

**Presentation to NASA's NEO Study Workshop**

**Rusty Schweickart**

**Threat Characterization:  
Trajectory Dynamics (039)**

**28 June 2006**

## Threat Characterization: Trajectory Dynamics

(White paper 039)

Russell Schweickart, Clark Chapman, Dan Durda, Piet Hut, Bill Bottke, David Nesvorny<sup>1</sup>

Summary: Given a primary interest in “mitigation of the potential hazard” of near-Earth objects impacting the Earth, the subject of characterization takes on an aspect not normally present when considering asteroids as abstract bodies. Many deflection concepts are interested in the classic geophysical characteristics of asteroids when considering the physical challenge of modifying their orbits in order to cause them to subsequently miss an impact with Earth. Yet for all deflection concepts there are characteristics of the threat which overwhelm these traditional factors. For example, a close gravitational encounter with Earth some years or decades prior to impact can reduce the velocity change necessary for deflection by several orders of magnitude if the deflection precedes the close encounter (or encounters). Conversely this “benefit” comes at a “price”; a corresponding increase in the accuracy of tracking required to determine the probability of impact. Societal issues, both national and international, also characterize the NEO deflection process and these may strongly contend with the purely technical issues normally considered. Therefore critical factors not normally considered must be brought into play as one characterizes the threat of NEO impacts.

**Schweickart - B612 Foundation; Hut - Institute for Advanced Study;  
Bottke, Chapman, Durda, Nesvorny - Southwest Research Institute**

*“The Congress declares that the general welfare and security of the United States require that the unique competence of the National Aeronautics and Space Administration be directed to detecting, tracking, cataloguing, and characterizing near-Earth asteroids and comets in order to provide warning and mitigation\* of the potential hazard of such near-Earth objects to the Earth.”*

*Section 102 of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2451), as amended.*

\* Underlining added

Therefore:

In the context of mitigating the hazard of NEO impacts with Earth..

..the definition (or understanding) of “characterization” should be broadened to the *characterization of the NEO threat*... not simply the geophysical characterization of the NEO per se.

# Agenda

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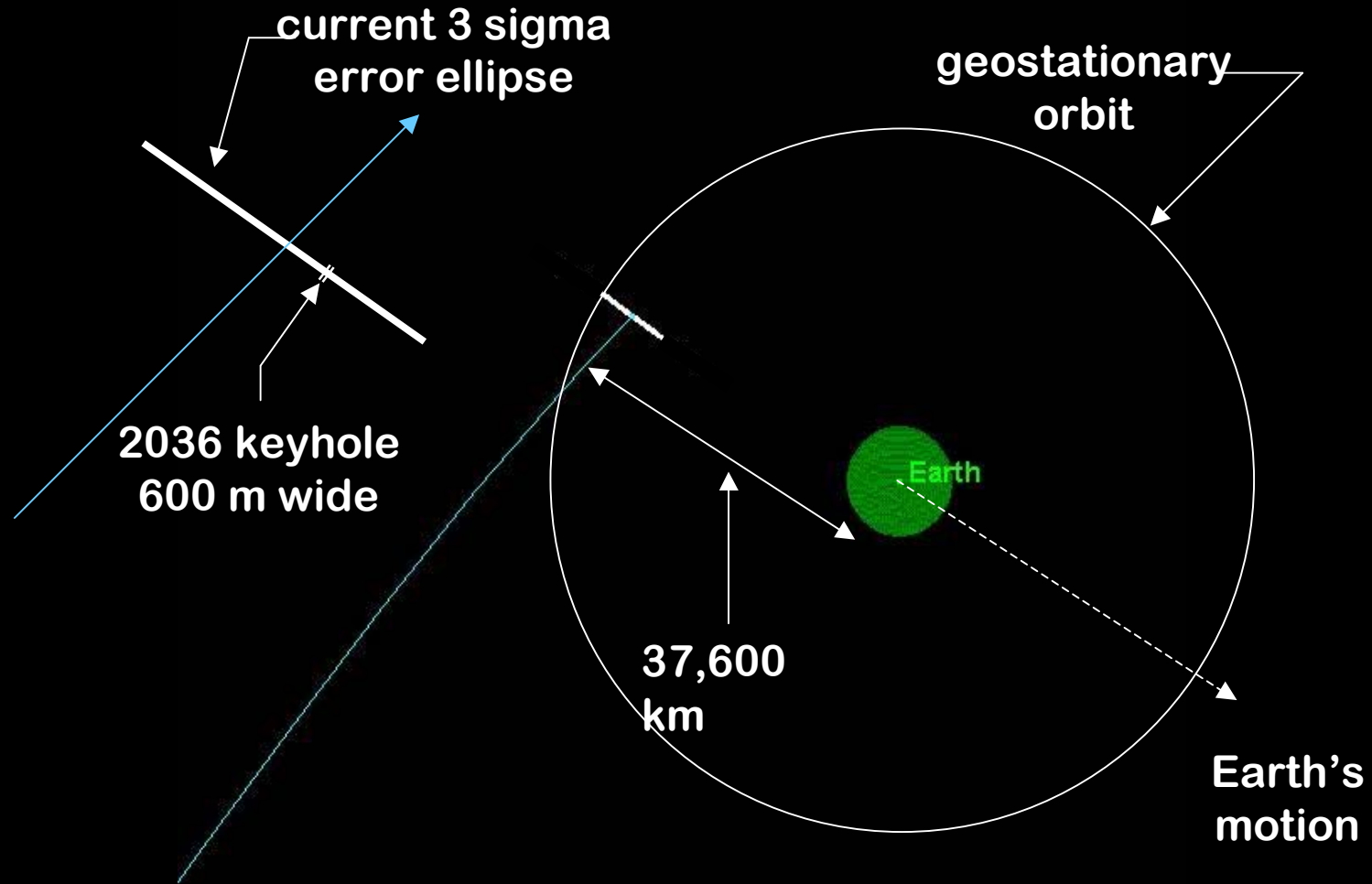
- ✓ Close Encounters, Resonant Returns and Keyholes
- ✓ Deflection and the Impact Probability Challenge
- ✓ Tracking Gaps and Launch Windows
- ✓ Deflection Decision-Making

The 2004MN4  
Situation as of 23 Dec 04



2029 Apr 11

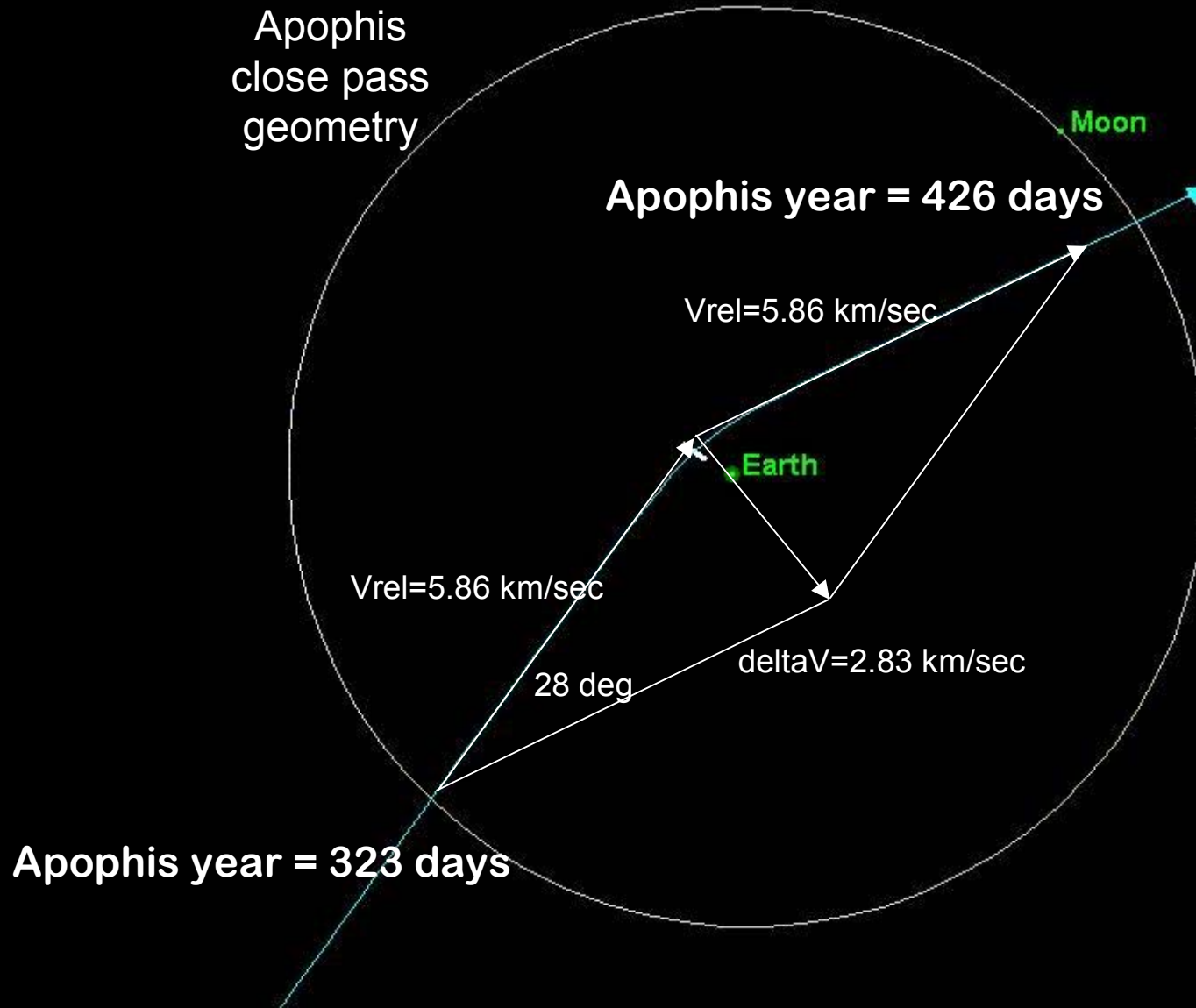
# Close Encounters, Resonant Returns and Keyholes



## Apophis 2029 Close Pass

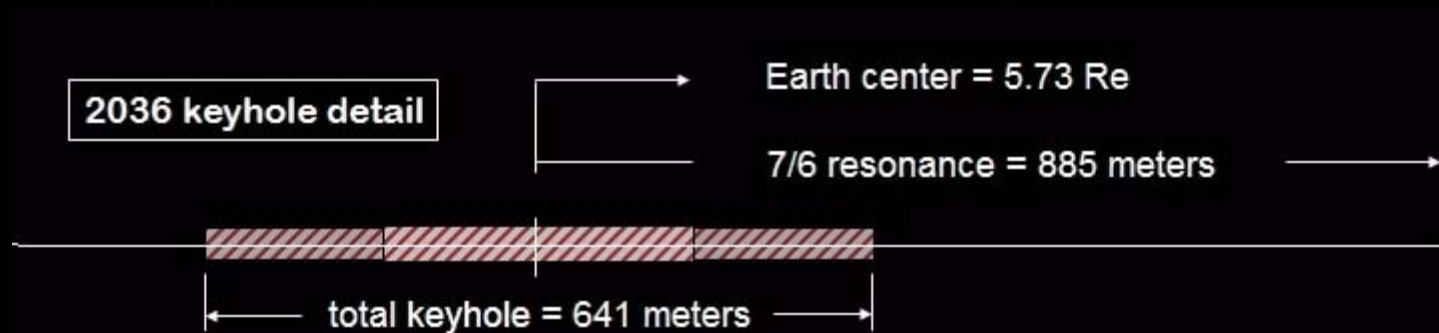
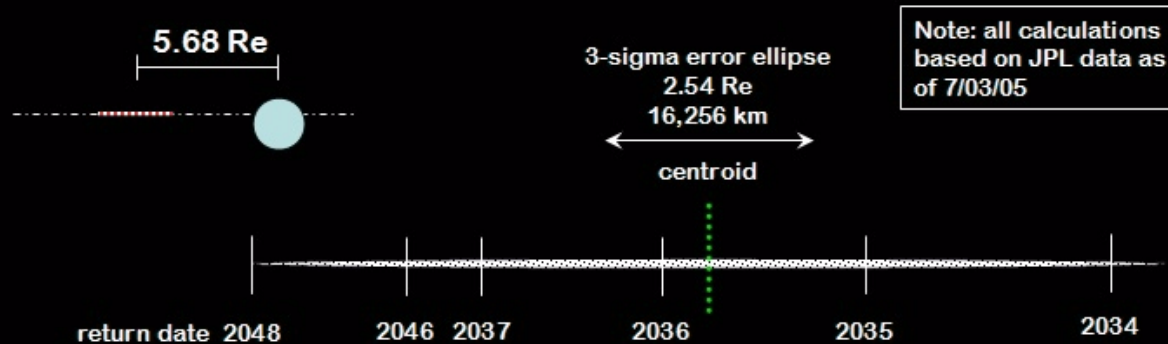
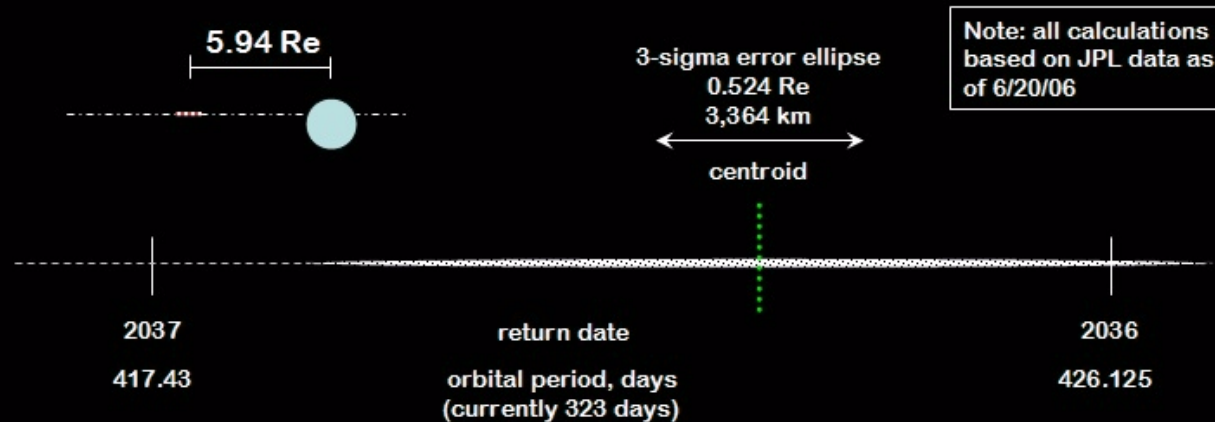
50000 km

# Close Encounters, Resonant Returns and Keyholes

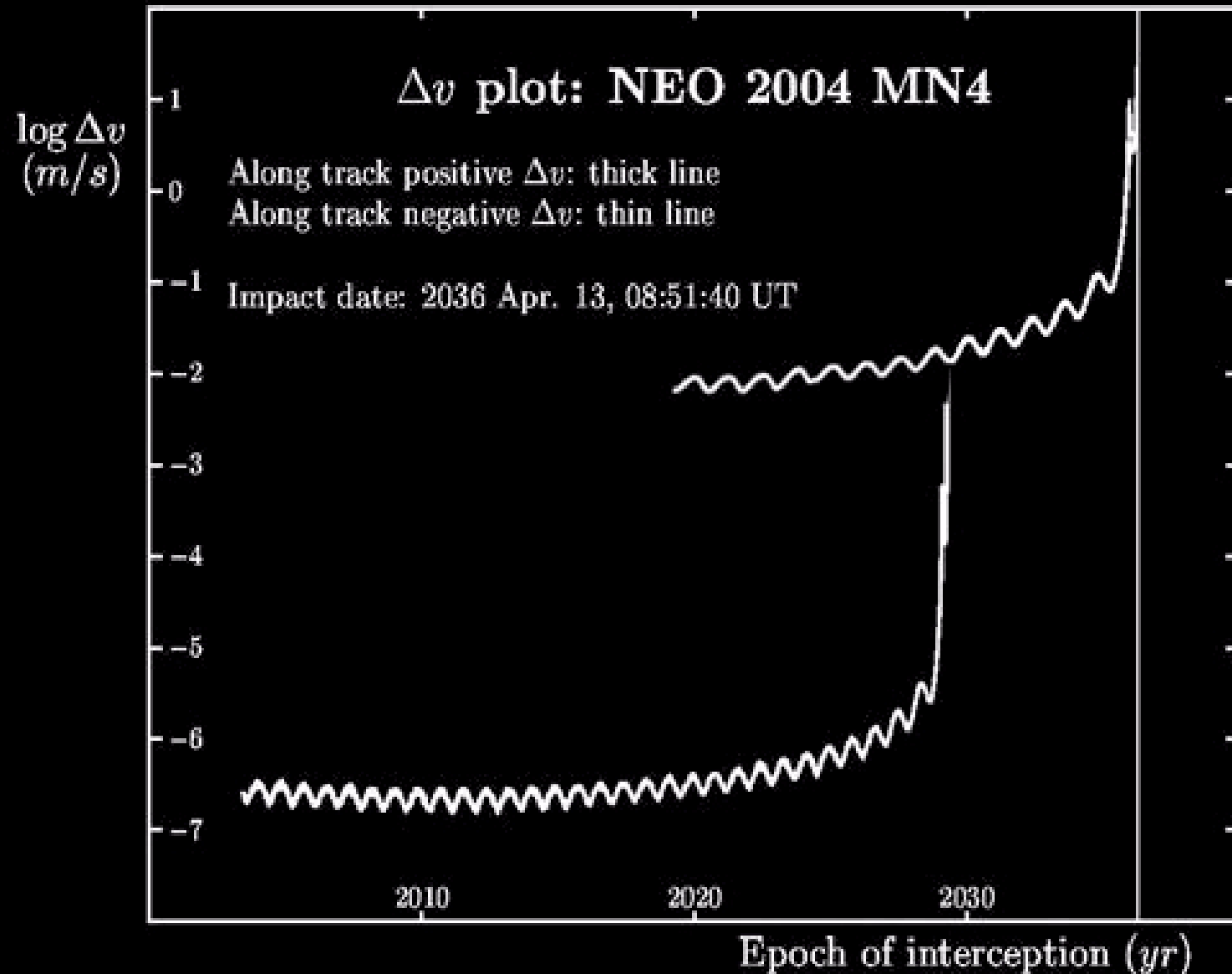




# Close Encounters, Resonant Returns and Keyholes

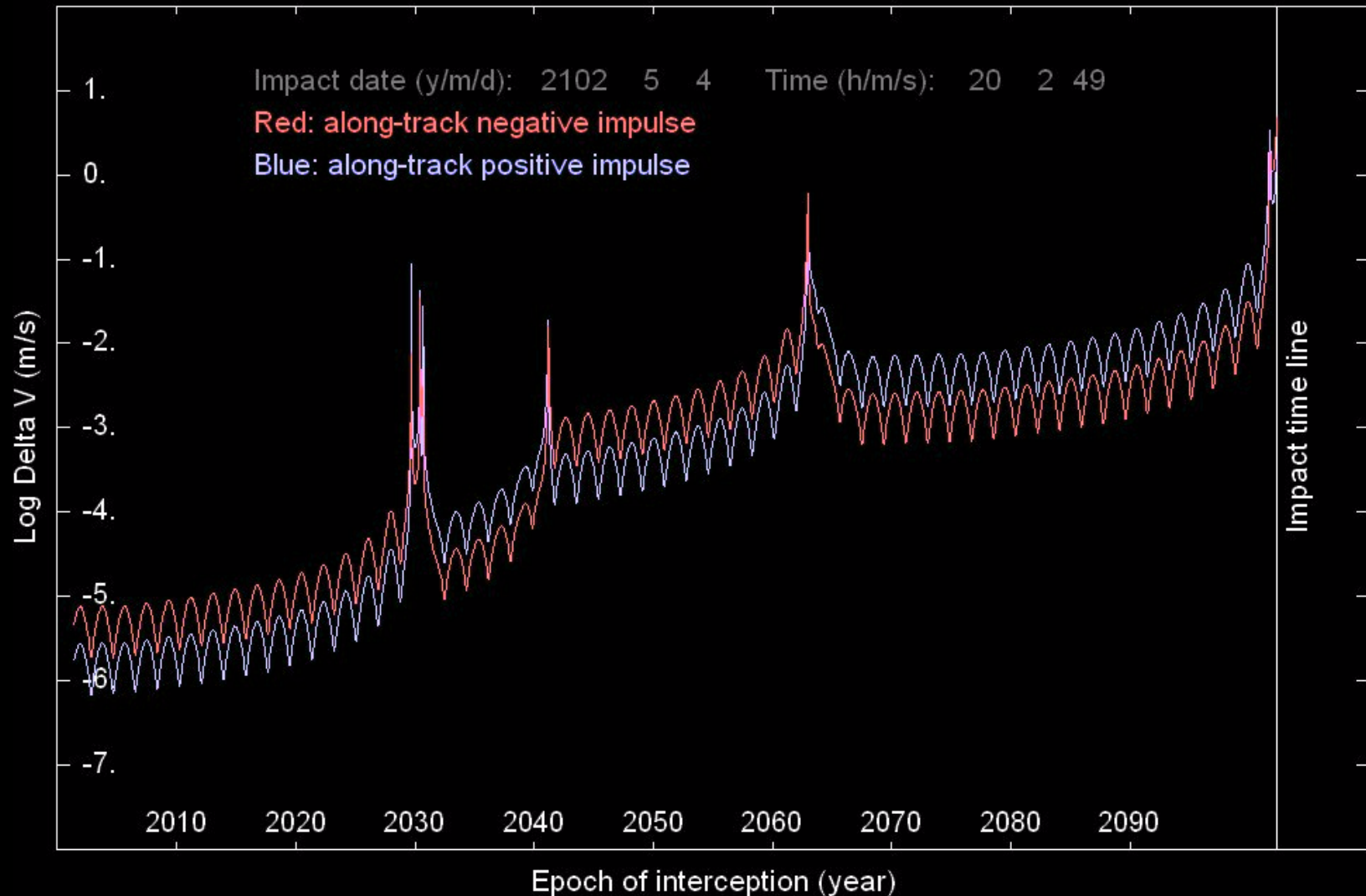


# Deflection and the Impact Probability Challenge

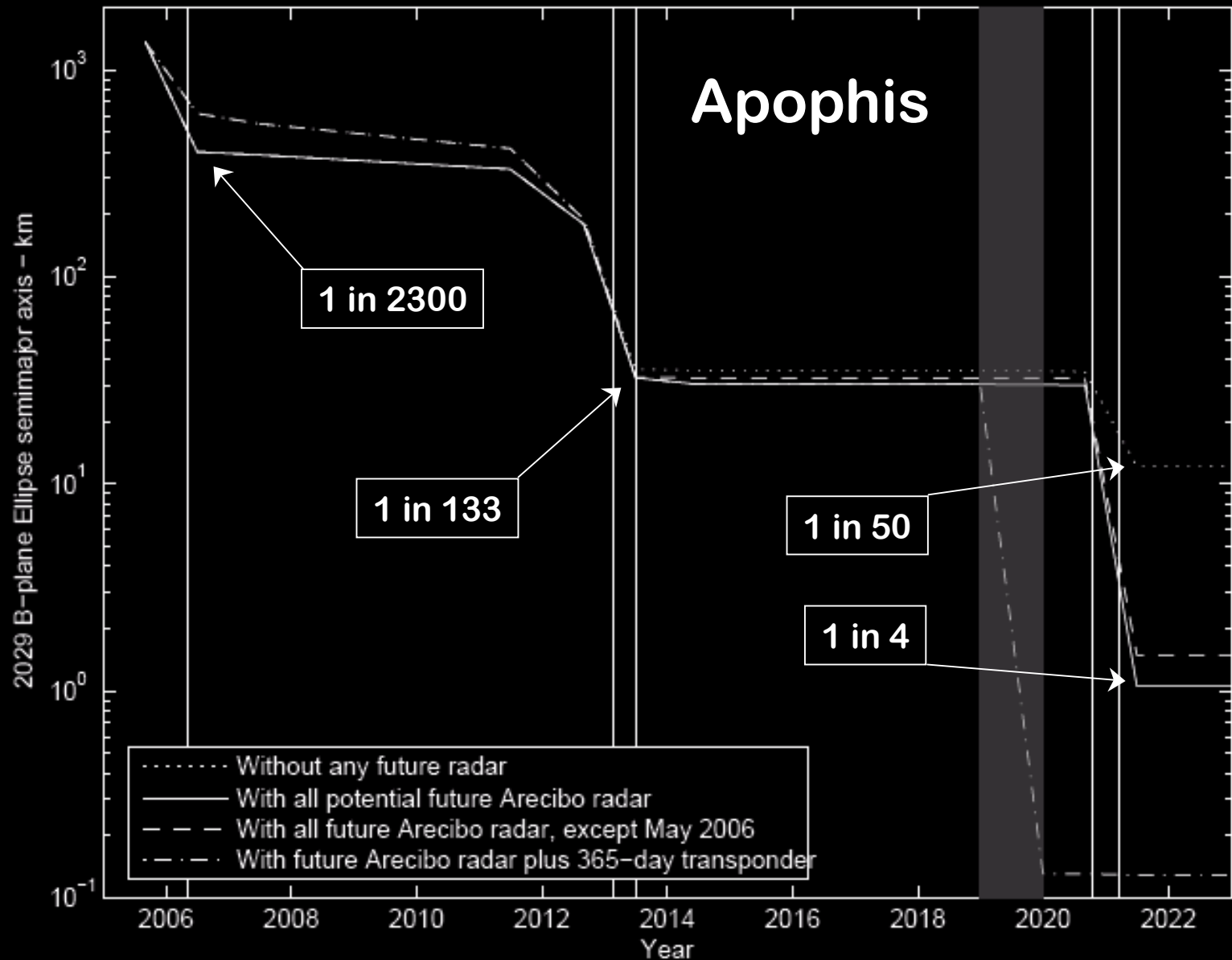


# Deflection and the Impact Probability Challenge

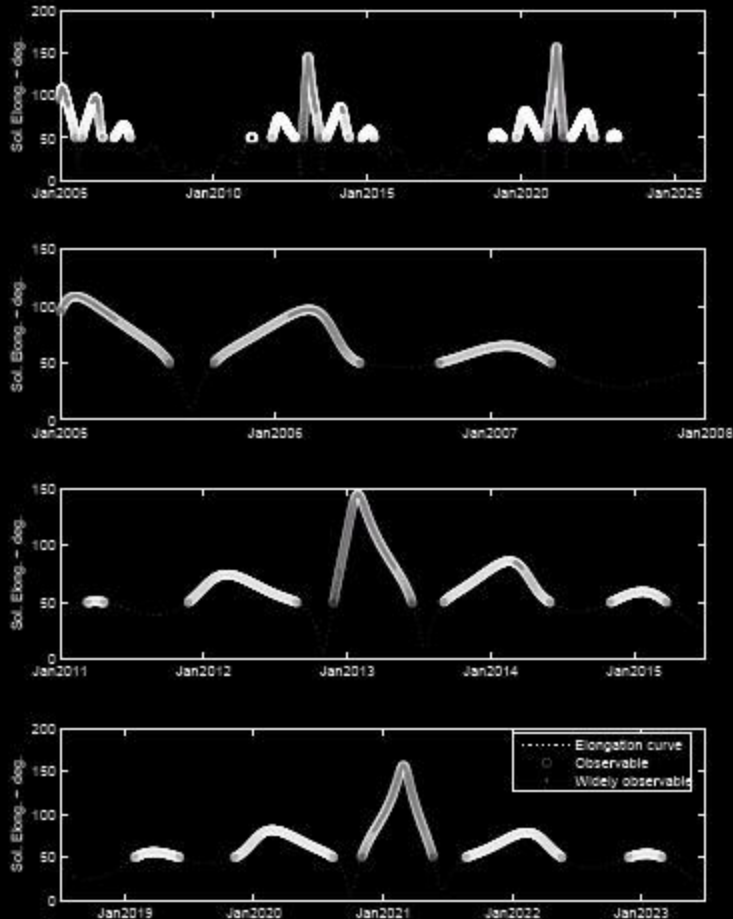
Delta V plot for 2004 VD17



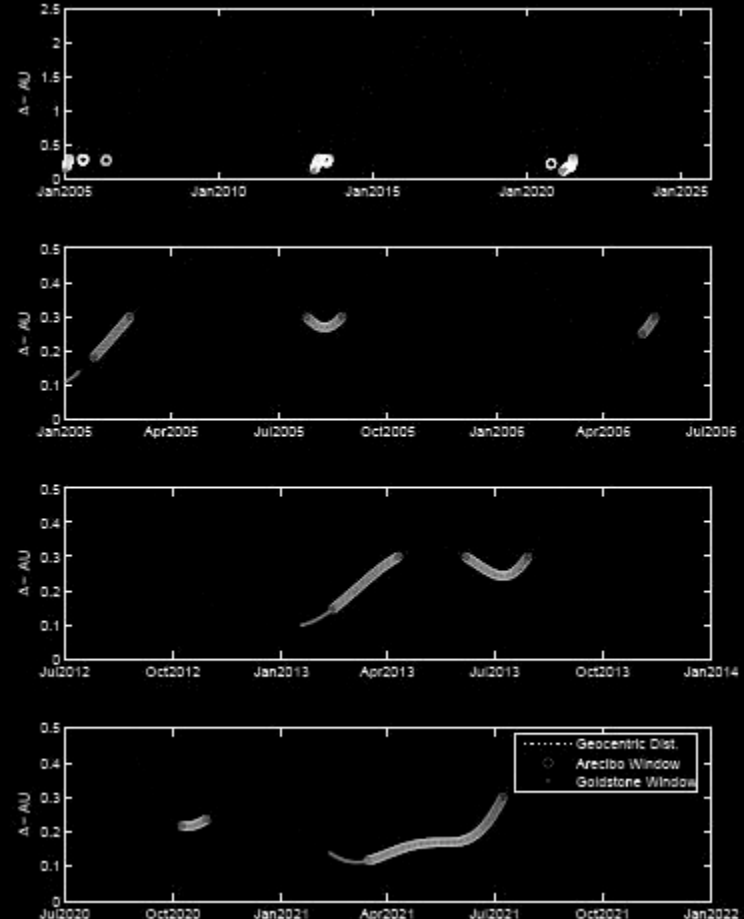
# Deflection and the Impact Probability Challenge



# Tracking Gaps and Launch Windows



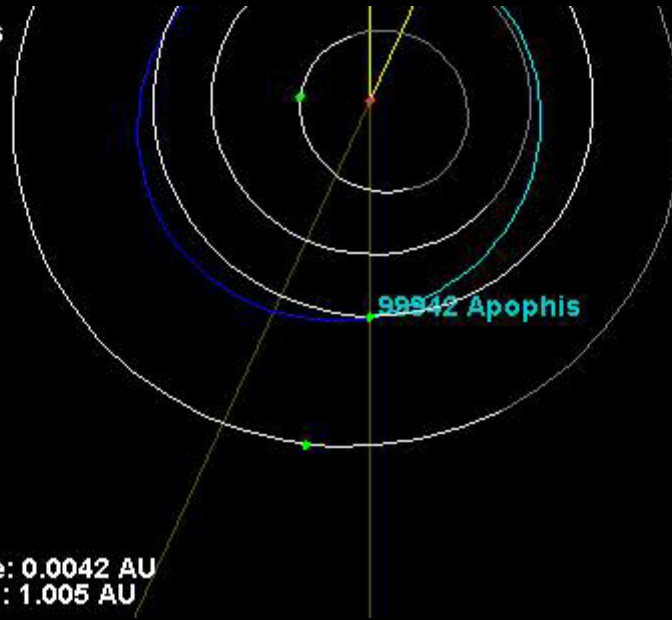
Optical



Radar

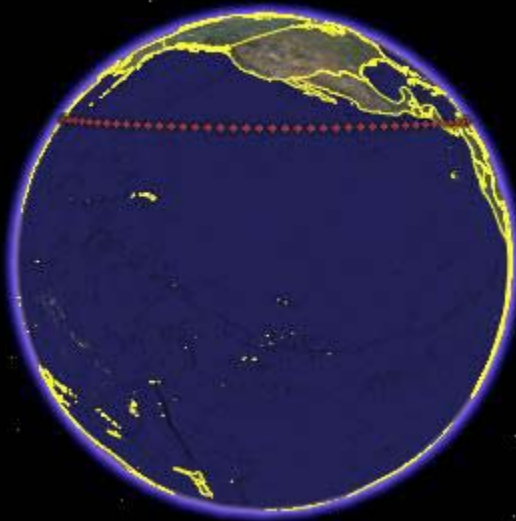
# Deflection Decision-Making

99942 Apophis



Earth Distance: 0.0042 AU  
Sun Distance : 1.005 AU

Apr 13, 2029

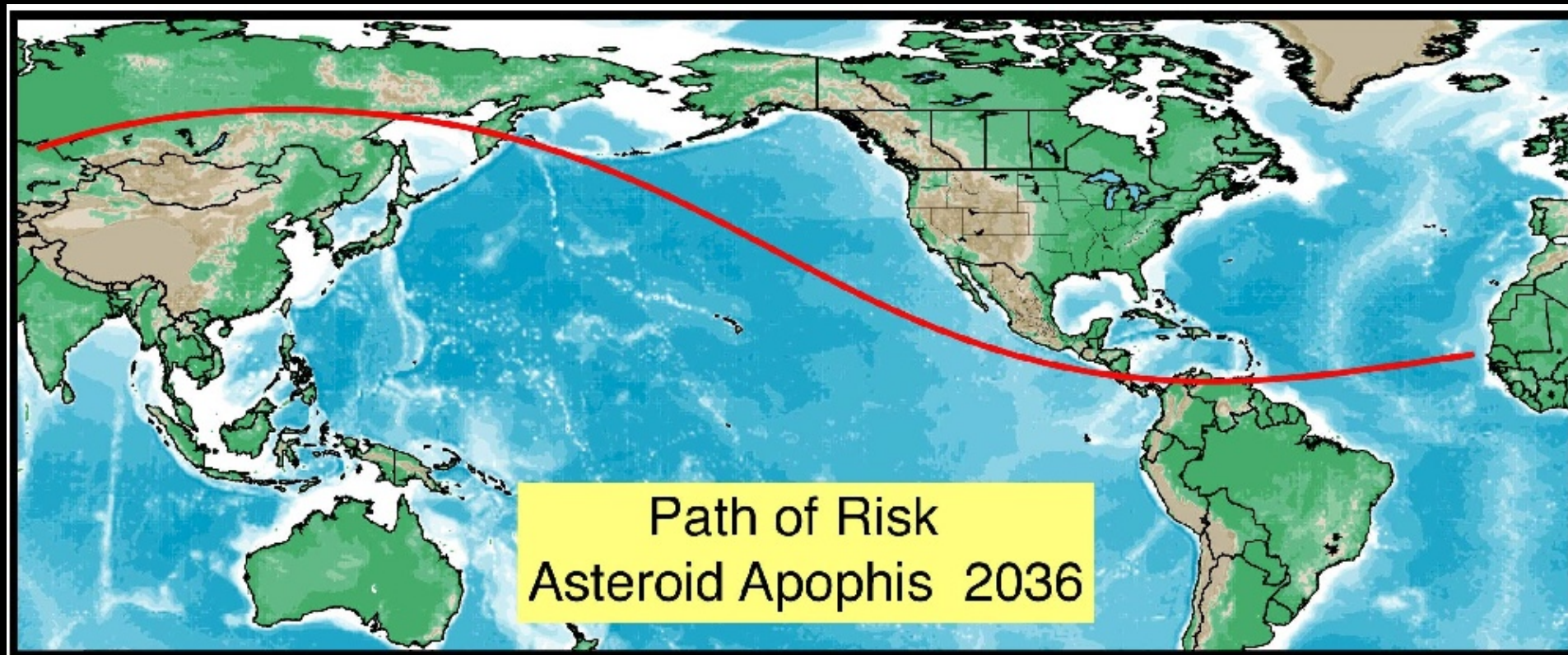




2036



# Deflection Decision-Making

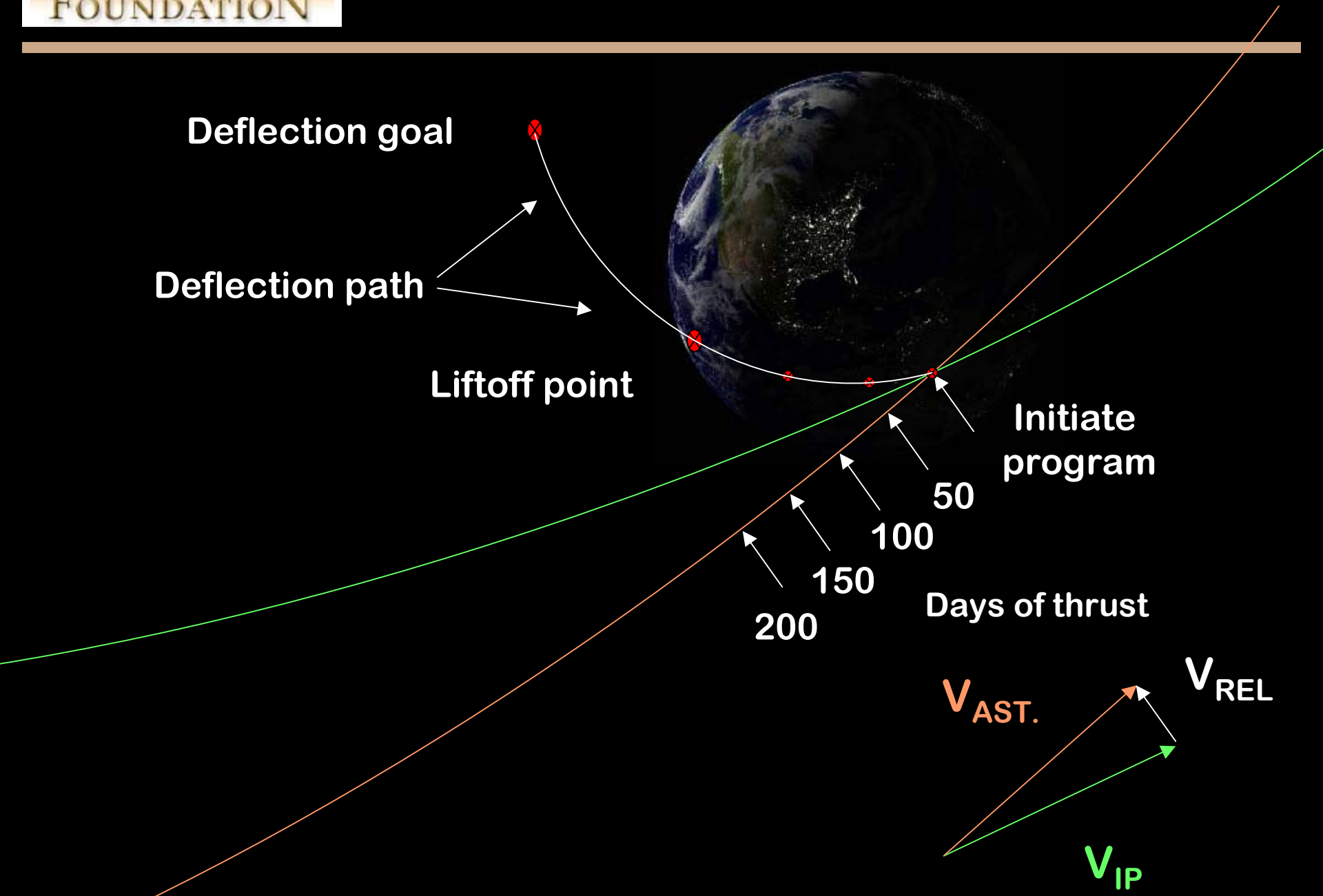


$V_{\text{impact}}$	12.59 km/s
$V_{\text{infinity}}$	5.87 km/s
H	19.2
Diameter	0.320 km
Mass	$4.6 \times 10^{10}$ kg
Energy	$8.8 \times 10^2$ MT

Path of Risk = 64 km x 30,250 km



# Deflection Decision-Making



# Deflection Decision-Making



# Recommendations

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## Analytical

1. Statistically analyze the NEO cohort with close gravitational encounters.
2. Make specific NEO close encounter data (dV plots, keyholes, etc.) routinely available to community.
3. Tracking gaps and launch window phasing should be analyzed and made available for specific NEOs
4. NEO deflection decision-making should be assumed from the outset to be international

# Recommendations

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## Operational

1. NEO discovery and tracking is not science, it is public safety. It should be placed on an independent and secure funding basis.
2. Radar tracking is critical to obtaining accurate and timely data on close encounter NEOs. It should be placed on a priority funding and maintenance basis.
3. High efficiency deep space propulsion capability is essential to get to most NEOs of concern. NEP, or equivalent, should be placed on priority development.