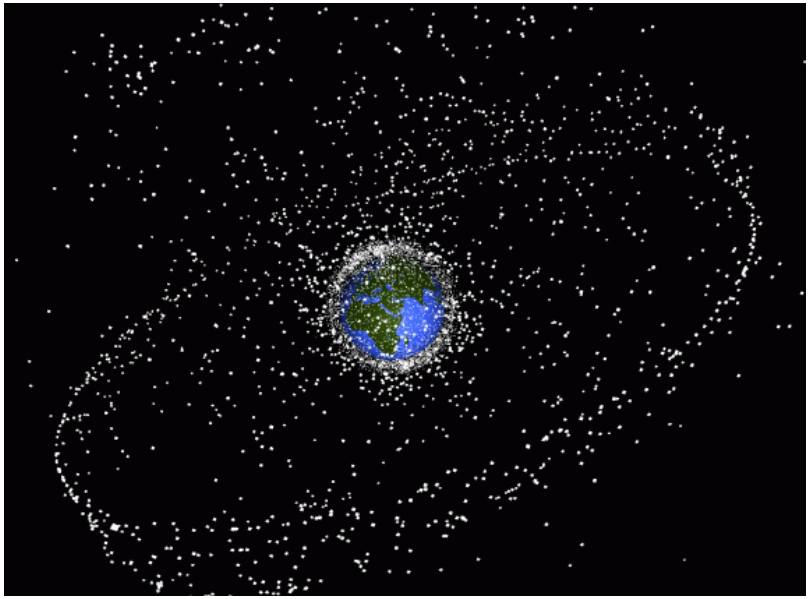
Space Debris Mitigation Activities at ESA

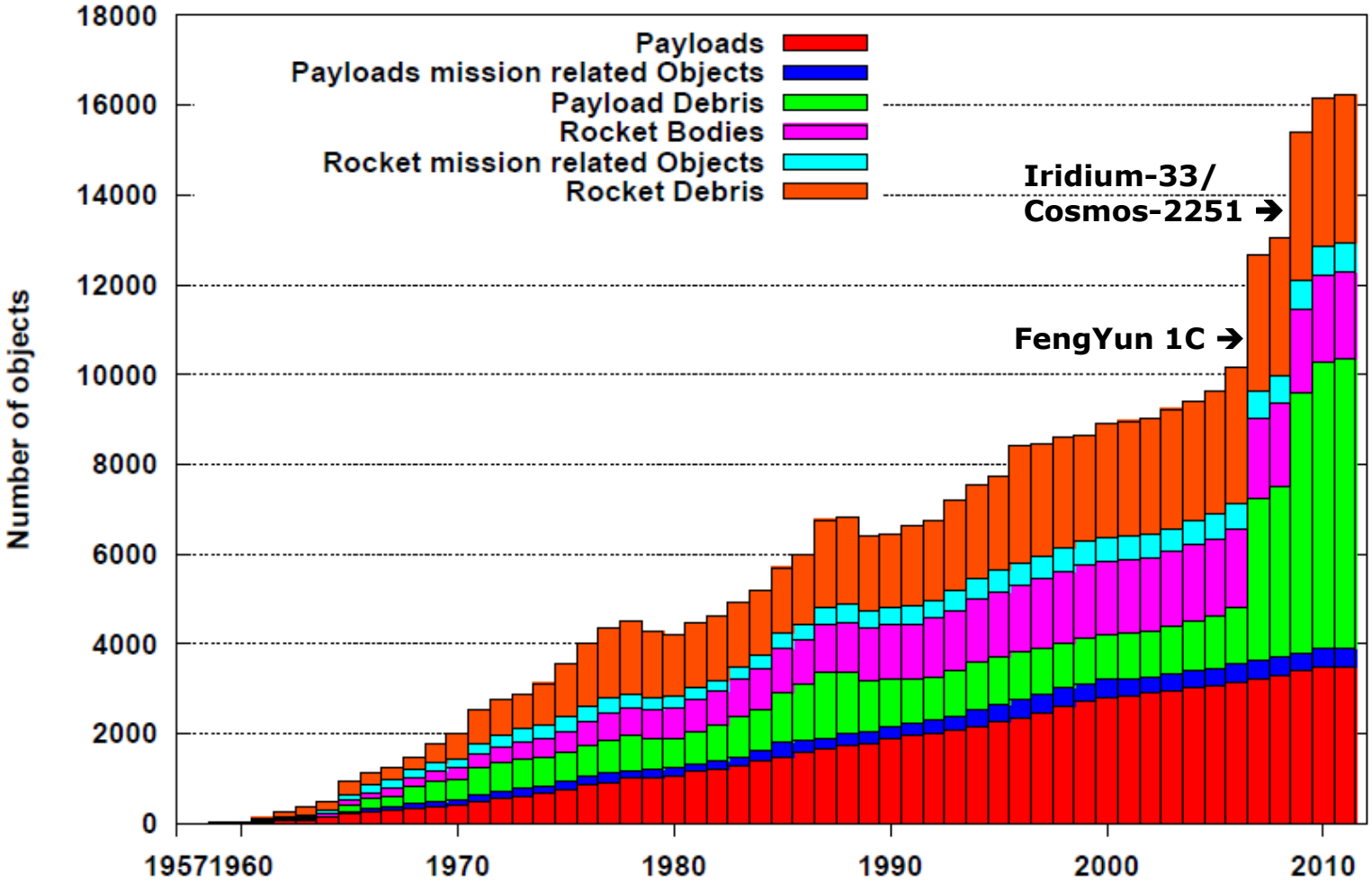
Heiner Klinkrad
ESA Space Debris Office

Space Debris Environment in 2010



- 4,765 launches and 251 on-orbit break-ups led to 16,200 objects in the US Space Surveillance Network (SSN) catalog by Dec. 2010
- launches in 2010 ⇨ 70
- mass on orbit ⇨ ~6,700 tons
- catalog orbital distribution:
  low Earth orbits ⇨ 77%;
  near-geostationary orbits ⇨ 6%;
  highly eccentric orbits ⇨ 10%;
  other orbits (incl. GNSS) ⇨ 7%
- catalog composition: 20% satellites (only ~6% operational), 11% rocket bodies, 5% mission-related objects, and 64% fragments (41% before the FengYun 1C ASAT test and the collision between Cosmos-2251 and Iridium 33)
- consequences of recent in-orbit engagements/collisions:
  FengYun 1C (11 Jan. 2007) ⇨ 3,040 cataloged fragments;
  Iridium-33/C-2251 (10 Feb. 2009) ⇨ 1961 cataloged fragments

History of On-Orbit Space Objects

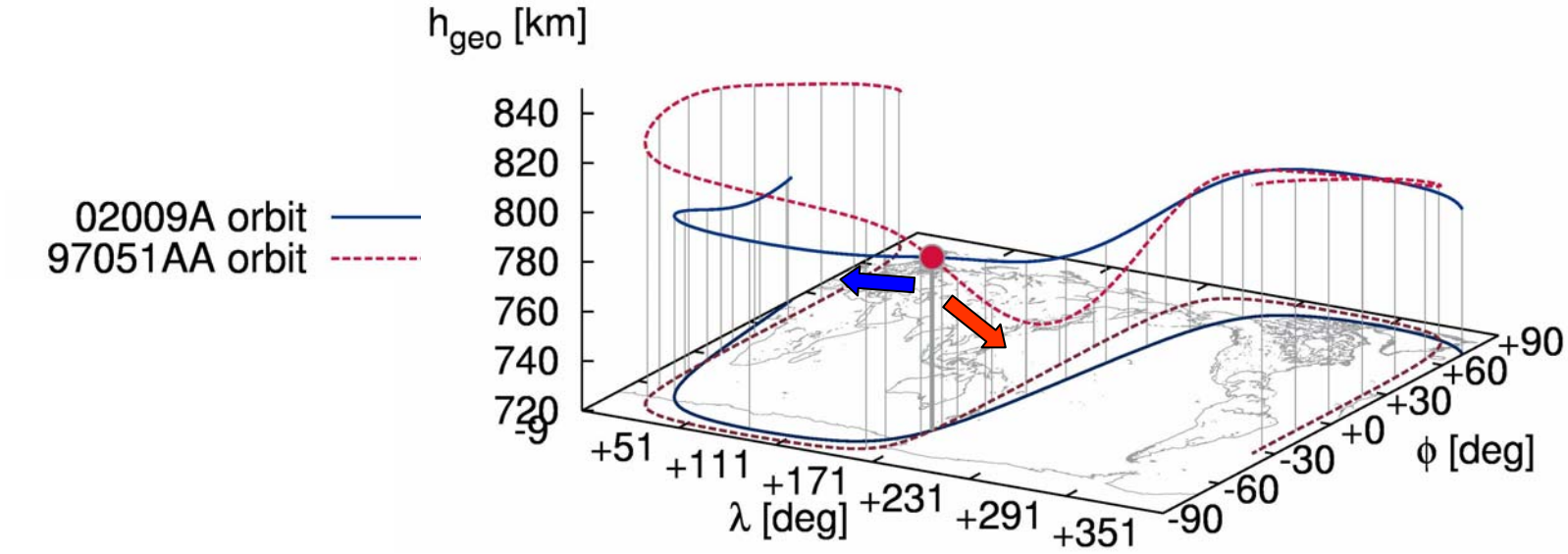


ESA Collision Event Statistics for 2010

- conjunction event screening process at ESA:
  - screened ESA satellites: Envisat, ERS-2, CryoSat-2
  - conjunction event screening performed with regard to all US SSN catalog objects; daily forecasts are performed automatically, on a 24/7 basis
  - avoidance maneuver criteria: collision probability exceeds 1 in 1,000; maneuver must be based on actionable orbit data (i.e. JSpOC or ESA orbit determinations with information on related uncertainties)
- conjunction event statistics for the year 2010:
  - 5 events exceeded a collision probability of 1 in 1,000 (4 for Envisat, 1 for ERS-2); 49 events exceeded a collision probability of 1 in 10,000 (43 for Envisat; 4 for ERS-2; 2 for Cryosat-2); near-miss events: 8 at < 100m, 22 at < 200m, 40 at < 300m, 70 at < 400m, and 104 at < 500m
  - conjunctor objects: 19% spacecraft, 4% orbital stages, 3% mission-related objects, and 75% fragmentation debris (25% Cosmos-2251, 20% Iridium-33, 14% FengYun 1C, 11% rocket bodies, 5% other spacecraft)
  - repeated close conjunctions: 118 conjunctions of Cryosat-2 with KITSAT; 98 conjunctions of Cryosat-2 with SwissCube
  - avoidance maneuvers: 9 in total (4 for Envisat, 4 for ERS-2, 1 for Cryosat-2)

Recent High-Risk Conjunction for Envisat

- conjunction of Envisat (02-009A) with an Iridium 33 fragment (97-051AA):
  - predicted conjunctions on Dec. 01, 2010, at 20:01| **21:41**| 23:41 UTC, at a total distance of 757m| **47m**| 794m, with a radial separation of −63m| **+25m** | +66m (based on JSpOC CSM data & ESA Envisat data)
  - Envisat: max. dimension 26m; Iridium fragment: max. dimension ~0.2m
  - collision probability at t−2d: 1 in 49 (highest so far at maneuver decision time)
  - a two-burn avoidance maneuver (2 × 1.5 cm/s) between the 1st and 2nd, and after the 3rd conjunction increased the min. separation to 160m (100m radial)



GEO Satellite Retirements in 2010*

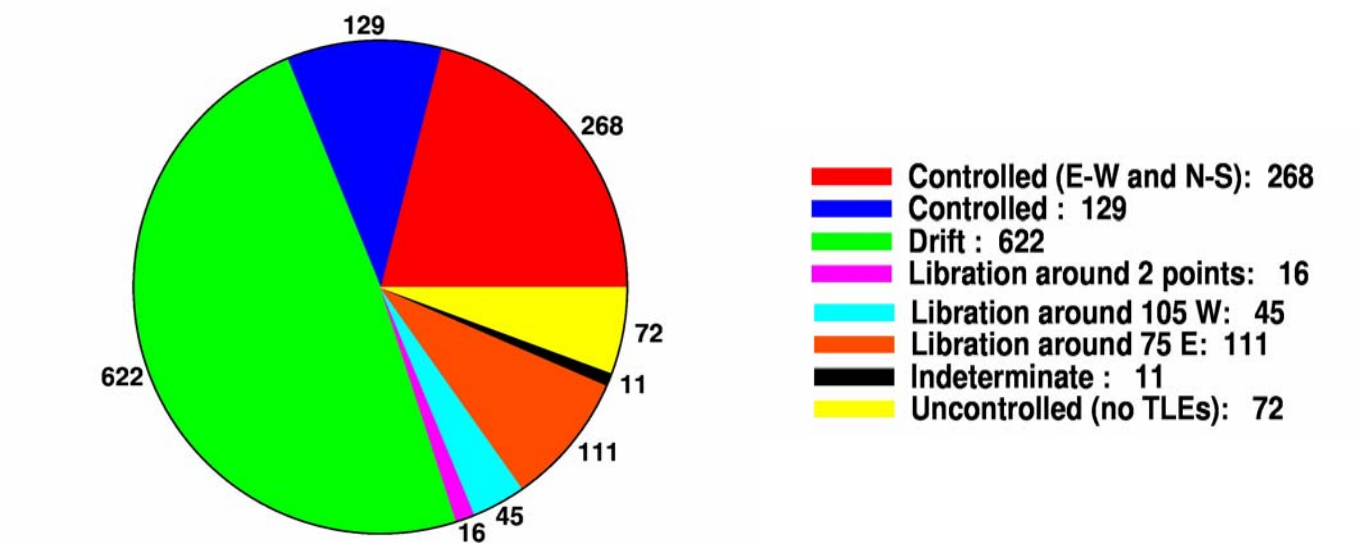
- GEO disposal statistics compiled by ESA with inputs from the USA, Russia, national space agencies, and commercial operators
- 11 satellites were re-orbited according to IADC Guidelines
  - TDRS-1 (83-026B, USA) ⇨ disposal at 357 km x 515 km above GEO
  - Satcom C-3 (92-060B, USA) ⇨ disposal at 826 km x 1056 km above GEO
  - Thaicom 1 (93-078B, Thailand) ⇨ disposal at 302 km x 317 km above GEO
  - Brazilsat B1 (94-049A, Brazil) ⇨ disposal at 282 km x 298 km above GEO
  - PAS 4 (95-040A, USA) ⇨ disposal at 803 km x 1011 km above GEO
  - Nahuel 1A (97-002B, Argentina) ⇨ disposal at 241 km x 265 km above GEO *
  - BSAT-1A (97-016B, Japan) ⇨ disposal at 309 km x 345 km above GEO
  - Intelsat VIII F-2 (97-031A, Int.) ⇨ disposal at 500 km x 738 km above GEO
  - Eutelsat W2 (98-056A, Eut.) ⇨ disposal at 281 km x 294 km above GEO
  - Insat 4CR (07-037A, India) ⇨ disposal at 275 km x 299 km above GEO
  - Rascom QAF 1 (07-063A, Mauritius) ⇨ disposal at 313 km x 372 km above GEO

* Nahuel 1A might marginally penetrate the 200 km zone within a 100-year prediction time span

GEO Satellite Retirements in 2010 (cont'd)

- 4 satellites were re-orbited too low (within GEO ± 200 km)
  - Thaicom 2 (94-065B, Thailand) ⇨ disposal at 192 km x 198 km above GEO
  - Galaxy 9 (96-033A, USA) ⇨ disposal at 178 km x 242 km above GEO
  - Insat 2E (99-016A, India) ⇨ disposal at 147 km x 205 km above GEO
  - Yamal-100 No.2 (99-047B, Russia) ⇨ disposal at 71 km x 95 km above GEO
- 1 satellites were left in the GEO protected region (GEO ± 200 km)
  - Turksat 3 (96-040B, Turkey) ⇨ left in libration around L1 (75 E)
- 2 satellites started to librate around L1 (within GEO ± 200 km)
  - Cosmos-2240 (08-033A, Russia) ⇨ identified by KIAM as being active
  - Beidou DW2 (Compass G2) (09-018A) ⇨ operational status uncertain
- Galaxy 15 (05-041A, USA) was in libration around L2 after a contingency; the spacecraft was recovered in Dec. 2010 and it is now back under control
- 1 orbital stage was left crossing the GEO protected region (GEO ± 200 km)
  - Delta 4 2nd stage (10-063B) ⇨ 33,857km x 35,673km (87km penetration)

Orbit Control Status of GEO Object in 2010



- 1,274 objects were in or near the GEO ring in Dec. 2010
- 16 satellites were retired; 24 satellites and 2 stages were newly inserted
- 397 satellites are orbit-controlled (266 of them in E-W and N-S)

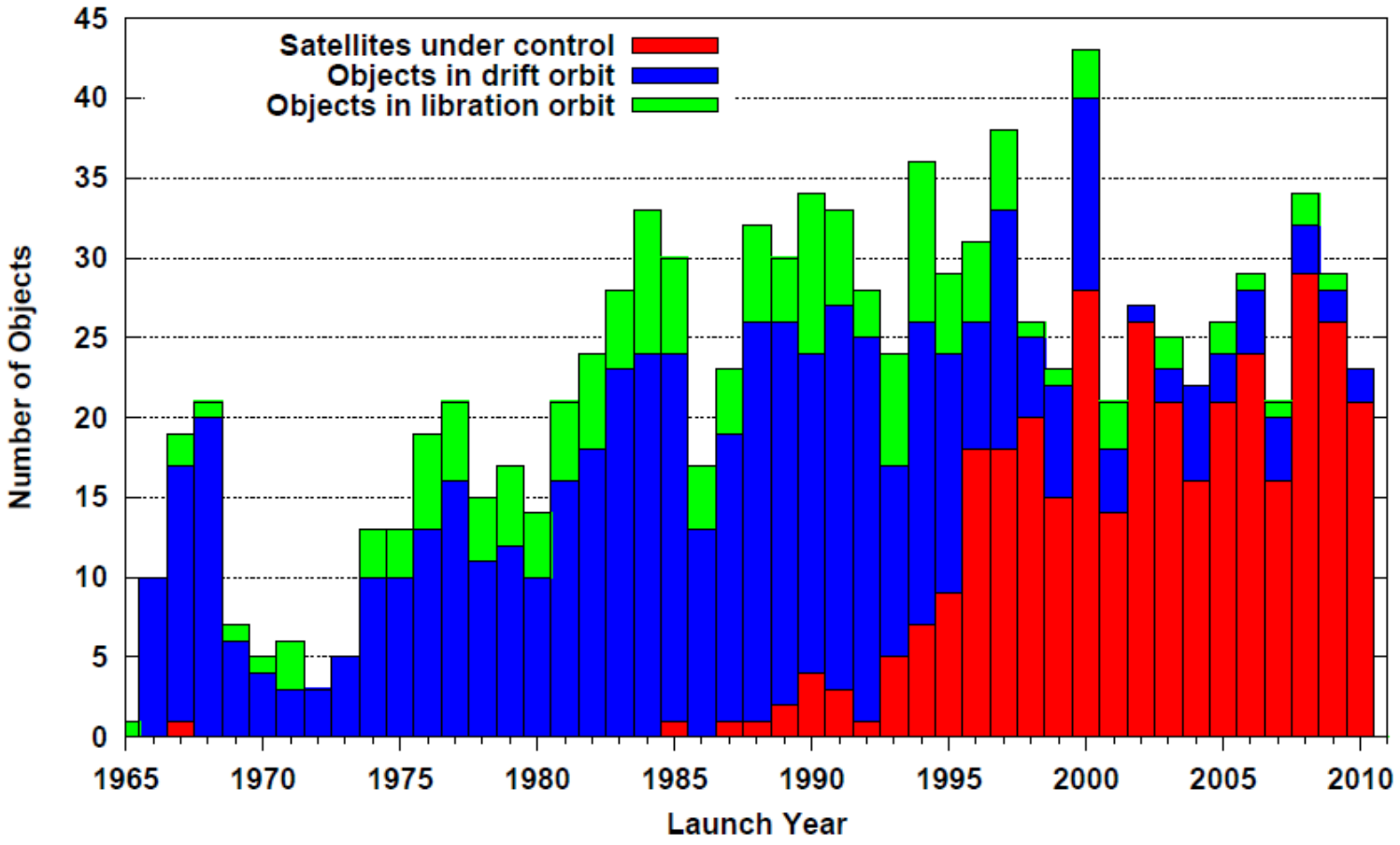
* based on US SSN catalog data, ESA's DISCOS Database, and KIAM/ISON data

GEO End-of-Life Disposal History

	99	00	01	02	03	04	05	06	07	08	09	10	Total	
• Left at L_1	5	3	5	1	–	2	1	2	1	2	3	1	26	(14.5%)
• Left at L_2	1	1	1	1	1	1	1	1	–	1	–	–	9	(5.1%)
• Left at L_1/L_2	–	2	–	–	–	–	1	–	–	1	–	–	4	(2.2%)
• Drift orbit (too low)	4	2	6	5	7	5	5	7	1	1	6	4	53	(29.6%)
• Drift orbit (compliant)	5	3	2	4	8	5	11	9	11	6	12	11	87	(48.6%)
Annual Total	15	11	14	11	16	13	19	19	13	11	21	16	179	(100%)

- compliance with IADC GEO end-of-life re-orbiting guidelines has improved during the past 12 years (from ~30% to ~60%)
- averaged over 12 years, 48.6% of the retired GEO spacecraft were properly re-orbited, 29.6% were insufficiently re-orbited, and 21.8% were abandonned in the GEO ring

Orbit Control Status vs. Satellite Age



Conclusions

- within 3 years the risk of catastrophic collisions for ESA satellites in low Earth orbits has increased twofold; evasive maneuvers for ESA satellites increased to 9 per year, with up to 4 per spacecraft
- the ratio of IADC compliant vs. non-compliant GEO disposals has improved from 1/3 to 2/3 over the past 12 years (with more room for improvement); ESA's "Classification of Geosynchronous Objects", Issue 13, will be released in March 2011; electronic copies can be requested from tim.flohrer@esa.int
- routine, operational surveillance and tracking capabilities are mandatory to maintain a reliable, actionable space situational awareness (SSA) picture; ESA has started to develop corresponding capabilities as part of a European SSA preparatory program
- space debris mitigation is a necessary, but insufficient step to maintain a sustainable use of outer space; it must soon be accompanied by space debris environment remediation (mass removal), particularly in the LEO regime; ESA supports the UNCOPUOS WG on the "Long-term Sustainability of Outer Space Activities"