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Applying Centrifugal Propulsion to Enable Asteroid Deflection

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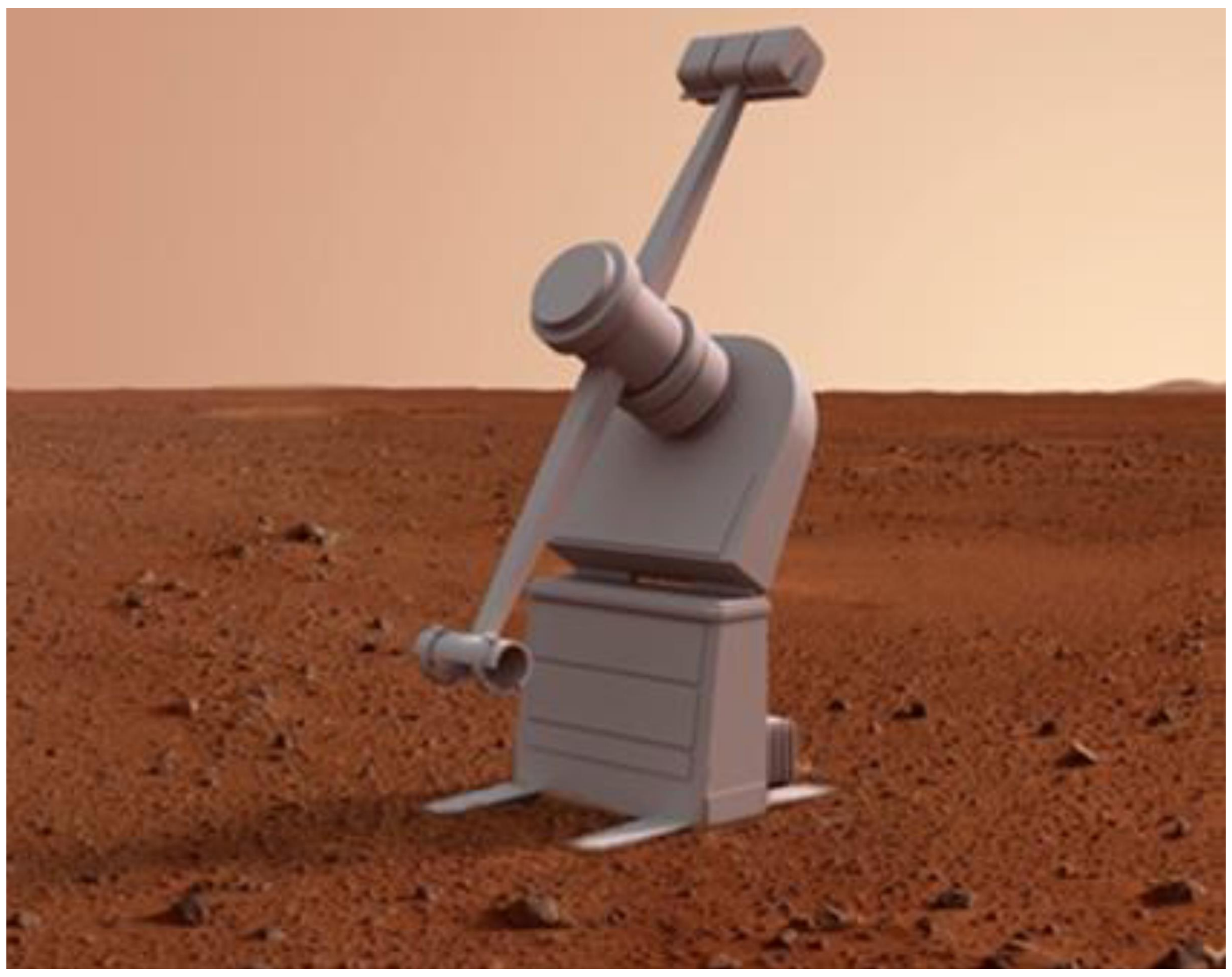
Introduction: The DART mission demonstrated the potential for high-impact divert of a potentially Earth-targeted asteroid. This impulsive approach is complemented by anchoring one or more centrifugal payloads and their power supplies onto the surface of a threatening asteroid. Small (~10 kg) amounts of regolith are collected and sequentially ejected at 1–2 km/sec in the direction of the asteroid velocity vector to divert the asteroid to a safe Earth passage over months or years of operation.

Once landed and anchored to an asteroid, the centrifugal system can operate indefinitely, entirely on electrical power. This technology can be designed and built for demonstration on the moon and then deployed to any asteroid of choice for confirmation of effectiveness. A commercial variant of this technology could be developed for utilization of space resources on these objects.

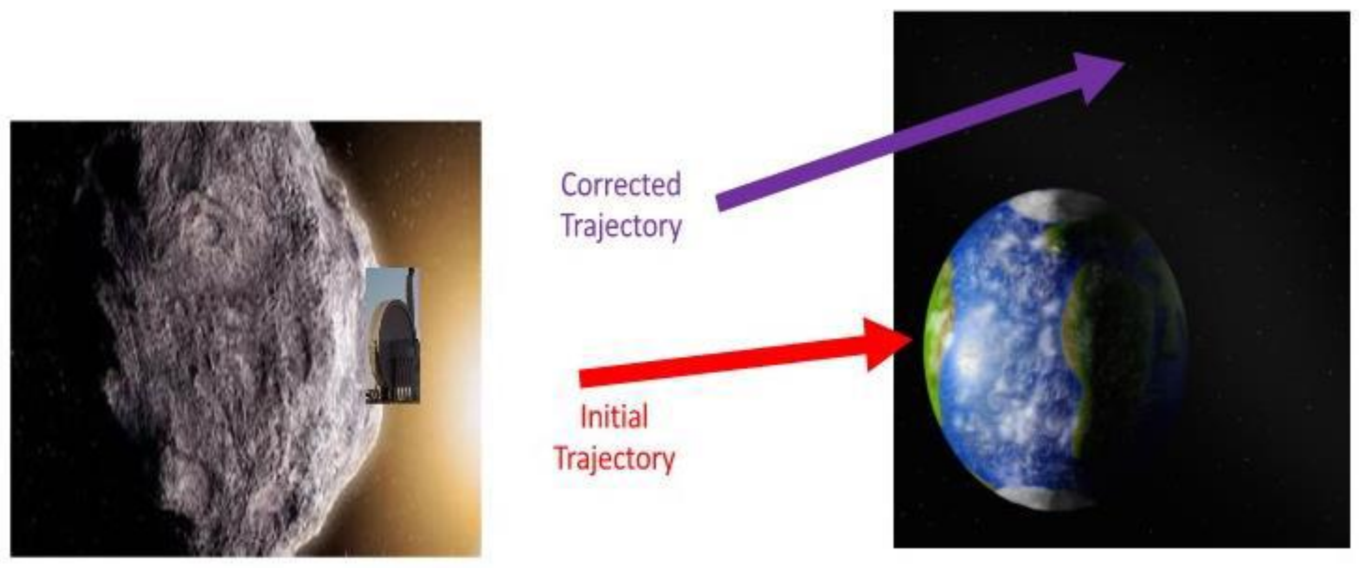
An on-site centrifuge could deflect Chelyabinsk- and Tunguska-size asteroids to miss Earth within a few weeks' operation. The asteroid Bennu could be deflected in a few years of continuous spinner operation, depending upon the parameters chosen, which would be sufficient to eliminate a potential collision with Earth in the late 22nd century.

This approach addresses aspects of Goal 3 of the 2018 U.S. government's "National Near-Earth Object (NEO) Preparedness Strategy and Action Plan"—"Develop Technologies for NEO Deflection and Disruption Missions." The centrifuge approach helps mitigate the asteroid risk by adding a sustainable and repeatable slow-push tool to the planetary defense toolbox.



Asteroid Deflection Example

- Astronomers measure asteroid trajectory, mass, and rotational rate.
- Compute needed deviation velocity and timeline.
- Determine optimum spinner quantities and landing locations.
- Launch Earth-to-asteroid spacecraft carrying one or more spinners.
- Land spinners with regolith scoops and power supplies.
- Upload CONOPS of ejection directions, mass, and cadence.
- Collect regolith into ~10 kg packages.
- Eject packages at @ 500–2,000 m/sec at best time and direction.
- Repeat process as often as needed to ensure safe asteroid trajectory.

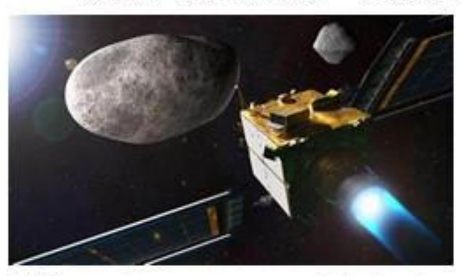


Comparing Asteroid Deflection Cases

Scenario: Deflection of a 30-meter object on collision course to hit Earth ~3 years before impact

Kinetic Impact Case

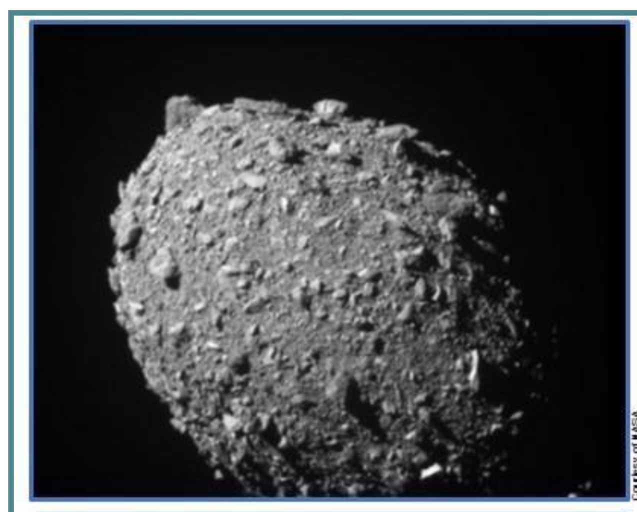
- 2,874 kg kinetic impactor mass
- 12.255 km/sec relative velocity
  - Diverted by 22.7 Earth Radii (R_E) = ~0.4 lunar distance – more than needed



- Effective asteroid delta v is 456 mm/sec (~50% of impact velocity) due to misalignment of the velocity vectors

Spinner Ejection Case

- 10 kg projectile masses, 6 per day
- 2 km/sec ejection velocity
  - 968 ejections for 22.7 R_E miss (~23 weeks) – more than needed
  - 82 ejections at 6/day for 1 R_E miss (~2 weeks)
- 1 km/sec ejection velocity
  - 1,936 ejections for 22.7 R_E miss (~46 weeks) – more than needed
  - 164 ejections at 6/day for 1 R_E miss (~4 weeks)
- Ejections aligned with the asteroid velocity vector



DART Adds to Our Insight into the Spinning Divert Opportunity

- Study of the DART imagery will give us a good estimate of the size distribution of the surface rubble that could be used as spin system ejecta.
- It also suggests CONOPS, such as a phased process:
  1. Hit the asteroid to create significant surface rubble.
  2. Orbit the asteroid to determine axis of rotation and spin rate relative to the object's velocity vector.
  3. Find the ideal landing point on the rotating asteroid.
  4. Land the spinner and proceed with the ejection process.

The spin approach allows an "eject a little – measure a lot" process to fine tune the trajectory diversion over time, rather than a single "big bang" that hopes for a good outcome.

Parametric Mission Design

Case	1	2	3	4
Asteroid diameter [m]	30	60	60	60
Asteroid density [g/cm³]	3	3	3	3
Asteroid mass [kg]	4.24E+7	3.39E+8	3.39E+8	3.39E+8
Asteroid orbital period [d]	971	971	971	971
Asteroid spin rate [rev/d]	3	3	3	2
Time before impact [d]	750	750	750	750
Earth miss distance [R_E]	1	1	1	1
Projectile mass [kg]	10	10	10	10
Projectile ejection relative velocity [km/sec]	2	2	2	2
Number of systems	2	2	6	6
Fraction of asteroid orbit [%]	1.4	12.1	4.1	6.1

Summary: On-site centrifuges can deflect 30–60-meter size asteroids to an Earth miss distance of 1 R_E within a few weeks of operation, approximated as impulsive because it occurs over a small fraction of the orbit. The 565-meter asteroid Bennu can be deflected to miss Earth by 1 R_E in a few years of continuous spinner operation, sufficient to eliminate its potential collision with Earth in the late 22nd century. Proof-of-concept prototype demonstrations could be done on Earth within 2 years and then on the moon in the near term.