

Large GEO Debris



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- This presentation solely represents the opinions of the author and should not be construed as being endorsed or validated by the US Government.
 - This information reflects efforts that have been conducted and does not address planned future US investments.

BACKGROUND

 USG National Space Policy (June 2010) called for NASA and DoD to pursue R&D on ADR, reducing hazards, and increasing understanding of debris environment.

NASA

- Centralized funding and policy implementation through NASA/HQ.
- Johnson Space Center is center of excellence for orbital debris mitigation.
 - Several other centers and Office of Chief Technologist have unique contributions.
- Space Technology Program applying resources for concept exploration
 and technology development.

• DoD

- ADR activities performed largely in labs (NRL, APL, AFRL, etc.) and the Defense Advanced Research Programs Agency (DARPA).
- Regular (at least annual) NASA/DoD OD Working Group meetings cover a full range of OD efforts to include ADR.



US ADR EFFORTS BY LIFE CYCLE

EVALUATION OF POSSIBLE ADR METHODS 2009 CONFERENCE IN US - CATALYST TO DISCUSSIONS

Debris object class	Removal method	Orbit	Feasible physics	Encounter velocity	Anti-collision maneuver?	Units needed	Acceptable	Issues
Large	Propulsive tug	Any	Yes	Near 0	Yes	< 10	Yes	Large amounts of delta-v, object capture, rotating objects
Large	Inflatable drag device	LEO	Yes	NA	No	10s per year	No	Collision with active or other large debris
Large	Solar sail	GEO	Maybe	NA	No	10s per year	No	Low mass object capture mechanism
Large	Electrodynamic tether	LEO	Maybe	TBD	Maybe	< 10	No	Complex control, dynamic stability, debris object capture method
Large	Momentum tether	Any	Maybe	TBD	Maybe	< 10	outdat	control, dynamic stability, object capture method
Large, Medum	Ground based laser	LEO	No	NA	and me	tricse	No	Engagement geometry, laser physics, detection & tracking
Large, Medum	Space based laser	LEO	No	Scores	MA	< 10	No	Engagement geometry, laser physics, detection & tracking
Medium	Passive sweeper	LEO	Yes	Up to 11 km/s	No	45,000	No	Infrequent debris encounters, collision with active or other large debris
Medium	Active sweeper	LEO	Yes	Up to 11 km/s	Yes	100	No	Need large numbers, large delta-v, advanced sensors
Medium	Liquid, Gas, Particulate cloud	LEO	Yes	Up to 11 km/s	No	10,000s	No	Need large numbers, effect on operational spacecraft
Medium	Electromagnetic	Any	Maybe	Up to 11 km/s	Yes	100s to 1,000s	No	Massive device, complex encounter geometry, detection & tracking, object composition

FOUR "MAINSTREAM" AREAS

• 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



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

THREE "NICHE" EFFORTS

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



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

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



ORGANIZING ADR OPTIONS

- Orbital solution creates potential risk to create more orbital debris vice <u>ballistic</u> (i.e. sub-orbital) system
- Options viable for certain orbital regions: LEO, GTO, and/or GEO
- Needing propellant to rendezvous adds cost/weight
- Needing propellant to remove adds cost/weight
- It is important to be able to <u>control deorbiting</u> to minimize risk to people on the ground
- Technology readiness level (<u>TRL</u>) provides measure of programmatic risk and potential investment needed to make operational
- <u>Cost per object removed</u> determines financial efficacy of approach
- <u>Cost per collision prevented</u> is a broader metric that may motivate examination of "other" approaches... such as just-intime collision avoidance (JCA)

ADR-RELATED OBSERVATIONS PERSONAL THOUGHTS

- 1. Need to examine metric for success for ADR for large derelict objects
 - Environmental stability is the common factor discussed but reduction in satellite operational lifetimes from collisions with nontrackable/lethal debris fragments might be more relevant
- 2. Detumbling of derelicts is often overlooked
 - May be significant component of solution
- 3. Include Just-in-Time Collision Avoidance (JCA) with ADR for "derelict collision prevention" mission space

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JCA Operations:

Prevent imminent orbital collision w/o going into orbit





PREVENTING DERELICT COLLISIONS

Active Debris Removal (ADR) -Requires many launches -Requires grapple/detumble -Execute over decades -Manage reentry risk STRATEGIC - Statistical

Removal

Just-In-Time CA (JCA) -Want low false alarms -Need enhanced el set accuracy -Hourly/daily response -No reentry risk TACTICAL - Deterministic

Avoidance





SYSTEM ENGINEERING ANALYSIS OF DERELICT COLLISION PREVENTION OPTIONS, 63rd International Astronautical Congress, Naples, IT; October 2012.

ADR AND JCA BOTH ARE DIFFICULT AND EXPENSIVE

	ADR	JCA
Number of objects moved/removed per collision prevented	~30-50	~5-3,000
Costs per collision prevented	~\$100M's-\$B's	~\$10M's-\$10B's
Game Changer(s) Needed	10s-100s of derelicts removed per launch	Improve el set accuracy by 25x (250m→10m) and ballistic launch less than \$1M

PARTING THOUGHT "PAY ME NOW OR PAY ME MORE LATER"

Timing for ADR...

research and development;
 demonstrations;
 industry scale-up;
 legal/policy evolution and codification;
 operations and maintenance; and
 accrued benefits

are uncertain.

• Tradeoff between acting too soon or acting too late needs to be examined.