

# EDDE

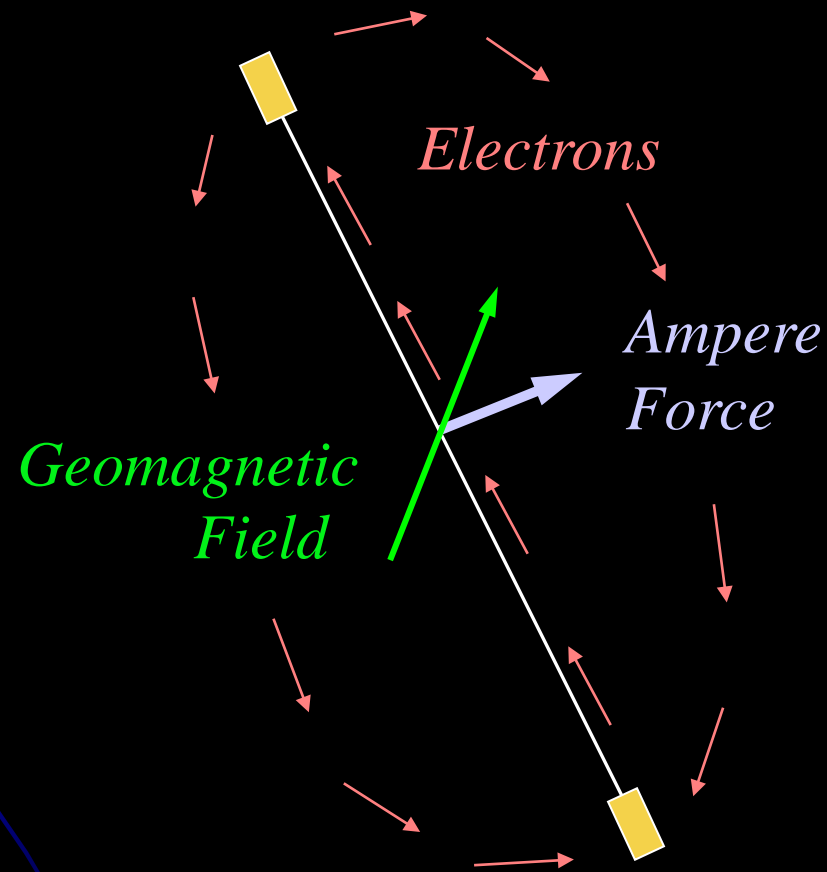
ElectroDynamic: Delivery Express  
and Debris Eliminator

Cal Poly Spring Cubesat Workshop  
April 18-20, 2012

Joseph Carroll, Tether Applications, Inc.,  
Jerome Pearson, Eugene Levin, & John Oldson  
Star Technology and Research, Inc.

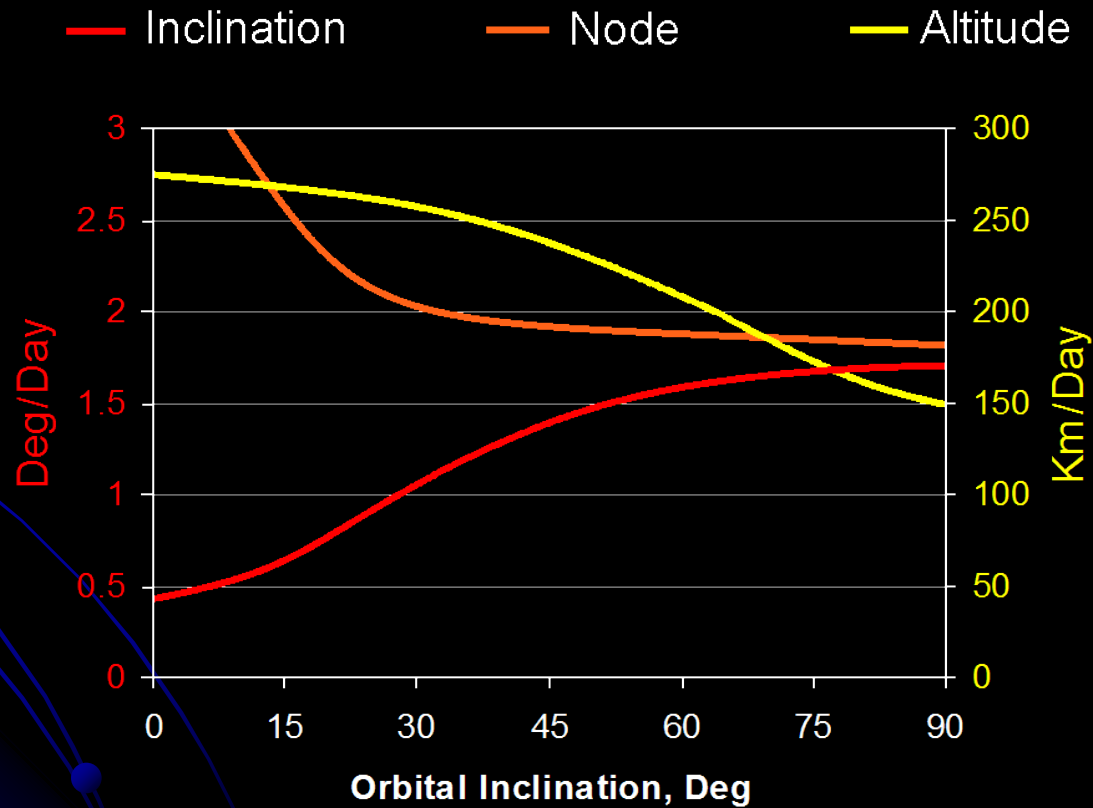
# Propellantless Propulsion

- Demonstrated by PMG (Plasma Motor Generator)

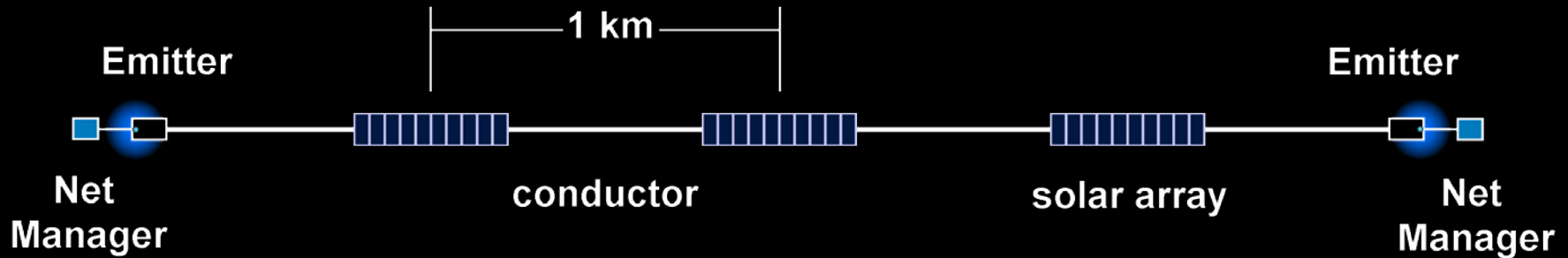


# EDDE Performance

- 100's of km/day altitude change at ~400-1000 km
- $>1^\circ$ /day orbital plane change (inclination & node)



# The EDDE Vehicle



- Each vehicle is <100 kg, and packs into 28"x24"x12"
- Each ESPA secondary payload slot can carry 2 EDDEs
- EDDE can distribute payloads, then collect orbital debris

# Key EDDE Components

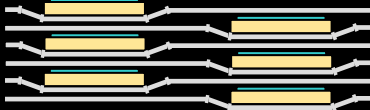
- **Conductor/collector**

Reinforced Al tape,  
30 mm x 38  $\mu$ m

Winding:



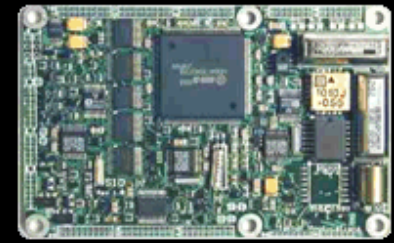
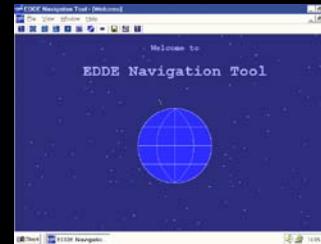
Stack:



- **Dynamics/control**

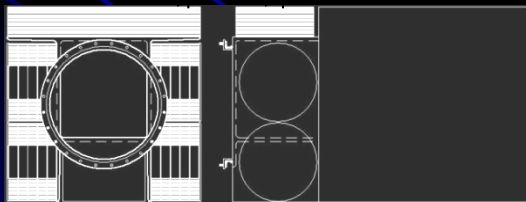
Orbit transfers optimized

Computer controls current



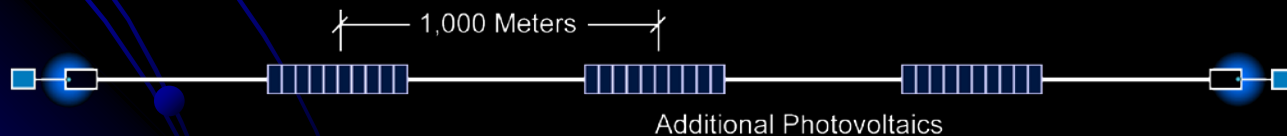
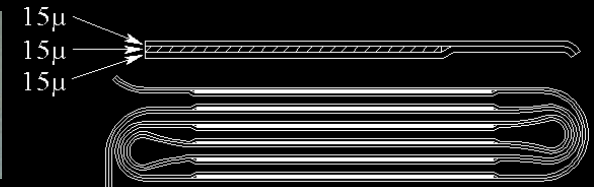
- **Packaging**

28"x24"x12", 2 fit in 1 ESPA slot



- **Electronics**

Emitters, folding solar arrays



# Secondary Payload Launch





# Small Payload Ride Options

1. Conventional secondary payload accommodations
2. Conventional + on-board propulsion
3. Conventional + upper stage with payload carrier
4. Dedicated nanosat launch, whenever you're ready

Each step down provides a better service, but raises costs and/or constraints, and (at least now) decreases credibility.

What is the potential market size for each of these options?

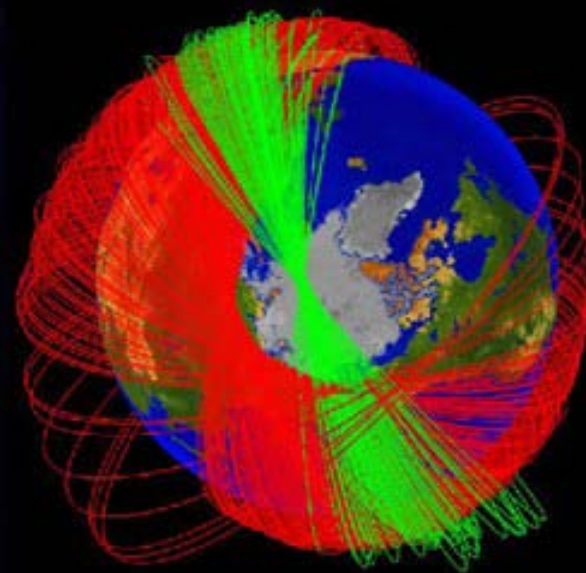
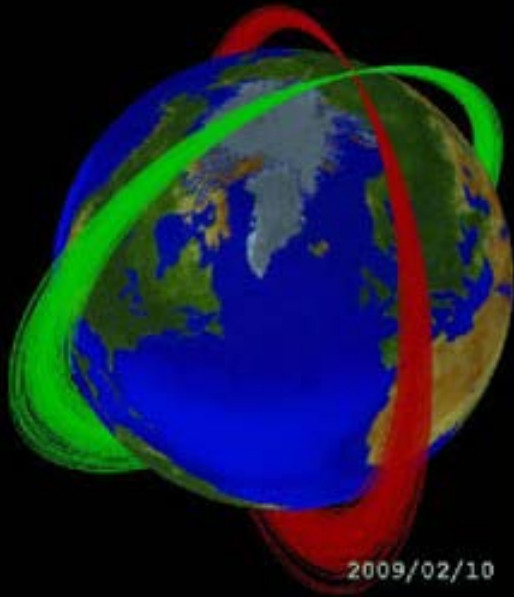


# “EDDE, Inc.” Business Vision

- Deliver small payloads to custom LEO orbits, at costs closer to secondary than dedicated launch.
- After distributing payloads, EDDE can go on to capture and relocate large debris in LEO
- Key questions:
  - How much extra will secondary payloads be willing to pay for custom orbits?
  - Who will pay to clean up LEO—and how much?



# When Satellites Collide



- Cosmos-Iridium collision of February 2009
- After collision, debris clouds from each object are clearly distinct
- Each object contributes its own mass in debris fragments
- With time, the clouds spread, polluting their altitude ranges

# Lethal Impactors in LEO

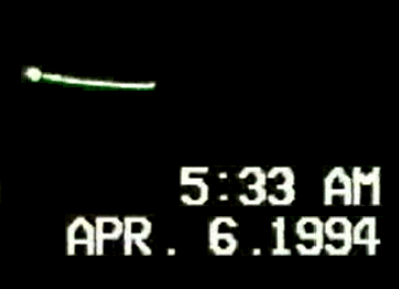
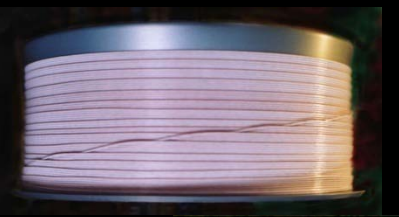
Type	Characteristics	Hazard
<b>“Cars”</b>	Tracked, >2 kg, ~1% of all lethal objects	Primary source of new shrapnel; ~99% of collision area and mass
<b>“Hubcaps”</b>	Tracked, >10 cm, <2 kg, ~4% of all lethal objects	Cause most known conjunctions and drive avoidance maneuvers
<b>“Shrapnel”</b>	Untracked, 1-2 to ~10 cm, ~95% of all lethal objects	Primary direct threat to satellites: too small to track and dodge, but too massive to shield against

- Most new shrapnel comes from “car/car” collisions
- Must remove cars to prevent LEO pollution by shrapnel

# Current EDDE Status

- Now 2 months into a 2 year NASA OCT contract
- We are maturing key components, stowage and deployment concepts, solar array steering, active collision avoidance, and failure-tolerant controls.
- Contract goal is a successful PDR for a subscale Mini-EDDE flight test using full-scale components
- We are looking for good nanosat-class sensors & actuators relevant to multi-year LEO missions
- NRL's TEPCE will test parts of EDDE next year

# 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, hollow cathode as part of large current loop

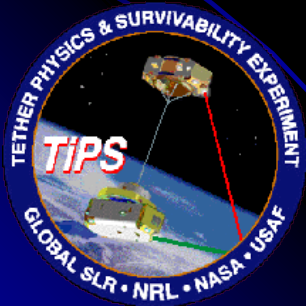
## SEDS-2, NASA Marshall

- Stabilized 20 km Spectra tether near vertical; cut after 4 days, but 7 km lasted till reentry

## TiPS, Naval Research Laboratory

- Libration damped out over several months, 2 mm x 4 km tether survived >10 yrs

• All tethers & deployers by Tether Applications



# If you're interested in:

- EDDE for payload delivery/distribution in LEO
- Or an agile sensing platform (anywhere in LEO)
- Or wholesale LEO debris capture and relocation
- Or providing or collaborating on nanosat-class sensors & actuators for multi-year LEO missions

Then please contact me at 619-980-1248 (cell)  
or [tether@cox.net](mailto:tether@cox.net)



# LEO Congestion & Cleanup