A Pragmatic, Evolutionary Path
to
Orbital Debris Removal
via
Customary International Law

What will be the "tipping point" event, which will induce multilateral action to *clean up* (not merely "mitigate") orbital debris?

The tipping point events to get 1968 ARRA finished were 1967 tragic deaths of Gus Grissom, Ed White, Roger Chaffee, Vladimir Komarov.

Do we need a “tipping point” tragedy or catastrophe in outer space to spur serious multilateral orbital debris cleanup?

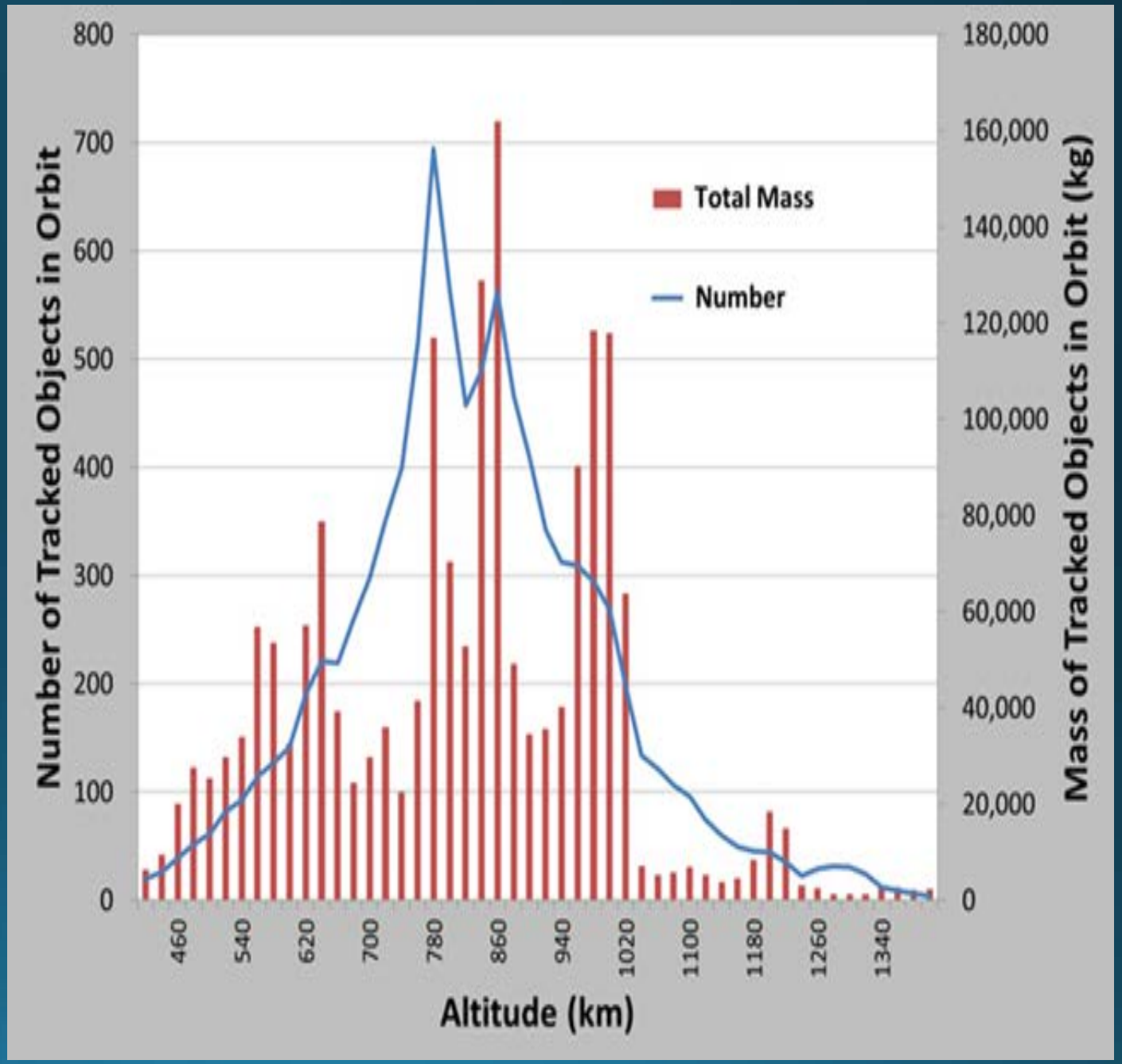
1) 23,000 debris objects > 10 cm.

2) > 1,000,000 *untrackable* dangerous debris objects (shrapnel) between 0.5 - 10 cm in size.

3) *Relative* impact velocities in LEO reaching 56,000 km/hr.

4) > 6300 tons of debris (9 x mass of ISS) already orbits the Earth – with only 1738 satellites functioning.

5) Debris will grow for 200 years *without any new launches.*



However, Space X, OneWeb, Boeing, Samsung, Telesat, and others are planning to launch more than ***20,000*** new satellites for broadband coverage, c. 16,000 into LEO & c. 4000 in MEO!

Governments & universities will be launching other spacecraft into orbit as well.

Orbital debris *mitigation* (i.e. minimizing quantity of new debris) is not enough!

We need orbital debris *remediation* (cleanup)
via
Active Debris Removal (ADR) & On-Orbit Servicing (OOS) to refuel, repair, reuse defunct spacecraft!

Heads up!

Space X, OneWeb, & Samsung are all planning for their mega-constellations of satellites to be around the altitude of 1200 – 1400 km, albeit at different inclination.

This could induce thousands of conjunction warnings each day.

If there is just one collision among these satellites or their upper stages, a runaway chain-reaction of collisions could result (Kessler Syndrome).

Satellite Services threatened:

1) Navigation on land, sea, & air, via GPS & voice communications.

2) Radio & TV

3) Business & Finance (credit cards, ATMs, **blockchain transactions**, banking/investing depend on GPS time-stamping)

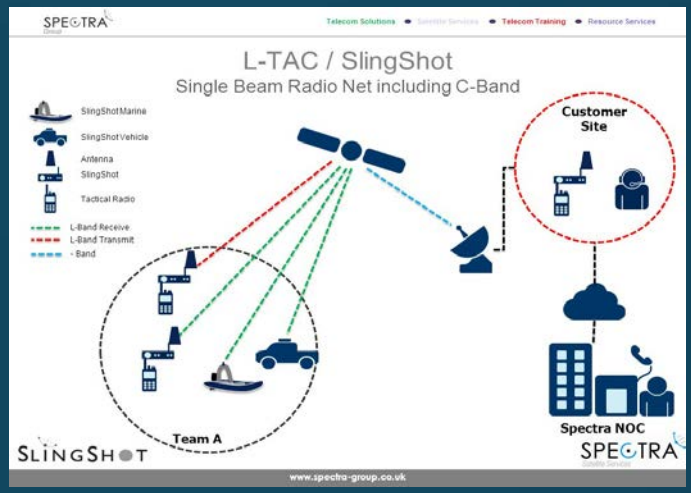
4) Weather reporting
(Before satellites: 8000 people died in 1900 when Galveston hit by hurricane.)

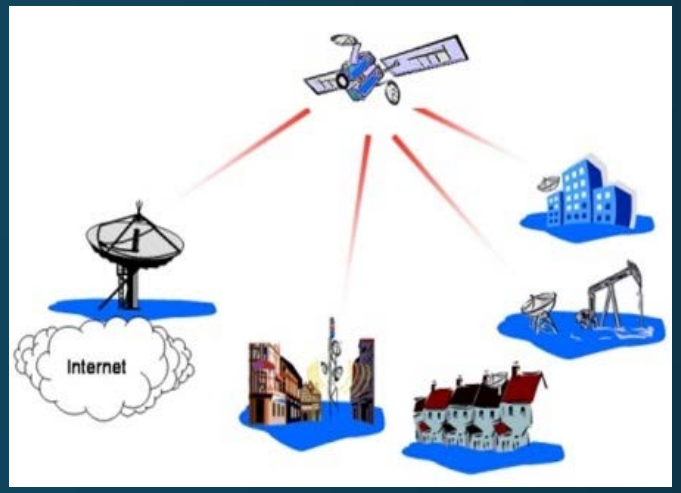
5) Climate & environmental monitoring, including water & land stewardship, farming.

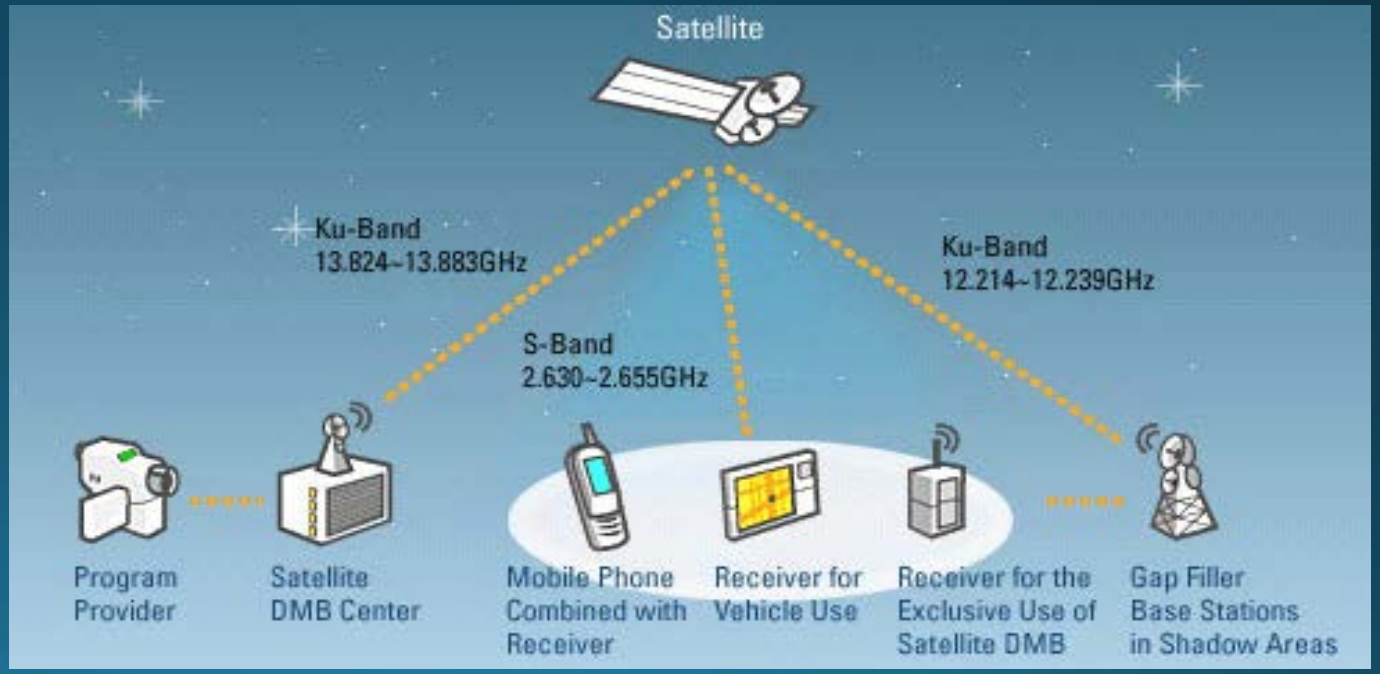
6) Cell phone & pagers (timing source & com relays)

7) Search & Rescue

8) Space science







WHAT is needed for the effective Active Debris Removal (ADR) of both large & small orbital debris objects?

Greatly enhanced
Space Situational Awareness
(SSA)

Debris objects (even as small as 0.5 cm diameter) must be spotted, tracked, & their analyzed trajectories integrated into a system that *frequently* & *accurately* predicts conjunctions with operating spacecraft & other debris objects.

In other words, we need…

Also, we need much better *worldwide*, *integrated*, & *comprehensive*

Space Traffic Management (STM)

i.e., National & *international* systems to carry out *enhanced* SSA & ADR via de-orbiting, moving debris to salvage orbits, or OOS.

Emerging "Cleanup" (via moving/de-orbiting) Technologies:

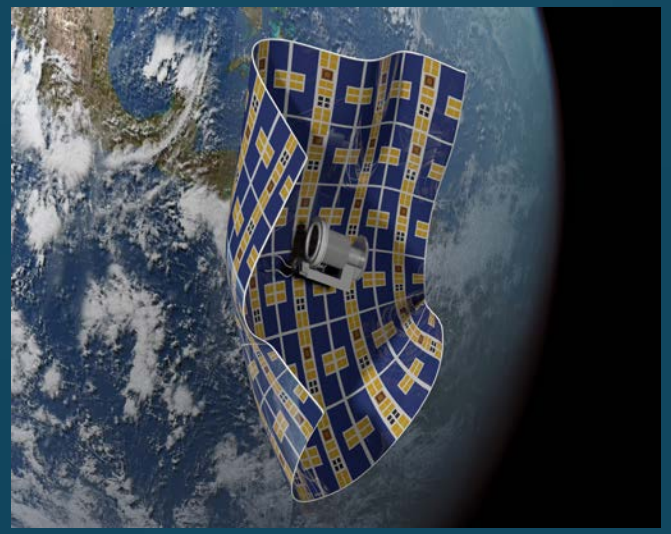
1) Swiss Federal Institute of Technology's CleanSpaceOne.

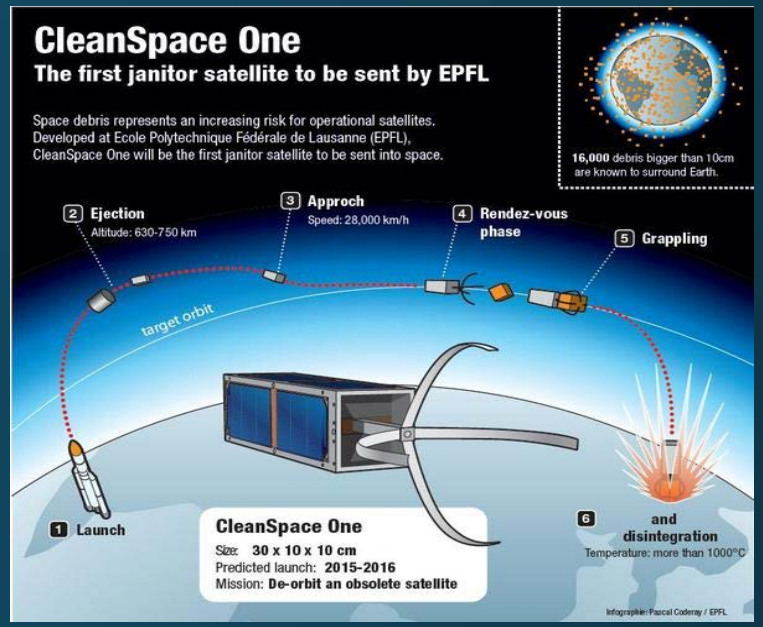
2) Hanspeter Schaub's Electro-static "touchless" Technology.

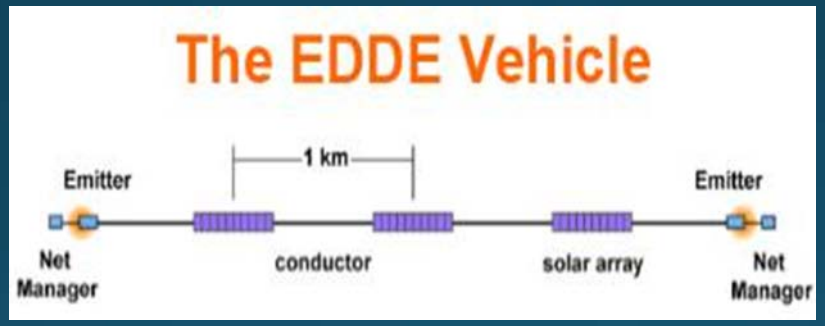
3) Aerospace Corporation's Branecraft.

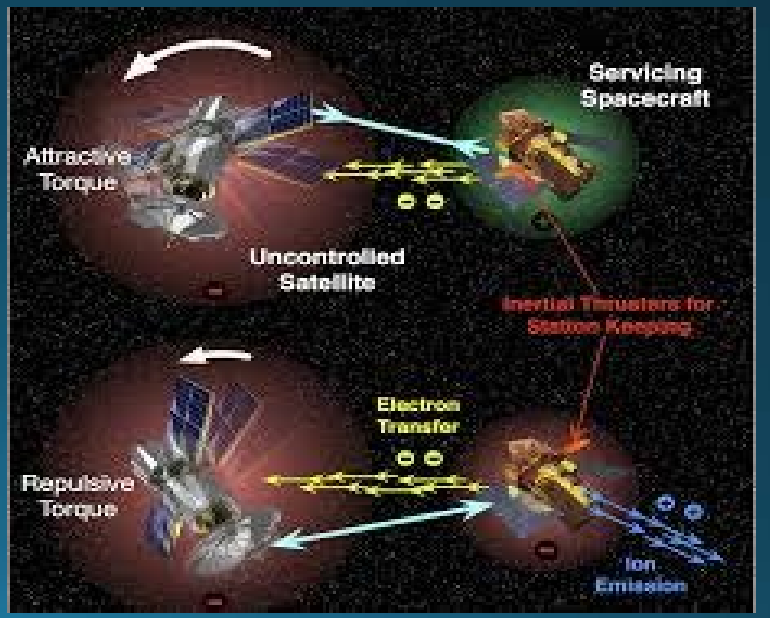
4) Star Technology & Research Inc.'s Electrodynamic Debris Eliminator (EDDE).

5) Tethers Unlimited Inc.'s de-orbiting Terminator Tapes & Terminator Tethers.









Instead of de-orbiting trash, how about OOS to repair, refuel, repurpose satellites?

National Aeronautics and Space Administration

Restore-L

Proving Satellite Servicing

Need extra gas or a tune-up for your satellite? For years, such services were outside the realm of possibility for most spacecraft. But now, one mission will break that paradigm.

Meet Restore-L, a robotic spacecraft equipped with the tools, technologies and techniques needed to extend satellites' lifespans – even if they were not designed to be serviced on orbit.

During its mission, the Restore-L servicer will rendezvous with, grasp, refuel and relocate a government-owned satellite to extend its life. But Restore-L's effect will not end there.

Successfully completing this mission will demonstrate that servicing technologies are ready for incorporation into other NASA missions, including exploration and science ventures. NASA also plans to transfer Restore-L's technologies to commercial entities to help jumpstart a new domestic servicing industry.

The benefits are many. Restore-L's capabilities can give satellite operators new ways to manage their fleets more efficiently, and derive more value from their initial investment. These capabilities could even help mitigate the looming problem of orbital debris.

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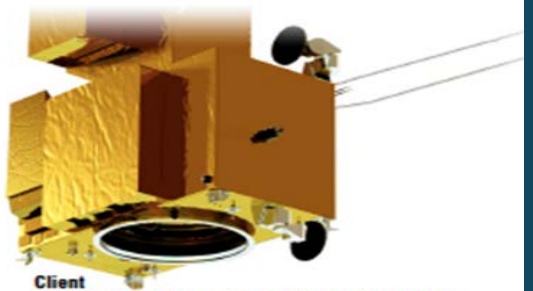
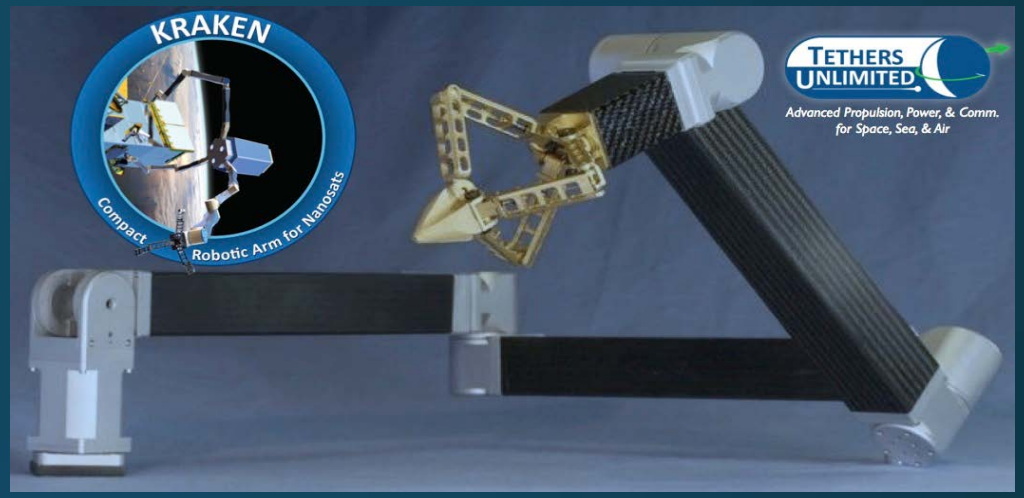


Client
More than 1,000 operational satellites exist in space today. Of these, only the Hubble Space Telescope and the International Space Station were designed to be serviceable – in part because robotic servicing is incredibly challenging.

Restore-L Servicer Spacecraft
Think of it as a robotic tow truck in space: a free-flying spacecraft equipped with life-extension technologies for satellites.



NSS recommendation #1:

The ISS has a large power-generation capacity, is *international*, & is already in LEO.

Orbital debris cleanup technologies could be tested either on the ISS or in conjunction with the ISS.

(See article by Anzaldua, Dunlop, Barnhard, & Phipps titled, "A path to a commercial orbital debris cleanup…using technology development missions at the ISS.")

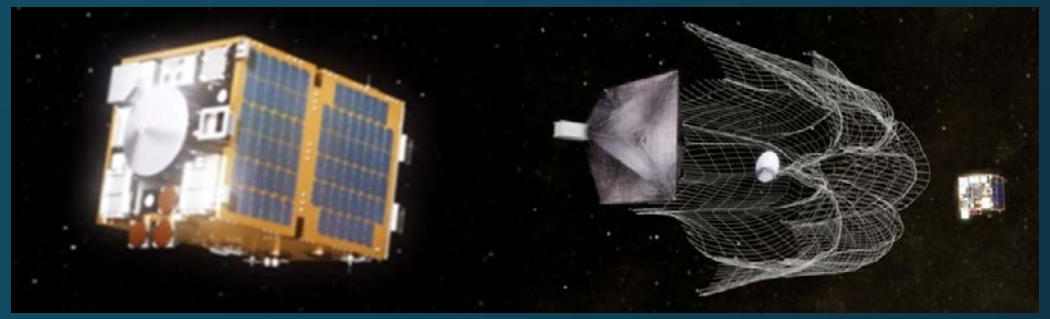
Examples of emerging OD tracking &/or cleanup technologies that could be tested on/off ISS:

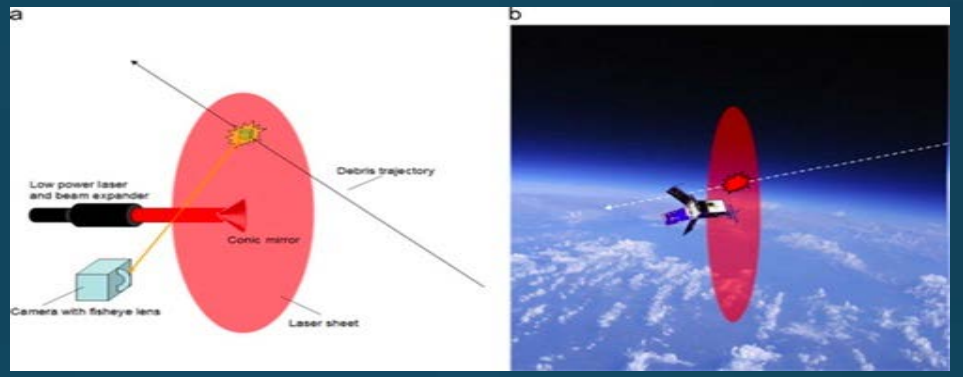
1) The Surrey Space Centre EU consortium's RemoveDEBRIS satellite to test net, harpoon, rendezvous navigation, and dragsail technologies. (Launched in collaboration with SpaceX and NanoRacks on 2 April 2018.)

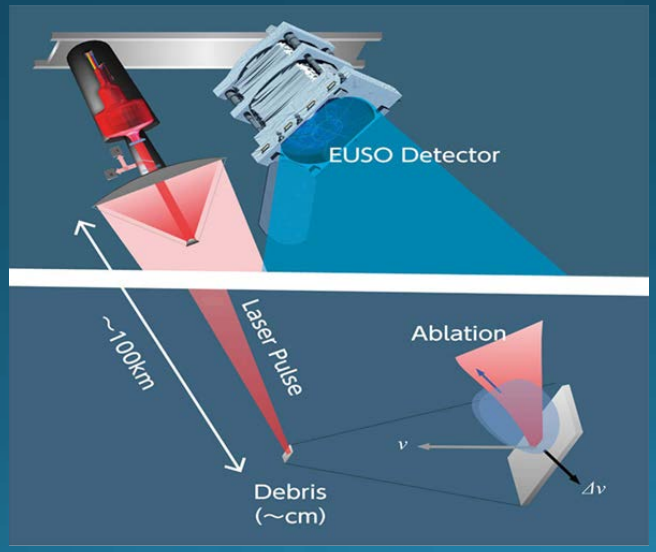
2) U.S. Naval Research Lab's Optical Orbital Debris Spotter (OODS)

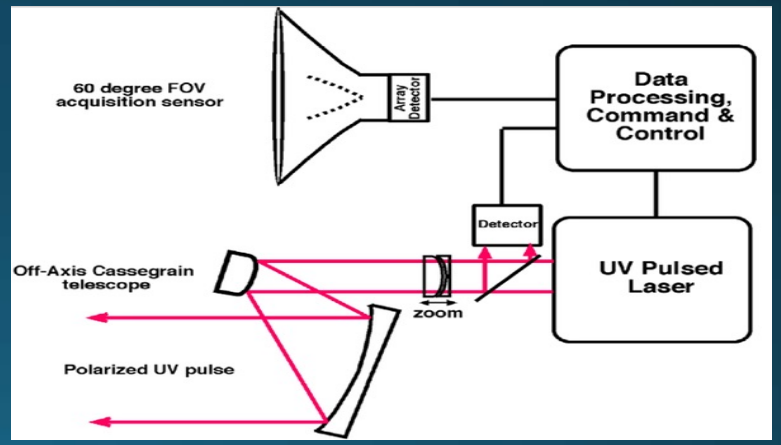
3) Laser Ablative Debris Removal by Orbital Impulse Transfer (L'ADROIT) System of Claude Phipps.

4) JEM-Extreme Universe Space Observatory (EUSO) Cosmic Ray, Neutrino, & *Orbital Debris Detector*, scheduled for after 2020.









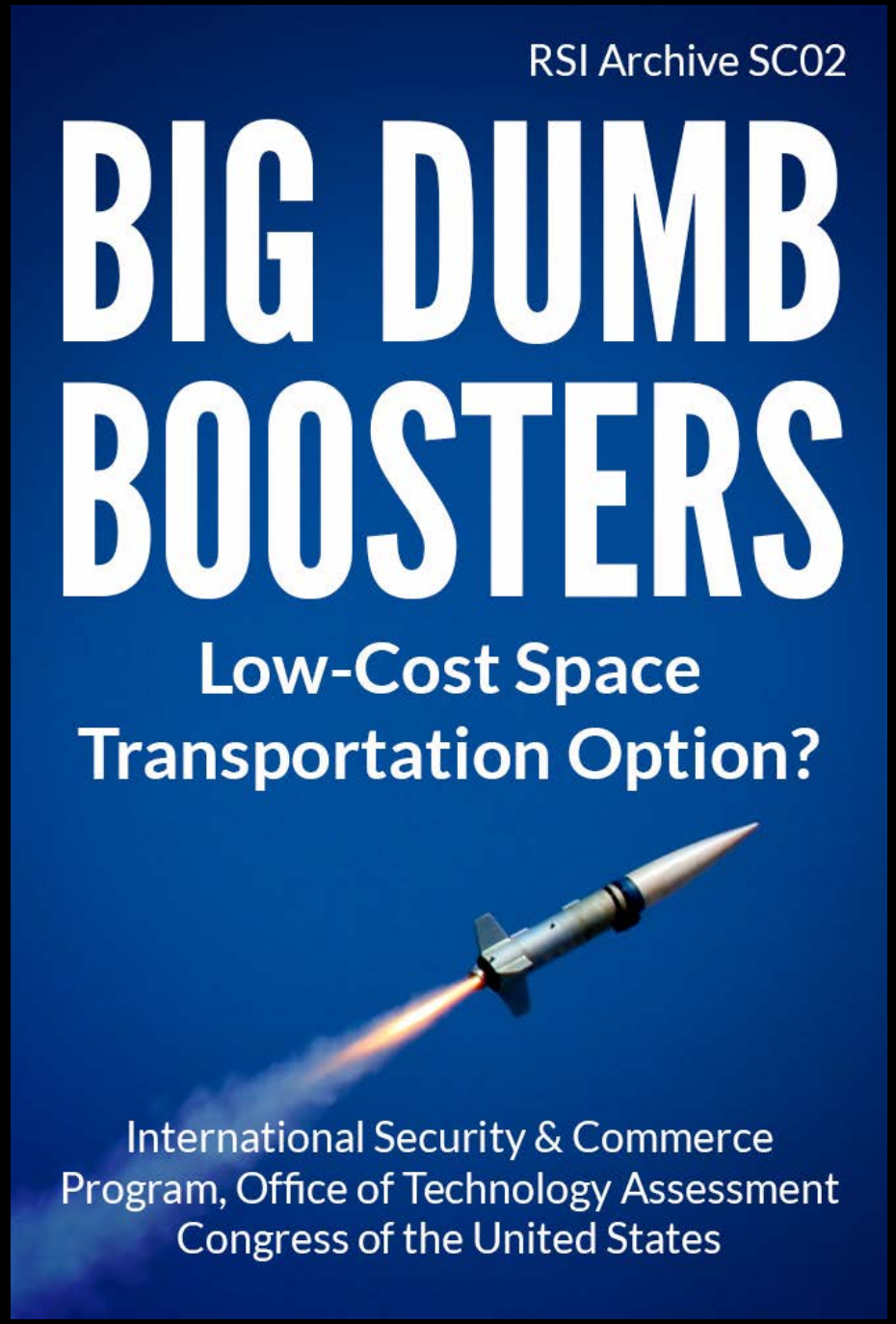
Recommendation #2:

Establish “Customary International Law” by a *series* of bilateral/multilateral actions, such as by…

Step A of sample scenario:

States Parties designate just one defunct big dumb booster* for de-orbiting or moving to a safe salvage orbit.

* Join the NSS “just one tank” movement.



STEP B (sample scenario)

*State X launched the target booster from its territory & nationally registered it.**

Launching States X, Y, & Z, agree to license commercial "salvor" (procured by Z) as their "agent" to deorbit (or move to a salvage orbit) State X's defunct booster.

State Y launches the salvor (procured by Z) from its territory & nationally registers the launch .*

The salvor is acting as agent of States X, Y, & Z.

*& therefore "owns" the spacecraft & retains "jurisdiction and control" per OST Art. VIII

THE LIABILITY QUAGMIRE*

* For full discussion see article by Anzaldua & Hanlon titled, "Maritime Tradition Can Inform Policy and Law for Commercial Active Debris Removal."

Per OST Art. VIII, the *nationally* registering State Party/launching state retains "jurisdiction & control" (ownership) of the launched spacecraft. = Liability Risk

Per OST Art. VI, all launching States involved would bear "international responsibility" for ADR by governmental & *non-governmental* entities (such as commercial salvors) & must carry out "authorization" & "continuing supervision" of their activities. = Liability Risk

OST Art. VII, identifies 4 possible Launching State categories* & declares that each is internationally liable for damage to another State Party.

Liability Convention Art. V para 1 makes clear that when two or more States jointly launch a space object, they remain jointly and severally liable for damage to another State Party.

* 1) State that launches, 2) State that procures the launch, 3) State from which object is launched, 4) State from whose territory object is launched, 4) State from whose facility the object is launched.

Avoiding the liability quagmire.

Example: The 1998 ISS Multilateral Agreement contains a cross-waiver of liability provision, which establishes "Protected Space Operations."

BONUS!

Such bilateral or multilateral Protected Space Operations established by liability-apportionment or waiver agreements among State Parties fulfill the OST Art. IX obligation to conduct space activities "so as to avoid … harmful contamination" or "harmful interference" and to adopt "appropriate measures" or undertake "appropriate international consultations" for these purposes.

Step C: Launching States pay the commercial salvor, *only if it safely de-orbits the debris object or moves debris to a storage orbit* (no cure – no pay per maritime tradition). *NO COST-PLUS CONTRACTS.*
Removal or salvage costs and eventual salvage profits are shared per agreement among launching States.

But how to pay for ADR*?

* as well as other elements of STM, such as enhanced SSA

Keep in mind: Pay something now, or pay more later!

Four ways to pay for an international, comprehensive Space Traffic Management Mechanism*:

1) With *internationally* coordinated national taxes.

2) With *internationally* coordinated national launch fees.

3) With *internationally* coordinated orbital "parking" fees, either throughout mission or post mission only.

4) With an *internationally* coordinated satellite-service end-user fee of 1 cent per USD, which would already generate over a $ 1 billion annually – *even before the 20,000 new commercial satellites are launched!* **

* including enhanced SSA & ADR
** International mechanism would have to be established to collect fees & pay commercial salvors.

Remember: Pay now, or pay more later!

Meanwhile, bilateral & multilateral orbital debris cleanup efforts could evolve into "Customary International Law."

And eventually (way down the road) --

Convene an International Space Anti-Dumping and Salvage Convention, *informed by customary international space law & maritime tradition & law* to codify & refine what has evolved from actual orbital debris cleanup practices over the years*.

* See handout "Maritime Tradition Can Inform Policy and Law for Commercial Active Debris Removal" by Anzaldua & Hanlon for an example of how the maritime tradition of salvaging was eventually codified by the 1989 International Convention on Salvage.

Potential Great Spoiler & Golden (Salvage) Opportunity.
Let's get started!!

EXTRA SLIDES

Instructive elements of maritime custom & law include:

1) "No cure no pay" (re compensation for property or *liability* salvage*)

2) Standardized salvage contracts & procedures per Lloyds Open Form 2011 (LOF 2011)

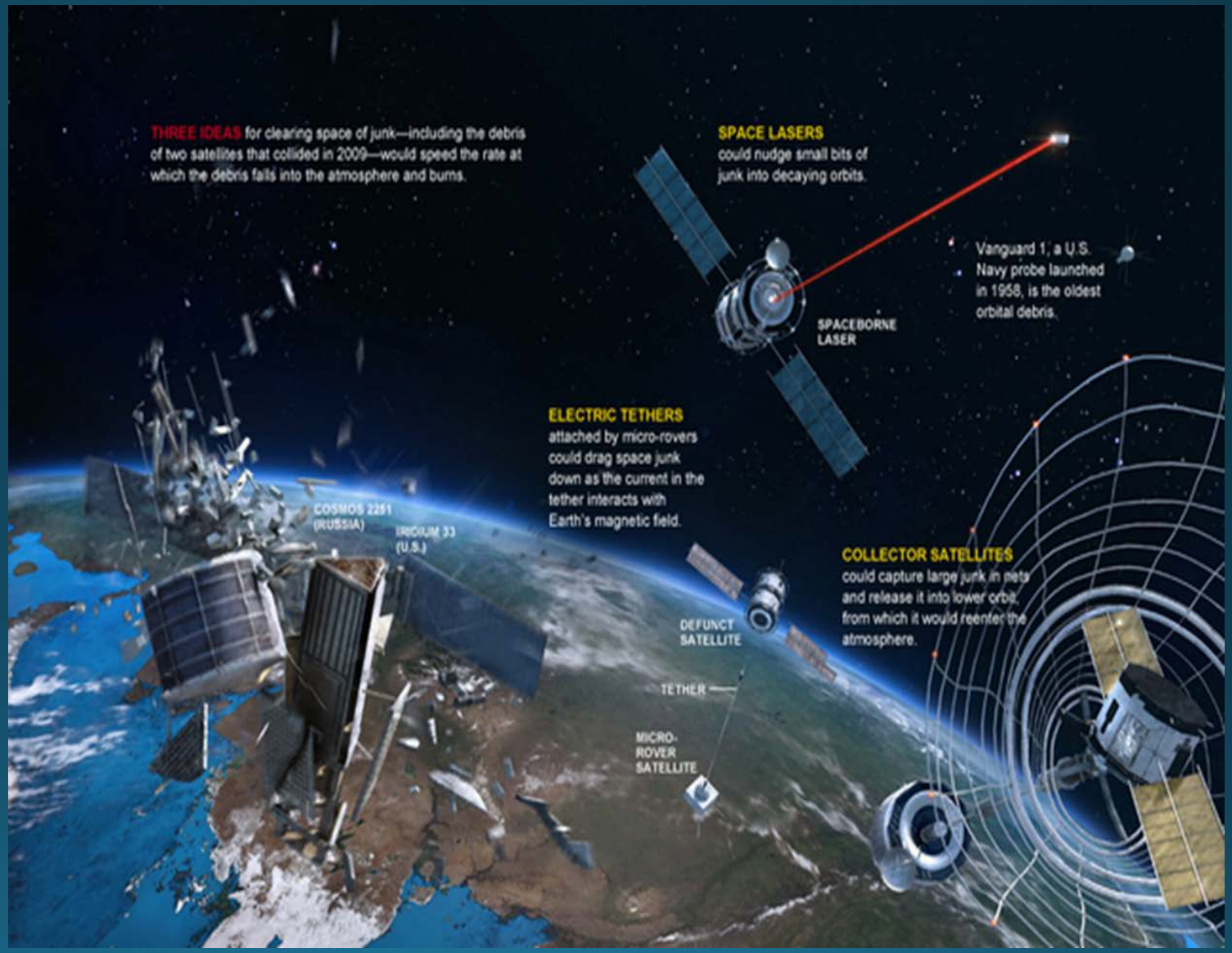
3) Ready arbitration body & court to resolve disputes.

4) Long-established maritime insurance industry.

5) International maritime customs, which have hardened into "International Customary Law."

* Special compensation ("liability salvage") to prevent contamination of the environment, holds per Art. 14 of 1989 Salvage Convention & optional Special Compensation P&I Clause (SCOPIC).

Here are just 3 ideas about how to realize ADR of orbital debris.



The orbital debris DANGER has seemed so

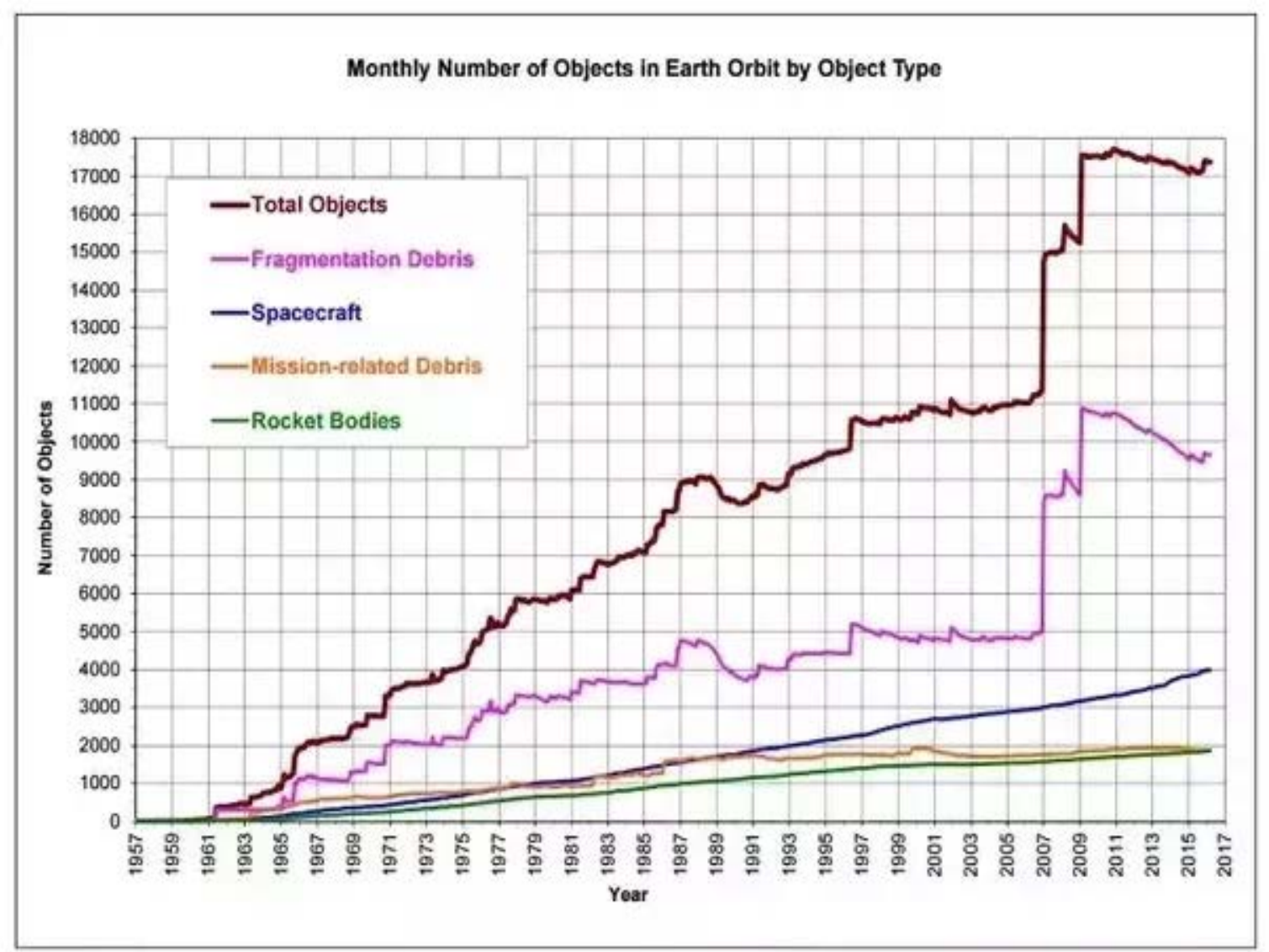
small ---

& so far away .....

Like with Near Earth Objects….

But is the THREAT – *really* so far away?

These mega-constellations of satellites will soon number >10 times the number of operating satellites in *all* Earth orbits!
(c.1740 sats overall.)



Monthly Number of Cataloged Objects in Earth Orbit by Object Type: This chart displays a summary of all objects in Earth orbit officially cataloged by the U.S. Space Surveillance Network. "Fragmentation debris" includes satellite breakup debris and anomalous event debris, while "mission-related debris" includes all objects dispensed, separated, or released as part of the planned mission.