Hazard from Orbital Debris

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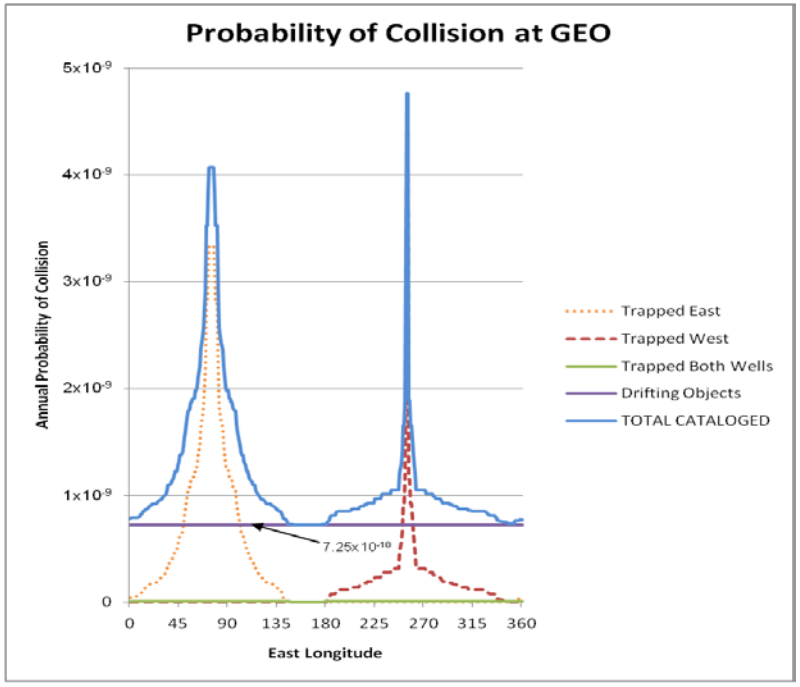
2009



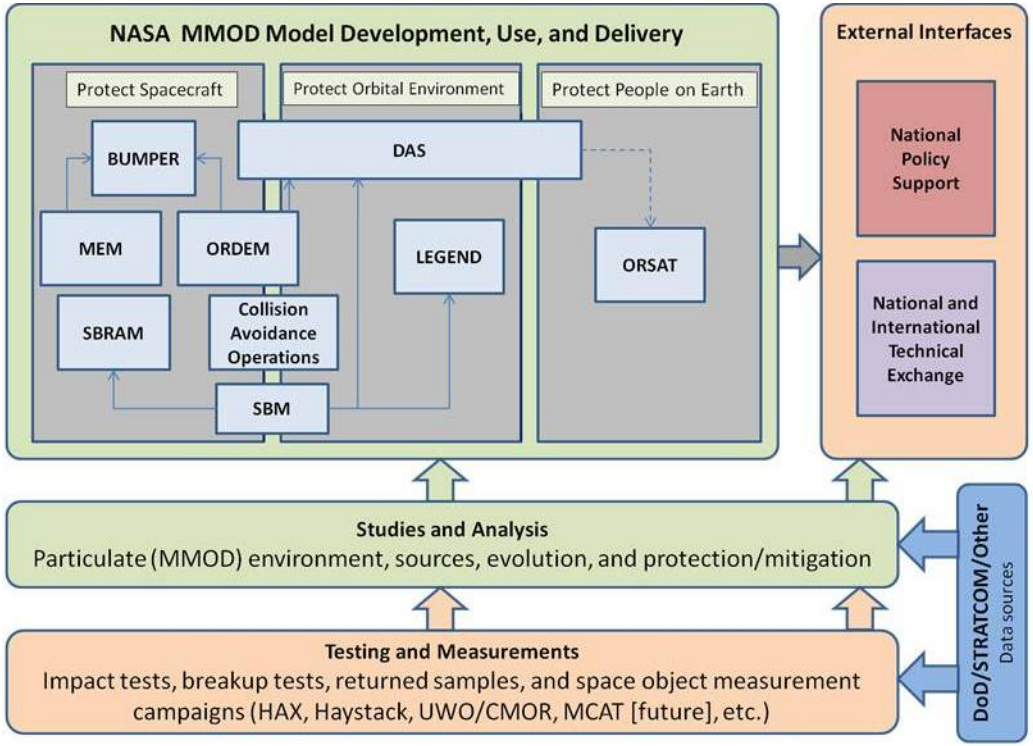
Overview

- On-orbit debris hazard is dynamic and complex
- The most hazardous regions are the most popular
- Natural perturbations are as important as manmade events
- Current hazard and future growth are uncertain

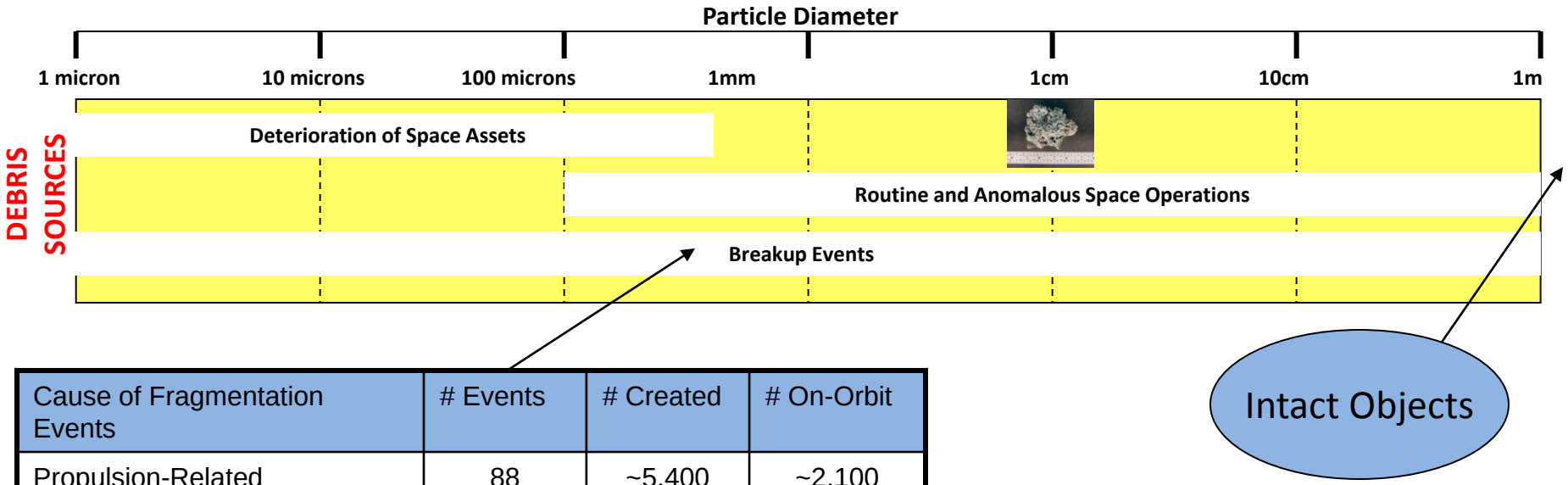
National Research Council Report

"Limiting Future Collision Risk to Spacecraft: An Assessment of NASA's Meteoroid and Orbital Debris Programs."

- Two primary tasks:
  - 1. Review NASA's existing efforts, policies, and organization with regards to orbital debris and meteoroids → → → →
  - 2. Assess whether NASA should initiate work in any new orbital debris or micrometeoroid areas.
    - **Satellite anomalies database**

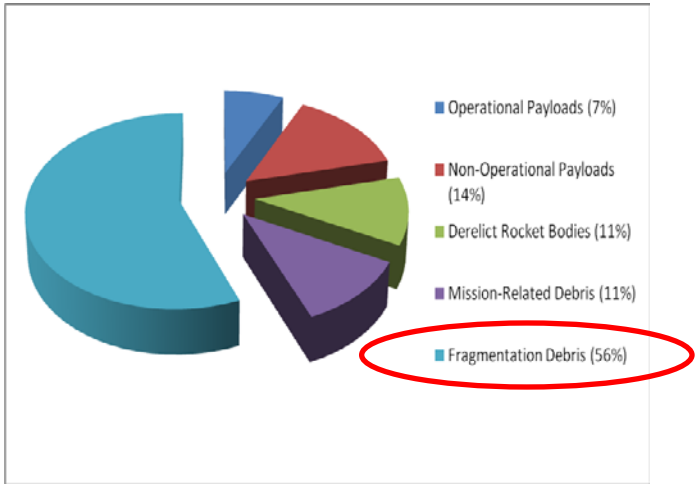


What is Orbital Debris?

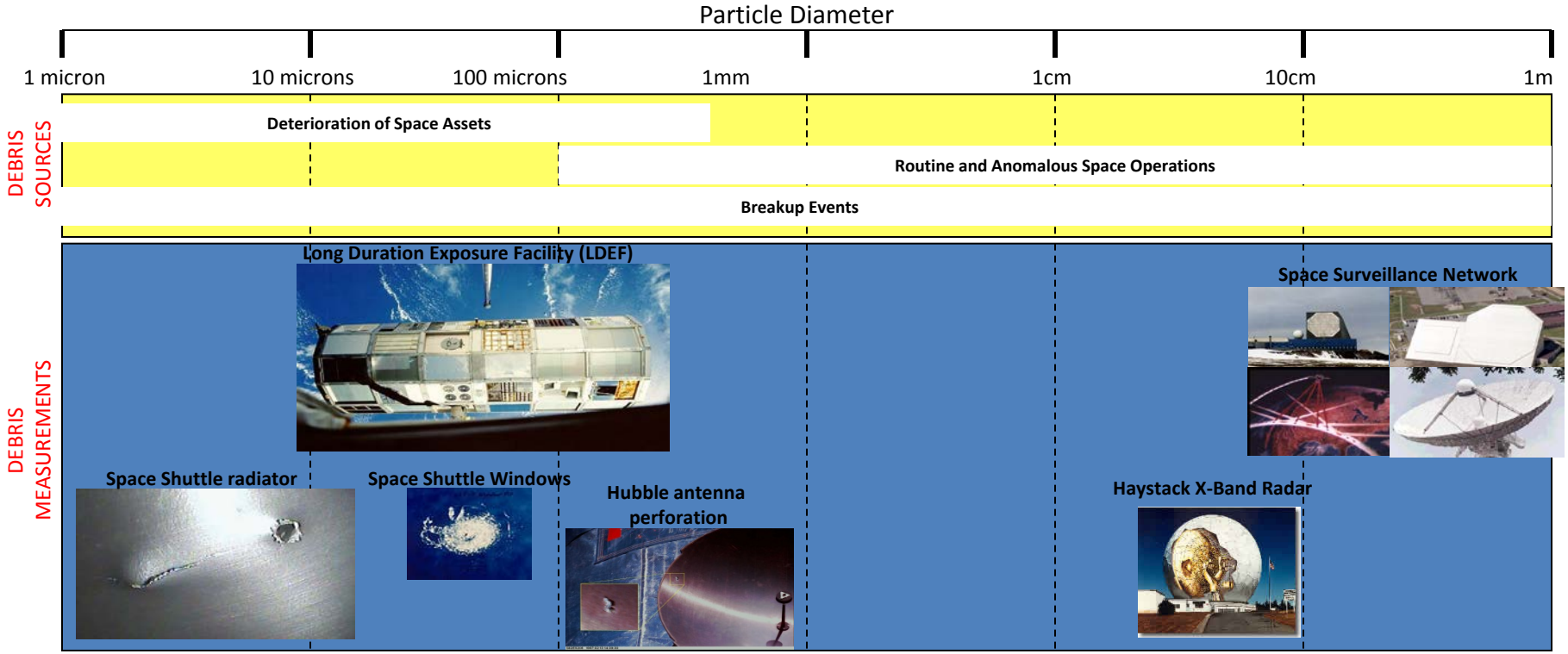


Cause of Fragmentation Events	# Events	# Created	# On-Orbit
Propulsion-Related	88	~5,400	~2,100
Deliberate Explosion/Collision	56	~4,500	~2,500
Accidental Collision	4	~800	~800
Battery	8	~600	~450
Unknown Cause	39	~2,300	~700
Total	195	~13,000	~6,000

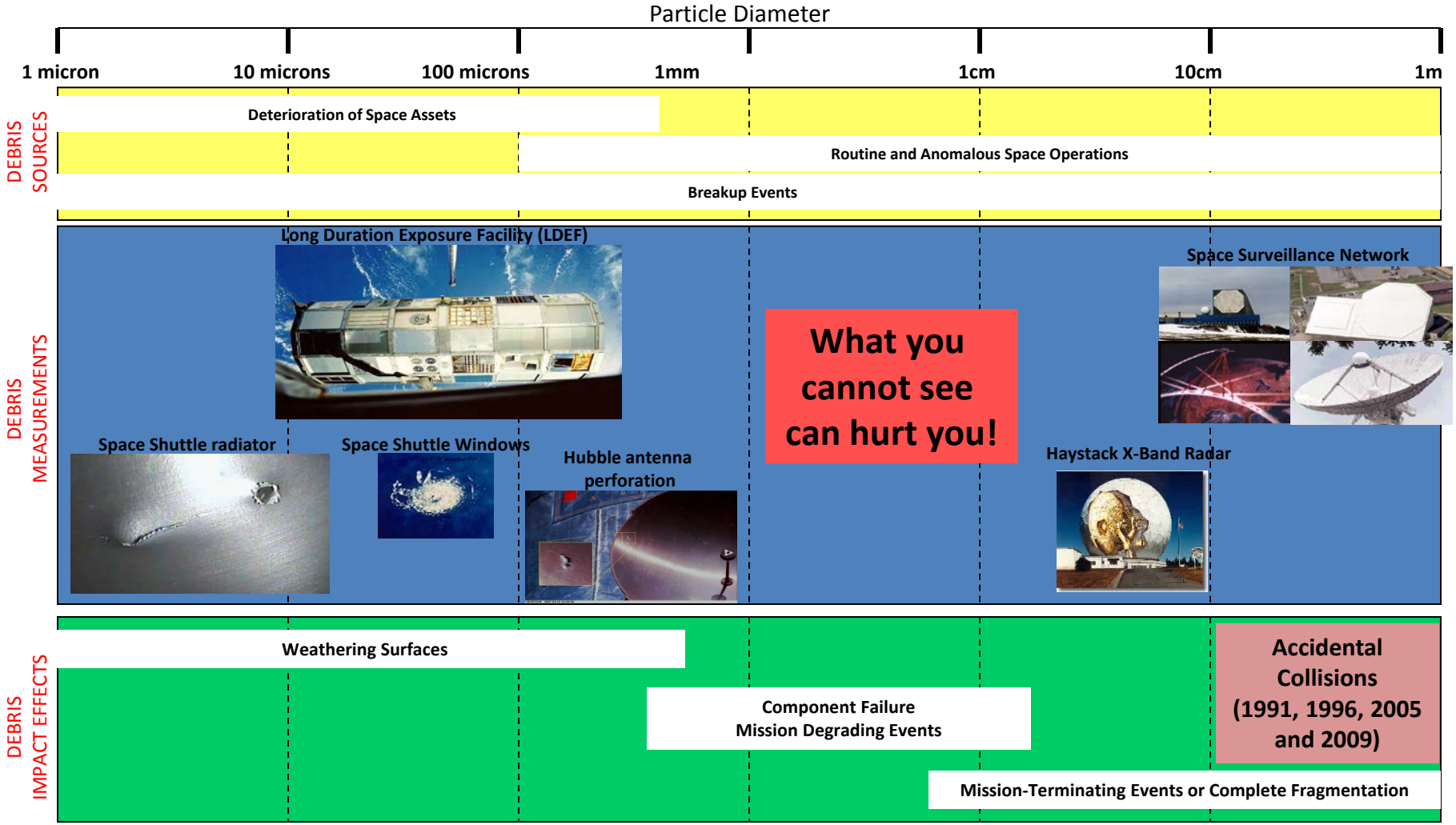
Source: NASA, History of On-Orbit Satellite Fragmentations, JUN08
Also includes +800 fragments from Feb 09 collision event



How Do We Sense Orbital Debris?



What Can Orbital Debris Do?



Spatial Density in LEO

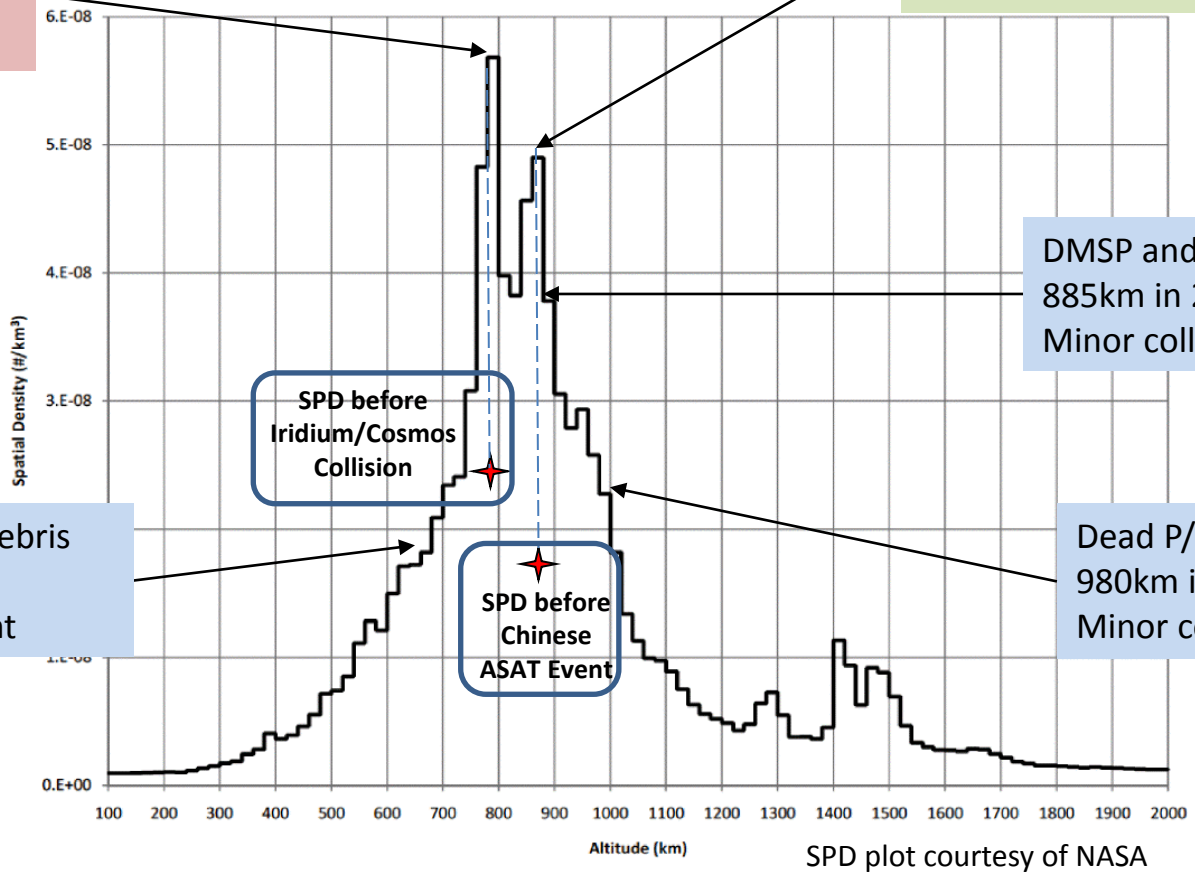
Iridium and C2251
790km in Feb 2009
Major collision event

Chinese ASAT Event
860km in Jan 2007
Major intentional collision

DMSP and CZ-4 Debris
885km in 2005
Minor collision event

Cerise and Ariane Debris
670km in 1996
Minor collision event

Dead P/L and Op Debris
980km in 1991
Minor collision event



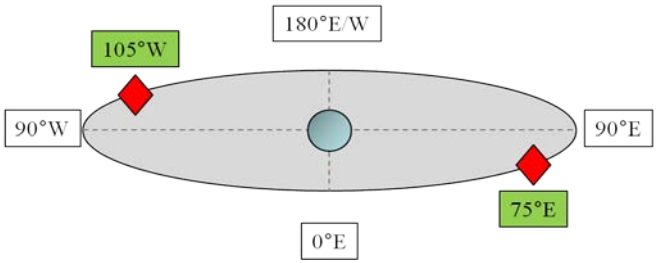
SPD plot courtesy of NASA

Spatial density data source: NASA/JSC

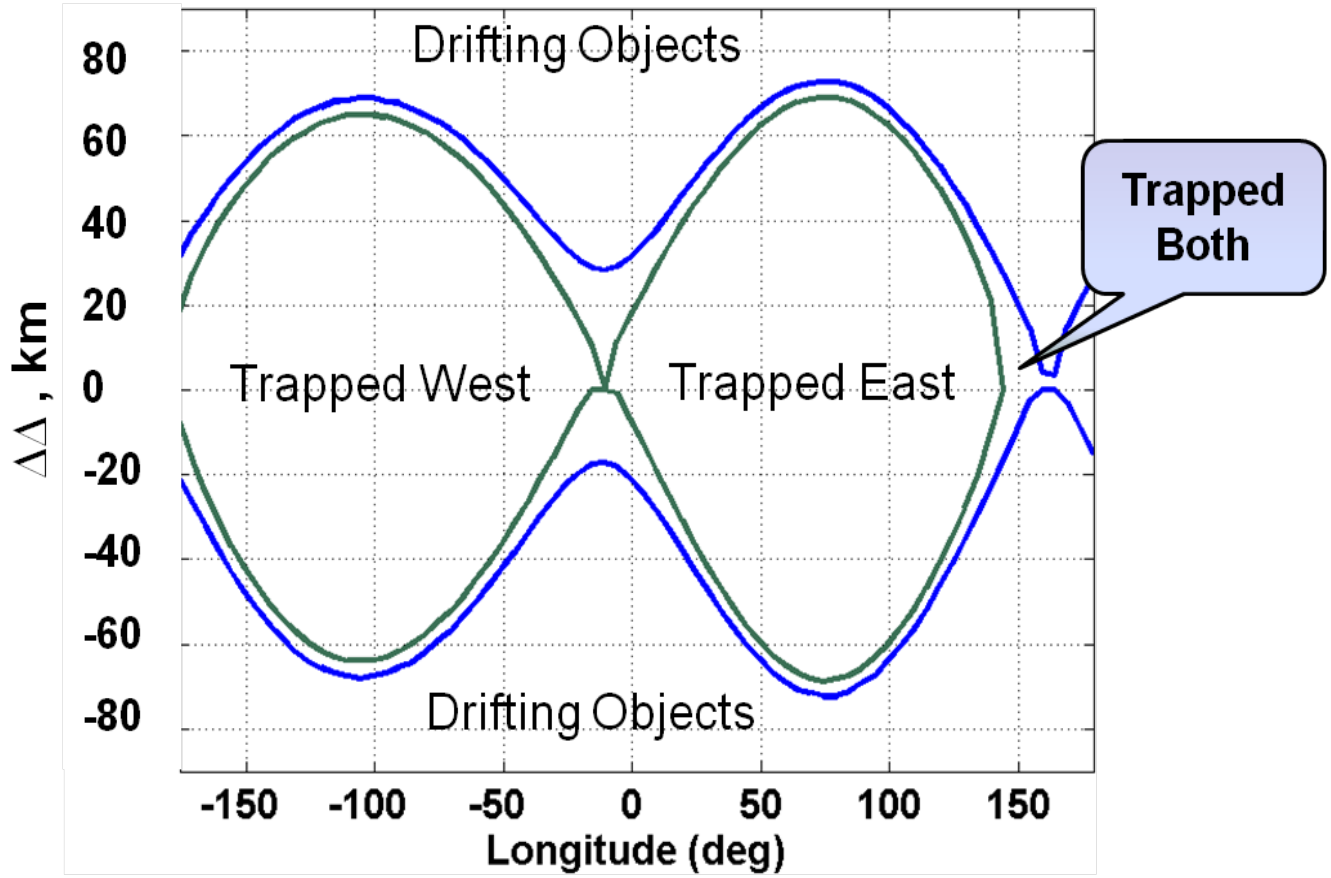
Objects Distributed in LEO and GEO

Object Type	LEO (>10 cm)		GEO (>1 m)	
	Number	Mass (kg)	Number	Mass (kg)
Functional Payloads	~400	~400,000	~400	~600,000
Non-Functional Payloads	~1,450	~800,000	~500	~600,000
Rocket Bodies	~850	~1,100,000	~230	~400,000
Fragmentation Debris	~7,800	~100,000	3	~ 0
Mission-Related Debris	~1,000	~0	16	~ 0
Total	~11,500	~2,400,000	~1,100 ~2,200 additional detected down to 10 cm	~1,600,000

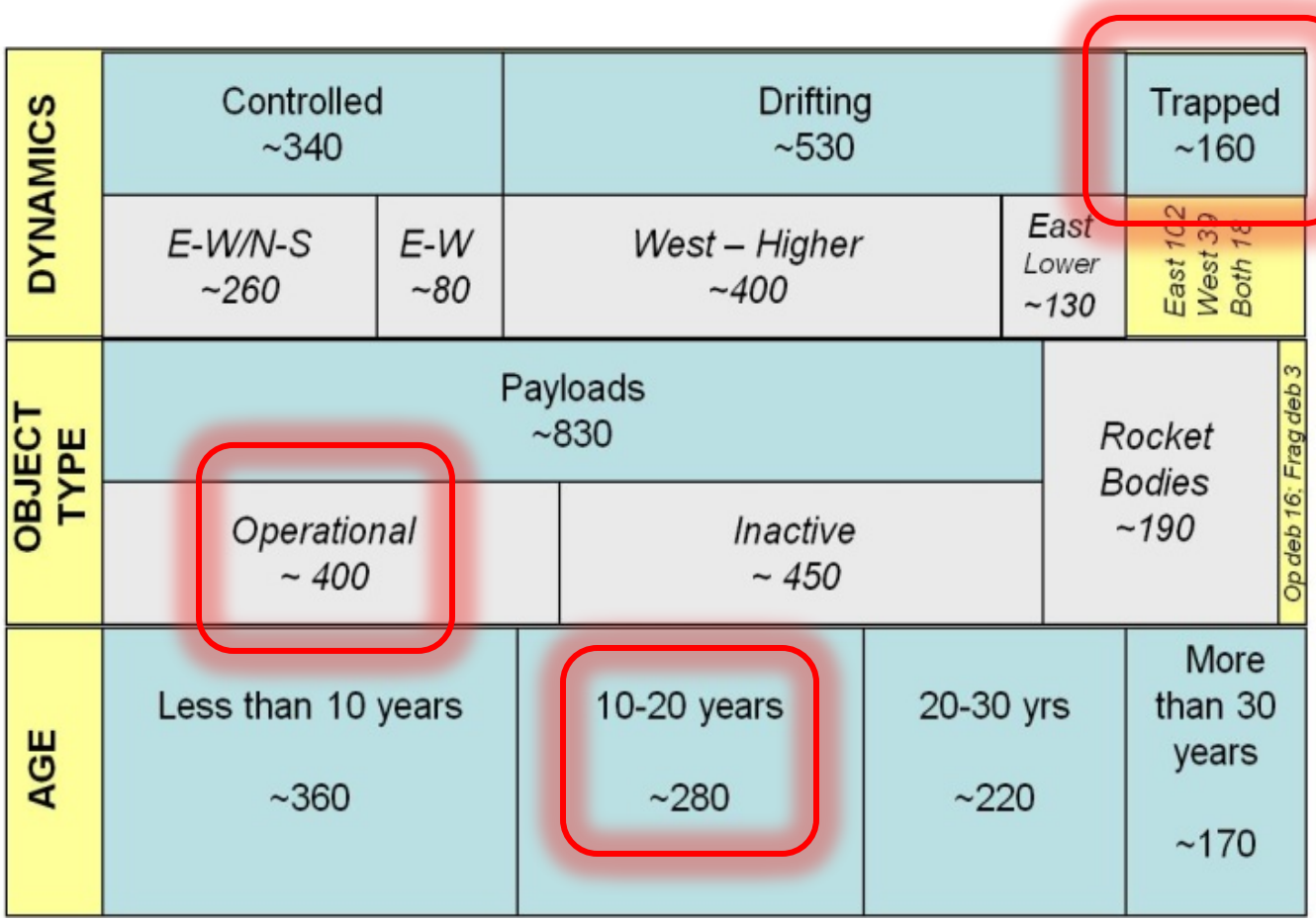
Data current as of February 2011



Geopotential Wells



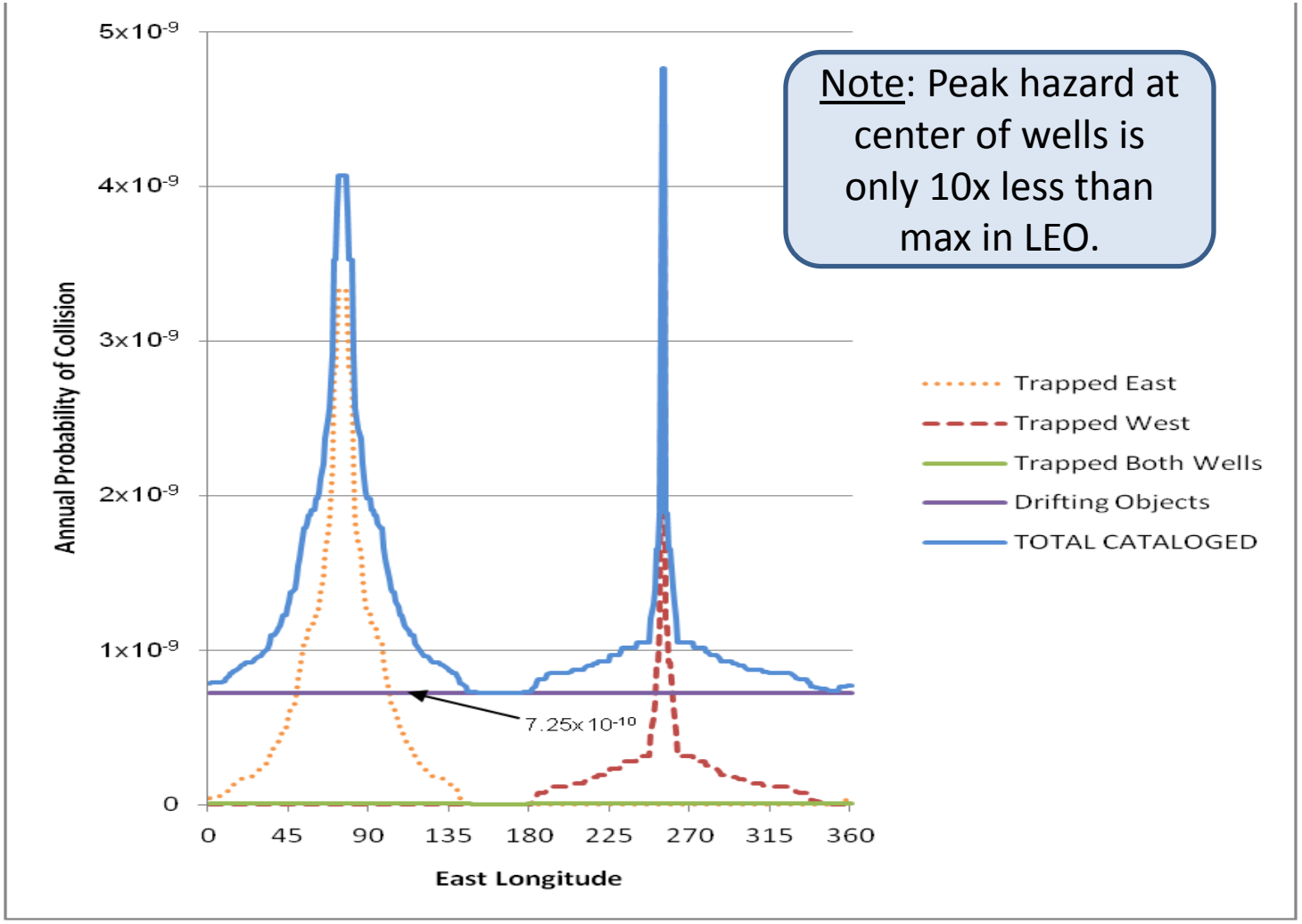
Cataloged Objects in GEO



Data current as of February 2011

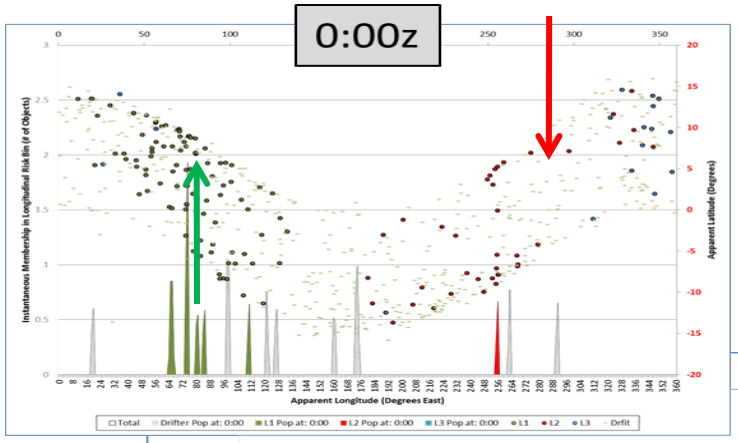
Probability of Collision at GEO

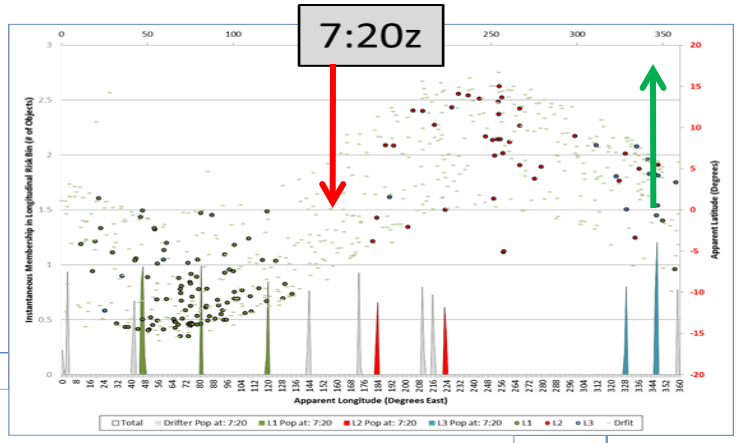
Longitudinally-Dependent

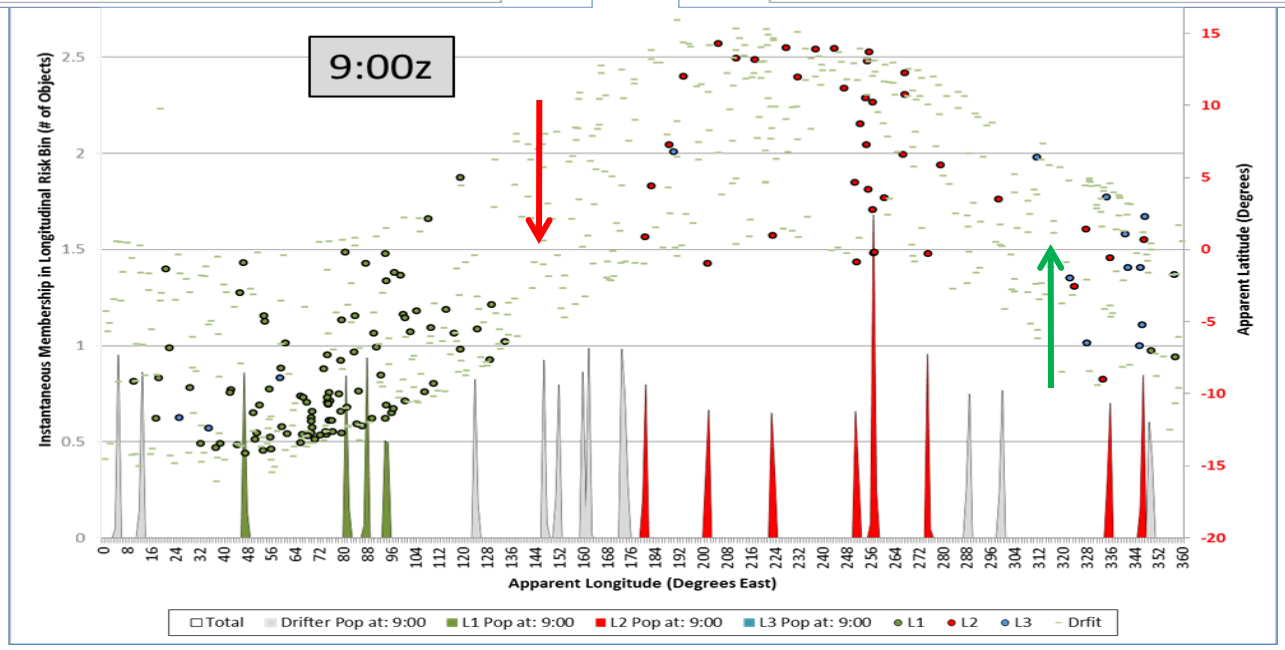


Note: Peak hazard at center of wells is only 10x less than max in LEO.

Daily Changes at GEO

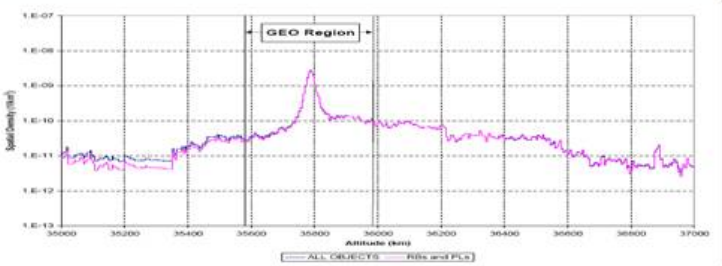
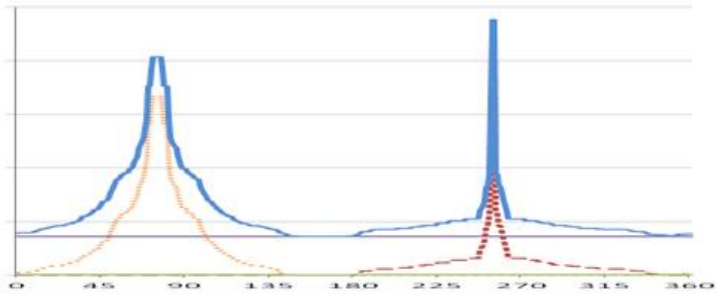
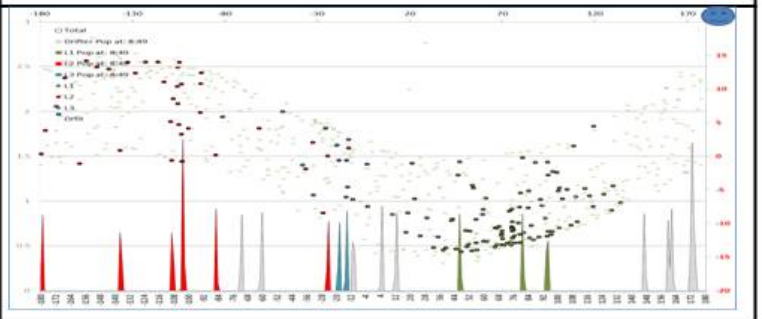






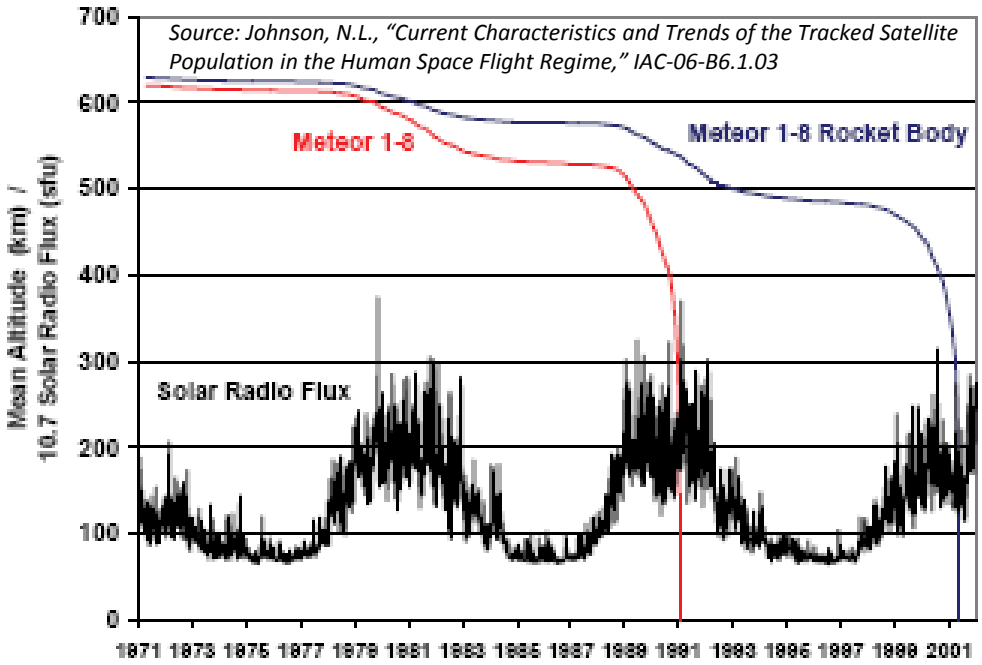
Note: Hazard will vary by a factor of 10,000x during the course of a day. 80% of hazard in 20% of the time!!

Hazard Understanding in GEO

Depiction	Resolution		Figure
	Temporal	Spatial	
Standard	Annual	Altitude only	
Wells	Annual	Altitude and Longitude	
Snapshot	Daily	Altitude and Longitude	

Drag Naturally Removes Debris From LEO

Solar Max Near 2012 - Accelerating Reentries – 9x over solar minimum



11-yr solar cycles impact objects ~650km and below

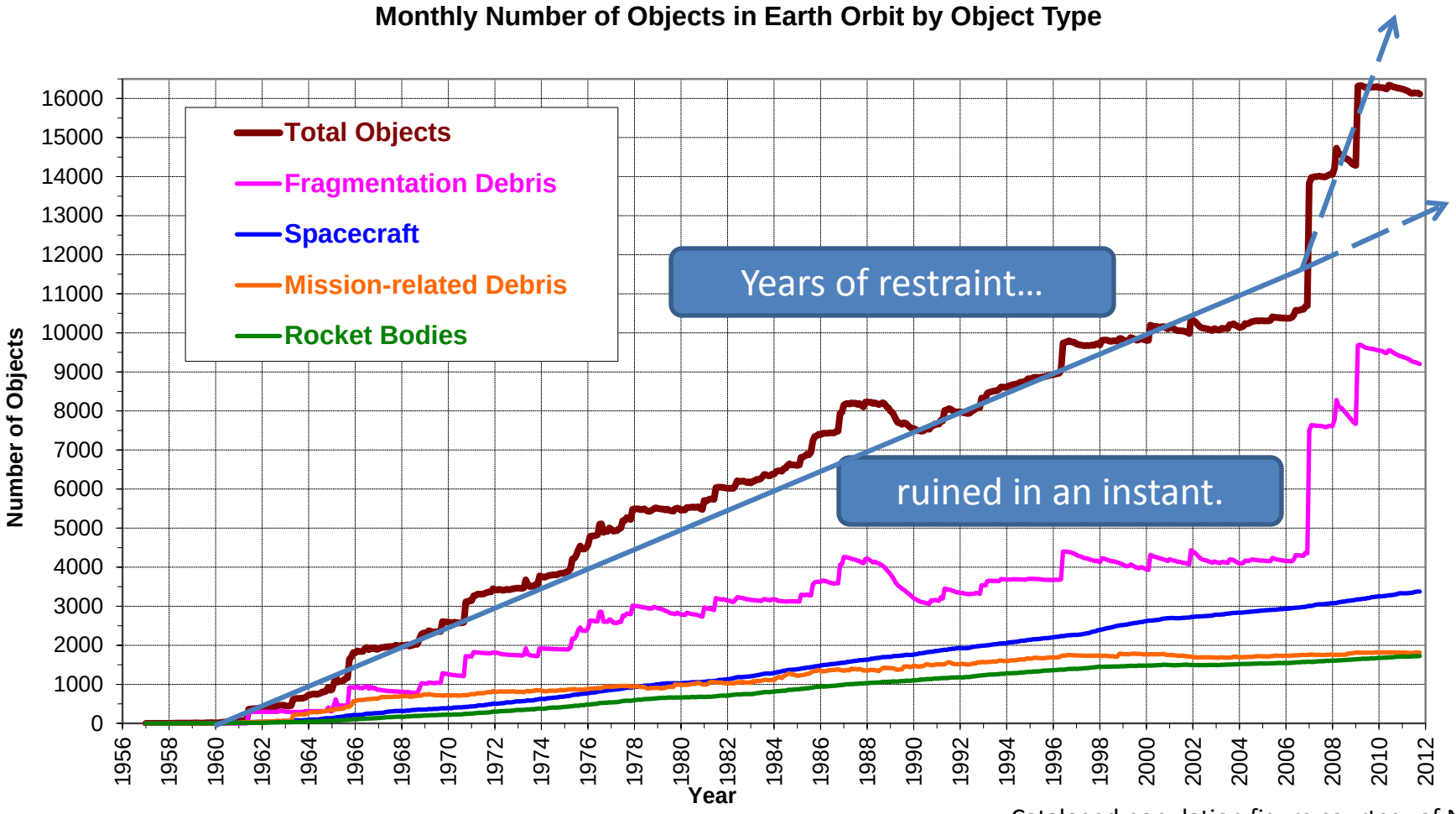
Since the dawning of the space age over 7,000 payloads and rocket bodies have reentered with only one person ever being struck and no injuries or casualties. ~4000 large derelict objects remain in orbit. Over 2/3 of Earth is covered by water and vast majority of mass does not survive reentry.

On 21 January 2001, a Delta 2 third stage, known as a PAM-D (Payload Assist Module - Delta), reentered the atmosphere over the Middle East. The titanium motor casing of the PAM-D, weighing about 70 kg, landed in Saudi Arabia.

[Source: NASA]

The sky <u>is</u> falling (sort of).

The Future…???



Cataloged population figure courtesy of NASA

Overview

- On-orbit debris hazard is dynamic and complex
  - Many sources
  - Geostationary orbit (GEO) hazard is clumped in time and space
  - Low Earth orbit (LEO) hazard is spiked by altitude
  - Reentry of manmade objects has thus far been statistically unimportant
- The most hazardous regions are the most popular
  - GEO and sun-synchronous (~800-900km)
- Natural perturbations are as important as manmade events
  - Drag in LEO and solar-lunar effects in GEO
- Current hazard and future growth are uncertain
  - Few events and many variables