# REORBITING OF SATELLITES IN HIGH ALTITUDES

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# Analysis of TLEs stored in DISCOS

DISCOS contains history of all catalogued objects since 1989.
Selection criteria:

- eccentricity smaller than 0.1
- mean motion between 0.9 and 1.1 revolutions per sidereal day, corresponding to a radius of 42,164 -2,500/ +3,150 km
- inclination lower than 30°

970 objects met these criteria as of 31 December 2008.

# Categories of GEO objects

**$C_1$**: objects under longitude and inclination control (E-W as well as N-S control) - the longitude is nearly constant and the inclination is smaller than 0.3º

**$C_2$**: objects under longitude control (only E-W control) - the longitude is nearly constant but the inclination is larger than 0.3º

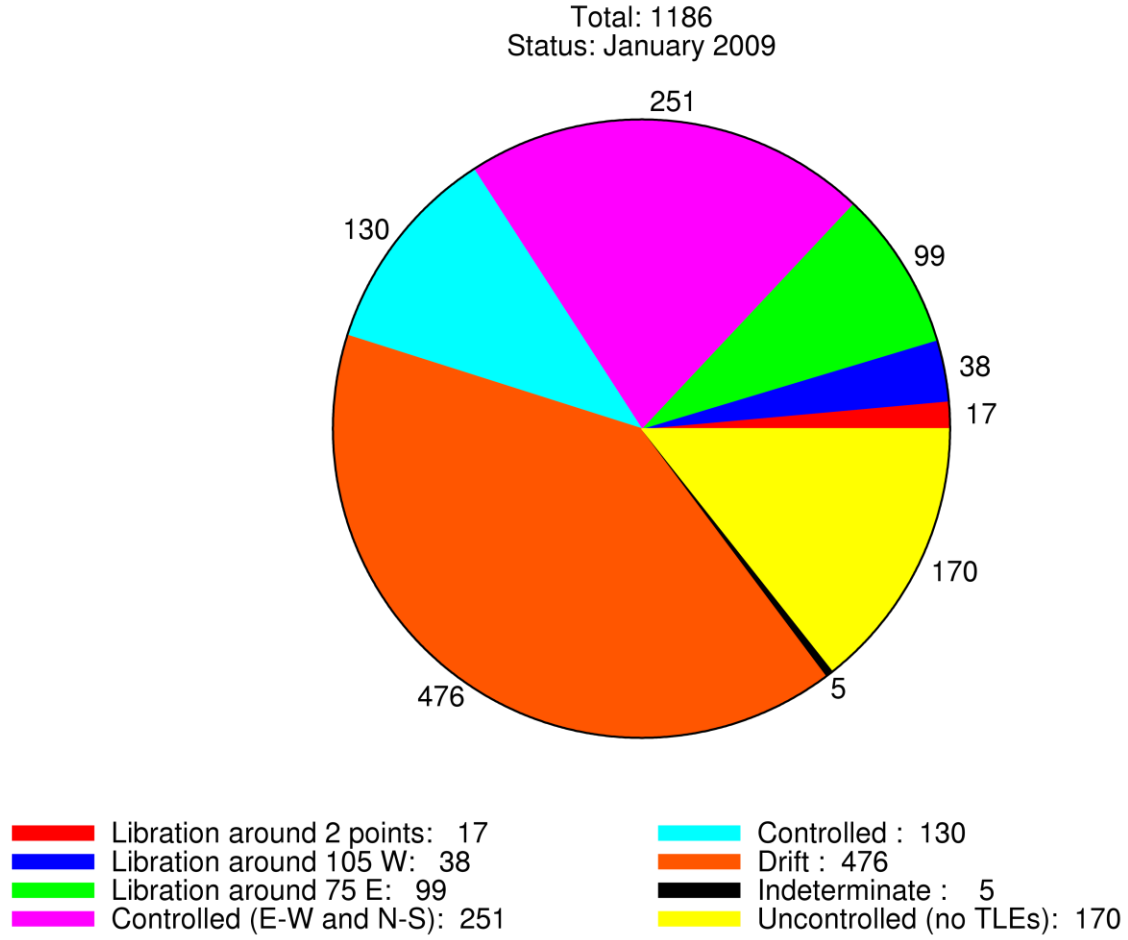
**D**: objects in a drift orbit

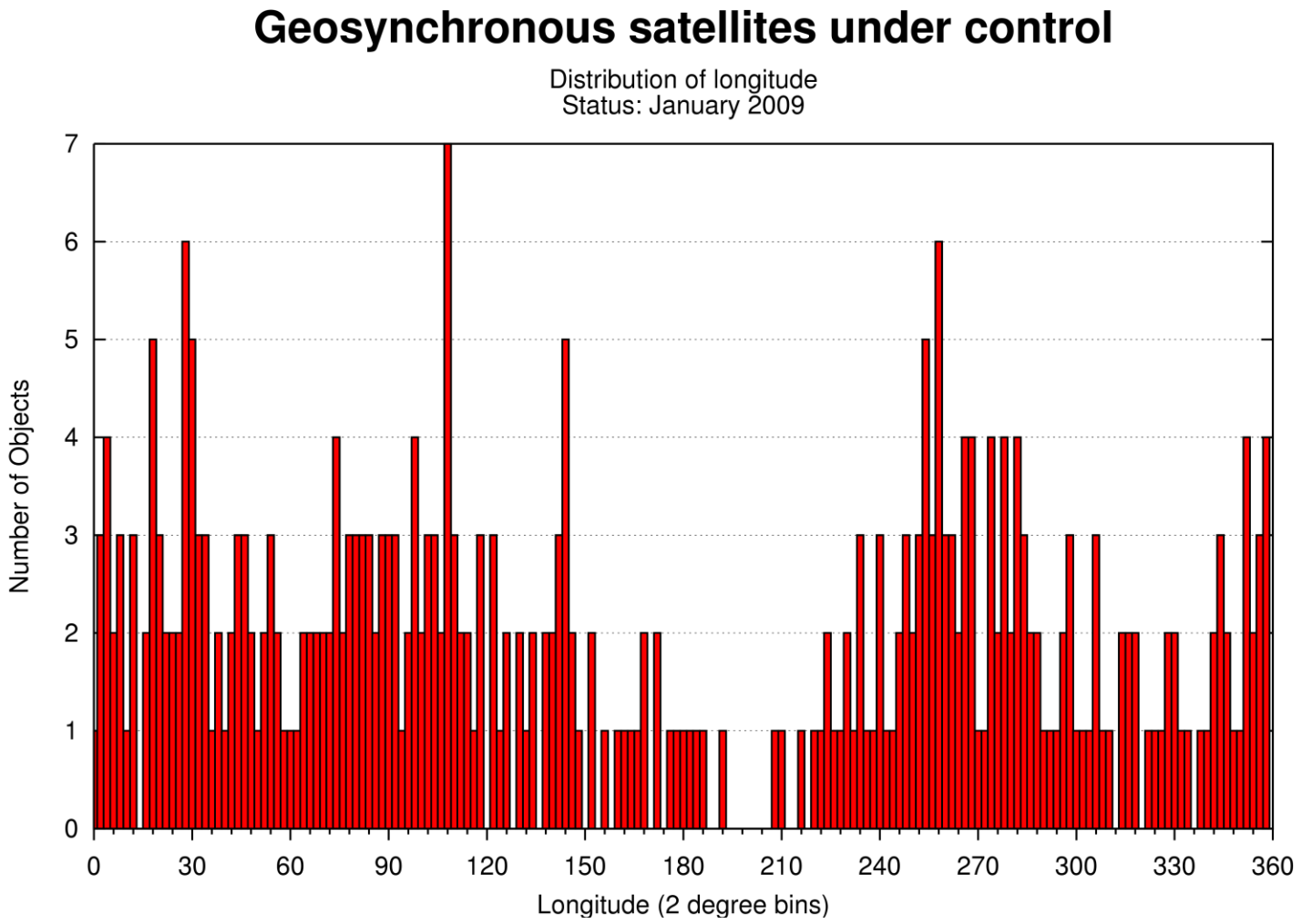
**$L_1$**: objects in a libration orbit around the Eastern stable point (longitude 75ºE)

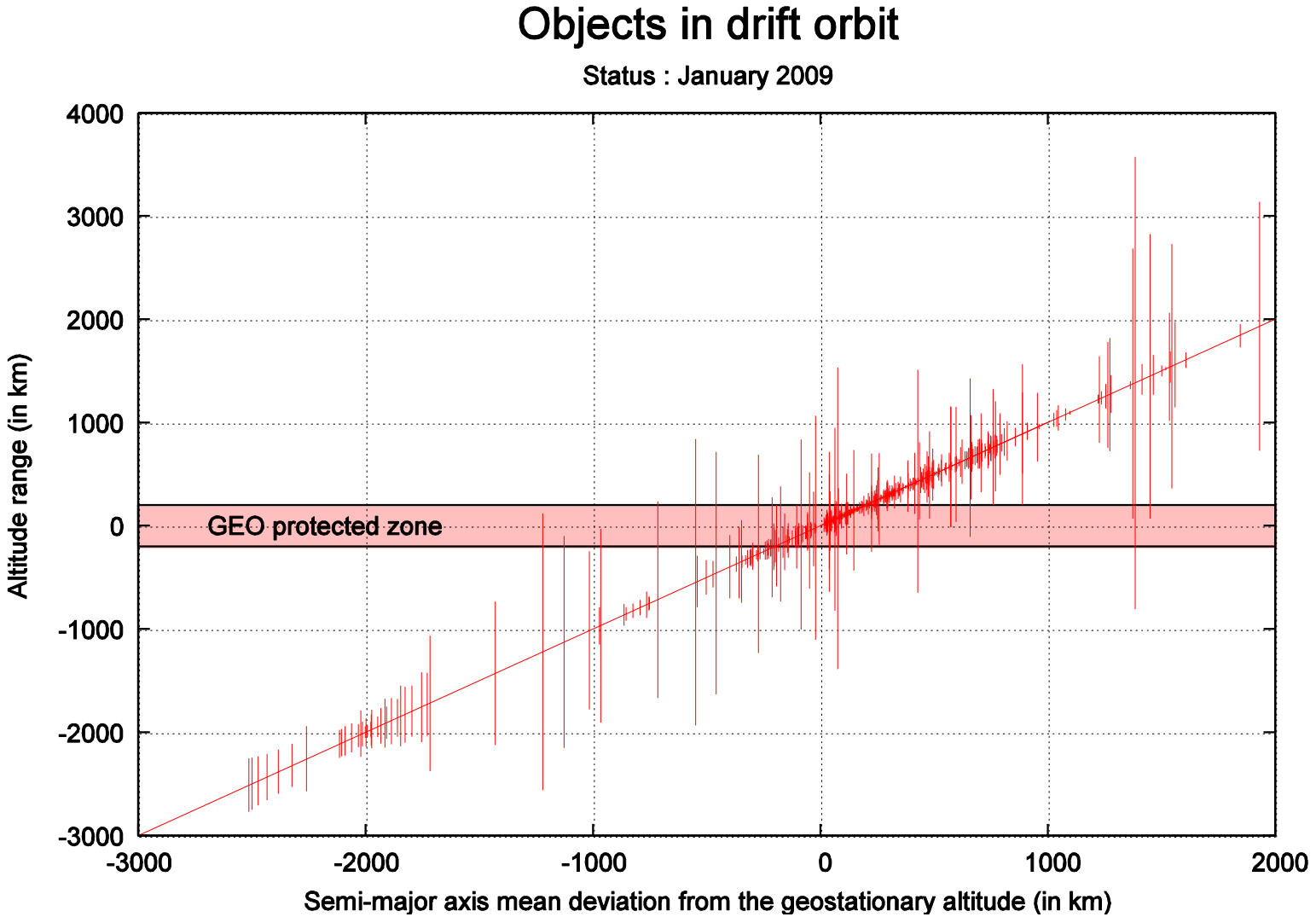
**$L_2$**: objects in a libration orbit around the Western stable point (longitude 105ºW)

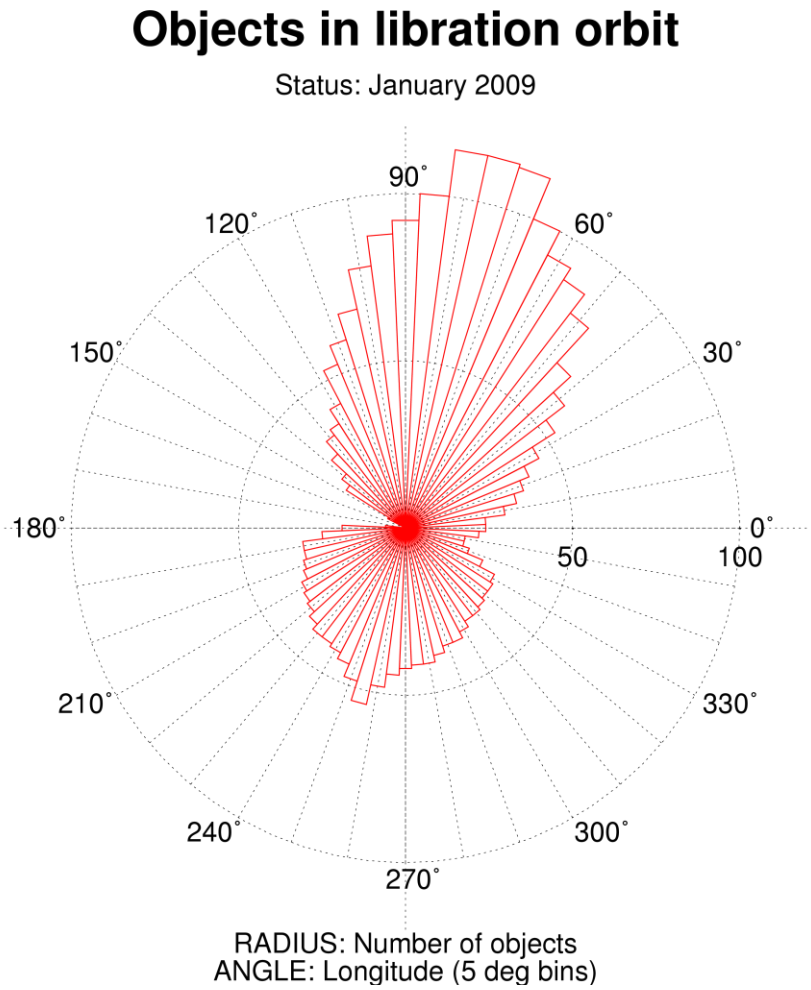
**$L_{1+2}$**: objects in a libration orbit around both stable points.

## Classification of geosynchronous objects




Geosynchronous satellites under control
Distribution of longitude
Status: January 2009
Number of Objects
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360
Longitude (2 degree bins)


Objects in drift orbit
Status : January 2009
Altitude range (in km)
4000
3000
2000
1000
0
-1000
-2000
-3000
GEO protected zone
-3000
-2000
-1000
0
1000
2000
Semi-major axis mean deviation from the geostationary altitude (in km)


Objects in libration orbit
Status: January 2009
90˚
120˚
60˚
150˚
30˚
180˚
0˚
50
100
210˚
330˚
240˚
300˚
270˚
RADIUS: Number of objects
ANGLE: Longitude (5 deg bins)

# Changes in 2008

In 2008 a total of 29 GEO new spacecraft were deployed, and 12 spacecraft were retired. 7 of these were re-orbited complying with the IADC guidelines:

- Marisat 3 (76101A, US, 330 x 1205 km)
- Optus A3 (87078A, Australia, 350 x 425 km)
- Optus B1 (92054A, Australia, 275 x 330 km)
- Superbird A1 (92084A, Japan, 290 x 365 km)
- Orion 1 (94079A, US, 390 x 570 km)
- Skynet 4D (98002A, Great Britain, 305 x 330 km)
- PAS 6B (98075A, US, 241 x 393 km)

2 satellites were not properly disposed:
- Gorizont 28 (93069A, Russia, 43 x 310 km)
- Galaxy 10R (0002A, US, 170 x 190 km)

3 satellites were left in libration orbits:
- Echostar 2 (96055A, US) around $L_2$
- Gorizont 33 (00029A, Russia) around $L_1$ and $L_2$
- Xinnuo 2 (06048A, China) around $L_1$

USA 197 (DSP F23, 07054A) failed and is now librating around $L_1$.

Probably also Nigcomsat 1 (07018A, Nigeria) got stranded in a libration orbit around $L_1$, but this remains to be confirmed.

# Rocket Bodies left in or close to GEO

Violation of IADC guidelines:

- Proton-K fourth stage of Cosmos 2440 launch (Block DM-2M, 08033D, Russia): $L_1$
- Zenith-3SLB third stage of Amos 3 launch (Block DM-SLB, 08022B, Russia) in drift orbit -800 x 3600 km wrt GEO

To be checked:

- The Briz M upper stage of Ekspress AM-33 launch (08003B, Russia): 1780 x 250 km below GEO

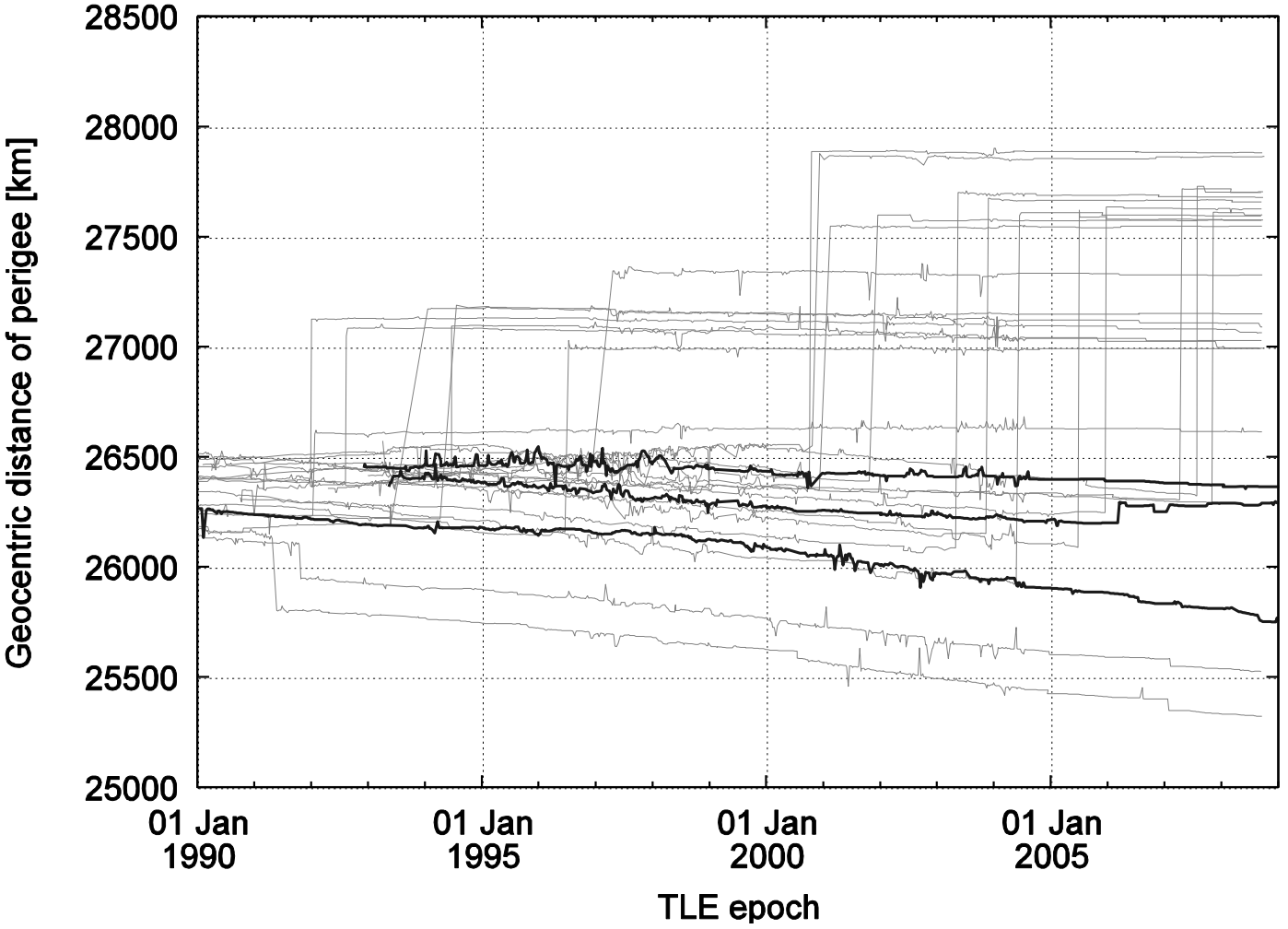
Ok:

- Apogee kick motor of Feng Yun 2E (08066C, China) 670 x 335 km below GEO

# Reorbiting practices from 1997 to 2008

| | '97 | '98 | '99 | '00 | '01 | '02 | '03 | '04 | '05 | '06 | '07 | '08 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Left at $L_1$ | 1 | 7 | 5 | 3 | 5 | 1 | - | 2 | - | 2 | 1 | 1 | **28** |
| Left at $L_2$ | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | 1 | **14** |
| Left at $L_1/L_2$ | - | - | - | 2 | - | - | - | - | 1 | - | - | 1 | **4** |
| Drift orbit (too low) | 6 | 6 | 4 | 2 | 6 | 5 | 7 | 5 | 5 | 7 | 1 | 2 | **56** |
| Drift orbit (IADC compliant) | - | - | 1 | - | - | 1 | 2 | - | 3 | - | 3 | 1 | **11** |
| Drift orbit (above 275 km) | 6 | 6 | 4 | 3 | 2 | 3 | 6 | 5 | 8 | 9 | 8 | 6 | **66** |
| Total | **15** | **22** | **15** | **11** | **14** | **11** | **16** | **13** | **18** | **19** | **13** | **12** | **179** |

# REORBITING OF GPS SATELLITES



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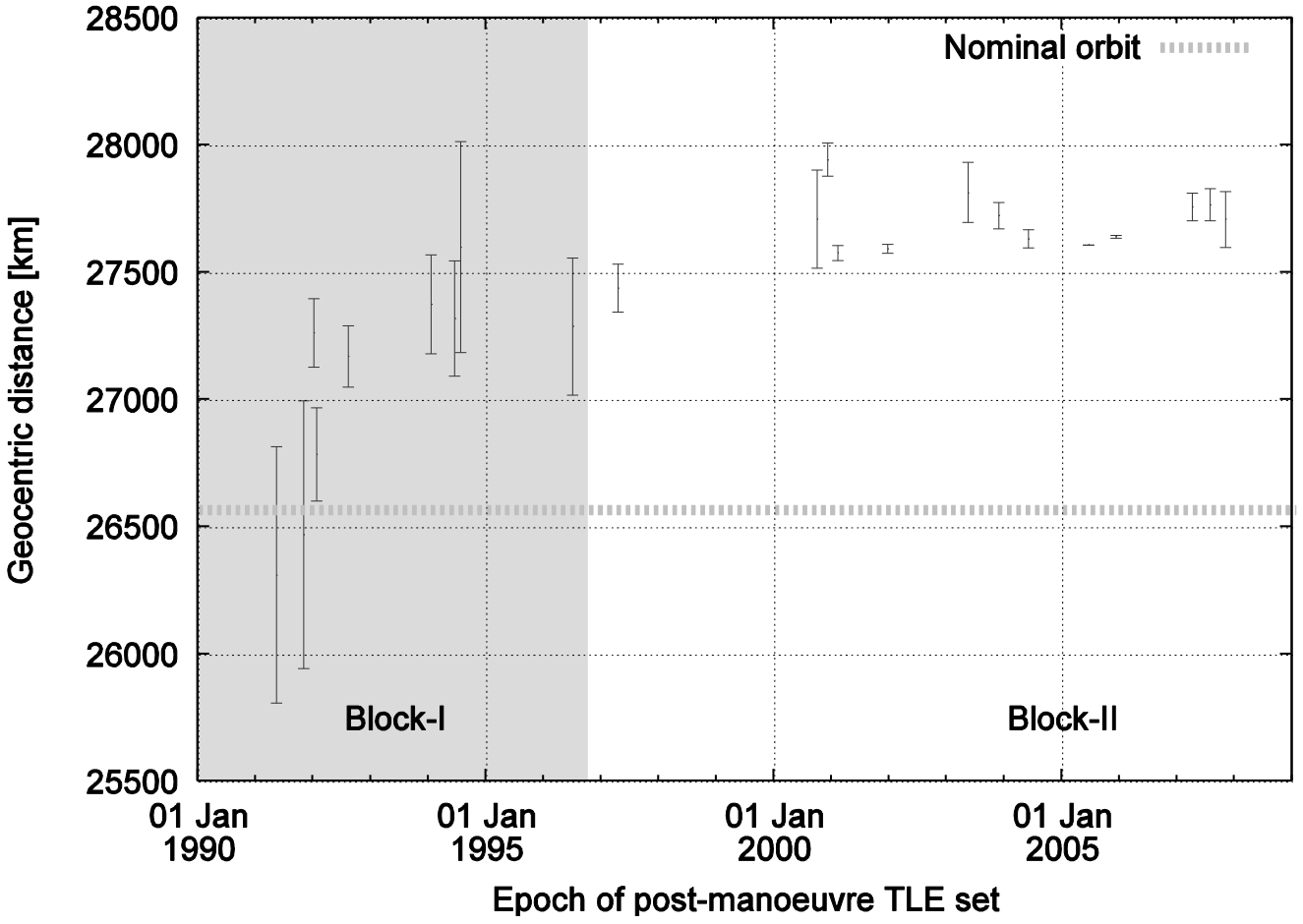
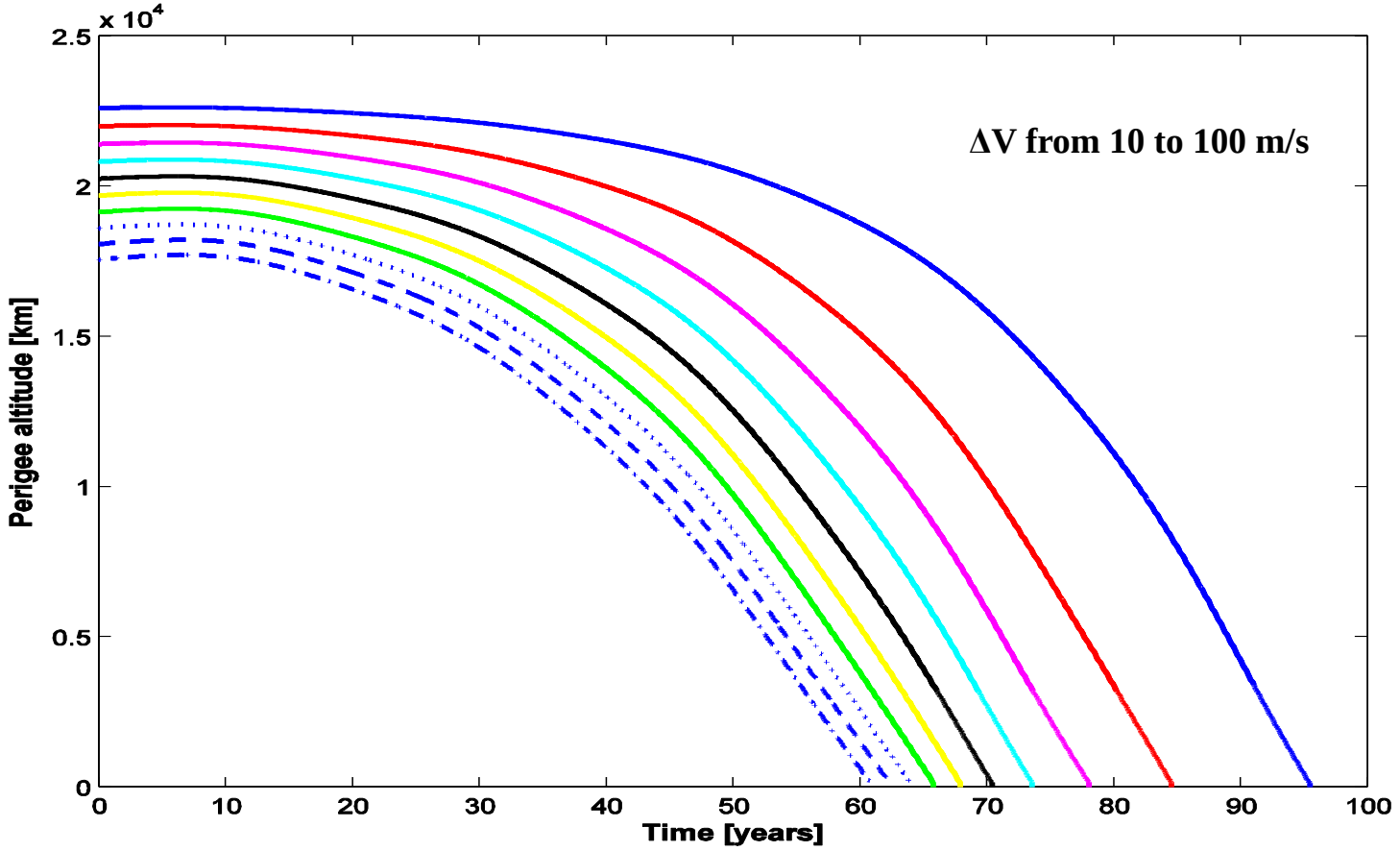


# REORBITING OF GALILEO SATELLITES

- 30 Satellites in a Walker 27/3/1 constellation
- Altitude: 29,600 km (above GPS and Glonass)
- Inclination: 56 deg
- Graveyard orbit: 300 km above nominal orbit ($\Delta V \approx 20$ m/s)
- Possible alternative: 29,000 x 29,600 km orbit with $\Omega$ and $\omega$ such that eccentricity growth is maximum
- Lifetimes $\leq$ 100 years
- Collision probability $\approx 10^{-7}$ during the century-long reentry

# REORBITING OF GALILEO SATELLITES



# Conclusions

- Graveyard orbit in GEO the only disposal solution right now
- This is more and more implemented: from 30 % (26 out of 87) in the years 1997-2002 to 55 % (51 out of 92) in 2003 – 2008
- But too many satellites and upper stages left around GEO
- Good record for GPS disposals (however, they will stay in orbit)
- Galileo could use a “growing eccentricity disposal orbit” to make their satellites re-enter in the atmosphere in ≤ 100 years
- Rossi et al. (Darmstadt 2009) show the global advantage of this option