The Alarming Problem of Trash in Space:

Dead Satellites, Rocket Pieces, and Other Space Debris

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About This Presentation

This slide show represents a lecture for sharing my personal investigations with the general public. ©2026 Behrooz Parhami

Background: On Earth, we have laws against littering the roads and other public spaces. It took a while for us to realize that such a law is even more important in space. As a result, a lot of space junk has accumulated in Earth orbit, endangering space travel as well as vital communication & surveillance satellites.

Edition	Released	Revised	Revised	Revised
First	Mar. 2026	July 2026		

File: http://www.ece.ucsb.edu/~parhami/pres_folder/parh26-the-problem-of-trash-in-space.pdf

Outline of My Presentation

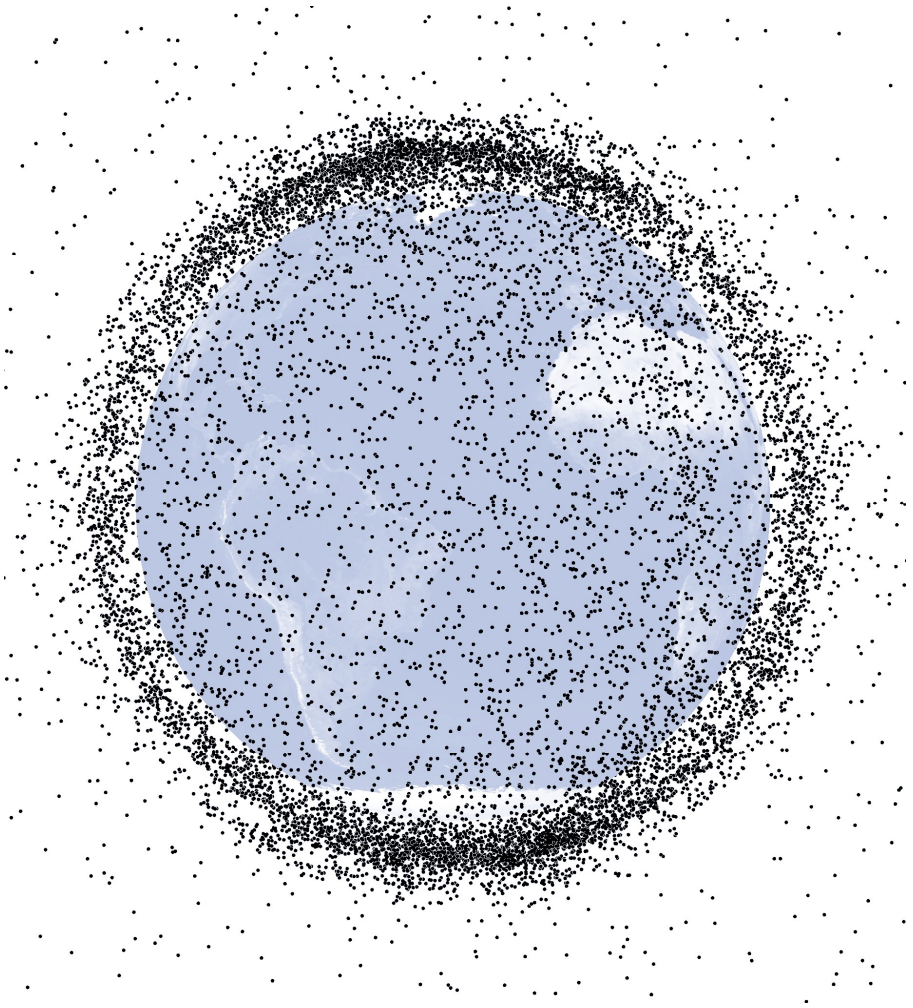
The Problem of Space Junk
Origin, extent, and risks

Trash Evasion Solutions
Is becoming more difficult

Trash Collection Solutions
Garbage satellites

Trash Destruction Solutions
Burning the trash

Environmentalism in Space
Laws and global cooperation



Peter G. Neumann [1932-2026]

For ~70 years, he shaped the computing field through pioneering work on risks, system dependability, security, fault tolerance; founder & moderator of The Risks Forum

THE RISKS DIGEST

Volume 34 Issue 91

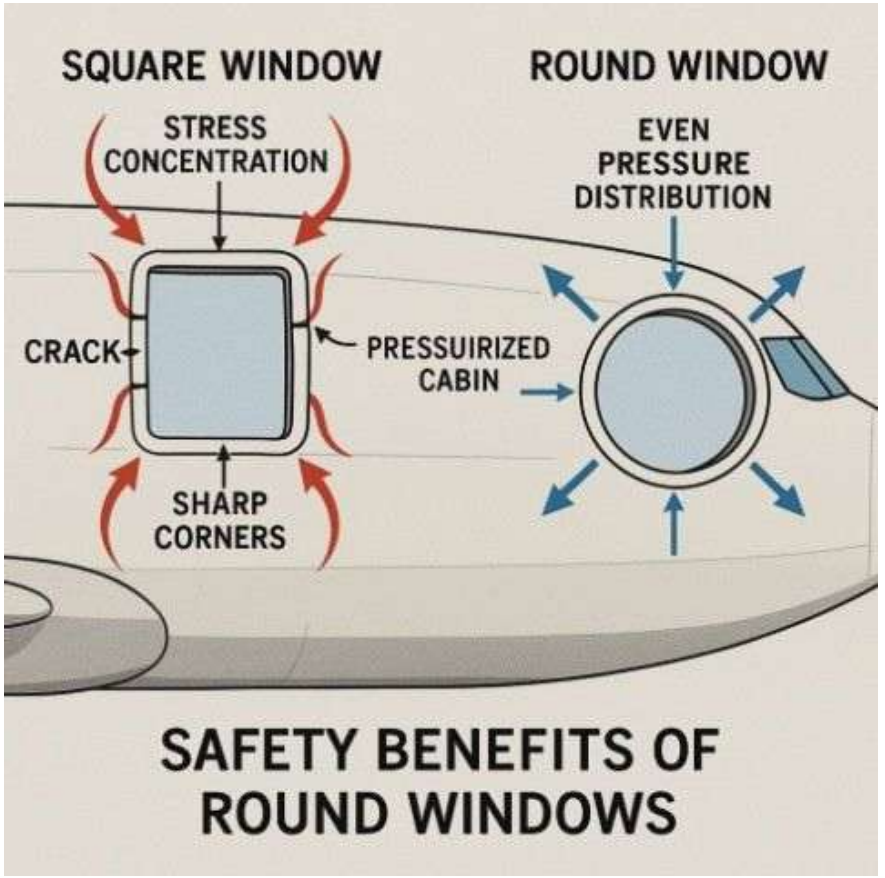
Sunday, 12th April 2026

Forum on Risks to the Public in Computers and Related Systems

ACM Committee on Computers and Public Policy, Peter G. Neumann, moderator

Musings of a Curious Engineer

Recurring LinkedIn posts on intriguing design problems, ranging from a short paragraph to a mini-article

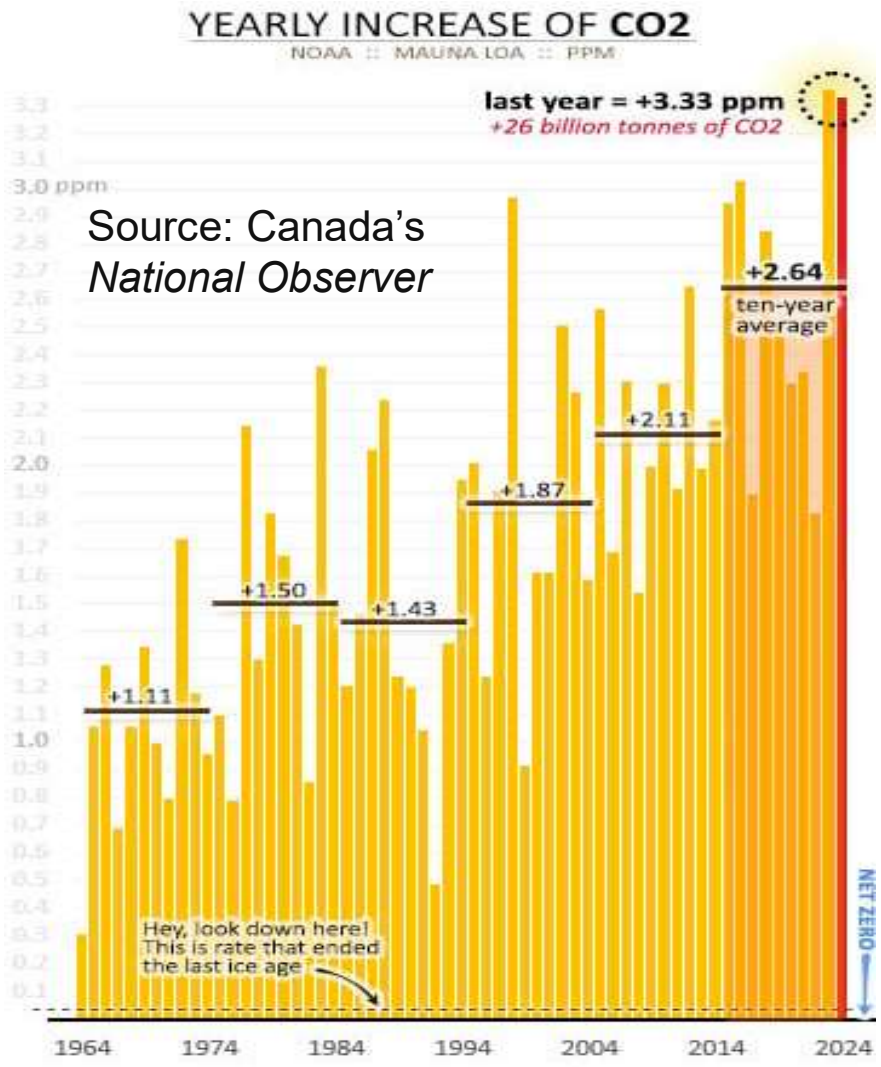


The Problem of Trash on Earth

The Problem of Trash in Oceans

Polluting the Atmosphere

During the last decade, CO2 rose 2.5 times faster than in the 1960s and 100+ times faster than during transition out of the last Ice Age



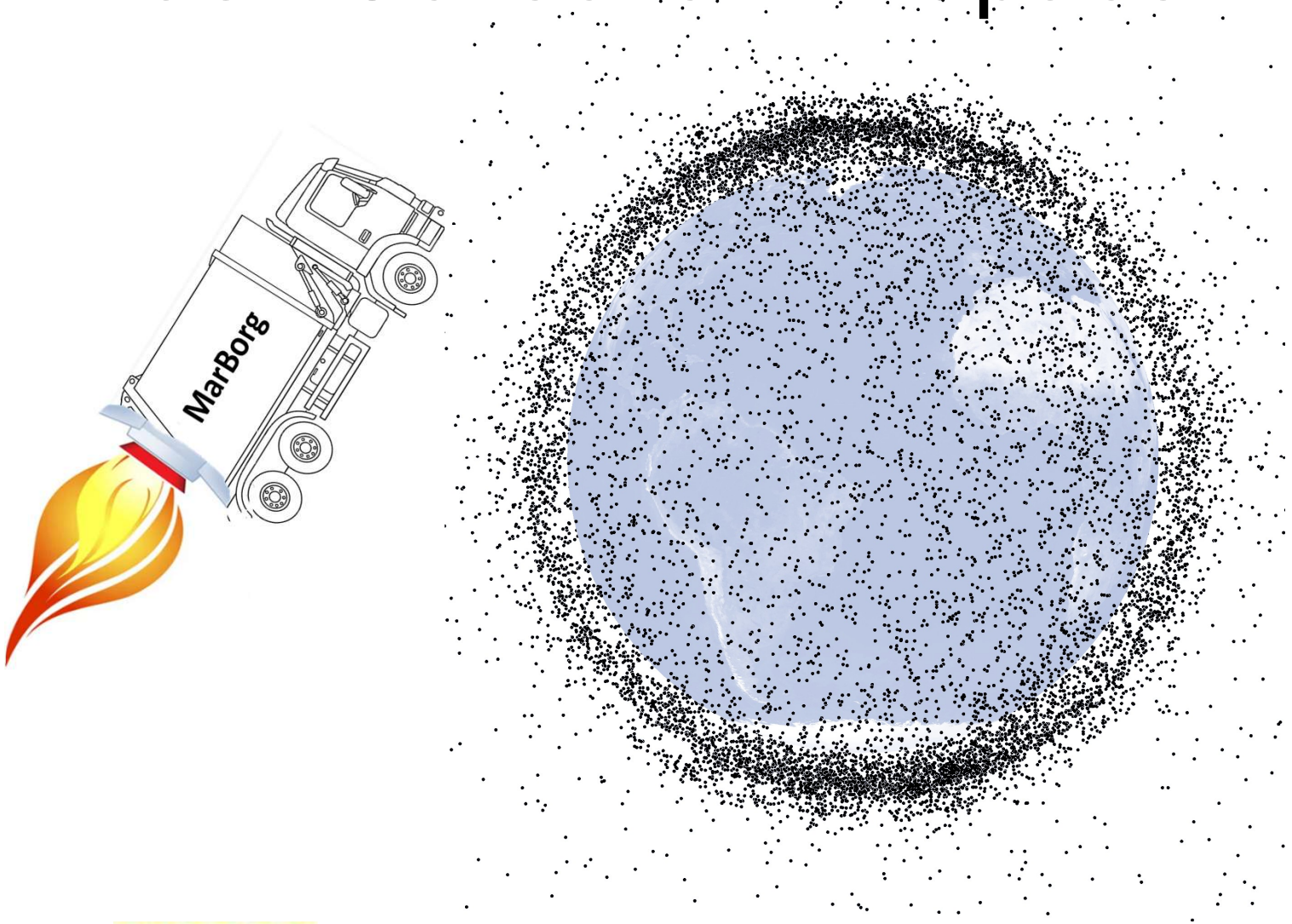
Waste Management in Space

ISS astronauts manually compact waste, which is then stored in cargo vehicles and eventually burned up upon atmospheric re-entry

NASA is developing a "Heat Melt Compactor" to compress waste to less than 1/8th of its original volume for long-duration missions

NASA is also working on recycling solutions for sustainable waste management on lunar missions

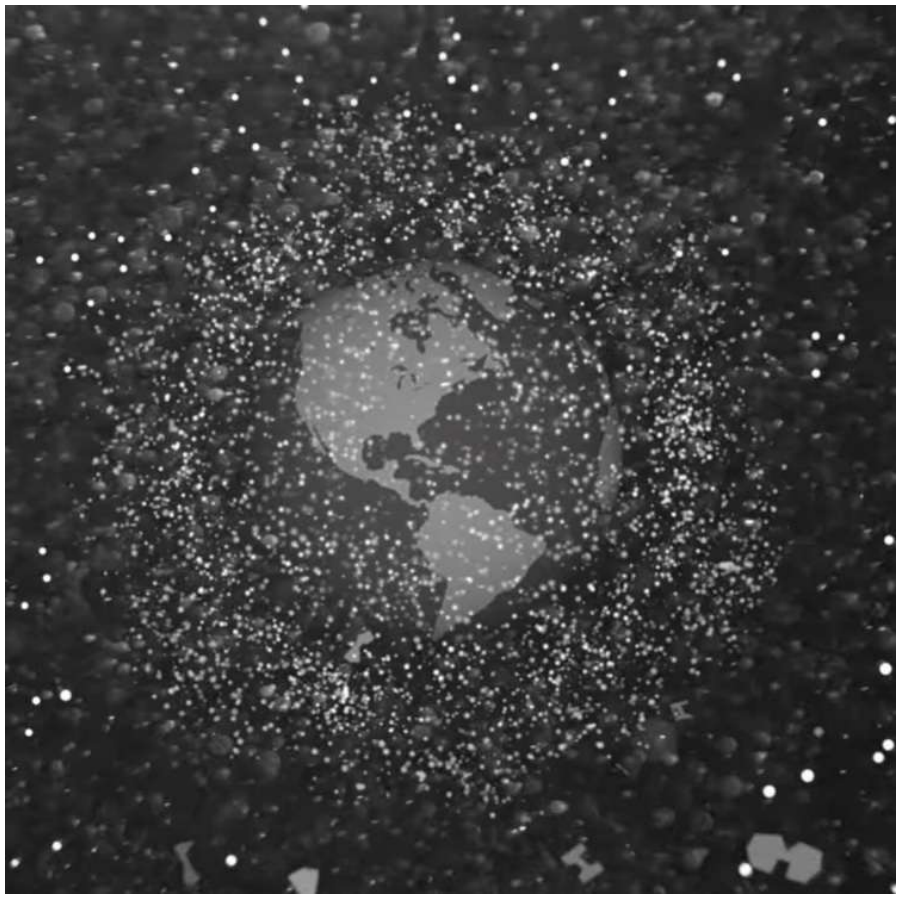
Trash Collection in Space



ChatGPT's Idea of Trash Collection in Space

Origins of Space Trash

Dead satellites, rocket fragments, explosion/collision debris



The Kessler Syndrome or Effect

As more satellites become junk, their risk of colliding & creating more junk increases. This could eventually lead to a domino effect, making low-earth-orbit too congested

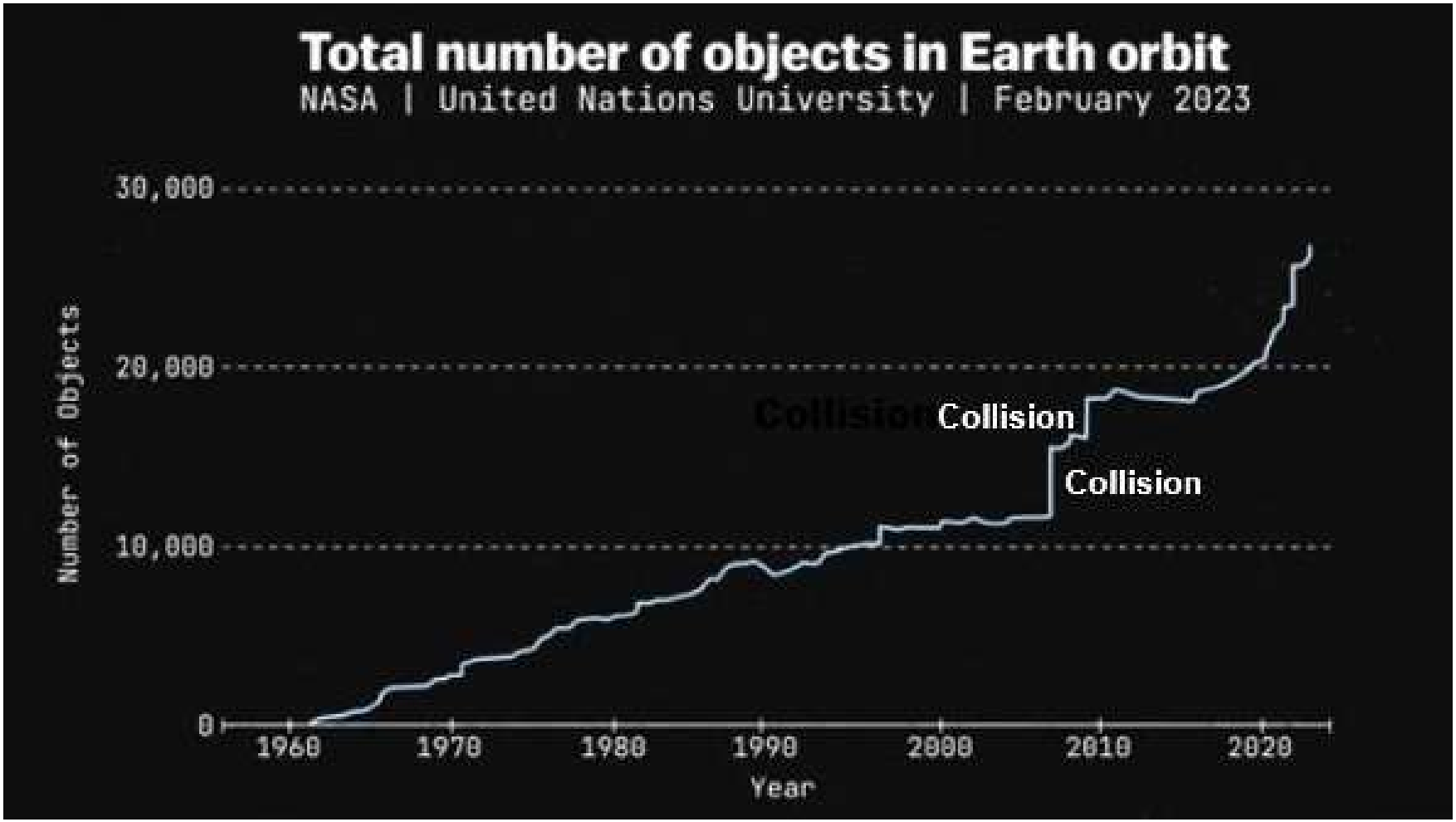
One collision or explosion produces 1000s of new fragments, which in turn cause more collisions, creating an exponential, uncontrollable increase in space junk.

This runaway chain reaction could make key orbital regions unusable for generations

Experts suggest we may already be in the early, slow-burn stages of this syndrome, with debris levels increasing 50% in the last five years. As of early 2024, there were over 14,000 satellites and 120 million smaller debris fragments in LEO

Amount of Space Trash

Nearly 30,000 pieces have been counted; but there is more



Examples of Collisions

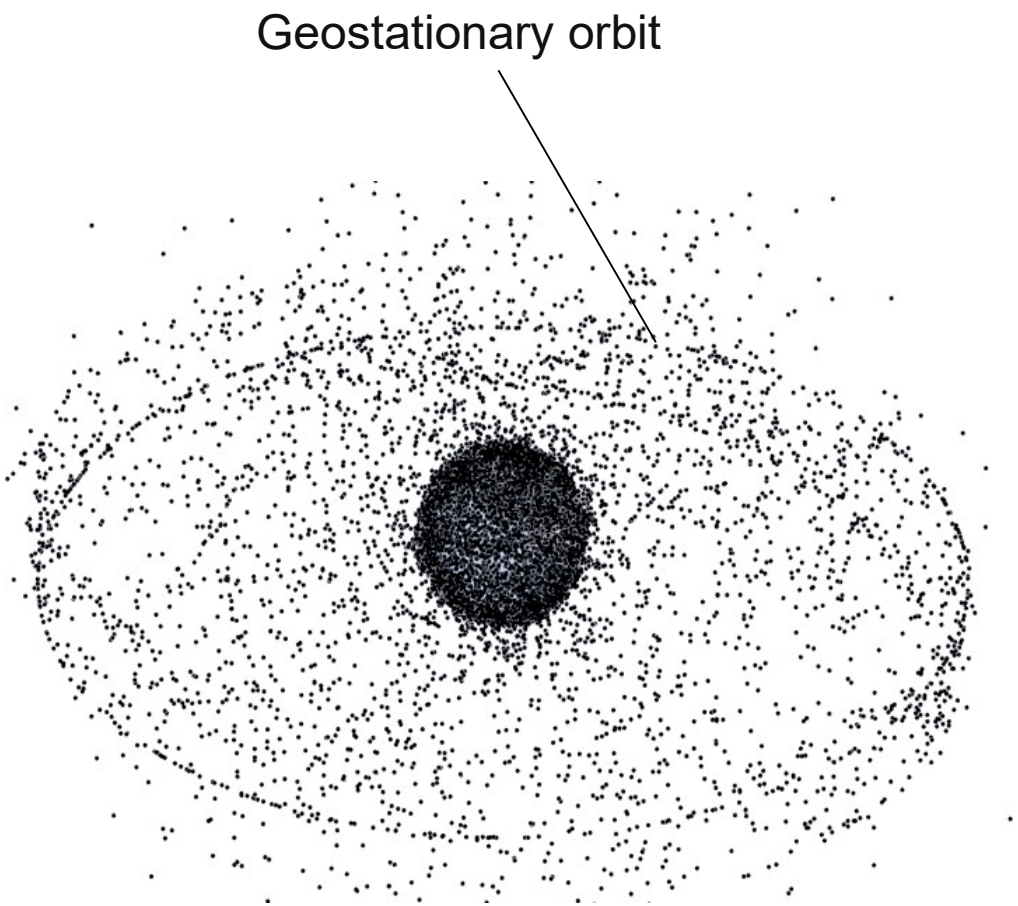
Chinese military maneuver

January 11, 2007:
China hit its own satellite as an anti-satellite test

Accidental collision

February 11, 2009:
US communications satellite owned by Iridium crashed into a abandoned Russian satellite, which broke both into thousands of pieces

Plus many near-misses



And It's Not Just Space Trash

The number of operational satellites is also increasing

Space X's 10,000+ Starlink satellites
Older or failed satellites de-orbited; 1-2/day fall on Earth

In Feb. 2026, SpaceX asked for permit to launch up to 1M satellites to set the groundwork for data centers in space

In July 2026, a CA company announced that it will place mirrors in space, to light up Earth's dark side

And Not Just a Matter of Space Safety

Earth-based telescopes are having a harder time getting an unobstructed view of the universe

Sooner or later, a human will be hit by space debris

Classification of Satellites

Low earth orbit:
ISS, communications, high-resolution imaging

Medium Earth orbit:
GPS, maritime, aviation, scientific research

Geostationary orbit:
Direct-to-home TV, weather tracking, war

Geosynchronous orbit:
Earth observation, weather tracking

VLEO <250 mi

	LEO (LOW EARTH ORBIT)	MEO (MEDIUM EARTH ORBIT)	GEO (GEOSTATIONARY EARTH ORBIT)
ORBIT HEIGHT	160 – 2,000 mi (257 – 3,219 km)	1,243 – 22,236 mi (2,000 – 35,786 km)	22,236 mi (35,786 km) (FIXED OVER ONE POINT)
ORBIT SPEED	17,500 – 17,900 mph (7.8 – 8.0 km/s)	8,900 – 12,300 mph (3.5 – 5.6 km/s)	6,900 mph (3.07 km/s)
LATENCY (ROUND-TRIP)	20 – 40 ms	100 – 150 ms	550 – 700 ms
COVERAGE	SMALL AREA (NEEDS MANY SATELLITES)	MODERATE AREA (FEWER SATELLITES)	VERY LARGE AREA (COVERS ~1/3 OF THE EARTH)
DATA SPEED	50 – 250 Mbps (0.05 – 0.25 Gbps)	10 – 100 Mbps (0.01 – 0.1 Gbps)	1 – 50 Mbps (0.001 – 0.05 Gbps)
BEST FOR	• HIGH-SPEED INTERNET • LOW LATENCY APPS • IOT & REMOTE AREAS	• NAVIGATION SYSTEMS • REGIONAL COVERAGE • MODERATE LATENCY APPS	• TV BROADCASTING • WEATHER MONITORING • WIDE AREA COVERAGE
EXAMPLES	STARLINK (SPACEX) INTERNET SERVICE	GPS (GLOBAL POSITIONING SYSTEM) NAVIGATION & POSITIONING	DIRECTV (COMMUNICATION SATELLITE) TV BROADCASTING

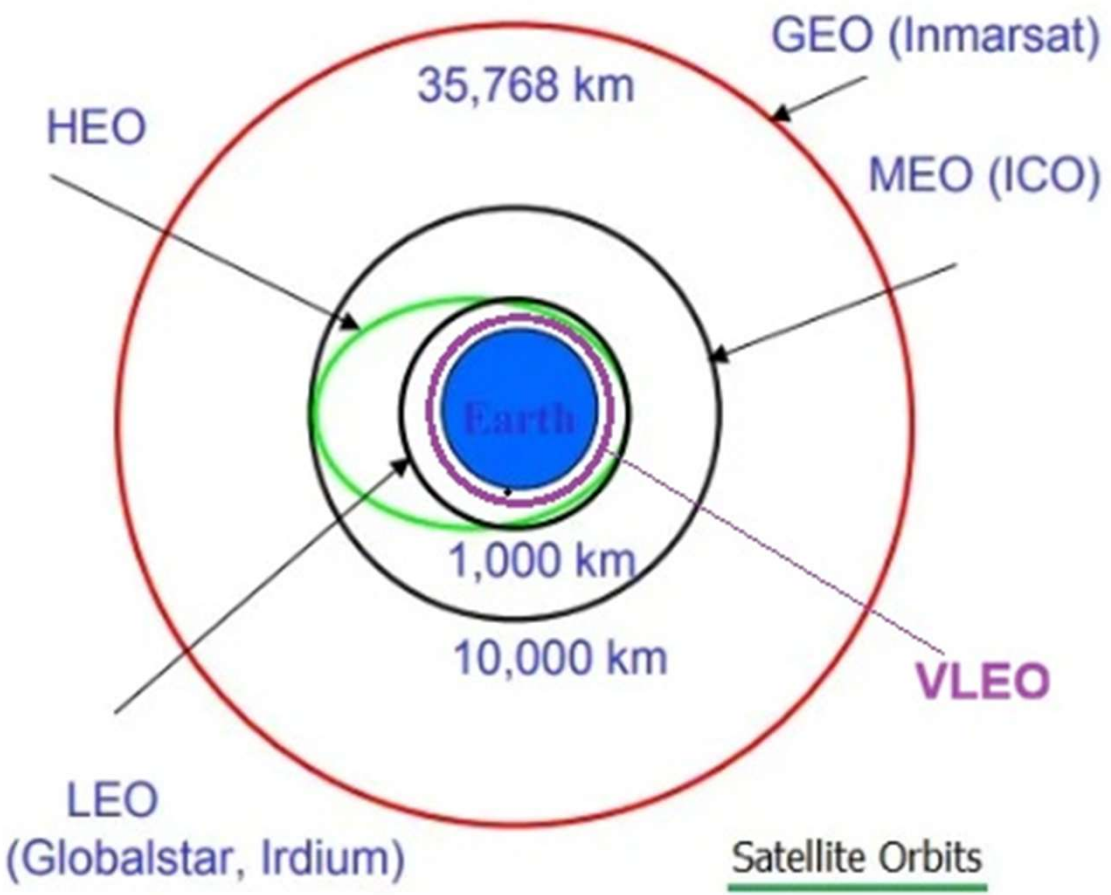
Adding the Very Low Earth Orbit

Key advantages:

Sharper images
Better signal quality
Better cloud monitoring
Higher data rates
Lower latency
Lower radiation levels
Simple de-orbiting

Main drawback:

Atmospheric drag leads to need for more fuel (which may be produced from air)



Objects in Moon's Orbit

While not as big a problem,
there's already much trash near the Moon

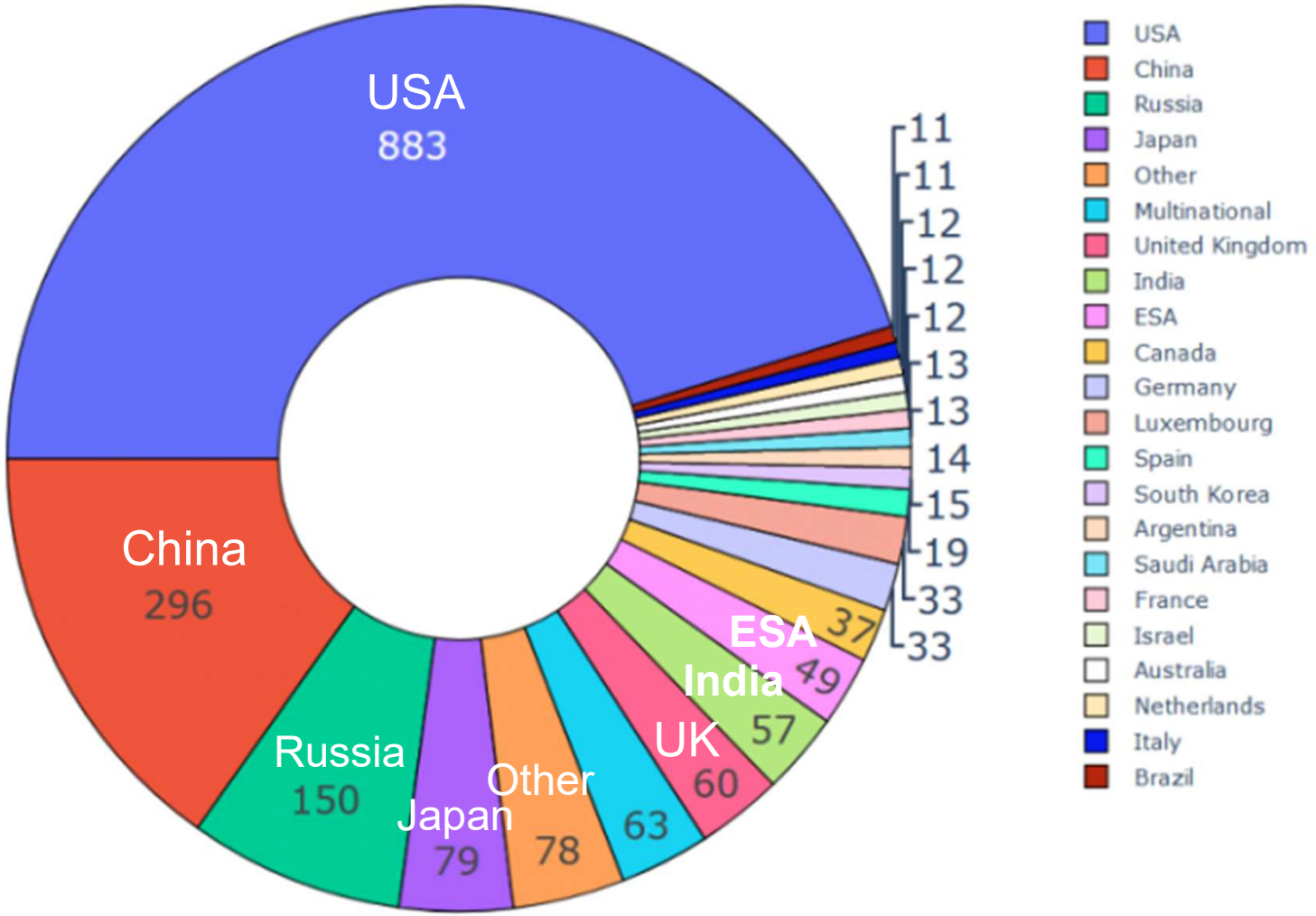
At least six orbiting satellites

Many more satellites placed there since the 1960s, but most have crashed or have otherwise been lost

More satellites are planned to help with Moon observation, communications, and navigation assistance

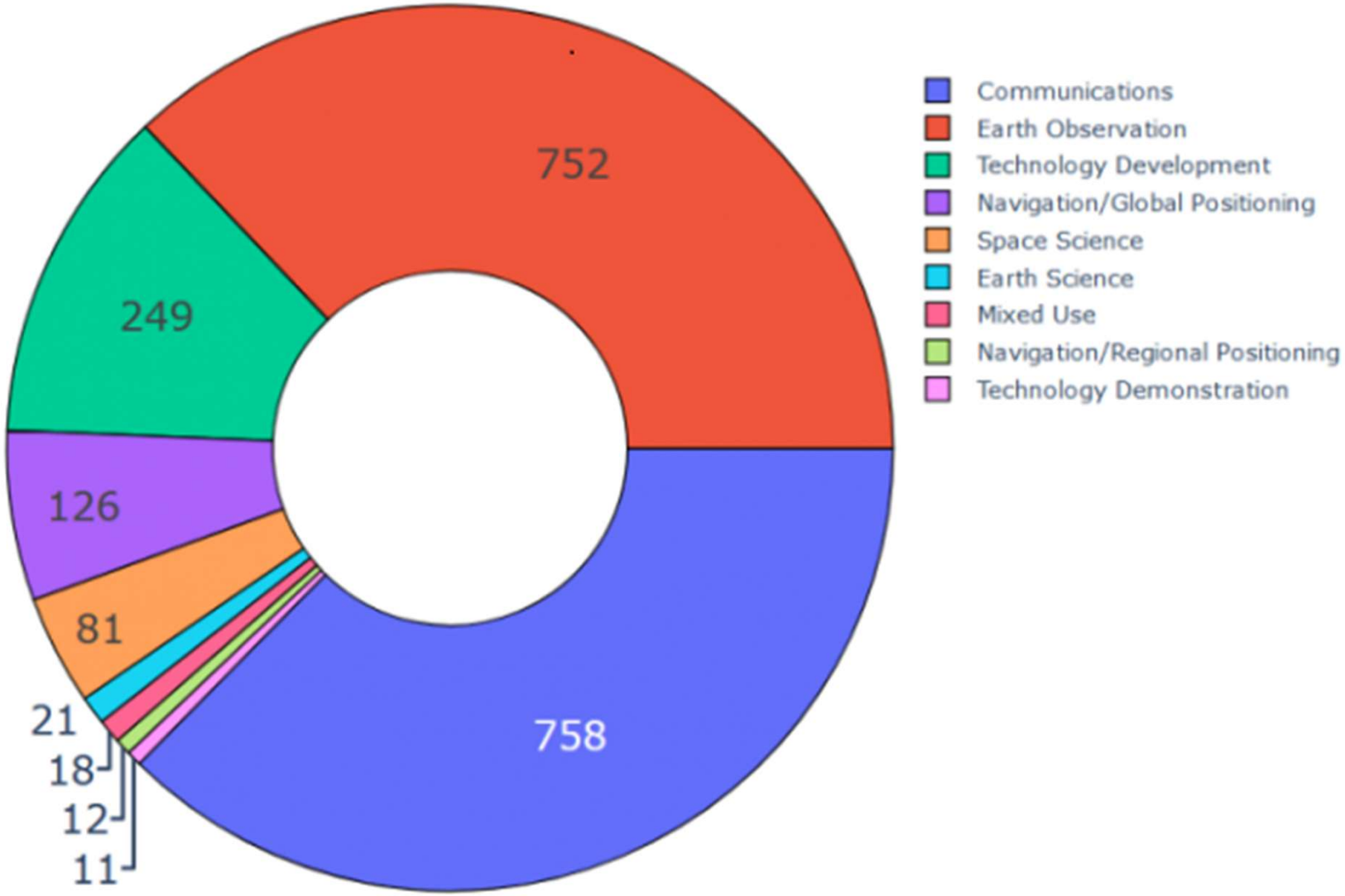
It's harder to find stable orbits around the Moon due to its highly variable gravity pull

Countries with More than 10 Satellites

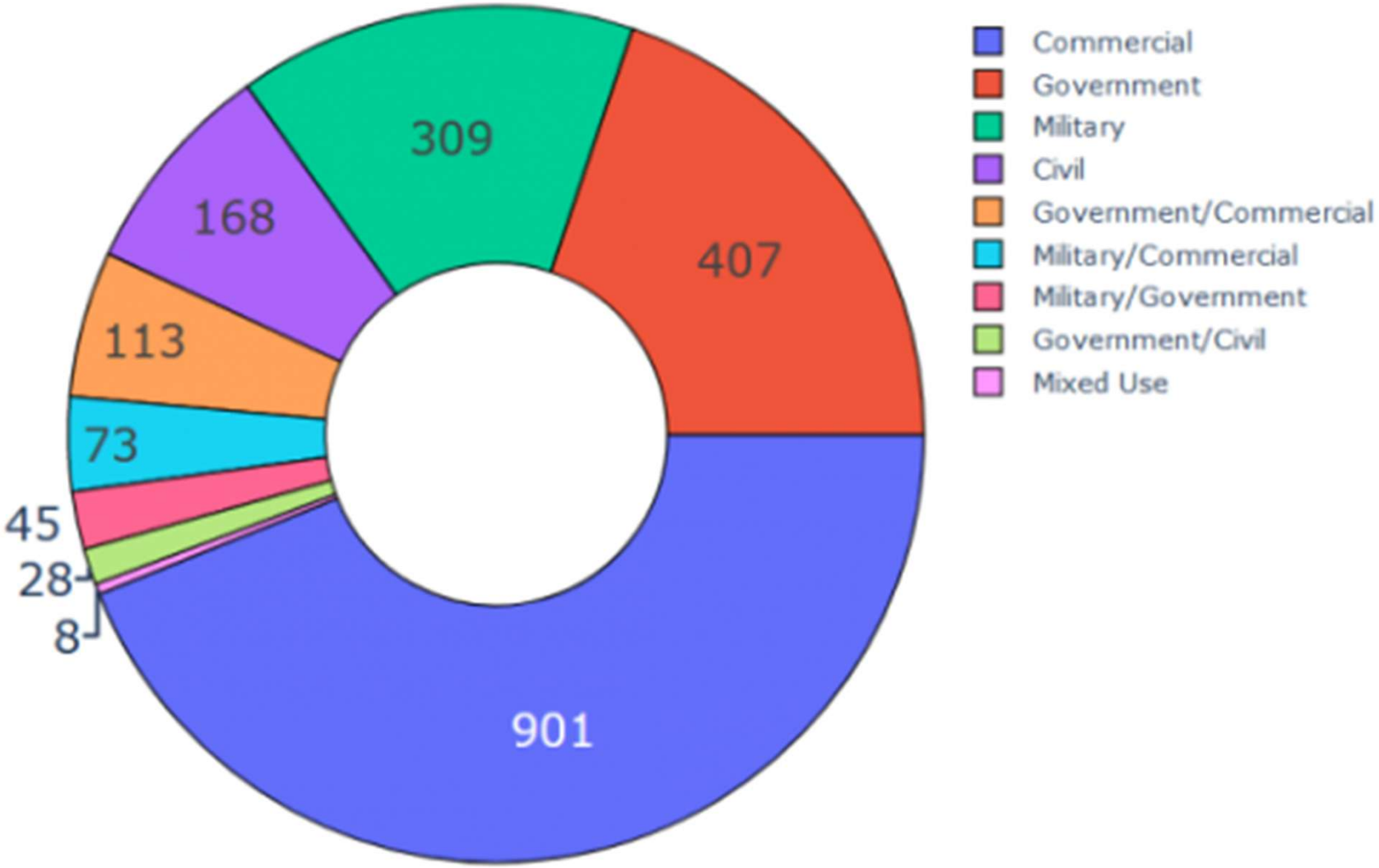


https://www.earth.com/earthpedia-articles/how-many-satellites-in-space-do-we-know-about/

Satellites by Function

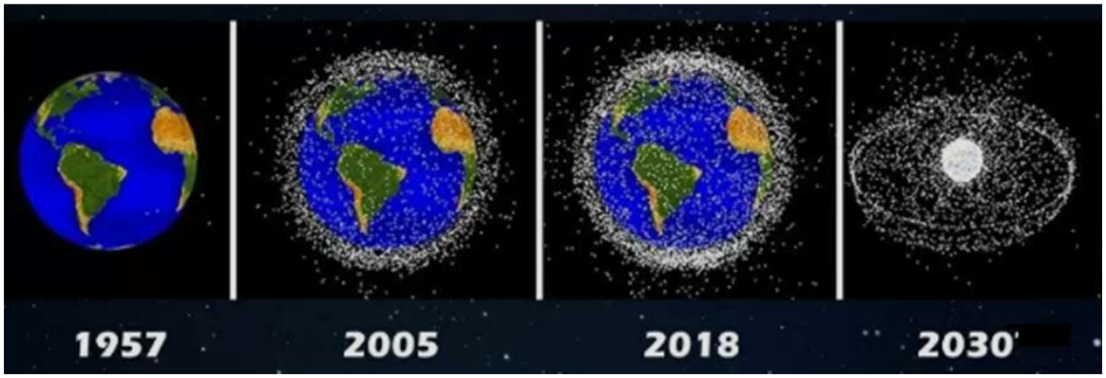


Satellites by User



Human-Made Space Objects by Size

Everything we send into space will eventually become junk



	Size of Debris	Number in Orbits
Chair +	> 1 m	5,400 objects
Baseball +	> 10 cm	Over 36,500 objects
Marble +	> 1 cm	1 million objects
Sugar +	> 1 mm	130 million objects

Potential Damage from Space Debris

Geostationary speed: 6875 MPH (3078 m/s)

At Mach 9, a marble-size object (5 g) causes

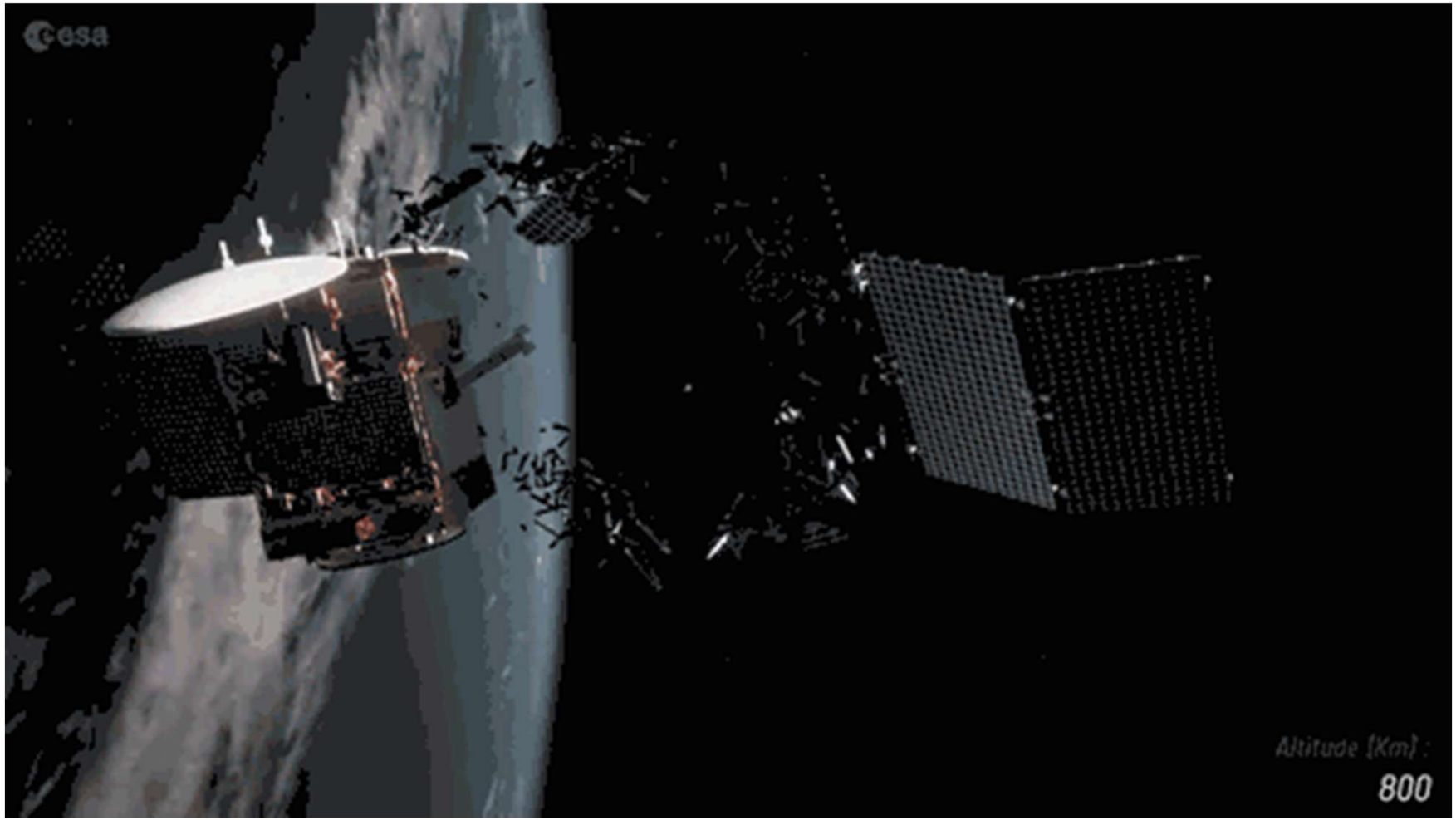
- Hydrodynamic penetration in hard objects, liquifying & blasting through thick steel plates or shattering concrete
- Structural obliteration of tissue beyond the entry hole, completely destroying organs & shattering bone

At Mach 9, a chair-size object (10 kg) causes

- Damage similar to a military-grade missile hit
- Destruction of a satellite or an entire module of ISS

Visualizing the Dangers in Space

A satellite being hit by space debris



Dangers of Space Junk to Earthlings

This piece of space junk that once connected sections of a rocket fell to Earth near a village in Kenya in 2024

A piece of Int'l Space Station crashed on a Florida home in 2024

***NYT* story (7/31/2026):**
https://www.nytimes.com/2026/07/31/world/asia/space-debris-falling-crashing-earth-risk.html

Tracking Space Debris

Debris tracking can be ground-based or done from space

LEOLABS plans to have six ground-based radars to track pieces of space junk down to 2 cm

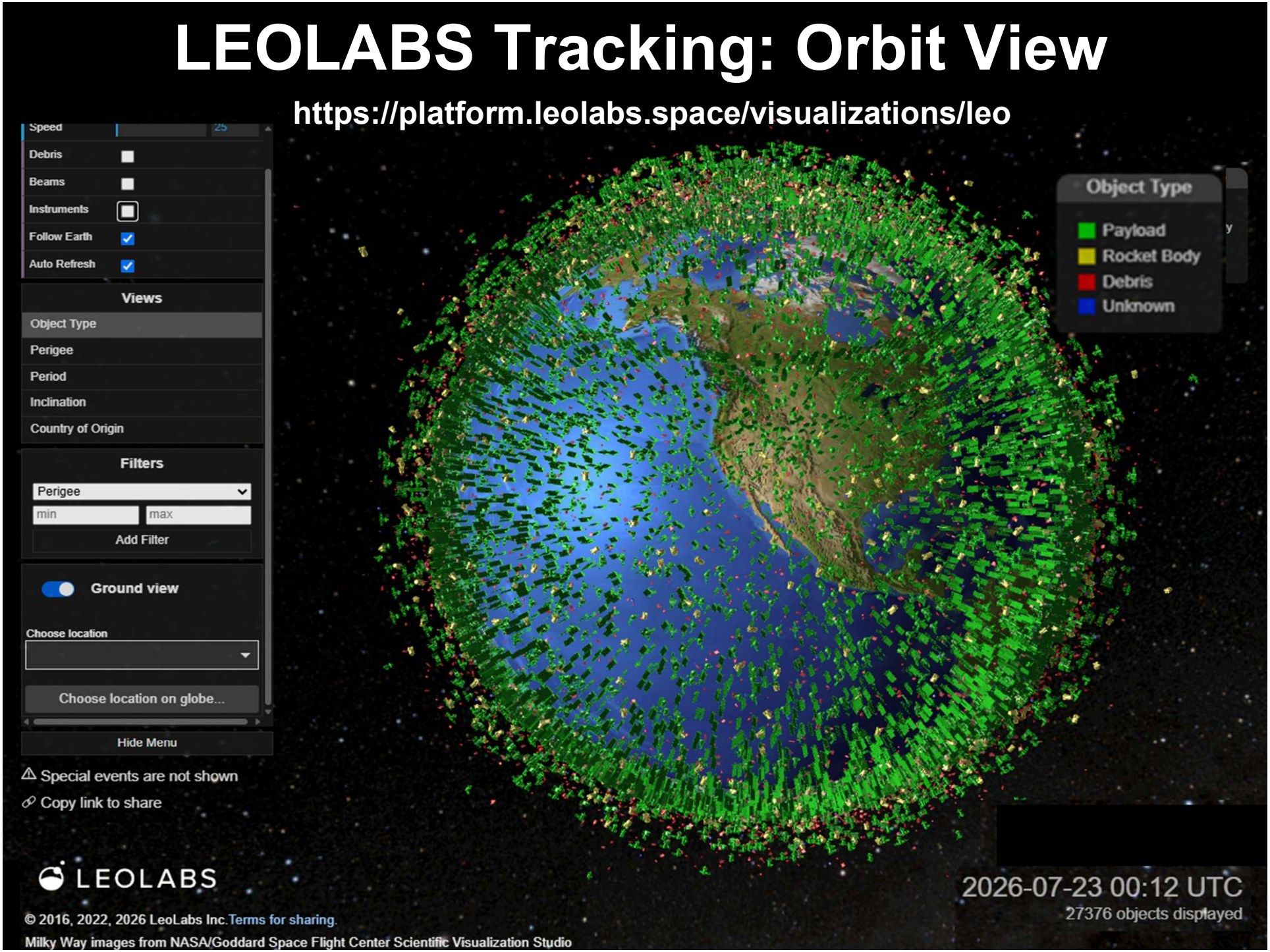
American aerospace & space tech company founded in 2016 to provide persistent orbital intelligence, tracking data, and mapping services for satellites and space debris in LEO

NorthStar Earth & Space: Space-junk-tracking satellites

Canadian space tech & data analytics company founded in 2015 to operate a dedicated satellite network to scan, detect, & track objects across all Earth orbits to prevent space collisions

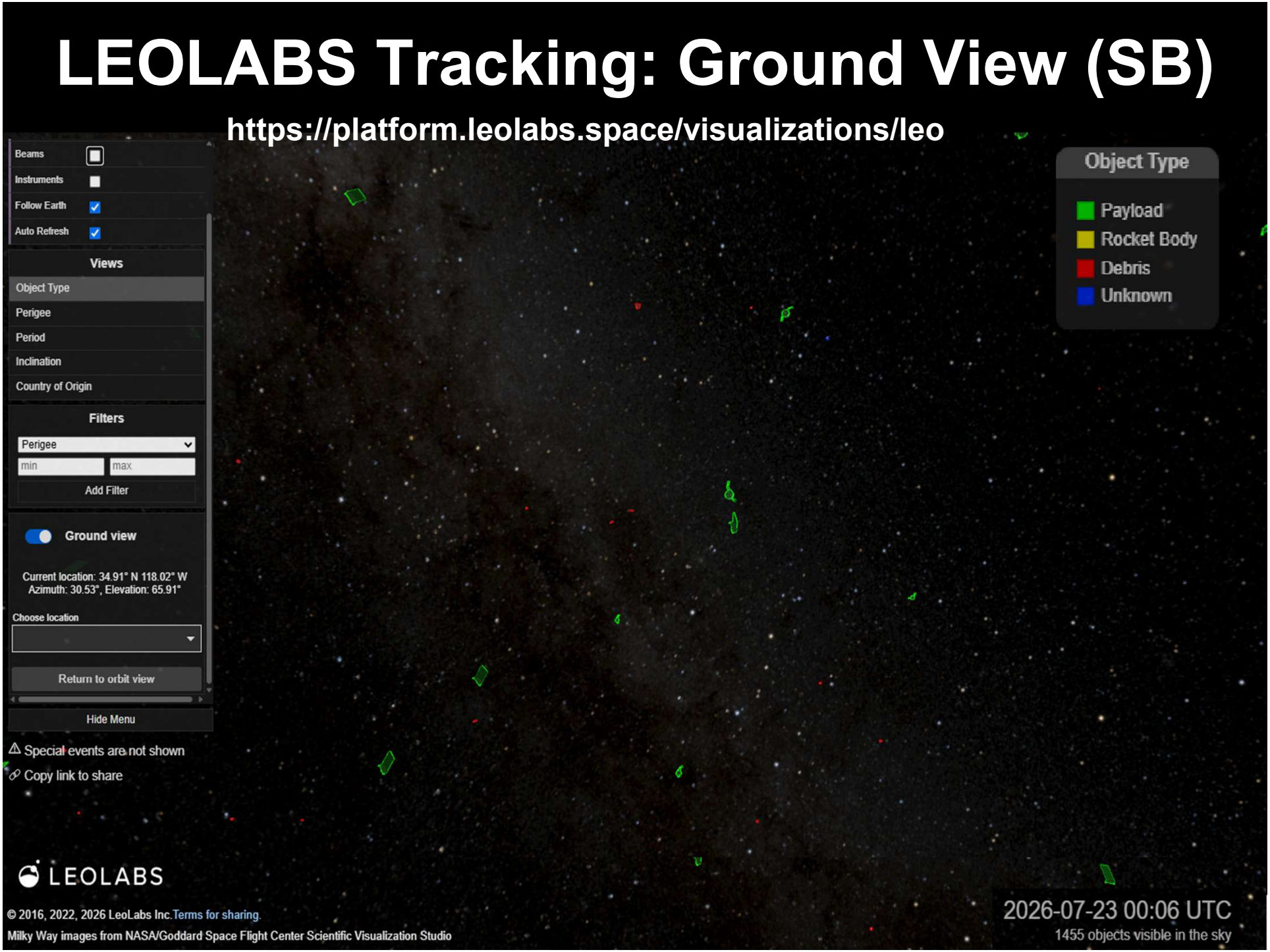
LEOLABS Tracking: Orbit View

https://platform.leolabs.space/visualizations/leo



LEOLABS Tracking: Ground View (SB)

https://platform.leolabs.space/visualizations/leo



Tracking Technology & Algorithms

NASA's Orbital Debris Program Office
Part of the Office of Safety and Mission Assurance
Tasks several organizations: JPL, Johnson Space Center, . . .

Of the 35,000 tracked human-generated objects in space:
~1/3 are active payloads
~2/3 are dead satellites and results of fragmentation events

We are getting better at detecting & tracking objects, estimated to number in hundreds of millions
New observation tech, some dedicated to space debris
New image-processing algorithms
Example: New objects detected by re-analyzing existing data sets from the Isaac Newton Telescope in Canary Islands

Trash Evasion Solutions

Evasion is the current way of dealing with space debris

Detect debris on possible collision course with the satellite

Evasion maneuver is costly due to limited fuel on board

Assess collision probability p

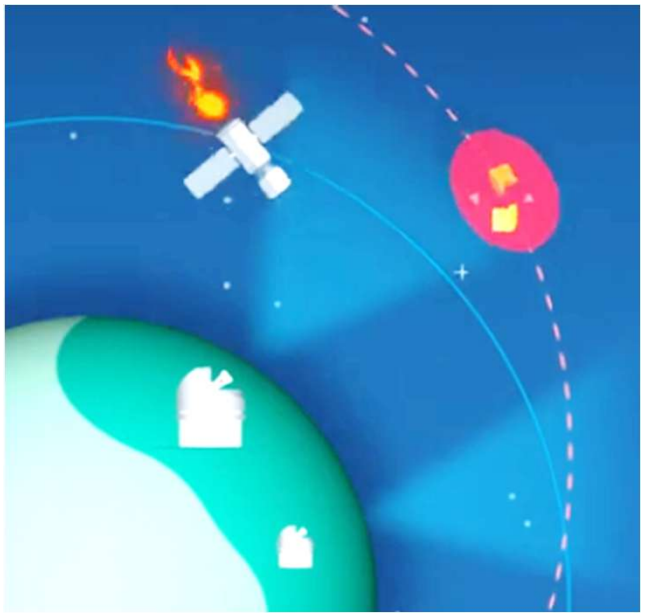
If $p > 10^{-4}$, execute evasion maneuver

Change orbit temporarily

Then, return to the original orbit

As density of space debris rises evasion becomes more difficult

Similar to midair collision avoidance on Earth, as drones, balloons, and other airborne objects proliferate



Challenges in Trash Evasion

Evasion maneuvers are costly; may become infeasible

https://www.youtube.com/watch?v=JOo3hgJcNyg

Trash Collection Solutions

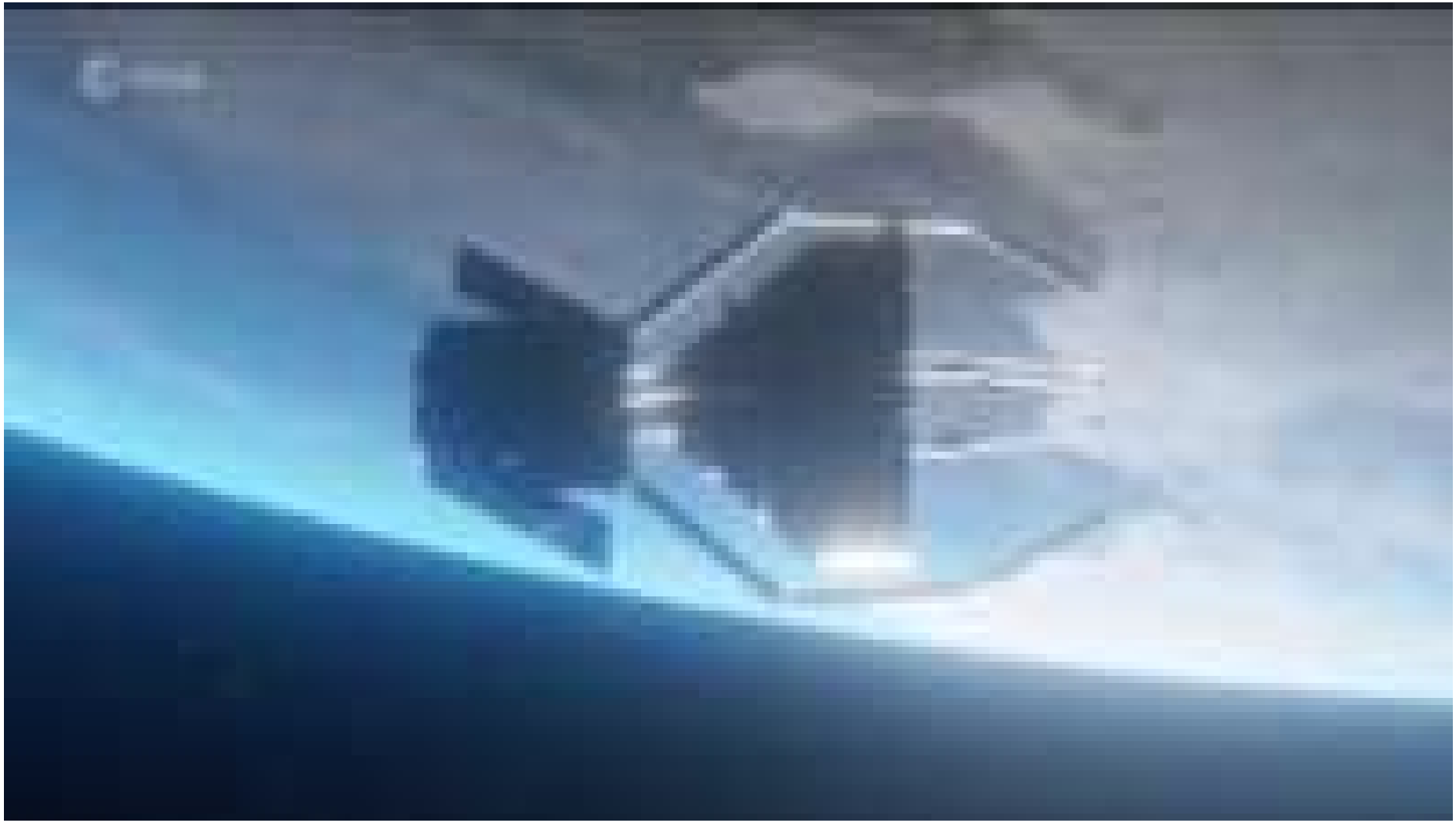
Trash collection satellites act like garbage trucks

Relatively large pieces of junk (1000+ kg) that could become sources of many smaller space junk are actively removed via claw capture, magnetic attraction, or harpoon & net

Rendezvous
Approach
Assess
Plan maneuver
Capture
Drag
Release

The collector & debris burn in Earth atmosphere

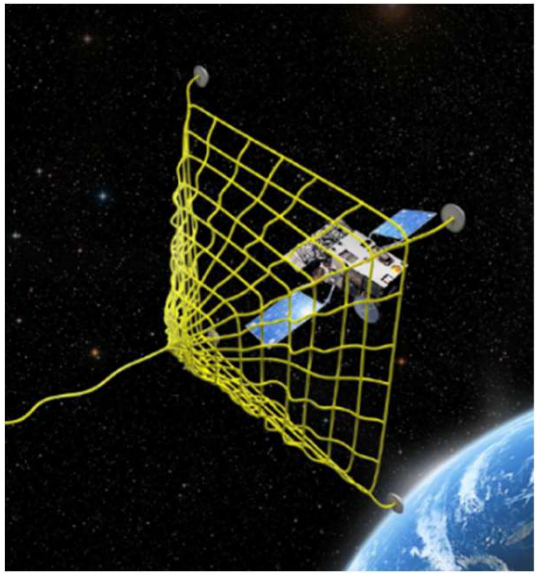
ClearSpace



https://www.youtube.com/watch?v=SMeyUBofJHw

Companies Tackling Space Trash

Reusable garbage collection satellites
Paladin Space, Australian start-up



Refuelable spacecraft
Portal Space Systems, US company

Active debris-removal services
ClearSpace, Swiss-based start-up

Bringing back & refurbishing used spacecraft
Lux Aeterna, Colorado start-up

Tracking orbital objects
Vymona & Aldoria, European situational-awareness firms

Trash Destruction Solutions

Similar to trash-burning on Earth

Space junk zapped by laser beams
Zapping can be done by
Earth-based or space-based lasers

Must be done carefully
May create additional pieces of junk

Zapping used to slow down the target
Which then falls to earth and burns

Zapping can also speed up the target
Which then disappears into space

Image from Japan's
Sky Perfect JSAT Corp.,
based in Tokyo

https://www.skyperfectjsat.space/jsat/en/

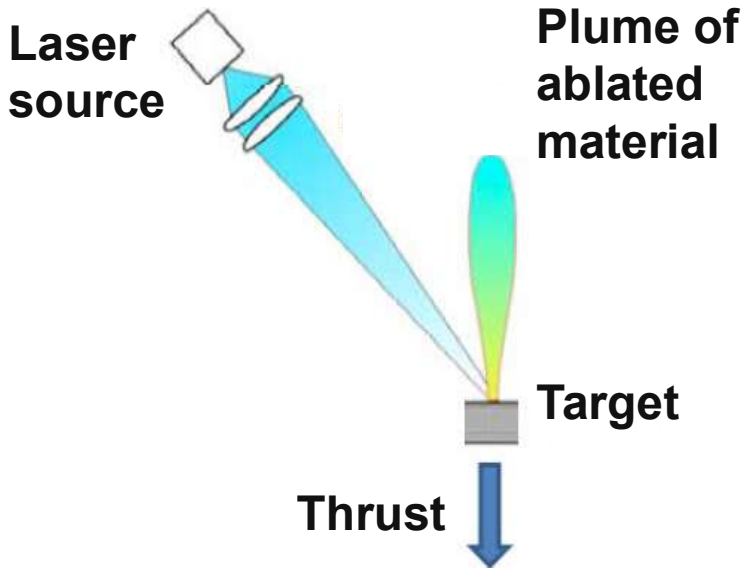
How Trash Destruction Works

High-Power Pulsed Lasers

Usually near-infrared (such as 1064 nm Nd:YAG systems)
Perhaps specialized ultraviolet lasers

Laser Ablation Vaporizes a Tiny Layer of the Trash

Expanding vapor & plasma
act like a tiny rocket engine
that thrusts the object
(slows it down or speeds it up)



Laser Broom Concept

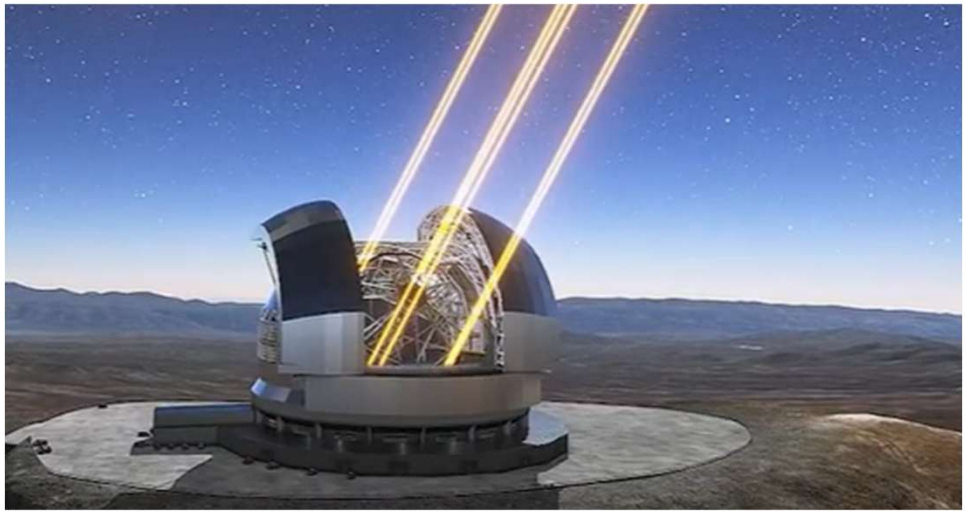
A laser beam clears debris
in size range of 1-10 cm
from the path of a satellite

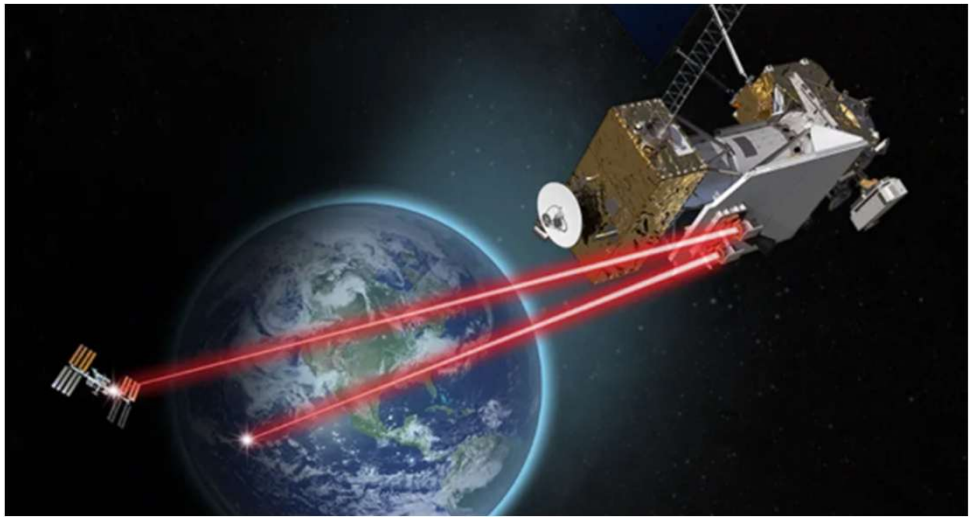
Challenges in Trash Destruction

Earth-based zapping
Distance can be a problem
Effects of the atmosphere
Ample energy is available

Space-based zapping
Energy limitation
Shorter distance to target
Ideal to push debris down

Overlap with weapons
Weapons are being built
We need int'l treaties
Trust/verification difficult





Responsible Use of Space

Create less Space Junk

SpaceX's reusable rockets
Self-decommissioning satellites

Use Longer-Life Satellites

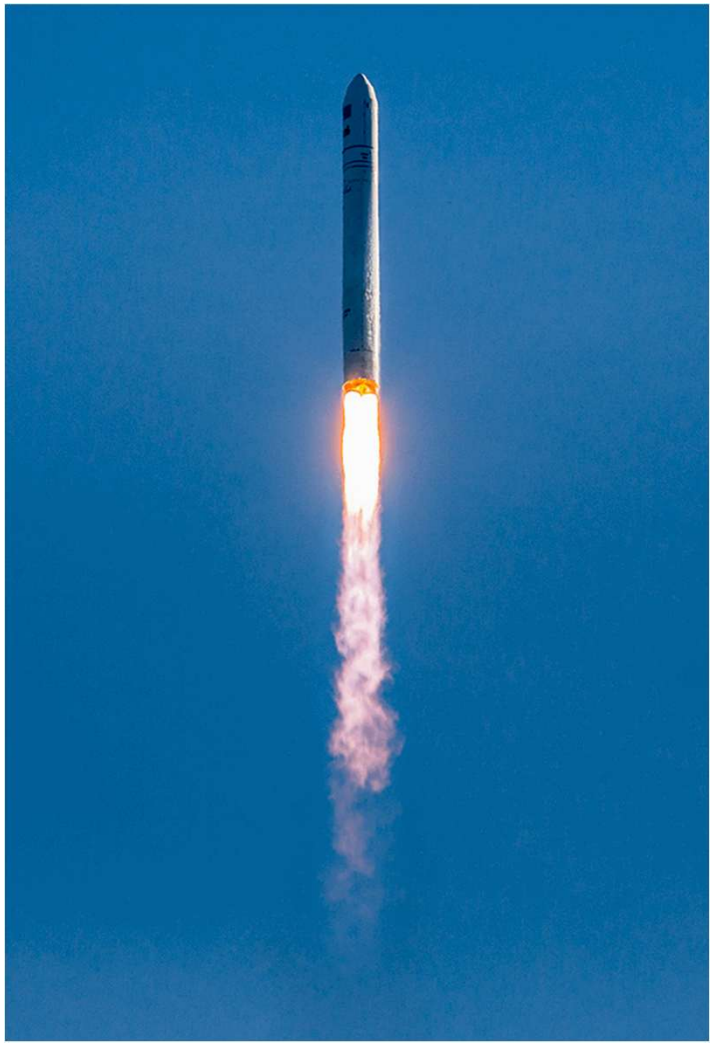
More efficient fuel
Life-extension missions

Recycle Parts

Russia reusing an ISS module

Multifunction Satellites

One satellite doing several tasks
International collaboration



Evaluating and Shaming

Space Sustainability Rating

https://spacesustainabilityrating.org/

"Our mission is to encourage space actors to design & implement sustainable space missions and operations"

"In the rapidly evolving space ecosystem, a shift is needed in how actors pursue sustainability and the ways in which sustainability practices are measured"

Danielle Wood (MIT)

Associate Professor of Media Arts and Sciences; Associate Professor (Joint) of Aeronautics and Astronautics

Liability and Space Insurance

There are companies covering space assets and liability

Just as cargo ships & oil tankers would not operate without insurance, so too expensive space assets and the attendant liability need to be protected

A variety of policies cover pre-launch, launch, in-orbit, and third-party legal liability

Difficult to identify where a piece of space debris came from

International Laws & Cooperation

Laws overseen by UN Office for Outer Space Affairs

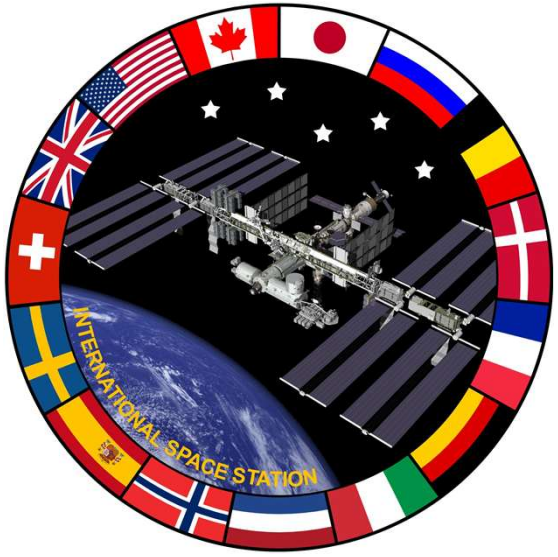
- Outer Space Treaty (1967): Space belongs to all mankind
- Rescue Agreement (1968): Assisting astronauts in distress
- Liability Convention (1972): Nations liable for damages
- Registration Convention (1975): Transparency on specs
- Moon Agreement (1979): Moon is common mankind heritage

Laws need to be updated due to

- Vastly increased commercial activity
- Alarming space “pollution”
- Potential for militarization

Cooperation is getting more difficult

- Some examples: US-Russia; ISS; EU



Conclusion

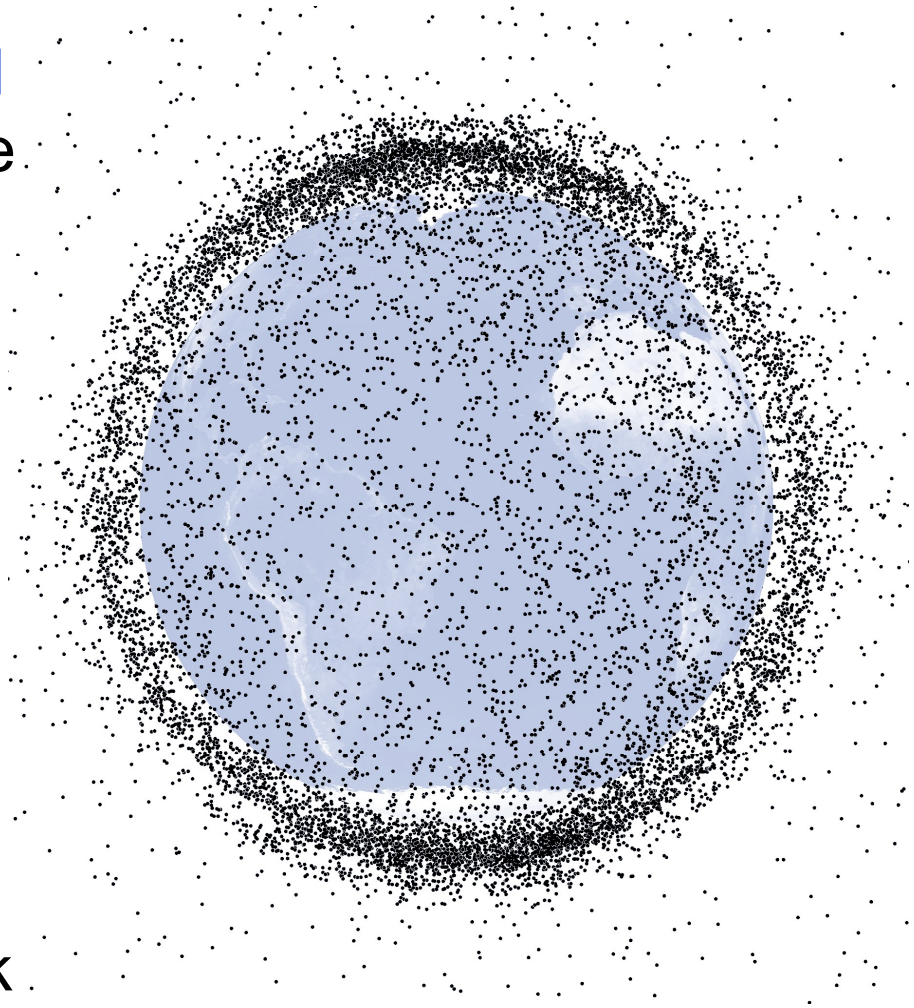
Space Junk Can't Be Ignored
Mitigation methods are overdue

Trash Evasion Solutions
are not viable in the long run

Trash Collection Satellites
are starting to be deployed

Trash Destruction Solutions
are in planning stages

Environmentalism in Space
means creating less space junk



Questions & Comments

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