Mass Driver Asteroid Deflection with Area-of-Effect Softbots

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Abstract

Many different methods have been proposed for deflecting potentially hazardous objects, however they generally fall into two categories: fast methods (i.e. nuclear or kinetic deflection) or long-lead methods (e.g. ion-beam, gravity tractor, mass drivers). Here, we focus on the concept of mass driver deflection enabled by a new spacecraft concept called Area-of-Effect Softbots (AoES) which have been developed under support from the NASA Innovative Advanced Concepts (NIAC) program.

AoES are soft-robotic spacecraft with large, actuated surface areas as pictured in Fig. 1 which allow for unique mobility and surface anchoring through contact electroadhesive forces. The ability to anchor regardless of the asteroid subsurface structure enables to possibility of gathering and launching material from the surface of a small NEA as pictured. By controlling when we launch the material from the surface, and by repeating this process for a period of time, we can produce measurable changes to an asteroid's orbit, and thus could conceivably be used as an asteroid deflection option given enough warning time.

Acknowledgements

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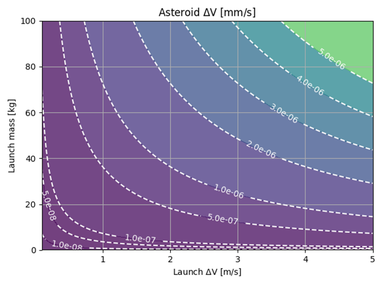
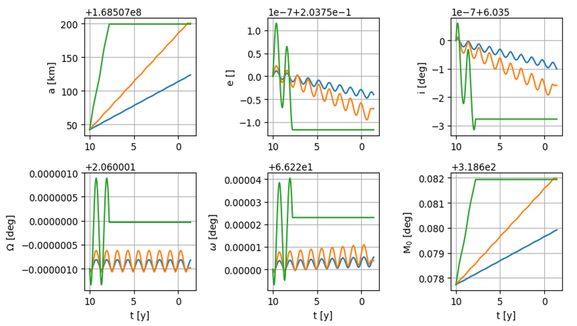
Conclusions

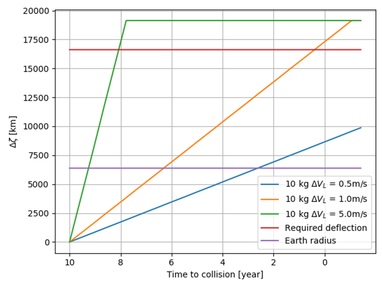
- AoES could be used to gather and launch kg of material
- Mass driver deflection with regular small-scale launches **can deflect NEAs in 1-10 years**
- This study assumes launching 10 kg mass of material with a frequency of 1 launch per hour with a launch velocity between 0.5 – 5.0 m/s
- Could use multiple AoES to achieve mission objectives

Asteroid	Time to MOID [years]	ΔV [m/s]	Time to deflection [years]	Intervals to deflection
Bennu	20	5.0	1.0	9k
	20	1.0	4.8	42k
	20	0.5	9.6	84k
	10	5.0	1.9	16k
	10	1.0	9.6	84k
	5	5.0	4.5	39k
Itokawa	20	5.0	0.4	3.5k
	20	1.0	1.9	16k
	20	0.5	3.7	32k
	10	5.0	0.75	6.5k
	10	1.0	3.8	33k
	10	0.5	7.5	65k
	5	5.0	1.75	15k

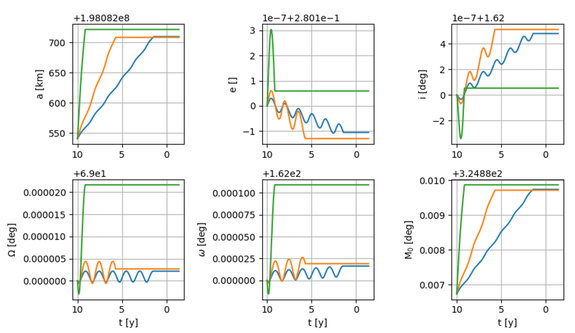
Bennu Deflection

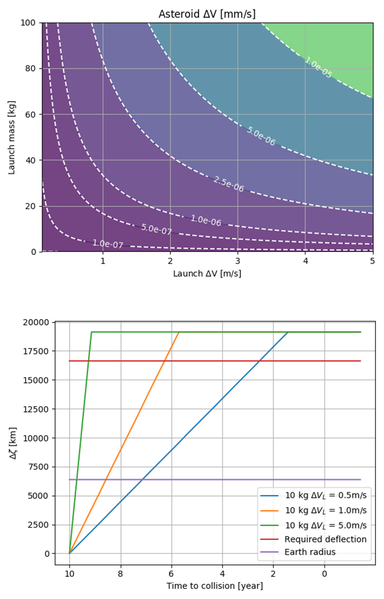






Itokawa Deflection





References

Mass driver deflection theory and modeling discussed in detail in:
Brack, D. N. & McMahon, J. W. "Active Mass Ejection for Asteroid Manipulation and Deflection."
J Spacecraft Rockets 57, 413–433 (2020).
https://doi.org/10.2514/1.A34631

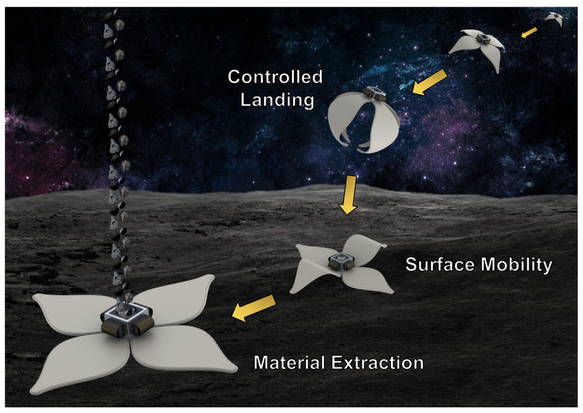
Further details in Daniel Brack's thesis:
Brack, D. N. (2020). "Investigations into the relationship between surface activity and the dynamical
state of asteroids" (Order No. 27669400).
Available from Dissertations & Theses @ University
of Colorado, Boulder. ProQuest Dissertations & Theses A&I. (2407339503).

AoES

Soft robotic spacecraft (AoES) with a large, flexible, actuated surface area uses electroadhesion to anchor to asteroid surfaces

Large surface area also allows for solar sailing orbit control and hopping across the asteroid surface

In the NIAC study, we designed AoES to support an ISRU mission by dismantling rubble pile asteroids by lofting material from the surface to be collected by an orbiting processing vehicle for resource extraction

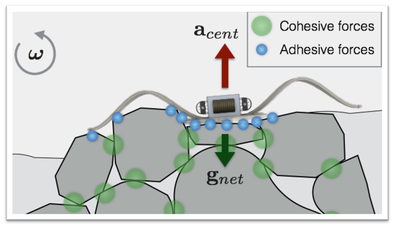


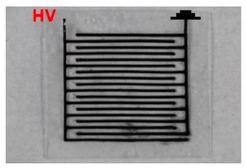
Initial lab testing with a variety of materials validates theory for a variety of materials

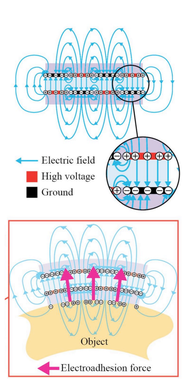
Including UCF asteroid regolith

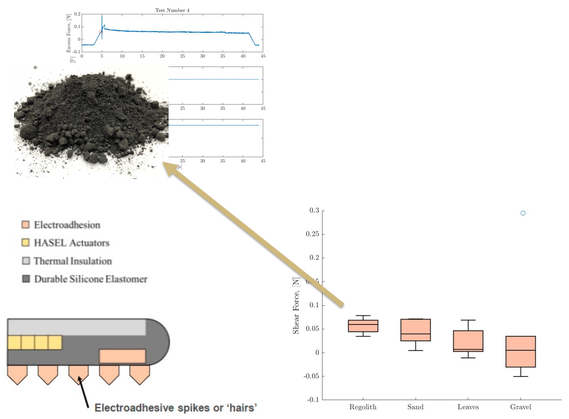
Strength sufficient to provide anchoring in micro-g environment

Testing of prototype Electroadhesive pads shown:









Robots build from actuated, flexible material

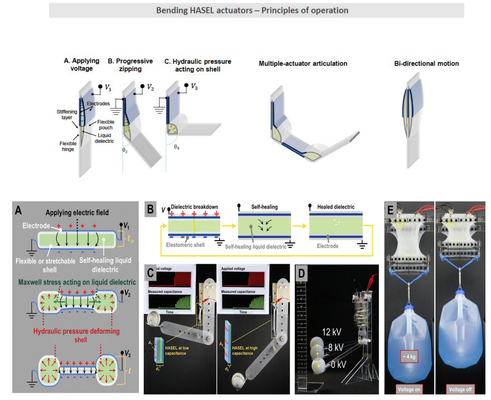
Often take inspiration from biological sources

Use HASEL actuators, developed by Christoph Keplinger* at CU

Extremely high energy efficiency

Wide variety of form-factors can be designed for different motions

*Now a Director at Max Planck Institute for Intelligent Systems



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