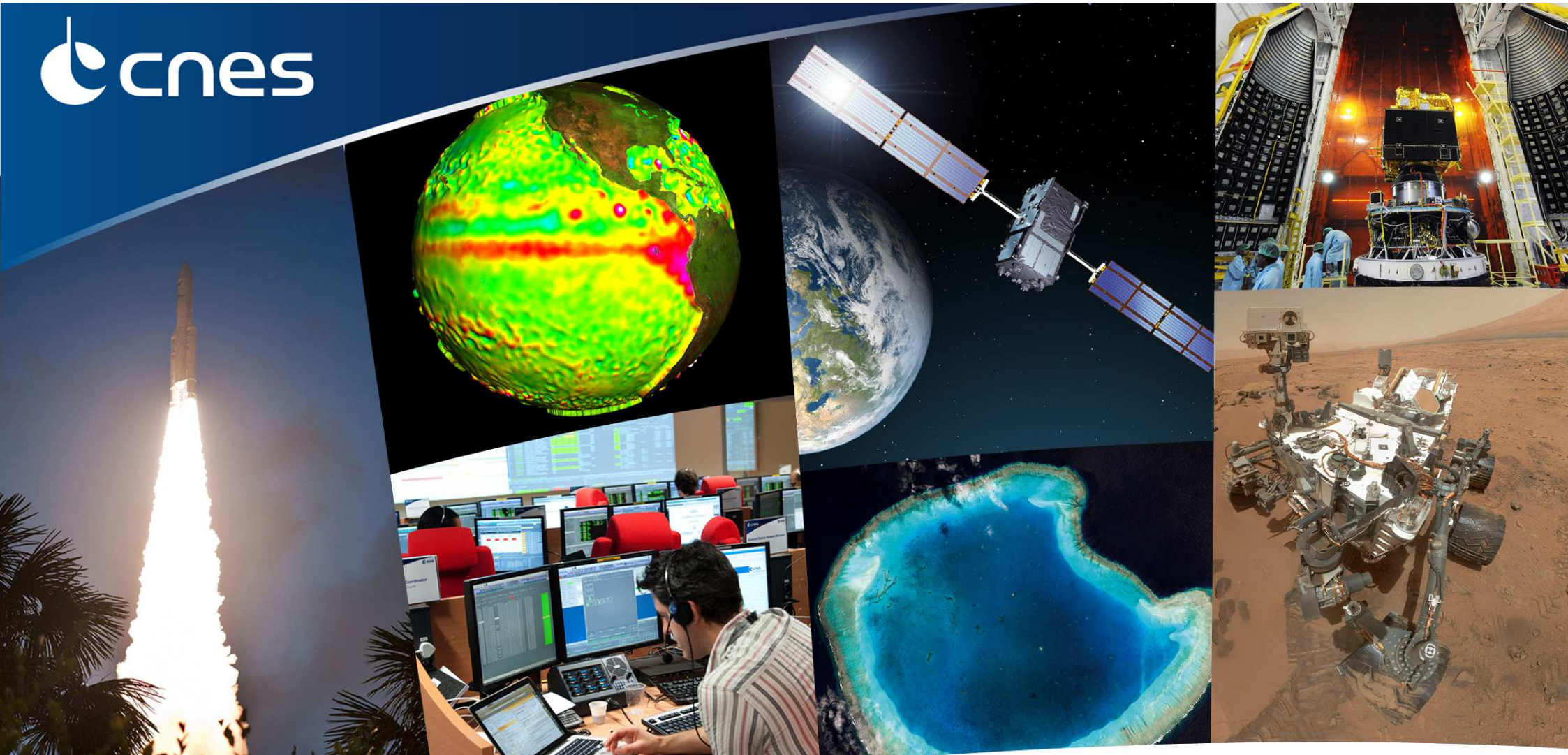


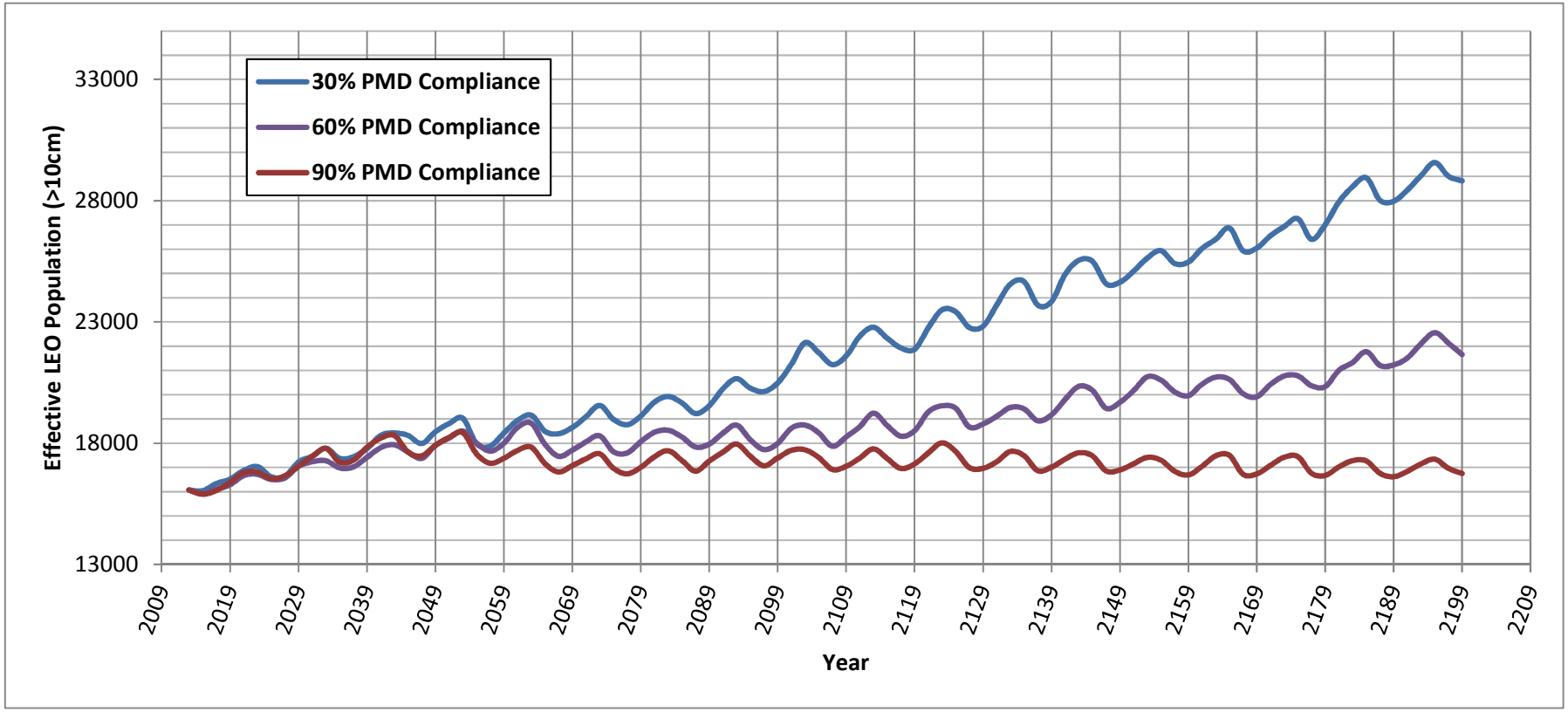
REVIEW OF MITIGATION RULES COMPLIANCE IN LEO (2000 – 2014)

Journée de Synthèse Débris CNES

Toulouse, 9th June 2015

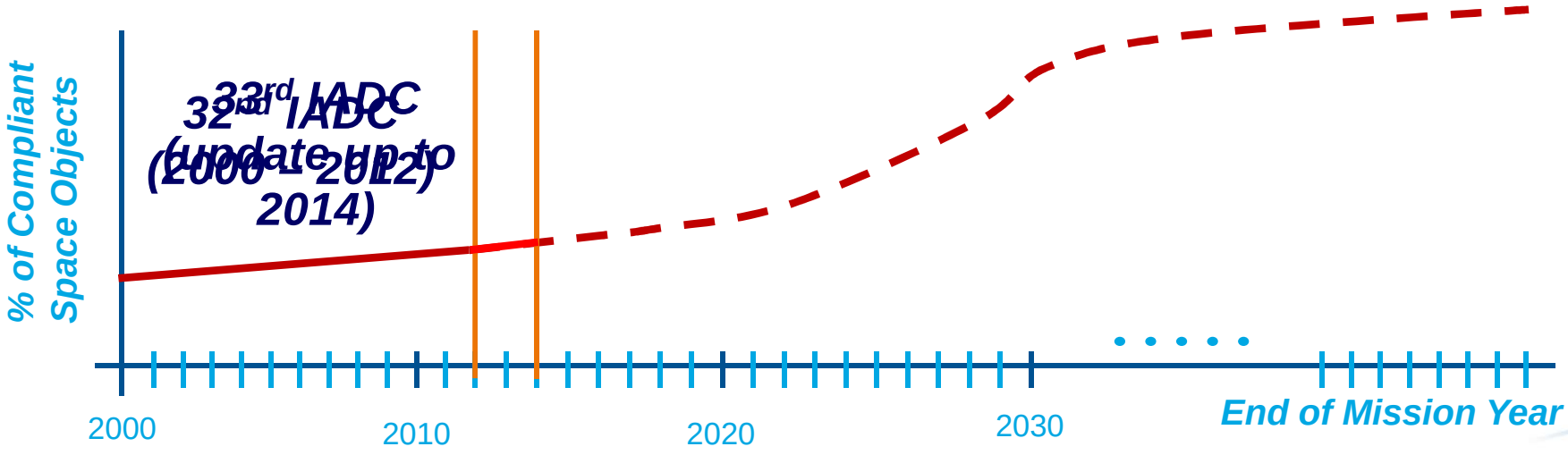
Dolado Perez J.C., Morand V., Pinede R., Hansdschuh D.A.

- **Long term evolution of space debris environment, shows a unstable behavior in the LEO regime, if efforts are not made to reduce the number of objects on the environment.**

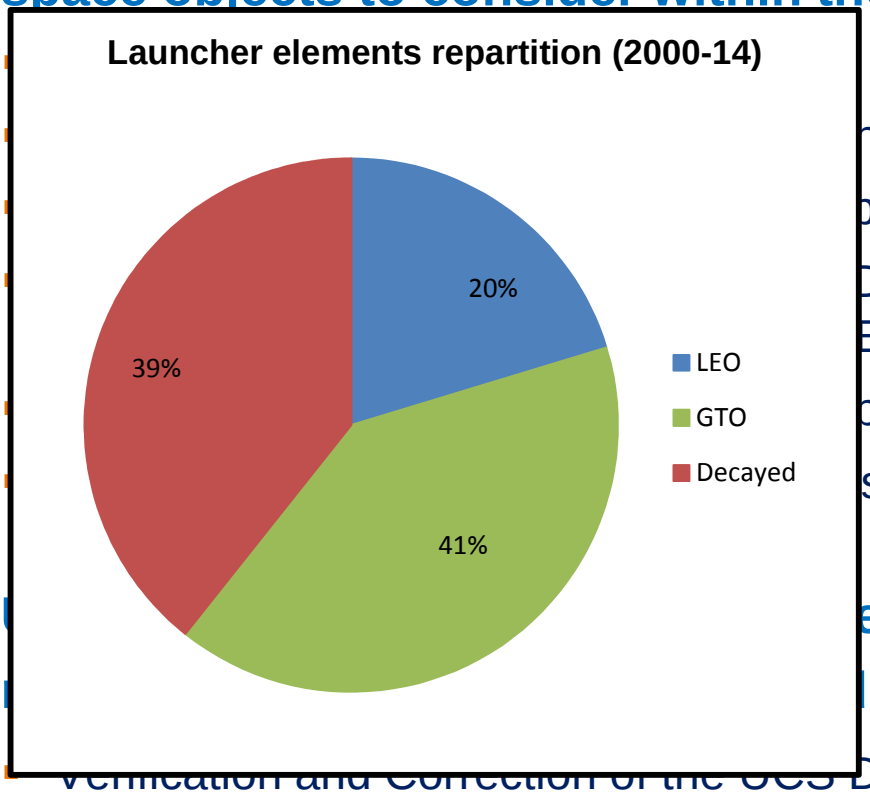


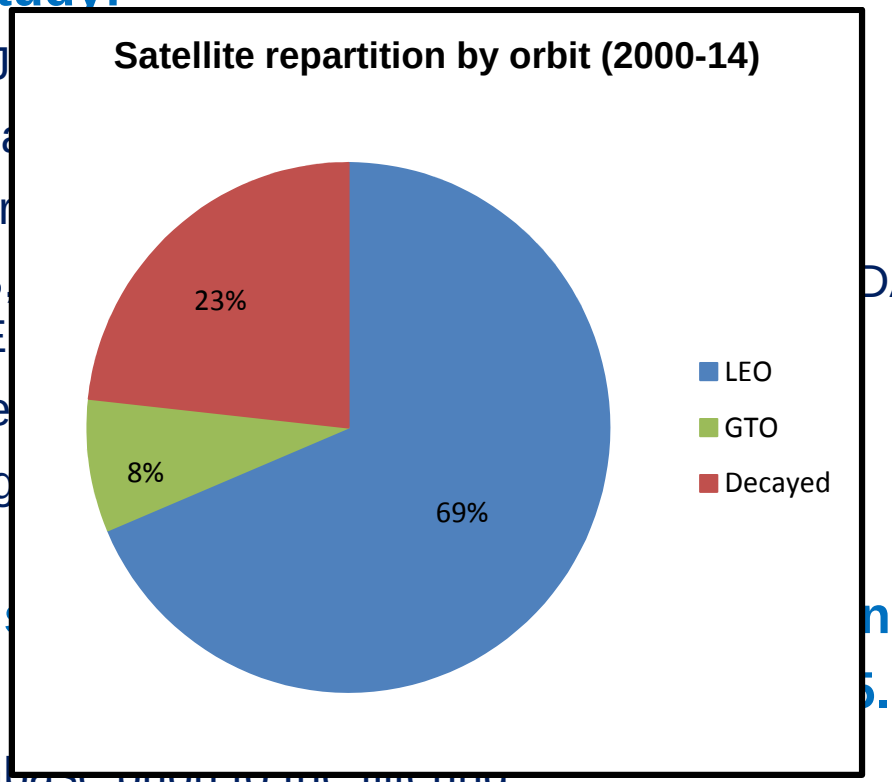
N.B.: *PMD Compliance refers to objects non compliant with the 25-Years rule that we have voluntarily de-orbited*

- **Fear that the future environment growth might be dominated by collisions, rather than by launches and explosions**
  - 2002: IADC Space Debris Mitigation Guidelines
  - 2006: European Code of Conduct
  - 2007: UN – COPUOS Outer Space Mitigation Guidelines
  - 2009: French Space Operation Act
  - …
- **Important to verify the compliance rate of such guidelines.**



- **Use of the USSTRATCOM's public catalogue, for the identification of the space objects to consider within the study:**

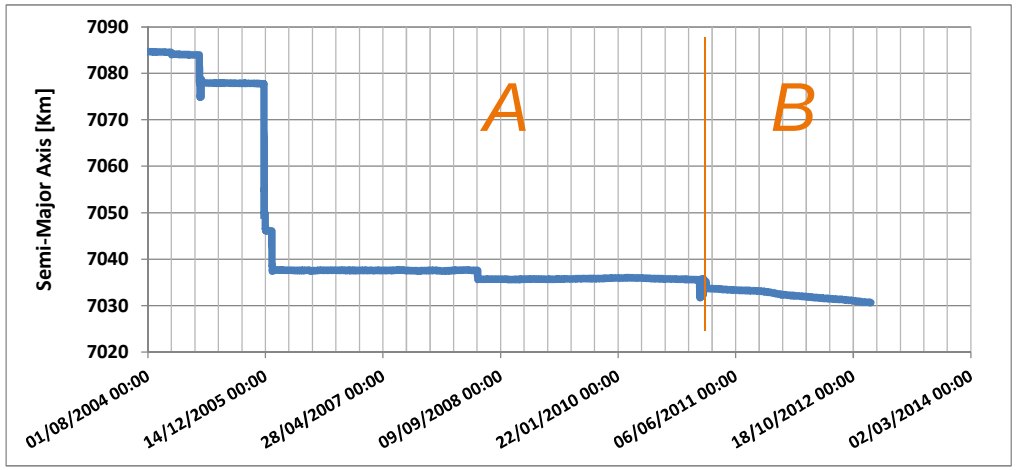


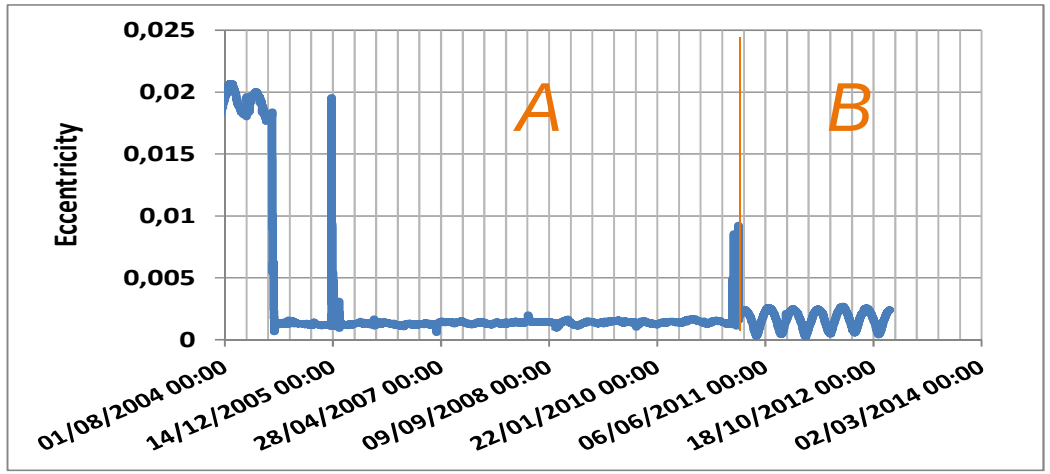


- **At the end 1559 objects are considered on the study**
  - 633 Space Crafts
  - 926 Rocket Bodies

- **Once that the objects to consider within the study have been identified we need to:**
  - **Identify their End of Mission date (A)**
  - **Estimate their physical parameters (B)**

→ Use of public catalogue data only





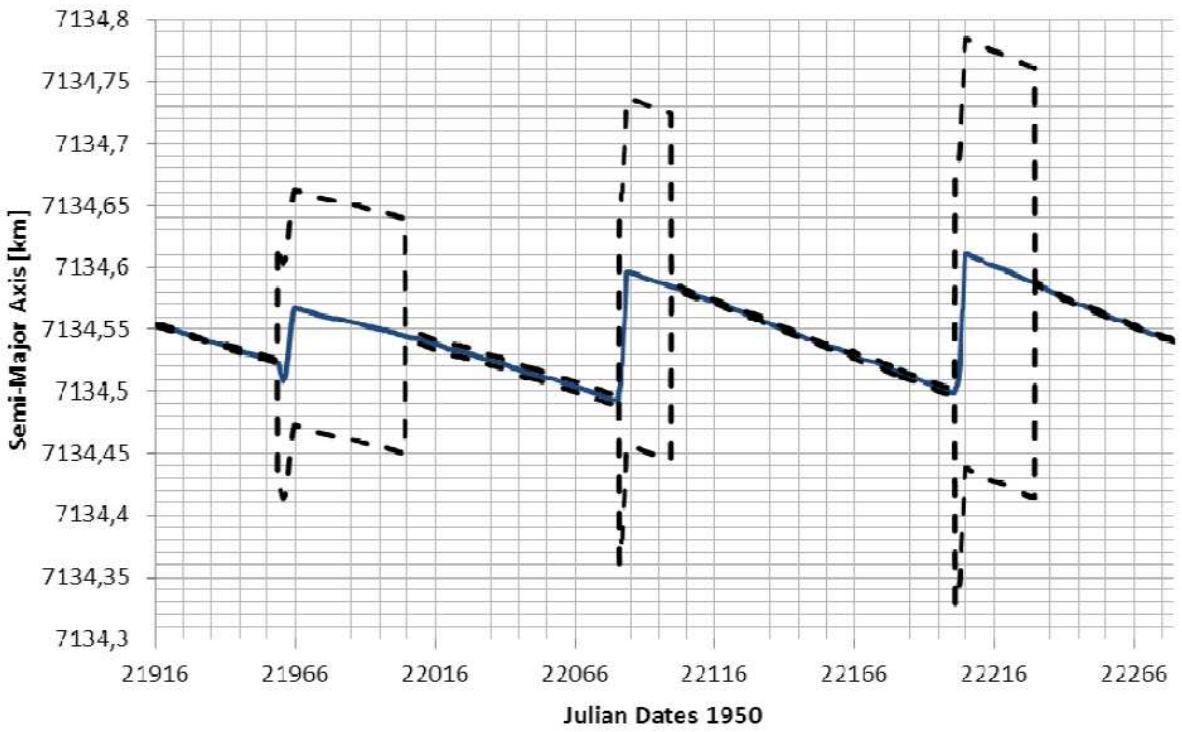
Launcher Elements

- **An EOM is supposed to arrive just after the injection of the upper stage in orbit.**
  - Detection of maneuverability and end of maneuverability is not performed for launcher elements
  - Orbital data after injection is extremely noisy and may drive to an important percentage of false detections
  - We suppose that 30 days after injection the de/re-orbitation maneuvers have been performed

Satellites

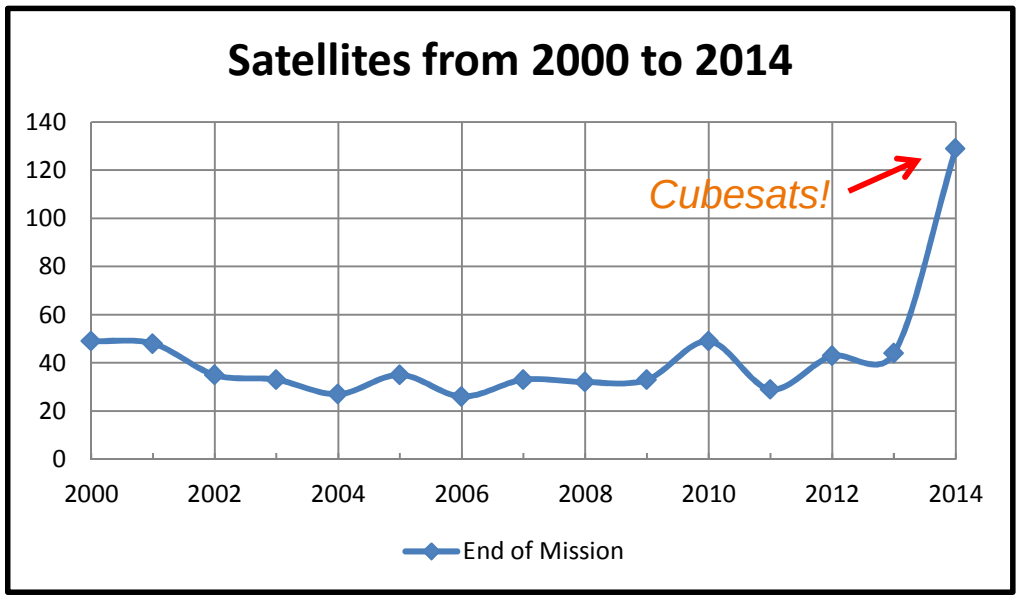
- **Development of dedicated algorithms for detection of maneuverability and end of maneuverability (OPERA)**

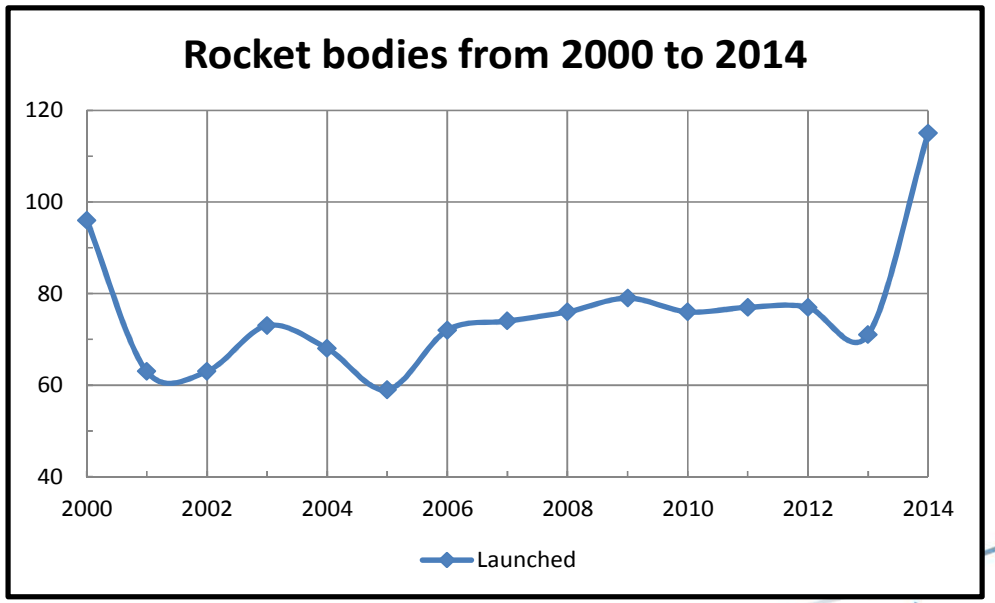
01/01/2010 – 01/01/2011
SMOS SMA evolution



Satellites

- **For non-maneuverable satellites, if no information on mission lifetimes, definition of standard orbital lifetimes**
  - 1 Year for Cubesats
  - 4 Years for COSMOS satellites
  - 10 Years for Molnyia and ORBCOMM FM satellites
  - 3 Years for UNISAT and MEGSAT satellites
- **Non maneuverable ILRS satellites, are excluded from the study**
  - Only 15 objects





The computation of physical parameters is done via an estimation process where the publicly available orbital data is taken as measurements (Use of OPERA tool)

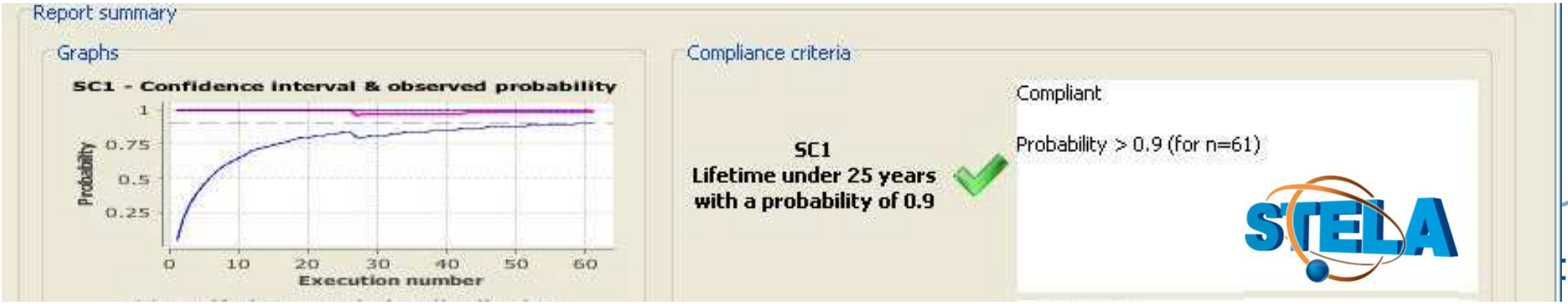
- **Computation of an initial Sdrag/m = Sref/m, by the application of the conservation of Energy principle**

$$\frac{1}{a(t_0)} - \frac{1}{a(t)} = -\frac{1}{\mu}\frac{S_{drag}}{m}\int_{t_0}^{t} \rho C_x V^3 dt \qquad \textit{(Eq. 1)}$$

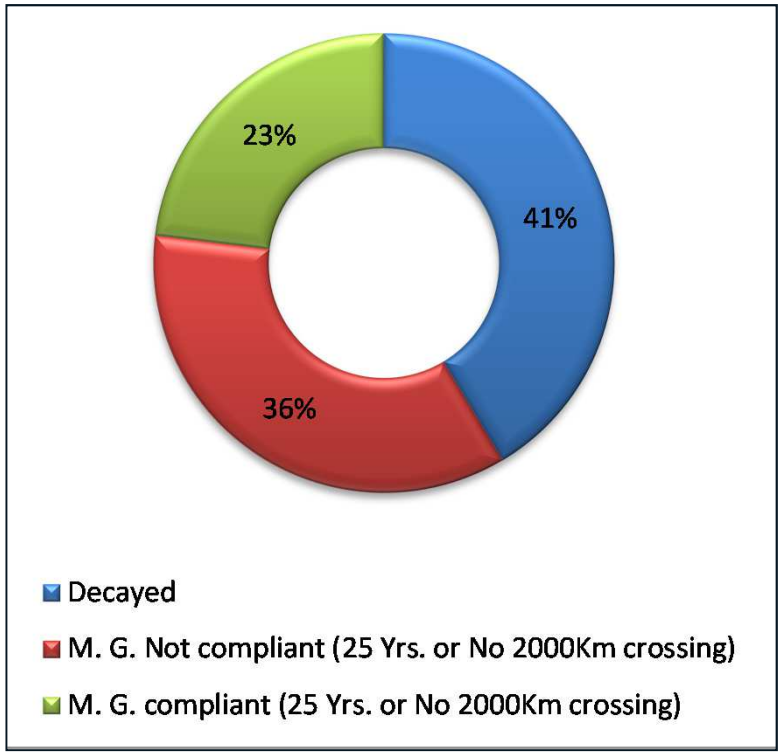
- **Computation of a more accurate estimate of Sref/m and Sdrag/m ratios**

$$\left.\frac{da}{dt}\right|^{TLE} = K_1 \left.\frac{da}{dt}\right|^{drag} + K_2 \left.\frac{da}{dt}\right|^{SRP}$$
$$\left.\frac{de}{dt}\right|^{TLE} - \left.\frac{de}{dt}\right|^{cons} = K_1 \left.\frac{de}{dt}\right|^{drag} + K_2 \left.\frac{de}{dt}\right|^{SRP} \qquad \textit{(Eq. 2)}$$

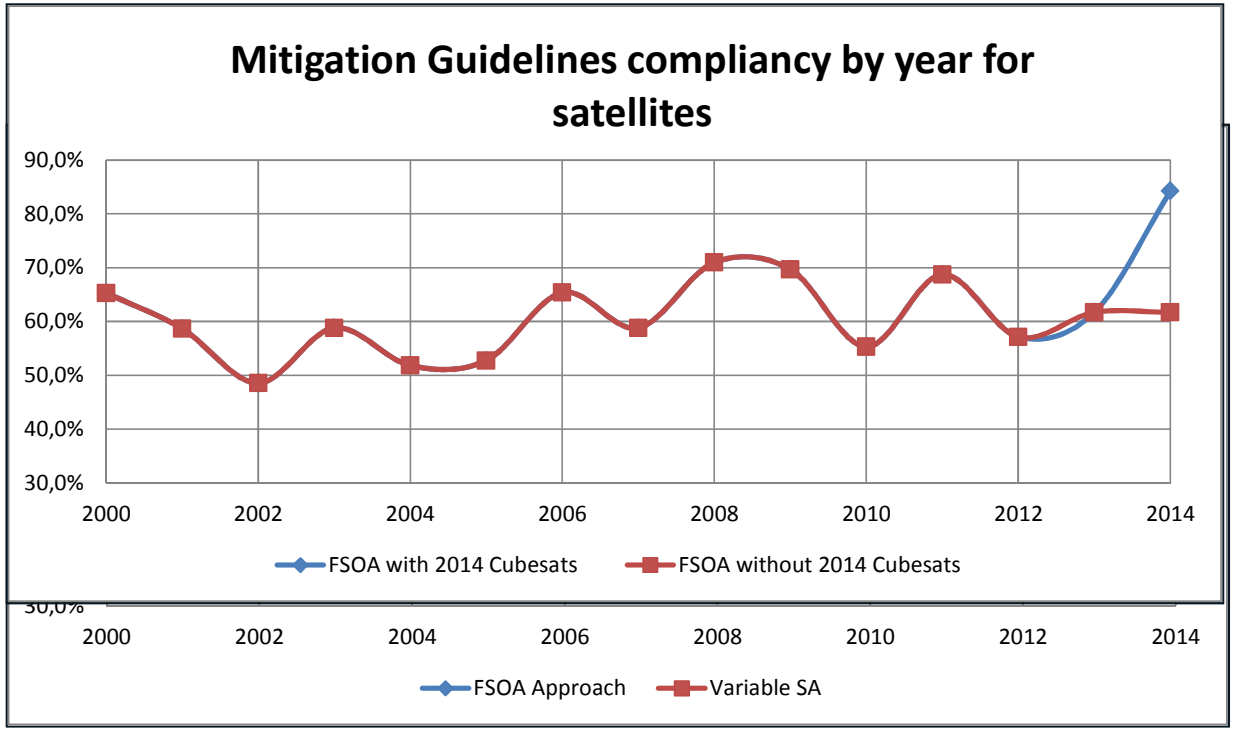
- The conformity with respect to the 25 years rule and to the Non-interference with the 2000 Km altitude region, is evaluated following the good practices attached with the FSOA
- For LEO objects, one STELA propagation is done:
  - From the end of the mission date, using the constant equivalent solar activity approach (FSOA)
  - From the last available TLE, using the NOAA/DAS solar activity prediction
- For GTO objects, one STELA statistical propagation is done:
  - From the end of the mission date, with a random solar activity using the five past solar cycles (FSOA)
  - From the last available TLE using a mixed solar activity (NOAA 2019 pred. + random)
  - Dispersion of +/-20% on the object's area to mass ratio and of the orbital parameters following Gaussian laws
  - The object is compliant if its lifetime is shorter than 25 years with a probability higher than 0,9



❑ SATELLITES

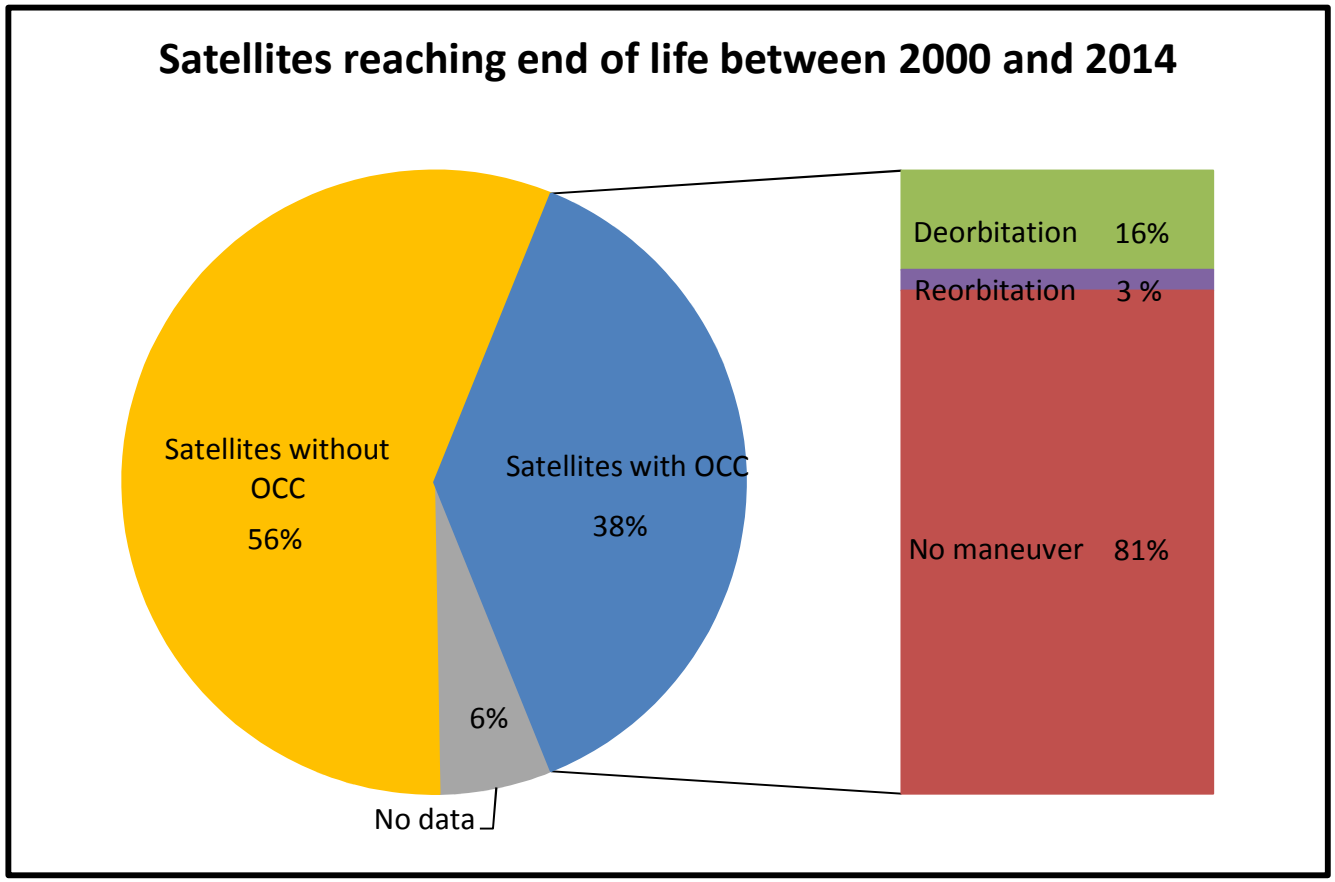


Global statistics on the overall S/C Population between 2000 - 2014



Yearly Statistics on the overall S/C Population between 2000 - 2014

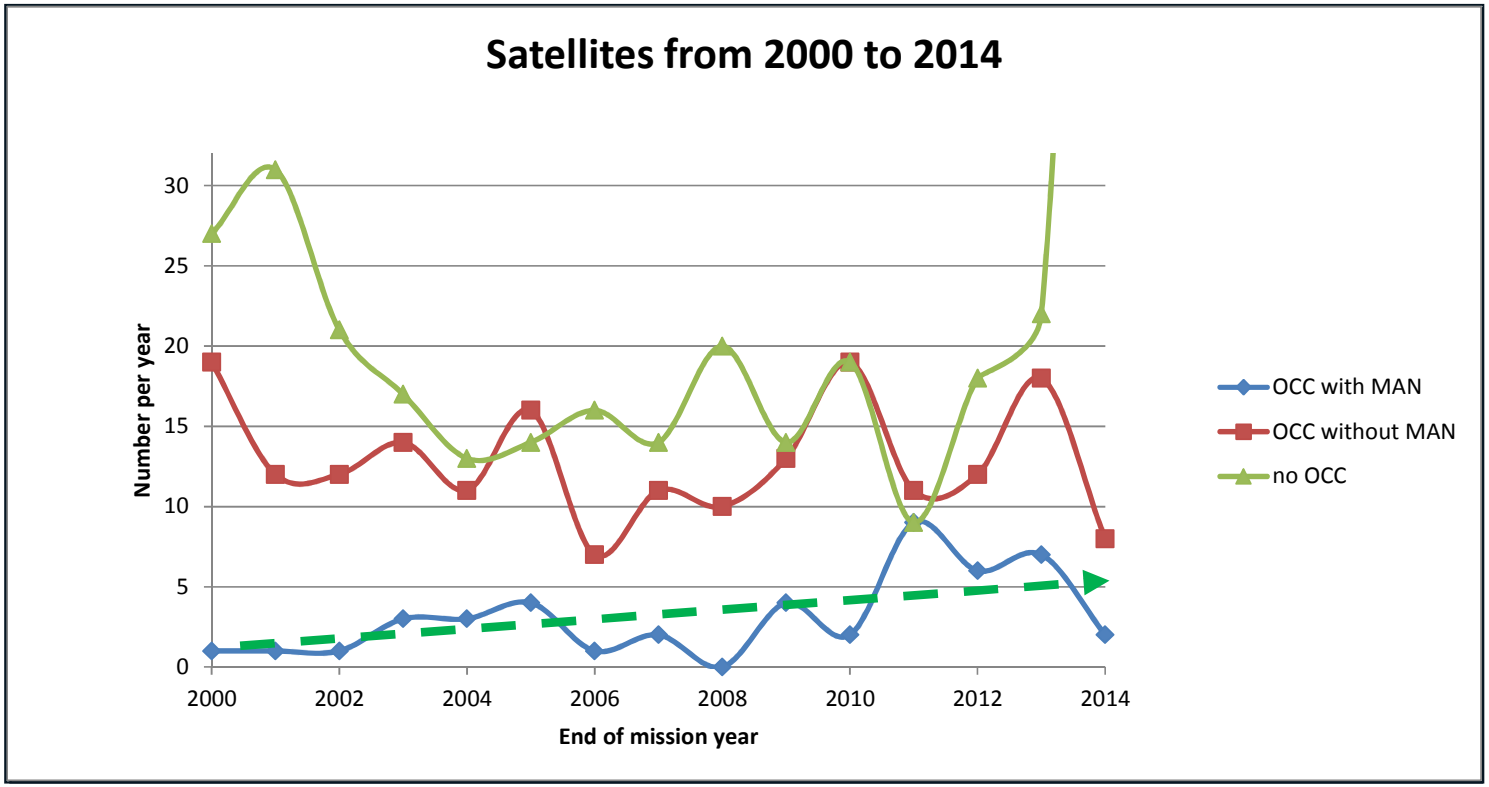
❑ Focus on SATELLITES Manoeuver capability



In 2014, None of the performed manoeuvers allowed to be compliant with the Mitigation guidelines (25 Yrs. Or 2000 Km Crossing) !!

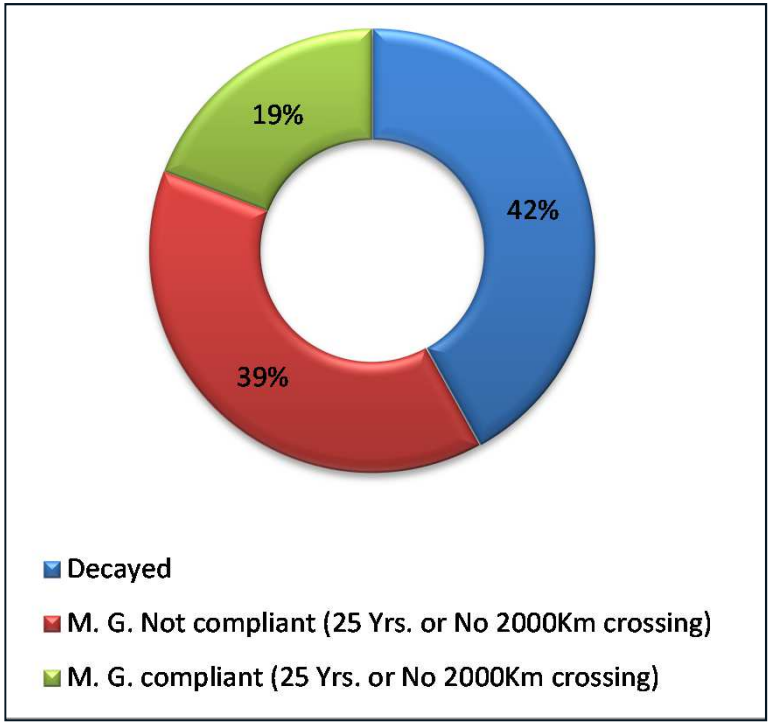
Global statistics on the OCC S/C Population between 2000 - 2014

❑ Focus on SATELLITES Manoeuver capability

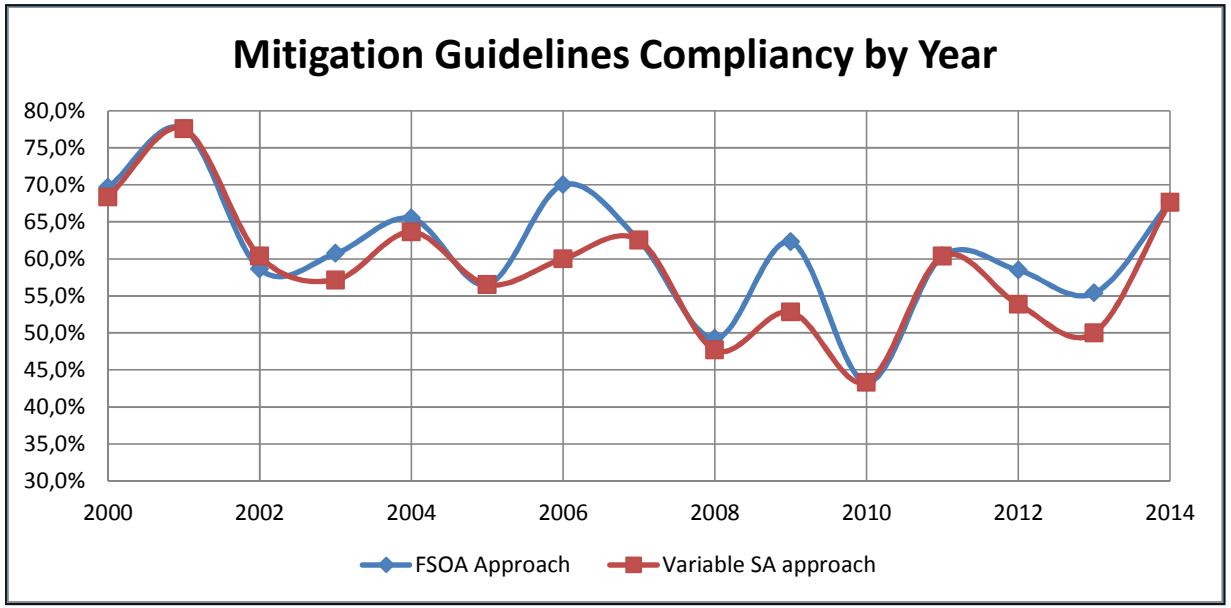


Yearly statistics on the S/C Population between 2000 - 2014

LAUNCHER ELEMENTS

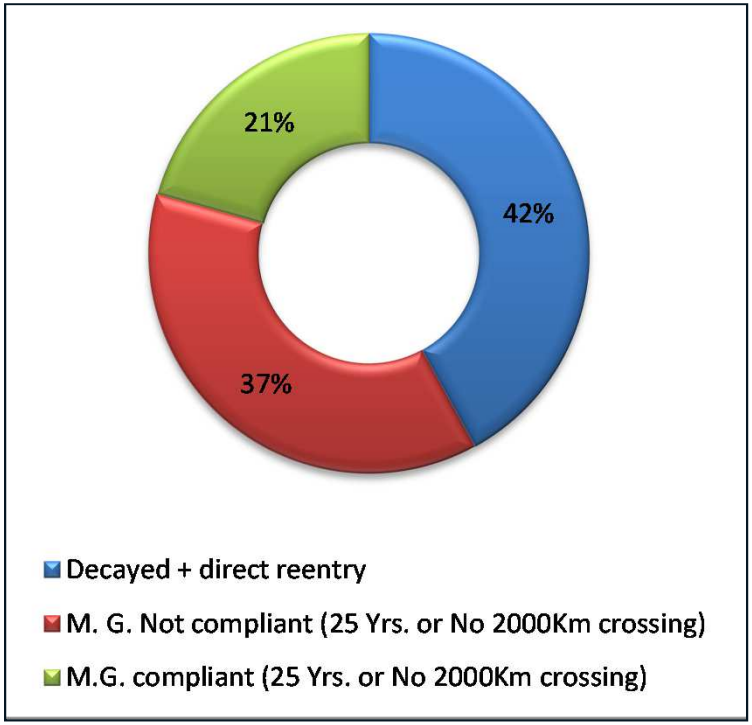


Global statistics on the R/B Population between 2000 - 2014

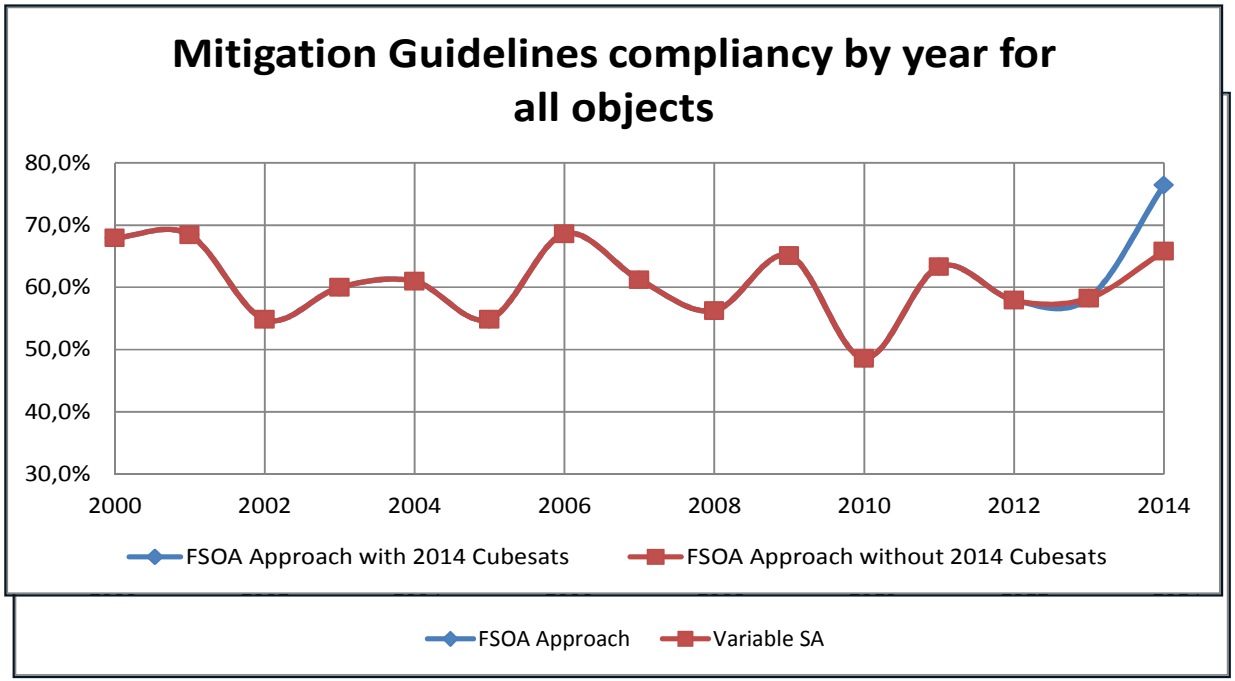


Yearly Statistics on the R/B Population between 2000 - 2014

GLOBAL RESULTS



Global statistics for all objects between 2000 - 2014



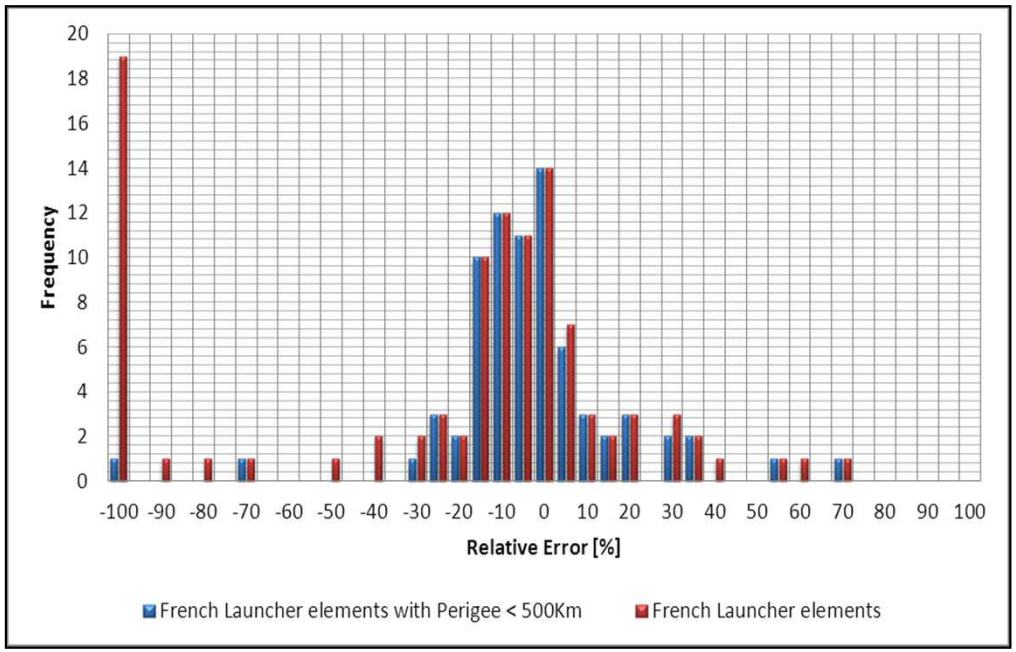
Yearly statistics for all objects between 2000 - 2014

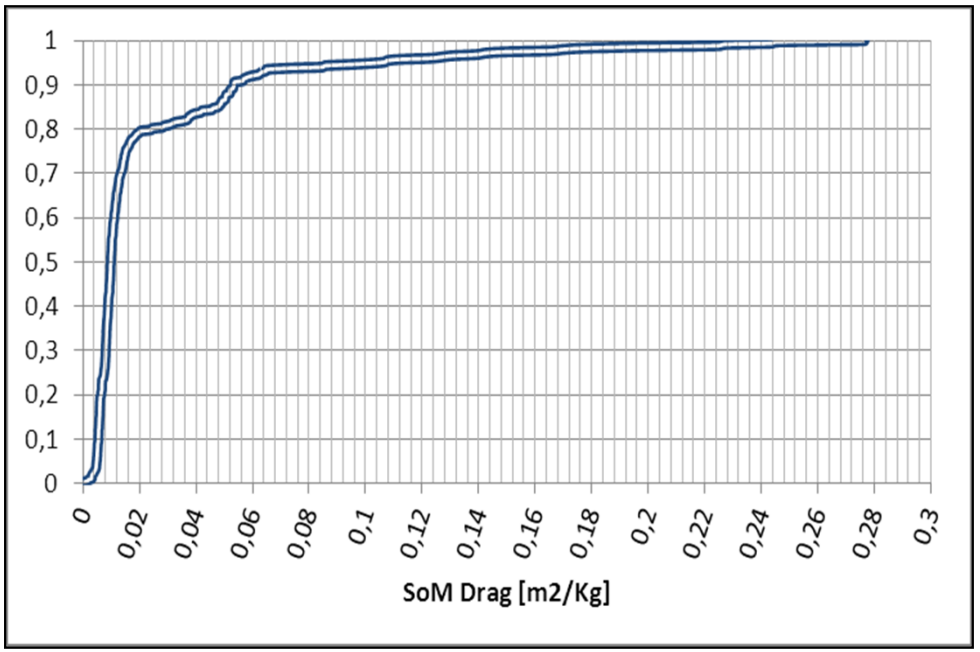
❑ CONCLUSIONS

- **On the global compliancy of mitigation guidelines, there is not (yet…) a clear trend of improvement towards the years**
  - A global compliancy of ~60% for S/C and R/B have been estimated for objects arrived to EOM between 2000 – 2014
    - ✓ Concerning the OCC satellites, an encouraging trend is observed
  - Very important increase on launched Cubesats
    - ✓ The overall statistics starts to be driven by this population
    - ✓ Need to establish a separate study between cubesats / « femto » sats. and the rest of S/C
      - ✓ Definition of a zero mission lifetime for such satellites (in agreement with FSOA Technical regulation)
- **Most of the analyzed satellites and launcher elements rely on natural effects to be compliant with mitigation guidelines**
  - Most of the objects performing de/re-orbitation maneuvers are doing so on a best effort basis, as they were designed and launched priori to the adoption of mitigation guidelines
  - In 2014, 20% of S/C population with OCC performed a de/re-orbitation maneuver. This maneuver does not allow the S/C to be compliant with Mitigation Guidelines
- **There is still a great effort to be done to improve the global compliancy of mitigation measures**

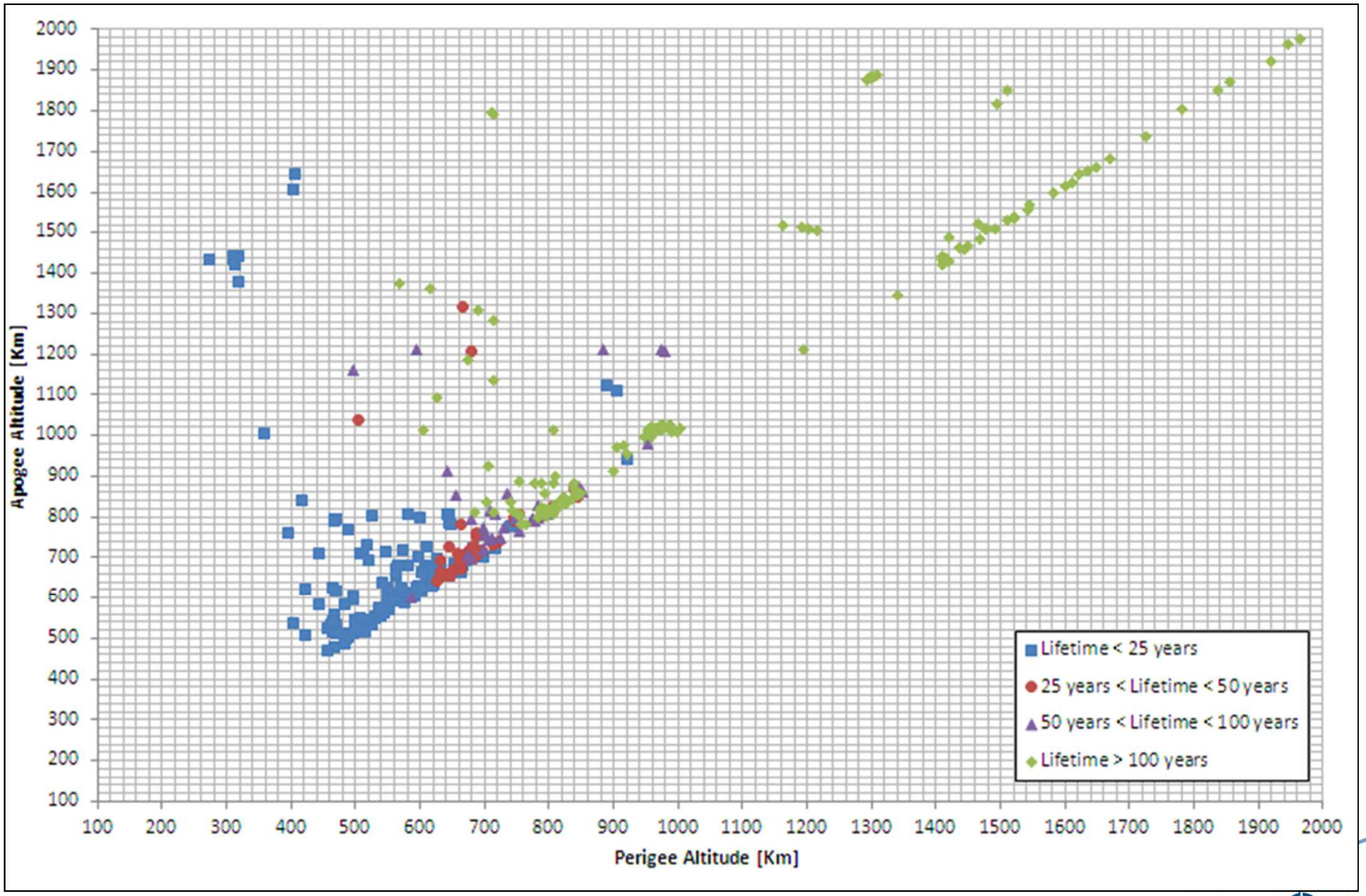
BACKUP SLIDES

❑ Validation of the computed physical parameters, by comparison with known satellites and launcher elements

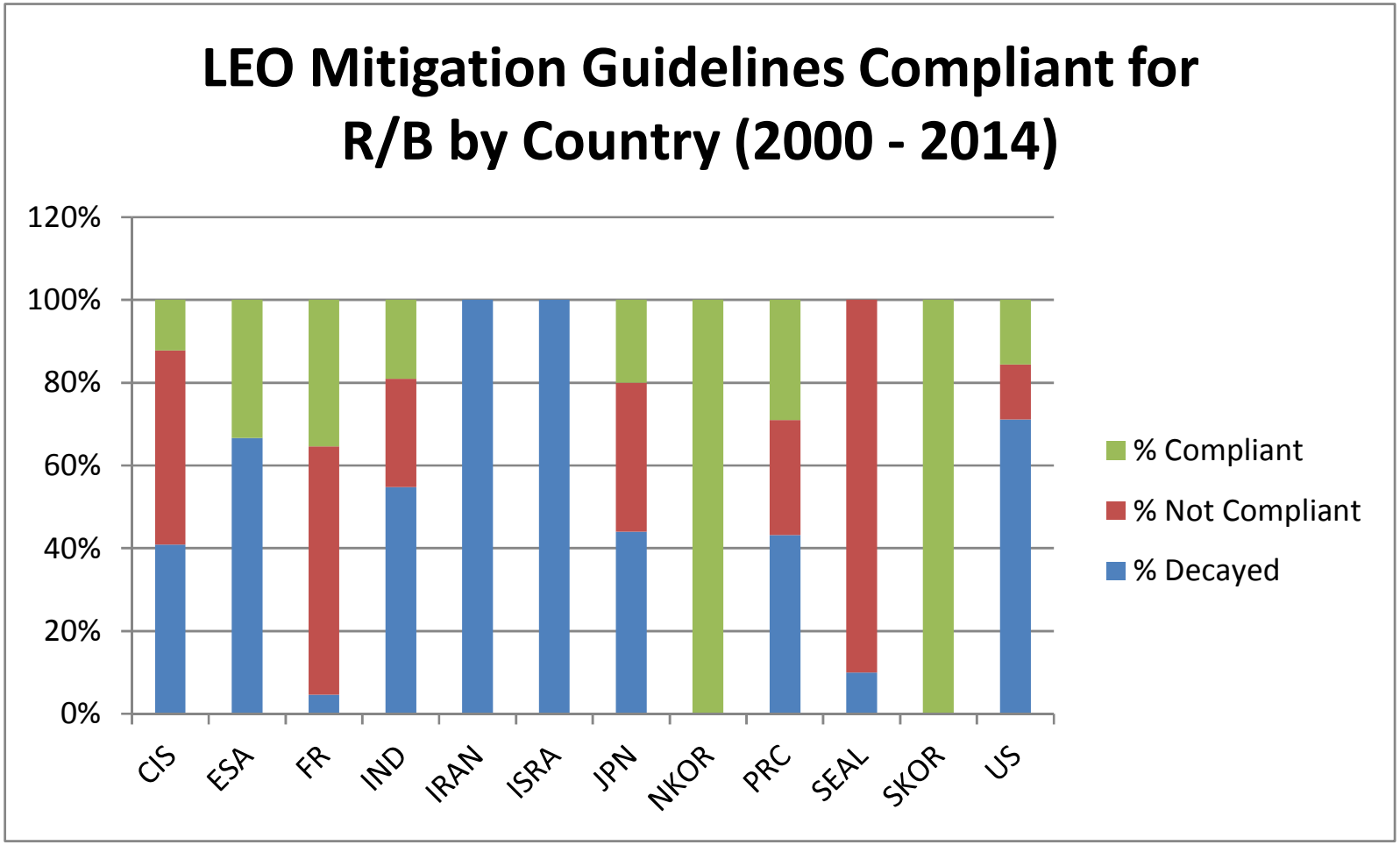




Median S/m is ~0,01 m2/Kg


Apogee Altitude [Km]
Perigee Altitude [Km]
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Lifetime < 25 years
25 years < Lifetime < 50 years
50 years < Lifetime < 100 years
Lifetime > 100 years

LAUNCHER ELEMENTS RESULTS BY COUNTRY



S/C RESULTS BY COUNTRY