



Application of IADC and UN Orbital Debris Mitigation Guidelines to Galileo

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REFERENCES



- [1] Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines, rev.1, September 2007.
- [2] United Nations Space Debris Mitigation Guidelines.
- [3] Space Systems – Space Debris Mitigation Requirements ISO 24113:2011, 5 May 2011.
- [4] Adoption Notice of ISO 24113. ECSS-U-AS-10C, February 10, 2012.
- [5] Space Debris Mitigation Policy for Agency Projects, ESA/ADMIN/IPOL(2014)2, 28 March 2014.
- [6] ESA Space Debris Mitigation Compliance Mitigation Guidelines, ESSB-HB-U-002, 19 February 2015.
- [7] REORBITING OF SATELLITES IN HIGH ALTITUDES, R. Jehn et al, 5th European Space Debris Conference, 2009.
- [8] MEO DYNAMICS AND GNSS DISPOSAL STRATEGIES, A. Rossi et al, 7th European Space Debris Conference, 2017.
- [9] LONG-TERM IMPLICATIONS OF GNSS DISPOSAL STRATEGIES FOR THE SPACE DEBRIS ENVIRONMENT. R. Domínguez-González et al, 7th European Space Debris Conference, 2017.

BACKGROUND

Orbital debris mitigation guidelines and requirements of relevance to Galileo are addressed in:

- IADC guidelines [1]
- UN guidelines [2]

Guidelines above are reflected (with more detail) in international standards:

- ISO [3]
- ECSS [4]

Complemented with ESA-level documents:

- ESA Policy documents on Orbit Debris Mitigation [5]
- ESA Space Debris Mitigation Compliance Mitigation Guidelines [6]

IADC ODM GENERAL GUIDELINES



- Topics/Areas addressed:
 - a) Limit debris released during normal operations
 - b) Minimise the potential for on-orbit break-up
 - c) Post mission disposal
 - d) Prevention of on-orbit collision
- Requirements aimed to minimize the occurrence of a), b) and d) are generic and do not depend of the type of orbit.
- Guidelines for post-mission disposal depend on type of orbit and aim to minimize the effects in the protected regions (GEO, LEO).

POST-MISSION DISPOSAL GUIDELINES

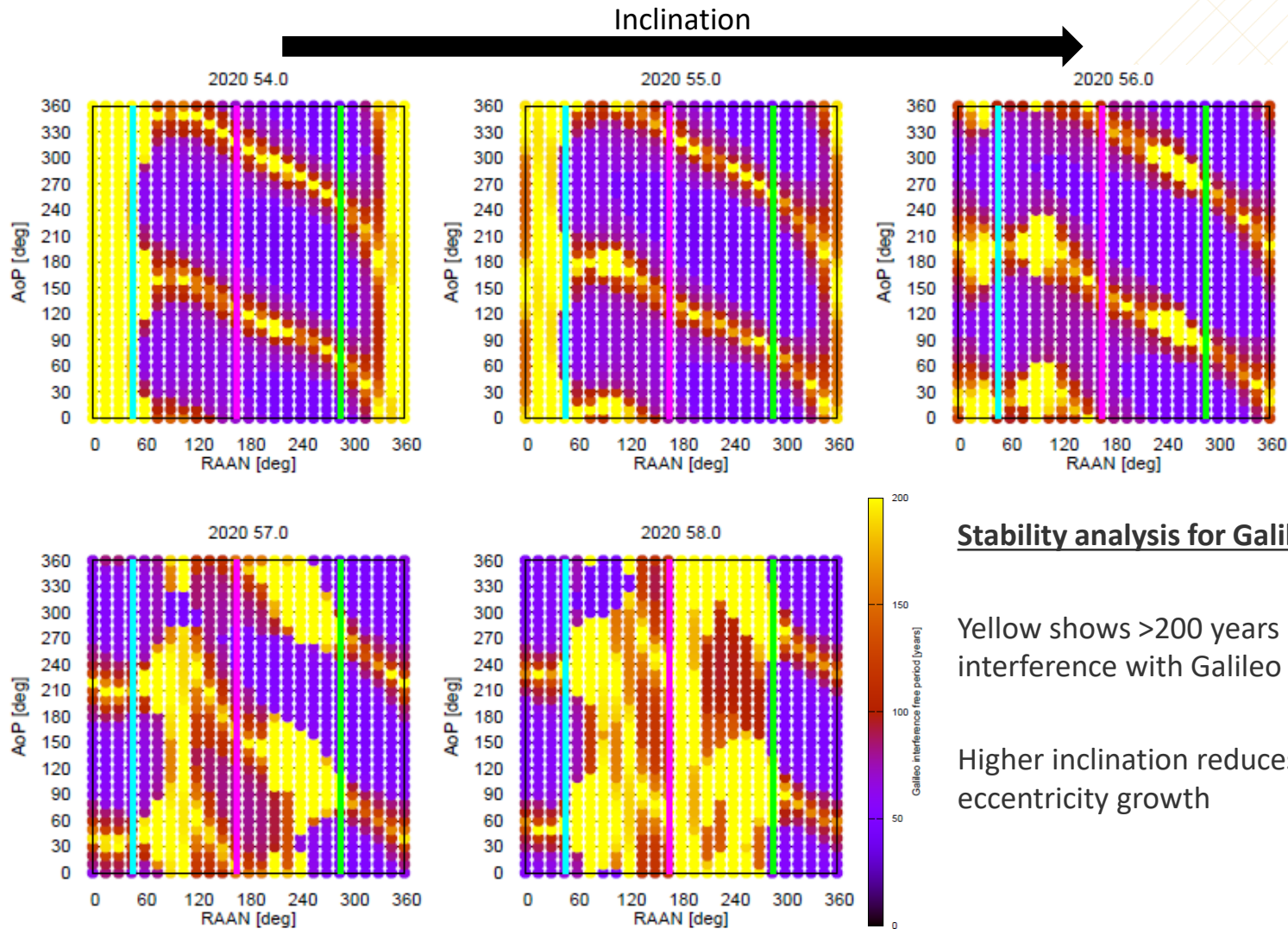
- Relevant to launch vehicle upper stages and EoL spacecraft.
- IADC guidelines:
 - Disposal orbits should avoid GEO protected area
 - Disposal orbits should minimize period of crossing through LEO protected area (25 years, reasonable number)
- ISO/ECSS standard and ESA guidelines provides further specific guidance:
 - Disposal orbit not to intersect GEO protected area, ever or at least for 100 years.
- Above guideline is being followed by Galileo adapted to the MEO case:
 - In general, disposal orbit defined above the Galileo orbit.
 - For some launch vehicle orbital stages, disposal below Galileo orbit.

GALILEO APPLICATION OF ODM GUIDELINES (1/4)



- Sufficient propellant allocated at satellite EoL for:
 - raising orbit to, as minimum, 300 km above the Galileo Orbit
 - target small eccentricity and optimum argument of perigee to **minimize eccentricity growth**
- The satellites are expected to have much more propellant available at the EoL. The extra propellant will be used to extend the time of non-interference with the Galileo constellation:
 - Further increasing semi-major axis
 - Changing inclination to further minimize the eccentricity growth

GALILEO APPLICATION OF ODM GUIDELINES (2/4)



Stability analysis for Galileo+300 km

Yellow shows >200 years no interference with Galileo orbit

Higher inclination reduces eccentricity growth

GALILEO APPLICATION OF ODM GUIDELINES (3/4)



- Disposal of Soyuz/Fregat Launcher upper stages of GIOVE-A (Dec 2005) and GIOVE-B (May 2008) followed this principle:
 - Semi-major axis 300 km above Galileo
 - Eccentricity as small as allowed by the accuracy of GNC
- GIOVE-A was graveyarded in 2009 (+150 km, no crossing of Galileo altitude for 200y)
- GIOVE-B was raised by 600 km, inclination slightly changed taking advantage of the excess propellant.
- First two Galileo IOV launches (Oct 2011, and Oct 2012), and five first FOC launches (Aug 2014* to May 2016), all on Soyuz/Fregat, also targeted a disposal orbit 300 km above Galileo for the launcher upper stage.
- Ariane-5 EPS upper stages are 300 km below Galileo. The achieved disposal orbits ensure no crossing of Galileo altitude for at least 40 years (> 100 years in some cases)

* First FOC launch in Aug 2014 had a launch vehicle failure and satellites and launch vehicle orbital stage were left on a degraded orbit

GALILEO APPLICATION OF ODM GUIDELINES (4/4)

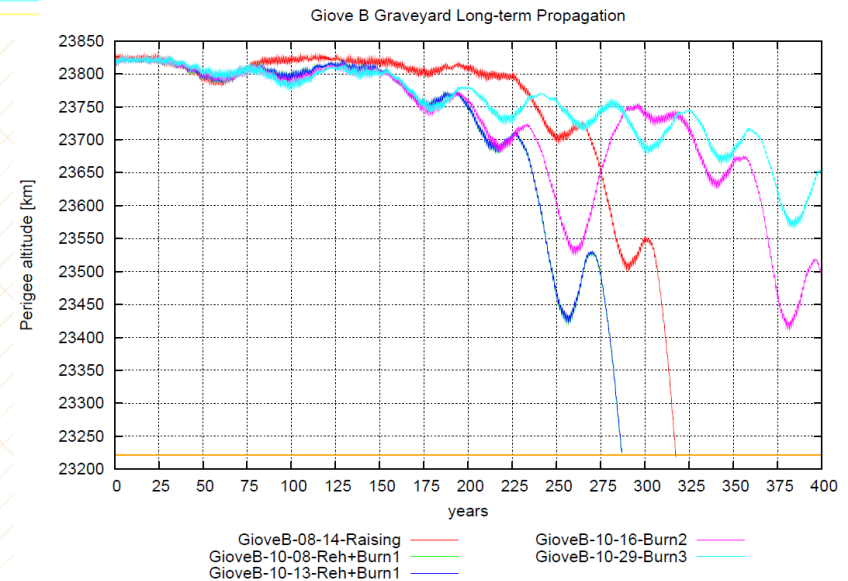
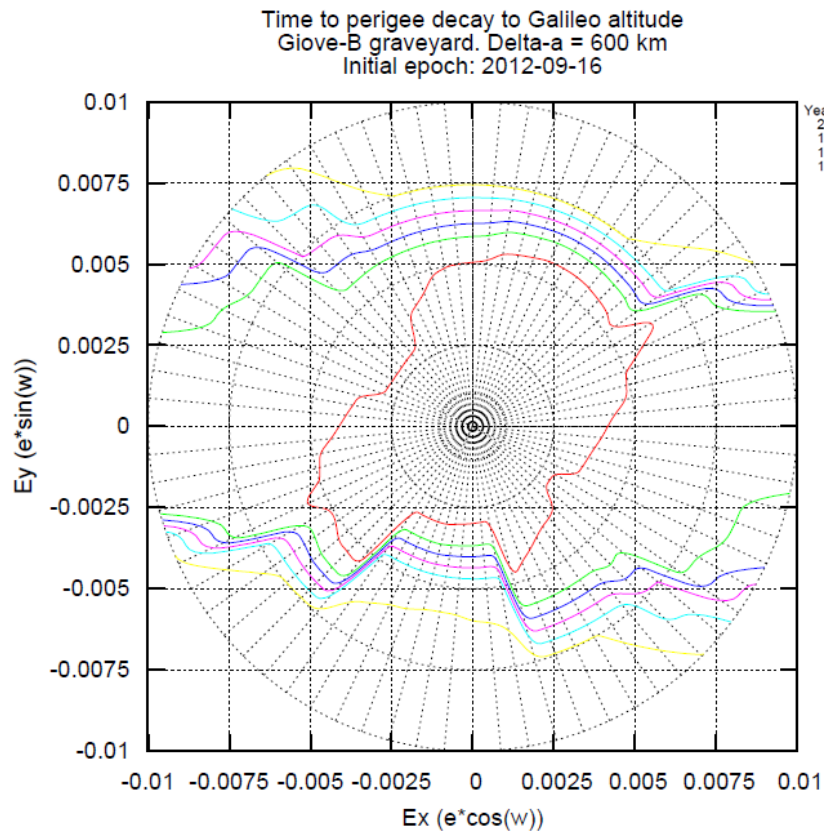
- Giove-B graveyarding operational example

Prior to disposal - Analysis to define target region for minimum eccentricity growth

Long term orbit evolution at intermediate stages during the disposal manoeuvres

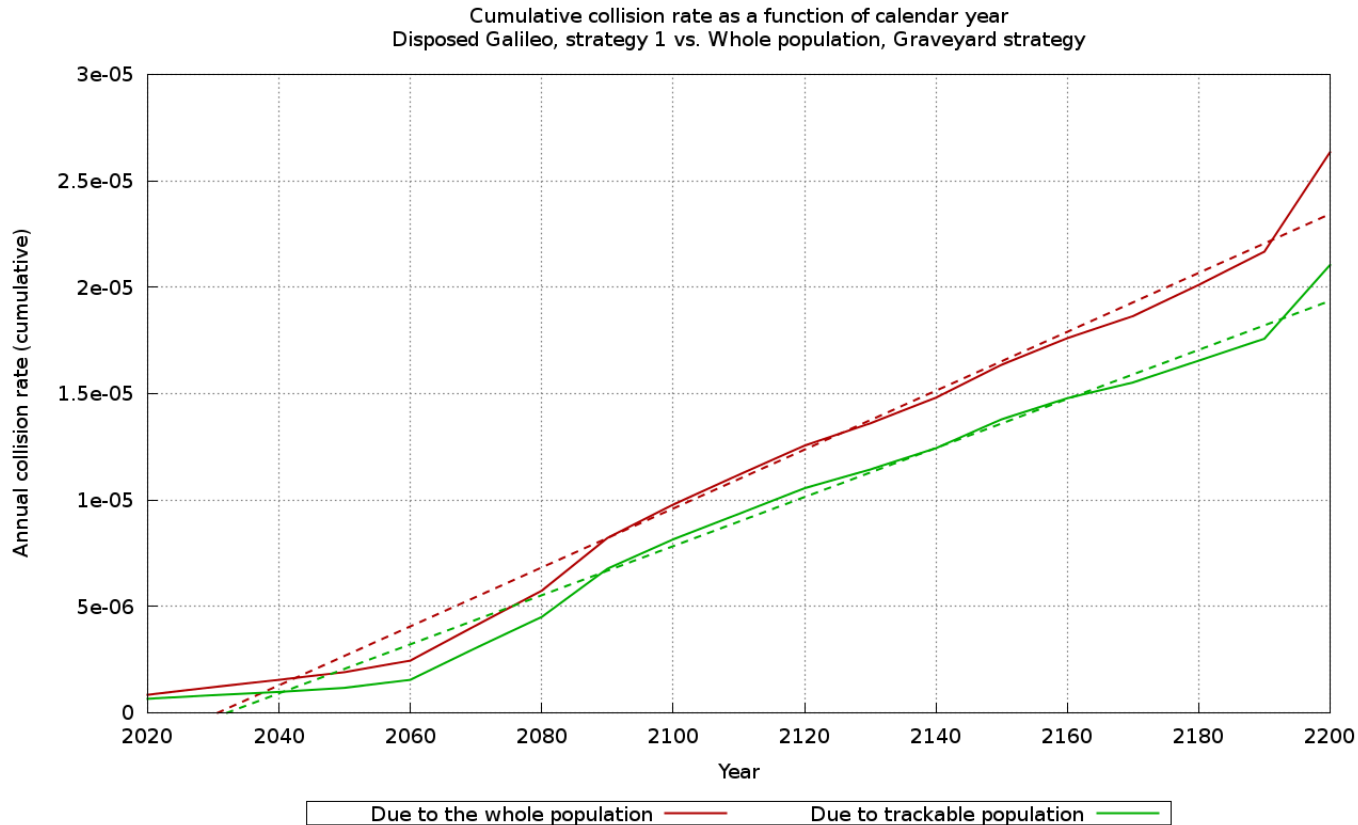
Achieved >400 years no interference with Galileo

Much longer to interfere with GEO/LEO



COLLISION RISK FOR DISPOSED GALILEO S/C

S/C disposed in min. eccentricity growth orbit
MEO Debris Population extrapolated ~180 years into the future



CONCLUSIONS

- Galileo (launcher and satellite) current disposal strategy is based on a graveyard orbit at a, preferably, higher altitude than nominal orbit and with minimum eccentricity growth.
 - Applies to satellites and launcher upper stages
- Alternative disposal based on maximum eccentricity growth targeting re-entry in less than 100 years with similar or lower collision risk
 - under study by several researchers (e.g ESA, academia)
 - might be of interest if larger Delta-V is available for graveyarding