The Space Environment: 2011

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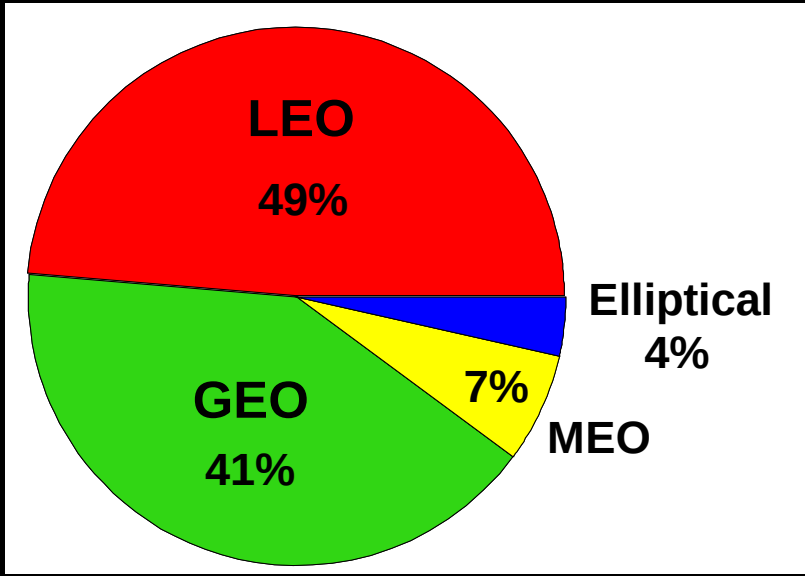
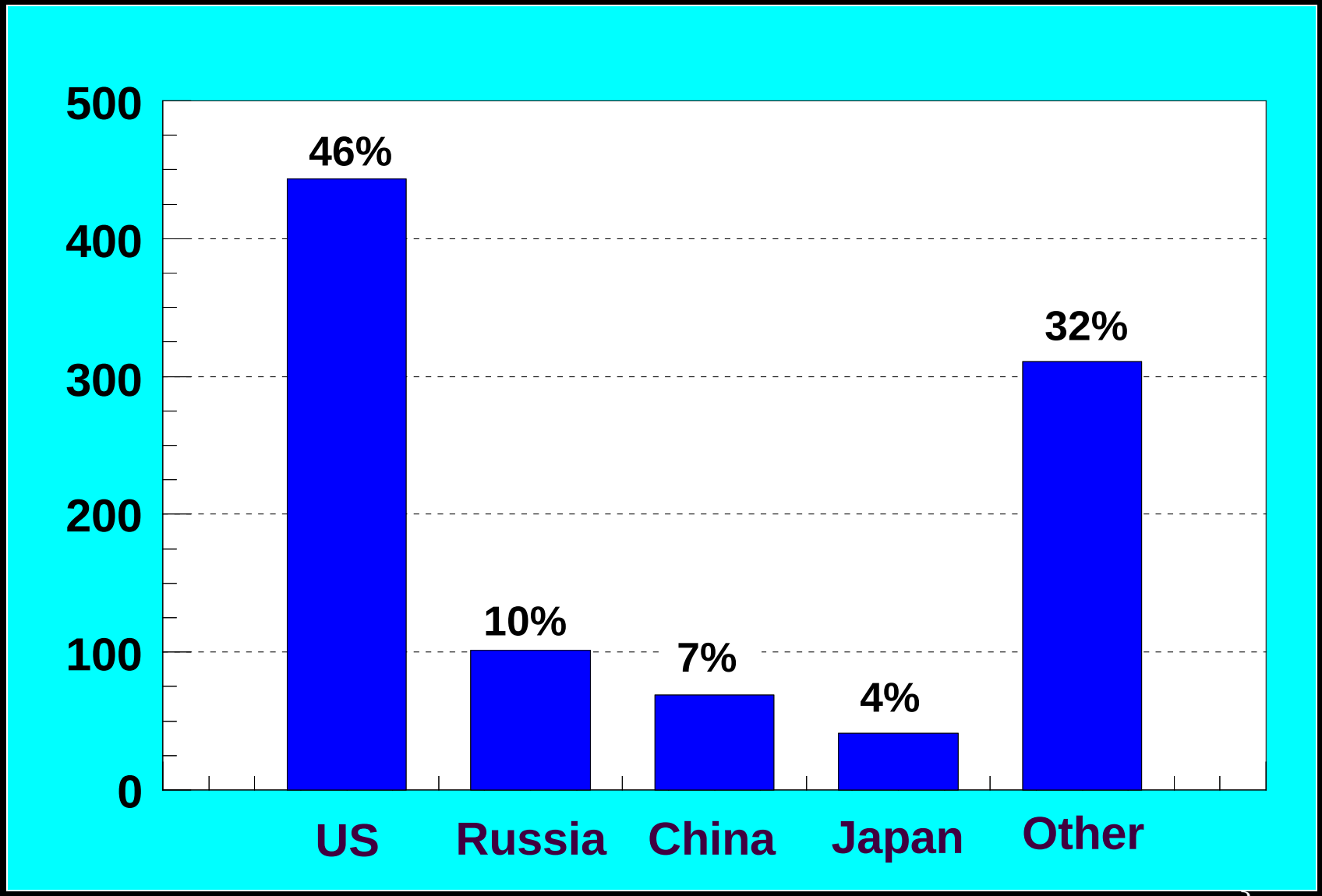
What's in Space Today?

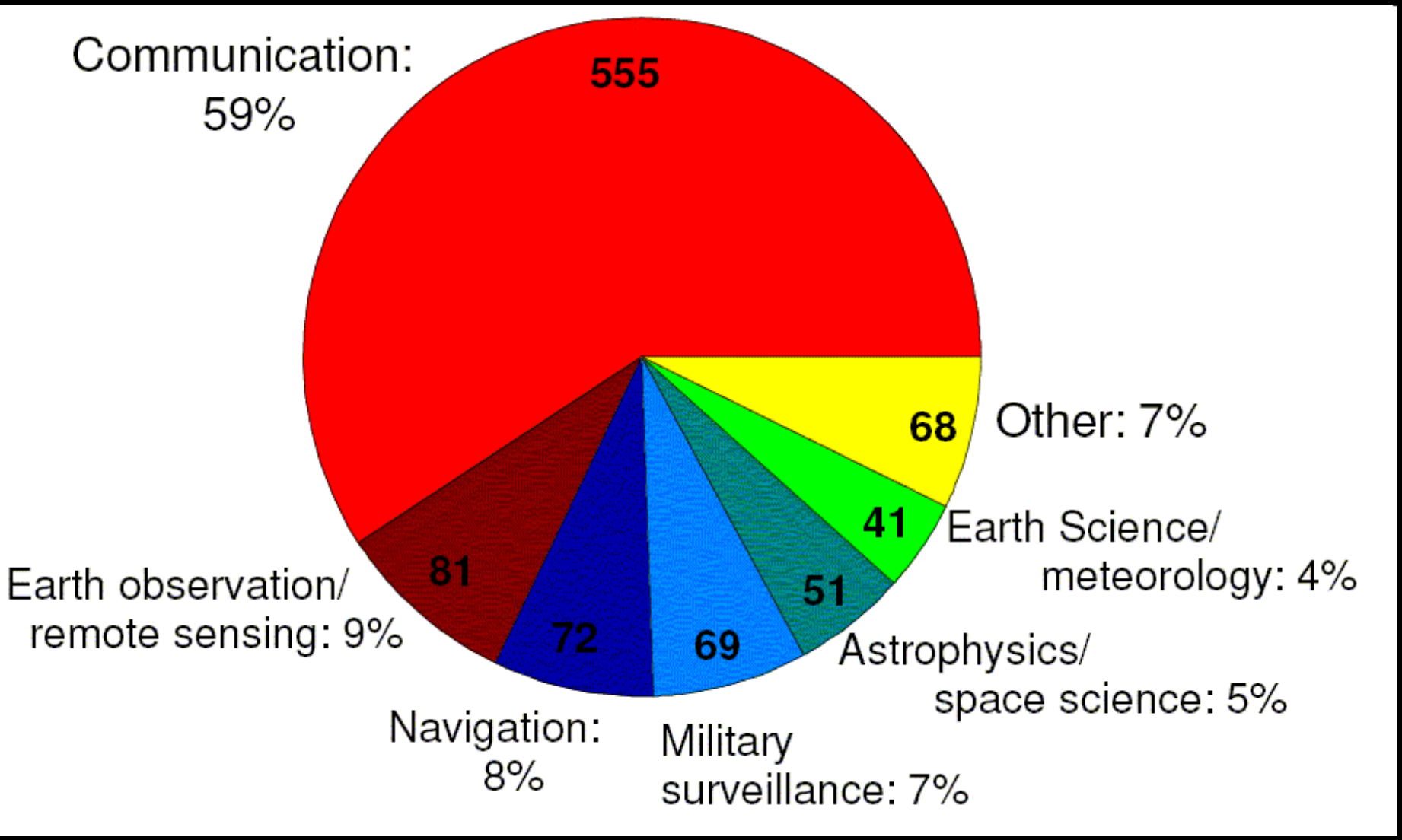
- Currently ~ 950 operational satellites
- 3 areas of space contain > 95% of operational satellites:
  - **Low earth orbit (LEO)**: 300-2,000 km altitude
    - 1.5 - 3 hour period
    - 7 - 8 km/s orbital speed
  - **Semi-synchronous (MEO)**: 20,000 km altitude
    - Navigation satellites (eg, GPS)
    - 12 hour period
    - 4 km/s orbital speed
  - **Geosynchronous (GEO)**: 36,000 km alt.
    - Communication/broadcast satellites
    - 24 hour period
    - 3 km/s orbital speed



Current Active Satellites



What Are Current Satellites Used For?



Data from 2010

“Total Debris” vs “Cataloged Debris”

- The U.S. tracks objects in space with radar and optical sensors in the Space Surveillance Network (SSN)
  - Can track objects in LEO larger than 5-10 cm in size
  - Can track objects in GEO larger than ~1 m in size

- U.S. keeps a Catalog of objects—currently ~16,000 objects

- To be in the Catalog:
  - the object must be tracked by SSN
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➔ The number of tracked objects is larger than the Catalog

➔ The total amount of debris is much larger than the Catalog

Categories of LEO Debris

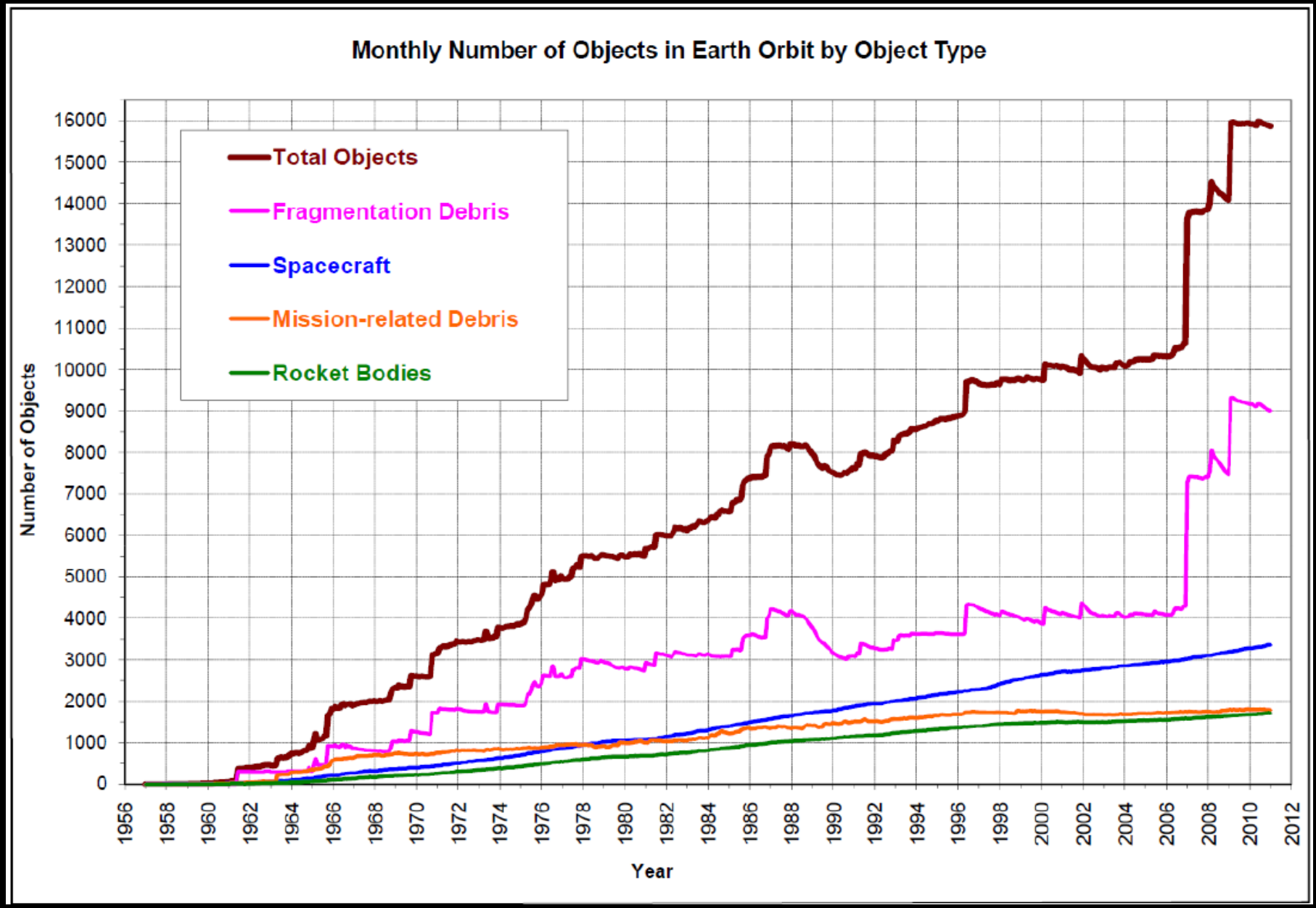
Physical Size	Comments	Potential Risk to Satellites
> 10 cm	-Can be tracked -No effective shielding	Complete destruction
1-10 cm	-Smaller objects in this range cannot be tracked -No effective shielding	Severe damage or complete destruction
< 1cm	-Cannot be tracked -Effective shielding exists	Damage

Current Estimates of Total Debris in Orbit

	1 to 10 cm	> 10 cm
LEO debris	400,000	14,000
Debris at all altitudes	750,000	24,000

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

Historical Growth of Space Debris Through 2011



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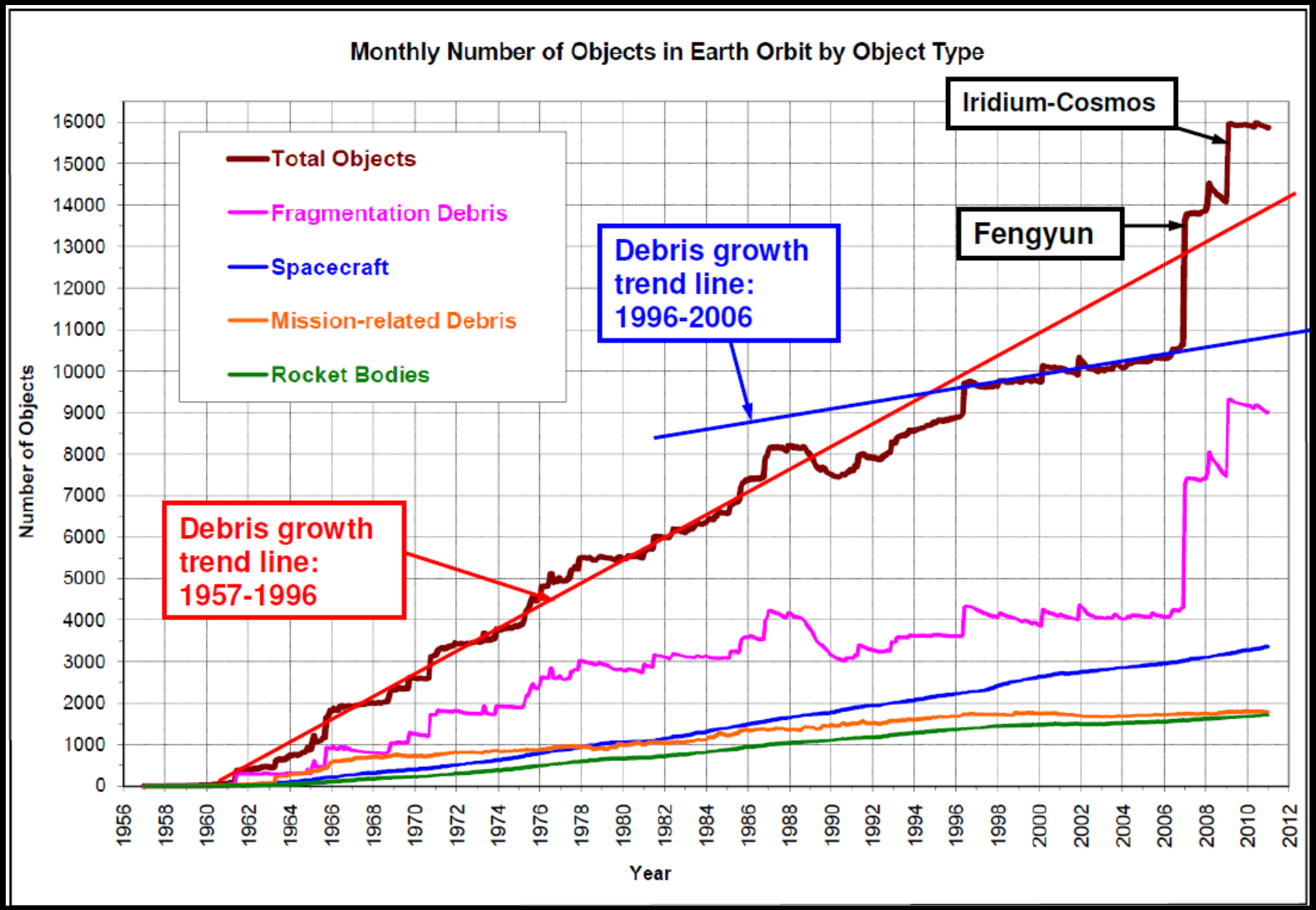
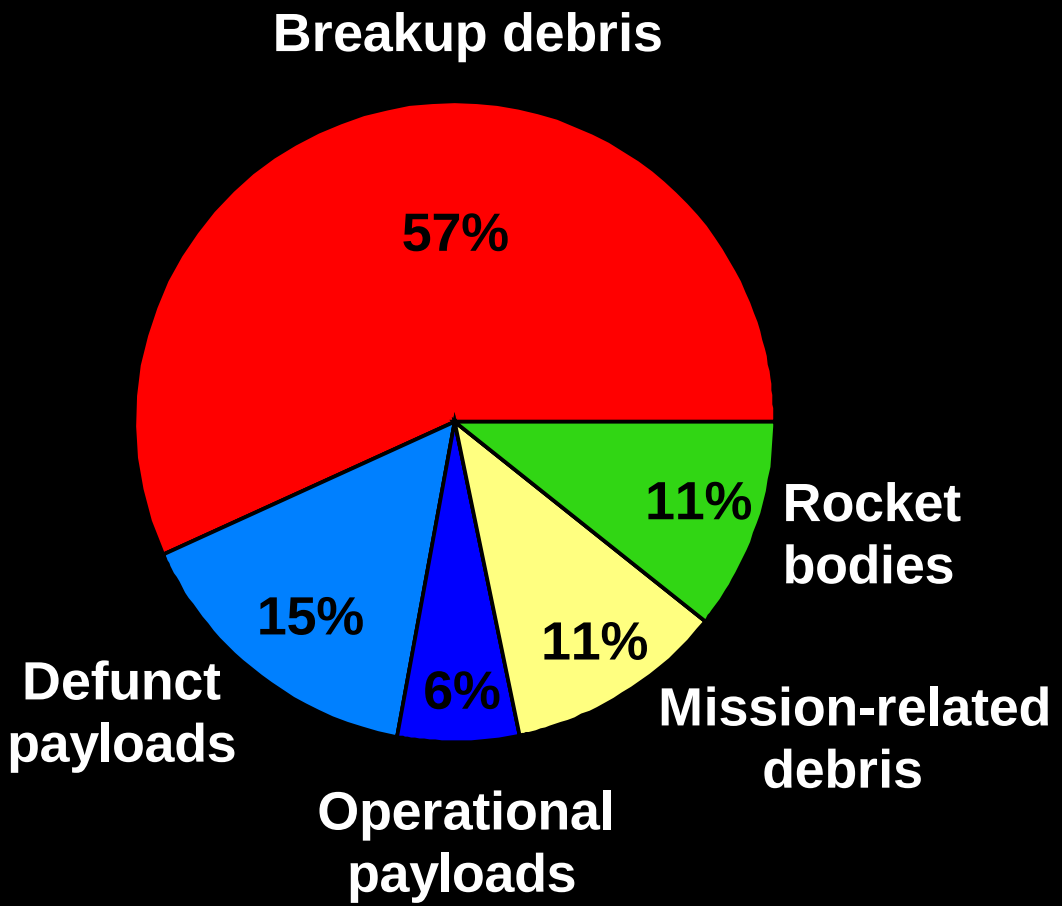


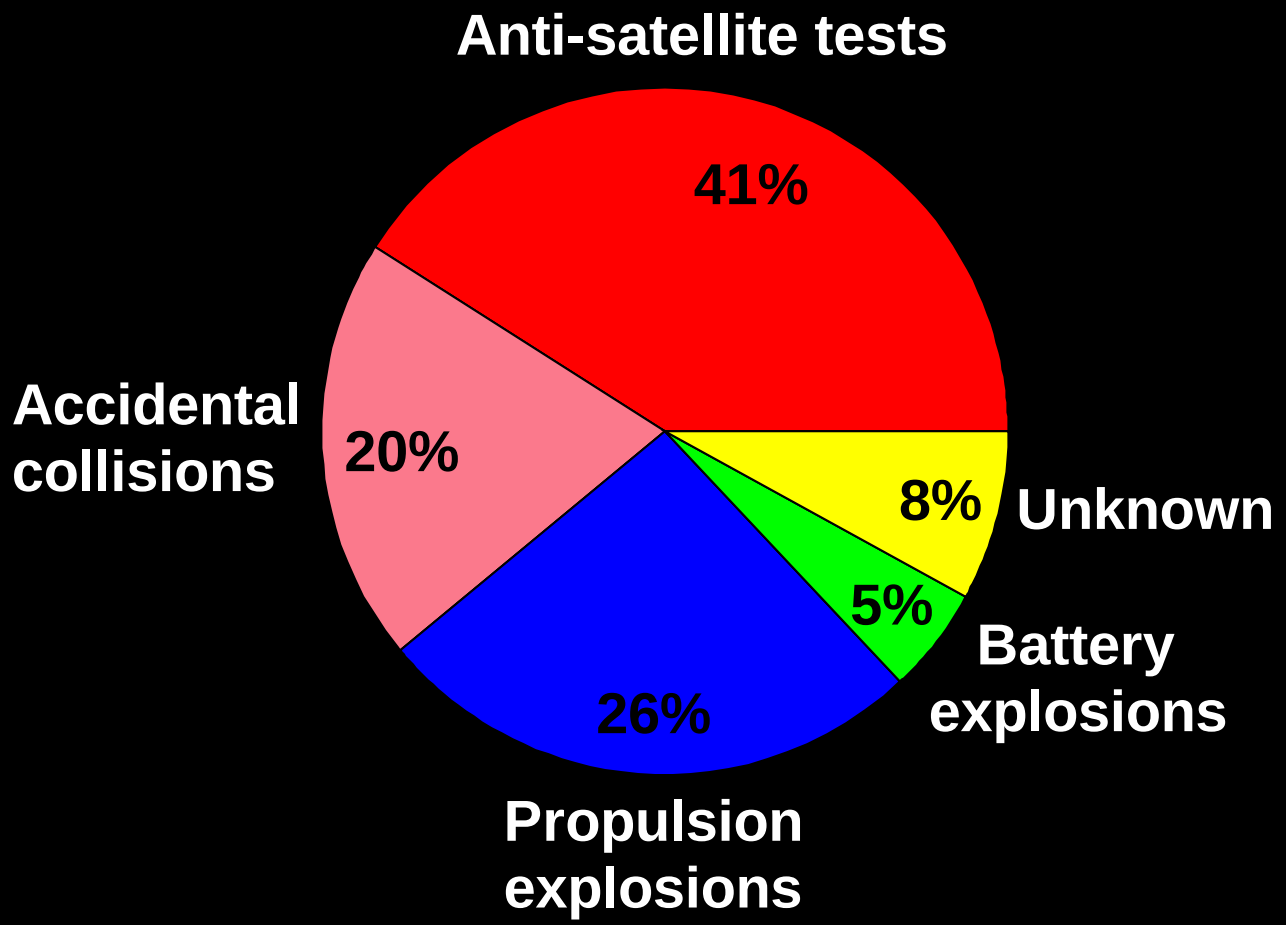
Where Did These Objects Come From?

Origin of Cataloged Objects in Space



Payloads and rocket bodies make up 99% of the mass of all objects in space. These are a source of future debris.

Origin of Breakup Debris



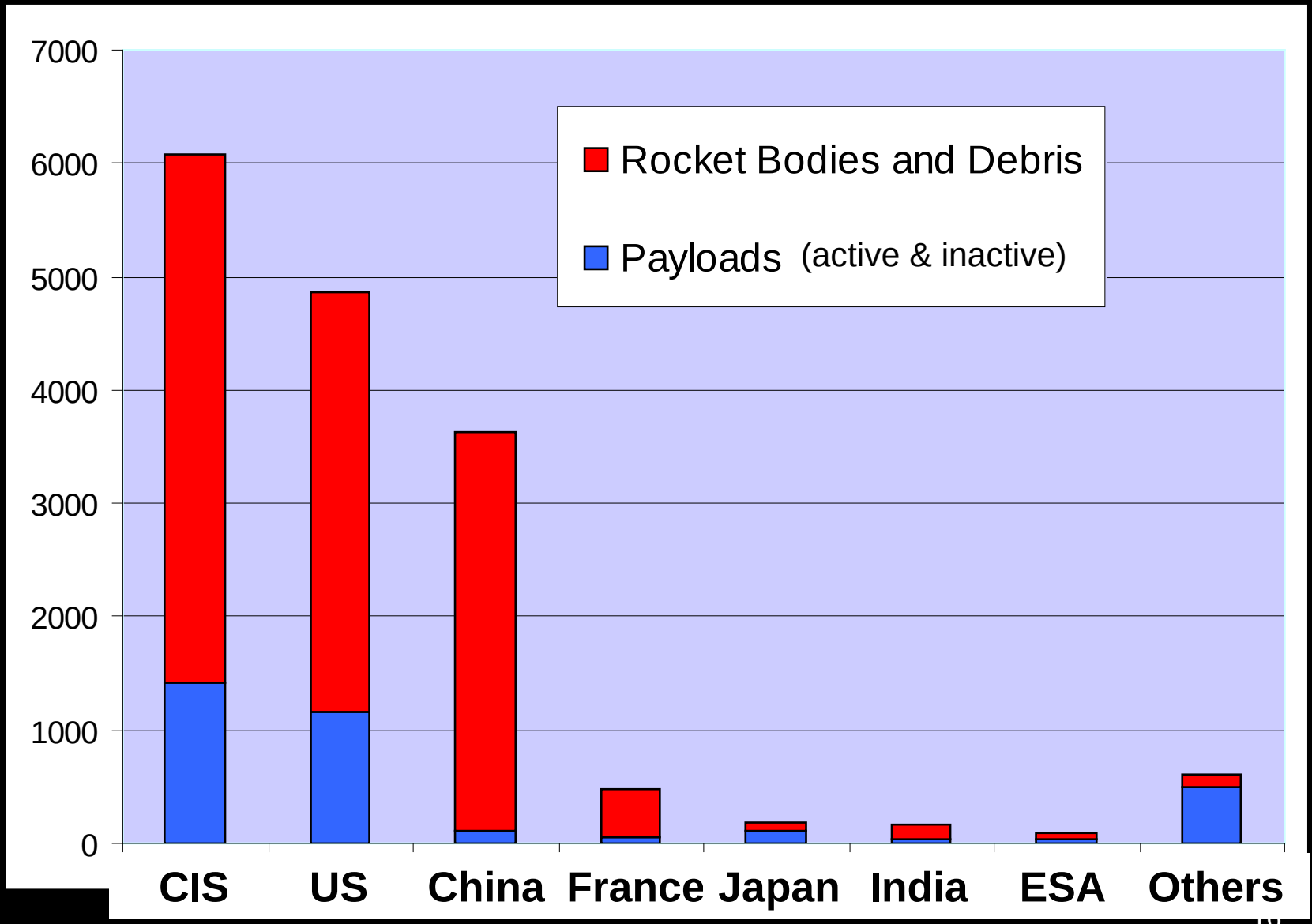
Top 10 Debris Events (as of May 2010)

Name	Year	Altitude	Cataloged Debris	Debris in Orbit	Cause
Fengyun-1C	2007	850 km	2841	2,756	Intentional collision
Cosmos 2251	2009	790 km	1267	1,215	Accidental collision
Briz-M RB	2007	500x15,000	85	> 1,000	Accidental explosion?
STEP 2 RB	1996	625 km	713	63	Accidental explosion
Iridium 33	2009	790 km	521	498	Accidental collision
Cosmos 2421	2008	410 km	509	18	Unknown
SPOT 1 RB	1986	805 km	492	33	Accidental explosion
OV 2-1/LCS 2 RB	1965	740 km	473	36	Accidental explosion
Nimbus 4 RB	1970	1075 km	374	248	Accidental explosion
TES RB	2001	670 km	370	116	Accidental explosion

= rocket body = last 5 years

Who Owns Them?

Number of Payloads + Debris by Country



Data from NASA Orbital Debris Quarterly News, Oct 2011

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

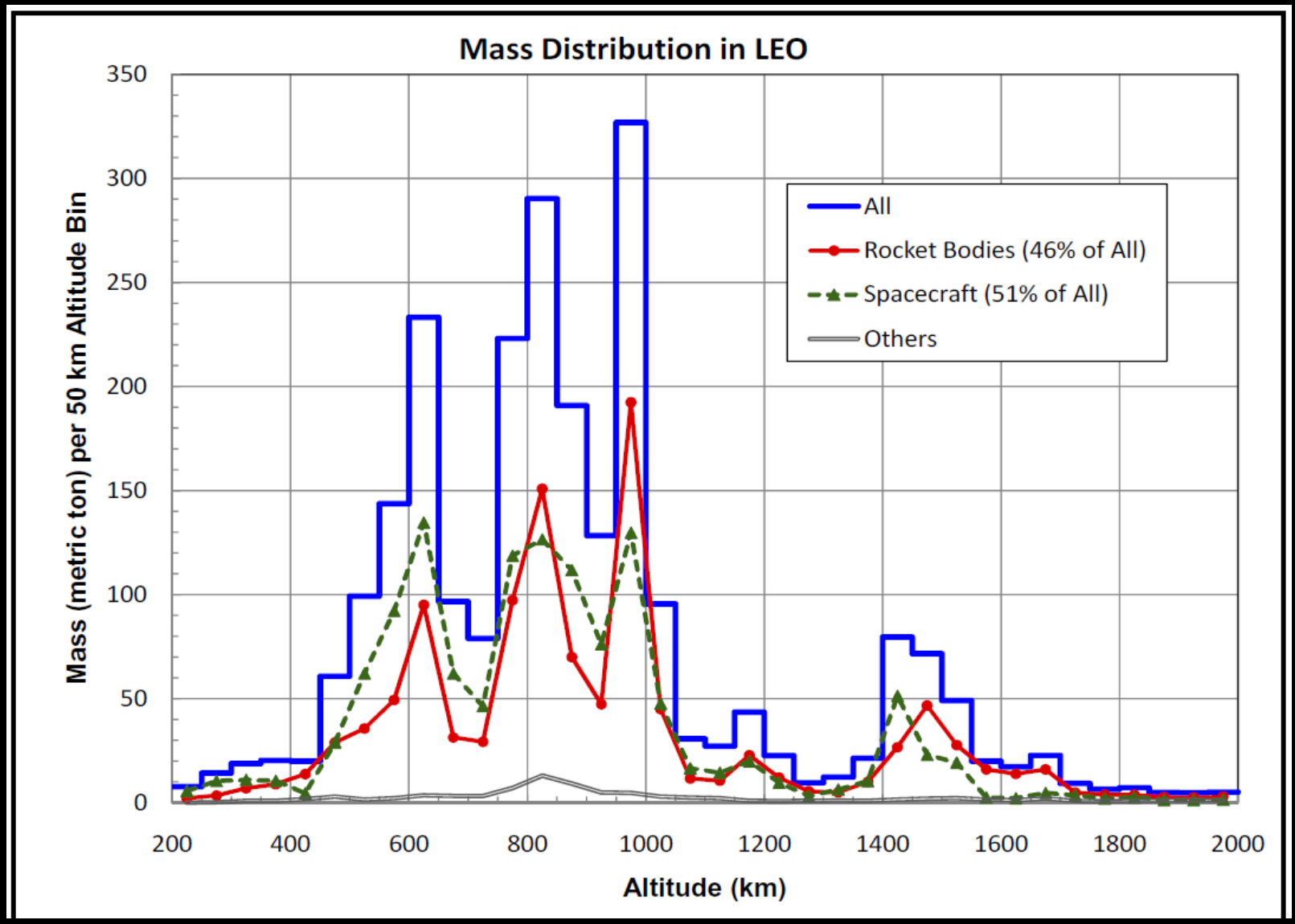
	Dec. 1996	Dec. 2006	Increase
CIS	3836	4277	11.5%
United States	3990	4152	4.1%
China	112	391	
Total for All Countries	8507	9949	17%

For the decade 1996-2006:

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

Where Are They?

Mass Distribution in LEO



From J.-C. Liou, “An Update on LEO Environmental Remediation with Active Debris Removal” (2011)

Debris Evolution from Breakup

Figure 2. Cloud of debris of size greater than 10 cm after 15 minutes.

Figure 3. Debris cloud after 10 days.

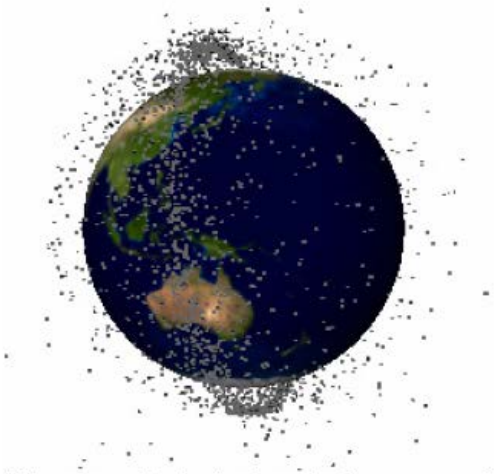


Figure 4: Debris cloud after 6 months.

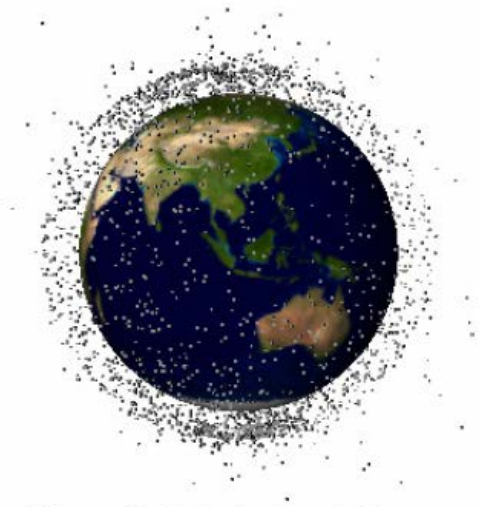
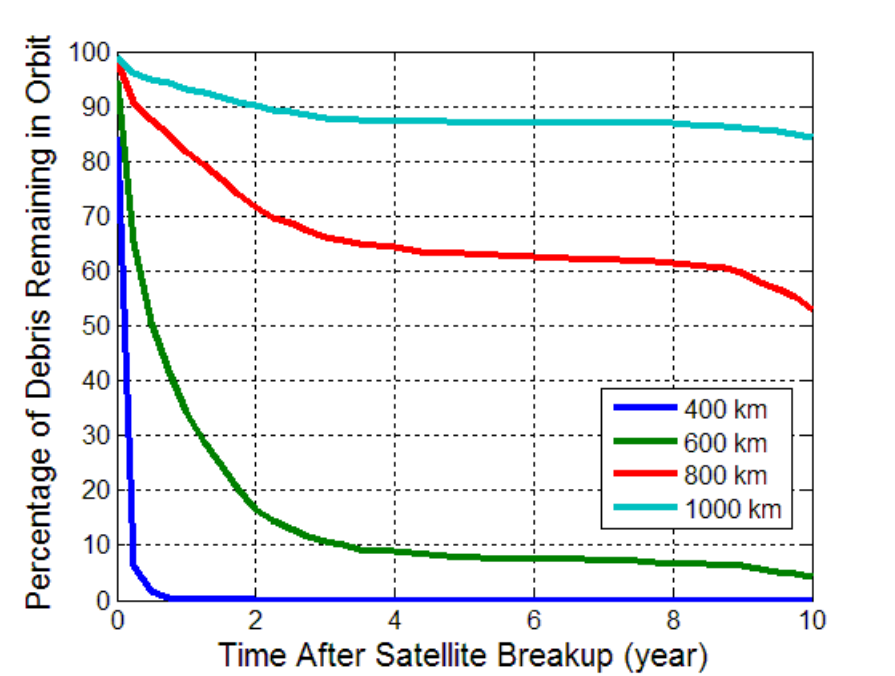


Figure 5: Debris cloud after 3 years.

Includes “J2” and “J4” terms to describe non-sphericity of earth

How Long Will They Stay In Space?

Debris Lifetime with Altitude

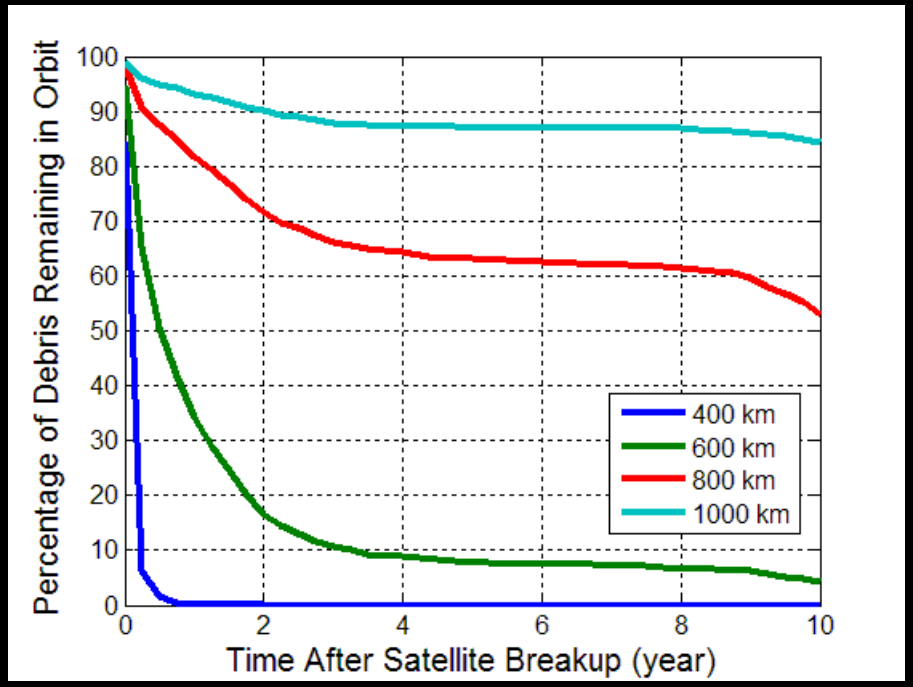


Breakup at solar maximum

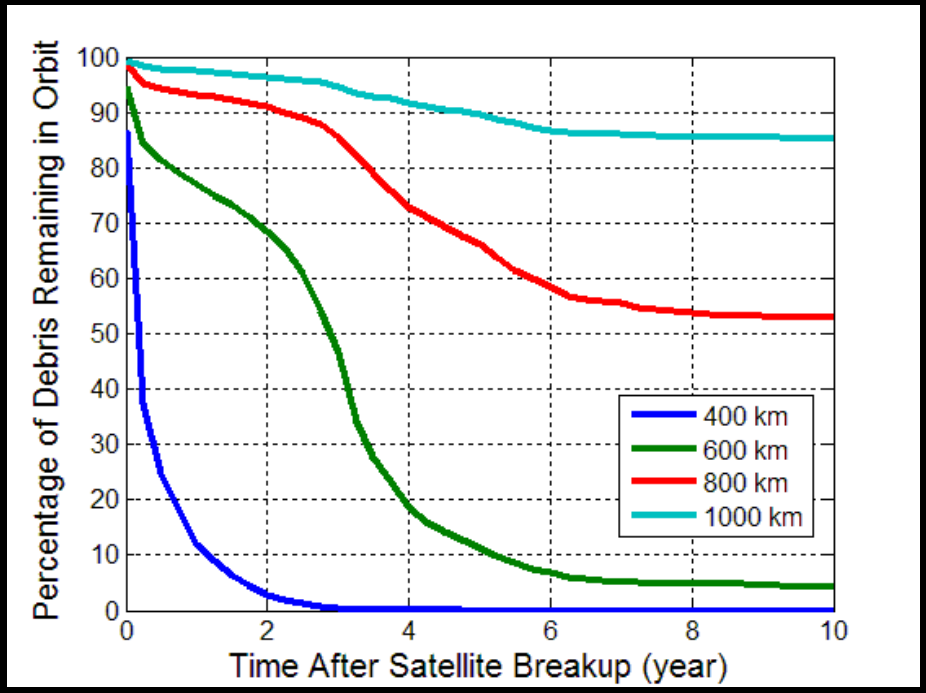
For > 10 cm debris from breakup of a 10-ton satellite

Calculation by Wang Ting, BUAA

Debris Lifetime with Altitude



Breakup at solar maximum

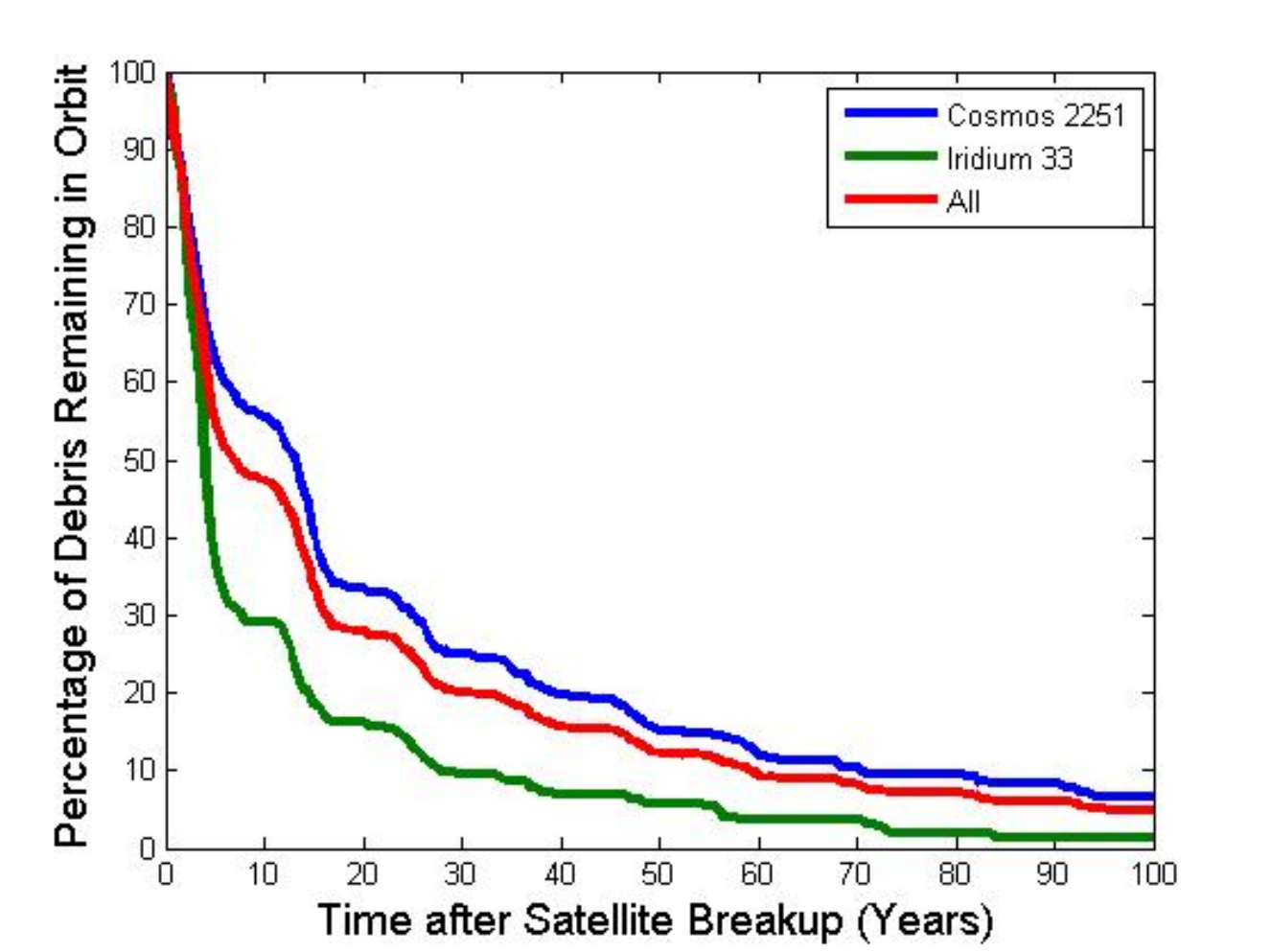


Breakup at solar minimum

For > 10 cm debris from breakup of a 10-ton satellite

Calculation by Wang Ting, BUAA

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



Calculation by Wang Ting, BUAA

Biggest Threats for Increasing Debris Population

- 18 of the 25 worst (non-deliberate) fragmentations have been rocket bodies (due to residual propellant exploding)
- Collisions in space are becoming more frequent
- Intentional destruction of satellites

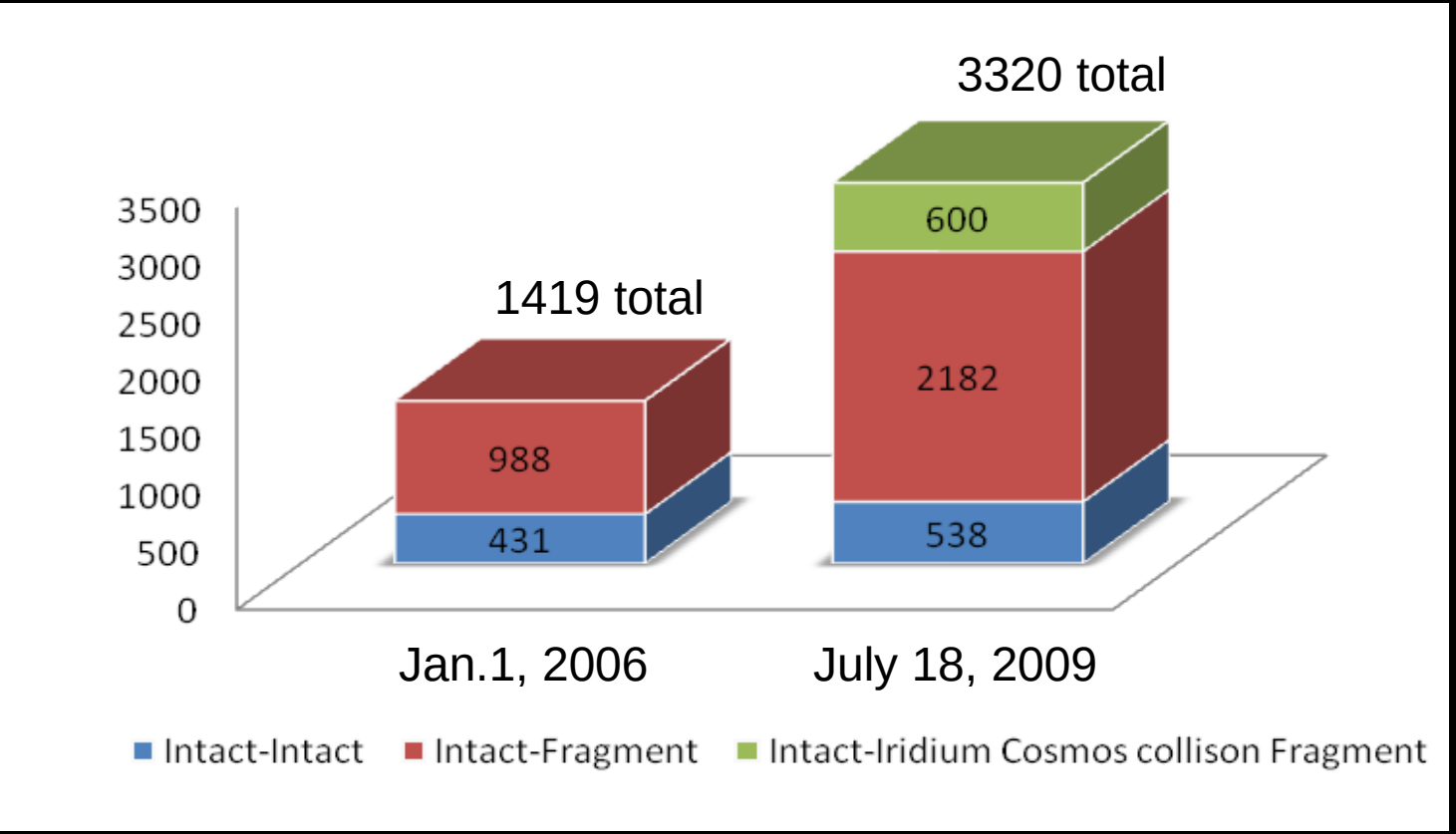
Year	Description
1991	Inactive Cosmos 1934 satellite hit by catalogued debris from Cosmos 296 satellite
1996	Active French Cerise satellite hit by catalogued debris from Ariane rocket stage
1997	Inactive NOAA 7 satellite hit by uncatalogued debris large enough to change its orbit and create additional debris
2002	Active Jason-1 satellite hit by uncatalogued debris
2002	Inactive Cosmos 539 satellite hit by uncatalogued debris large enough to change its orbit and create additional debris
2005	U.S. rocket body hit by catalogued debris from Chinese rocket stage
2007	Active Meteosat 8 satellite hit by uncatalogued debris large enough to change its orbit
2007	Inactive NASA UARS satellite believed hit by uncatalogued debris large enough to create additional debris
2009	Active Iridium satellite hit by inactive Cosmos 2251

Known Collisions in Orbit

Yellow highlighted events involve active satellites

Underlined events are between two cataloged objects

Collision Risk for LEO Objects Doubled Between 2006-2009

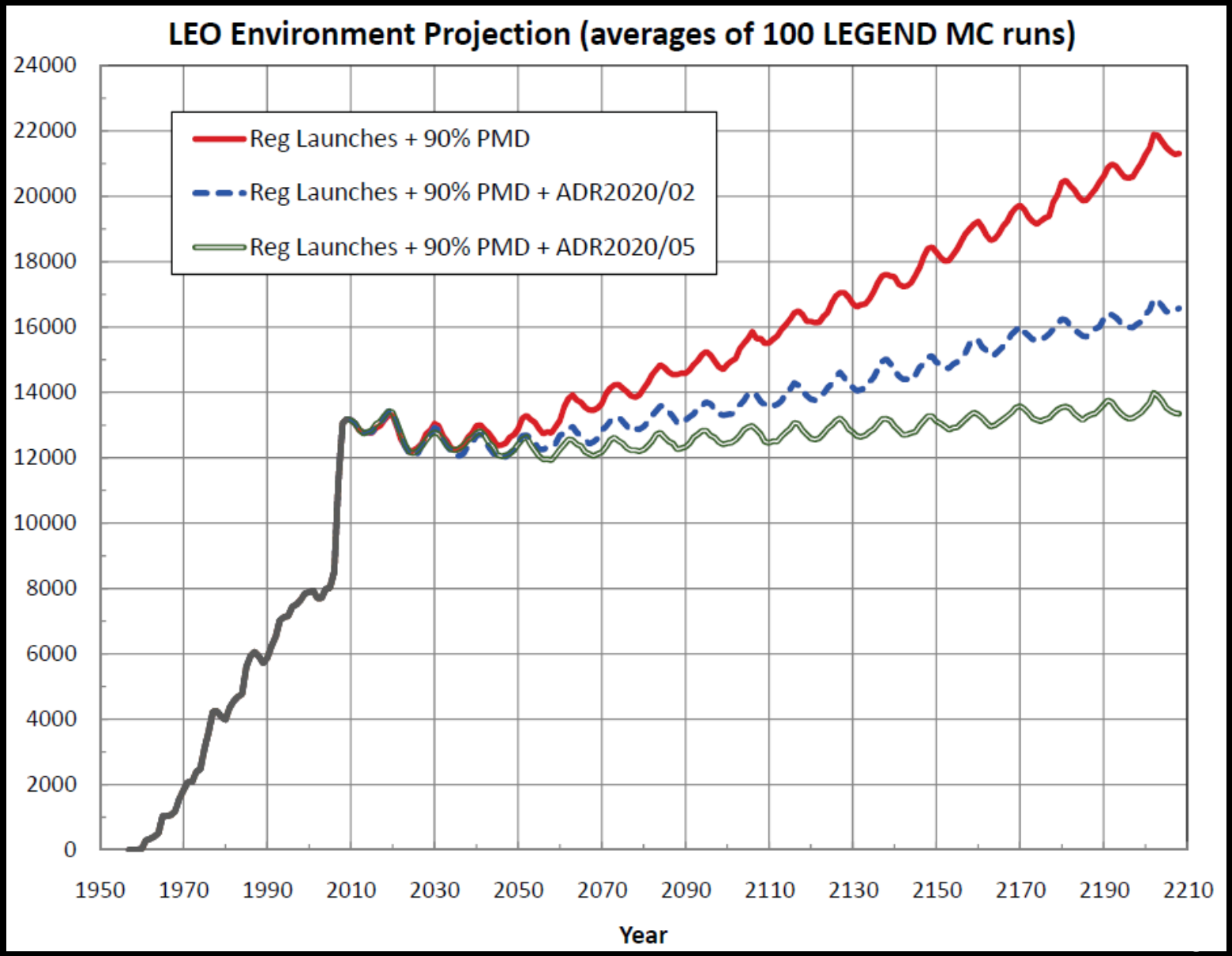


Number of conjunctions (< 5 km) of LEO objects in 24 hour period

Collision risk is proportional to the number of conjunctions.

Calculation by Wang Ting, BUAA

200-year Debris Evolution in LEO



J.-C. Liou, “An Update on LEO Environment Remediation,” 2011

Debris Estimates from the Breakup of a Single Large Satellite

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

➔ **The destruction of a *single* 10-ton satellite could double or triple the amount of > 1 cm debris in LEO**

Numbers based on NASA Standard Breakup Model and Fengyun breakup