Debris Mitigation Efforts

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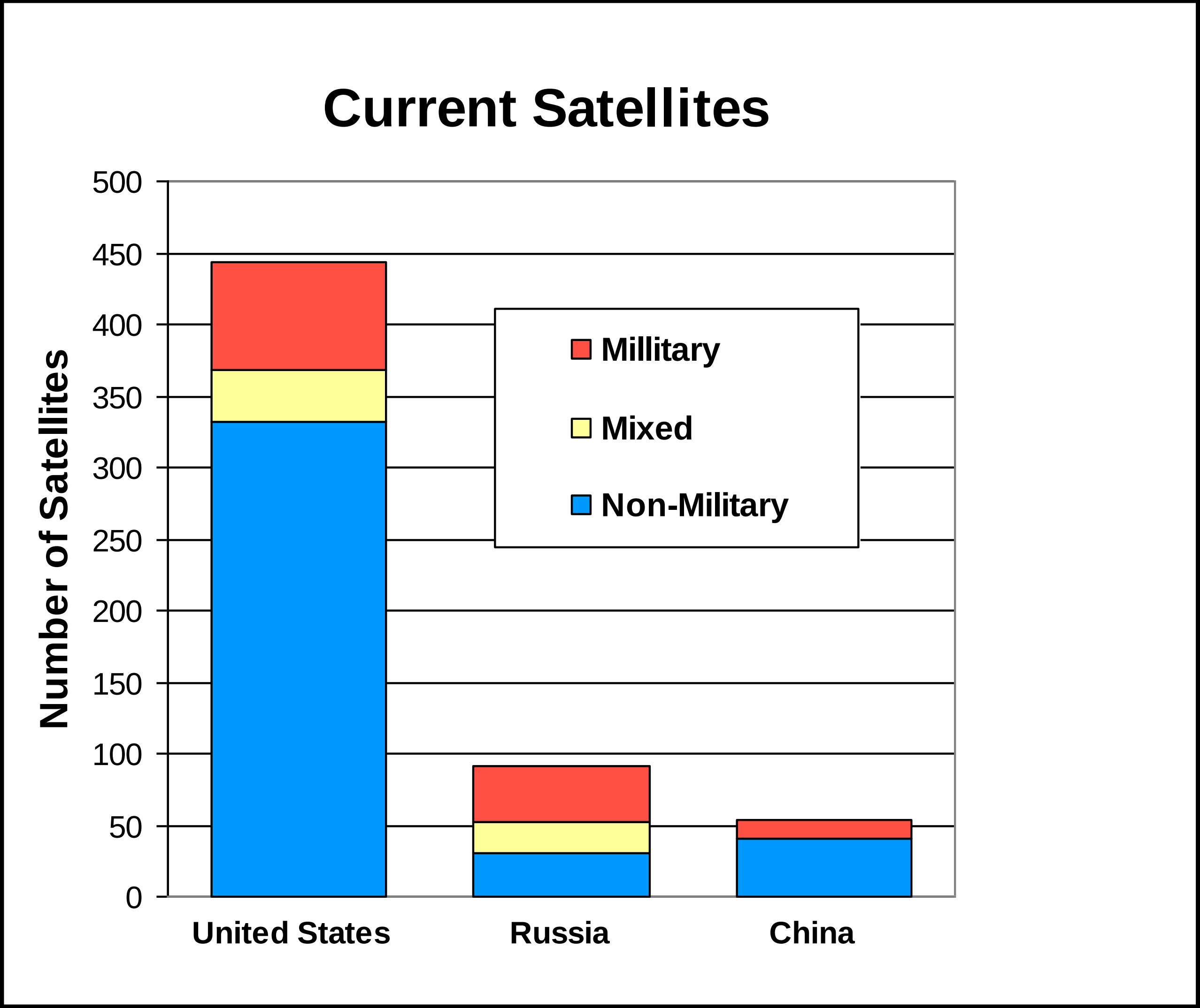
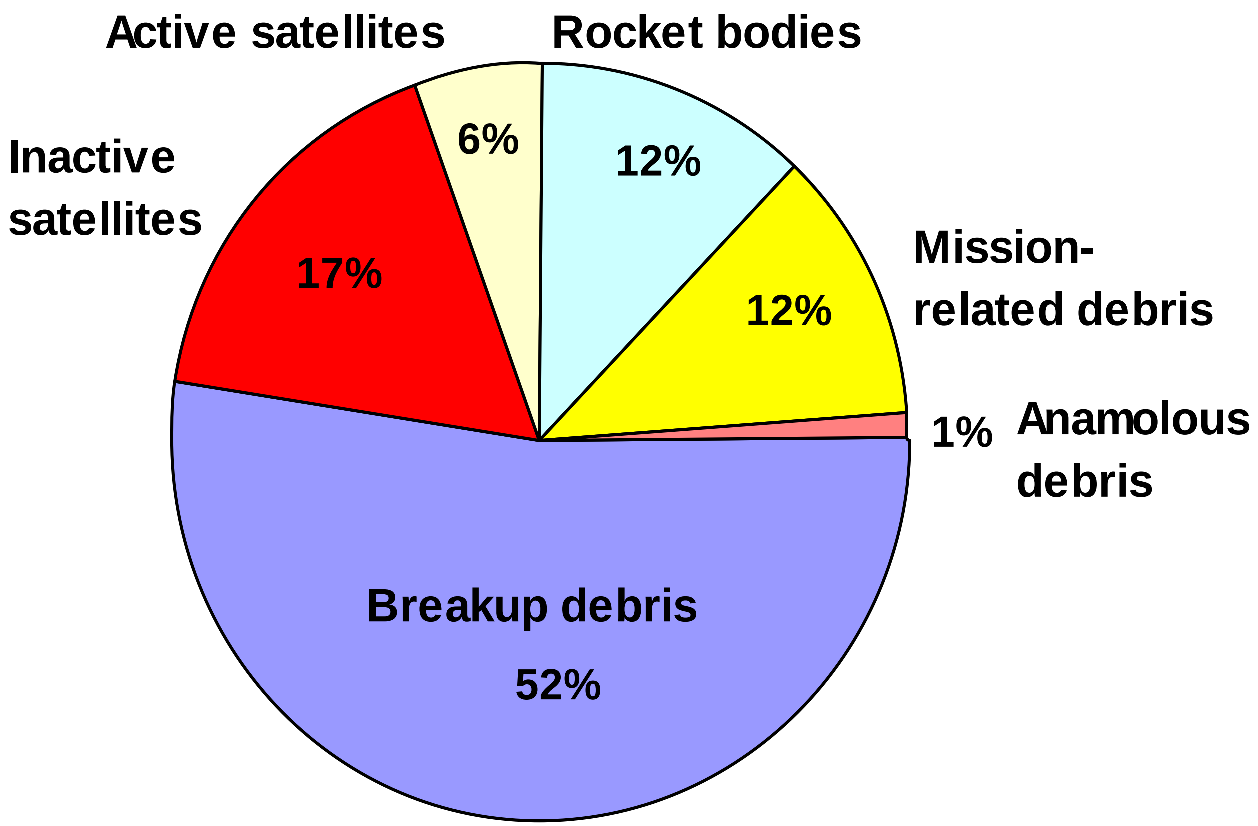


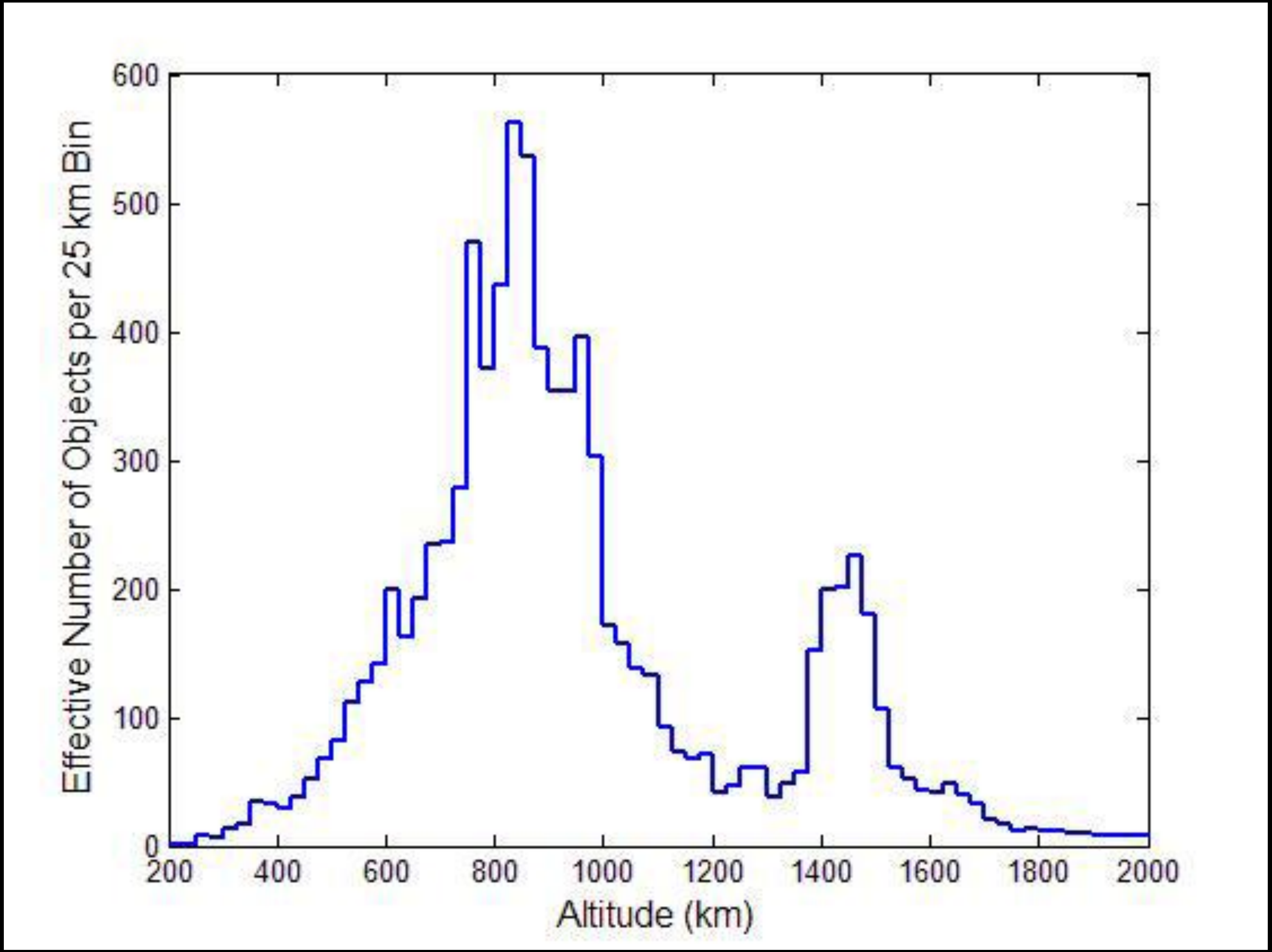
Currently, 900 active satellites in orbit

Origin of Cataloged Objects in Space

- U.S. caused ~ 33% of debris
- Russia ~ 36%
- China ~ 21%



Distribution of Debris with Altitude in LEO



Debris Threat to Satellites

Known collisions:

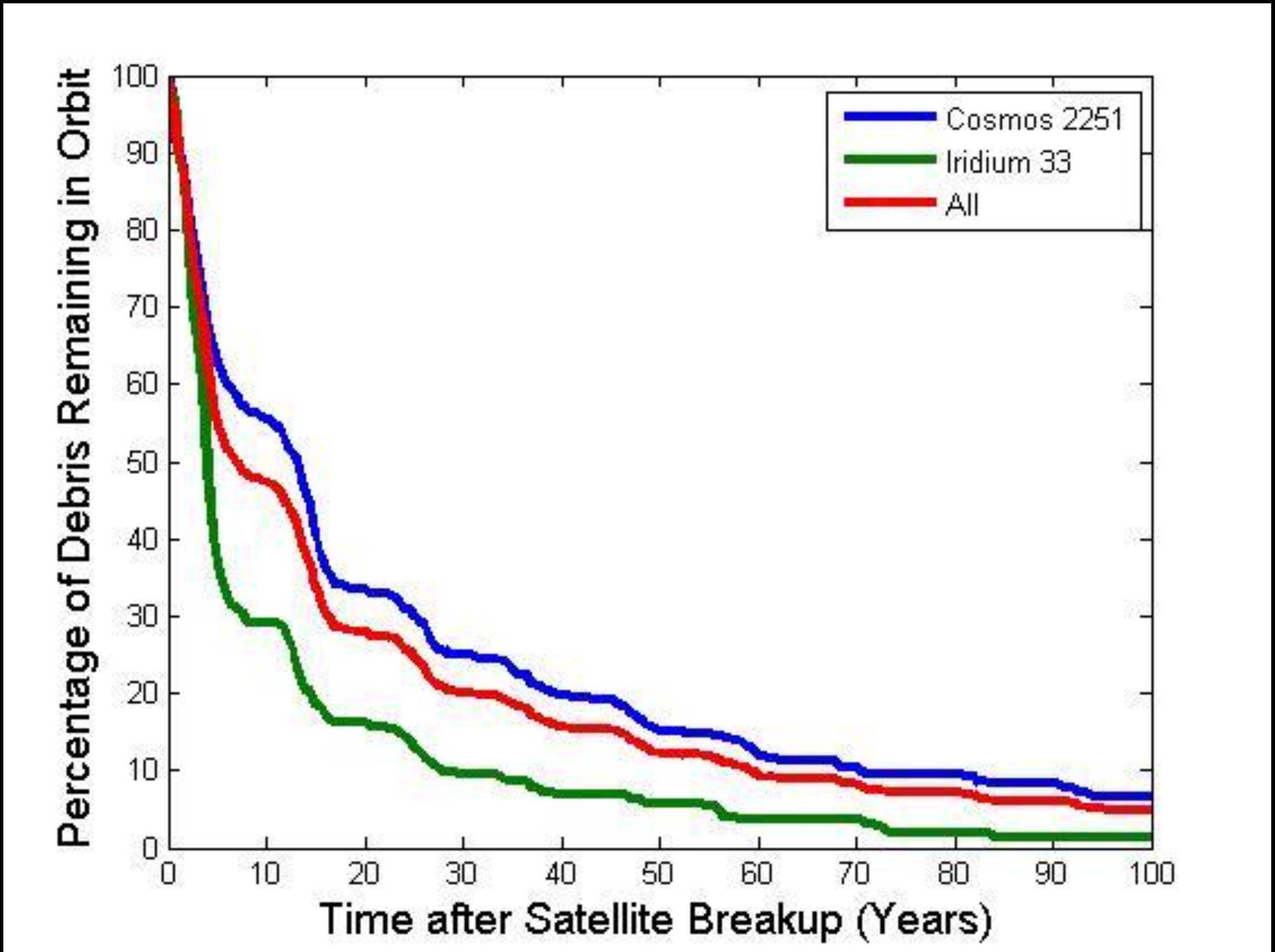
- Active satellites hit by debris: 1996, 2007, 2009
- Collisions between two pieces of debris:

  1991, 1997, 2002, 2005, 2007

- Average time between collision of debris (> 1 cm) with some active satellite in low Earth orbit:

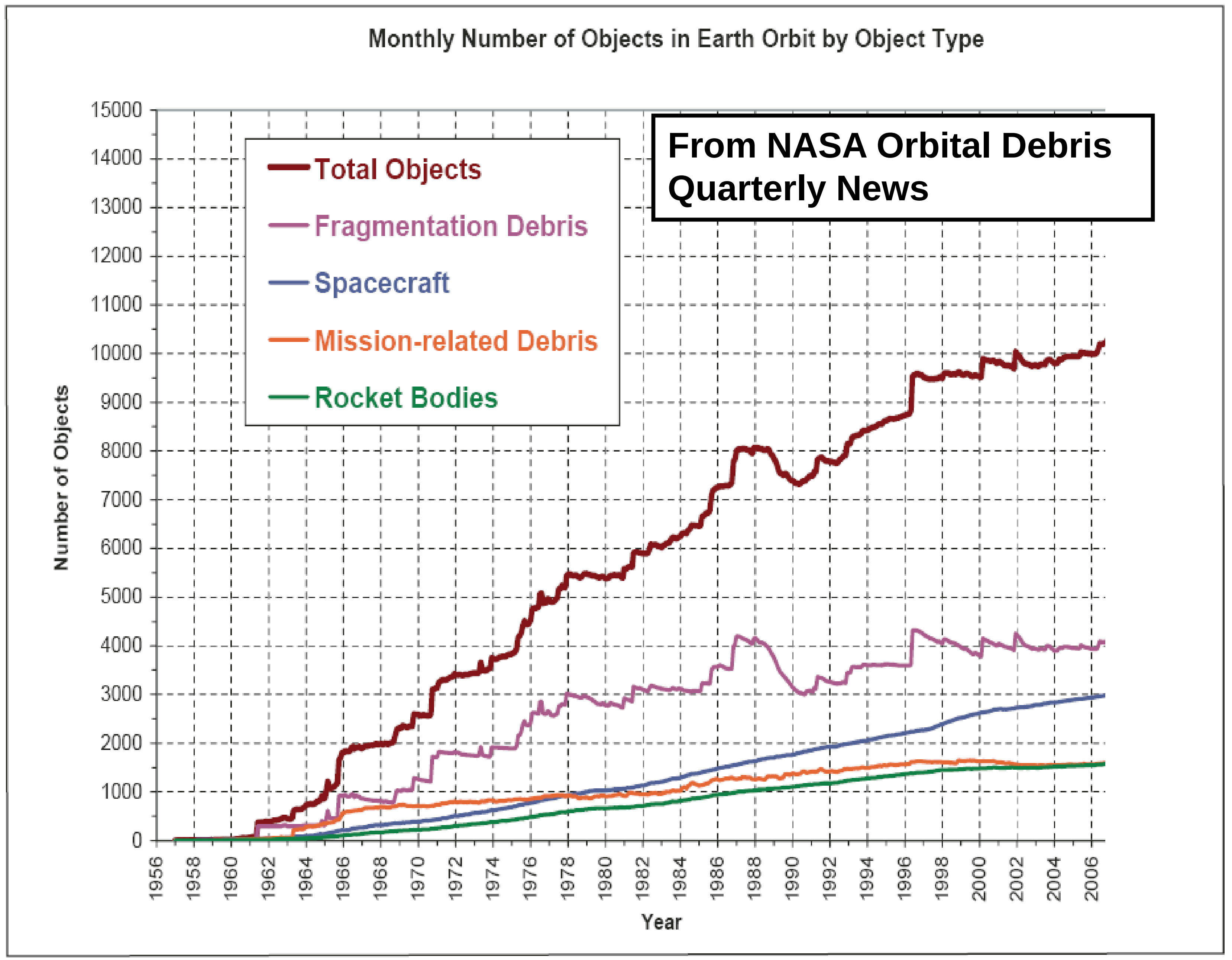
  3-4 years

Estimated Lifetime of Debris from Iridium-Cosmos Collision (790 km)

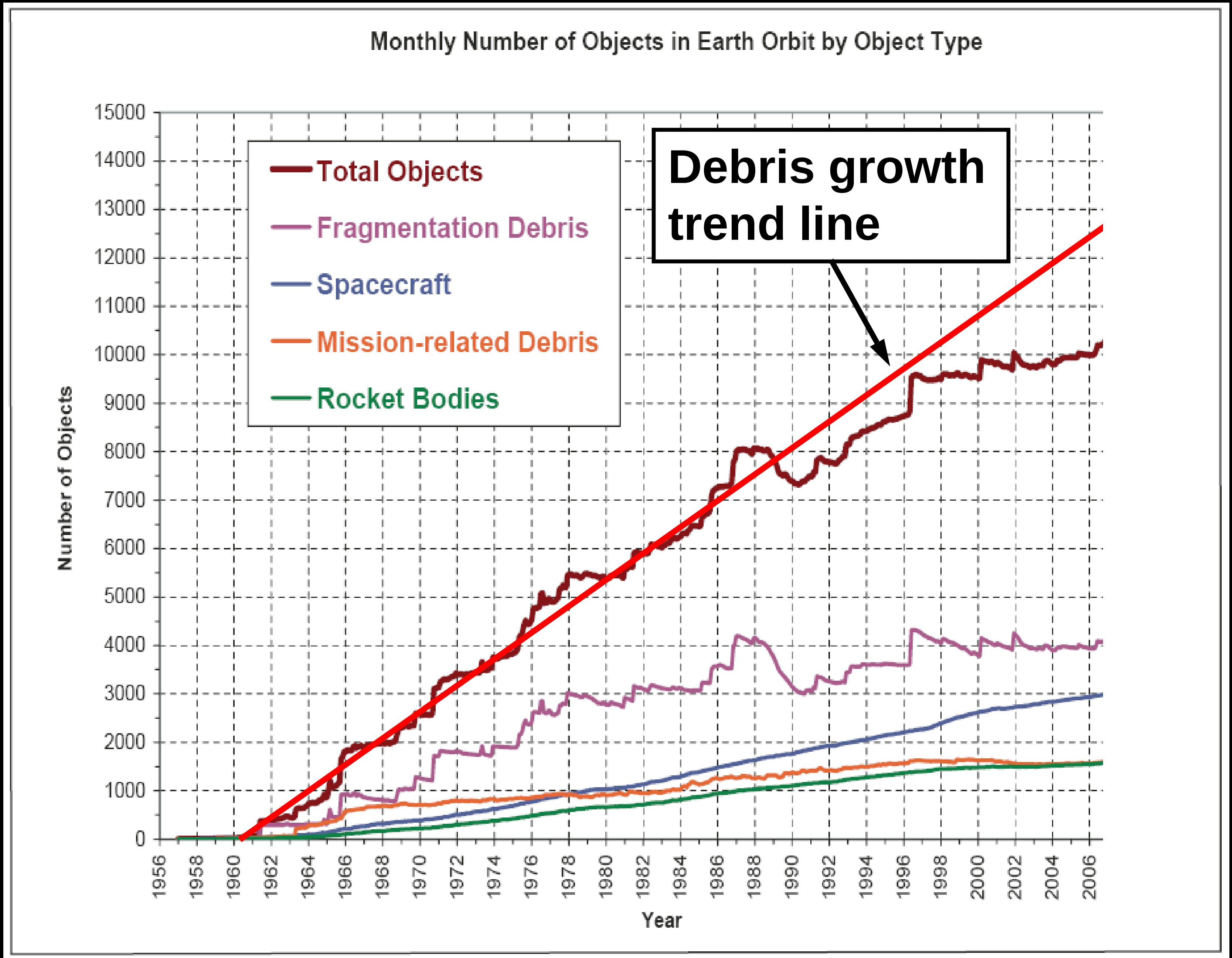


Calculation by Wang Ting, BUAA

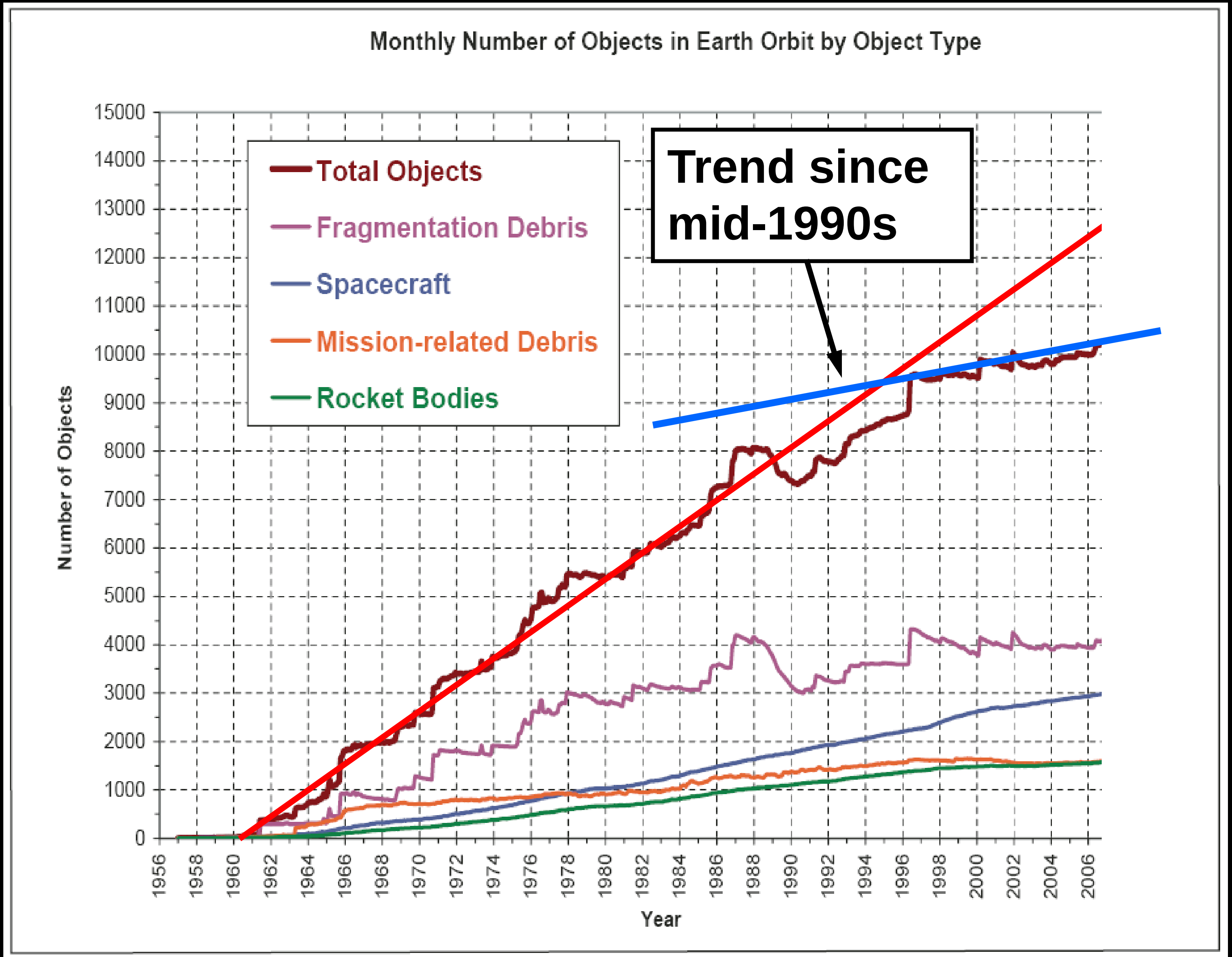
Historical Growth of Cataloged Objects



Historical Growth of Cataloged Objects Through 2006



Historical Growth of Cataloged Objects Through 2006



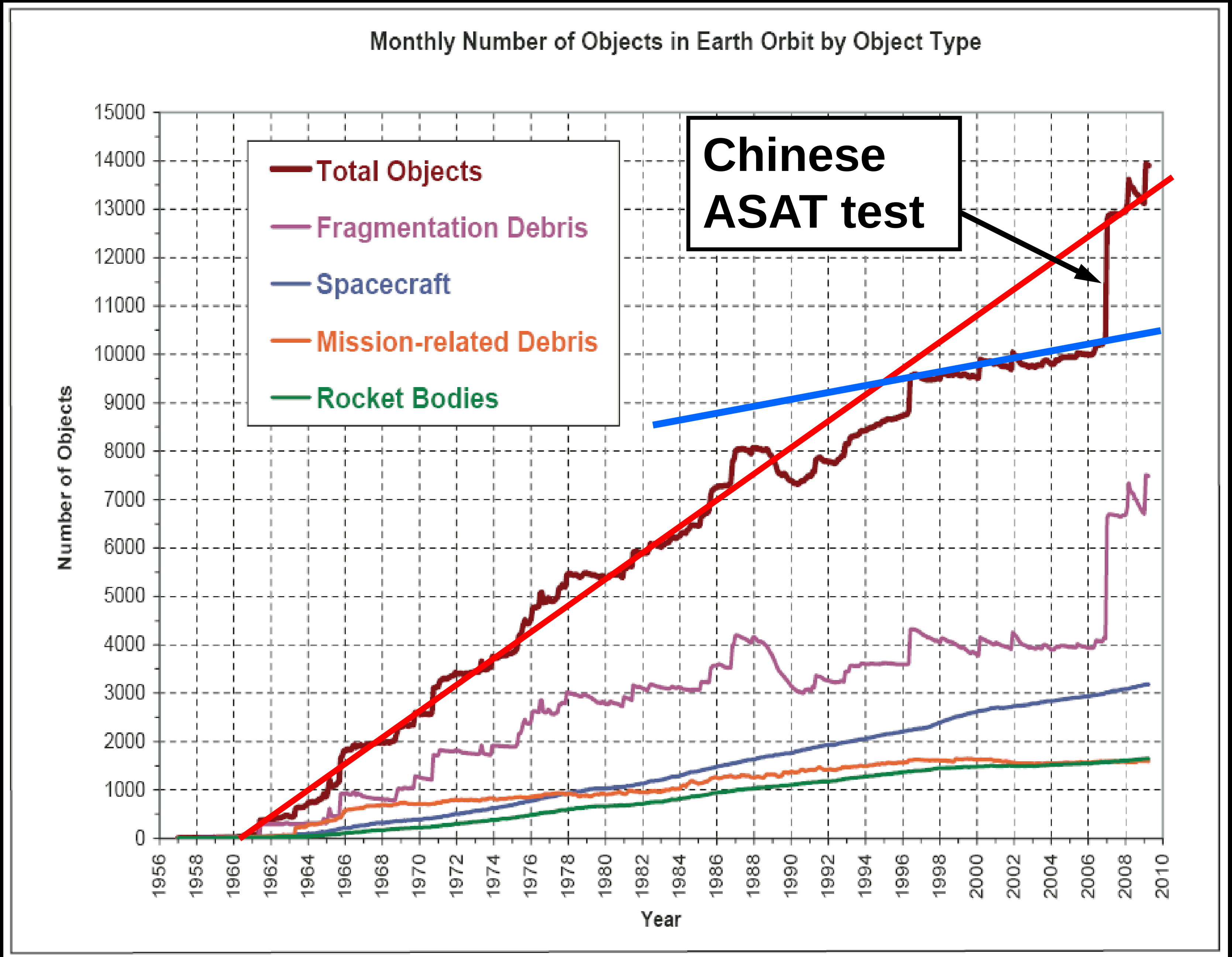
Through 1996, U.S. and Soviets/CIS added an average of 100-120 objects/year to the catalog.

	Dec. 1996	Dec. 2006	Increase
CIS	3836	4277	11.5%
United States	3990	4152	4.1%
China	112	391	
Total for All Countries	8507	9949	17%

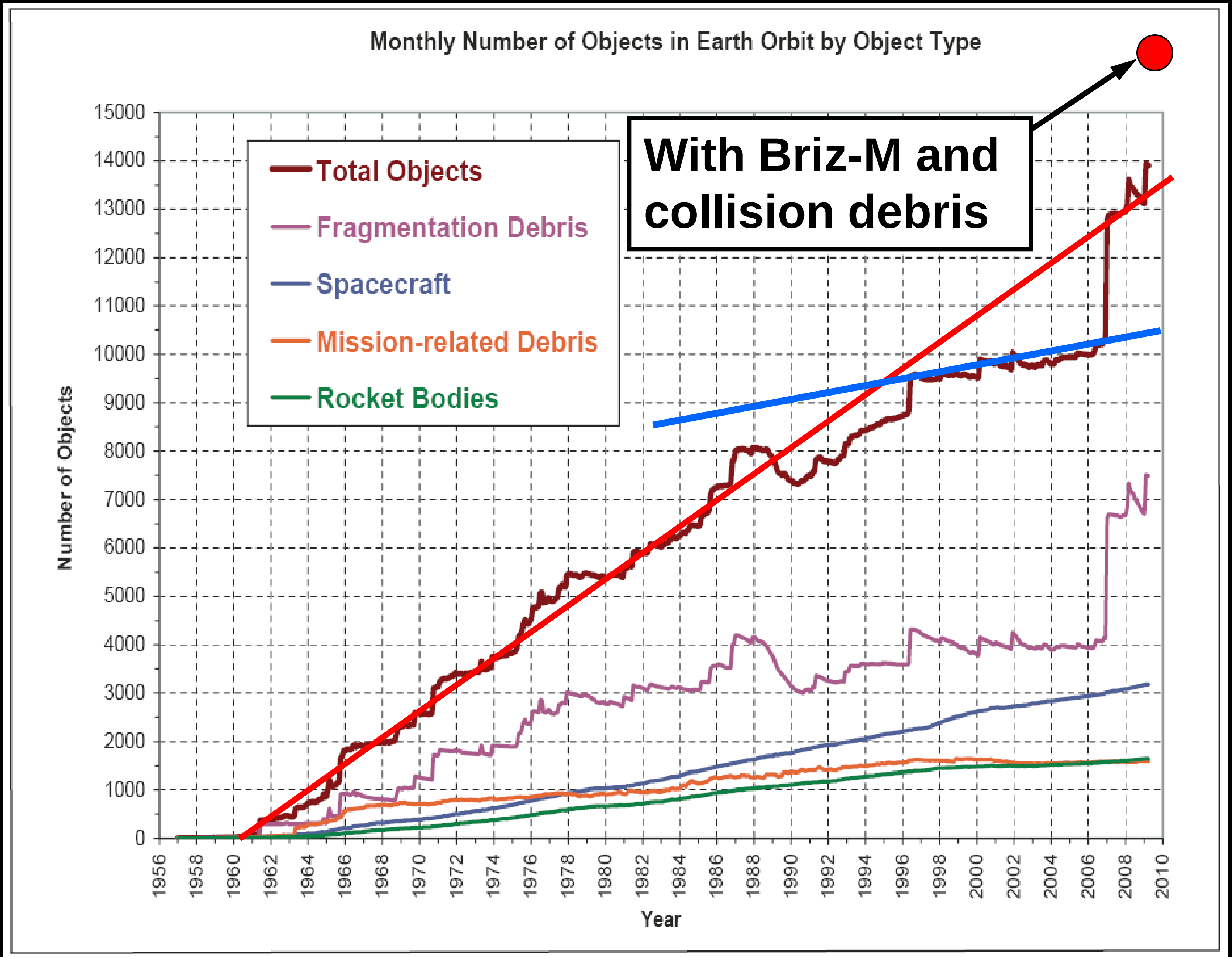
For the decade 1996-2006:

- CIS added average of 44 objects/year
- U.S. added average of 16 objects/year

Historical Growth of Cataloged Objects



Historical Growth of Cataloged Objects



Debris Estimates from FY-1C

	1 to 10 cm	> 10 cm
LEO debris before Jan. 07	220,000	10,000
Debris from Chinese ASAT test	150,000	2,500

Debris Estimates

	1 to 10 cm	> 10 cm
Current LEO debris	370,000	14,000
Debris from 10-ton satellite	250,000 - 750,000	5,000 - 15,000

➔ The destruction of a *single* 10-ton satellite could double or triple the amount of large debris in LEO

Known Cosmos Deliberate Destructions

Year	Number of Destructions	Number of Destructions above 300 km
1960-64	1	0
1965-69	8	7
1970-74	5	5
1975-79	11	11
1980-84	10	10
1985-89	10	6
1990-94	6	1
1995-99	1	0
2000-04	1	0
2005-09	1	0

Other Fragmentations (1)

- 18 of the 25 worst (non-deliberate) fragmentations have been rocket bodies (due to residual propellant exploding)

- Strict enforcement of the guidelines should be able to reduce this debris source significantly, but fragmentations continue

- The Briz-M breakup probably could have been avoided by adding a backup system to vent the propellant once there was a propulsion failure

- True for other events as well, including CIS ullage motors
  - 37 have fragmented since 1984 ➔ 250 fragments still in orbit

Known Ullage Motor Breakups

Year	Number of Breakups	Debris Still in Orbit
1960-64	0	0
1965-69	0	0
1970-74	0	0
1975-79	0	0
1980-84	1	0
1985-89	1	6
1990-94	8	21
1995-99	10	19
2000-04	9	57
2005-09	6	>114

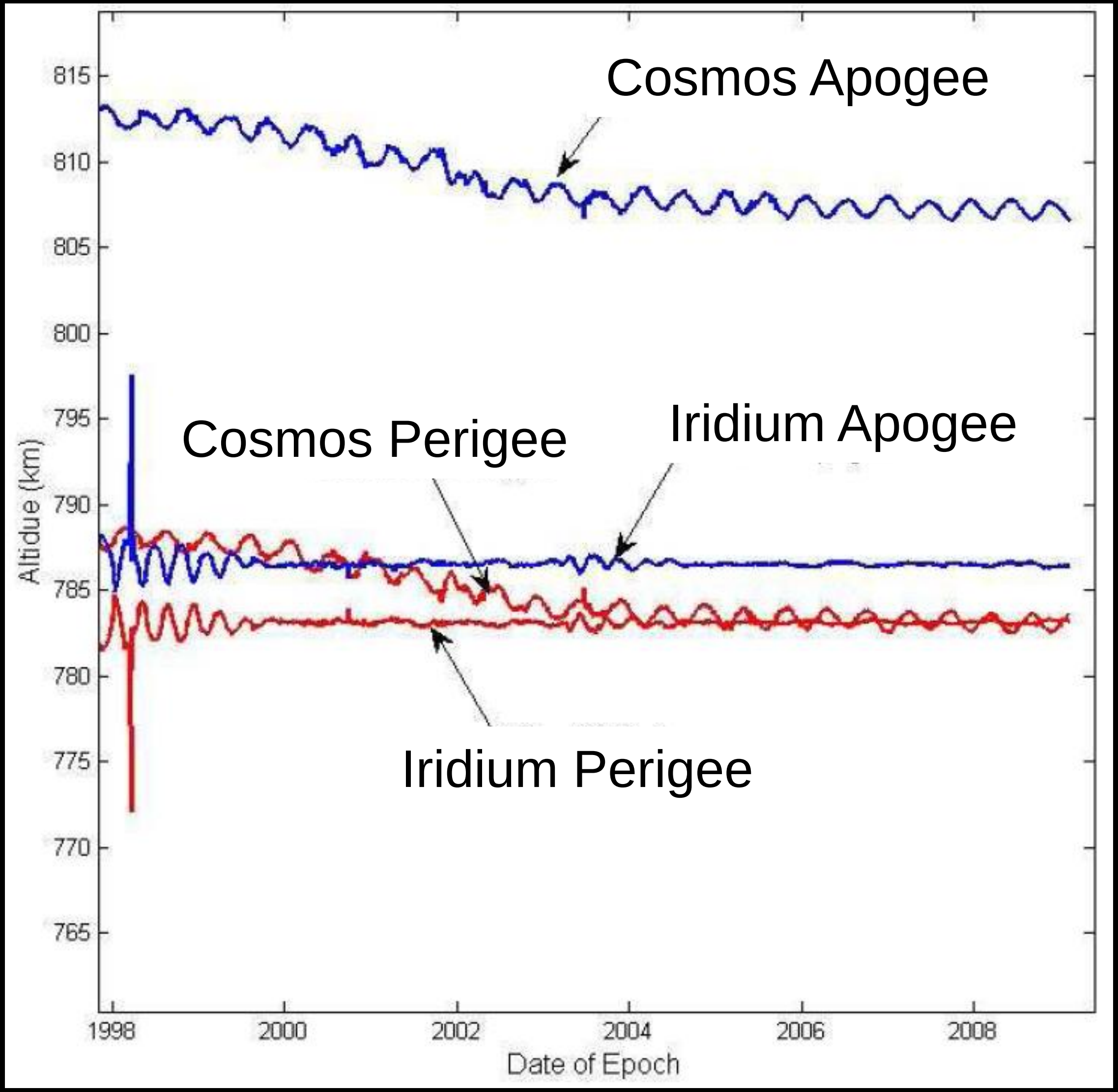
This should be solvable by passivation of motors

Other Fragmentations (2)

- NASA's Upper Atmos Research Sat (UARS) may be an example of success of passivation:
  - Fuel was vented after it failed
  - may have been hit by debris in 11/07 but did not explode

- Important to watch for warning signs

Iridium-Cosmos Collision (Feb. 2009)



From
Geoff
Forden

Delta Second Stage Fragmentations

- 9 stages launched in 1972-8 created 1600 fragments, 909 of which are still in orbit
- 53 Deltas were launched in this period, so 1 in 6 had a fragmenting 2nd stage

- By end of 1977, 6 had fragmented
- In 1978, 10 more were launched, and 2 stages fragmented

- Recently, Delta IV and H-IIA 2nd stages have shown odd behavior and should be watched

Conclusions (1)

- There are mixed signs about how well the mitigation guidelines are working in practice

- There is evidence that standard practices are getting better, especially in the U.S., which is important given its level of space activity

- But years of successful mitigation can be negated by a single large event

- Not doing as well overall as we need to.

Conclusions (2)

- Important to stop deliberate destructions, especially at high altitudes

- Destruction of very large mass satellites is unlikely from random processes, but these are some of the most likely targets if someone wanted to attack a satellite in a conflict. Would create very large amounts of debris.

➔ Priority is to keep kinetic ASAT weapons from being used in a conflict

Conclusions (3)

- Briz-M and other events show the importance of doing better at passivation
- Iridium-Cosmos collision shows the importance of getting defunct objects out of orbit
  - Re-examine 25-year rule
- Importance to pay attention to warning signs, like orbit change of Cosmos or Delta 2nd stage fragmentations

Conclusions (4)

- Require increased transparency
  - U.S. did not release orbit information about DSP-23 after it became space debris
- Mitigation guidelines should be made mandatory with enforcement mechanisms
  - Look at the issue of liability as an enforcement mechanism
- Important to instill good practices in emerging space-faring countries
- Need additional international work on remediation, not just mitigation

UCS Database of Active Satellites

- Data on ~ 900 satellites, updated quarterly
- Available at www.ucsusa.org

Microsoft Excel

File Edit View Insert Format Tools Data Window Help

Type a question for help

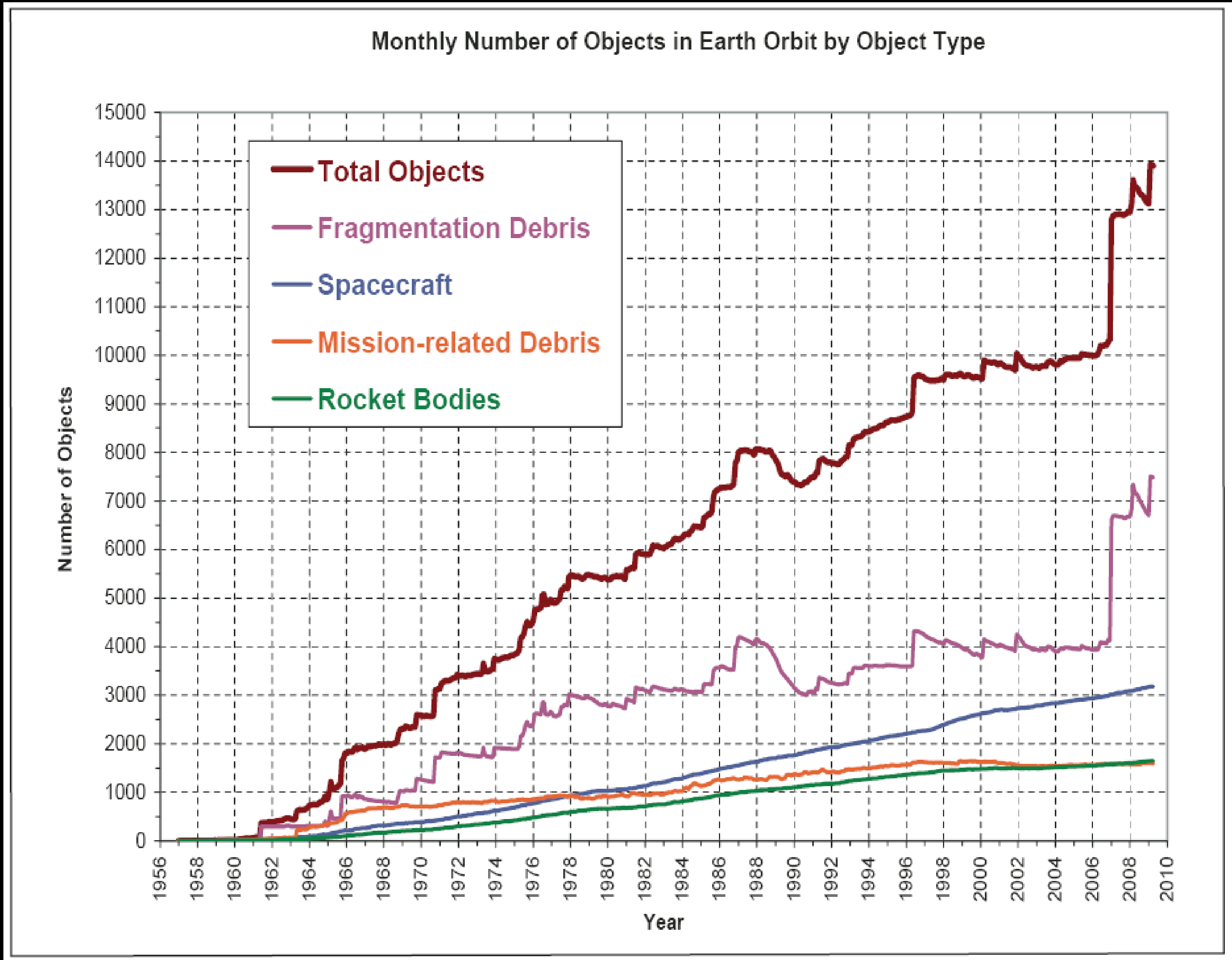
75% Arial 10

C1 Operator/Owner

UCS_Satellite_Database_10-6-08

	A	B	C	D	E	F	G	H	I	J	
1	Name of Satellite, Alternate Names	Country of Operator/Owner	Operator/Owner	Users	Purpose	Type of Orbit	Longitude of GEO	Perigee (km)	Apogee (km)	Eccentricity	Inclinat
377	Yamal-201	Russia	Gazcom (subsidiary of Gaz	Commercial	Communications	GEO, 89.94° E	+89.84	35,777	35,795	2.13E-04	
378	Yamal-202	Russia	Gazcom (subsidiary of Gaz	Commercial	Communications	GEO, 49.04° E	+49.04	35,781	35,789	9.49E-05	
379	Yubileiny (Jubilejnyj, Radio Sputnik 3	Russia	Research Laboratory of Aerospace Technol		Technology Develo	LEO/I		1,480	1,508	1.78E-03	
380	Express AM22 (Sesat 2)	Russia/Multinational	Russian Satellite Communi	Commercial	Communications	GEO, 54.81° E	+54.81	35,870	35,894	2.84E-04	
381	Saudicomsat-1	Saudi Arabia	Riyadh Space Research Ins	Commercial	Technology Develo	LEO, Sun-sync.		699	734	2.47E-03	
382	Saudicomsat-2	Saudi Arabia	Riyadh Space Research Ins	Commercial	Technology Develo	LEO, Sun-sync.		699	764	4.58E-03	
383	Saudicomsat-3	Saudi Arabia	Riyadh Space Research Ins	Commercial	Communications	LEO, Sun-sync.		653	717	4.54E-03	
384	Saudicomsat-4	Saudi Arabia	Riyadh Space Research Ins	Commercial	Communications	LEO, Sun-sync.		650	750	7.07E-03	
385	Saudicomsat-5	Saudi Arabia	Riyadh Space Research Ins	Commercial	Communications	LEO, Sun-sync.		652	728	5.38E-03	
386	Saudicomsat-6	Saudi Arabia	Riyadh Space Research Ins	Commercial	Communications	LEO, Sun-sync.		649	761	7.92E-03	
387	Saudicomsat-7	Saudi Arabia	Riyadh Space Research Ins	Commercial	Communications	LEO, Sun-sync.		651	739	6.23E-03	
388	Saudisat 1C (Oscar 50, SO 50)	Saudi Arabia	Space Research Institute, I	Government	Research	LEO/I		633	689	3.98E-03	
389	Saudisat-2	Saudi Arabia	Riyadh Space Research Ins	Government	Research on remot	LEO, Sun-sync.		686	723	2.62E-03	
390	Saudisat-3	Saudi Arabia	Riyadh Space Research Ins	Government	Earth Observation F	LEO		658	677	1.35E-03	
391	ST-1 (SinGalazy-Tel 1)	Singapore/Taiwan	Singapore Telecommunicat	Commercial	Communications	GEO, 87.93° E	+87.93	35,771	35,802	3.68E-04	
392	Kompsat-2 (Arirang 2, Korean planne	South Korea	Korea Aerospace Researct	Government/C	Earth Observation/T	LEO, Sun-sync.		675	702	1.91E-03	
393	Koreasat 2 (Mugunghwa 2)	South Korea	KT Corporation	Commercial	Communications	GEO, 112.97° E	+112.97	35,782	35,791	1.07E-04	
394	Koreasat 3 (Mugungwha 3)	South Korea	KT Corporation	Commercial	Communications	GEO, 116.03° E	+116.03	35,764	35,810	5.46E-04	
395	Koreasat 5 (Mugungwha 5)	South Korea	KT Corporation/Korean Ag	Military/Comm	Communications	GEO, 113° E	+113.00	35,775	35,820	5.34E-04	
396	Hispasat 1C	Spain	Hispasat	Comm/Gov/Mi	Communications	GEO, 29.95° W	-29.95	35,770	35,803	3.91E-04	
397	Hispasat 1D	Spain	Hispasat	Comm/Gov/Mi	Communications	GEO, 29.98° W	-29.98	35,763	35,810	5.57E-04	
398	Nanosat-1	Spain	Instituto Nacional de Técnia Aeroespacial (INTA)	Government	Communications	LEO, Sun-sync.		658	666	5.69E-04	
399	Spainsat	Spain	Hisdesat/Ministry of Defen	Military	Communications	GEO, 30° W	-30.00	35,777	35,797	2.37E-04	
400	XTAR-EUR	Spain	Ministry of Defense/XTAR	Military/Gover	Communications	GEO, 29° E	+29.00	35,782	35,791	1.07E-04	
401	Astra-5 (Sirius 2, GE-1E)	Sweden	SES Sirius AB	Commercial	Communications	GEO, 31.5° E	+31.5	35,783	35,788	5.93E-05	
402	Odin	Sweden	Swedish National Space Bc	Government	Astrophysics/Earth	LEO, Sun-sync.		611	620	6.44E-04	
403	Sirius 3	Sweden	SES Sirius AB	Commercial	Communications	GEO, 5.03° E	+5.03	35,778	35,793	1.78E-04	
404	Sirius 4 (Astra 4A)	Sweden	SES Sirius AB	Commercial	Communications	GEO, 5.00° E	+5.00	35,784	35,790	7.12E-05	
405	Formosat-2 (ROCSAT-2, Republic of	Taiwan	National Space Program O	Government/M	Remote Sensing	LEO, Sun-sync.		725	743	1.27E-03	
406	COSMIC-A (Formosat-3A, Constella	Taiwan/USA	National Space Program O	Government/C	Remote Sensing	LEO, Sun-sync.		800	800	0.00E+00	
407	COSMIC-B (Formosat-3B, Constella	Taiwan/USA	National Space Program O	Government/C	Remote Sensing	LEO, Sun-sync.		800	800	0.00E+00	
408	COSMIC-C (Formosat-3C, Constella	Taiwan/USA	National Space Program O	Government/C	Remote Sensing	LEO, Sun-sync.		800	800	0.00E+00	
409	COSMIC-D (Formosat-3D, Constella	Taiwan/USA	National Space Program O	Government/C	Remote Sensing	LEO, Sun-sync.		800	800	0.00E+00	
410	COSMIC-E (Formosat-3E, Constellat	Taiwan/USA	National Space Program O	Government/C	Remote Sensing	LEO, Sun-sync.		800	800	0.00E+00	
411	COSMIC-F (Formosat-3F, Constellat	Taiwan/USA	National Space Program O	Government/C	Remote Sensing	LEO, Sun-sync.		800	800	0.00E+00	
412	Thaicom-1A (Thaicom 1)	Thailand	Shin Satellite Public Comp.	Commercial	Communications	GEO, 119.91° E	+119.91	35,780	35,796	1.90E-04	

Historical Growth of Cataloged Objects



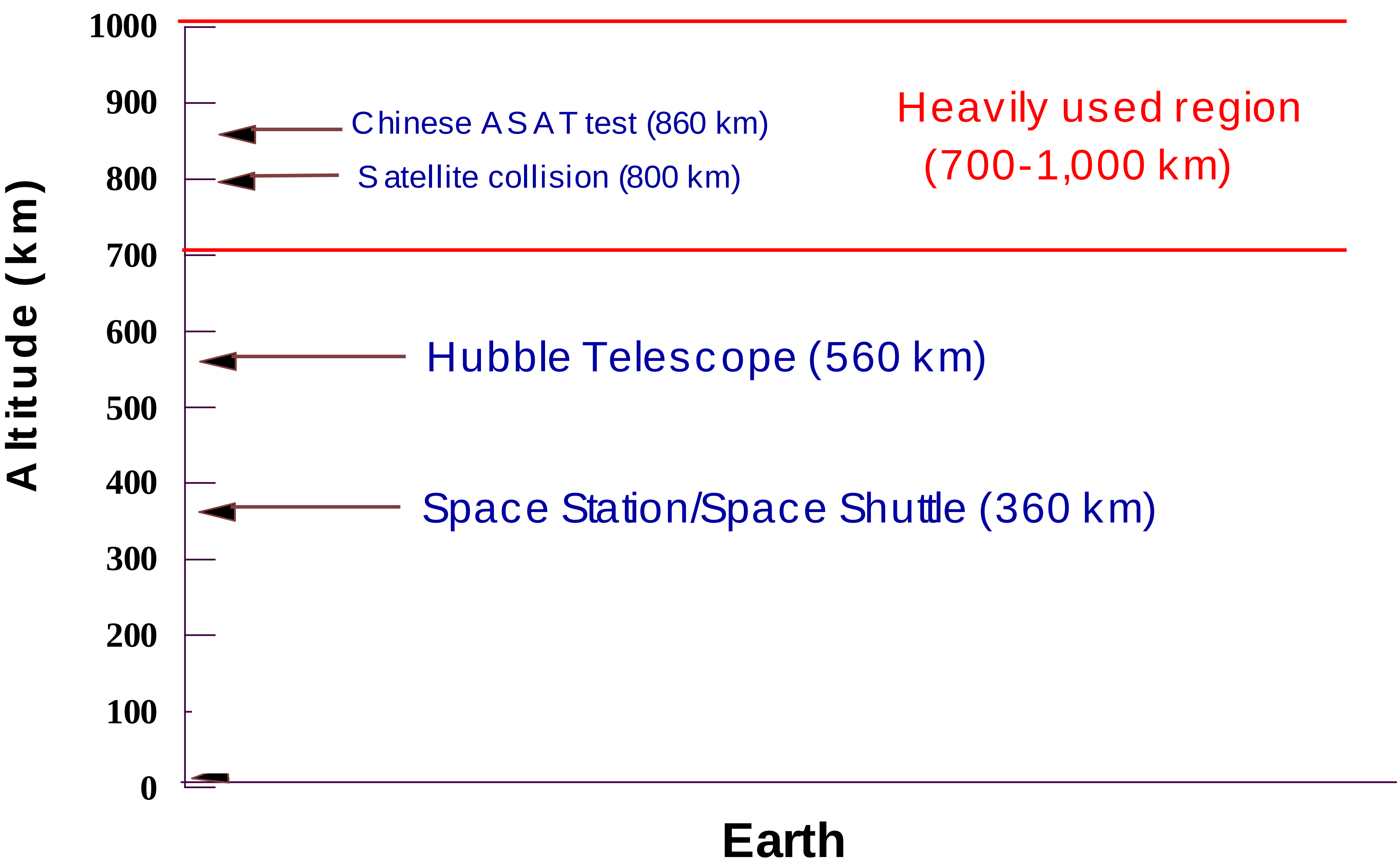
Known Collisions in Orbit

1991	Inactive Cosmos 1934 satellite hit by cataloged debris from Cosmos 296 satellite
1996	Active French Cerise satellite hit by cataloged debris from Ariane rocket stage
1997	Inactive NOAA 7 satellite hit by uncataloged debris large enough to change its orbit and create additional debris
2002	Inactive Cosmos 539 satellite hit by uncataloged debris large enough to change its orbit and create additional debris
2005	U.S. rocket body hit by cataloged debris from Chinese rocket stage
2007	Active Meteosat 8 satellite hit by uncataloged debris large enough to change its orbit
2007	Inactive NASA UARS satellite believed hit by uncataloged debris large enough to create additional debris
2009	Active Iridium satellite hit by inactive Cosmos 2251

Current Estimates of Debris in Orbit

	1 to 10 cm	> 10 cm
LEO debris	370,000	14,000
Debris at all altitudes	750,000	22,000

Roughly half of all debris of this size is in Low Earth Orbit
(or LEO, which is < 2,000 km altitude)



1000
900
800
700
600
500
400
300
200
100
0
Altitude (km)
Chinese ASAT test (860 km)
Satellite collision (800 km)
Heavily used region
(700-1,000 km)
Hubble Telescope (560 km)
Space Station/Space Shuttle (360 km)
Earth