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An Update on EDDE

the ElectroDynamic Debris Eliminator

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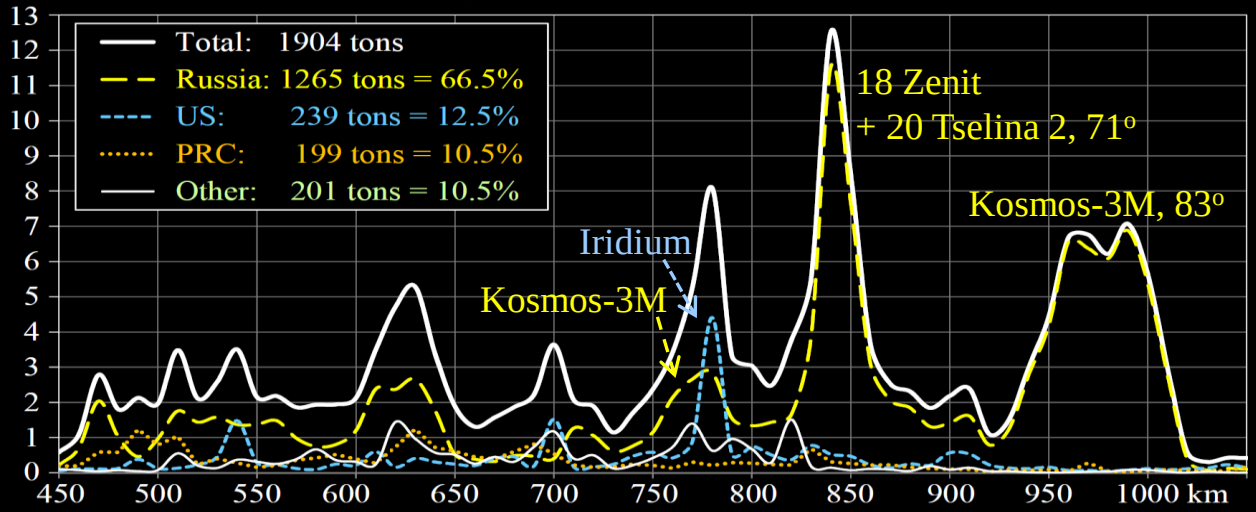
Why Does Orbital Debris Really Matter?

We worry about an eventual chain-reaction of ~kg-class "hubcaps" shredding ton-class intact but dead "cars" & making more hubcaps.

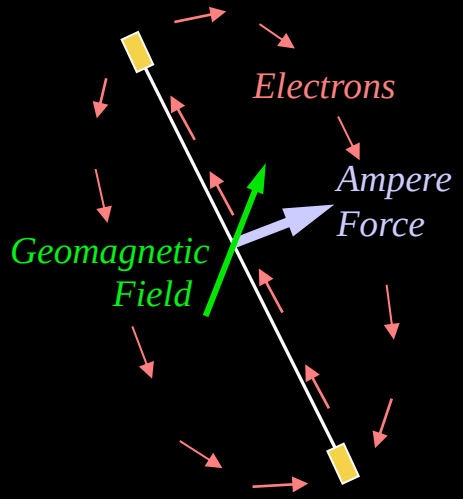
But before that happens, ~100X more gram-class lethal shrapnel will disable more and more satellites, allowing far more car/car collisions!



To paraphrase Winston Churchhill:

Orbital debris is a technical riddle, wrapped in an economic mystery, inside a diplomatic enigma.

EDDE Concept and Design



Electrodynamic Propulsion

External return allows a net force on EDDE:

- Current flows in tape, and returns in ionosphere.
- "One-way" tape current in mag. field allows net force.
- Current loop closure in plasma causes opposite force.

Key EDDE design features:

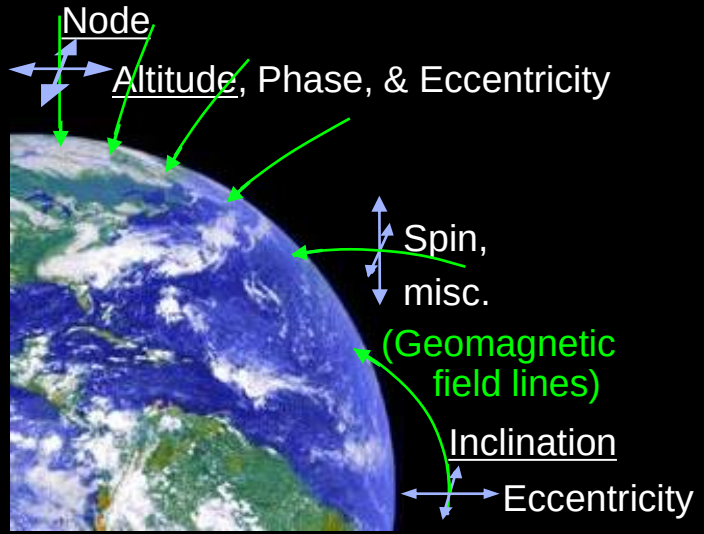
1. EDDE rotates end-over-end to improve agility & stability.
2. Solar arrays are along length, to reduce peak voltages.
3. Unsteered paired bifacial solar arrays raise power/mass.

EDDE Vehicle Layout

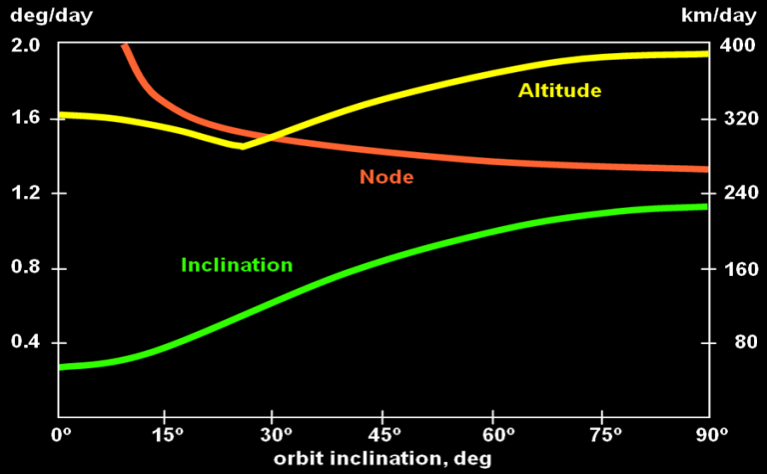
EDDE Maneuver Capability

- 100's of km/day climb at ~400-1000 km; descent even faster
- ~1º/day orbital plane change (inclination & node) near 500 km

Orbit elements changed by EDDE :



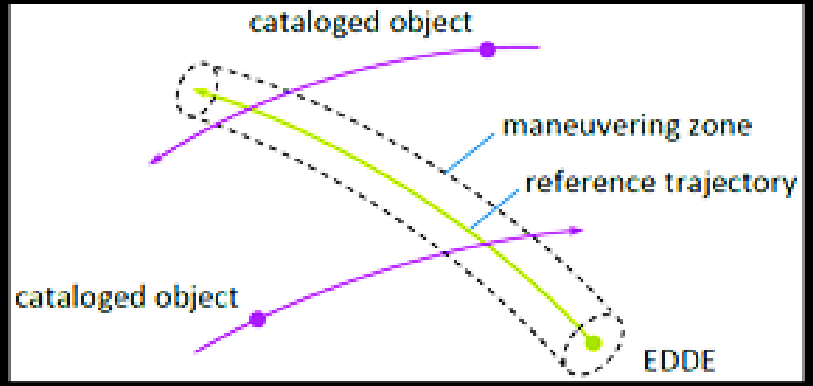
Element changes vs. latitude



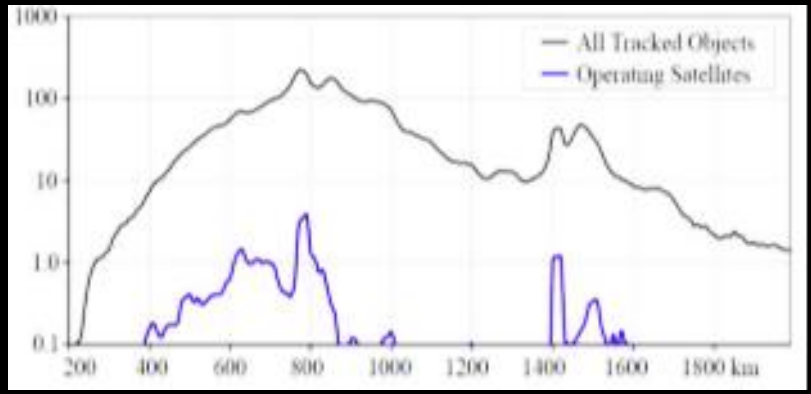
EDDE orbit change rates per amp of orbit-average current

(scale by M_{EDDE}/M_{total})

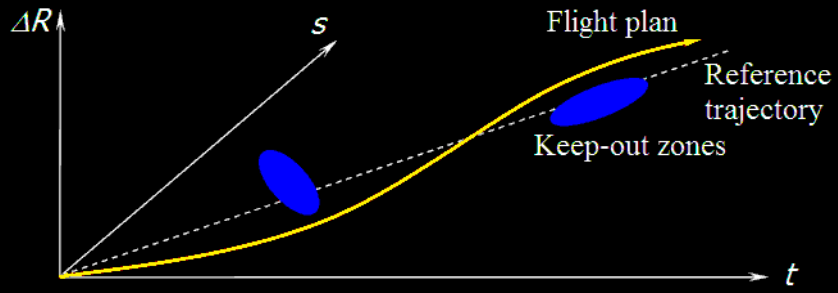
Active Collision Avoidance by EDDE



EDDE will do active avoidance, while staying in a published moving tube.



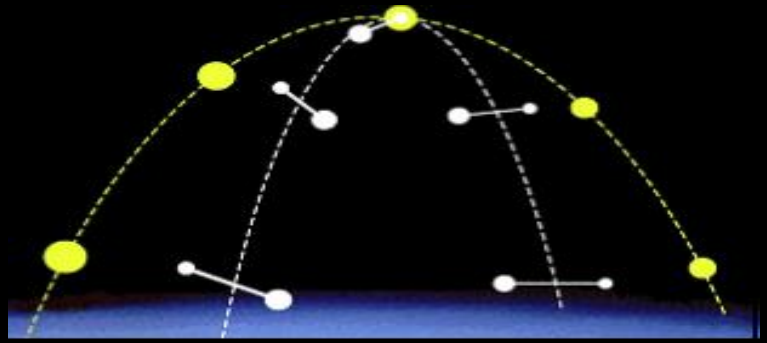
Crossings/day of 30x200 km tube, by operating sats & all tracked objects



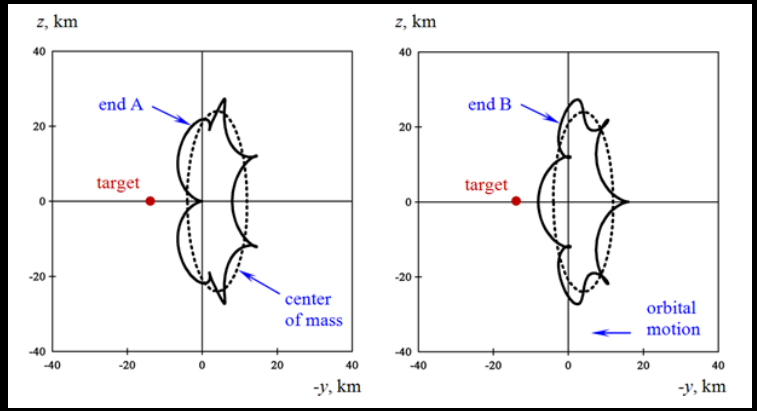
EDDE maneuvers in phase space

Repeating Cusp Approaches

- EDDE does repeated close passes from a “nearly matching” orbit
- Imaging target against starfield at each end allows good ranging



Free-Return Out-of-Plane
Cusp Rendezvous



Free return Approach Trajectories

Quadratic ranging uncertainty

Debris Capture by EDDE Nets

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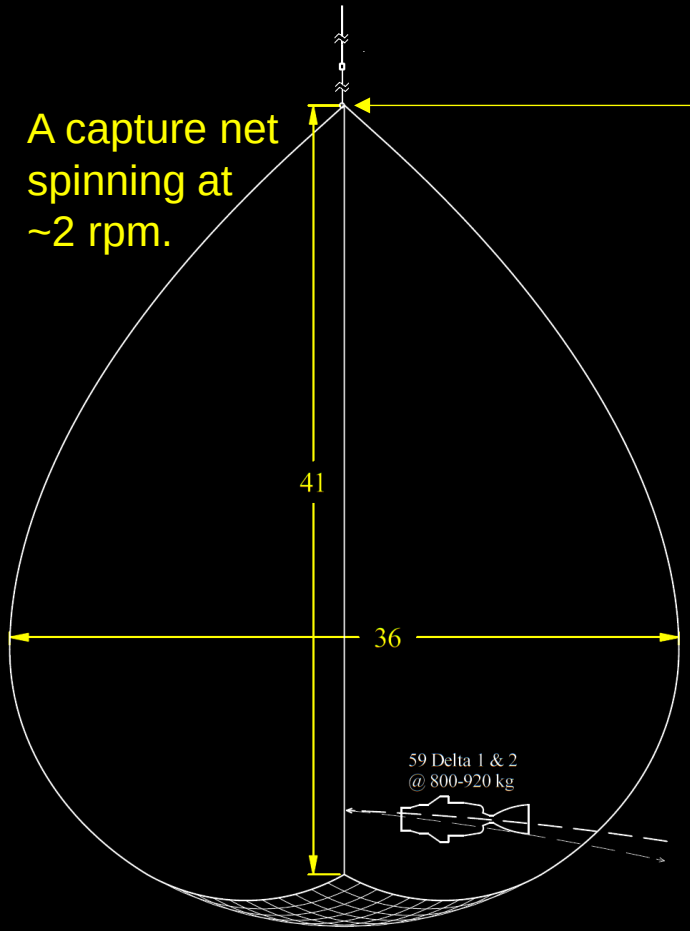
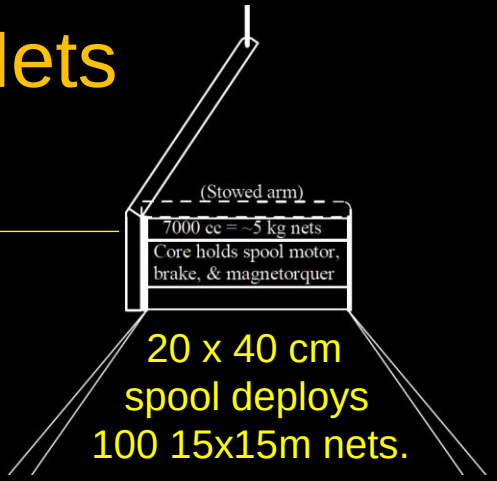
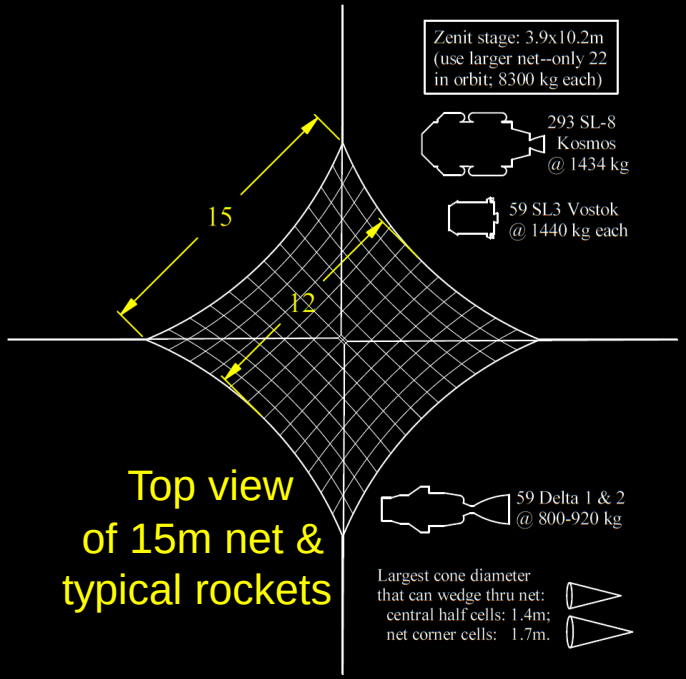
A capture net spinning at ~2 rpm.





20 x 40 cm spool deploys 100 15x15m nets.



Top view of 15m net & typical rockets

2002 spin-up test of bead-chain net

TEPCE, NRL's EDDE Precursor Test

TEPCE = Tethered Electrodynamic Propulsion Cubesat Experiment

- 1 km conductive tether & stacer spring stow between ends (TAI concept).
- Collects electrons on ~25mm wide metal "measuring tapes," **like EDDE.**
- Uses enhanced thoriated thermionic electron emitting wires, **like EDDE.**
- Will test libration, maneuvers, and active collision avoidance, **like EDDE.**
- TEPCE is now in orbit and being checked out. May deploy this month,,,

3U 4kg cubesat

1km 0.4 kg conductive Kevlar braid (stacer spring stows in core)

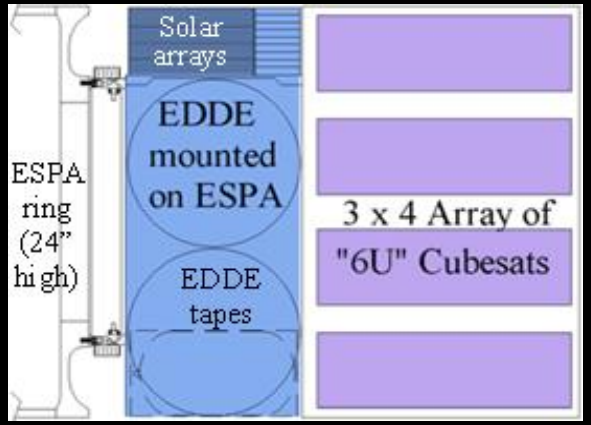
EDDE Sizing and Packaging

An 80 kg EDDE can fit in the inner 1/3 of an ESPA envelope

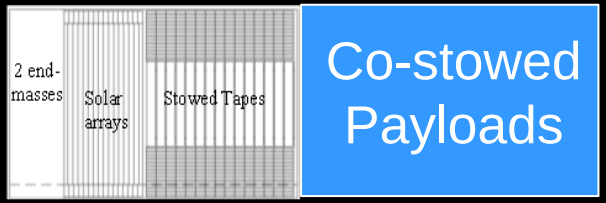
- That leaves another 100 kg for payloads EDDE can carry & distribute.
- This lets EDDE offer “custom LEO orbits *without a custom launch*.”

The smallest operationally useful EDDE is about 30 kg & 12U:

- It’s hard to both collect enough current and also conduct it far enough!



EDDE+CubeSats on ESPA



A 2x2x6U carrier can fit a 12U EDDE + 12U of payloads.

After distributing its payloads, this EDDE can do inspections.

Potential EDDE Applications

1. Secondary Payload Delivery *(easy: no rendezvous or capture)*
2. LEO Object Inspections *(requires accurate rendezvous)*
3. Satellite Service Support *(requires cooperative captures)*
4. **Debris Removal or Collection** *(requires capturing debris)*

Each EDDE application above has substantial value on its own, and also allows in-space functional tests for the next (& more valuable!) application.

An 80 kg EDDE can capture 5-25 tons/year of debris mass at 600-1200 km and release it at ~350 km (details in paper!).

Summary and Conclusions

1. EDDE has a natural sequence of 4 LEO applications:

- Each role has more challenges but also has more potential payoff.

2. Debris removal (role #4) is challenging but very valuable:

- Mega-constellations may dispose of fewer satellites than they plan.
- We must remove most dead LEO mass for sustainable use of LEO.
- Each 80 kg EDDE can remove 5-25 tons/year from ~600-1200 km.

3. TEPCE will soon test 3 key EDDE features:

- Electron collection by long ~3cm wide metal tape
- Electron emission by enhanced thoriated tungsten
- Controlled thrust, torque, and active avoidance