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EDDE

ElectroDynamic Debris Eliminator For Active Debris Removal

NASA-DARPA International Conference
on Orbital Debris Removal
8-10 December 2009

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Low Earth Orbit Cleanup

- ***Remove all*** 2465 objects over 2 kg from LEO
  - Reduces future collision-generated LEO debris by 99%
  - Prevents “debris runaway” from future debris collisions
- Controlled de-boost
  - Actively avoid all tracked satellites and debris
  - Allow for targeted re-entry if needed
- EDDE vehicles can eliminate almost all future collision-generated debris from LEO ***in 7 years***

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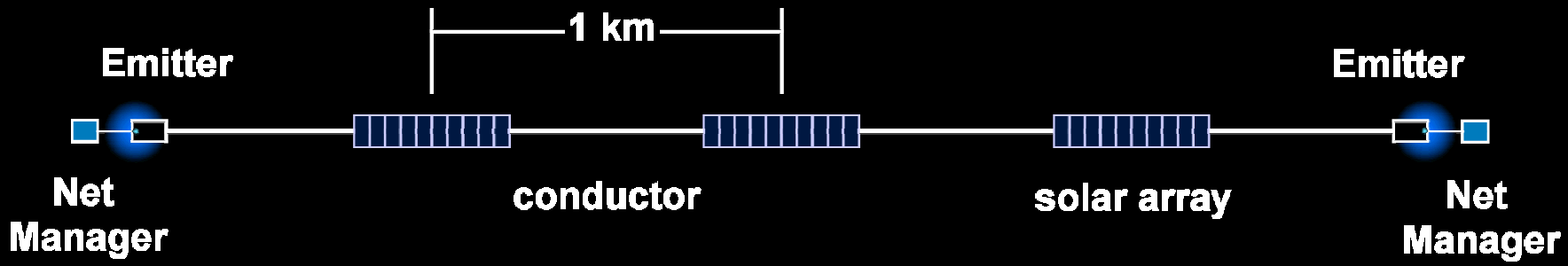
The EDDE Vehicle



- Each vehicle is only 100 kg, and packs into 24”x24”x12”
- Each ESPA secondary payload slot can carry 2 EDDEs

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EDDE Enabling Concepts

- Orbit transfers use solar power & electrodynamic thrust
- Rotation gives stability and high maneuverability
  - 3 patents awarded for vehicle methods and apparatus
- Tape conductor for greatest survivability
- Debris is captured in large lightweight nets
- Supported by data from previous space tether flights
  - SEDS-1, PMG, SEDS-2, and TiPS
  - All tethers and deployers by J. Carroll of TAI

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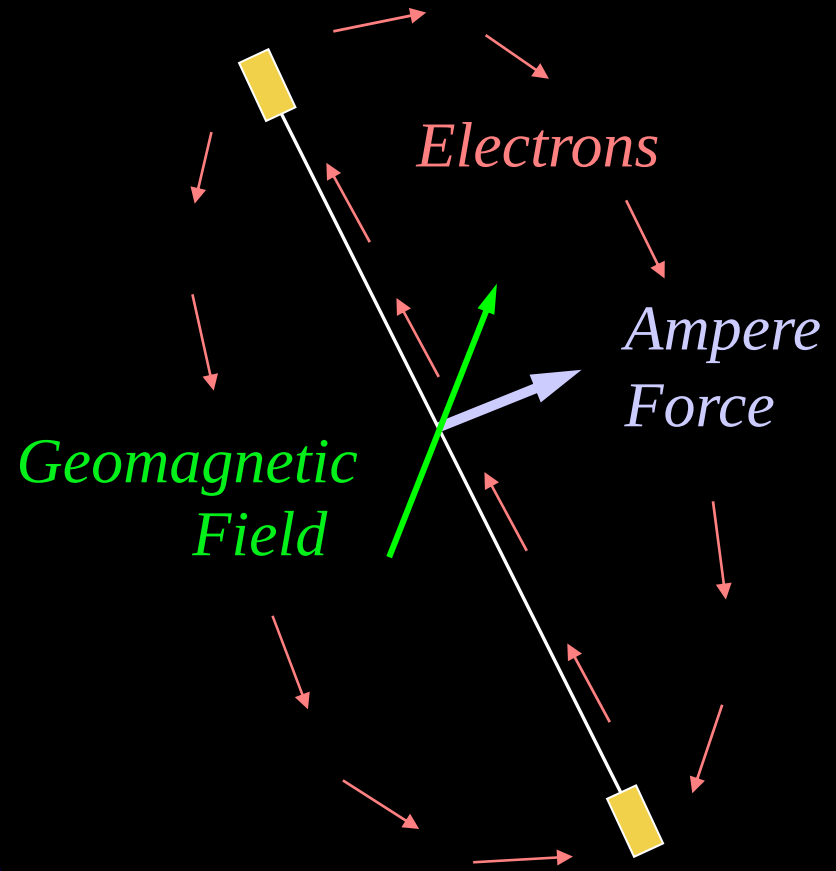
Propellantless Propulsion

- Demonstrated in orbit by NASA/JSC on their Plasma Motor Generator (PMG) flight



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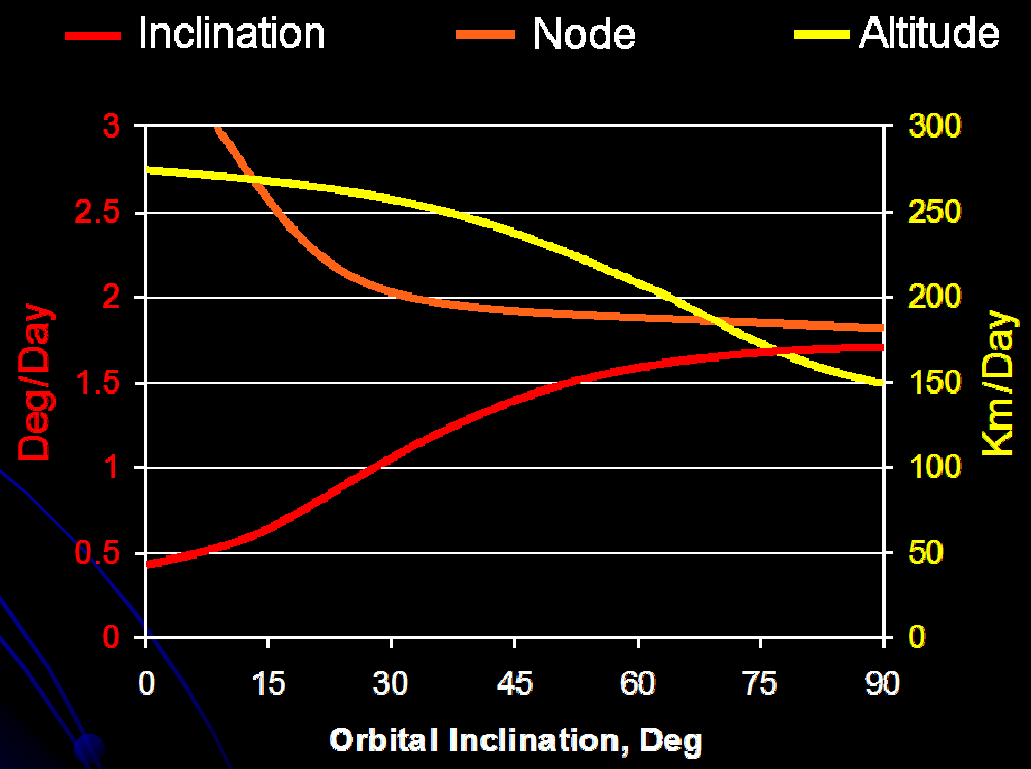
EDDE Performance

- 100's of km per day altitude changes
- Over 1 deg per day orbital plane changes



Capture in Lightweight Nets

- Each Net Manager holds 100 expendable mesh nets, 50 grams each
- EDDE end passes target at 2-3 m/s, captures object in net, and damps out capture dynamics
- Centrifugal force from EDDE's spin keeps debris in the net even if it was tumbling before capture

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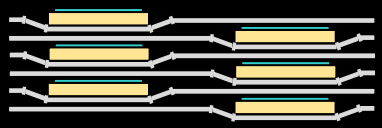
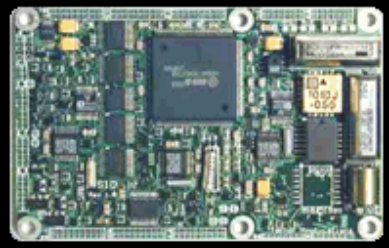
EDDE System Design

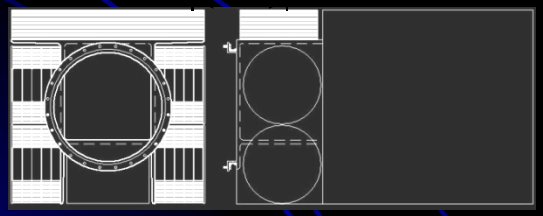
- Conductor/collector
  - Reinforced Al tape,
  - 30 mm x 38 μm
  - Winding:
  - Stack:



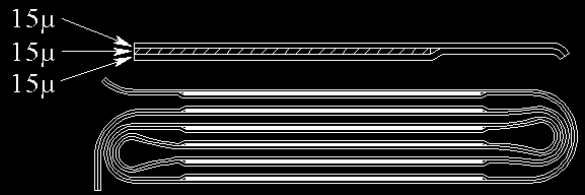
- Dynamics/control
  - Orbit transfers optimized
  - Computer controls current

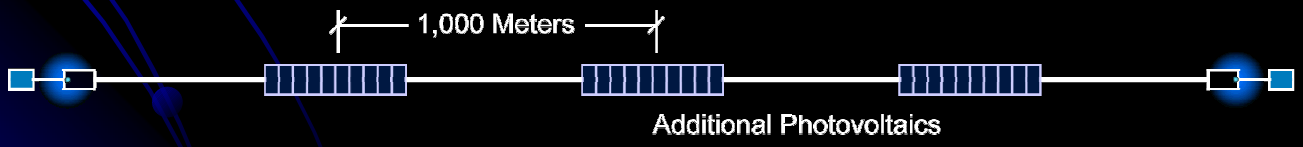


- Packaging
  - 24”x24”x12”, 2 fit in 1 ESPA slot



- Electronics
  - Emitters, folding solar arrays





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Concept of Operations

- EDDE is piggyback launched to LEO and deploys
- Transfers orbit for precise rendezvous with target
- Approaches target from sunlit side using binocular vision and positive control of EDDE position/attitude
- Captures debris with lightweight net, using real-time video under ground control
- Drags object below ISS for quick re-entry, actively avoids other objects, and re-boosts to next target

Typical Removal Operations

- Drag each object below ISS to ~330 km altitude, reducing its orbit life to a few months

Operation	Days	Average Parameters
Phase to next target	0.4	>400 km ΔAltitude, ½ orbit average
Climb and tune orbit	2.9	200 km/day, + 20% for plane change
Approach and capture	0.5	6-8 orbits at 808 km average altitude
Deboost and release	5.7	100 km/day,+20% margin
Total per target	**9.5**	**1087 kg, 808 km to 330 km altitude**

- Each EDDE vehicle can remove 40 tons per year (400 times its own mass per year)

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EDDE Advantage

- The job: ***remove all*** 2465 objects over 2 kg from LEO (2166 metric tons total)

Propulsion System	Isp, sec	Typical Number of Vehicles	Estimated Total Mass in Orbit
Bipropellant	300	900	800 tons
NH_3 Arcjet	800	300	250 tons
Ion Thruster	3000	120	65 tons
VASIMR	10000	30	25 tons
EDDE	**---**	**12**	**1 ton**

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EDDE Demonstration

- Fly piggyback on any flight with payload margin
- Demonstrate orbit transfer and rendezvous
- Capture and drag down an inactive US object

Example: Pegasus Upper Stage
581x 599 km, 97.8°, 176 kg, 1x1.3 m

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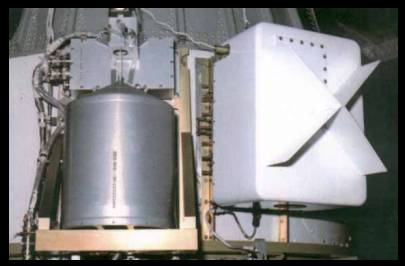
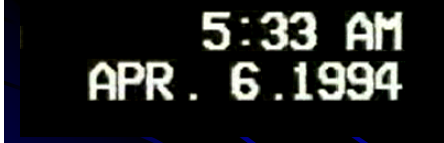
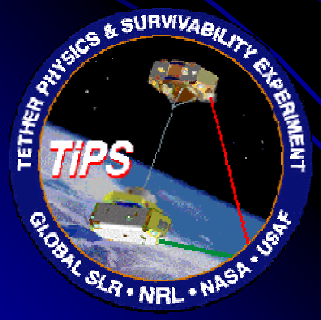
4-for-4 Flight Record







SEDS-1, NASA Marshall

- Deployed 20 km braided Spectra tether; sent 26 kg end-mass into controlled reentry

PMG (Plasma Motor Generator), NASA JSC

- Demonstrated motor/generator operation; enables EDDE vehicle

SEDS-2, NASA Marshall

- Deployed 20 km braided Spectra tether; demonstrated stable vertical position

TiPS, Naval Research Laboratory

- Libration damped in months; demonstrated 10-year lifetime for 2 mm x 4 km tether

All tethers and deployers by J. Carroll, TAI

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EDDE: The LEO Solution

- Compact, low-cost; piggyback launch to any LEO
- Maneuverable over all LEO, to any inclination
- Propellantless, for virtually unlimited orbit maneuvers
- Reusable, each capable of removing many targets
- Simple debris capture with lightweight nets
- 1 EDDE removes 136 US sun-synch objects in 3 years
- 12 EDDEs ***remove all*** 2465 LEO debris >2 kg ***in 7 years***