# Active Debris Removal and On-orbit Satellite Servicing

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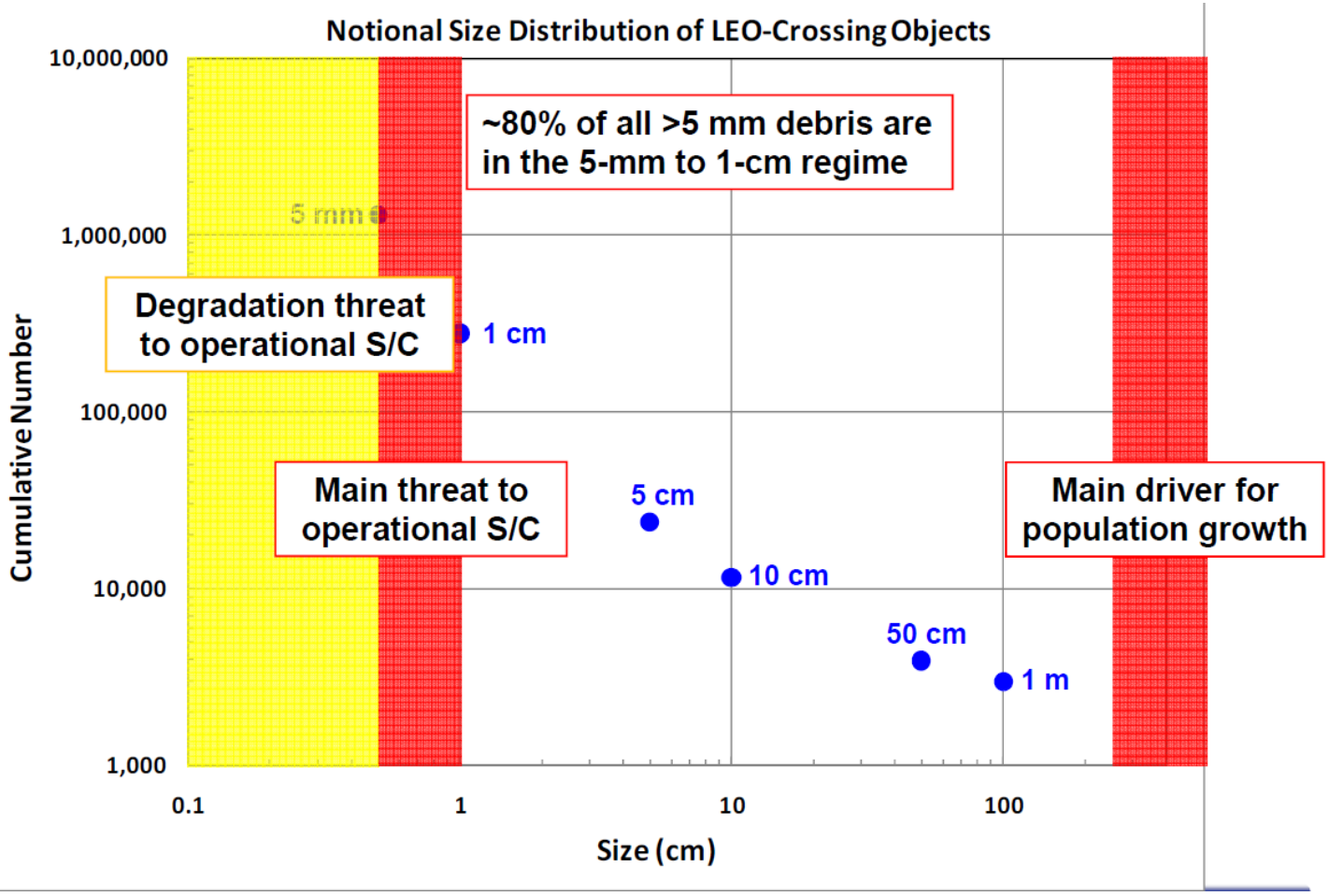
# ACTIVE DEBRIS REMOVAL (ADR)
# AKA "REMEDIATION"

# Threat from space debris

- What's in space
  - 1,300 active satellites in orbit (half LEO, half GEO)
  - ~22,000 pieces of ***tracked*** space debris (bigger than 10 cm)
  - ~500,000 pieces of ***untracked*** space debris (1-10 cm)

- U.S. military currently provides close approach warnings to all satellite operators
  - Average of 23 "emergency" notifications per day in 2014
  - Operators performed 121 avoidance maneuvers in 2014 to reduce risk of potential collisions

# Size of space debris vs threat to spacecraft




*Source: Dr. J.-C. Liou, NASA Johnson Spaceflight Center*

# Three main strategies

- Remove the big stuff
  - Reduce the growth in the space debris population over time
  - Will not change the probability of collisions in the near-term

- Remove the little stuff (1-10 cm)
  - Currently not tracked and can't be avoided by active satellites
  - Technically very challenging (~500,000 objects)

- Do "just-in-time" collision avoidance (JCA)
  - Change the orbits of small debris so they don't collide with big debris
  - Delays Kessler Syndrome, but doesn't solve the root causes

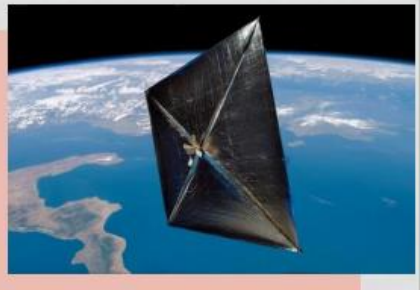
# Four "mainstream" concepts

- **EDDE (ElectroDynamic Debris Eliminator)**
- E-tether uses Earth's magnetic field to create propulsive force
- Use force to both rendezvous for grappling and to move derelict
- Some partially successful testing in the past

- **GOLD (Gossamer Orbit Lowering Device)**
- Inflatable
- Simple, effective
- Better long-term collision risk than any ADR system except for propulsive tug



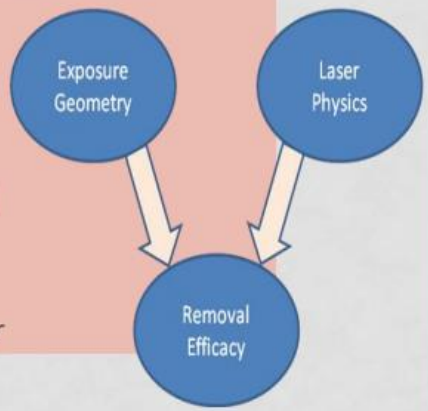
- **Solar Sail**
- Uses solar photon pressure to move derelicts
- Similar systems deployed previously but not for operational ADR applications
- Fragile and slow process



- **Propulsive Tug**
- Traditional propulsion system still the most mature capability
- High impulse and controllability for reentry risk mitigation
- Exemplar for several satellite servicing initiatives

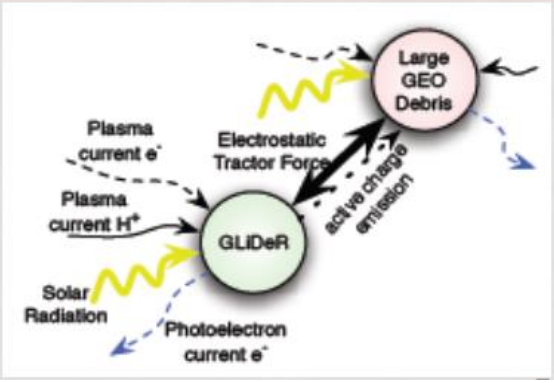
*Source: Dr. Darren McKnight, Integrity Applications Inc.*
*http://www.iafastro.org/wp-content/uploads/2014/04/Darren-McKnight-Presentation_11-Feb.-2013.pdf*

- **Laser Removal from ground or space**
  - No need to detumble or even go to space for groundbased version
  - Physics of dwell time and laser interaction are unproven
  - Feasibility for ADR unclear




- **Geosynchronous Large Debris Reorbiter (GLiDeR)**
  - Contactless-coupling plus ion thrusters in GEO only
  - No need to detumble
  - Unproven, limited applications
  - Deposit in GEO graveyard, not deorbit

- **Tungsten Dust**
  - Remove derelicts by depositing tons of dust in space to "wash out" medium-large debris
  - Significant effects on operational spacecraft
  - Feasible only for "start over" mode




*Source: Dr. Darren McKnight, Integrity Applications Inc.*
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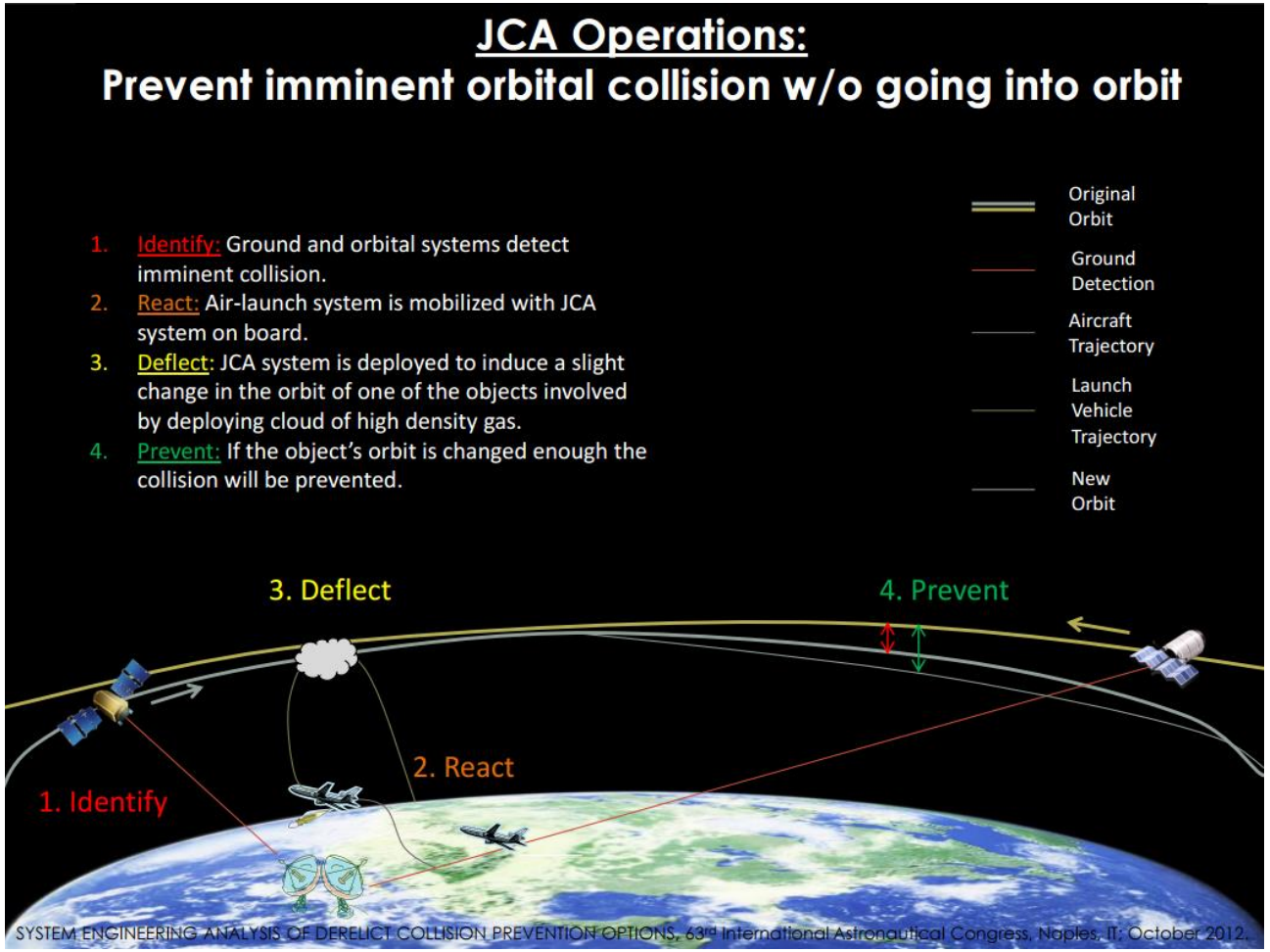
# JCA

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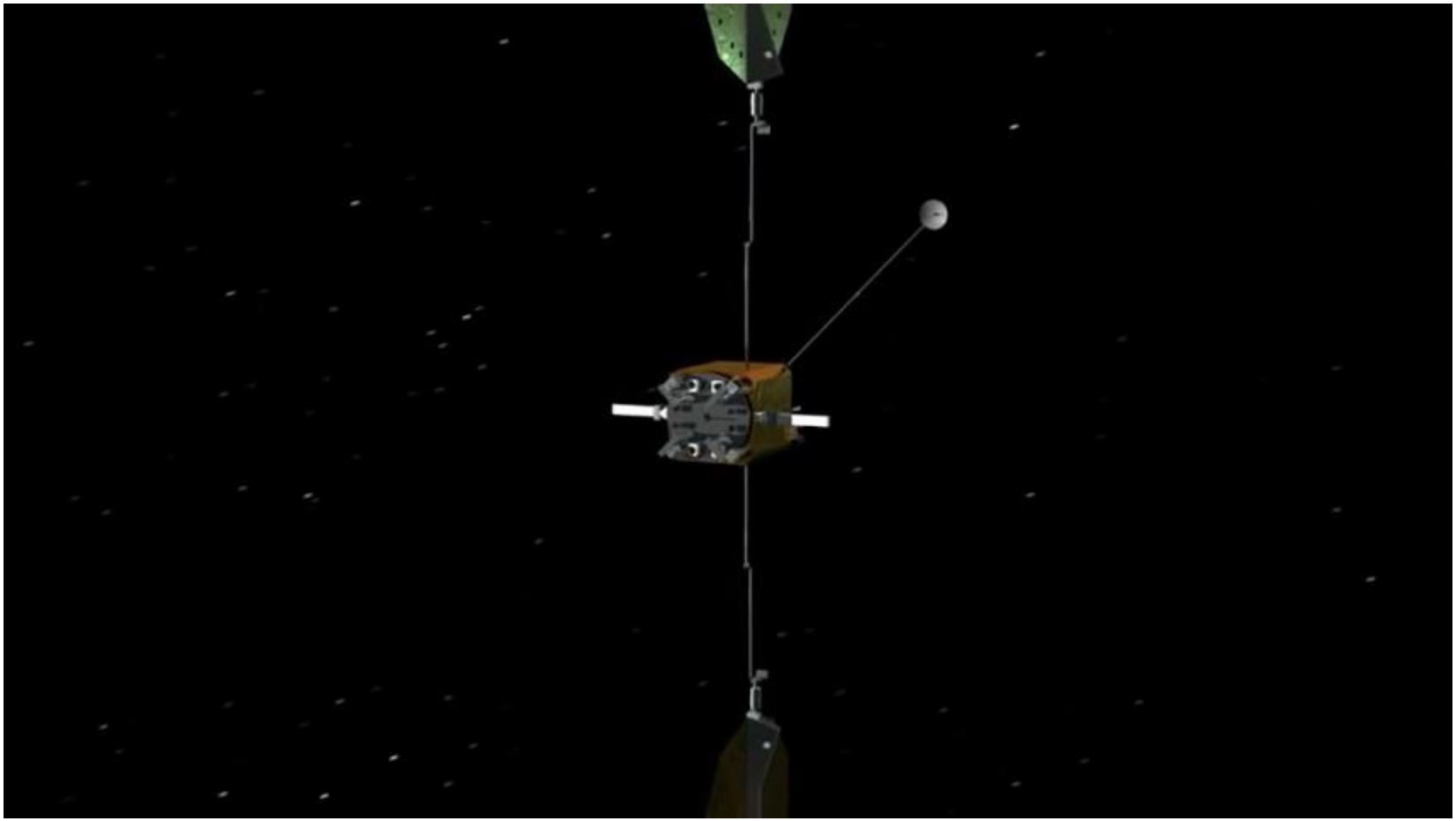
# ON-ORBIT SATELLITE SERVICING (OOS)

# On-orbit satellite servicing

- Shift from viewing satellites as dynamic, instead of static, investments
  - Old: once launched, their capabilities and lifetime were fixed and could only stay same or decline
  - New: satellites re-fueled, repaired, or even upgraded while on orbit

- Quest to improve knowledge about anomalies and failures
  - Old: long-distance detective work to try and figure out what happened (defect, environment, or hostile?)
  - New: up close and personal inspection

# Vivisat's Life Extension Vehicle



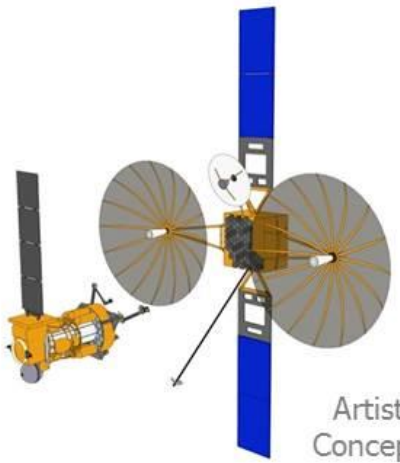
*Source: Vivisat (Youtube)*
*https://www.youtube.com/watch?v=n5Ya4-V860k*

# DARPA Satlet Concept

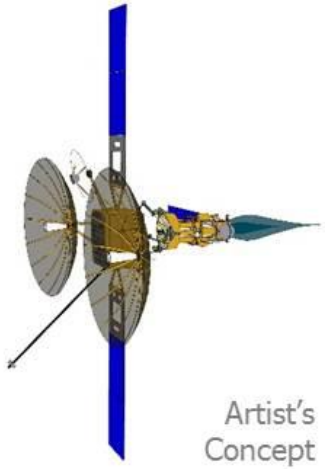

*Source: DARPA (Youtube)*
*https://www.youtube.com/watch?v=OeKzdk0sWjI*

# DARPA Phoenix

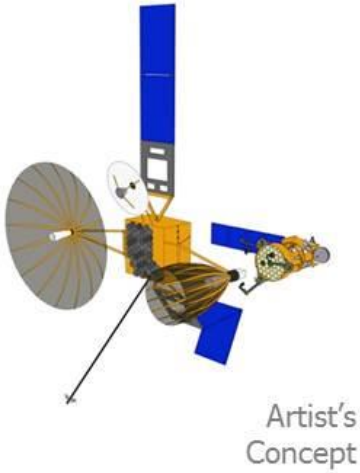
## DARPA Goals for GEO Robotics Servicing




**Cooperatively inspect spacecraft experiencing anomalies**




**Cooperatively assist with orbit adjustments**

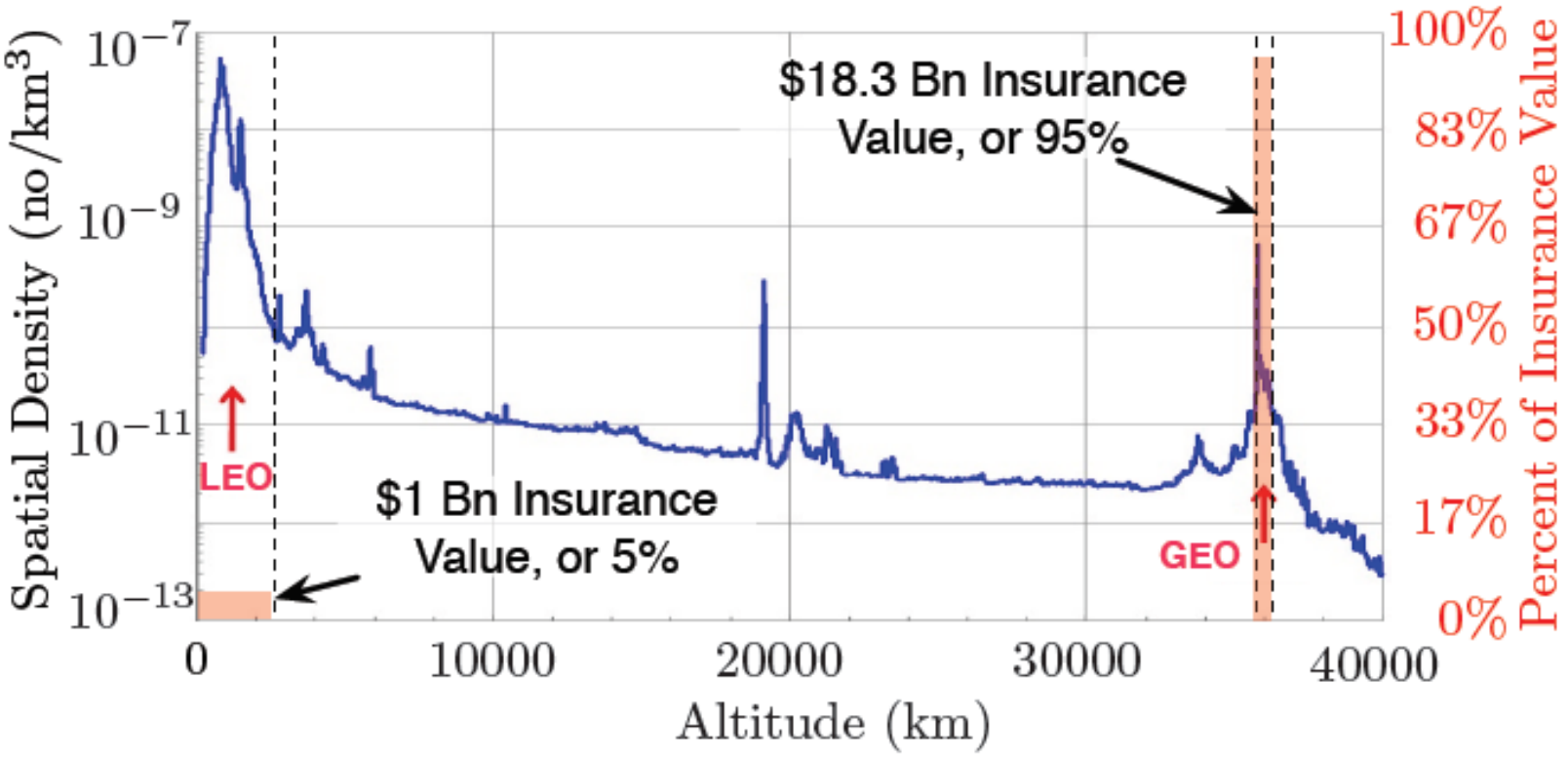



**Cooperatively correct mechanical problems**

*Source: DARPA*

# ECONOMIC, LEGAL, POLICY CHALLENGES

# Who will pay for debris removal?




*Source: Jasper, Anderson, Schaub, and McKnight (2014)*
*http://hanspeterschaub.info/Papers/Jasper2014c.pdf*

# Who do you ask for "permission to touch"?

## Search Results

Important Note: Information in square brackets ([ and ]) and highlighted in green has been obtained from other sources and has not been communicated officially to the United Nations.
Reference to external websites does not imply endorsement by the United Nations Office for Outer Space Affairs (UNOOSA) of their contents. The views expressed are those of the authors and do not necessarily reflect the policies or views of UNOOSA. The hyperlinks are provided solely for informational purposes.

Criterias:
UN Registered:'Yes'
Presently in Space:'Yes'

Result:
**3529** Objects found. Displaying **20** per page.

So there are only 3,529 space objects, right?

0-20 of 3529»»

| International Designator | Name of Space Object | State/ Organization | Date of Launch | GSO Location | Nuclear Power Source | UN Registered | Document of Registration | Status | Date of Decay or Change | Document of Decay or Change | Function of Space Object | Remarks | External Web Site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1958-BETA 2 | [VANGUA 1] | | | | | | | | | | | | LINK |
| 1959-ALPHA 1 | [VANGUA 2] | | | | | | | | | | | | |
| 1959-ETA 1 | [VANGUA 3] | | | | | | | | | | | | |
| 1959-IOTA 1 | [EXPLORE (S-1A)] | | | | | | | | | | | | |
| [1959-MU 1] | First spac rocket [LUNA 1] | | | | | | | | | | | | |
| 1959-NU 1 | [PIONEE | | | | | | | | | | | | LINK |
| 1960-ALPHA 1 | [PIONEE | | | | | | | | | | | | |
| 1960-BETA 2 | [TIROS 1 | | | | | | | | | | | | LINK |
| 1960-ETA 1 | [TRANSI 2A] | | | | | | | | | | | | |

Welcome | Box Score | SATCAT | Decay/Reentry | Query Builder | Favorites | TLE Search

COUNTRY TOTALS:

Not according to USSTRATCOM

Show 10

| | IN ORBIT | | | | |
|---|---|---|---|---|---|
| COUNTRY | UNASSIGNED | PAYLOAD | ROCKET BODY | DEBRIS | TOTAL |
| VIETNAM (VTNM) | 0 | 3 | 0 | 0 | 3 |
| ALL (ALL) | 1 | 3913 | 1992 | 10991 | 16897 |

Showing 81 to 82 of 82 entries

# US federal oversight

- Existing authorities
  - NOAA: Remote sensing licenses
  - FCC: Radiofrequency spectrum licenses
  - FAA: Launch, re-entry, and operation of launch facilities
  - DoD: Space situational awareness and close approach warnings

- Gaps specific to ADR/OOS
  - Specific licensing authority for supervision of ADR/OOS
  - No civil agency with “traffic management” and on-orbit safety responsibility/authority
  - No single entity responsible for cleaning up space debris/managing the environment (if its everyone’s job, it’s no one’s job)

# Thank You

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