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 all, 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

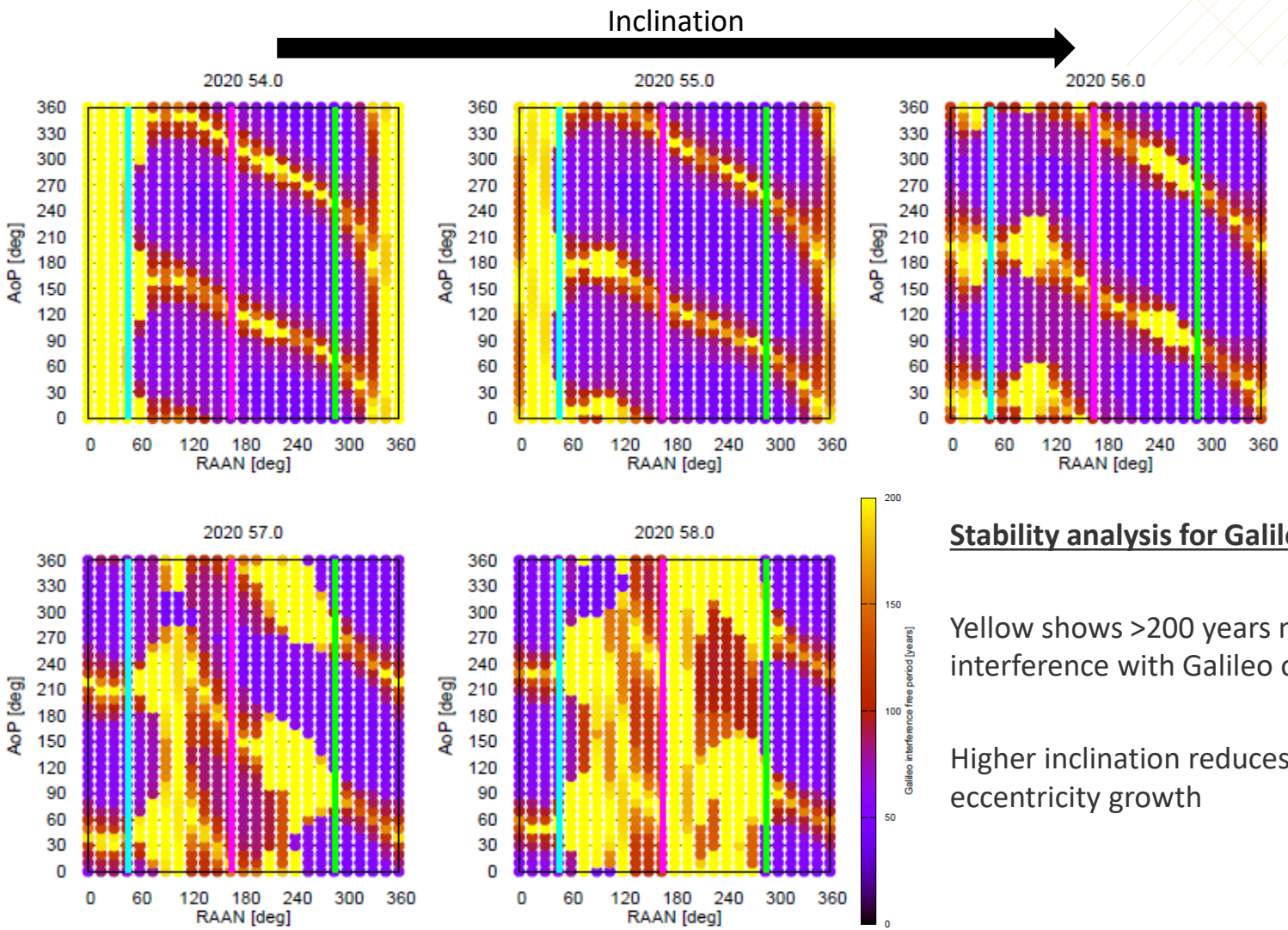
- Relevant to launch vehicle upper stages and EoL spacecraft.
- IADC guidelines:
  - Disposal orbits should avoid GEO protected area
  - Disposal orbits should minimize period of crossing through LEO protected area (25 years, reasonable number)
- ISO/ECSS standard and ESA guidelines provides further 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.

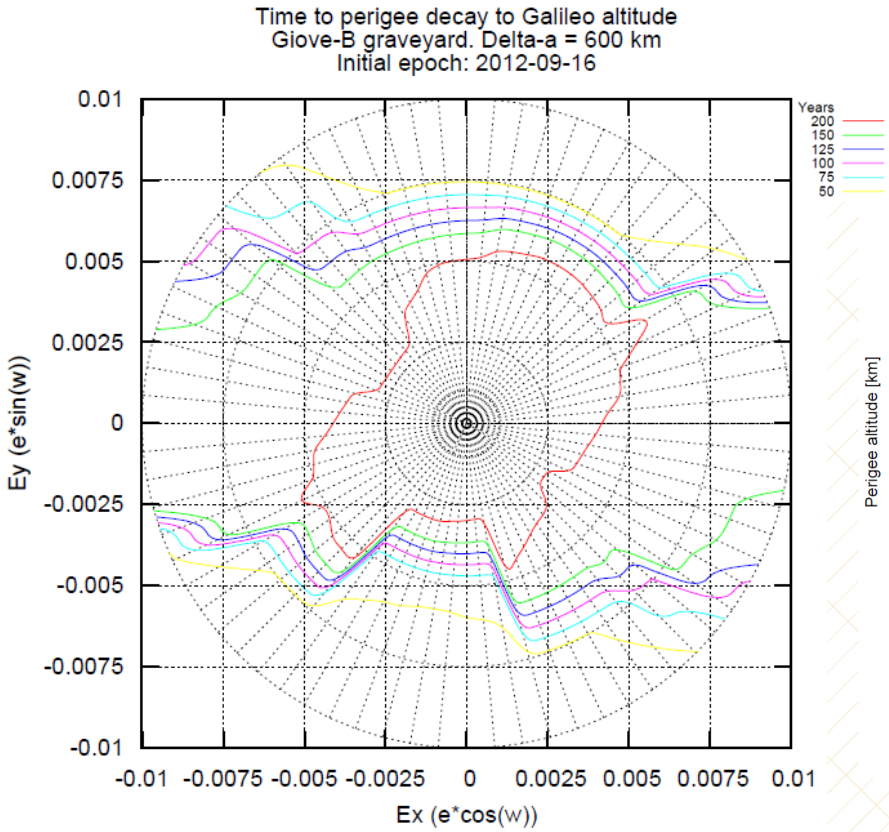
- Ariane-5 EPS upper stages are 300 km below Galileo. The achieved disposal orbits ensure no crossing of Galileo altitude for at least 40 years (> 100 years in some cases)

* 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

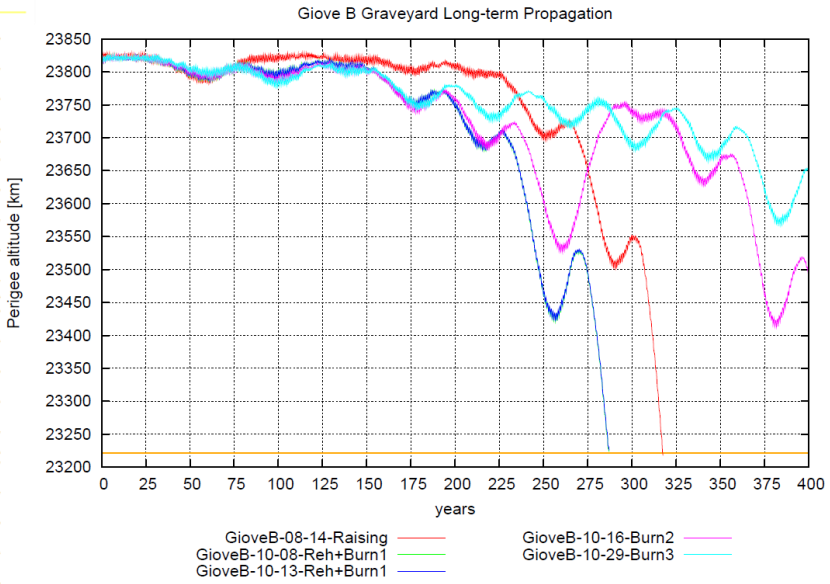
Prior to disposal - Analysis to define target region for minimum eccentricity growth



Long term orbit evolution at intermediate stages during the disposal manoeuvres

Achieved >400 years no interference with Galileo

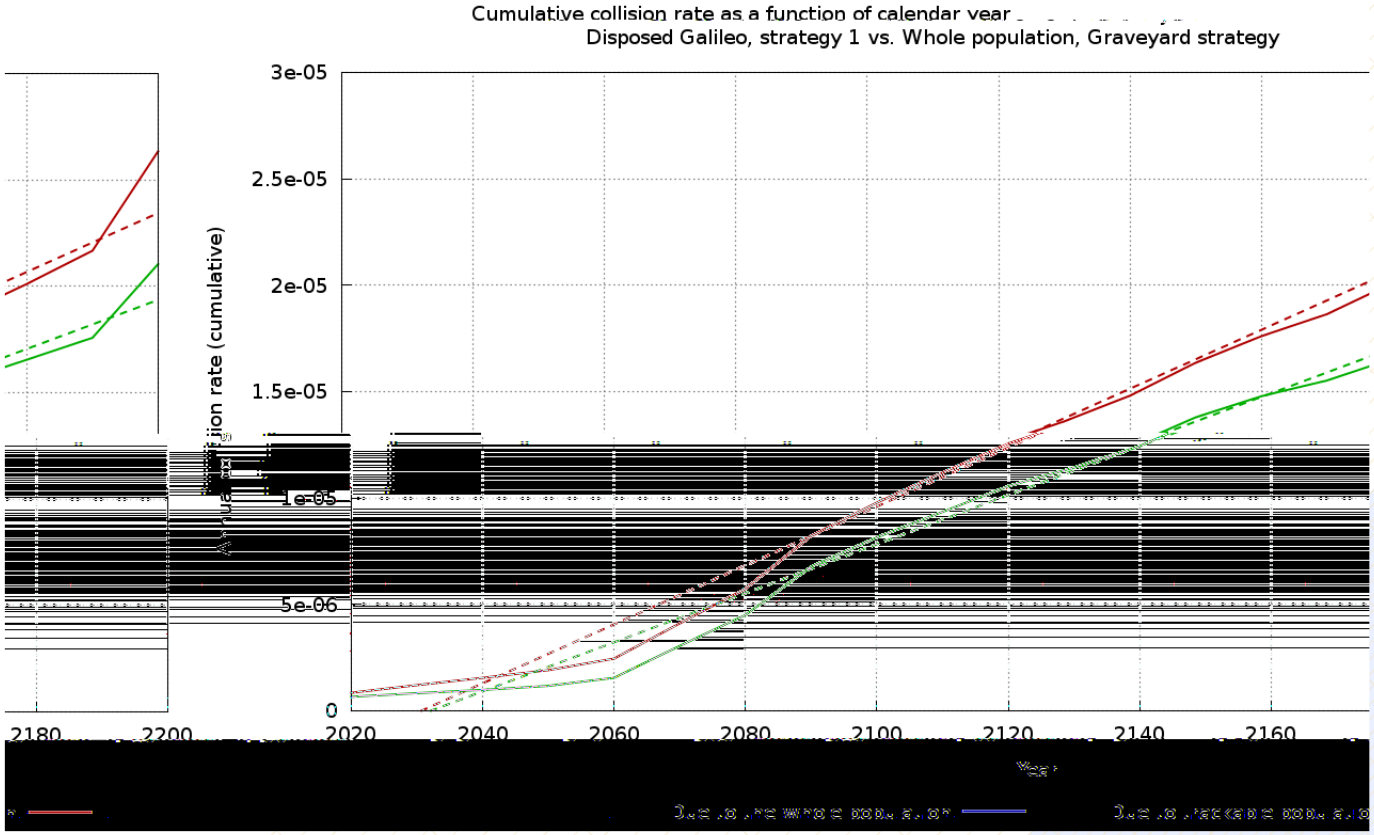
Much longer to interfere with GEO/LEO



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