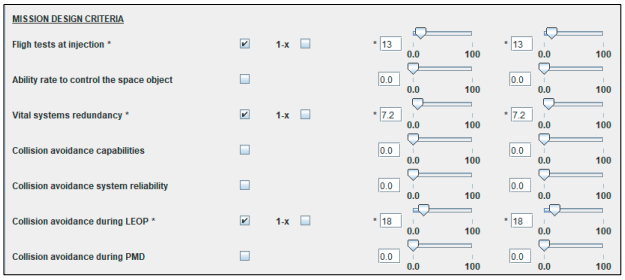
The criticality of Space Objects to the environment, shall be used

- **On the certification process**
- **To decide about the premature End of Mission of a given Space Object**
- **To prioritize remediation operations**

Environmental Indexes have been developed for years at International level

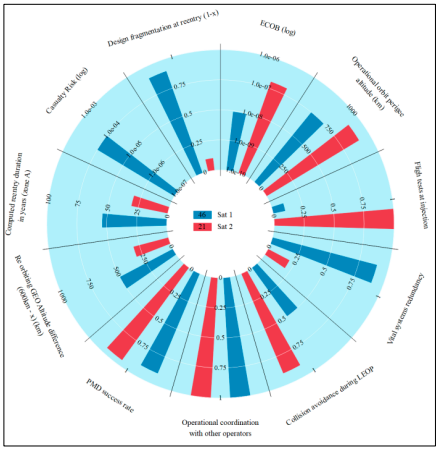
Different Indexes for different purposes (e.g. regulatory, footprint of mission on the environment, ,,,)

The Capability of an object to generate debris in the event of a fragmentation, may be just an « ingredient » of the Indexes



Example of CNES Environmental Index Evaluation Tool – INDIGENE (**Regulatory purposes**)

Qualitative Output Example



SUSTAINABLE SPACE & REGULATION

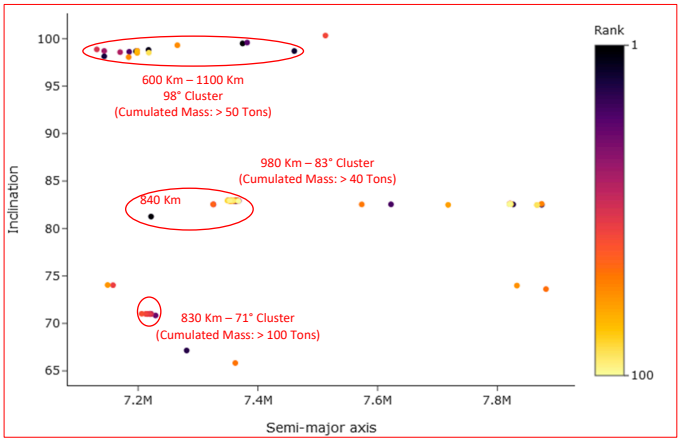
Need to Evaluate the Criticality of Space Objects to the Environment

All the objects do not represent the same risk to the Environment

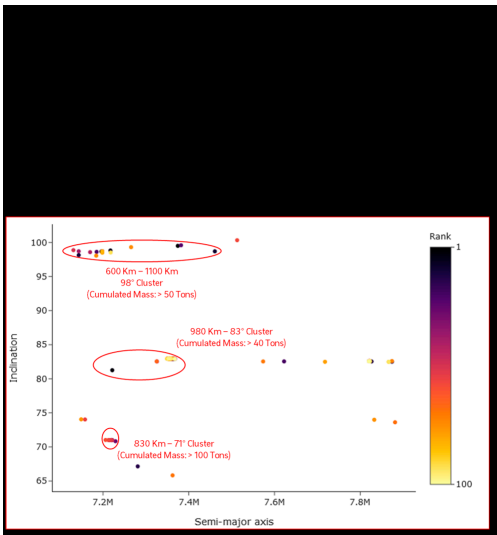
Existence of several indexes at international level mostly centered on the debris generation capability, and consequent risk increase, of space objects

International effort, assembling 11 Criticality Evaluation algorithms and 13 organizations (Centauri, ESA, CNES, CNR, AXA XL, JAXA, Samara University, University of Southampton, LeoLabs, CNSA, KIAM, Bauman Moscow State University)

- First identification of a consolidated list of the top 50 statistical most concerning objects in LEO
- D. McKnight et al. Identifying the 50 Statistically Most Concerning Objects in LEO. Acta Astronautica, volume 181, April 2021, Pages 282-291 https://doi.org/10.1016/j.actaastro.2021.01.021



6 CONCLUSION



CONCLUSION

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- Strong Heritage, inducing several fragmentations per year
- Need to consider (<10cm) population to properly represent the evolution of the environment and the collisional process
- **Without new space activity**, even at 1 Exp/year, without new launches, population continue to increase
- Considering a "fresh" start, **current mitigation guidelines** (90% PMD, 1/1000 probability of unintentional fragmentation), **does not allow to maintain a stable population** in particular in the presence of mega-constellations