cnes

6th IAASS International Space Safety Conference
Session 1: Space debris and space debris removal - Part 1

LIFETIME ESTIMATION FOR LAUNCHERS DEBRIS IN GTO

David-Alexis HANDSCHUH

21st of May 2013

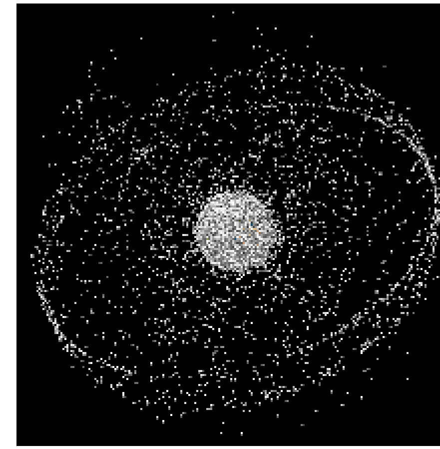
CONTENTS

cnes

REMINDERS

Critical increase of orbital debris

« Small debris » (1mm < L < 1cm) (not catalogued)	« Medium debris » (1cm < L < 10cm) (not catalogued)	Large objects (10cm ≤ L) (catalogued)
> 150 millions	> 500 000	22 000 (estimation)

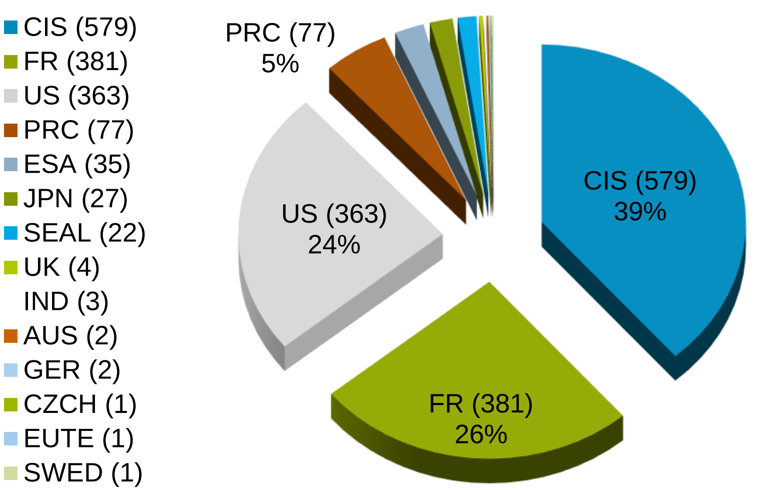


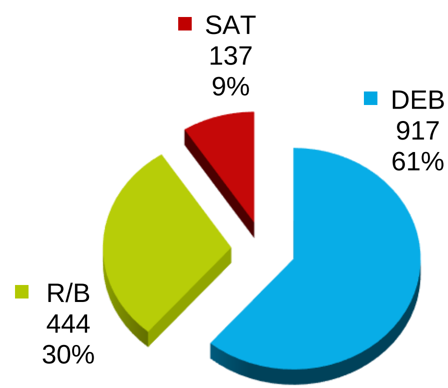
16909 catalogued objects on SpaceTrack (01.01.2013)

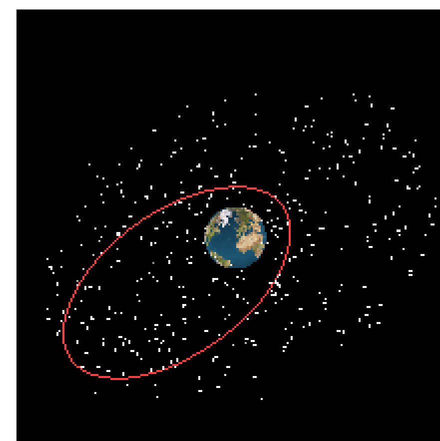
» 3700 operational objects
» 13209 debris and upper stages

Some Low Earth Orbits are under critical evolution (Kessler syndrome)

Orbital population in GTO (05.15.2013)







cnes

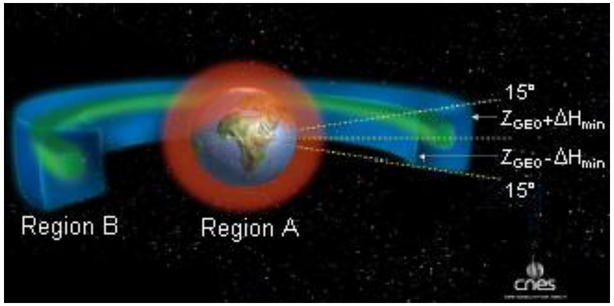
THE FRENCH LEGAL CONTEXT

The French Space Operations Act

Entered into force in December 2010
One article entirely dedicated to Space Debris Limitation during launch operations

Definition of two protected areas:

- LEO protected region (called "Region A")
  - altitude < 2000 km
  - every inclinations
- GEO protected region (called "Region B")
  - altitude ∈ 35786 ± 200 km
  - inclination ∈ 0° ± 15°



The technical regulation asks for:

- Direct and controlled atmospheric re-entry
- If the impossibility of a re-entry can be duly proven:
  - to free Region A in less than 25 years
  - to free Region B in less than 1 year and ensure this release during at least 100 years

The French Space Operations Act is applicable to all launchers developed after December 2010 and operated from French Guyana Space Centre

THE FRENCH LEGAL CONTEXT

Good practices associated to the French Space Operations Act

Many variables are to be considered in extrapolation and lifetime evaluation of orbital objects:

- Minimal dynamical model for orbit propagation
- Input parameters as:
  - initial orbital parameters of the object
  - physical parameters of the objects
  - solar activity
- Criteria to check the compliance to the requirements

Good practices are proposed by CNES to check the compliance to the technical regulation

- Le Fèvre, C. & al. (2012). Paper No IAC-12-A6.4.1
  Compliance of disposal orbits with the French space act: the good practices and the STELA tool.
- Le Fèvre, C. & al. (2013). IAASS 2013
  Orbit propagation techniques and statistical methods to address the compliance of GTO with the French Space Operations Act.

Recommendation to use STELA tool to evaluate the orbital lifetime and the protected areas release

EXTRAPOLATIONS IN GTO

GTO extrapolations

Accumulation of perturbations seen in LEO and GEO
High eccentricity induce high sensitivity to initial parameters

Main contributors to orbital perturbation in GTO:
- third body perturbation
- atmospheric drag
- Earth potential
- solar activity

A coupled effect of J2 and the sun perturbation can induce a resonance and a conservation of the semi-major axis leading to an extended lifetime of the object
Initial conditions to resonate are very precarious
Resonance effect can occur only for a certain semi-major axis length

Specific lack of knowledge

Unknown orientation induces unknown precise dragging surface
Unknown precise mass, especially for Rocket Bodies (unused propellant, long-term passivation evolution, …)
Unknown future solar activity
Unknown precise actual position and velocity

- Leads to a statistical approach

EXTRAPOLATIONS IN GTO

Inputs

Global ballistic coefficient: ±20% uniform dispersion

Random solar activity combining past solar cycles

Initial orbital parameters based on Space Track TLE

Utilisation of TLE

Use of TLE is subject to many discussions but
- » considered as the public best known orbital situation
- » considered as the public most recent orbital situation

SDP-SGP model not valid for high eccentricities (due to limitations in the SGP4-SDP4 short period model)
- » approximation: TLE parameters used as osculating parameters (without any conversion through SGP4-SDP4 model)

Added uniform dispersions

Zp	Za	I	Ω	ω	M
[km]	[km]	[°]	[°]	[°]	[°]
10	0	0	1	2	0

OVERVIEW OF FRENCH LAUNCHERS DEBRIS IN GTO

Definition

GTO objects ≡ Objects that terminates its operational mission with

- » 31000 km ≤ Za ≤ 41000 km
- » Zp ≤ 2000 km

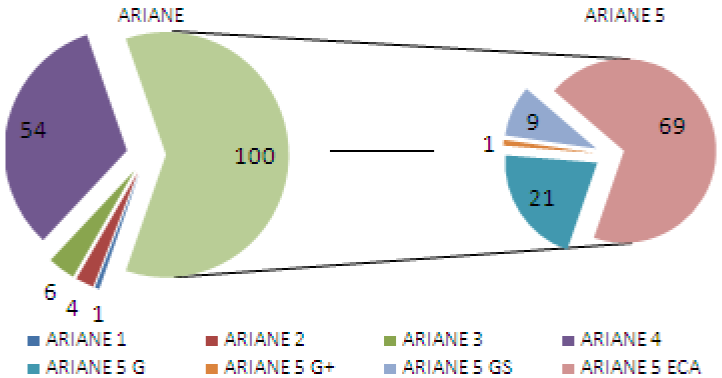
Study's framework

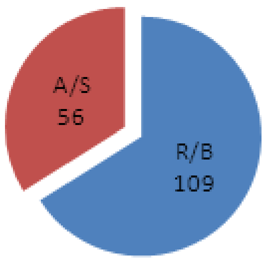
French objects
Launchers debris

Past French launchers activity in GTO

274 French injected objects since the Ariane 1 Rocket Body on the 23rd of May 1984 (re-entered 17.03.1986)

- » 109 re-entered naturally with an average lifetime of 4.59 years
- » 165 are still orbiting the Earth



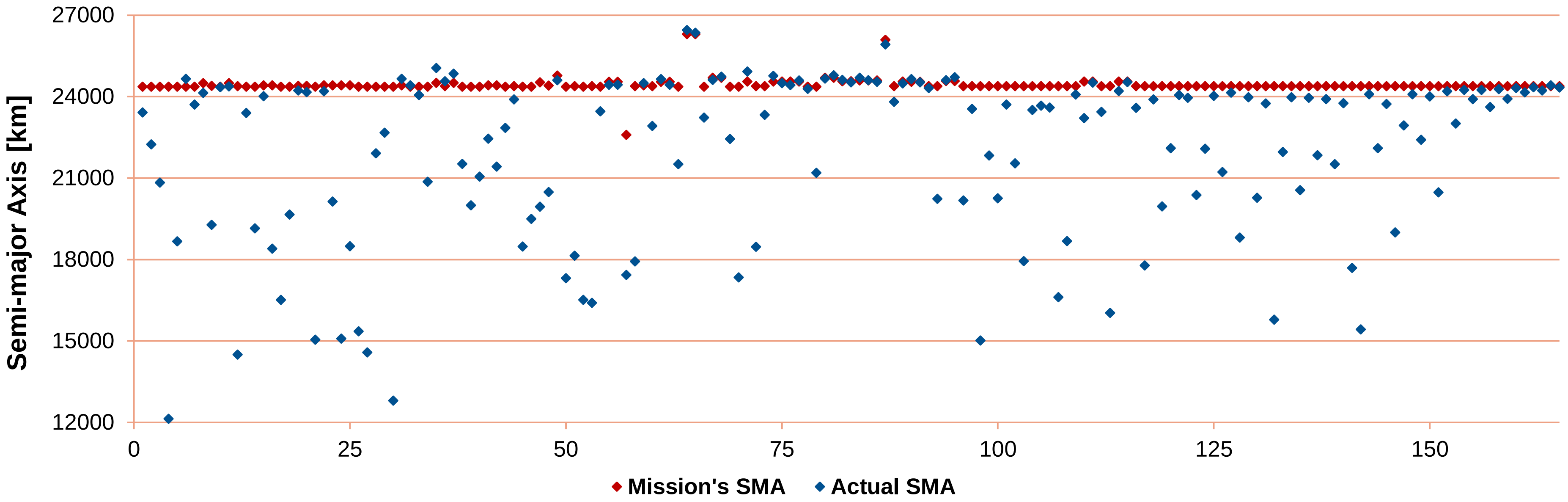


1/3 are adaptive structures

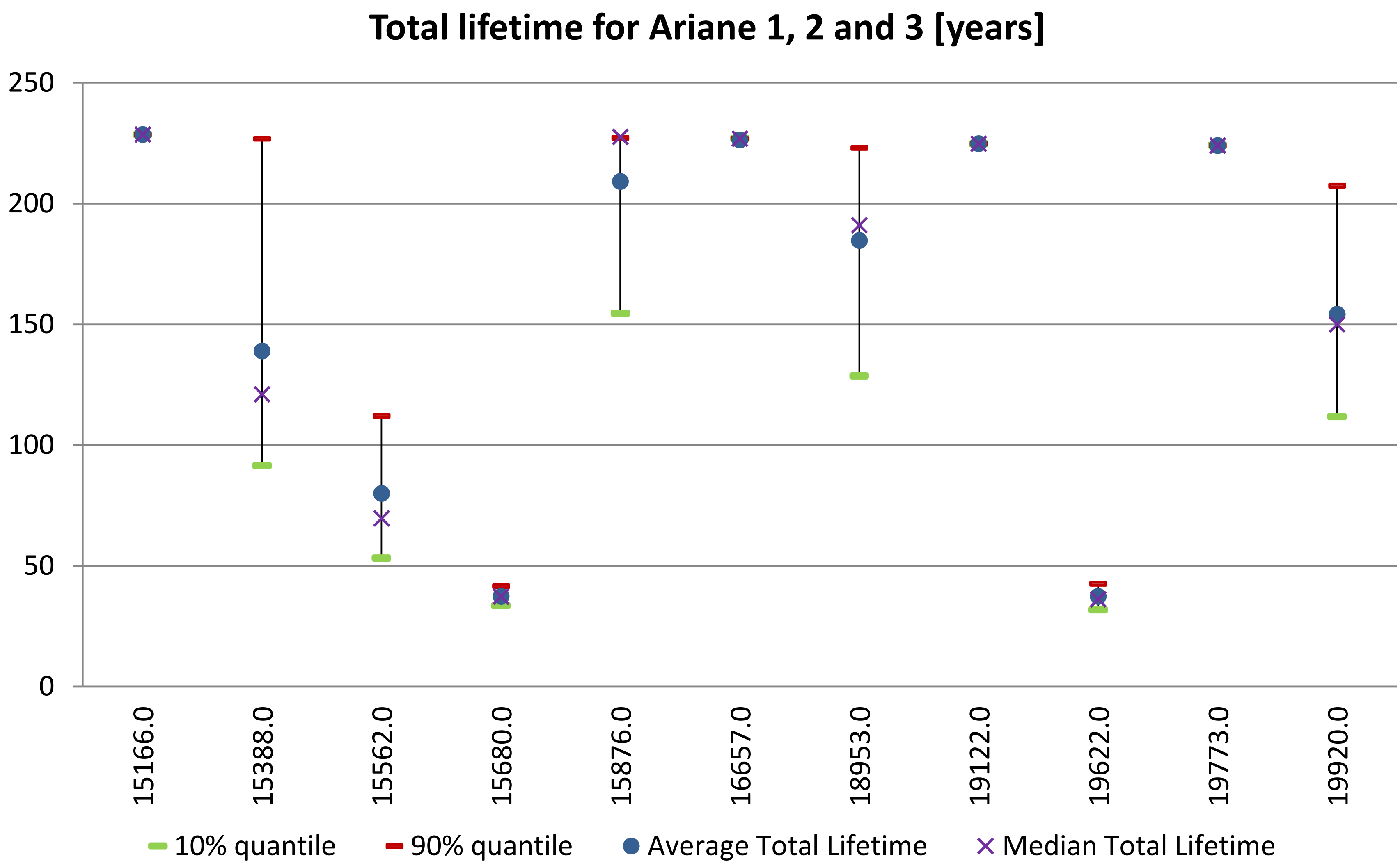
OVERVIEW OF FRENCH LAUNCHERS DEBRIS IN GTO

Actual orbits with respect to the reached one

Most part of them have already begun their orbital erosion
5% of them have an SMA smaller than the resonant one

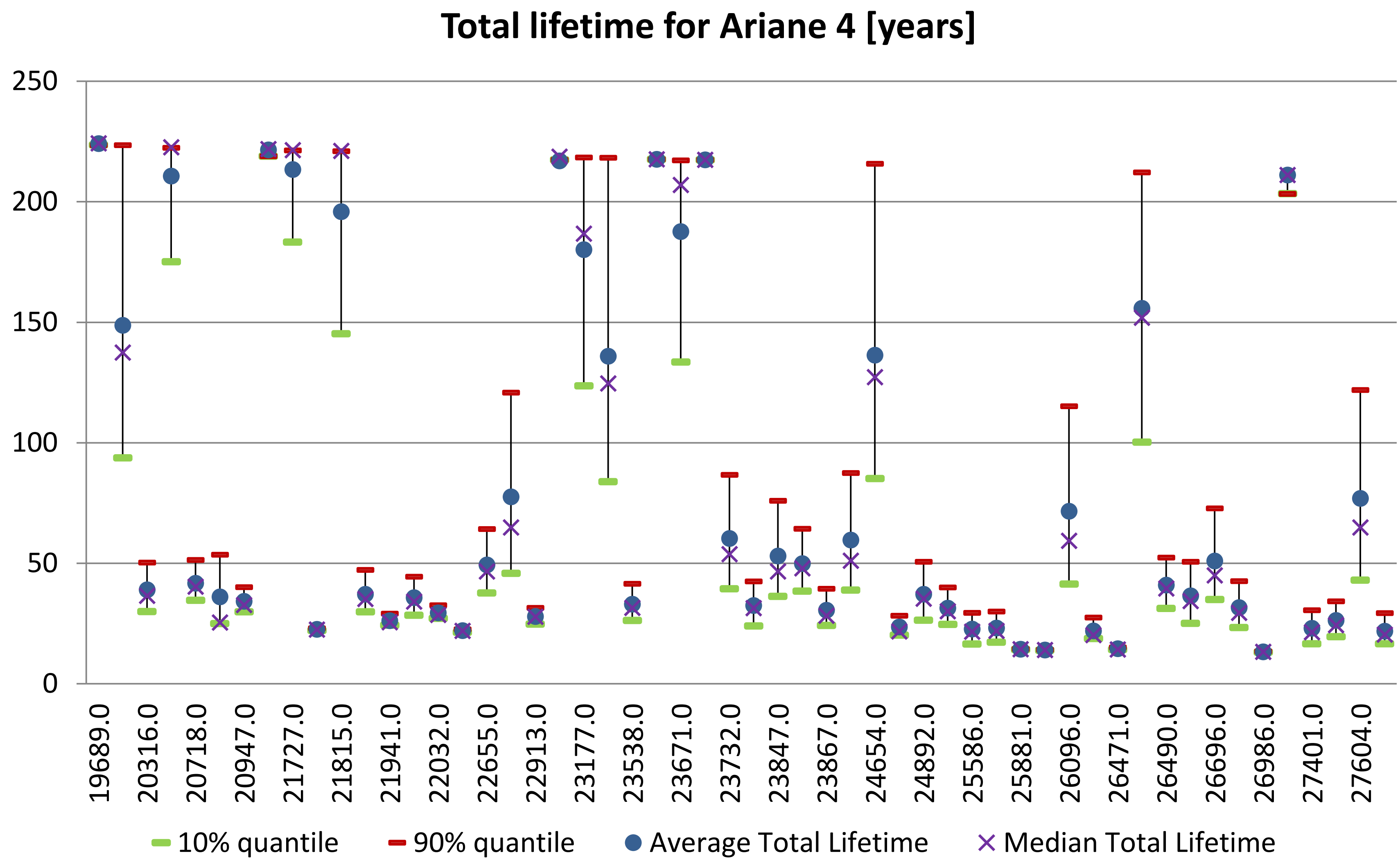


FRENCH LAUNCHERS DEBRIS' LIFETIME IN GTO

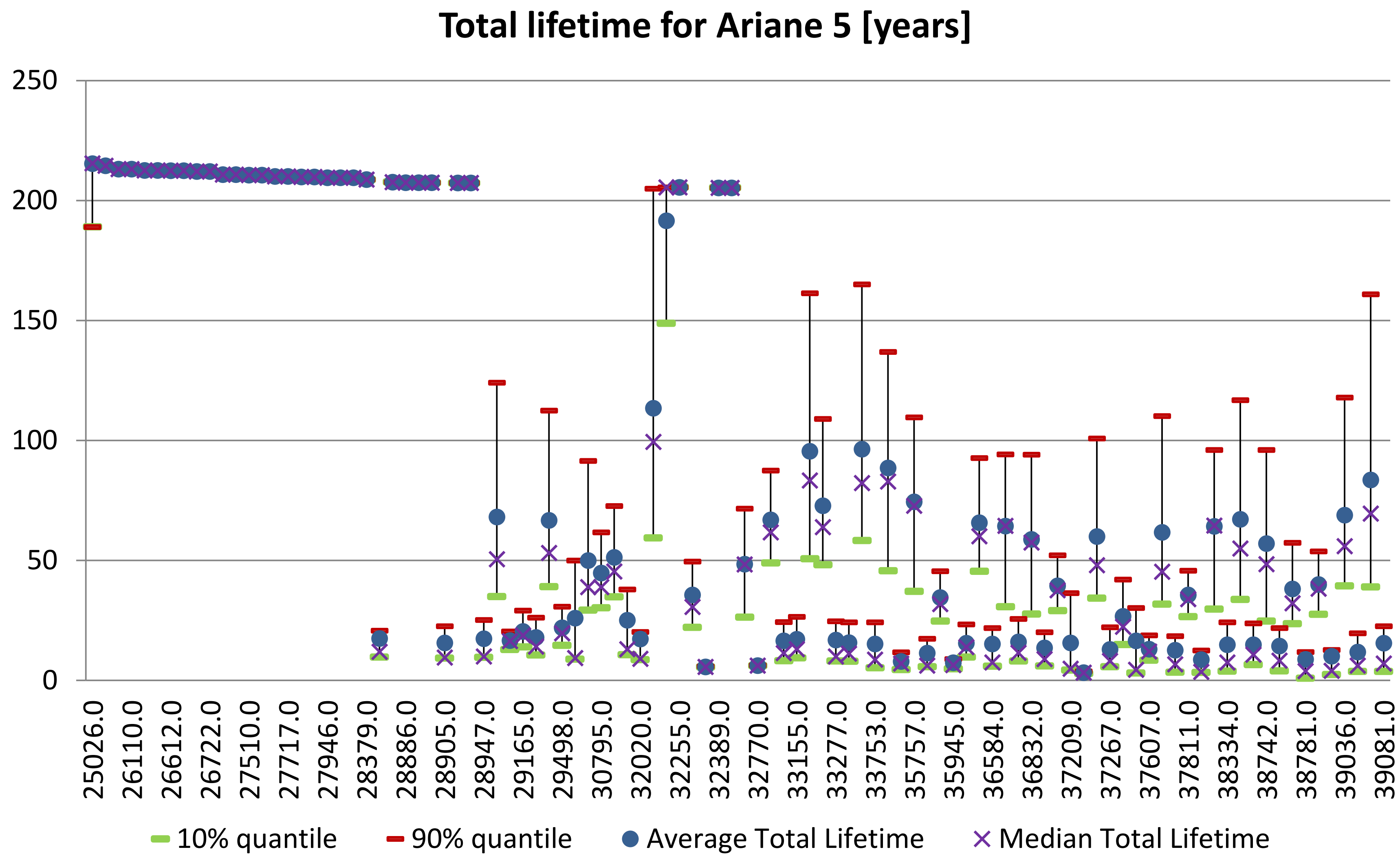


cnes

FRENCH LAUNCHERS DEBRIS' LIFETIME IN GTO



FRENCH LAUNCHERS DEBRIS' LIFETIME IN GTO



cnes

CONCLUSIONS

Lifetime estimation on GTO is particularly tricky

- Results are to be considered with caution

Resonances may induce estimation errors

- Can be managed with Monte Carlo approach

TLE utilisation is now the main concern

- Some improvement ways are planned

Lifetime of already launched objects can be long…

Actual European launcher Ariane 5 ECA has a better situation:

- Average lifetime of R/B ~57 years
- Average lifetime of adaptive structure ~15 years

Tomorrow, thanks to FSOA, new developments like A5ME and Ariane 6 will directly include deorbitation process