

Head-On Impact Deflection of NEAs: A Case Study for 99942 Apophis

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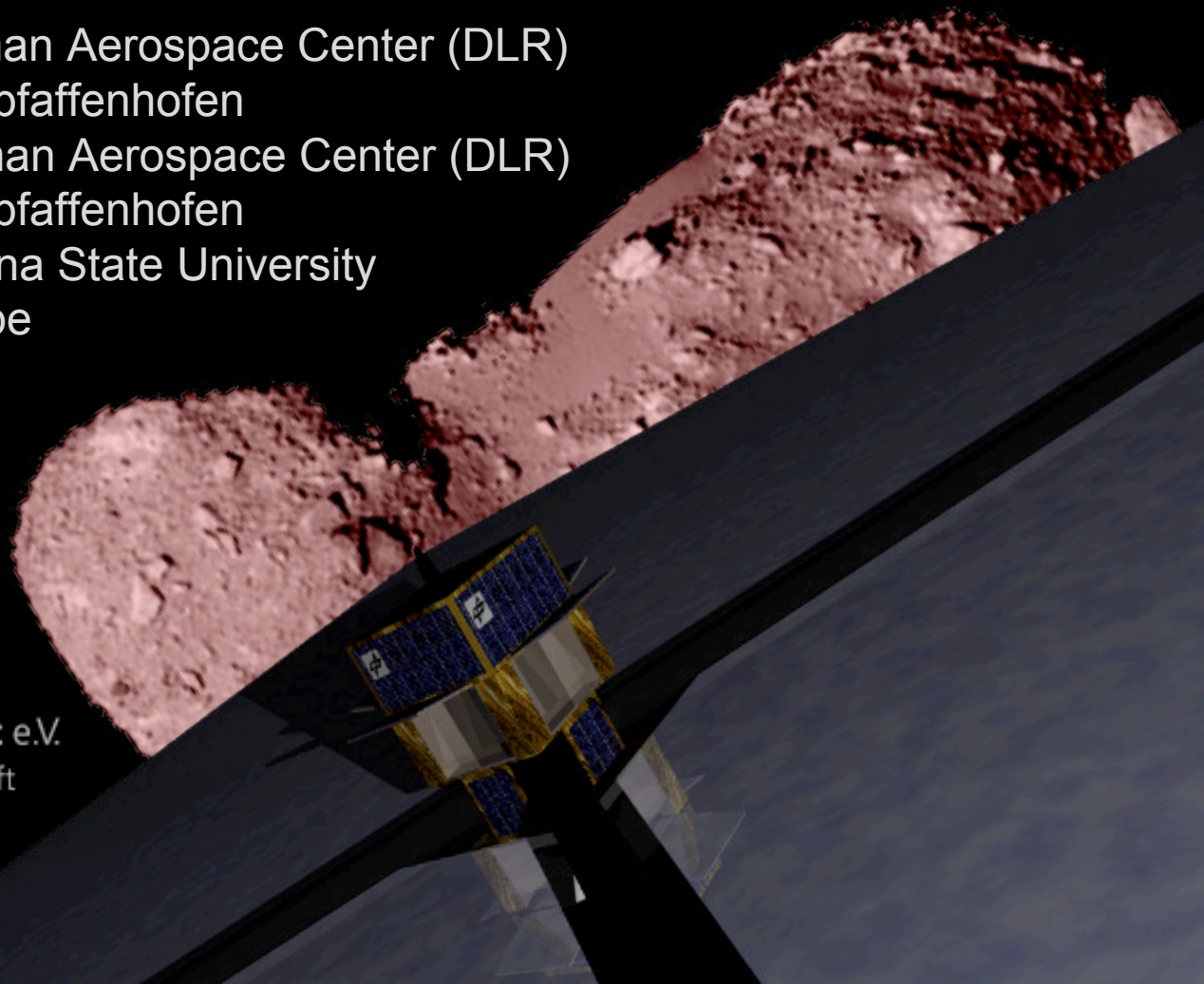
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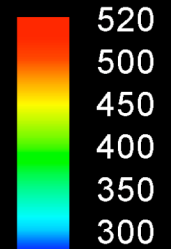
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A Potential Solution for a Real Problem

Mission duration: 6 years
Impact velocity: 75.4 km/s

Sail Temp. [K]



Launch at Earth

Apophis orbit

Earth orbit

Retrograde Apophis impact

The solar sail might be the better propulsion system for such a mission.

Using chemical or electric propulsion, too many gravity assists and therefore too much time is required to make a spacecraft trajectory retrograde (≈ 30 years).

The highest impact velocity can be achieved from a retrograde orbit.

The simplest way to deflect a NEO is to impact it with a massive projectile at a high relative velocity.

Pre-2029-Encounter Apophis Impact

At 01 Jan 2020, a solar sail Kinetic Energy Impactor (KEI) is launched from Earth ($C_3 = 0 \text{ km}^2/\text{s}^2$):

- 160 m x 160 m, 168 kg solar sail assembly and 150 kg impactor (sail is to be jettisoned before impact)
- maximum acceleration at 1 AU solar distance is 0.5 mm/s^2
- sail film temperature limit is $240 \text{ }^\circ\text{C}$
- For a pre-2029-encounter impact, a retrograde impact with a single KEI is sufficient to nudge Apophis out of a keyhole ($\varnothing \approx 600 \text{ m}$)
- An exactly retrograde orbit (spacecraft encounters Apophis at every perihelion and aphelion passage) offers more flexibility and might therefore be the better choice

KEI head-on impact velocity [km/s]

- △— Trajectory that maximizes impact velocity
- Exactly retrograde orbit

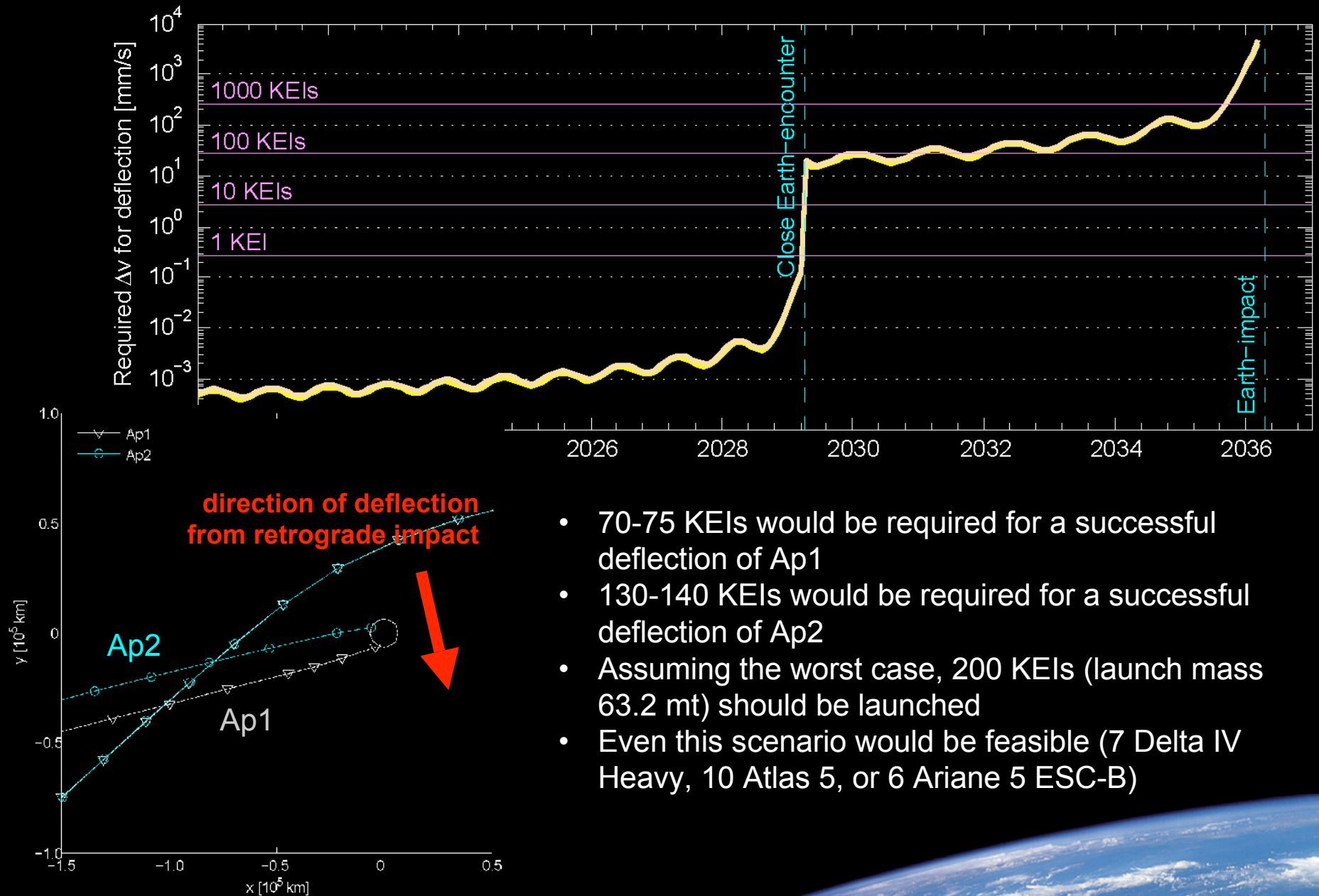
Lead time [days]

Deflection from a single KEI [km]

- △— Trajectory that maximizes impact velocity
- Exactly retrograde orbit

Lead time [days]

Post-2029-Encounter Apophis Impact



- 70-75 KEIs would be required for a successful deflection of Ap1
- 130-140 KEIs would be required for a successful deflection of Ap2
- Assuming the worst case, 200 KEIs (launch mass 63.2 mt) should be launched
- Even this scenario would be feasible (7 Delta IV Heavy, 10 Atlas 5, or 6 Ariane 5 ESC-B)