# IGSO De-orbit Way

# and

# GEO Protected Region

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## Contents

# IGSO De-orbit Way and GEO Protected Region

## 1. Introduction

In the previous meeting at Nov. 2019, this presentation proposed the work flow to seek the appropriate solution for the current possible issues between the de-orbit and operation area of LEO, GEO and IGSO.

After receiving helpful comments at the meeting, this subject aimed the issues between GEO protected region and IGSO disposal, and searched other organization's activities by following Step3 and Step4 which were proposed at the previous meeting.

Step3: to confirm other organizations' activities similar to this work

Step4: to discuss the expected issues with other organizations and to cooperate in order to seek the appropriate solution

## 2. Purpose

Fortunately, other organization(*1)'s activities similar to this subject were introduced and they accepted the opportunity to cooperate for this subject. (*1: CNR: National Research Council)

As a result, this material hopes to introduce the possibility of the alternative disposal methods of inclined GEO satellites (IGSO) and propose to discuss the possibility regarding modification of current GEO disposal guidelines.

## 3. Current possible issues between GEO protected region and IGSO disposal

### 3.1 CNR analysis

CNR analysis shows the disposal issues of inclined GEO satellites (IGSO) relating to the inclination.

When i<30 degrees, it is always possible to avoid a significant eccentricity growth over 200 years, irrespective of the other initial conditions (i.e. epoch, right ascension of the ascending node and argument of perigee).

The current disposal guideline might be practical up to i=30 degrees, with a maximum delta velocity penalty of 11.5 m/s.

## 3. Current possible issues between GEO protected region and IGSO disposal

### 3.1 CNR analysis

Table 1 (*1) shows the initial disposal inclination (i0) and height (h0) to ensure no further interference with the GEO protected region over 200 years by following the current disposal guidelines. Figure 1 (*1) shows the additional delta-velocity as a function of height.

(*1: On the end-of-life disposal of spacecraft and orbital stages operating in inclined geosynchronous orbits Luciano Anselmo, Carmen Pardini)

Table 1

| $h_0$ (km) | $i_0$ |
|---|---|
| 235 | ≤ 2° |
| 285 | ≤ 18° |
| 300 | ≤ 20° |
| 350 | ≤ 26° |
| 400 | ≤ 28° |
| 500 | ≤ 29° |
| 550 | ≤ 30° |

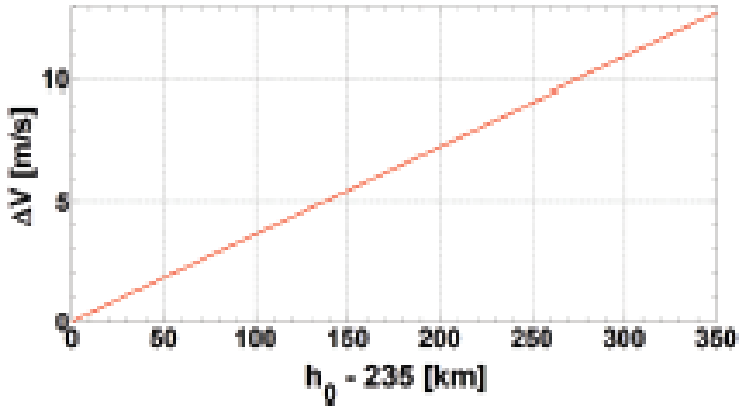


Figure 1

## 3. Current possible issues between GEO protected region and IGSO disposal

### 3.1 CNR analysis

However, when i>30 degrees, it is not possible to define end-of-life disposal strategies and which are also simple, universal and inexpensive at the same time. Reducing the initial inclination and/or changing the initial right ascension of the ascending node of the disposal orbit would of course be far too expensive and unfeasible.

Only specific initial conditions would be able to guarantee a relative stability of the eccentricity.

Certain combinations of the initial conditions (inclination, semi-major axis and eccentricity) lead to a considerable eccentricity growth.

## 3. Current possible issues between GEO protected region and IGSO disposal

# 3.2 MELCO analysis

MELCO introduced the similar issues as CNR analysis by the simulations of QZSS, BeiDou, and NAVIC. The detailed results are shown in Table 2 and the following figure -2, -3, and -4.

- i<30 degrees:

NAVIC, i=29 degrees, can avoid a significant eccentricity growth over 200 years, simply following the current disposal guideline.

- i>30 degrees:

QZSS, i=36~47 degrees, are being planned to be disposed to 3,600 km higher than GEO and that assures to avoid a significant eccentricity growth over 200 years. BeiDou, i=54 degrees, with simulated initial condition leads to a considerable eccentricity growth and interferes the GEO protected region.

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## 3. Current possible issues between GEO protected region and IGSO disposal

### Table 2 Interference Summary

| Figure | IGSO | De-orbit height [km] | RAAN [deg] | Inclination [deg] | Interference in | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | protected region | Operation region | | |
| | | | | | GSO | BeiDou | NAVIC | QZSS |
| 1-7<br>1-8 | QZSS-QZO<br>QZSS-GEO | 3600<br>1920 | 0-360 | 36-47<br>0.05 | No | No | No | No |
| 1-9 | BeiDou | 350 | 189 | 54 | Yes | Yes | Yes | Yes |
| 1-10 | | 350 | 69 | 54 | Yes | Yes | Yes | Yes |
| 1-11 | | 350 | 309 | 54 | Yes | Yes | Yes | Yes |
| 1-12 | | 1000 | 69 | 54 | Yes | Yes | Yes | Yes |
| 1-13 | NAVIC | 350 | 70 | 29 | No | No | No | Yes |
| 1-14 | | 350 | 190 | 29 | No | No | No | Yes |
| 1-15 | | 350 | 310 | 29 | No | No | No | Yes |
| 1-16 | | 2000 | 310 | 29 | No | No | No | Yes |

# IGSO De-orbit Way and GEO Protected Region

## 3. Current possible issues between GEO protected region and IGSO disposal

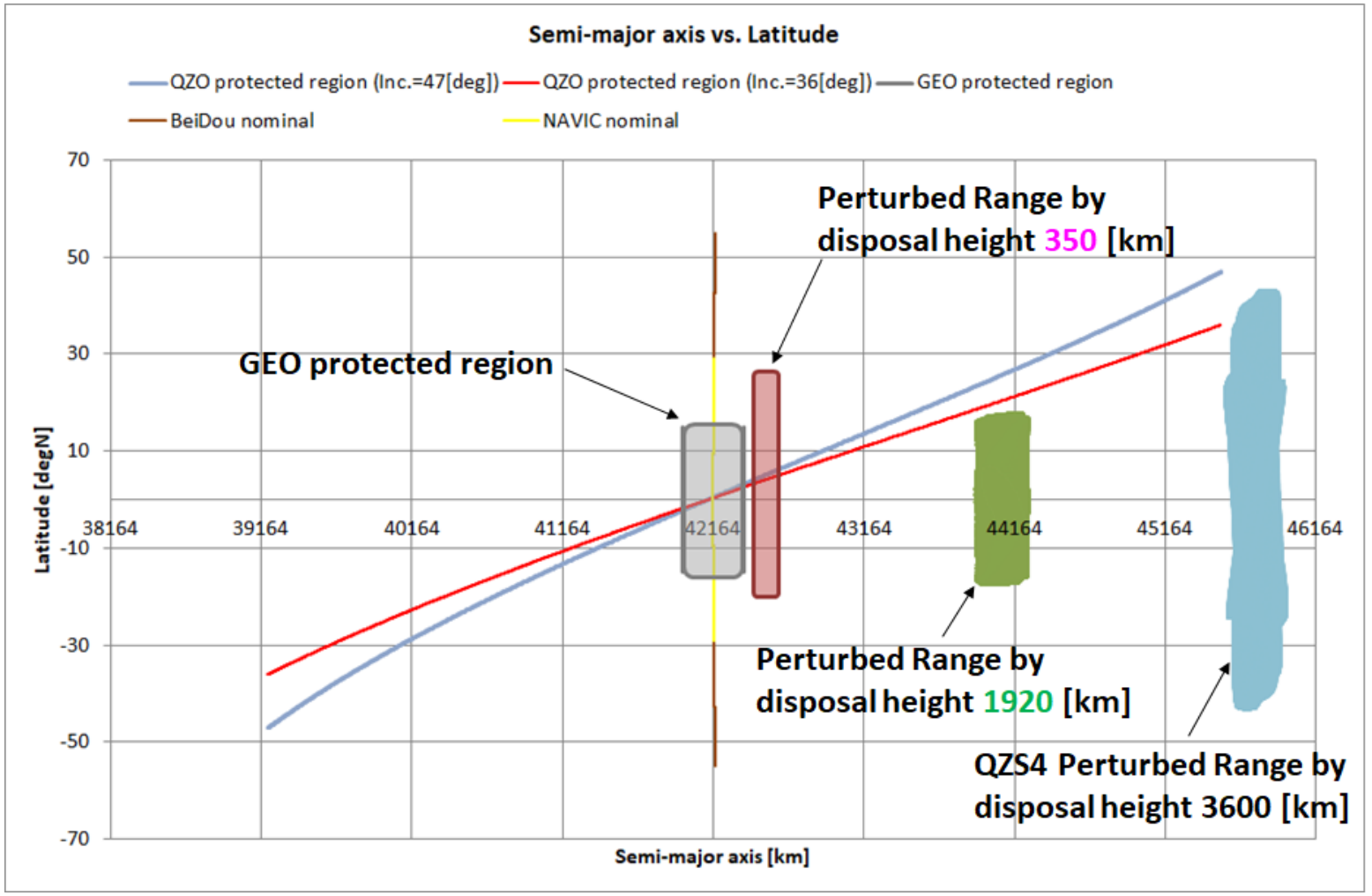


Fig 2 (=Fig.1-7 in Table 2) QZS4 Disposal Orbit Height 3600km and Perturbed Range during 100 years

# IGSO De-orbit Way and GEO Protected Region

## 3. Current possible issues between GEO protected region and IGSO disposal

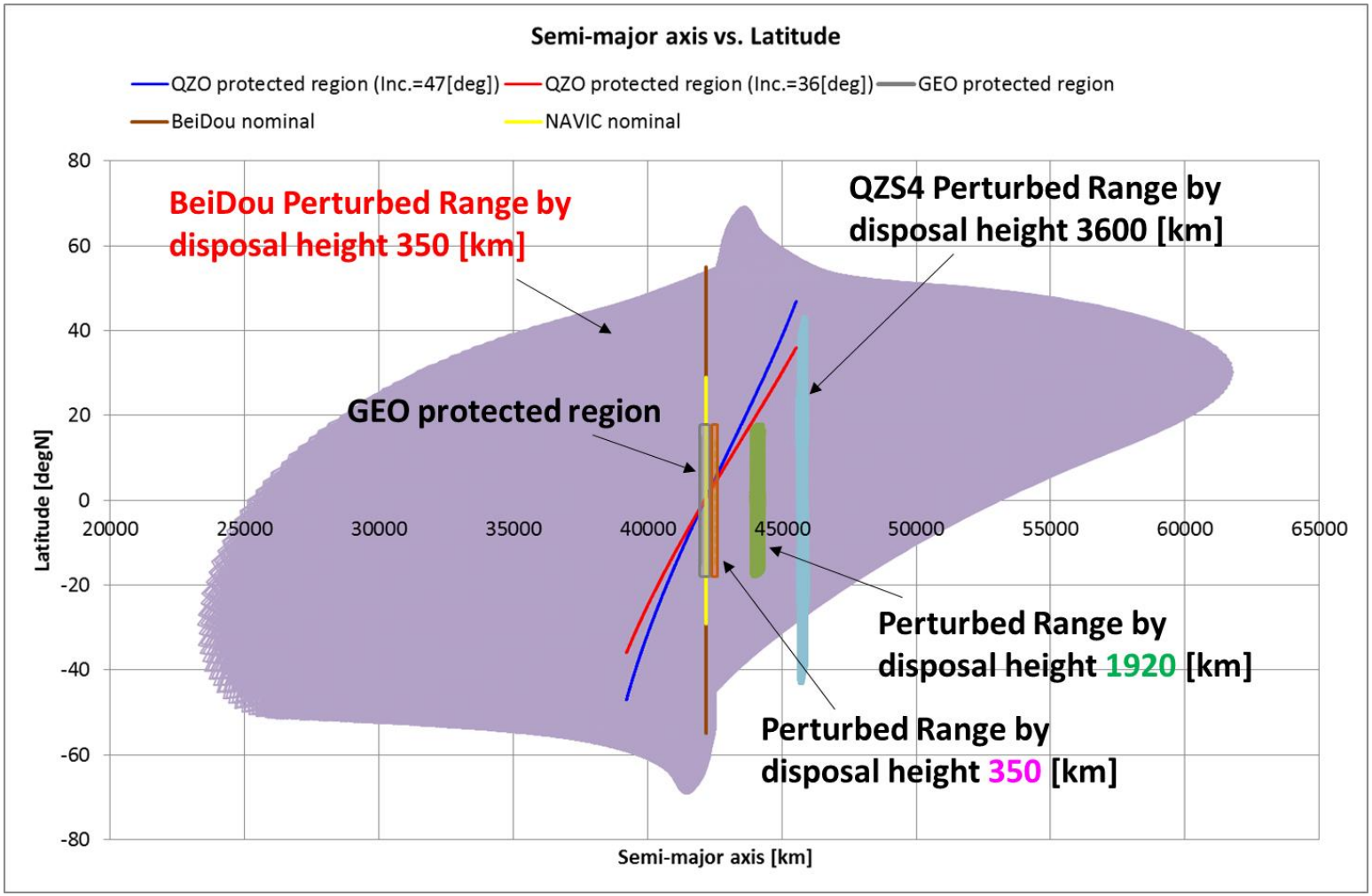


Fig.3 (=Fig.1-9 in Table 2) BeiDou Disposal Orbit Height 350km and Perturbed Range during 100 years

# IGSO De-orbit Way and GEO Protected Region

## 3. Current possible issues between GEO protected region and IGSO disposal

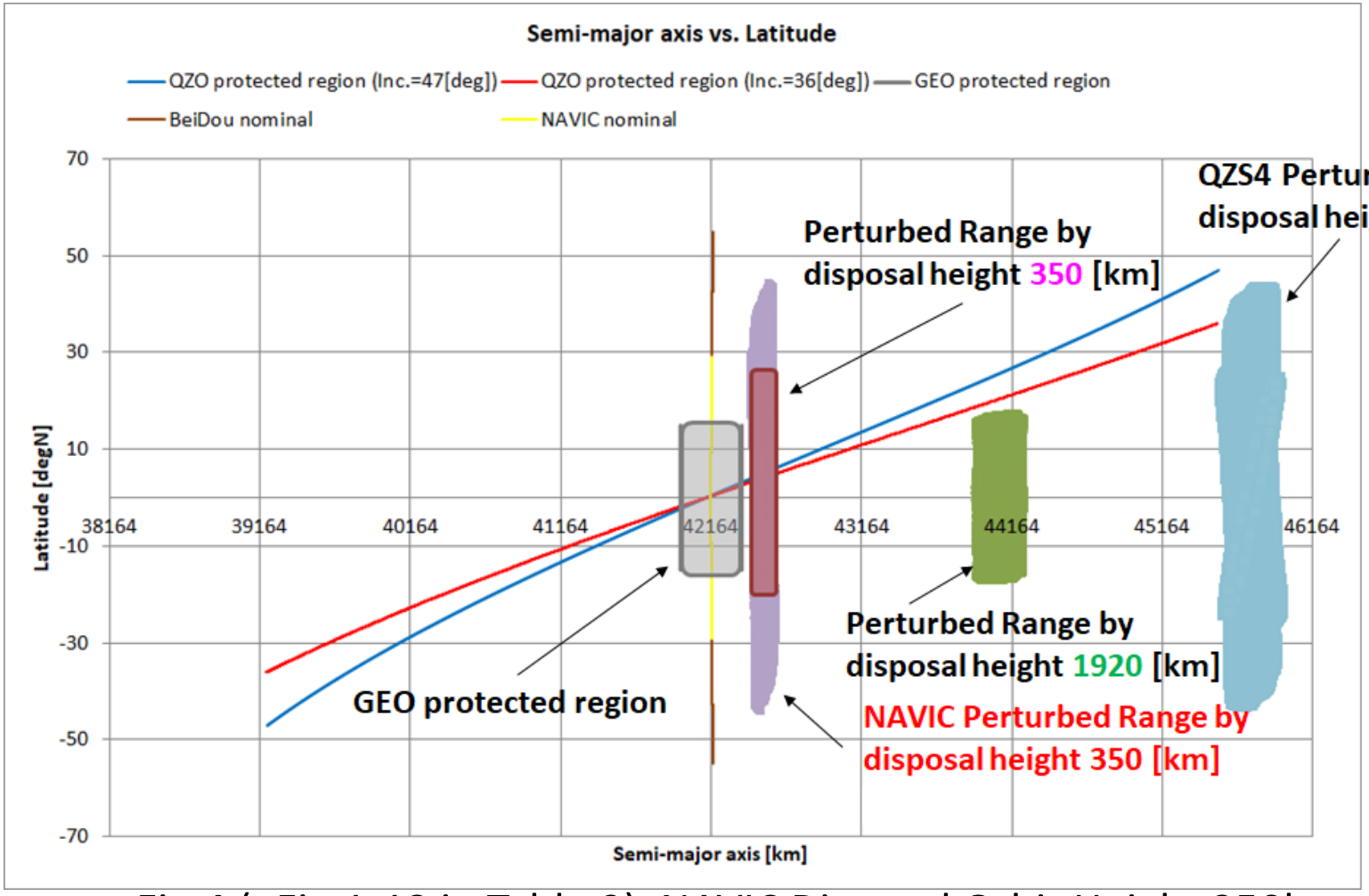


Fig.4 (=Fig.1-13 in Table 2) NAVIC Disposal Orbit Height 350km and Perturbed Range during 100 years

# IGSO De-orbit Way and GEO Protected Region

## 4. Possible resolution

CNR analysis shows the possibility of IGSO disposal way in accordance with the initial inclination.

Table 3

| Initial inclination (degrees) | Solution |
|---|---|
| < 40 | **Graveyard:** The stability remains in any initial disposal condition with normal height. |
| 40<60 | **Re-entry:** Delta-velocity>200 m/s<br>**Graveyard:** The stability varies depending on the perigee orientation. |
| 60< | **Re-entry:** Delta-velocity can go from 1 up to 200 m/s.<br>The 17-year re-entry can be found with some initial condition. |

# IGSO De-orbit Way and GEO Protected Region

## 4. Possible resolution

Fig.5 (*2) by CNR show that only specific initial conditions of inclination, semi-major axis and eccentricity would be able to guarantee a relative stability of the eccentricity.

(*2: Towards a sustainable exploitation of the geosynchronous orbital region
Loannis Gkolias, Camilla Colombo, Martin Lara, Alessandro Rossi, IADC, Rome, May 2019)

Phase spaces

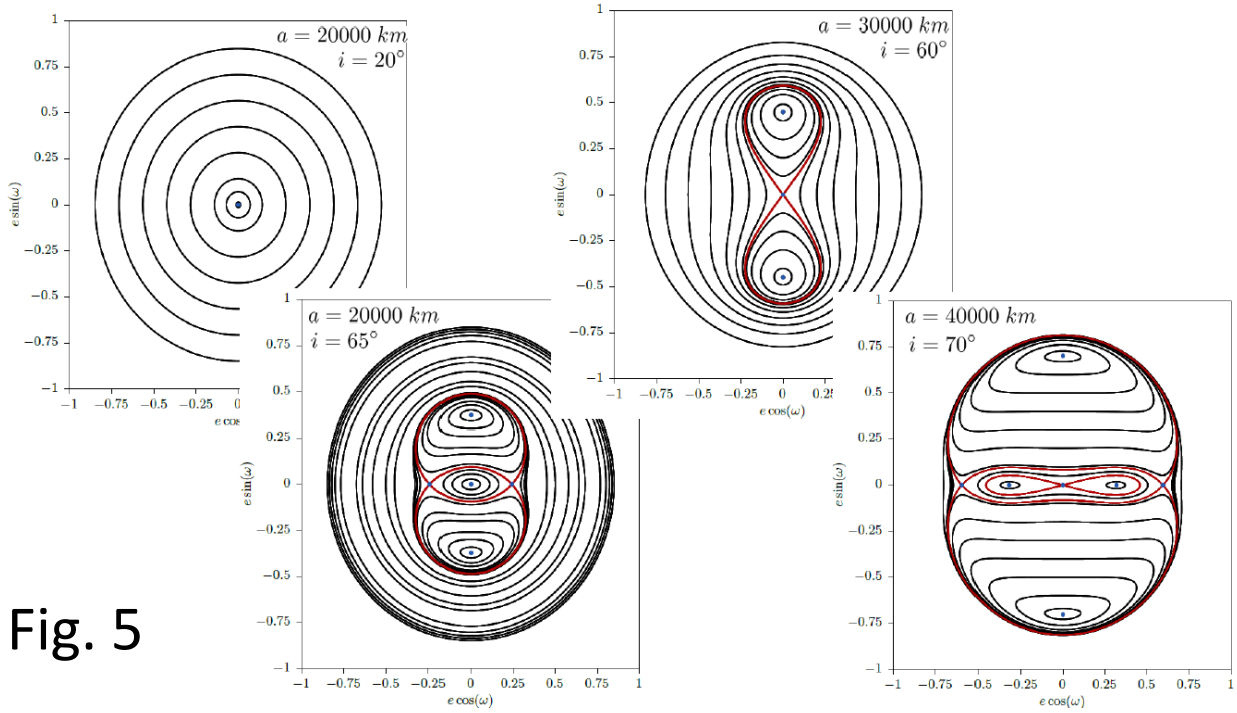


Fig. 5

# IGSO De-orbit Way and GEO Protected Region

## 4. Possible resolution

Fig.6 (*2) by CNR summarizes the possibility of IGSO disposal way in accordance with the initial inclination, semi-major axis and eccentricity. Fig.6 is consistent with the explanation of Table 3.

Bifurcation diagram

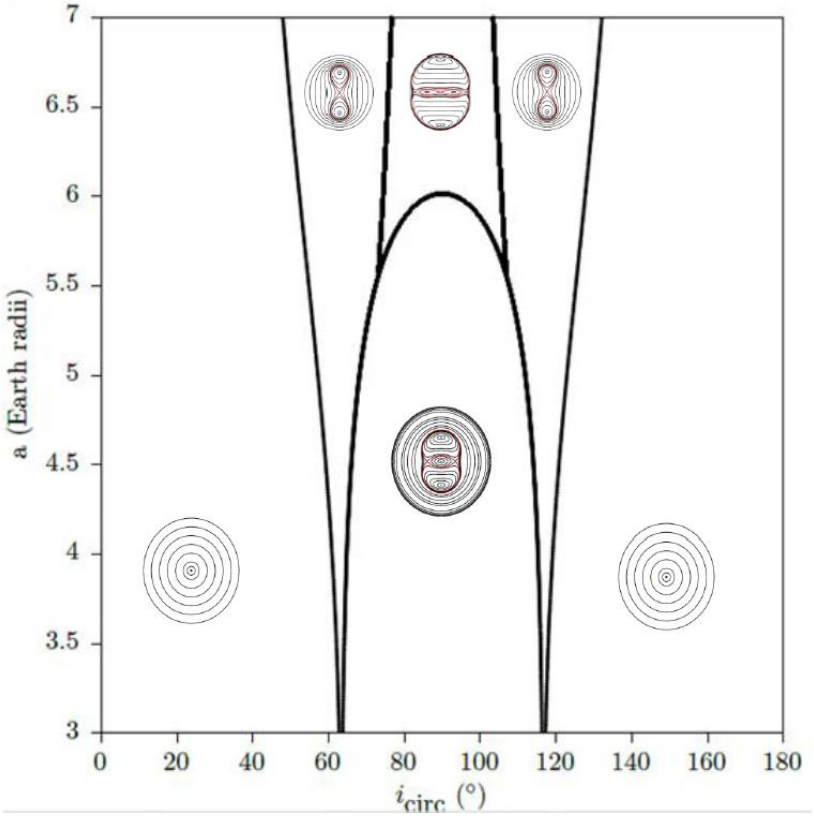


Fig. 6

# IGSO De-orbit Way and GEO Protected Region

## 4. Possible resolution

Fig.7 (*2) by CNR is one example of fast re-entering orbit.

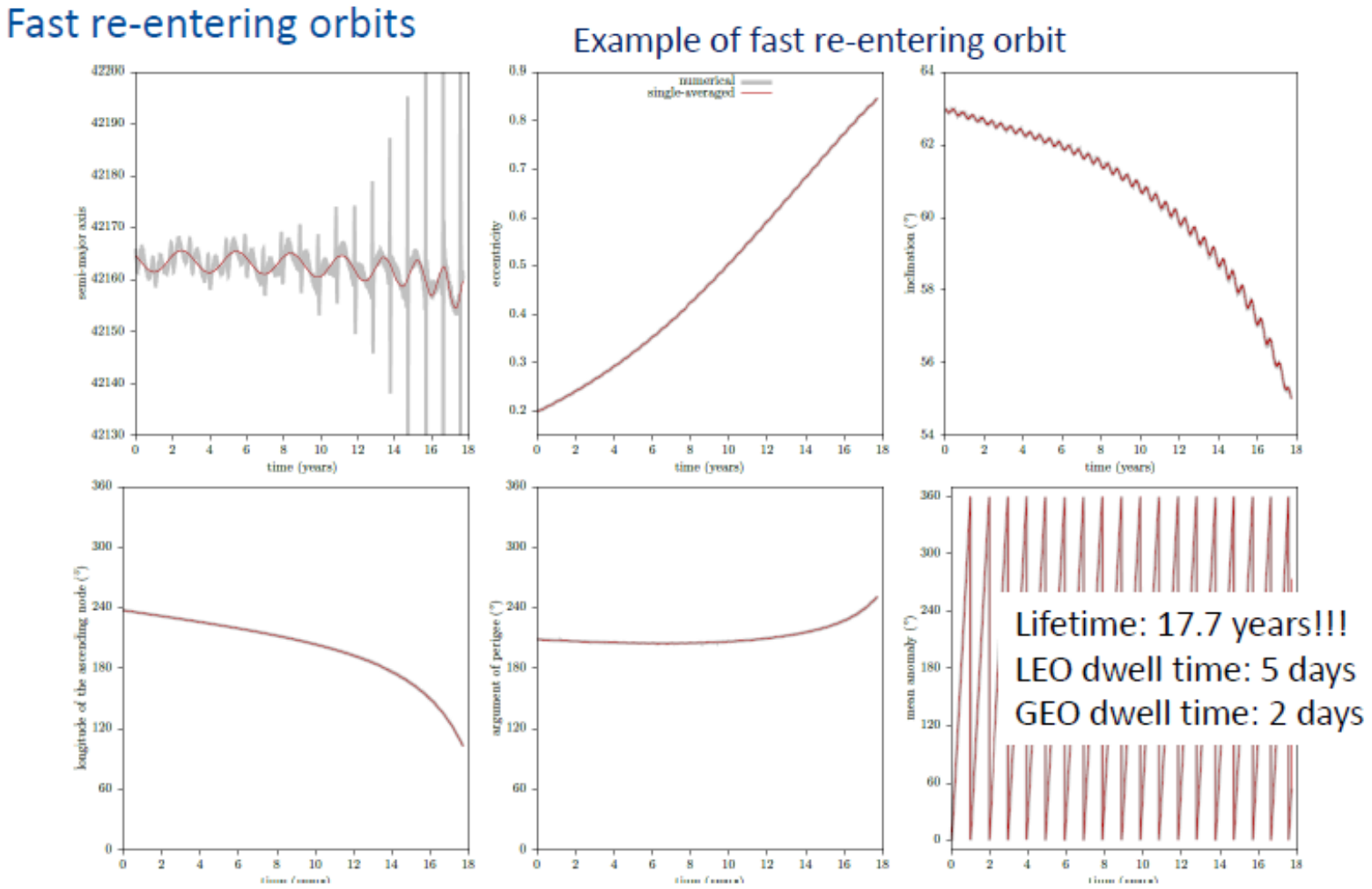


Fig. 7

## 5. Conclusions

There are increasing trends of the use of inclined GEO orbit (for example, BaiDou, NAVIC and QZSS).

By only using the current disposal guideline, it is not possible to define end-of-life disposal strategies and which are also simple, universal and inexpensive at the same time.

However, the natural re-entry solutions for the inclined GEO satellite exist.

The solutions depend on the eccentricity and ascending node of spacecraft.

Therefore, this material proposes to discuss the possibility to add item c) into sub-clause 6.3.2 /ISO 24113 to consider the possibility of re-entry from inclined GEO. Next page shows the idea of updated ISO 24113, 6.3.2.2.

As an alternative proposal, the option of re-entry can be mentioned in sub-clause 7.2.3 in ISO 23312 " Detailed space debris mitigation requirements for spacecraft ".

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## 5. Conclusions

**<Proposed update of the GEO disposal ISO 24113 or 23312>**

**6.3.2.2** A spacecraft operating in the GEO protected region with a continuous presence shall be disposed of in such a way that its orbital state, after disposal manoeuvres, satisfies at least one of the following conditions:

a) the orbit has an initial eccentricity less than 0,003 and a minimum perigee altitude $\Delta H$ (in km) above the geostationary altitude, in accordance with Formula (1):

$$H=235+(1000 \times CR \times A/m) \quad \ldots (1)$$

b) the orbit has a perigee altitude sufficiently above the geostationary altitude that long-term perturbation forces do not cause the spacecraft to enter the GEO protected region within 100 years after its end of life.

NOTE Formula (1) was derived to ensure that long-term perturbations will not cause a spacecraft to re-enter a protected zone of geostationary altitude plus 200 km.

**c)** In the case of inclined GEO satellites, re-entry option will be possible with feasible velocity increase depending on the specific initial combination of inclination, eccentricity and ascending node. If the orbital lifetime and dwell time passing through the protective orbital regions are acceptable considering the contents of this standard, it can be taken as a disposal option.

*(Detailed methodology can be attached to 24113 as informative Annex, if needed.)*

**6.3.2.3** A spacecraft operating in the GEO protected region with a periodic presence shall be disposed of in such a way that long-term perturbation forces do not cause it to enter the GEO protected region within 100 years after its end of life.

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Thank you for your attention.