Ball Aerospace Tech Talk
6 March 2015

Geopolitical Reality & Planetary Defense
Some Technical Consequences

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B612 Foundation

What I'll Address

What Options do we have re Mitigation

Civil Defense or Impact Prevention

How and Who Decides

What are the Likely Key Drivers

A Closer Look at Deflection

What are the Technical Implications


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13
АНТИРАБИЧЕСКИЙ КАБИНЕТ

HD FTSE 6319.19
METEOR STRIKE
US HAS BEEN FORMALLY CHARGED WITH ONE COUNT OF MURDER
BREAKING NEWS

Deflection

Kinetic Impact

Pushes the asteroid via direct impact
(KI = robust but imprecise)

Nuclear Explosion

Explodes surface off NEO to create impulsive push

Gravity Tractor

Pulls the asteroid using mutual gravity as a tow-rope
(GT = weak but precise)

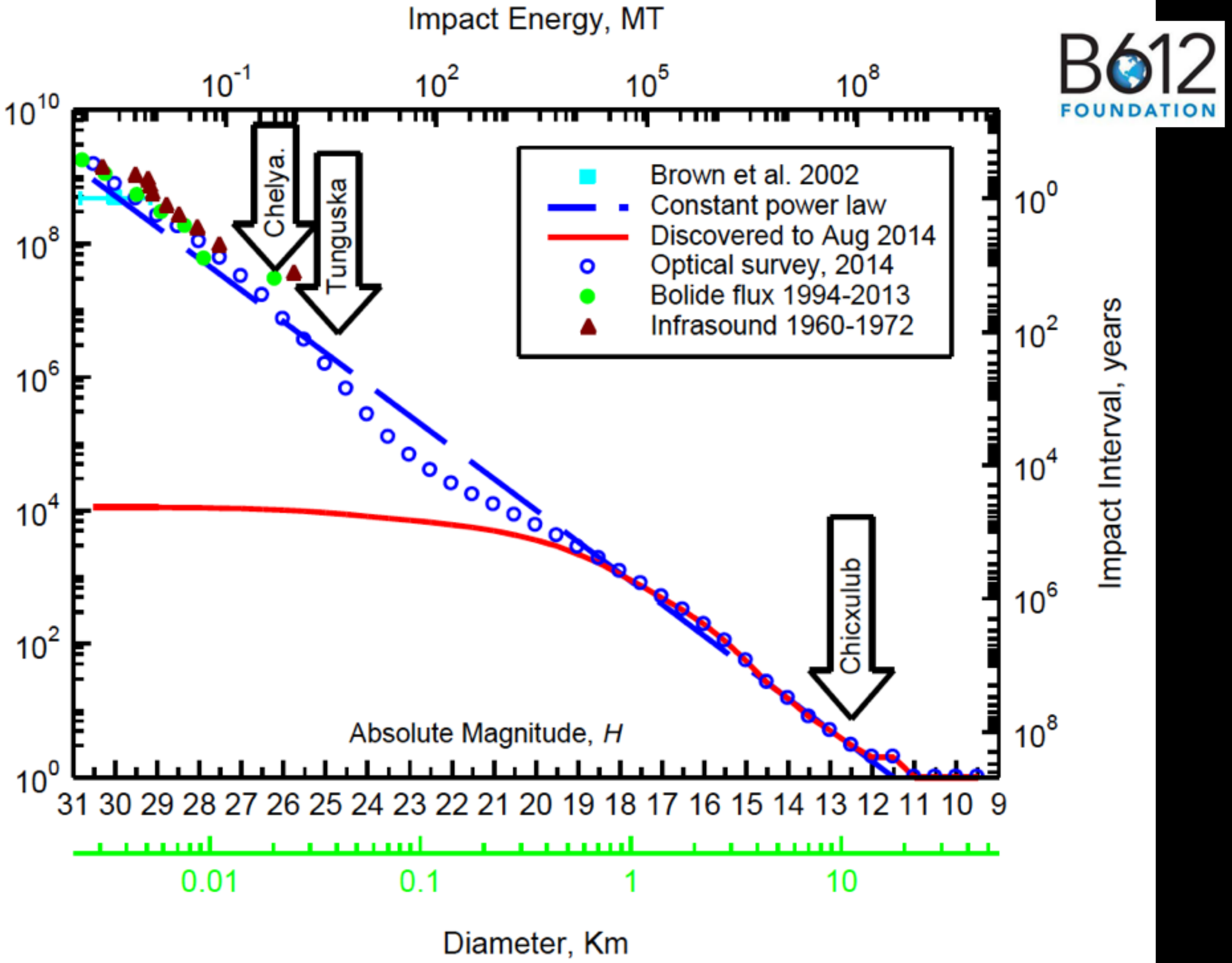
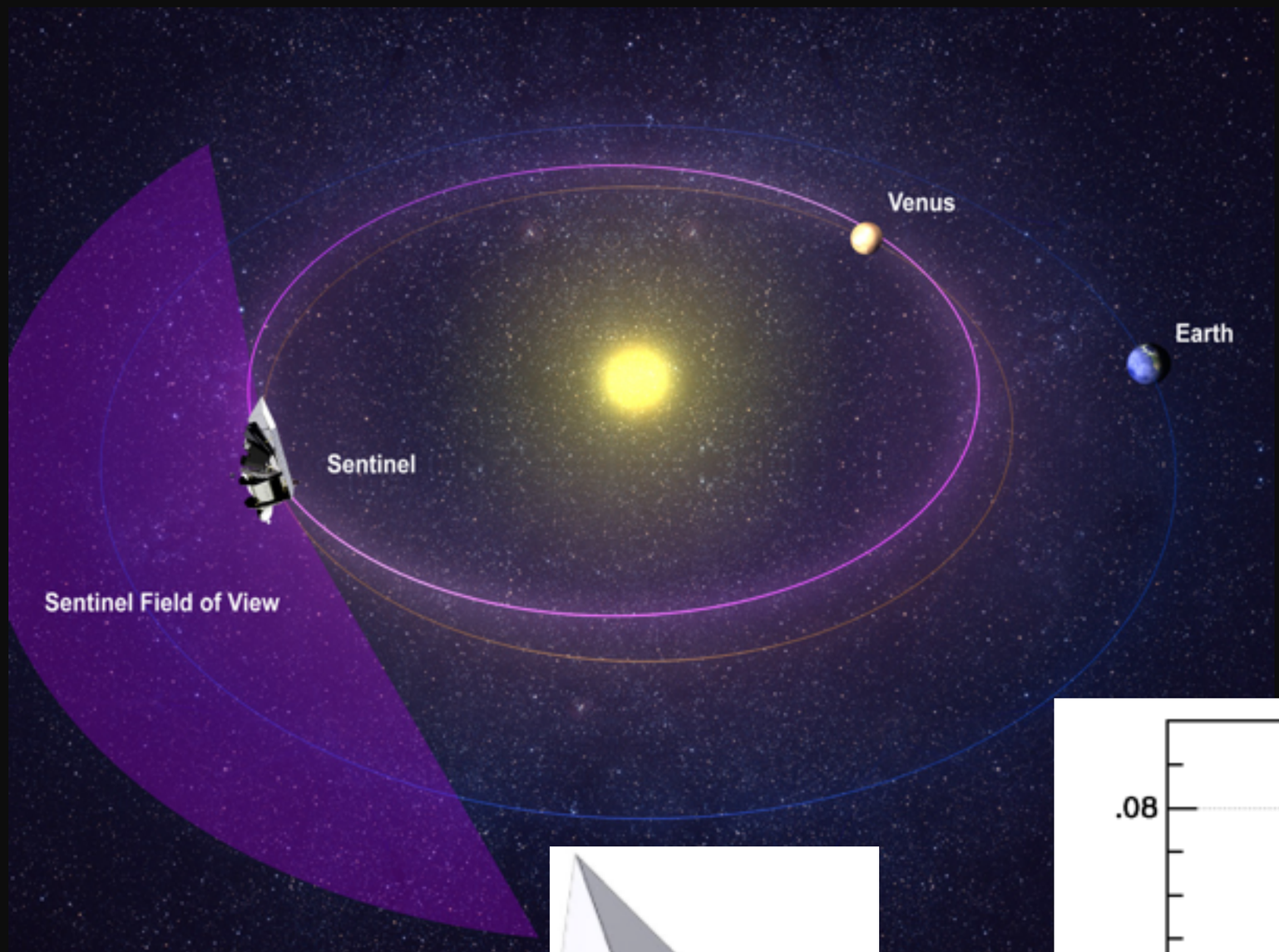
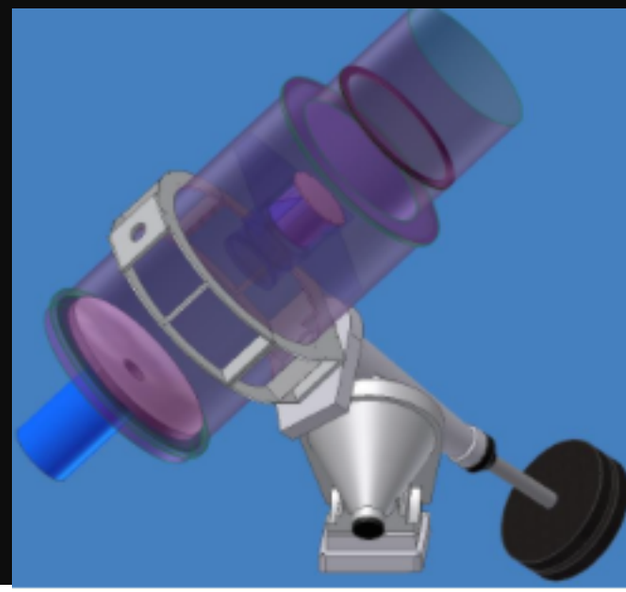
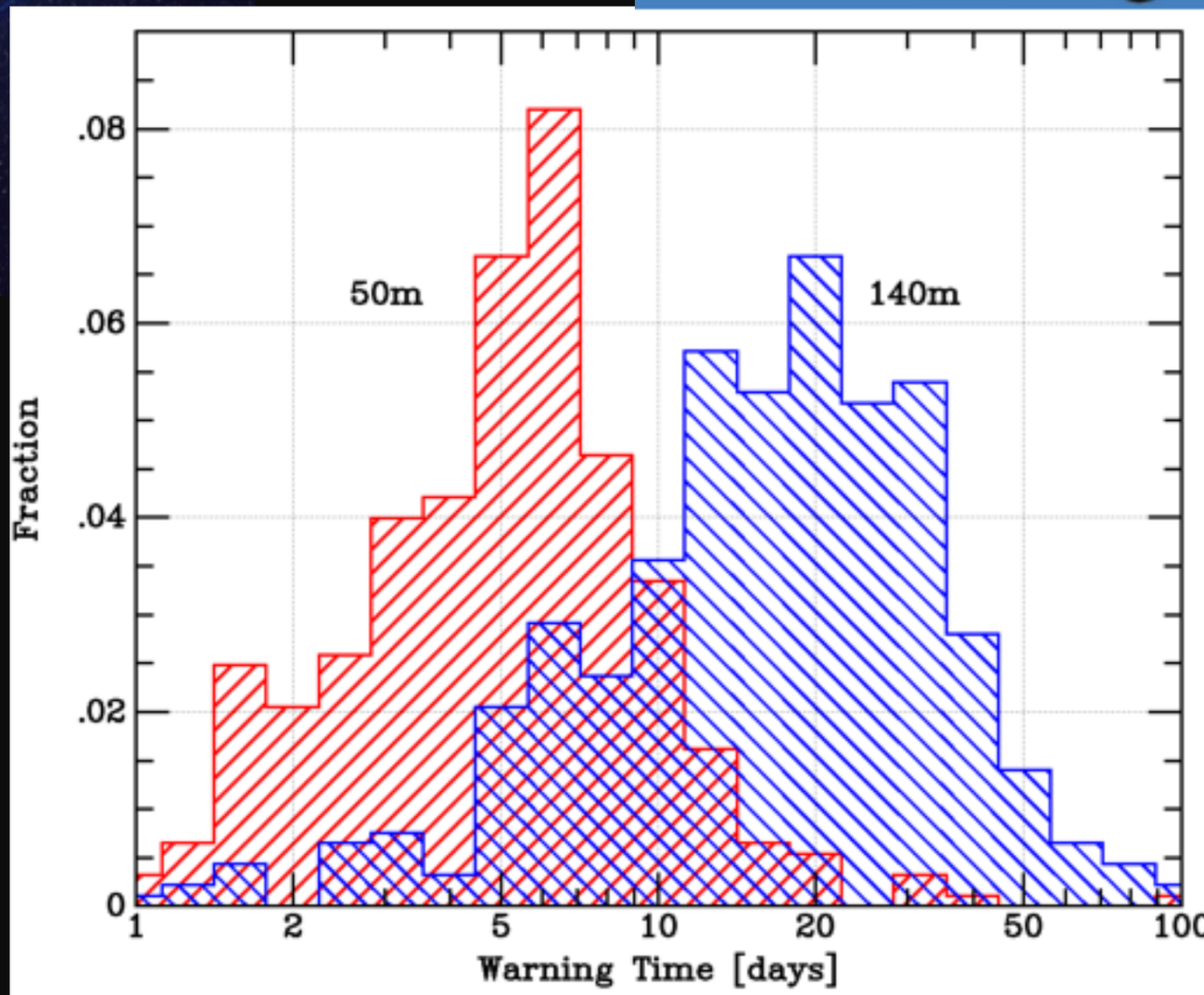


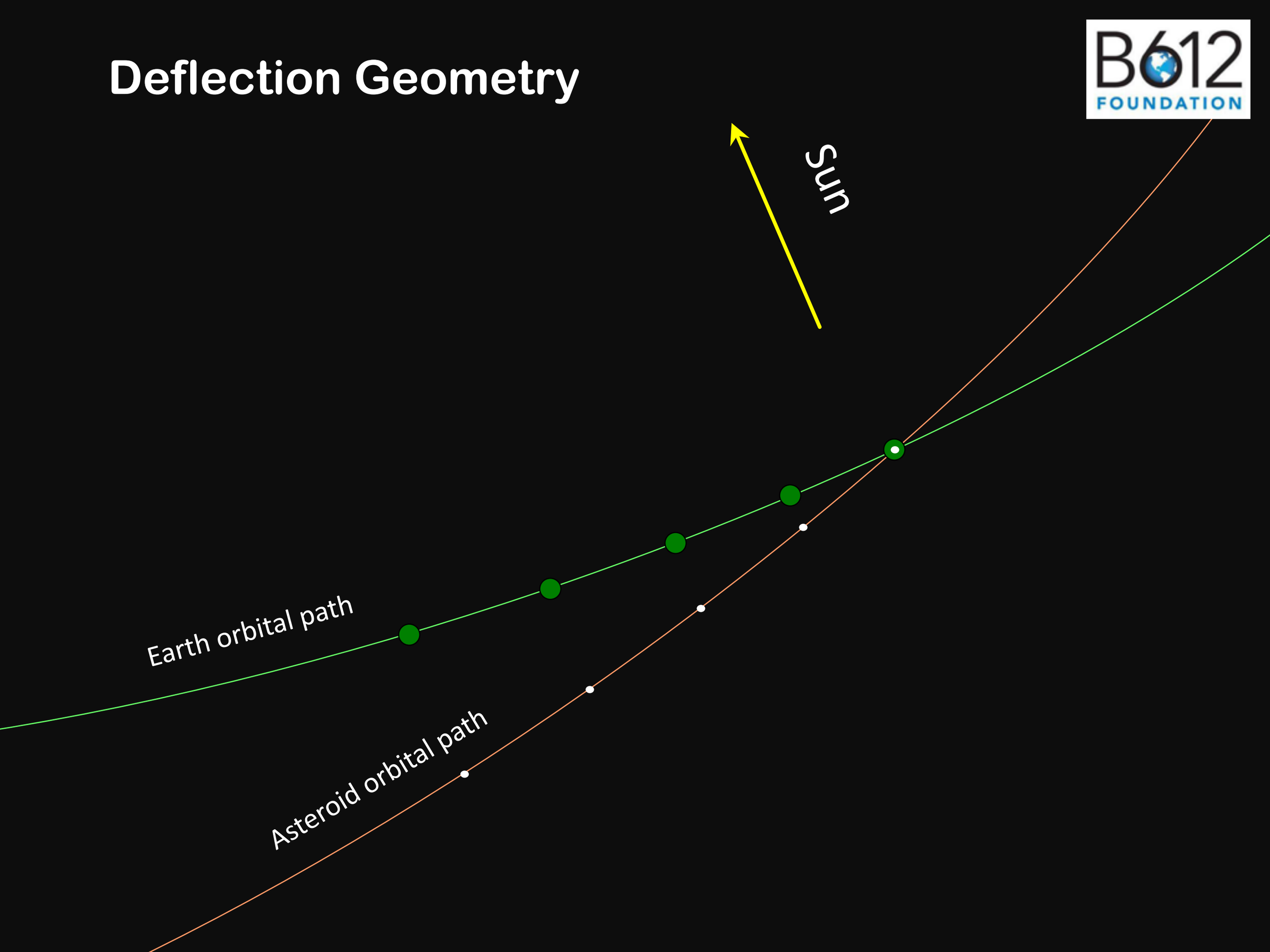
Figure 5 – Estimated cumulative population of NEAs.

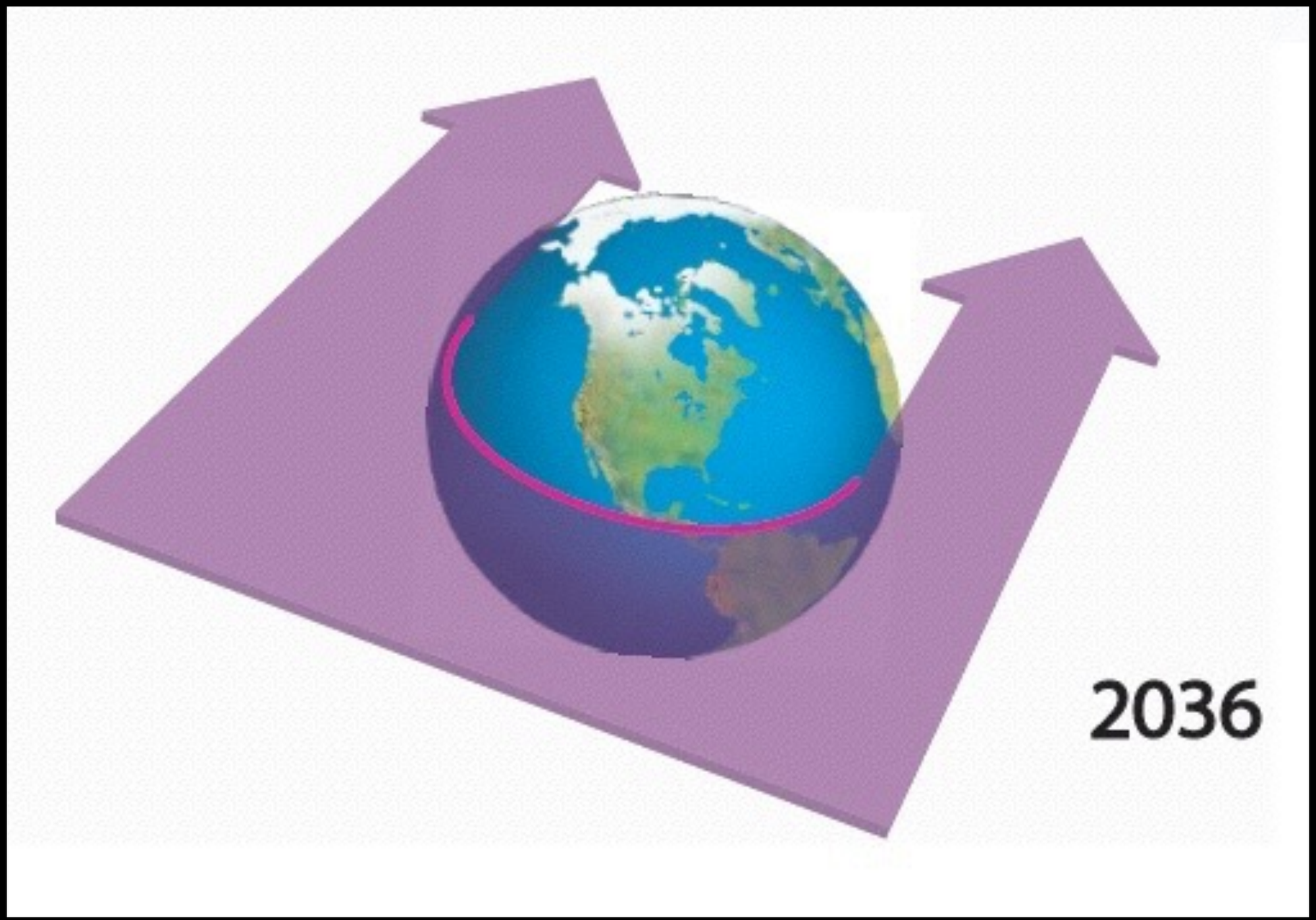

Venus
Earth
Sentinel
Sentinel Field of View




.08
.06
.04
.02
0
Fraction
50m
140m
1
2
5
10
20
50
100
Warning Time [days]

Deflection Geometry



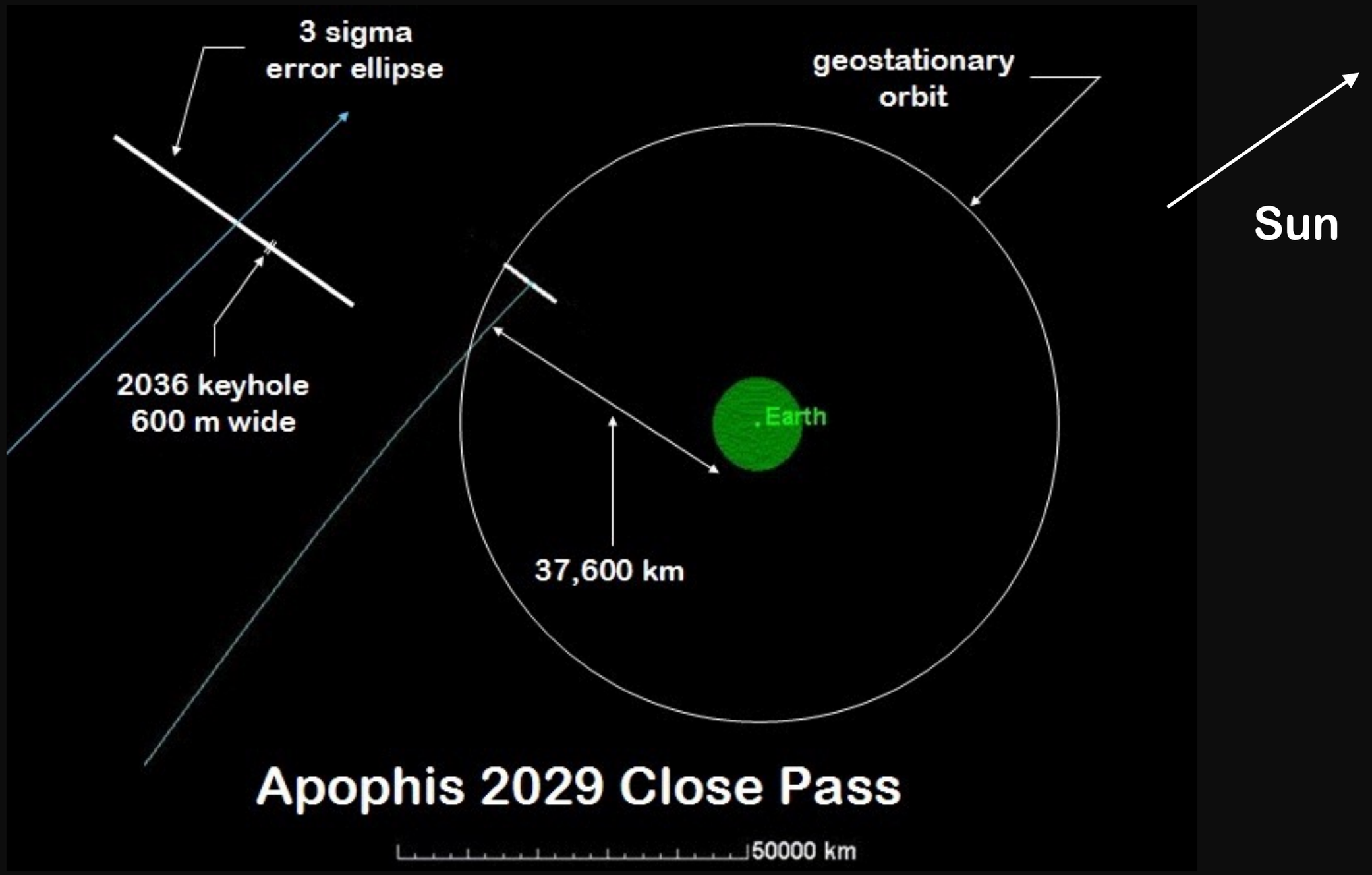

2036

Association of Space Explorers (ASE)

www.space-explorers.org

Geopolitical Decision

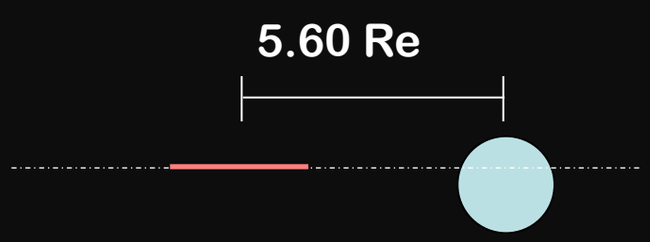

AMERICAN MUSEUM & NATURAL HIST
Defending Earth from Asteroids
with Neil deGrasse Tyson
A panel discussion with the
Association of Sp Explorers
ay, Octob
- 12 PM EST


3 sigma
error ellipse
geostationary
orbit
Sun
2036 keyhole
600 m wide
Earth
37,600 km
Apophis 2029 Close Pass
50000 km

Apophis 2029 close pass

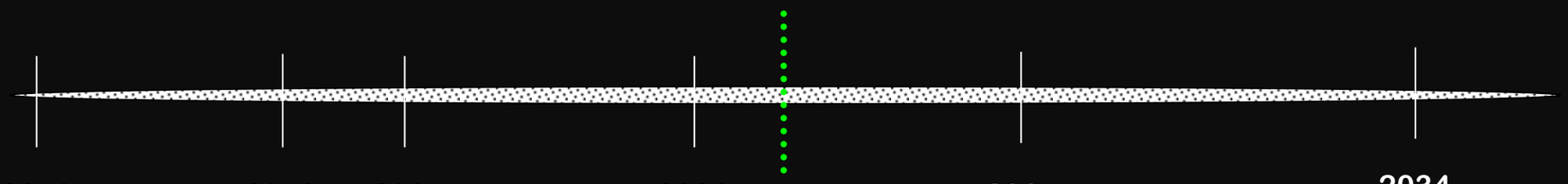
Resonances & Keyholes

Note: all calculations based on JPL data as of 4/11/05.

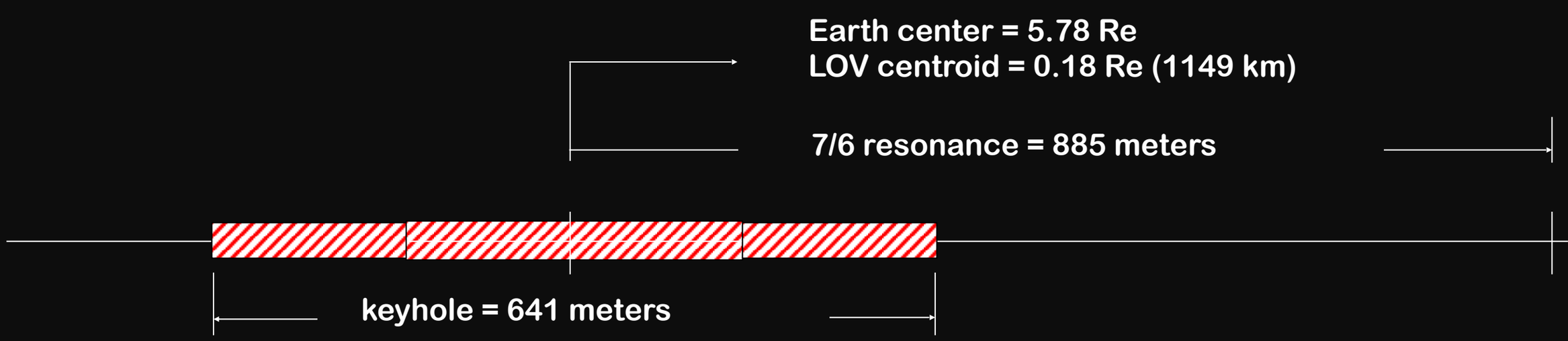


3-sigma error ellipse
2.96 Re
18,960 km

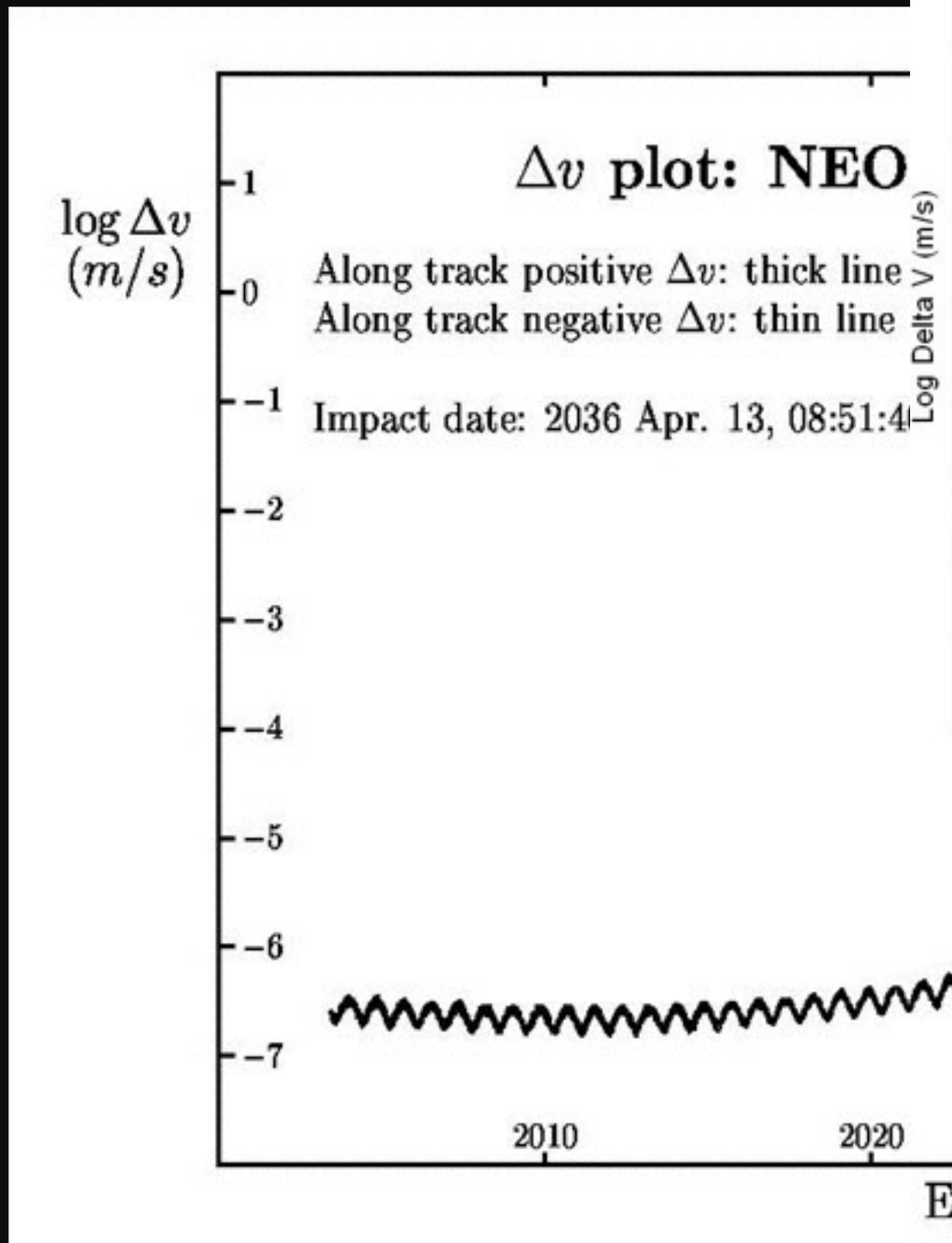
centroid

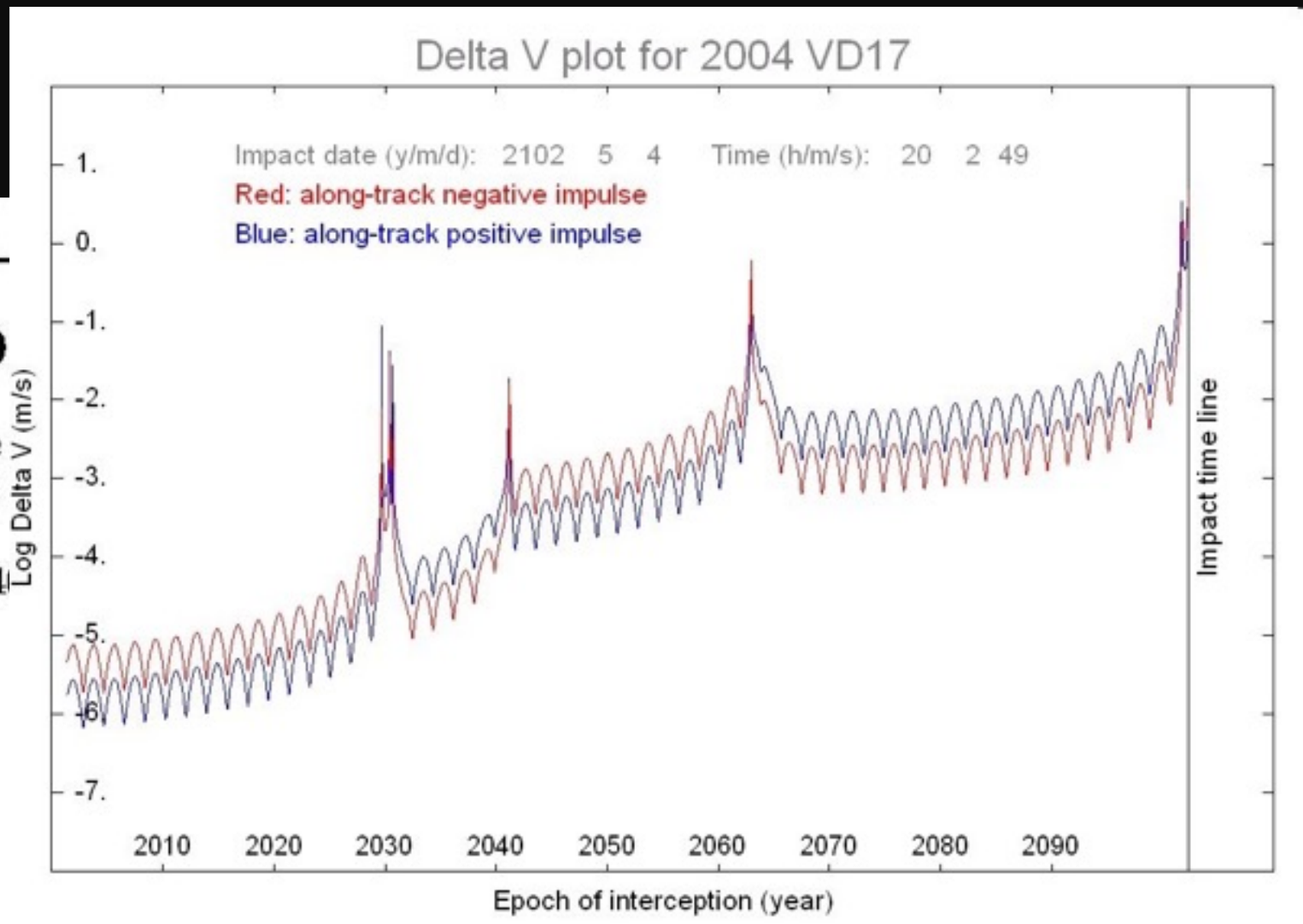


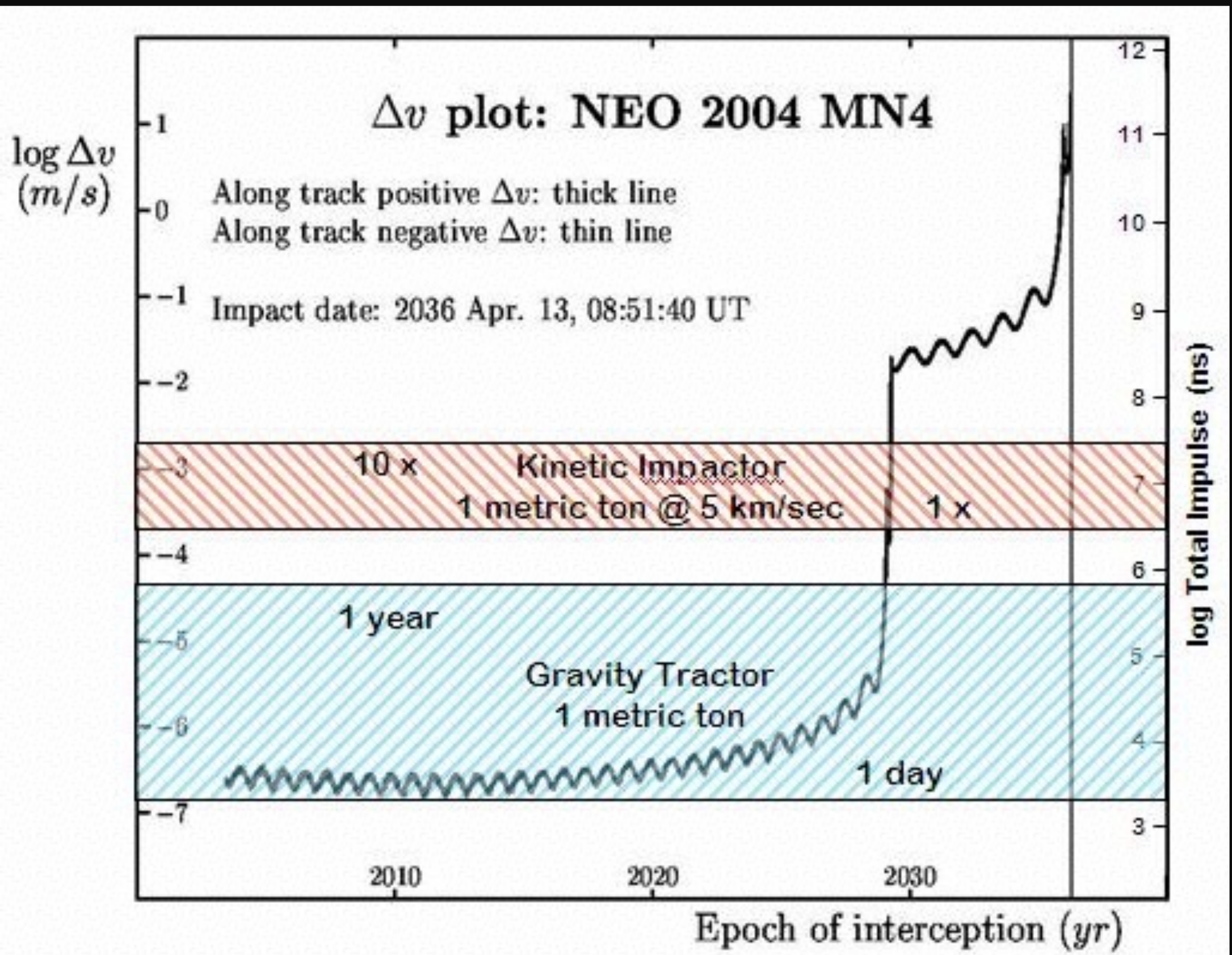
return date	2048	2046	2037	2036	2035	2034
orbital period, days (currently 323 days)	408	414	417	426	438	457



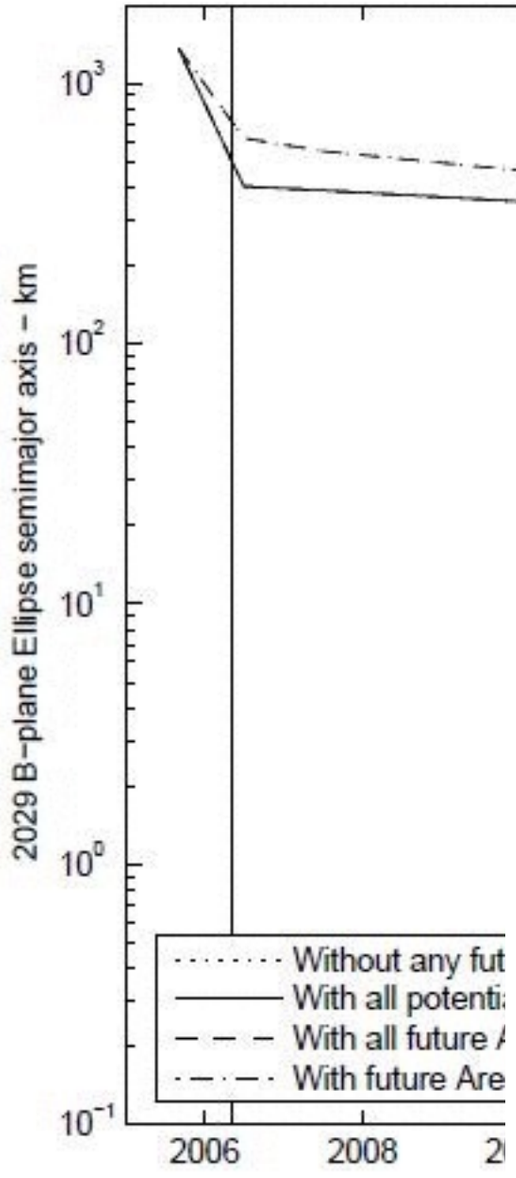
(426.125 days – 3.4 minutes) = Period = 426.125 days

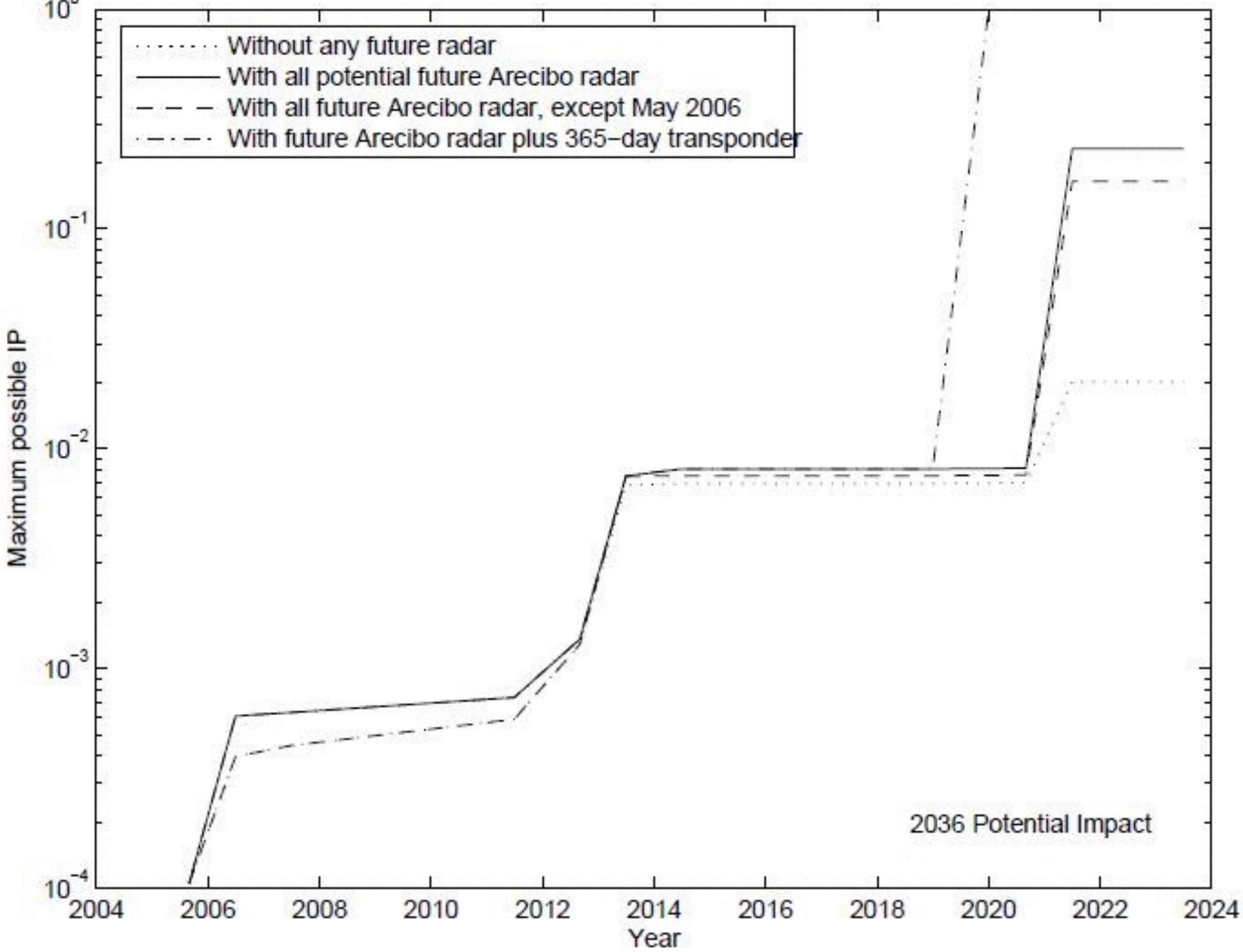

Δv plot: NEO
Along track positive Δv: thick line
Along track negative Δv: thin line
Impact date: 2036 Apr. 13, 08:51:4
$\log \Delta v$ (m/s)
1
0
−1
−2
−3
−4
−5
−6
−7
2010
2020
2030
Epoch of interception (yr)


Delta V plot for 2004 VD17
Impact date (y/m/d): 2102 5 4
Time (h/m/s): 20 2 49
Red: along-track negative impulse
Blue: along-track positive impulse
Log Delta V (m/s)
1.
0.
-1.
-2.
-3.
-4.
-5.
-6.
-7.
2010
2020
2030
2040
2050
2060
2070
2080
2090
Impact time line
Epoch of interception (year)


Δv plot: NEO 2004 MN4
log Δv (m/s)
Along track positive Δv: thick line
Along track negative Δv: thin line
Impact date: 2036 Apr. 13, 08:51:40 UT
10 x
Kinetic Impactor
1 metric ton @ 5 km/sec
1 x
1 year
Gravity Tractor
1 metric ton
1 day
1
0
−1
−2
−3
−4
−5
−6
−7
12
11
10
9
8
7
6
5
4
3
2010
2020
2030
Epoch of interception (yr)
log Total Impulse (ns)

Potential Impact Detection





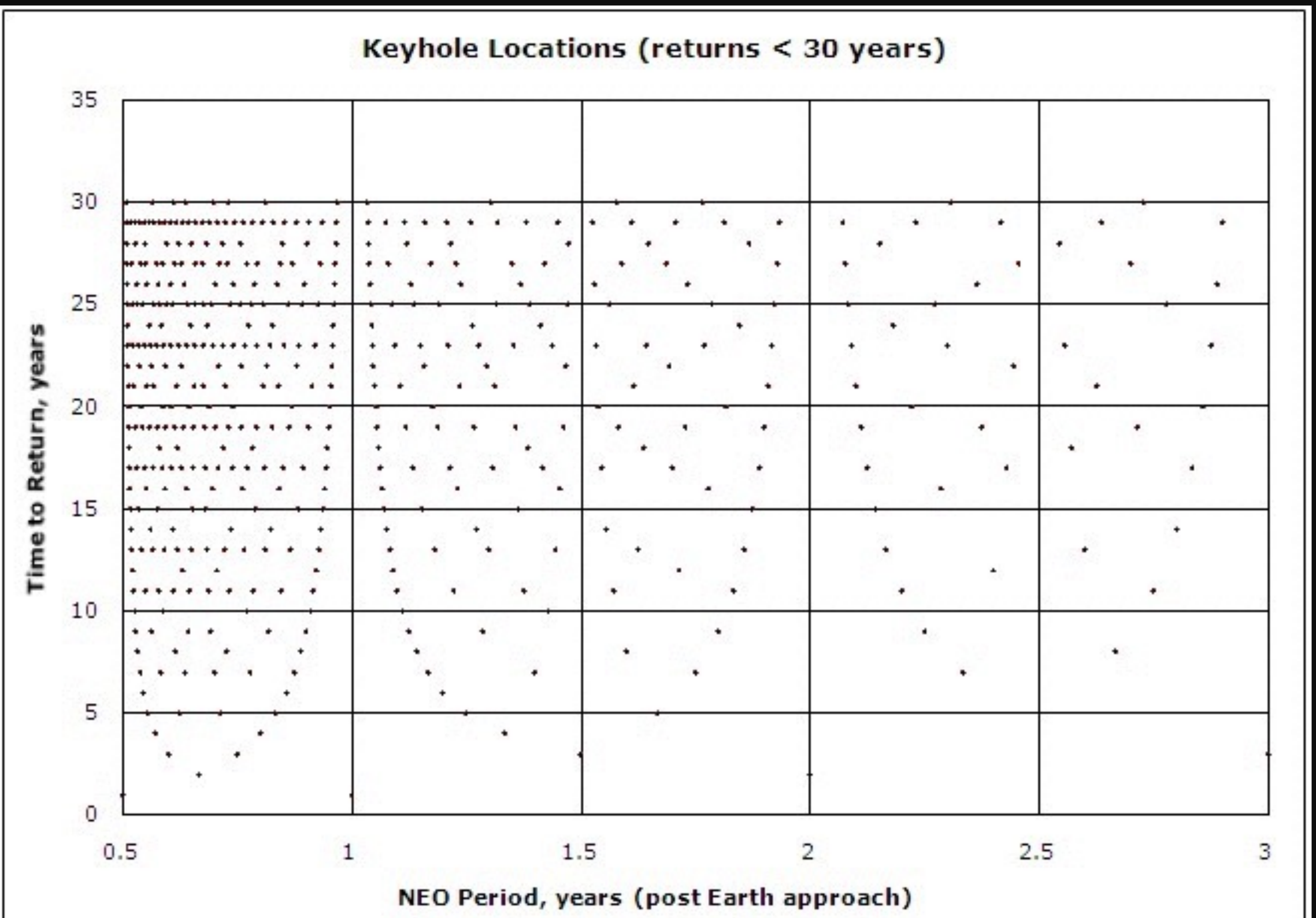
Assumptions and Implications

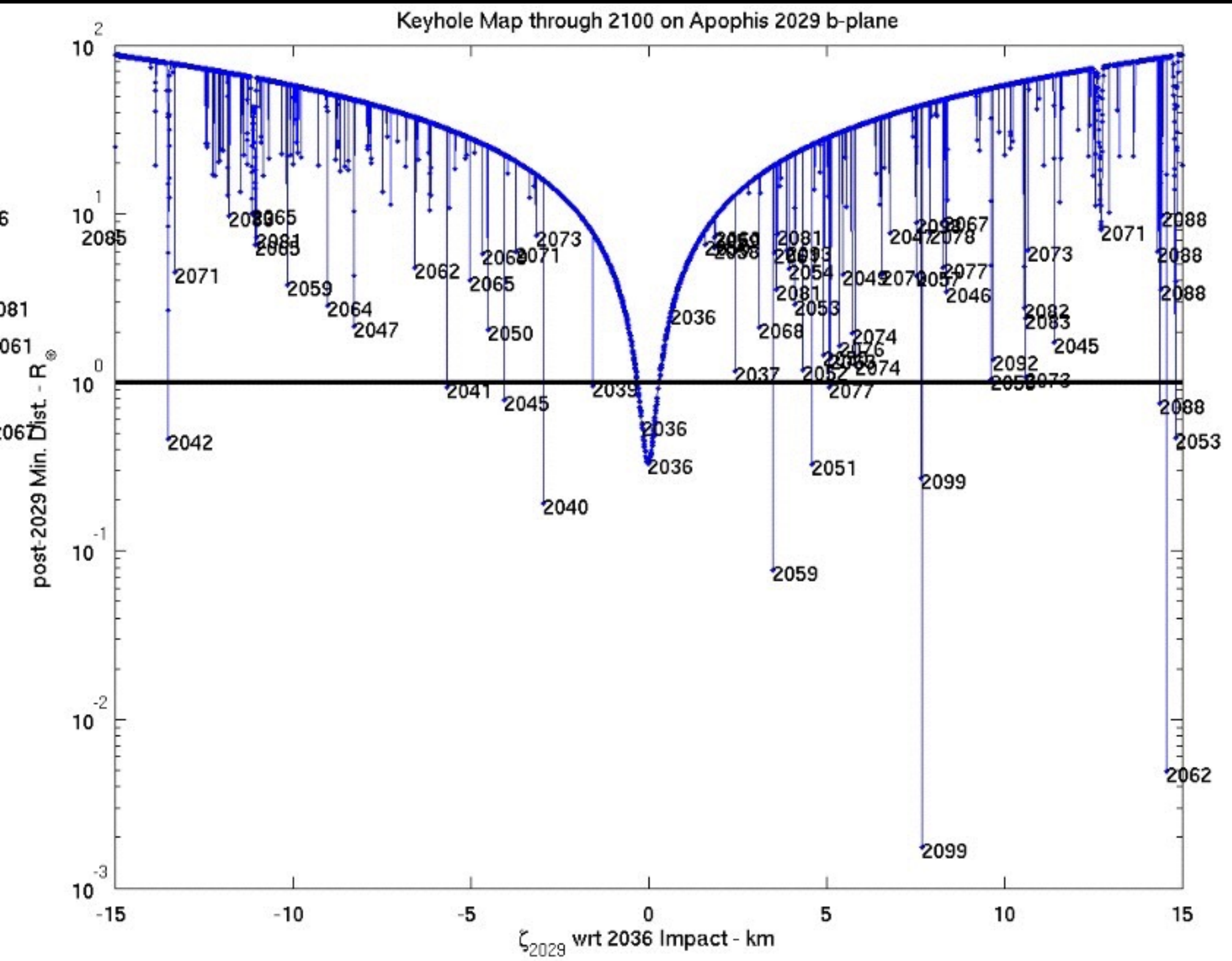
A commitment to deflect will only be made for a direct impact, i.e. after a keyhole passage is confirmed

The likelihood of mounting a successful deflection campaign is critically dependent on immediate response post keyhole passage

Radar confirmation of keyhole passage is essential to maximize success potential

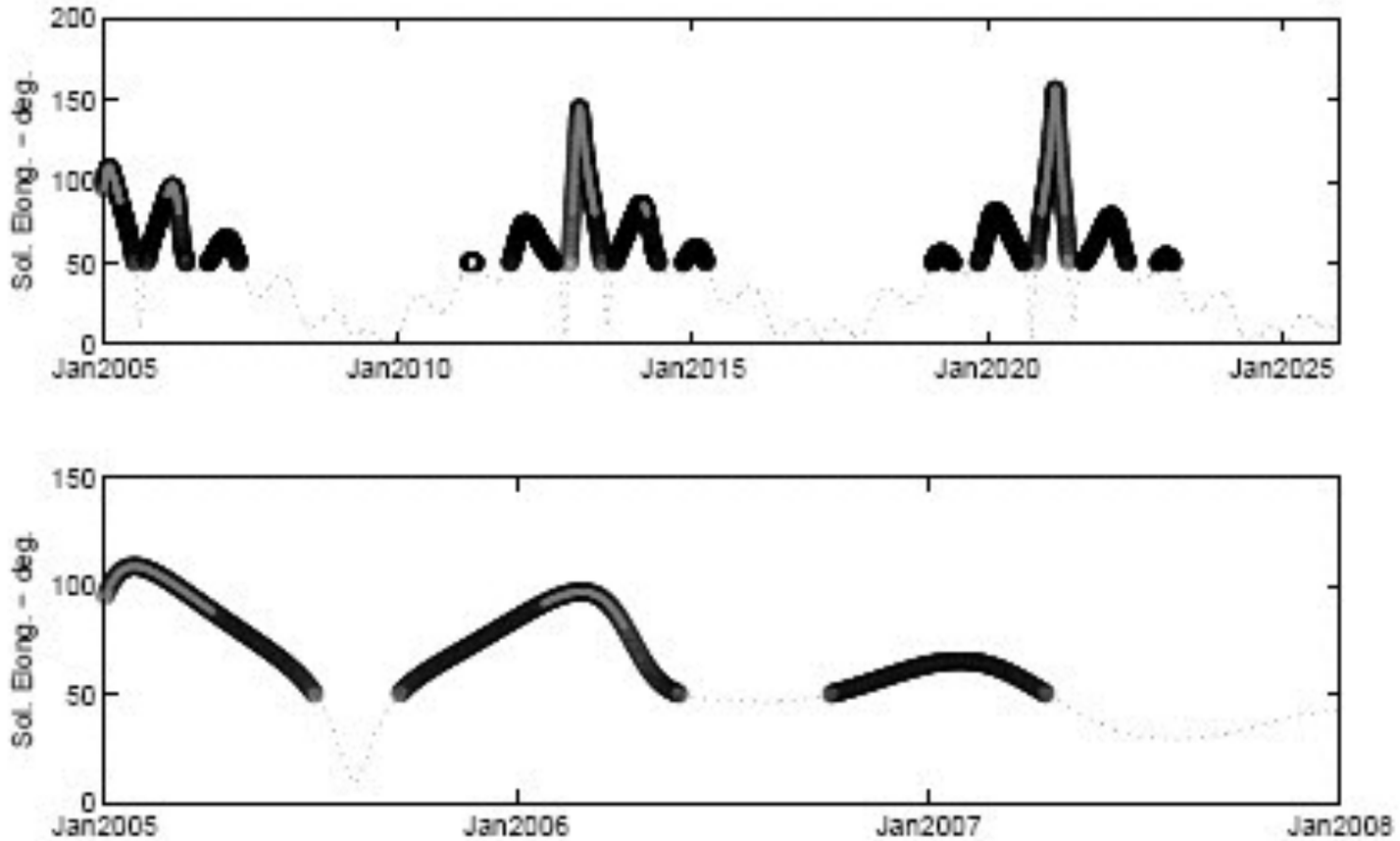
The likelihood of the need for the use of nuclear explosives is maximized by this geopolitical reality

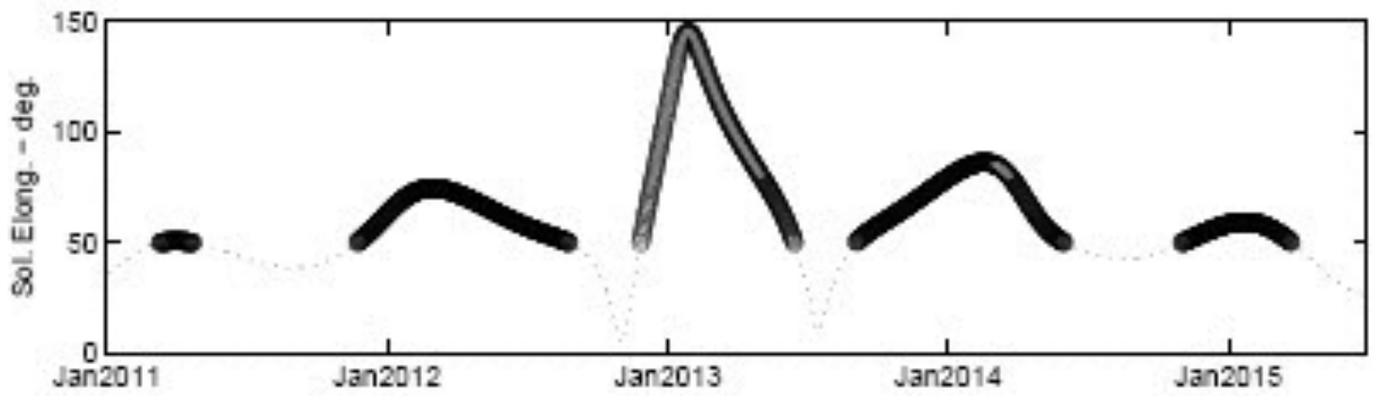

Keyhole Locations (returns < 30 years)
Time to Return, years
35
30
25
20
15
10
5
0
0.5
1
1.5
2
2.5
3
NEO Period, years (post Earth approach)

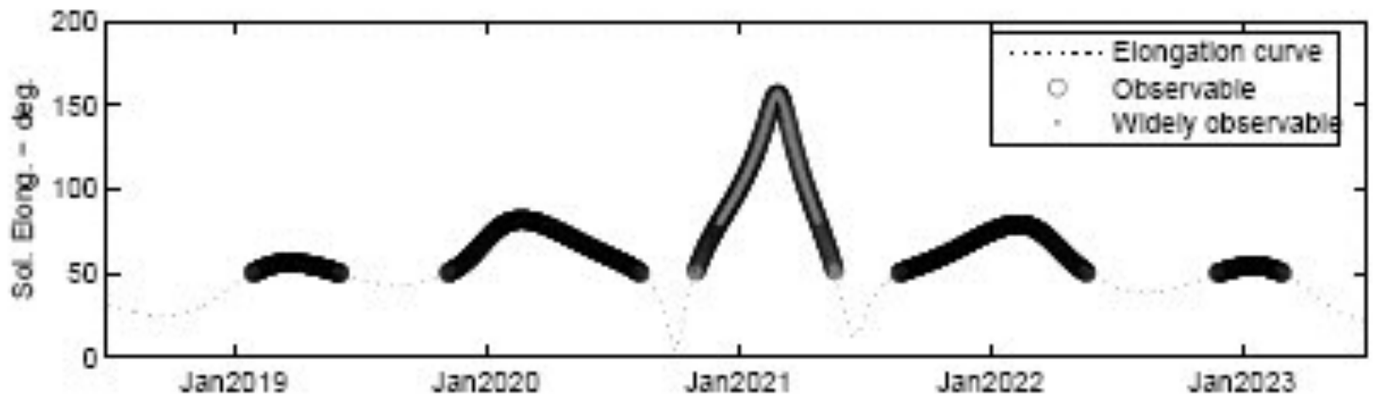


Keyhole Map through 2100 on Apophis 2029 b-plane
post-2029 Min. Dist. - R⊕
ζ2029 wrt 2036 Impact - km
10^2
10^1
10^0
10^-1
10^-2
10^-3
-15
-10
-5
0
5
10
15
2085
2071
2059
2064
2047
2062
2065
2050
2073
2071
2041
2045
2039
2042
2040
2036
2036
2036
2037
2068
2081
2054
2053
2074
2077
2051
2059
2099
2099
2047
2078
2067
2077
2046
2073
2082
2083
2045
2092
2071
2088
2088
2088
2088
2053
2062

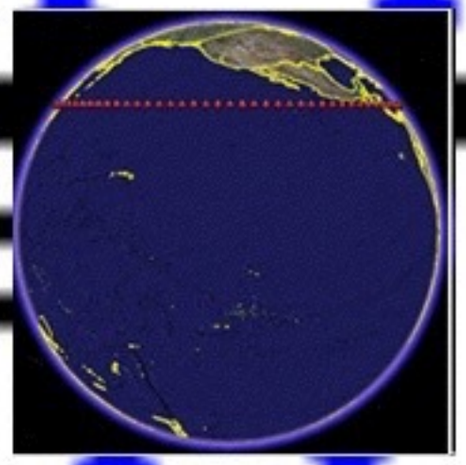
Potential Impact Detection







Earth to left in b-plane



2039

Earth to left in b-plane

2039