NNSA

EXERCISE

2019 PDC Mitigation Mission Options

Conference Day 4

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Current Status

- Current date: 2024-09-03
- Asteroid was accidentally fragmented by the kinetic impactors
- Nuclear devices were not deployed to the asteroid due to widespread controversy that was not resolved in time
- No active spacecraft remain from the original fleet:
  - All KI spacecraft and rendezvous recon spacecraft were destroyed or disabled
    - 1 KI experienced launch failure
    - 2 KIs experienced system failures before reaching asteroid
    - 3 KIs succeeded in striking the asteroid
    - Purpose-built rendezvous recon spacecraft experienced system failure before reaching asteroid
    - Re-tasked rendezvous observer succeeded in reaching and surveying asteroid, but was disable or destroyed by debris generated by the KI strikes
- Final telemetry from the rendezvous recon spacecraft indicates:
  - First KI (launched by NASA) to strike asteroid unexpectedly fragmented the asteroid
  - A ~50—80 m asteroid fragment remains on an Earth-impacting trajectory; Earth impact location uncertain
  - Fragment density likely to be ~1.5 to 2.5 g/cm^3
- SMPAG has created some emergency plans for last-ditch spacecraft missions to perform a nuclear disruption of the fragment; these plans are outlined herein

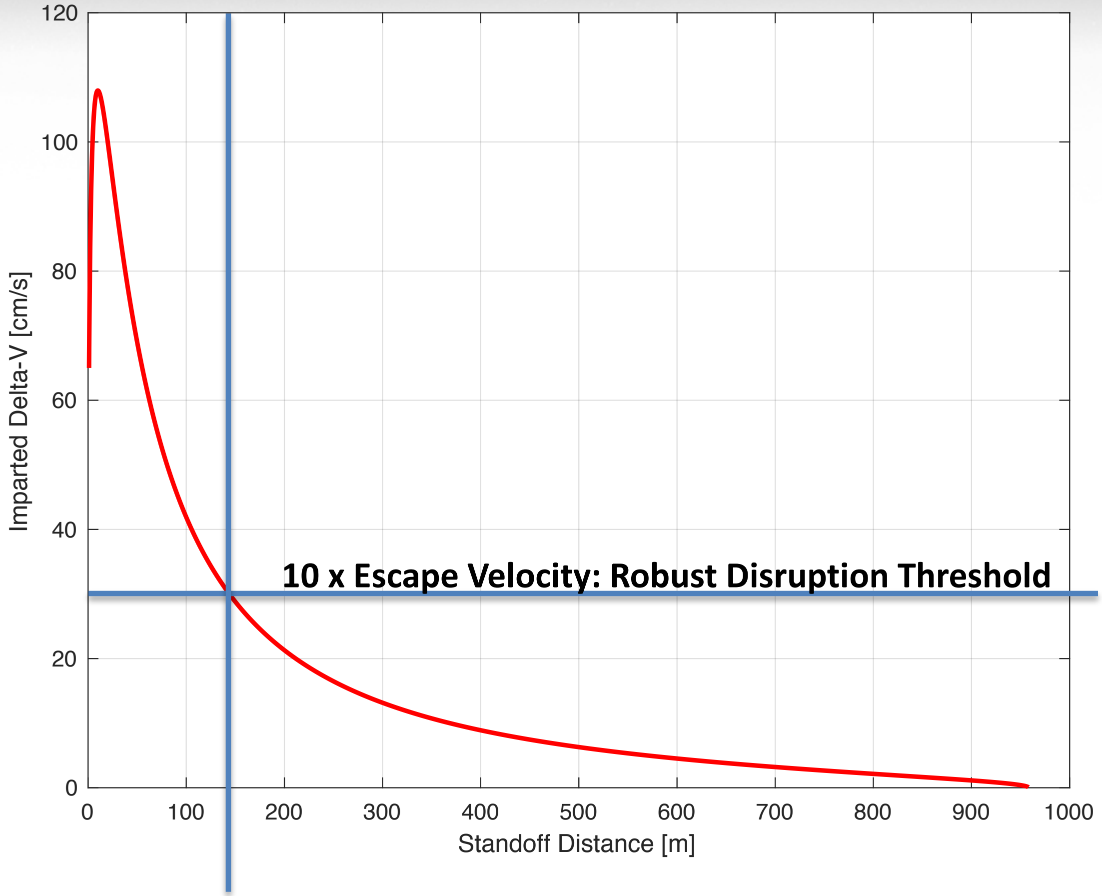
Asteroid Disruption vs. Deflection

- As time moves forward and the asteroid fragment comes closer in space and time to Earth impact, the required deflection DV increases
- The asteroid is only ~50—80 m and has a relatively low surface escape velocity
- Thus, the DV that would be required to deflect the asteroid (as a whole) is so large (relative to the fragment's escape velocity) that any deflection attempt would at least weakly disrupt the asteroid (making the situation worse)
- So, we purposely design a robust disruption mission:
  - Deliberately apply a very large DV to the asteroid, at least ~10x the asteroid's escape velocity (a notional heuristic for robust disruption)
  - The objective is to disrupt the asteroid into many pieces that are all (a) small enough to be easily absorbed by Earth's atmosphere, and (b) so widely scattered that very, very few---if any---would go on to hit the Earth anyhow
- During the asteroid's final solar orbit before Earth encounter, the optimal deflection direction becomes increasingly radial and out-of-plane (rather than along-track), as a consequence of orbital physics, and so we position the nuclear device along that direction to help maximize dispersal of the disrupted asteroid material

Asteroid Disruption Via 300 KT NED

- Asteroid mass: 9.8×10^7 – 6.7×10^8 kg
- Asteroid escape velocity: 1.9 to 4.1 cm/s
- Maximum DV imparted to asteroid by a 300 KT NED: 55 to 251 cm/s
  - 13 to 130 times the escape velocity
  - Notionally sufficient for robust disruption of any combination of the asteroid diameter and density (50—80 m, 1.5—2.5 g/cm^3)
- Standoff detonation distance for maximum imparted DV: 8 to 12 m

Disruption Performance Example: 300 KT NED vs. 65 m, 2 g/cm³ Asteroid



Detonation can occur at up to ~145 m from asteroid

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Example Emergency Nuclear Disruption Launch Options

- 1 Falcon Heavy (expendable) launch vehicle
- Solar electric low-thrust propulsion: 2 x BPT-4000 (XR5) w/ 90% duty cycle
- Power: 11 kW @ 1 au
- 300 KT NED mass: ~170 kg

Type	Launch	Prep time for launch (days)	C_3 (km^2/s^2)	DLA (deg)	Launch Mass (kg)	Arrival	Arrival (days before Earth encounter)	Arrival Mass (kg)	Arrival Relative Speed (km/s)
Intercept	2025-09-22	336	97.11	22.23	938	2027-02-28	61	600	5
Intercept	2025-04-17	178	37.69	-28.5	1231.5	2027-02-28	61	600	1
Rendezvous	2025-03-22	152	92.85	-22.9	1222	2027-02-28	61	600	0
Intercept	2025-04-11	173	94.34	-21.86	1120.5	2026-12-28	123	600	1
Rendezvous	2025-04-13	175	93.74	-22.54	1160.6	2027-02-06	83	600	0

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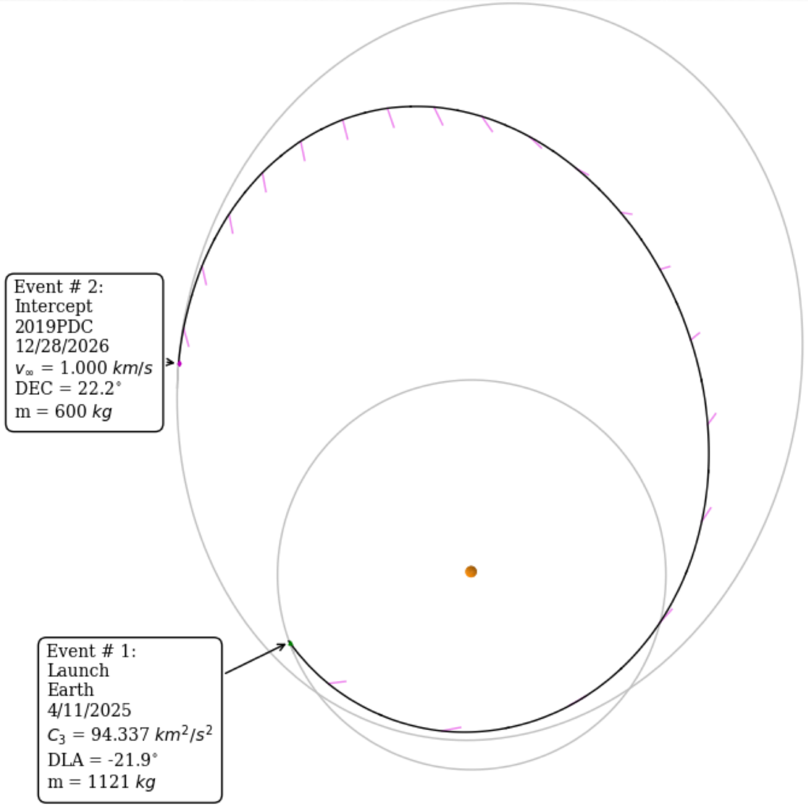
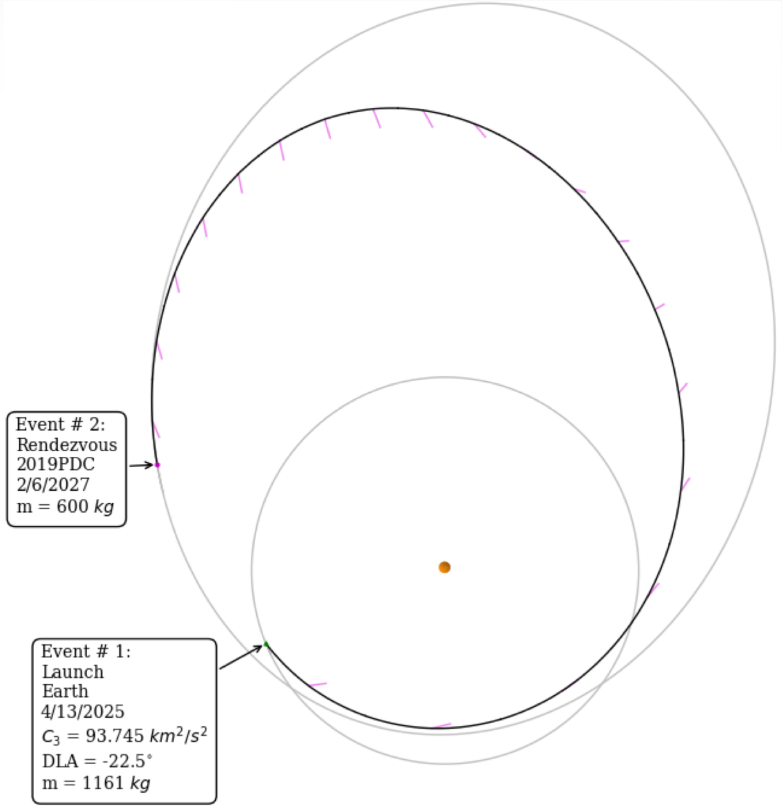
Example Emergency Nuclear Disruption Launch Trajectories



1 km/s Intercept ~4 months before Earth encounter



Rendezvous ~1.4 months before Earth encounter

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Disruption Mission Effectiveness

- Detailed modeling of robust disruption is important future work, but, for reference: previous work has indicated that, for example, subsurface disruption of a 270 m asteroid with a 300 KT NED at 20 days before Earth encounter reduces the asteroid mass interacting with Earth to be roughly equivalent to the Tunguska event
  - See: Kaplinger, B., Wie, B., Dearborn, D., Earth-impact modeling and analysis of a near-Earth object fragmented and dispersed by Nuclear Subsurface Explosions, Journal of the Astronautical Sciences, Vol. 59, Nos. 1 & 2, January 2014, pp. 103—121
- Thus, 300 KT standoff disruption of a ~50—80 m asteroid at ~60—120 days before Earth encounter is likely to prevent any significant effects on Earth