

AI 22.1 - GEO Disposal Orbit Eccentricity Comparison of results

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Contributions by:

- **ASI**, L. Anselmo (ISTI-CNR)
- **BNSC**, H. Lewis (Qinetiq + University of Southampton)
- **CNSA**, Jingyaoxiang
- **ESA**, Rüdiger Jehn
- **ISRO**, N.S. Gopinath and A.S. Ganeshan
- **NASA**, G. Chao and S. Campbell (Aerospace Corporation)



Study parameters

- Angle between the Sun and the perigee direction: $0^\circ, 45^\circ, 90^\circ$
- Eccentricity: $0.005, 0.05, 0.1$
- Perigee altitude above GEO ($H_{GEO} = 35786$ km): $\Delta H_{IADC}, 2 \times \Delta H_{IADC}, 3 \times \Delta H_{IADC}$
- Inclination: 0.1°
- Spacecraft area over mass ratio: $0.02 \text{ m}^2/\text{kg}$
- Spacecraft radiation pressure coefficient: $C_R = 1.2$
- Initial epoch of the propagation: **January 1, 2005**
- Propagation time span: **100 years**

Orbital propagators

- **ASI:** FOP, semi-analytical, variation of parameters theory based on the integration of the Lagrange planetary equations (8×8 Earth gravity field, Sun-Moon attractions, Solar Rad. Press. w. eclipses)
- **BNSC, Qinetiq:** Orbit Software Suite, numerical (5×5 , Sun-Moon, SRP w. eclipses)
- **BNSC, Univ. Southampton:** DAMAGE, semi-analytical (J_2, J_3, J_{22} , Sun-Moon, SRP w. eclipses)
- **CNSA:** numerical integrator (8×8 GMT3, Sun-Moon, SRP)
- **ESA:** LEGO, analytical, based on the averaging techniques by J. Van der Ha (4×4 , Sun-Moon, SRP)
- **ISRO:** numerical integrator (12×12 , Sun-Moon, SRP)
- **NASA:** TRACE, Gauss-Jackson numerical integrator (8×8 WGS84, Sun-Moon, SRP w. eclipses)

General remarks

- All the plots show the time evolution of the perigee altitude above the nominal geostationary orbit, assumed at $H_{GEO} = 35786$ km;
- The integration time is **100 years**, except for the runs of BNSC (Qinetiq, labelled **BNSC**), that are for **40 years**;
- The NASA lines in the plots for $e = 0.005$, actually refer to an orbit with initial eccentricity $e = 0.01$;

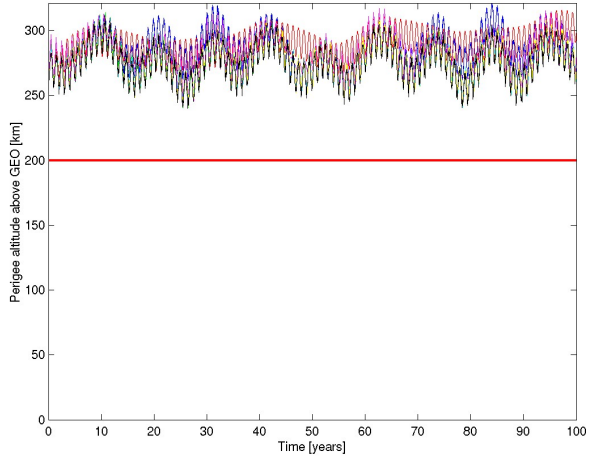
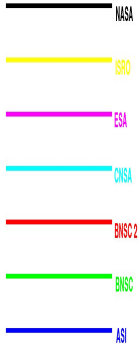


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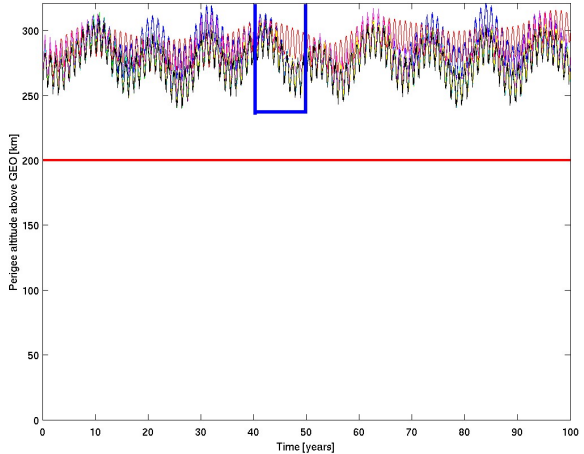
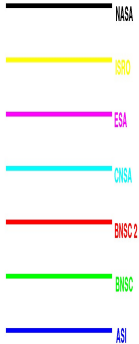
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- 2 Comparison Results
 - $\Delta H = 1 \times$ IADC Formula
 - $\Delta H = 2 \times$ IADC Formula
 - $\Delta H = 3 \times$ IADC Formula
- 3 Conclusions



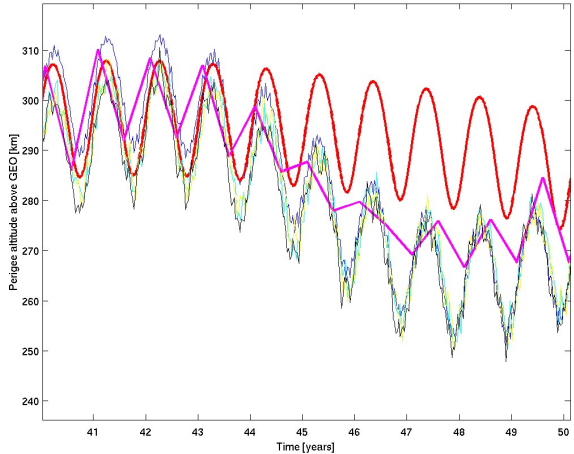
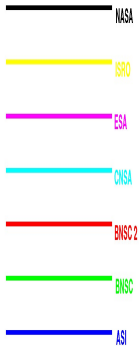
$$\Delta H = 1, \text{ S.P.A.} = 0^\circ, e = 0.005$$



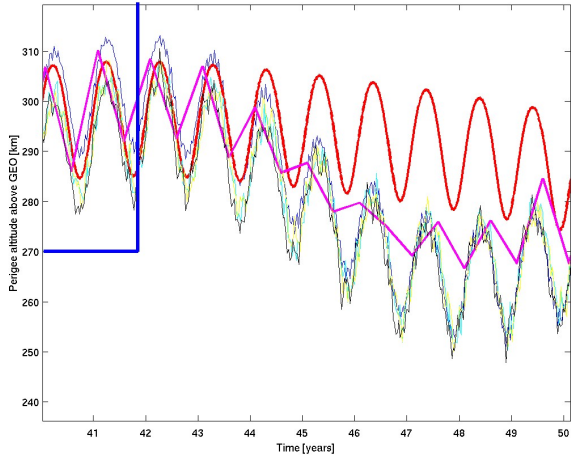
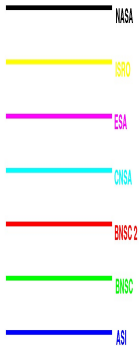
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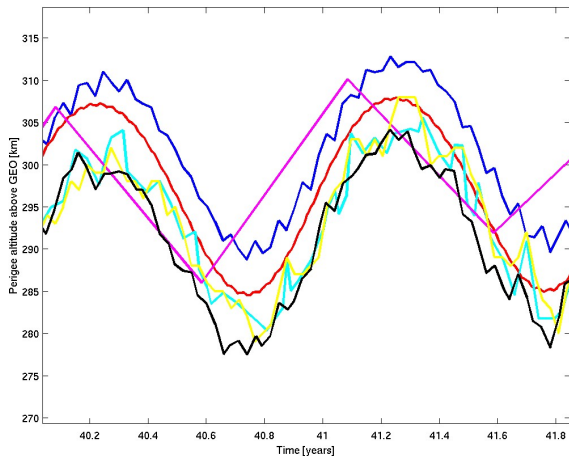
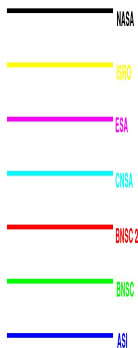
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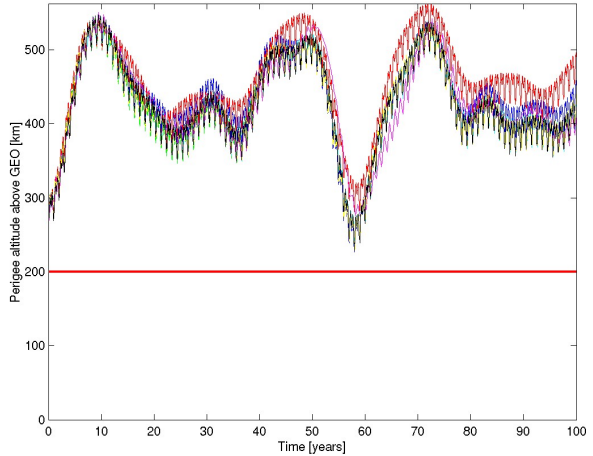
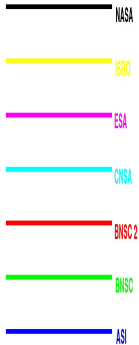
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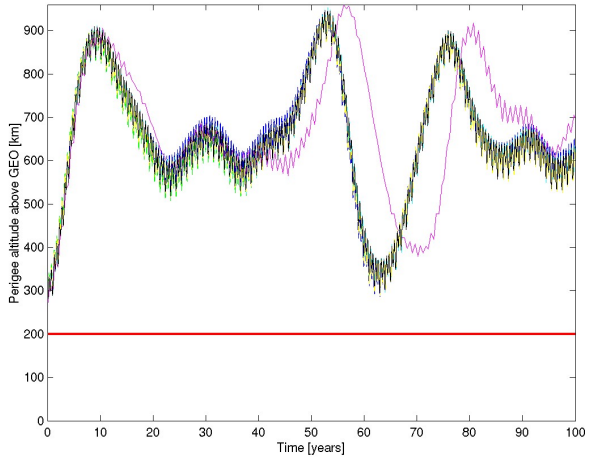
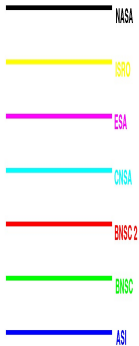
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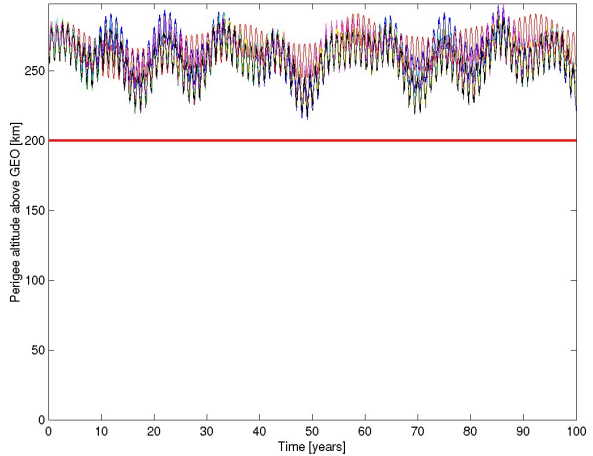
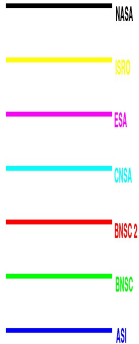
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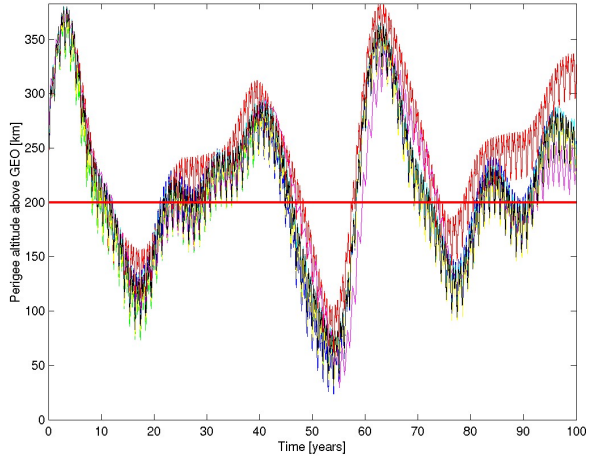
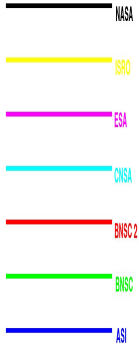
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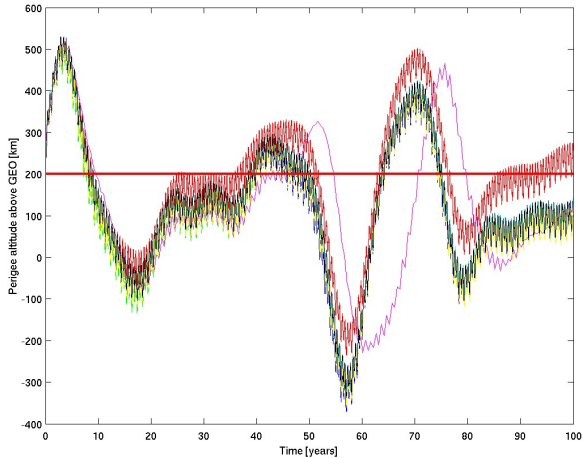
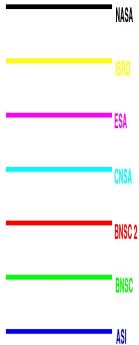
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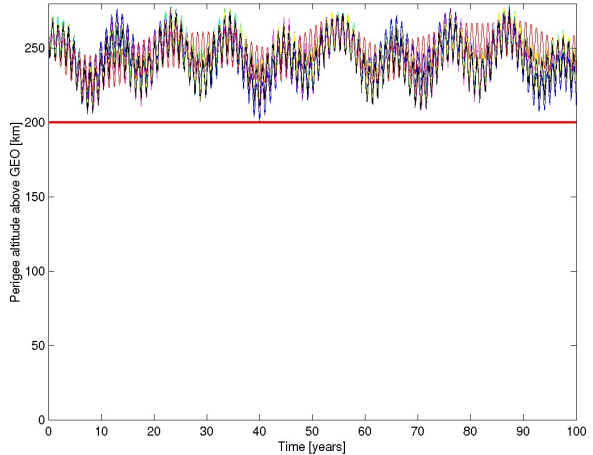
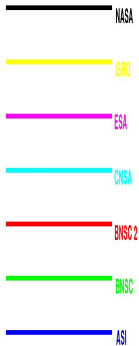
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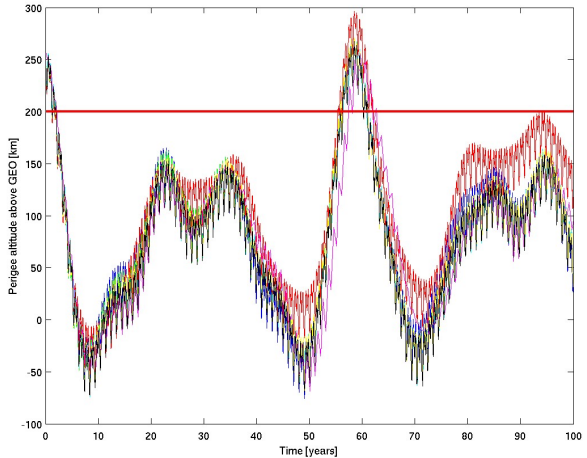
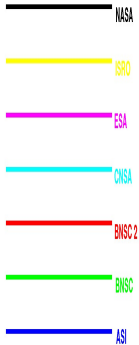
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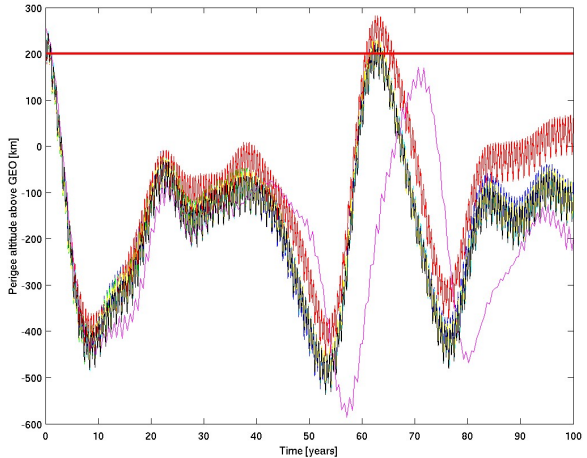
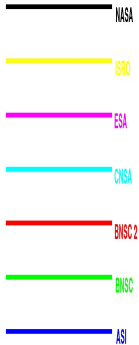
$$\Delta H = 1, \text{ S.P.A.} = 90^\circ, e = 0.005$$



$$\Delta H = 1, \text{ S.P.A.} = 90^\circ, e = 0.05$$



$$\Delta H = 1, \text{ S.P.A.} = 90^\circ, e = 0.1$$



Summary of the $\Delta H = 1$ cases:

- 1 Sun Pointing Angle = $0^\circ \implies$ ALL OK
- 2 Sun Pointing Angle = 45° :
 - Eccentricity = 0.005 \implies OK
 - Eccentricity = 0.05 \implies **CROSSES PROTECTED REGION AFTER $\approx 15y$**
 - Eccentricity = 0.1 \implies **CROSSES AFTER $\approx 10y$**
- 3 Sun Pointing Angle = 90° :
 - Eccentricity = 0.005 \implies OK
 - Eccentricity = 0.05 \implies **CROSSES AFTER $\approx 4y$**
 - Eccentricity = 0.1 \implies **CROSSES AFTER $\approx 1y$**

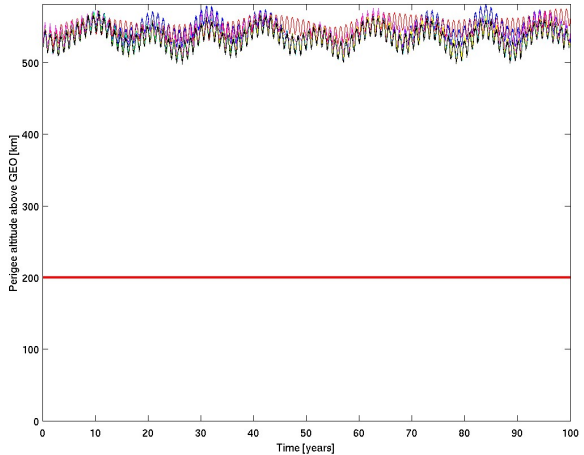
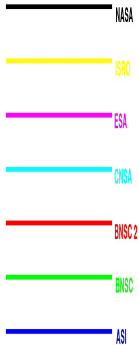


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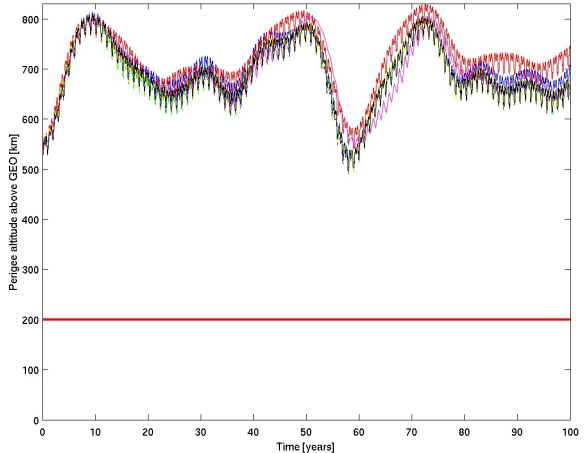
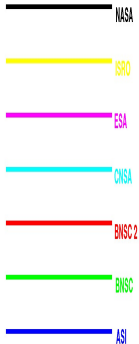
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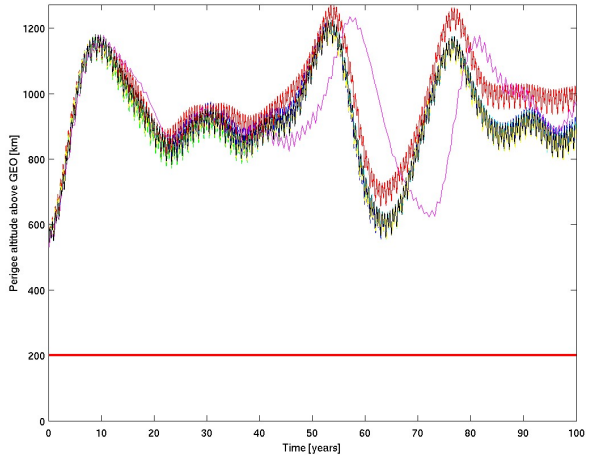
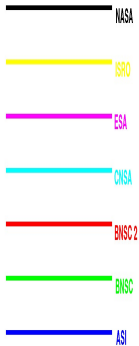
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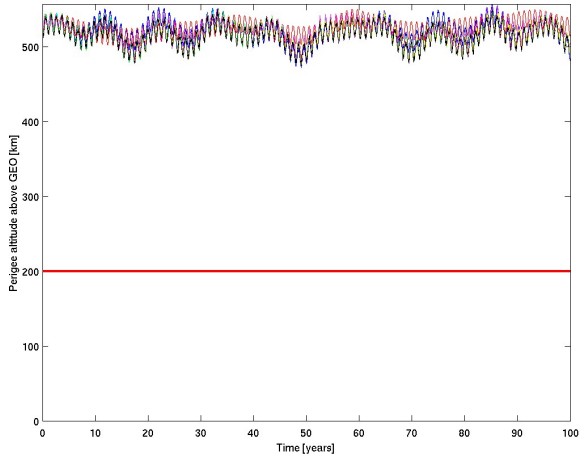
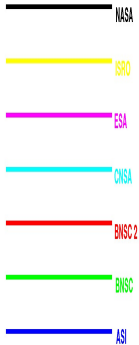
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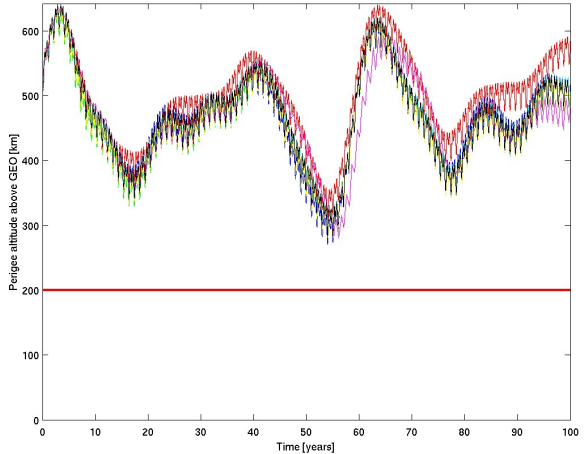
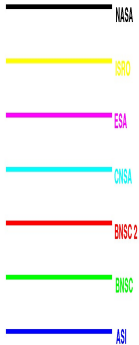
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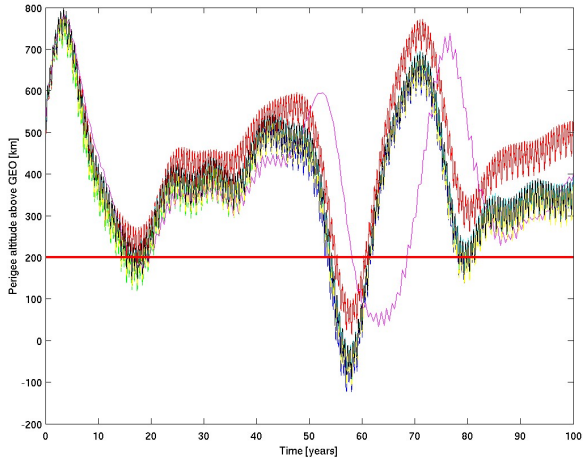
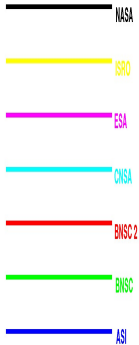
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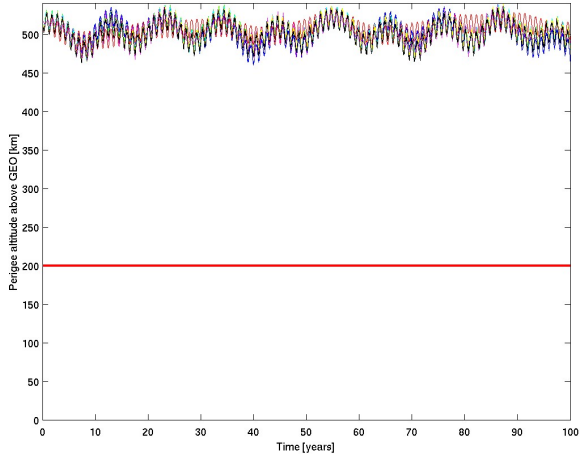
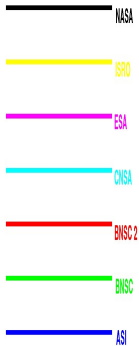
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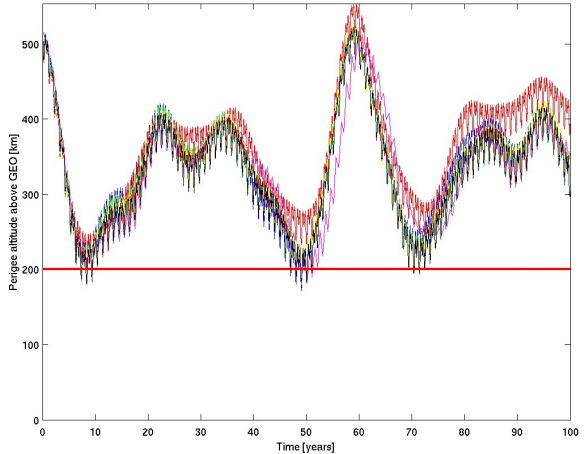
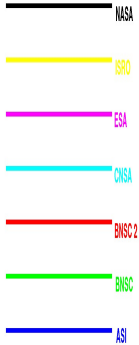
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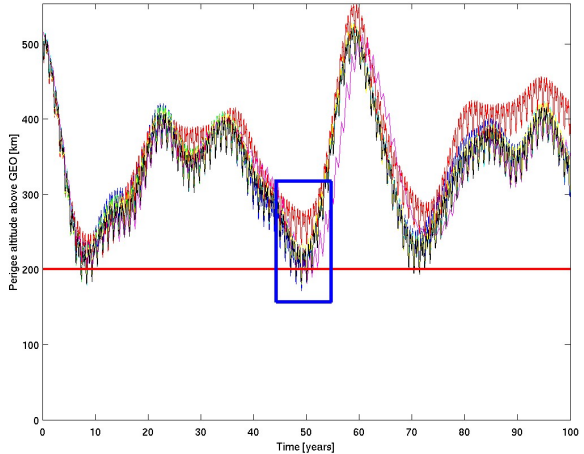
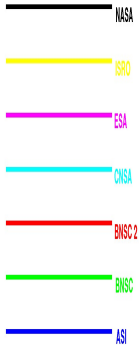
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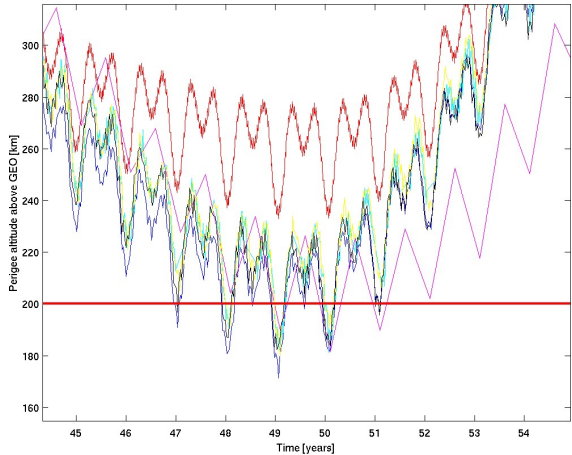
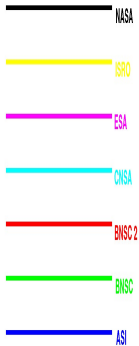
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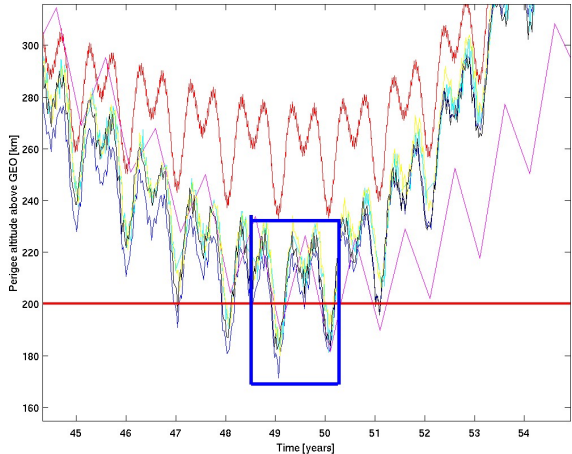
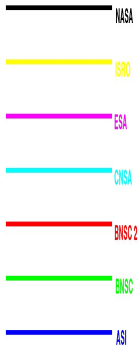
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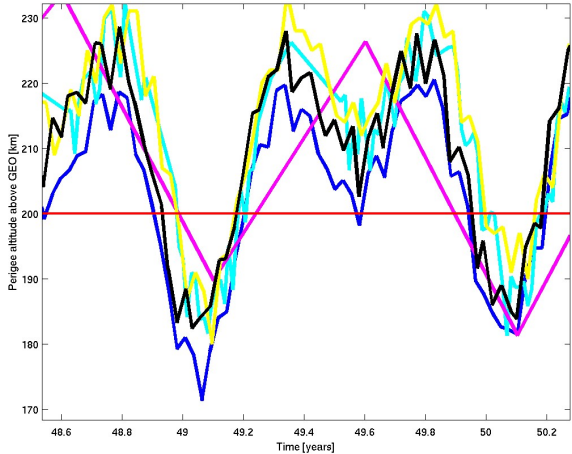
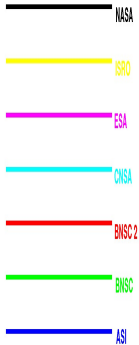
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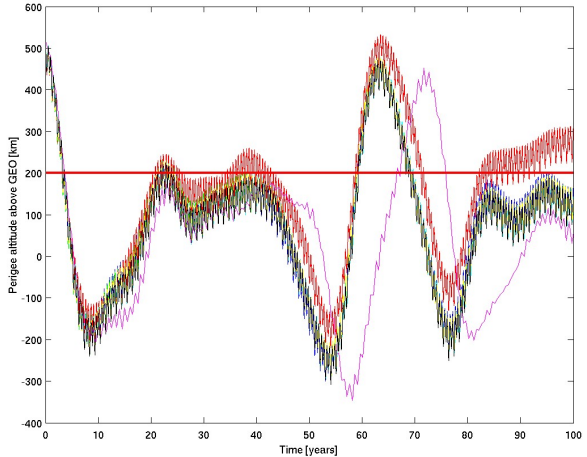
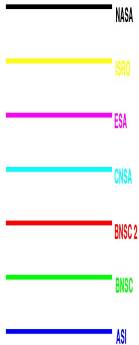
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$\Delta H = 2$, S.P.A. = 90° , $e = 0.05$



$$\Delta H = 2, \text{ S.P.A.} = 90^\circ, e = 0.1$$



Summary of the $\Delta H = 2$ cases:

- 1 Sun Pointing Angle = $0^\circ \implies$ ALL OK
- 2 Sun Pointing Angle = 45° :
 - Eccentricity = 0.005 \implies OK
 - Eccentricity = 0.05 \implies OK
 - Eccentricity = 0.1 \implies **CROSSES AFTER $\approx 15y$**
- 3 Sun Pointing Angle = 90° :
 - Eccentricity = 0.005 \implies OK
 - Eccentricity = 0.05 \implies **CROSSES AFTER $\approx 8y$**
 - Eccentricity = 0.1 \implies **CROSSES AFTER $\approx 5y$**

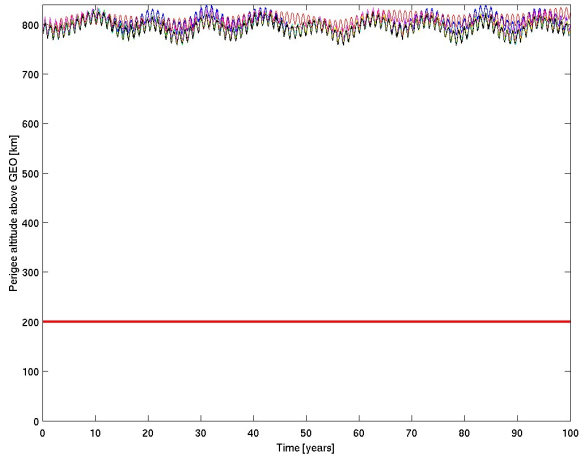
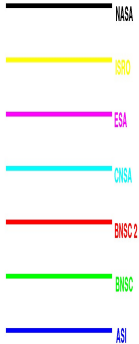


Outline

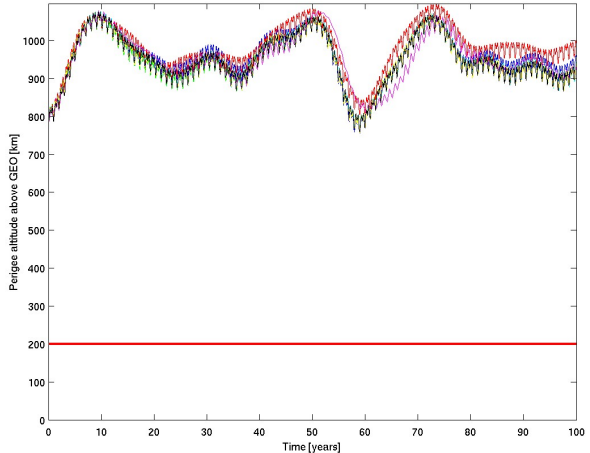
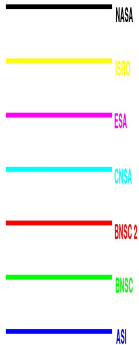
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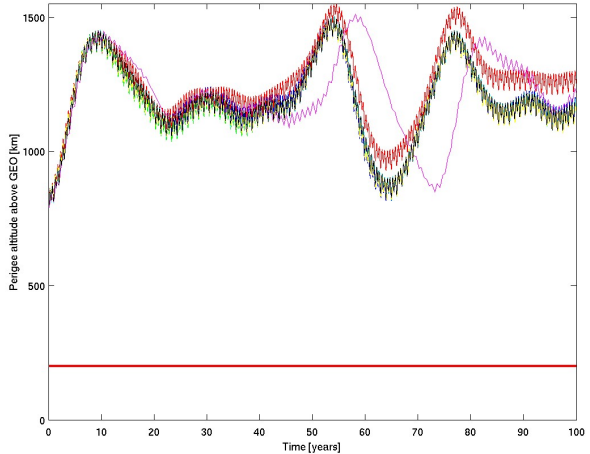
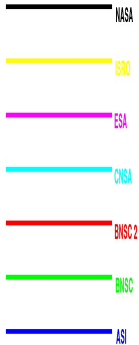
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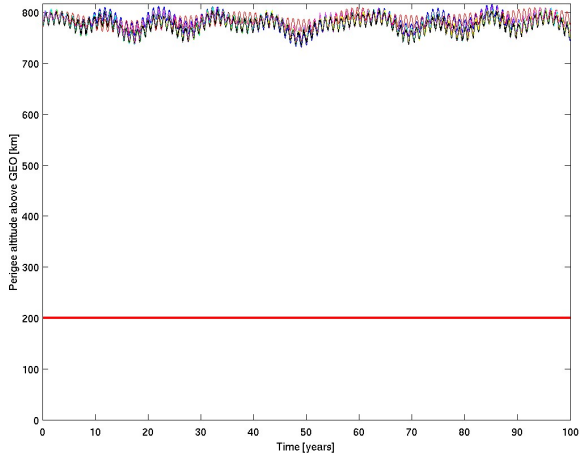
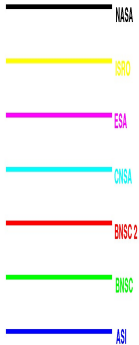
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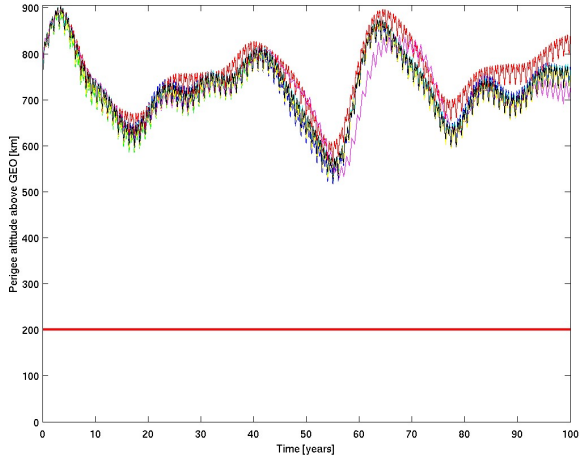
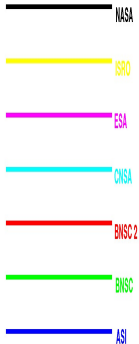
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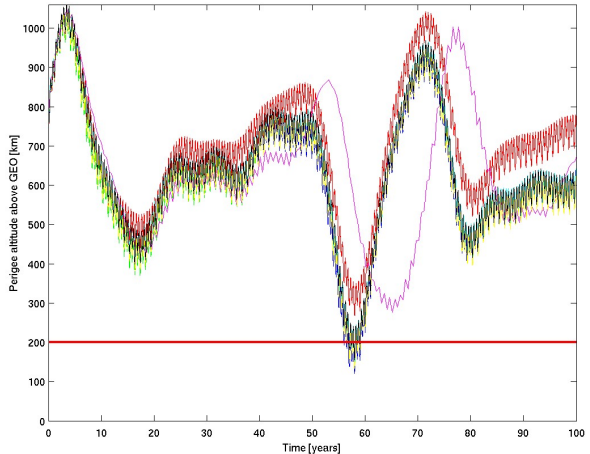
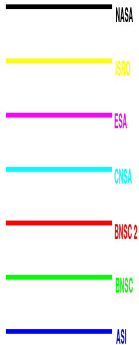
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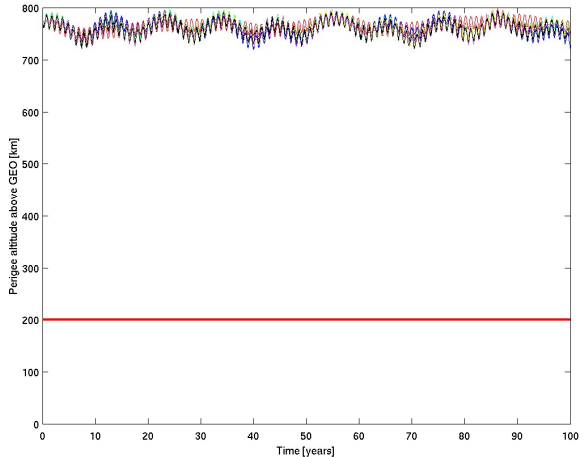
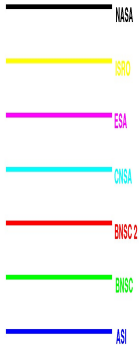
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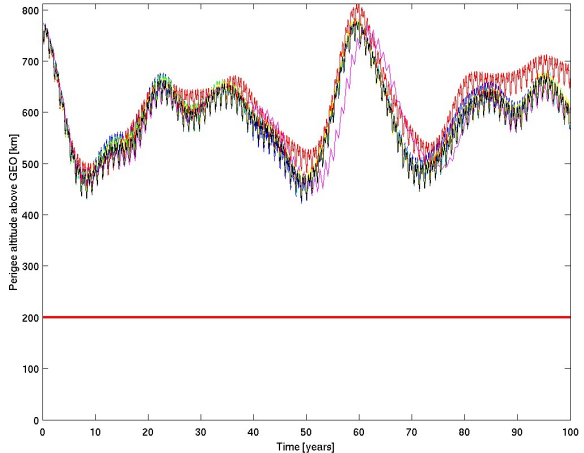
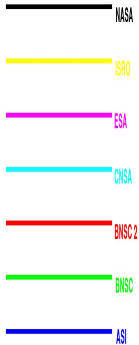
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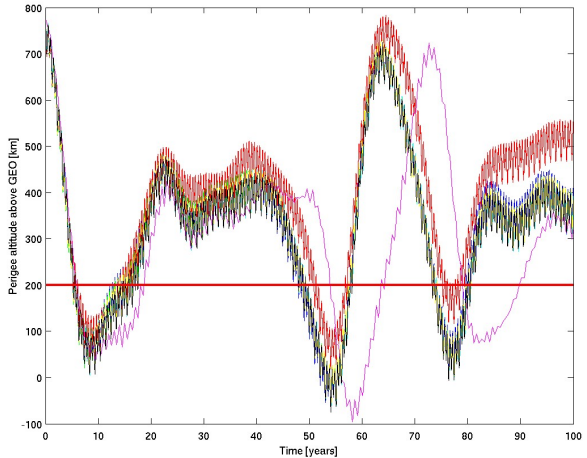
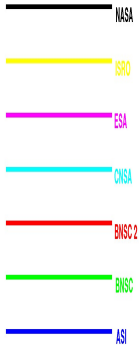
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$$\Delta H = 3, \text{ S.P.A.} = 90^\circ, e = 0.05$$



$$\Delta H = 3, \text{ S.P.A.} = 90^\circ, e = 0.1$$



Summary of the $\Delta H = 3$ cases:

- 1 Sun Pointing Angle = $0^\circ \implies$ ALL OK
- 2 Sun Pointing Angle = 45° :
 - Eccentricity = 0.005 \implies OK
 - Eccentricity = 0.05 \implies OK
 - Eccentricity = 0.1 \implies **CROSSES AFTER** $\approx 55y$
- 3 Sun Pointing Angle = 90° :
 - Eccentricity = 0.005 \implies OK
 - Eccentricity = 0.05 \implies OK
 - Eccentricity = 0.1 \implies **CROSSES AFTER** $\approx 7y$

Conclusions

DISCLAIMER

The following slide is **not** intended as a recommendation to the WG 4 concerning the Guidelines!!!

It is just a summary of the findings **out of the 27 cases selected.**



Conclusions

- There is a remarkable consensus between the results of the different groups, in nearly all the cases examined.
- Whenever the perigee vector is pointing to the Sun direction, the disposal orbits never cross the GEO region, for every value of the altitude displacement and of the initial eccentricity.
- Disposal orbits with initial eccentricity of 0.005° never cross the GEO region, for every value of the altitude displacement and of the Sun Pointing Angle.
- A part from the cases with $\text{SPA} = 0^\circ$, an initial eccentricity of 0.1° never satisfies the non-crossing constraints.
- Sun Pointing Angle and eccentricity control appear more effective than altitude displacement increase in assuring no-crossing in the long term.

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Appendix Outline

4 Appendix

Study parameters

IADC Formula, ΔH_{IADC}

$$\Delta H_{IADC} = 235 + 1000 \times C_R \times \frac{A}{M}$$

Which means that in our cases we have:

- 1 $\Delta H_1 = 259$ km
- 2 $\Delta H_2 = 518$ km
- 3 $\Delta H_3 = 777$ km

◀ Return

