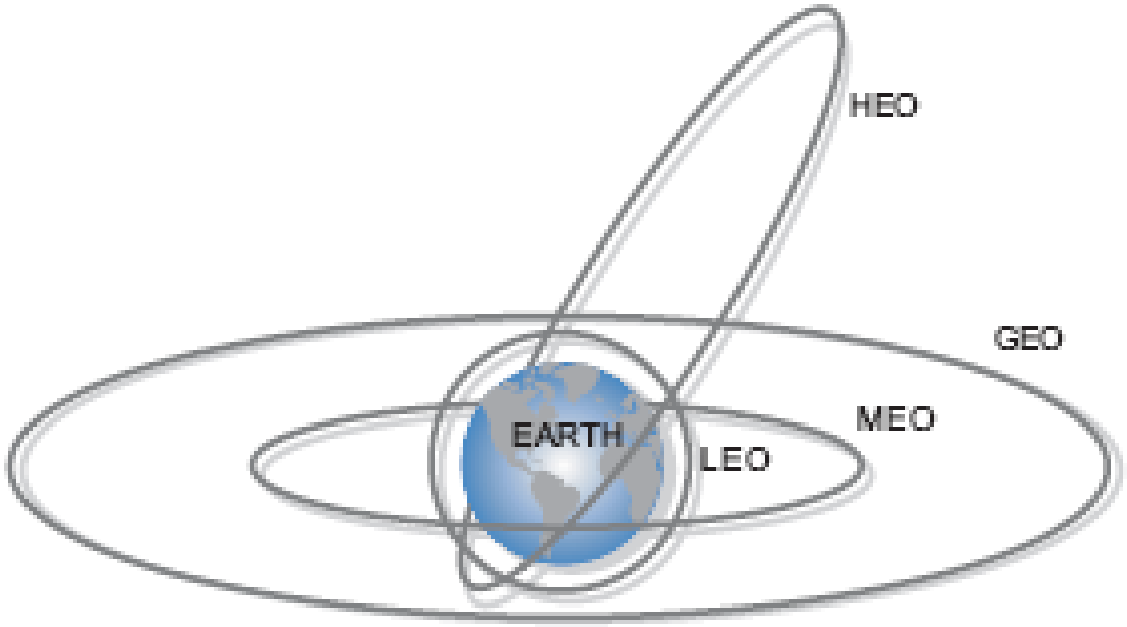
Overview of Space Debris and Cubesats

Brian Weeden
Technical Advisor
Secure World Foundation

WHAT'S IN EARTH ORBIT

Current satellite population



	Name	Altitude	Inclination	Shape	Active Satellites
LEO	Low Earth Orbit	250 - 2,000 km	Varies, many 80-100°	Mostly circular	**669**
MEO	Medium Earth Orbit	10,000 - 12,000 km	Varies	Circular	**94**
HEO	Highly Elliptical Orbit	1,000 km (perigee) 40,000 km (apogee)	63°	Elliptical	**37**
GEO	Geostationary Earth Orbit	36,000 km	Typically 0°	Circular	**465**
				Total	**1,265**

Source: Union of Concerned Scientists Satellite Database (includes launches through 31 Jan 2015)
http://www.ucsusa.org/nuclear_weapons_and_global_security/solutions/space-weapons/ucs-satellite-database.html

Current space debris population

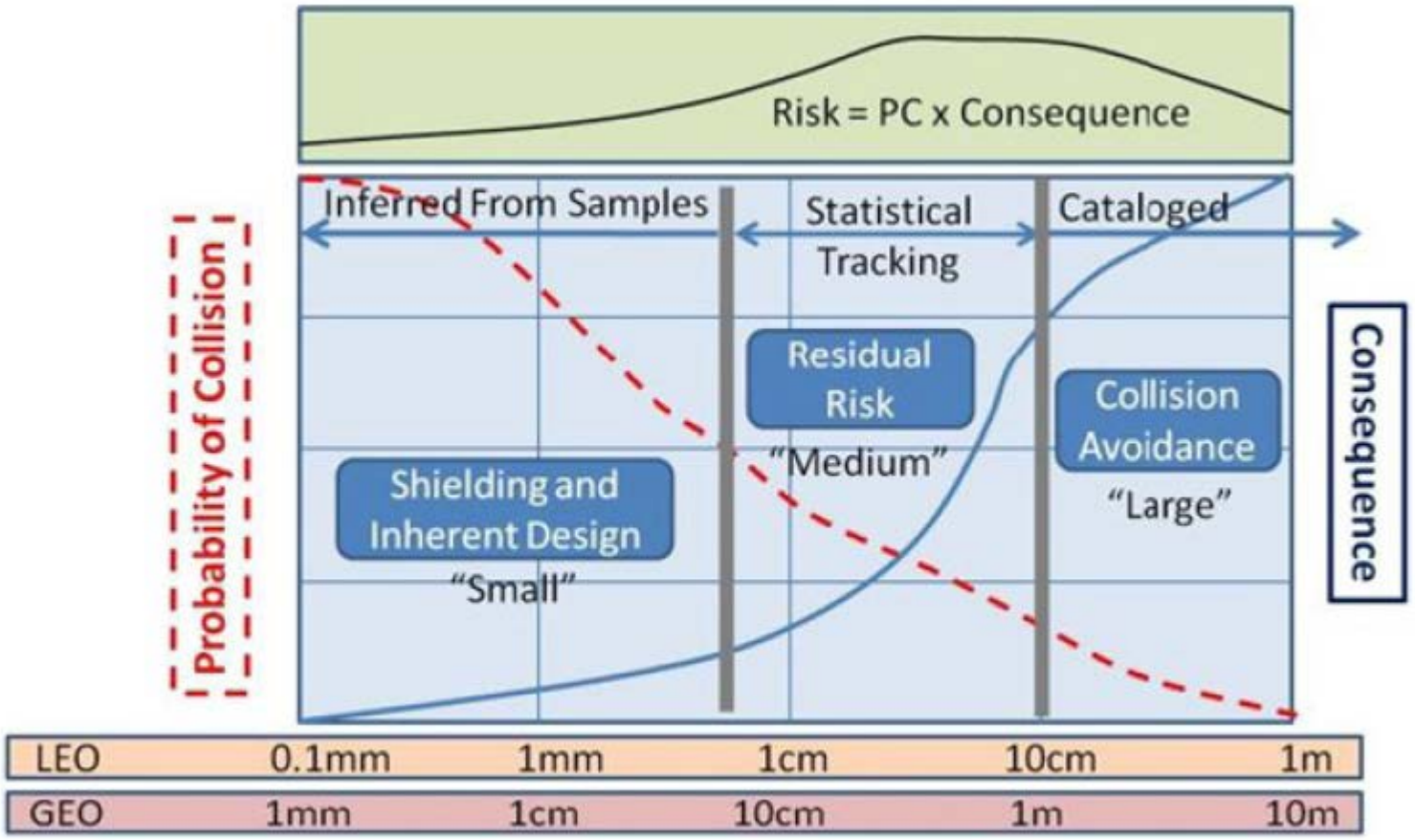
Softball size or larger (≥10 cm): ~20,000 to 22,000 (tracked by the U.S. Space Surveillance Network, SSN)

Marble size or larger (≥1 cm): ~500,000

Dot or larger (≥1 mm): >100,000,000 (a grain of salt)

J-C Liou, NASA Orbital Debris Program Office, 2014

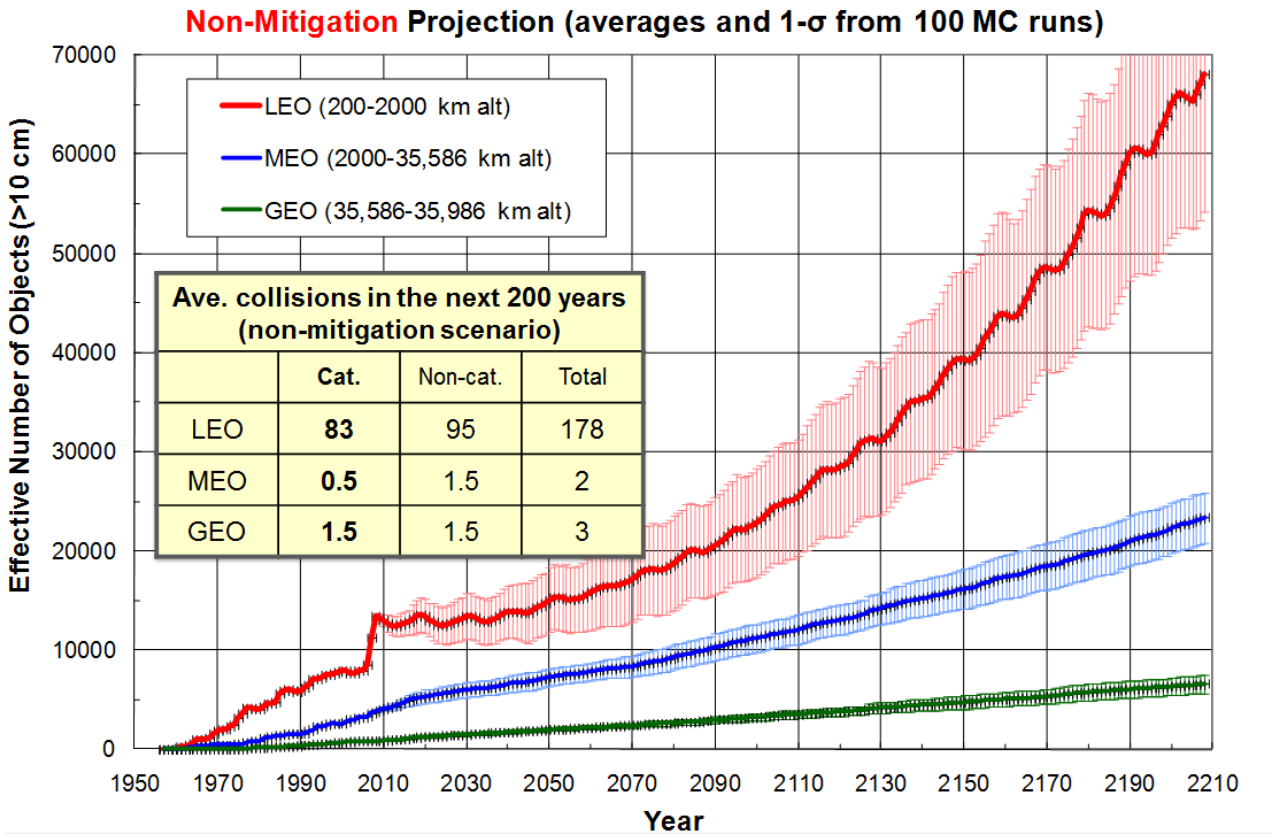
Collision risk to spacecraft



McKnight & Di Pentino (2013)
http://www.sciencedirect.com/science/article/pii/S0094576512004869

Kessler Syndrome

Collisional cascading: debris-on-debris collisions generate more new debris than is removed through atmospheric decay



Ave. collisions in the next 200 years (non-mitigation scenario)

	Cat.	Non-cat.	Total
LEO	**83**	95	178
MEO	**0.5**	1.5	2
GEO	**1.5**	1.5	3

J-C Liou, NASA Orbital Debris Program Office, 2009
http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100017146.pdf

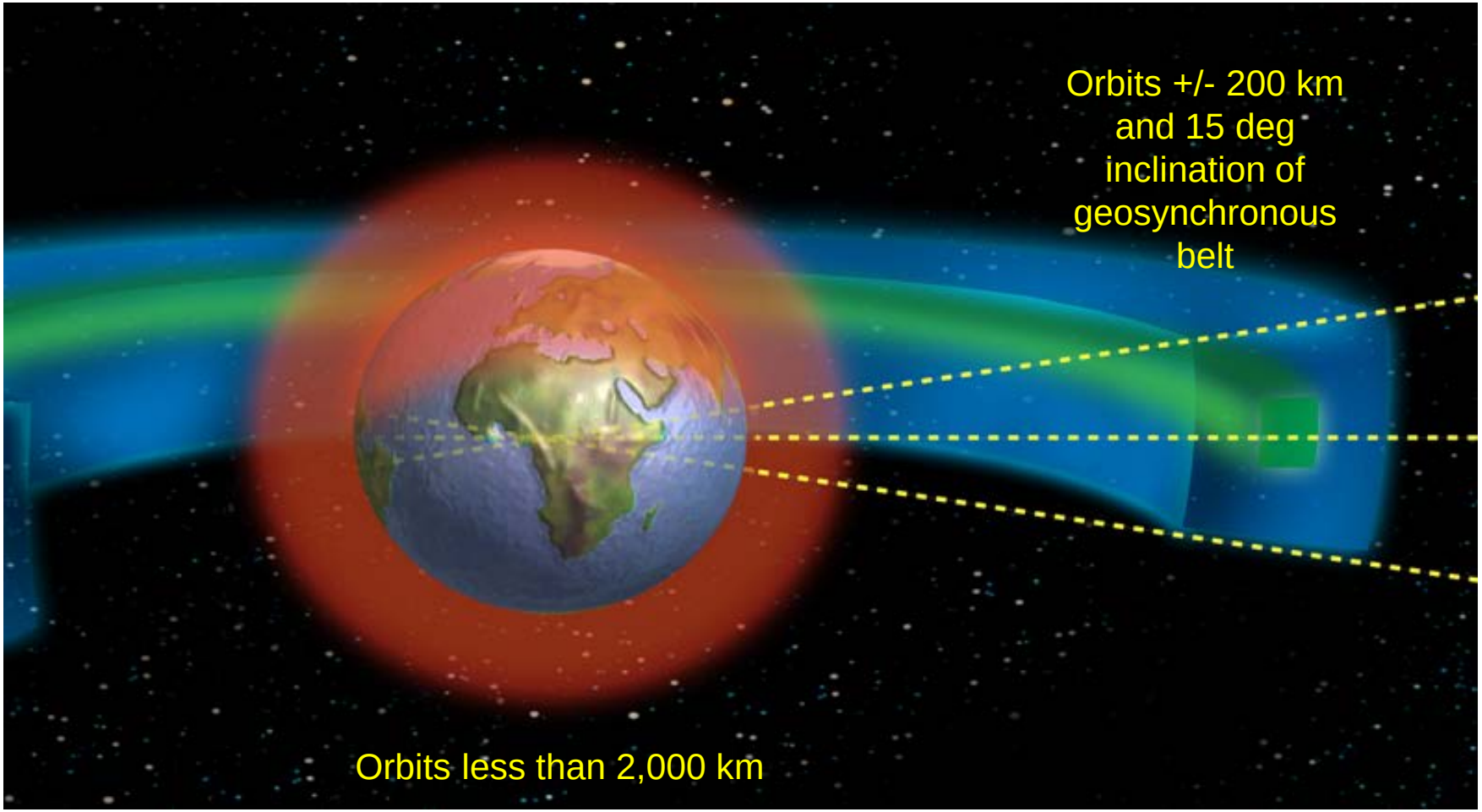
Debris mitigation guidelines

- Inter-Agency Space Debris Coordination Committee (IADC)
  - Created in mid-1990s by several major space agencies
  - 2007: Published voluntary technical guidelines for mitigating space debris
  - 2009: Simplified version endorsed by the United Nations (but still voluntary)

- **25-year rule**: no objects associated with a launch should be left in critical regions more than 25 years after end of mission
  - Adopted as ISO Standard 24113 in 2011

- Up to countries to put in place national law/policy to implement/enforce

IADC protected regions



IADC Space Debris Mitigation Guidelines (2007)
http://www.iadc-online.org/Documents/IADC-2002-01,%20IADC%20Space%20Debris%20Guidelines,%20Revision%201.pdf

The debate over active debris removal (ADR)

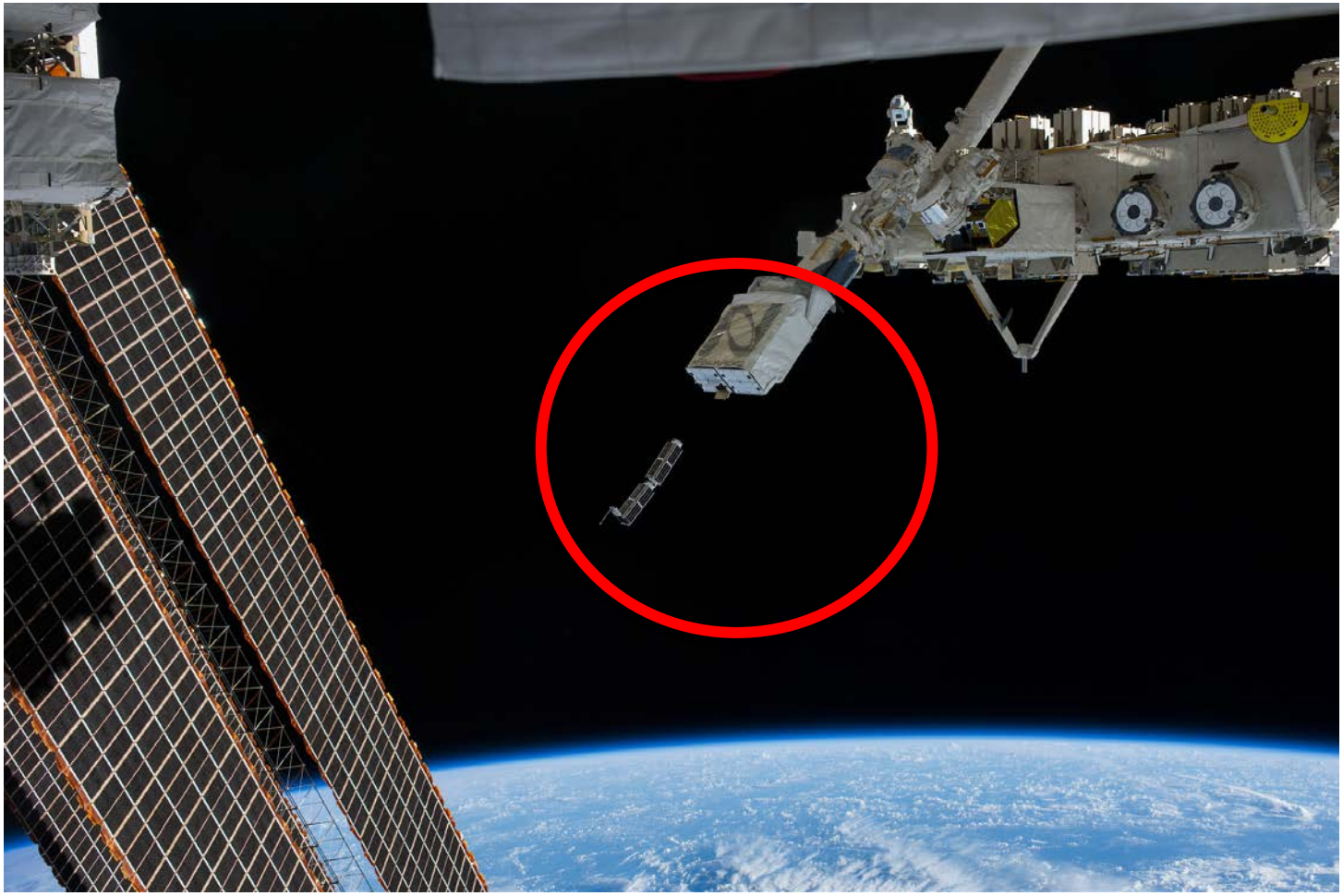
- **Remove the big stuff**
  - Remove 5-10 of the most massive objects per year
  - Reduces long-term growth in debris population & future risk
  - Does little for the short/medium-term risk to satellites
- **Remove the little stuff**
  - Target debris 1-10 cm in size we can't currently track or avoid
  - Reduces the short/medium-term risk to satellites
  - More challenging technically & legally
- **"Just-in-time collision avoidance"**
  - Use lasers to change the orbit of debris to eliminate debris-on-debris collisions
  - Delaying tactic, could give more time to develop technology for other solutions
  - Lots of policy challenges

SPECIFIC CHALLENGES WITH CUBESATS

Main challenges with cubesats

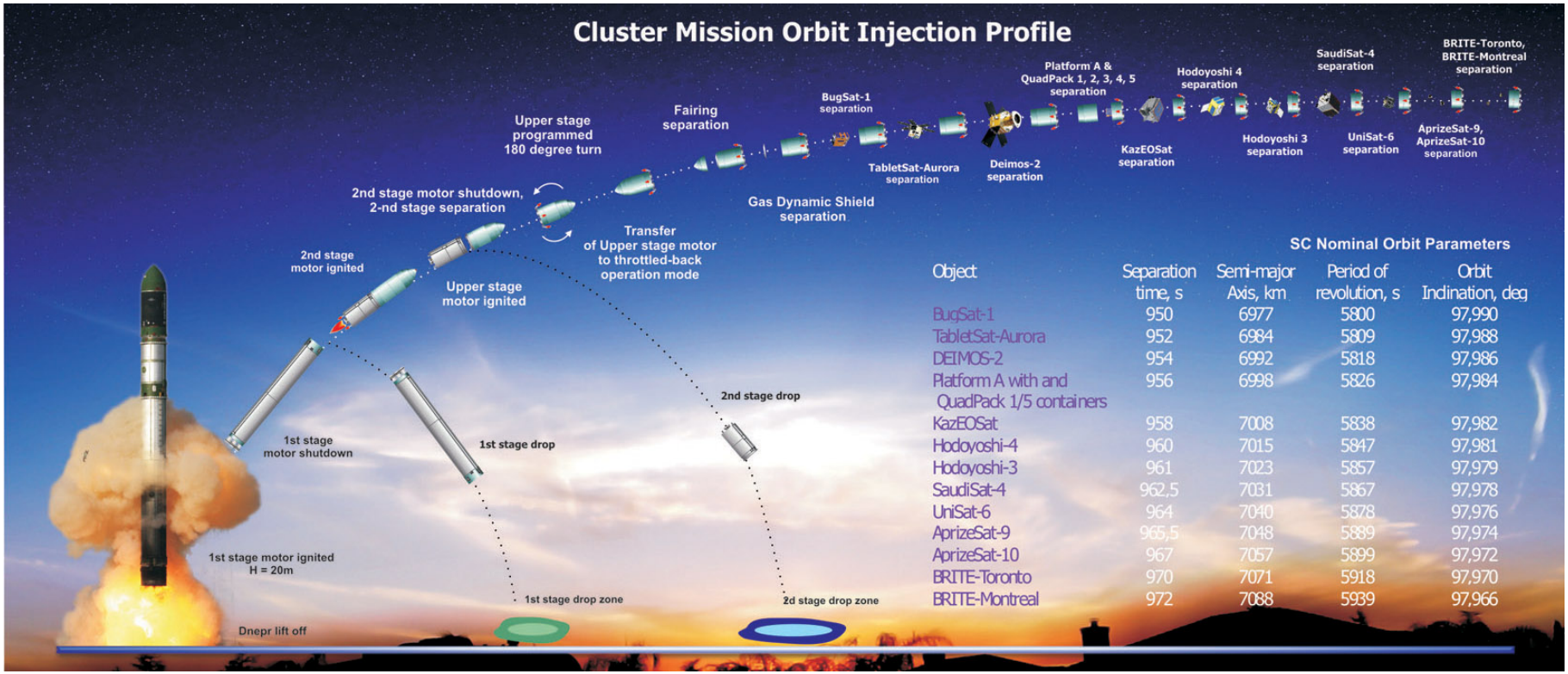
- Relatively hard to track (with currently deployed technology)
- Hard to positively identify
  - Often deployed in clusters, lack distinguishing features
- Limited or no maneuverability
  - Cannot themselves maneuver to avoid a potential collision
  - Cannot comply with "25-year rule" (unless by original constellation design)
- Cubesat operators may have little to no experience in satellite operations
- Some cubesats are being launched by countries that may not have much national regulation/oversight in place

Deployment of Cubesats from ISS



Deployment of PlanetLabs 3U cubesats from NanoRacks deployer on ISS
Photo: NASA

Dnepr cubesat deployment



SC Nominal Orbit Parameters

Object	Separation time, s	Semi-major Axis, km	Period of revolution, s	Orbit Indination, deg
BugSat-1	950	6977	5800	97,990
TabletSat-Aurora	952	6984	5809	97,988
DEIMOS-2	954	6992	5818	97,986
Platform A with and QuadPack 1/5 containers	956	6998	5826	97,984
KazEOSat	958	7008	5838	97,982
Hodoyoshi-4	960	7015	5847	97,981
Hodoyoshi-3	961	7023	5857	97,979
SaudiSat-4	962,5	7031	5867	97,978
UniSat-6	964	7040	5878	97,976
AprizeSat-9	965,5	7048	5889	97,974
AprizeSat-10	967	7057	5899	97,972
BRITE-Toronto	970	7071	5918	97,970
BRITE-Montreal	972	7088	5939	97,966

Image: ISC Kosmotras
http://www.kosmotras.ru/en/launch15/

Atlas V cubesat deployment

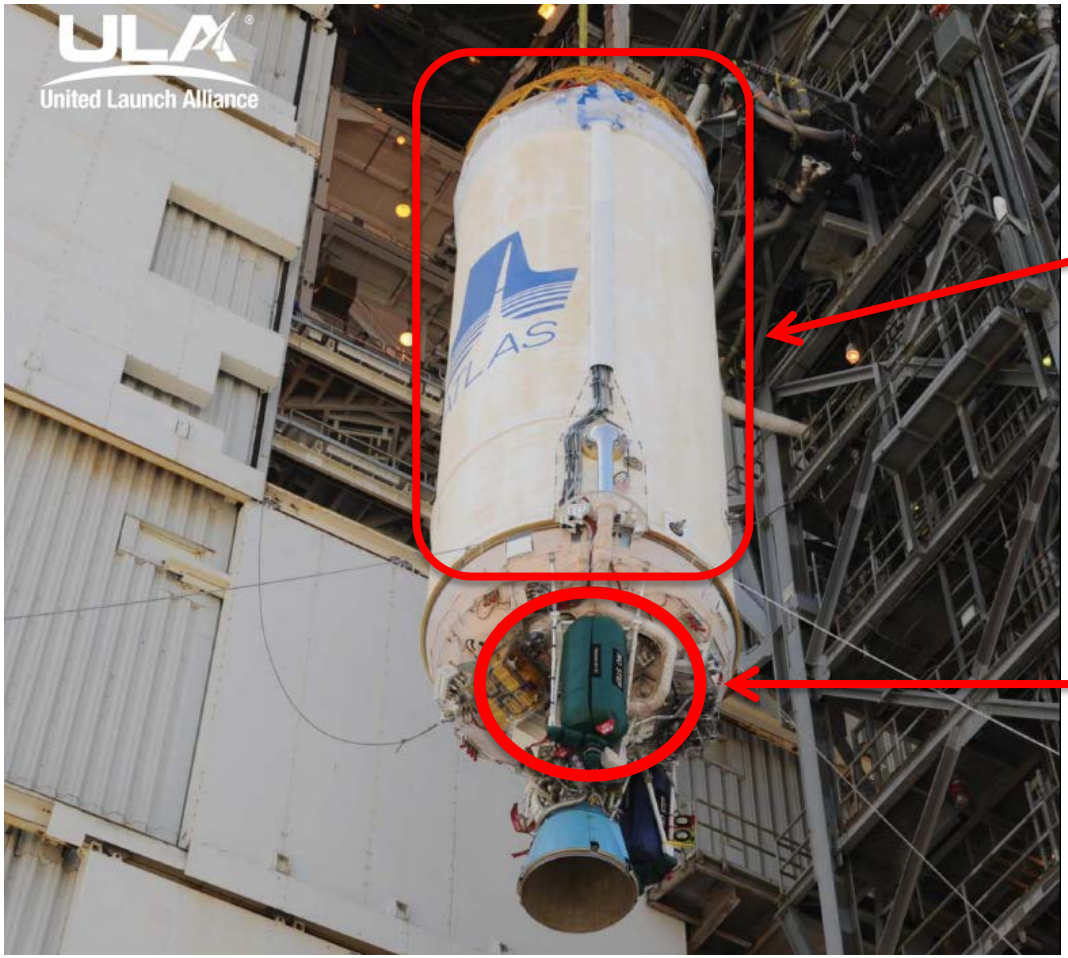
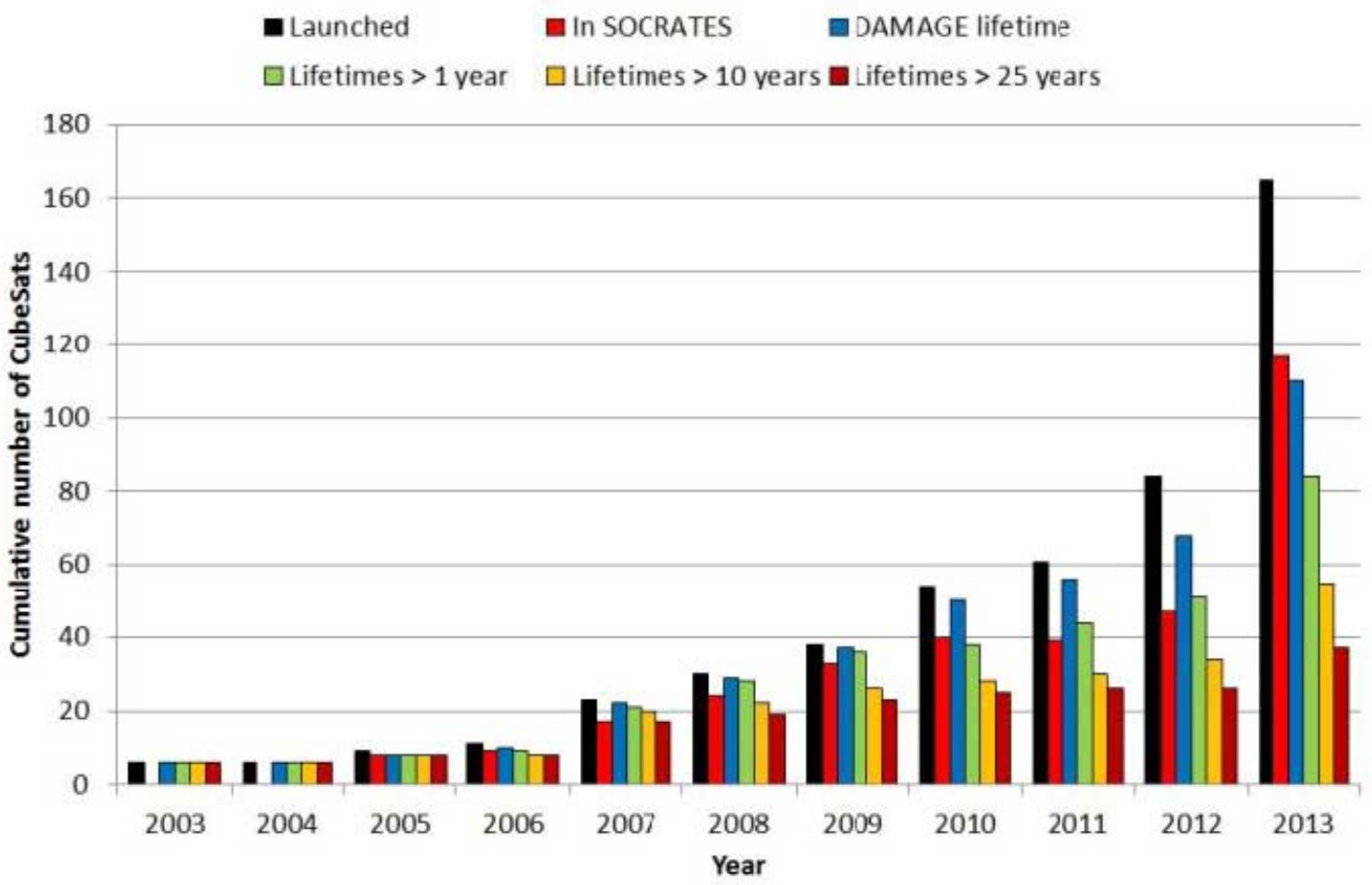


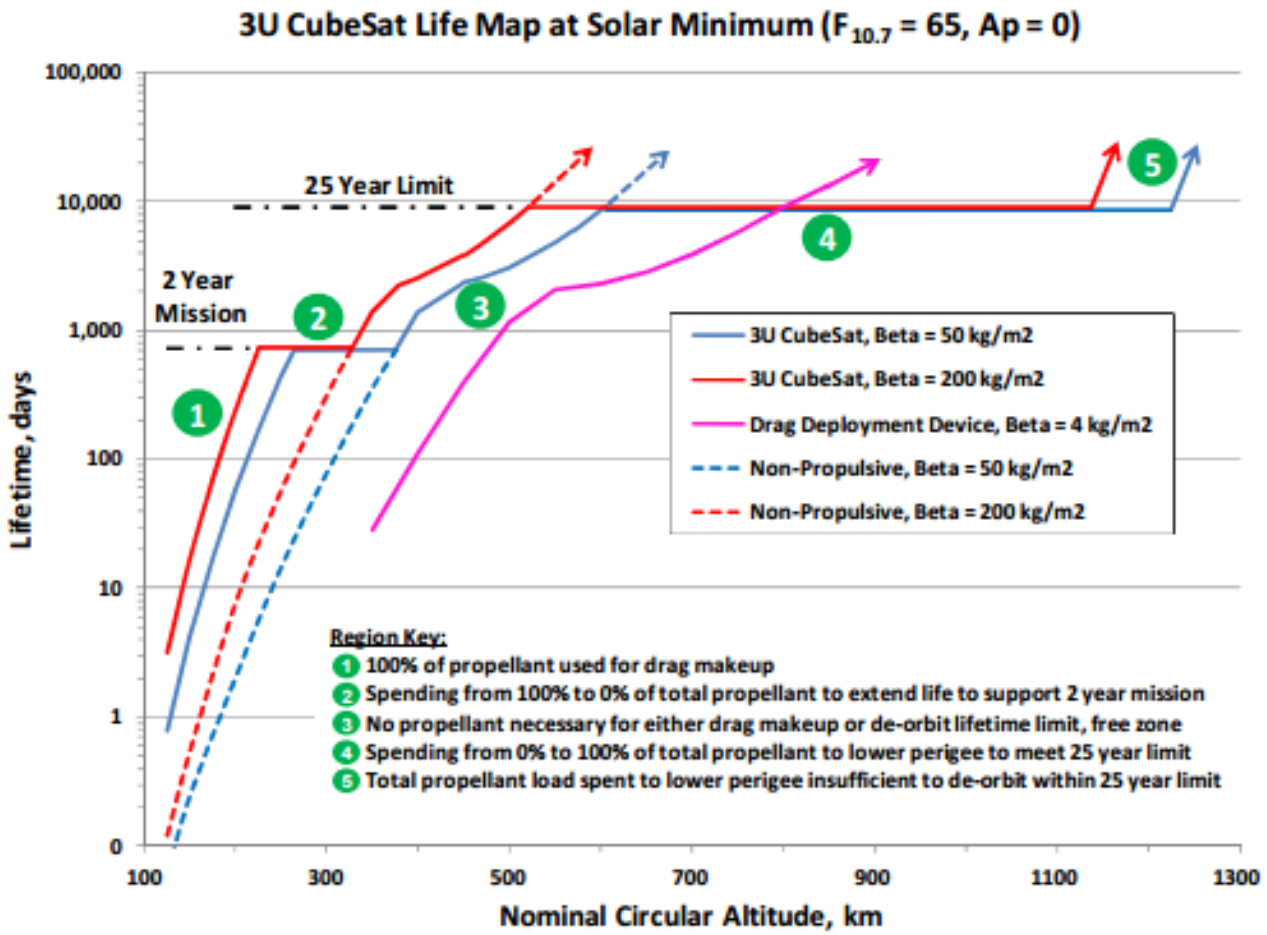
Image: United Launch Alliance
http://www.ulalaunch.com/uploads/docs/launch_vehicles/abc_users_guide_2014.pdf

Cubesat lifetimes



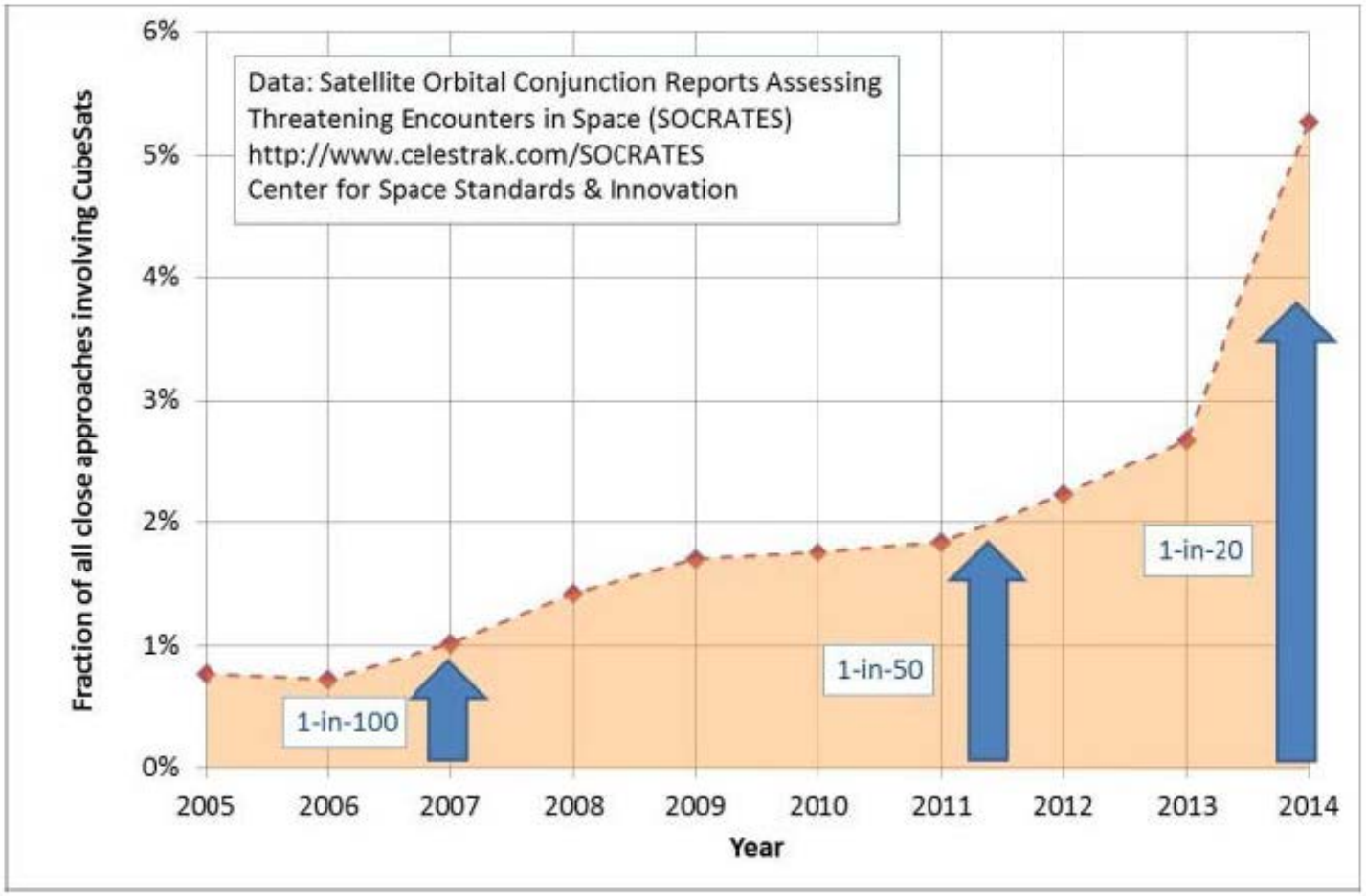
Lewis, Schwarz, George, and Stokes (2014)
http://eprints.soton.ac.uk/369583/1/IAC-14%2CA6%2C4%2C1%2Cx26805.pdf

Orbit lifetime vs altitude for a 3U cubesat



Shmuland, Carpenter, and Masse (2012)
https://www.rocket.com/files/aerojet/documents/CubeSat/AIAA-2012-4269.pdf

Close approaches involving cubesats



Lewis, Schwarz, George, and Stokes (2014)
http://eprints.soton.ac.uk/369583/1/IAC-14%2CA6%2C4%2C1%2Cx26805.pdf

Major policy issues being debated

- Should cubesats in protected regions be required to have "transponders" or "RFID" tags to facilitate tracking and identification?
- Should cubesats be restricted to low altitudes when they naturally decay within 25 years (< 500 km)?
- Should cubesats in certain regions (ISS?) be required to have maneuvering capability?
- Should launching entities enforce debris mitigation guidelines?

Open research questions

- Do cubesats pose more of a threat than large satellites?
  - Less area, which means less likely to collide
  - Less mass to create new debris as a result of a collision

- Is the surge in cubesats a ***substitution*** for or a ***complement*** to large satellites?
  - Complement is more worrisome

- How to quantify the actual risk posed by space debris and cubesats?

Thank you. Questions?

bweeden@swfound.org