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SWF-ASE-ESA

NEO Workshop - MPOG

27-29 October 2010

Implementation of the MPOG

(Mission Planning and Operations Group)

Rusty Schweickart
ASE-NEO Committee

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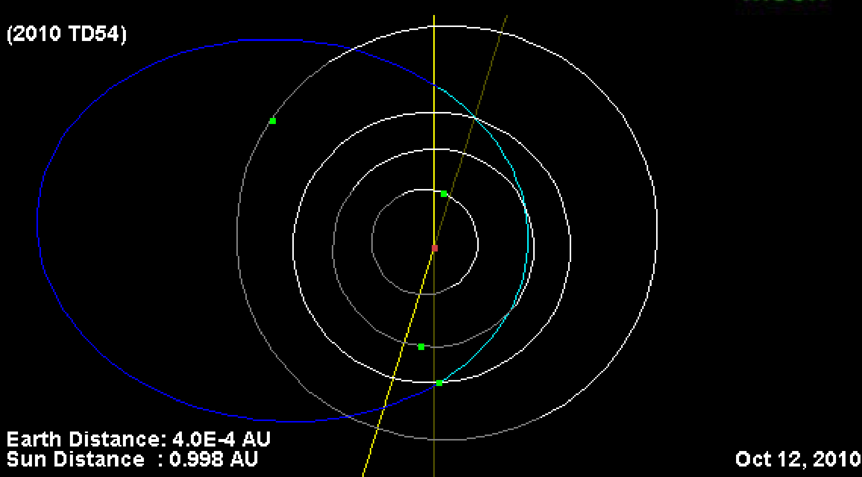
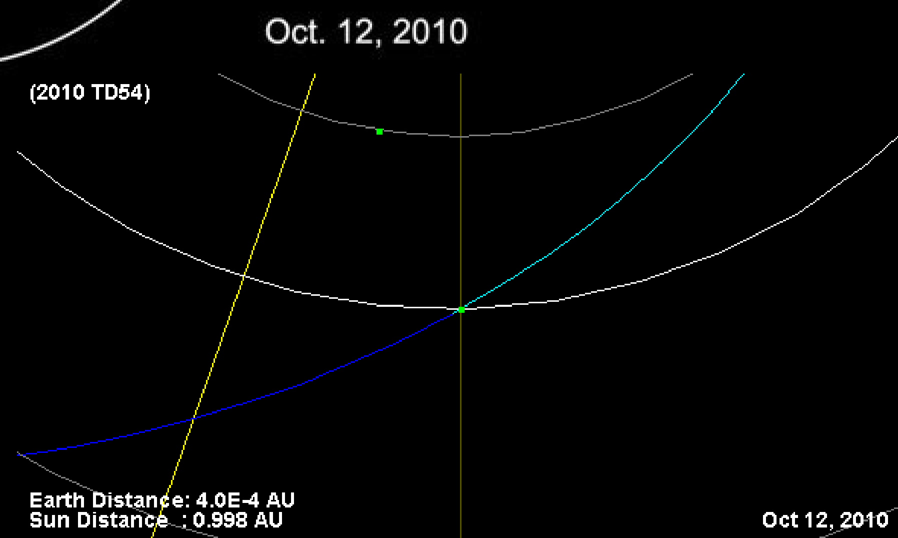
Dia = ~ 7 meter
Vinf =17.1 km/sec
Min miss = ~ 45K km (8.3 Earth radii)
Energy imp = ~ 250 KT





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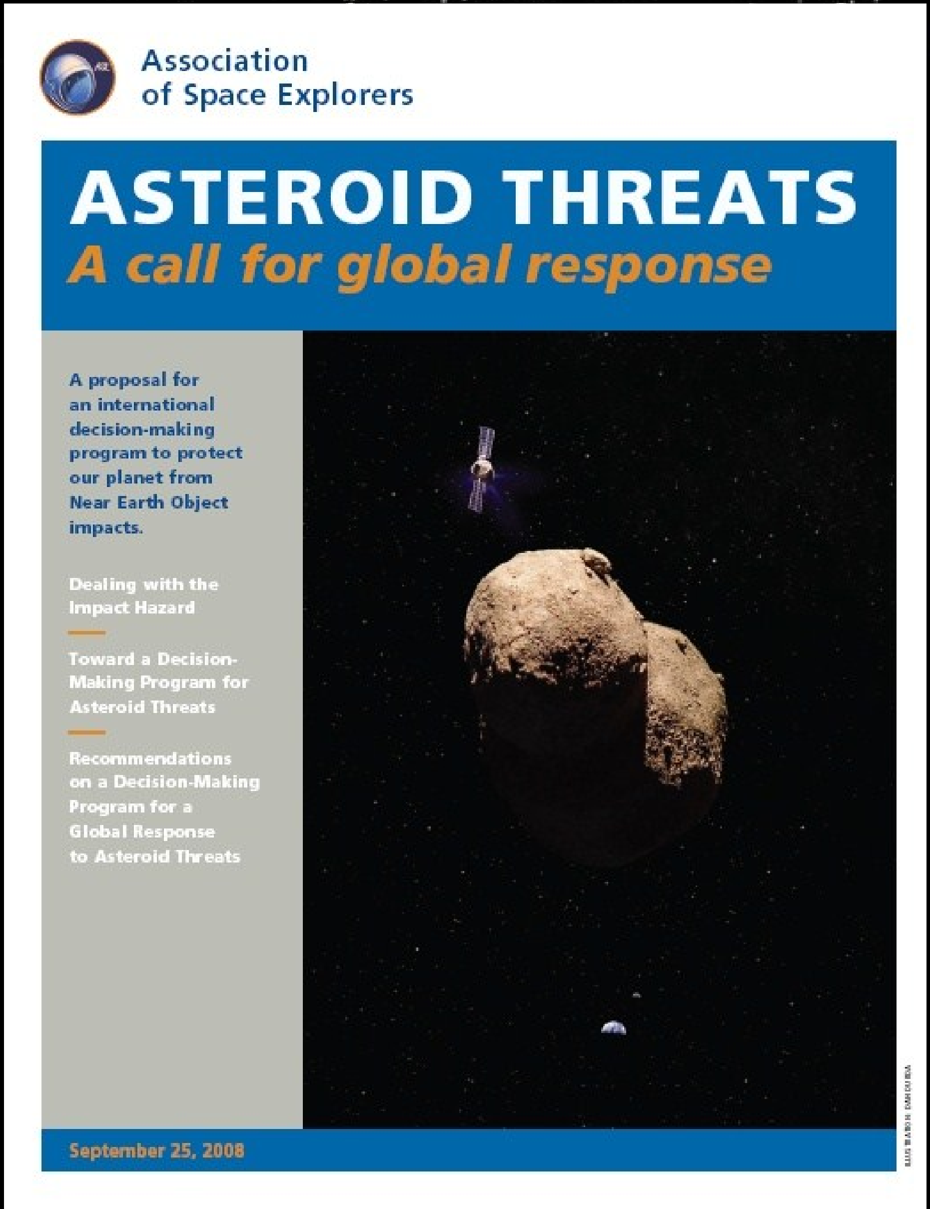
A Decision Program re NEO threats, submitted to the UN by the ASE and its international Panel on Asteroid Threat Mitigation

Presented to STSC in February 09 & full COPUOS in June 09. Being coordinated within COPUOS by Action Team-14



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Members of the ASE Committee on Near Earth Objects

Rusty Schweickart, Chair
Sergei Avdeev (Russia)
Chris Hadfield (Canada)
Thomas Jones (USA)
Edward Lu (USA)
Dumitru Prunariu (Romania)
Viktor Savinykh (Russia)
Franklin Chang-Diaz (USA/Costa Rica)

Members of the Panel on Asteroid Threat Mitigation

Adigun Ade Abiodun, Nigeria
Vallampadugai Arunachalam, India
Roger-Maurice Bonnet, Switzerland
Sergio Camacho-Lara, Mexico
James George, Canada
Tomifumi Godai, Japan
Peter Jankowitsch, Austria
Sergey Kapitza, Russia
Paul Kovacs, Canada
Walther Lichem, Austria
Gordon McBean, Canada
Lord Martin Rees, United Kingdom
Karlene Roberts, United States
Michael Simpson, United States
Sir Crispin Tickell, United Kingdom
Richard Tremayne-Smith, United Kingdom
Frans von der Dunk, Netherlands
James Zimmerman, United States

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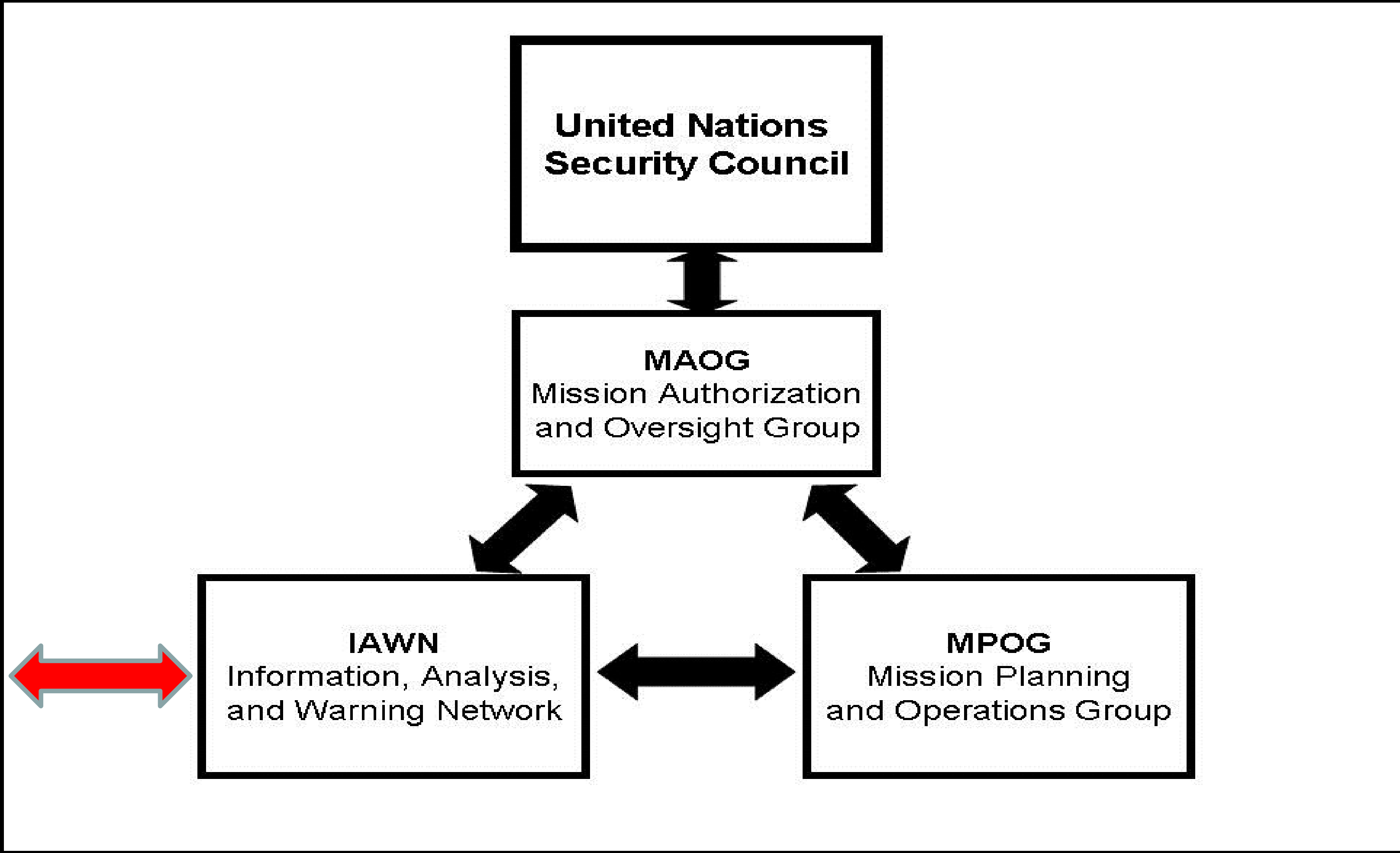
Key Recommendations
Defined functional responsibilities



Agenda

1) Early Warning
2) Orbital Dynamics
3) Deflection Options

Early Warning

1) NEO Inventory
2) Statistical size-frequency distribution
3) Future discovery rate

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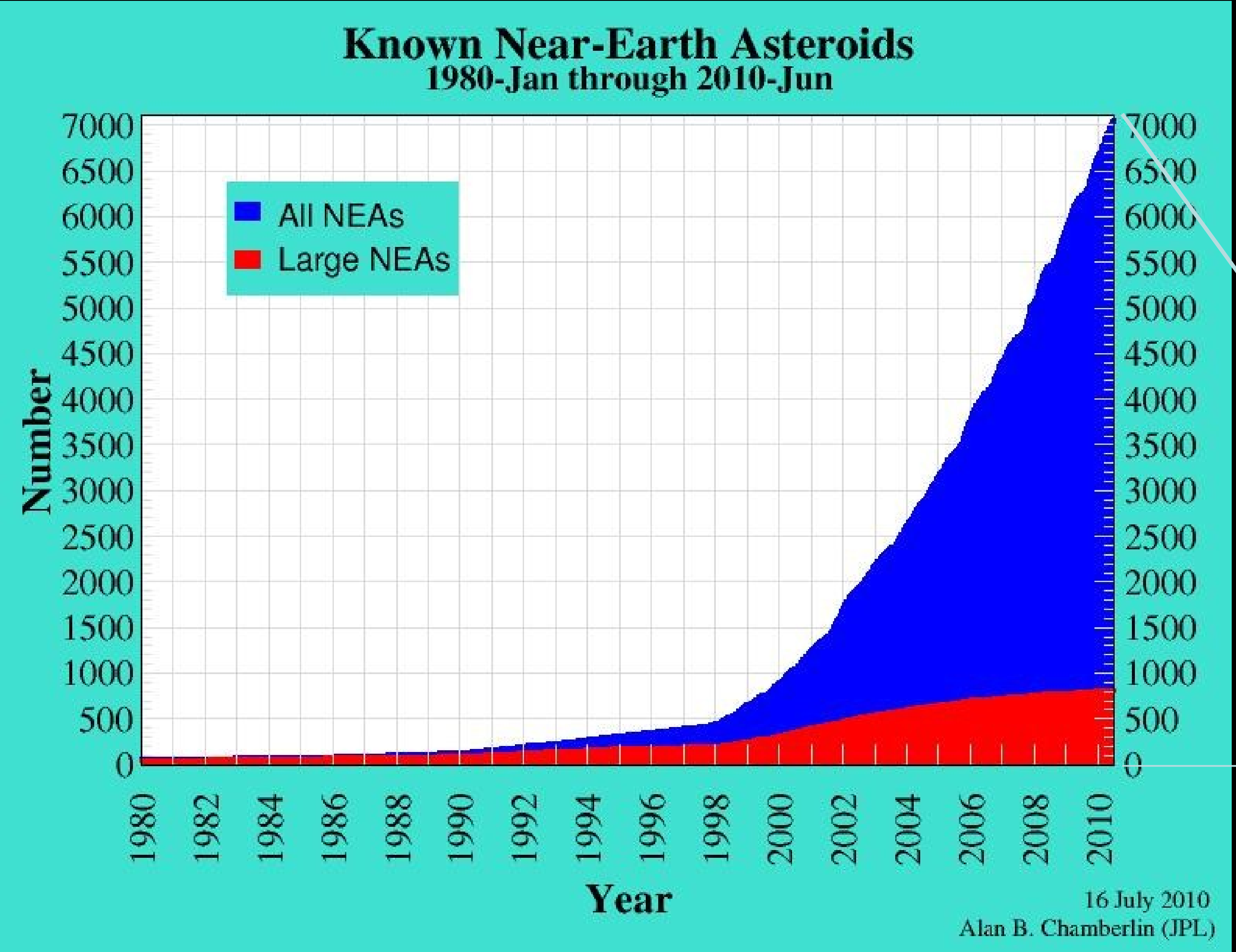

> 1,000,000 Total by ~2025

> 300,000 Tunguska or larger

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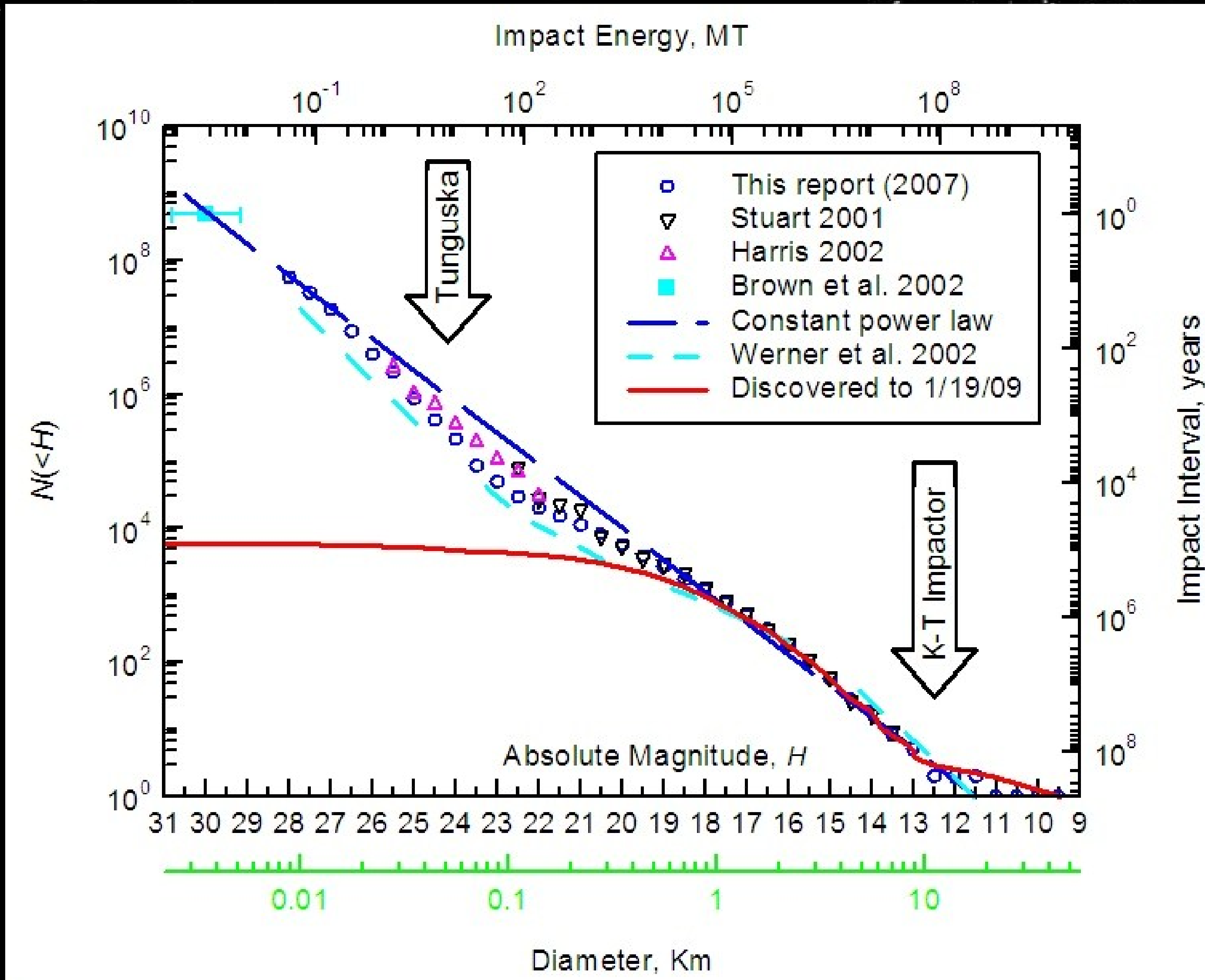

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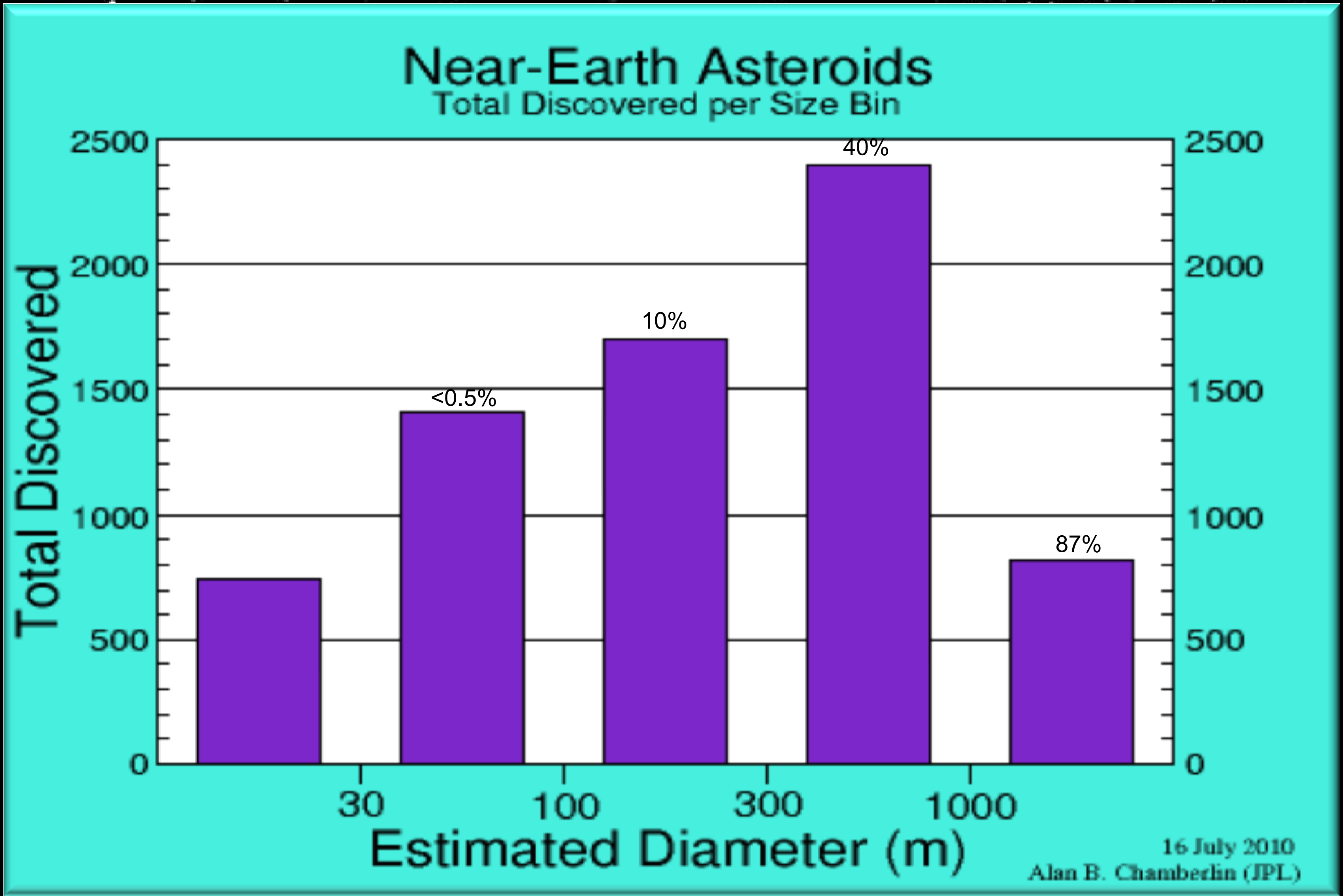

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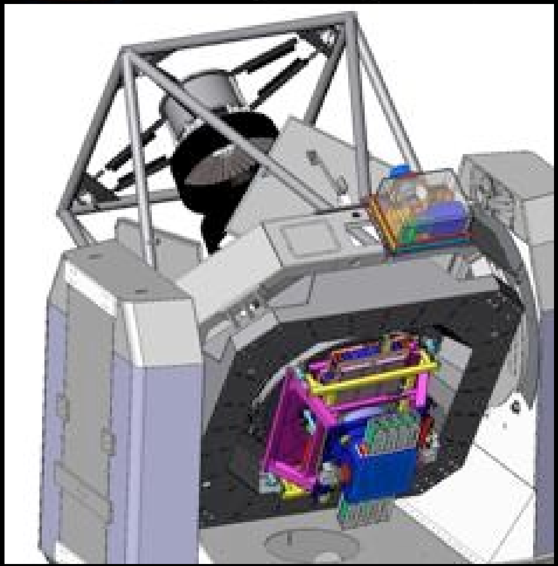

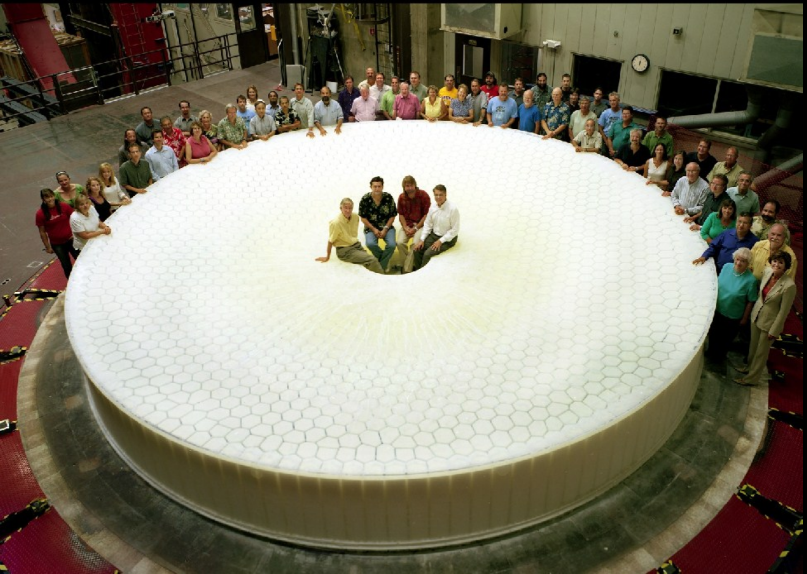

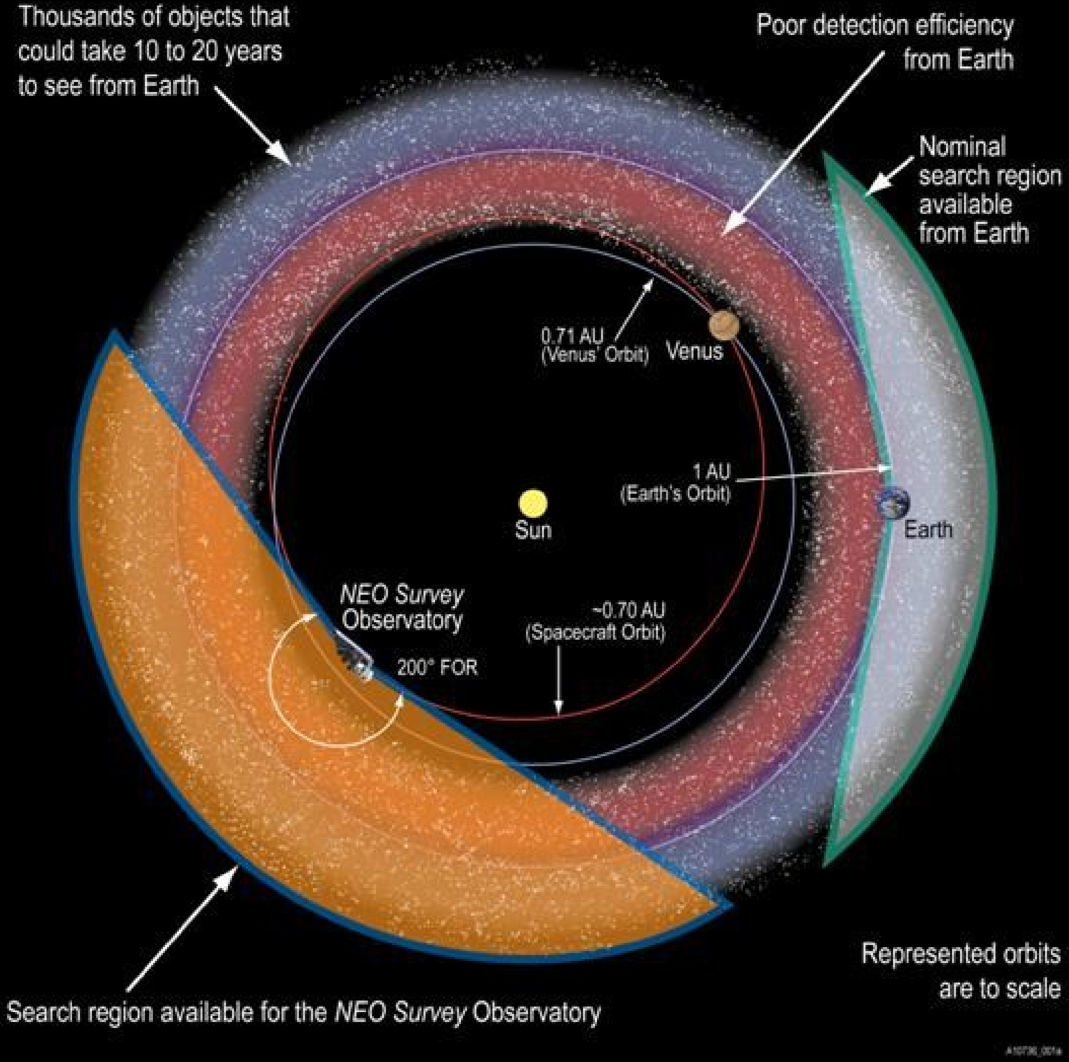

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These results were computed on Oct 07, 2009

99942 Apophis (2004 MN4)
Earth Impact Table

Date	Distance	Width	Sigma Impact	Sigma LOV	Stretch LOV	Impact Probability	Impact Energy	Palermo Scale	Torino Scale
YYYY-MM-DD.DD	(r_{Earth})	(r_{Earth})			(r_{Earth})		(MT)		
2036-04-13.37	0.53	< 1.e-04	0.000	-3.276	1.03e+03	4.3e-06	5.06e+02	-3.08	0
2056-04-13.37	0.66	< 1.e-04	0.000	0.304	5.53e+06	1.0e-07	5.06e+02	-4.97	0
2068-04-13.37	0.02	< 1.e-04	0.000	0.335	3.11e+05	2.5e-06	5.06e+02	-3.70	0
2068-04-13.37	0.00	< 1.e-04	0.000	1.039	4.09e+06	1.1e-07	5.06e+02	-5.04	0
2076-04-13.37	0.10	< 1.e-04	0.000	0.350	3.35e+06	2.2e-07	5.06e+02	-4.79	0
2103-04-13.37	0.61	< 1.e-04	0.000	0.334	4.25e+06	1.3e-07	5.06e+02	-5.17	0

Energy	5.1e+02 MT

all above are mean values weighted by impact probability

Analysis based on 2 radar delay, 5 Doppler, and 633 optical observations spanning 1395.6 days (2004-Mar-15.10789 to 2008-Jan-09.665088)

Orbit diagram and elements available here.

Object Design									
101955									
2007 V									
99942									
1994 W									
1979 X									
2010 A									
2000 SG344	2068-2073	12	1.3e-03	1.38	24.8	0.037	-3.13	-3.39	0
2006 QV89	2019-2042	14	3.2e-04	5.17	25.3	0.030	-3.17	-3.18	0
2008 CK70	2030-2031	2	2.9e-04	15.29	25.2	0.031	-3.17	-3.17	0

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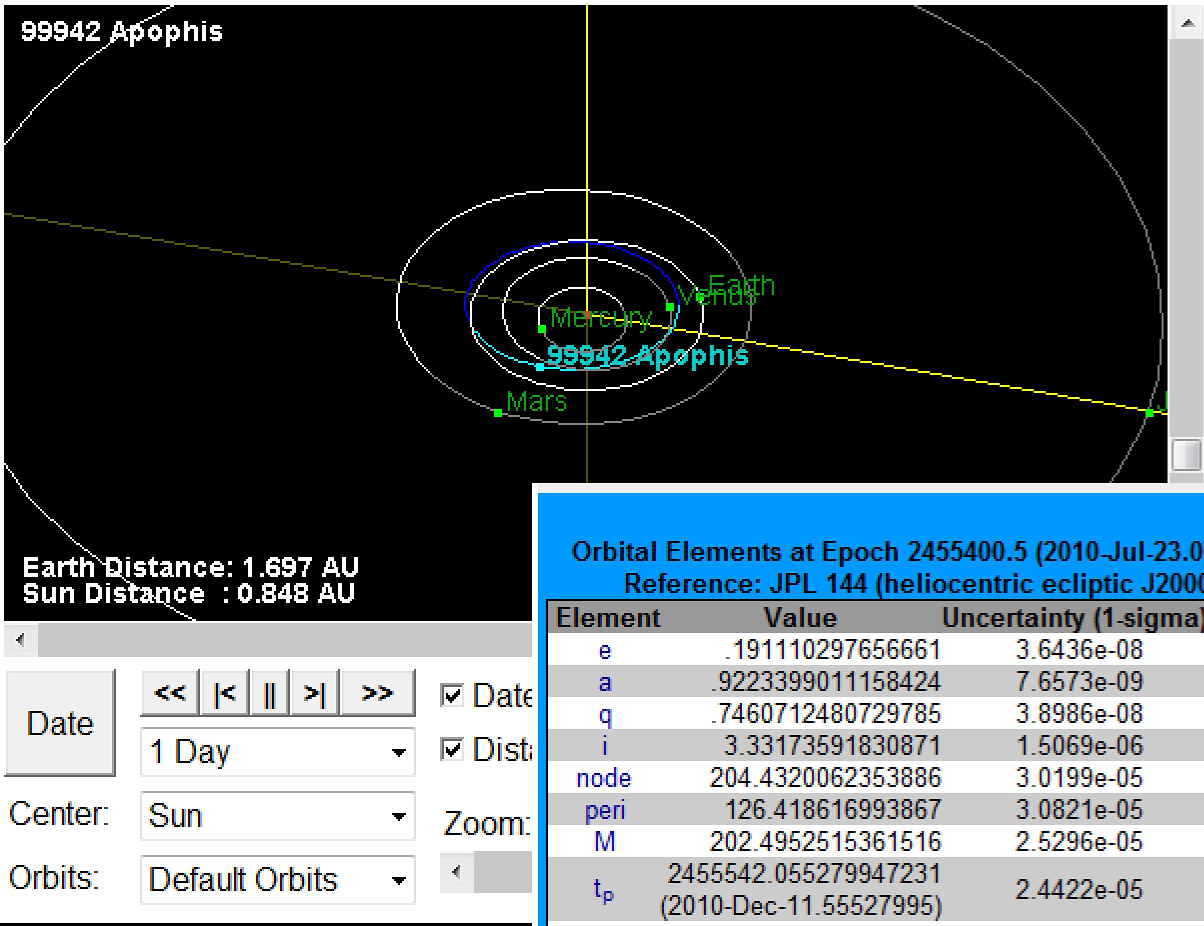

Orbital Elements at Epoch 2455400.5 (2010-Jul-23.0) TDB
Reference: JPL 144 (heliocentric ecliptic J2000)

Element	Value	Uncertainty (1-sigma)	Units
e	.1911029765661	3.6436e-08	
a	.9223399011158424	7.6573e-09	AU
q	.7460712480729785	3.8986e-08	AU
i	3.33173591830871	1.5069e-06	deg
node	204.4320062353886	3.0199e-05	deg
peri	126.418616993867	3.0821e-05	deg
M	202.4952515361516	2.5296e-05	deg
t_p	2455542.055279947231 (2010-Dec-11.55527995)	2.4422e-05	JED
period	323.5451710378104	4.0291e-06	d
	0.89	1.103e-08	yr
n	1.112673073887199	1.3856e-08	deg/d
Q	1.098608554158706	9.1207e-09	AU

Orbit Determination Parameters

# obs. used (total)	640
# delay obs. used	2
# Doppler obs. used	5
data-arc span	1395 days (3.82 yr)
first obs. used	2004-03-15
last obs. used	2008-01-09
planetary ephem.	DE405
SB-pert. ephem.	SB-BIG16-1
condition code	0
fit RMS	.48956
data source	ORB
producer	Steven R. Chesley
solution date	2009-Oct-23 11:54:34

Additional Information

Earth MOID = 8.12667E-5 AU
T_jup = 6.467

Orbital Dynamics

1) Geometry
2) Line of Variations (LOV)
3) Keyholes
4) Risk corridor & implications

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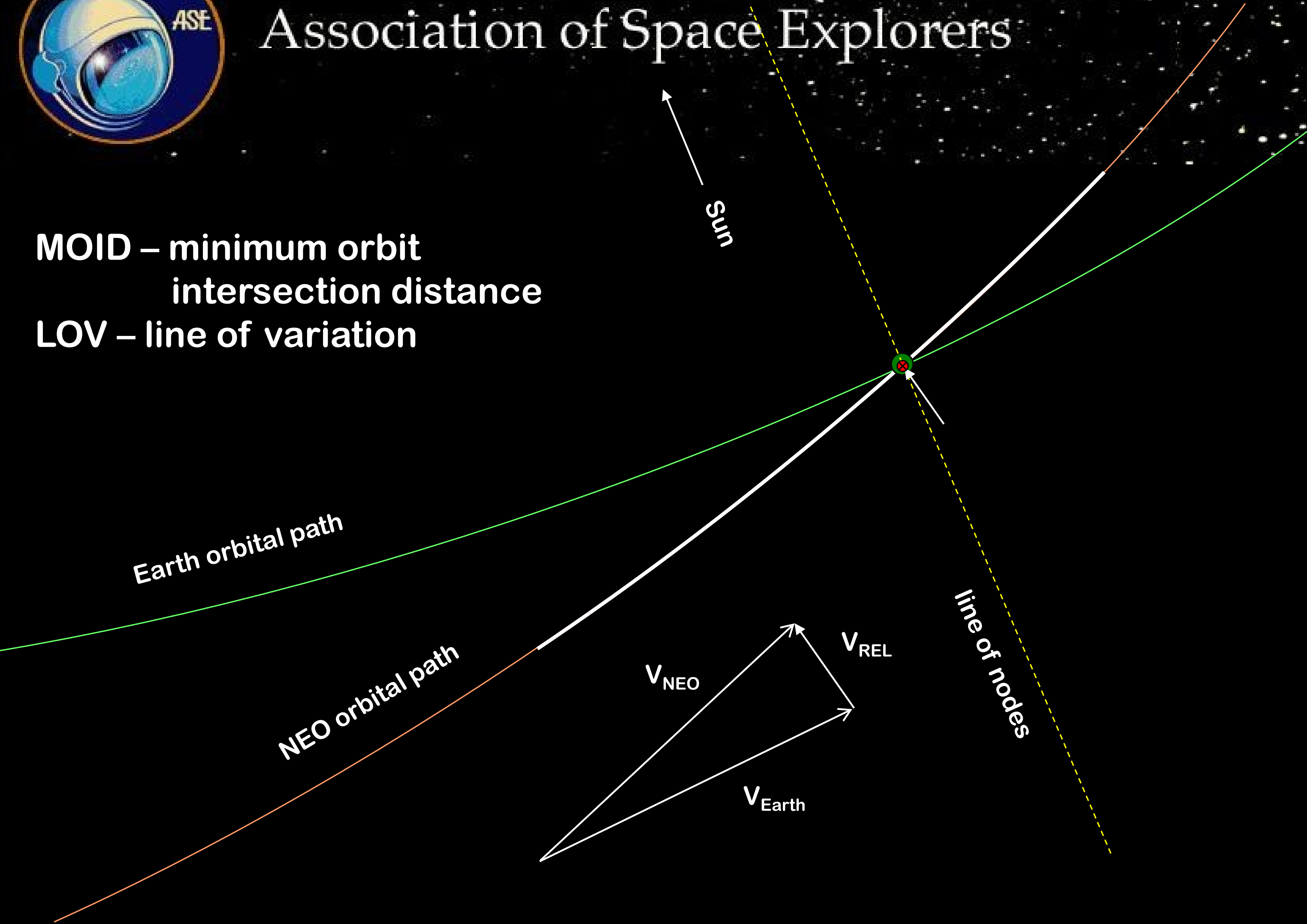
MOID – minimum orbit intersection distance

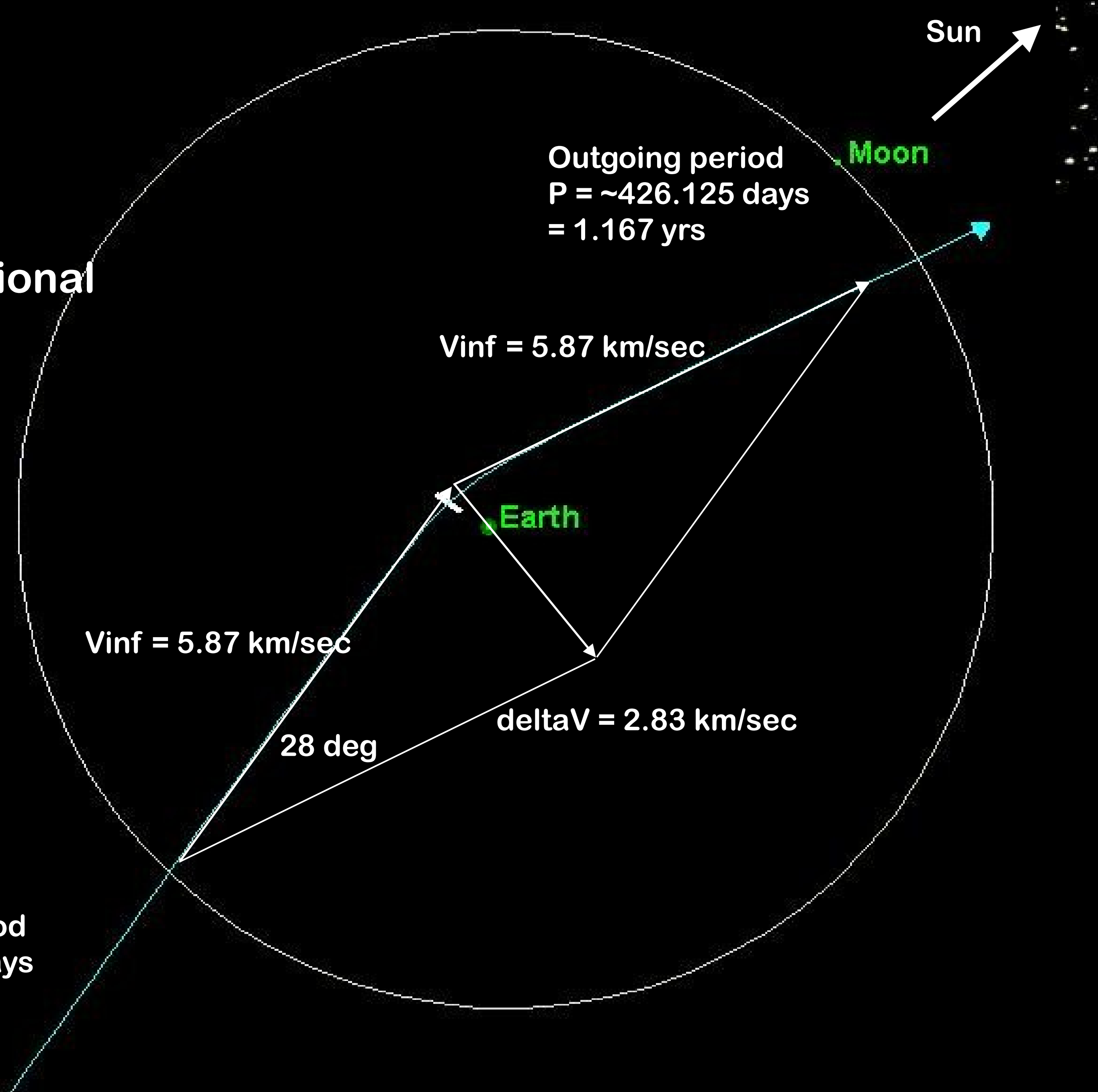
LOV – line of variation



cge – close gravitational encounter

Apophis

close encounter geometry
Friday, 13 April 2029
~21:00 UT



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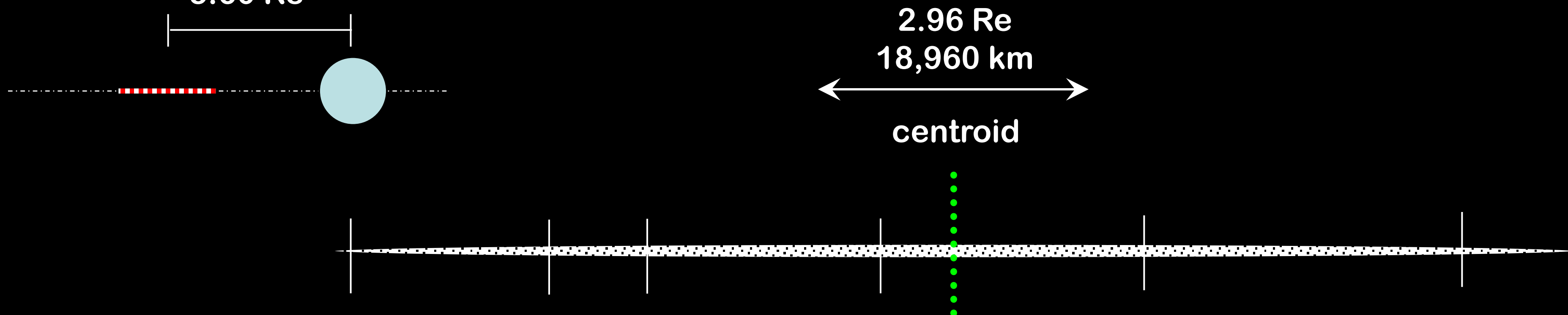
Resonances & Keyholes
Early Apophis situation as example

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



(426.125 days – 3.4 minutes) = Period = 426.12499 days

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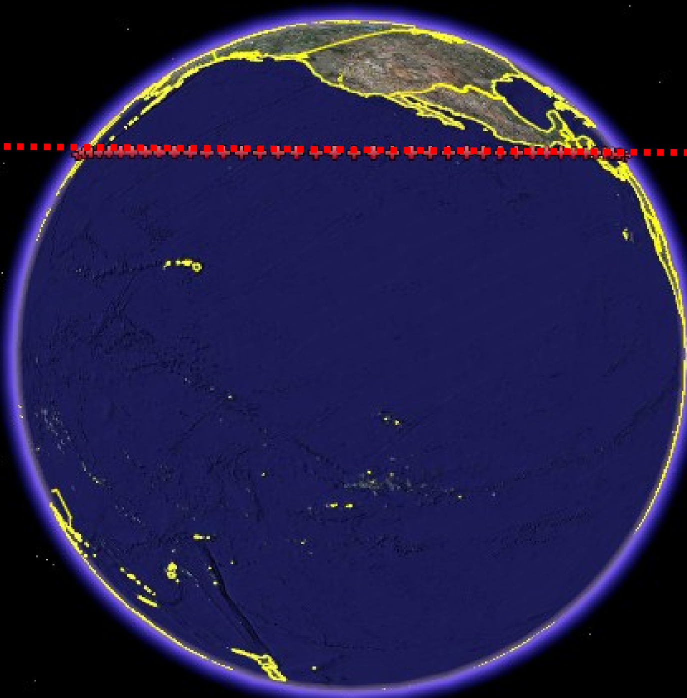
Both strength <u>AND</u> precision are needed for a successful deflection campaign

Total impulse required
1.15e8 newton seconds
10900 kilometers
(5140 x 2.12)

Primary Deflection =
Miss the Earth

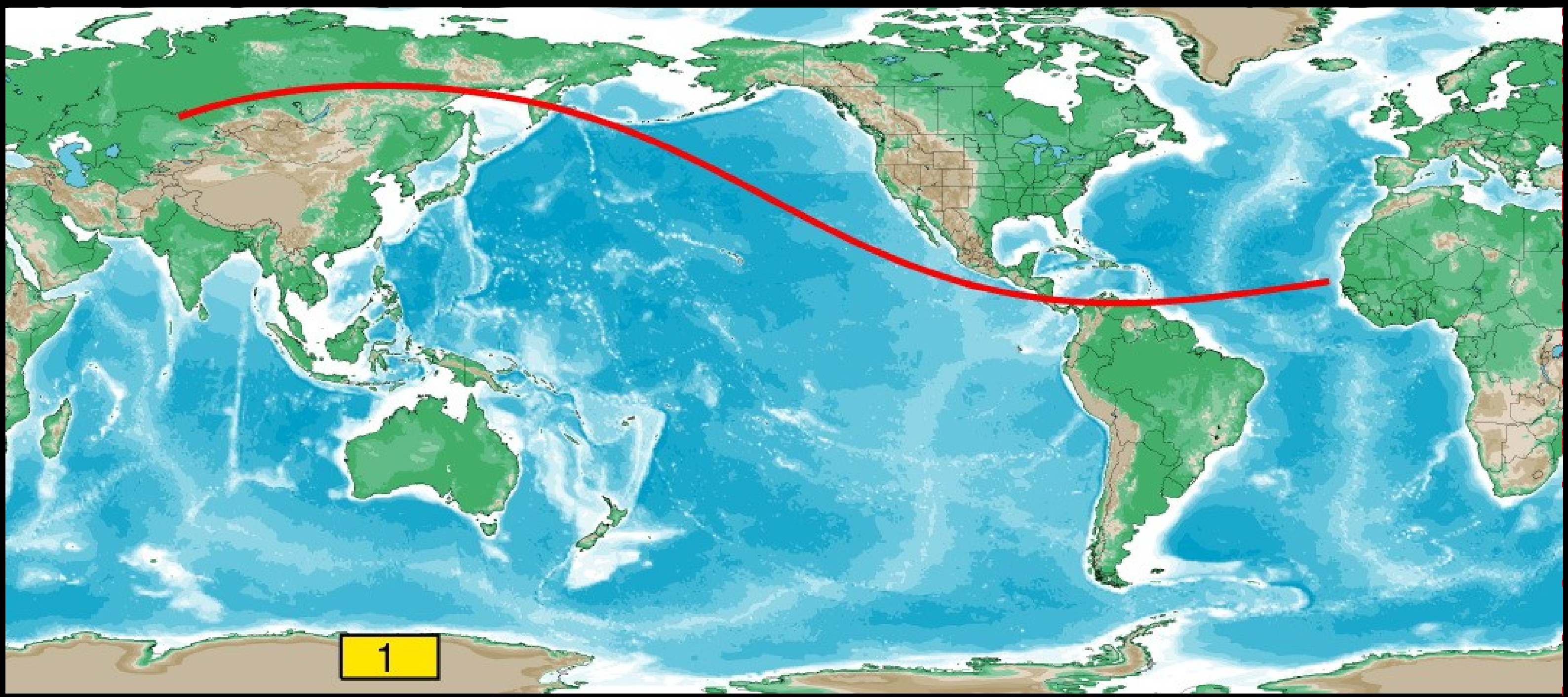


Shepherding =
Guide between keyholes

Total impulse required
1e4 newton seconds
0.6 kilometers

12,840 kilometers

F Risk Corridor, Apophis, 13 Apr 2036 ?



Deflection Options
(characteristics & capabilities)

1) ΔV required (1 Earth radius)
2) Targetting (minimum miss?)
3) Precision to avoid Keyholes
4) Kinetic Impact & Nuclear
5) Gravity tractor (or equivalent)
6) Deflection Campaign

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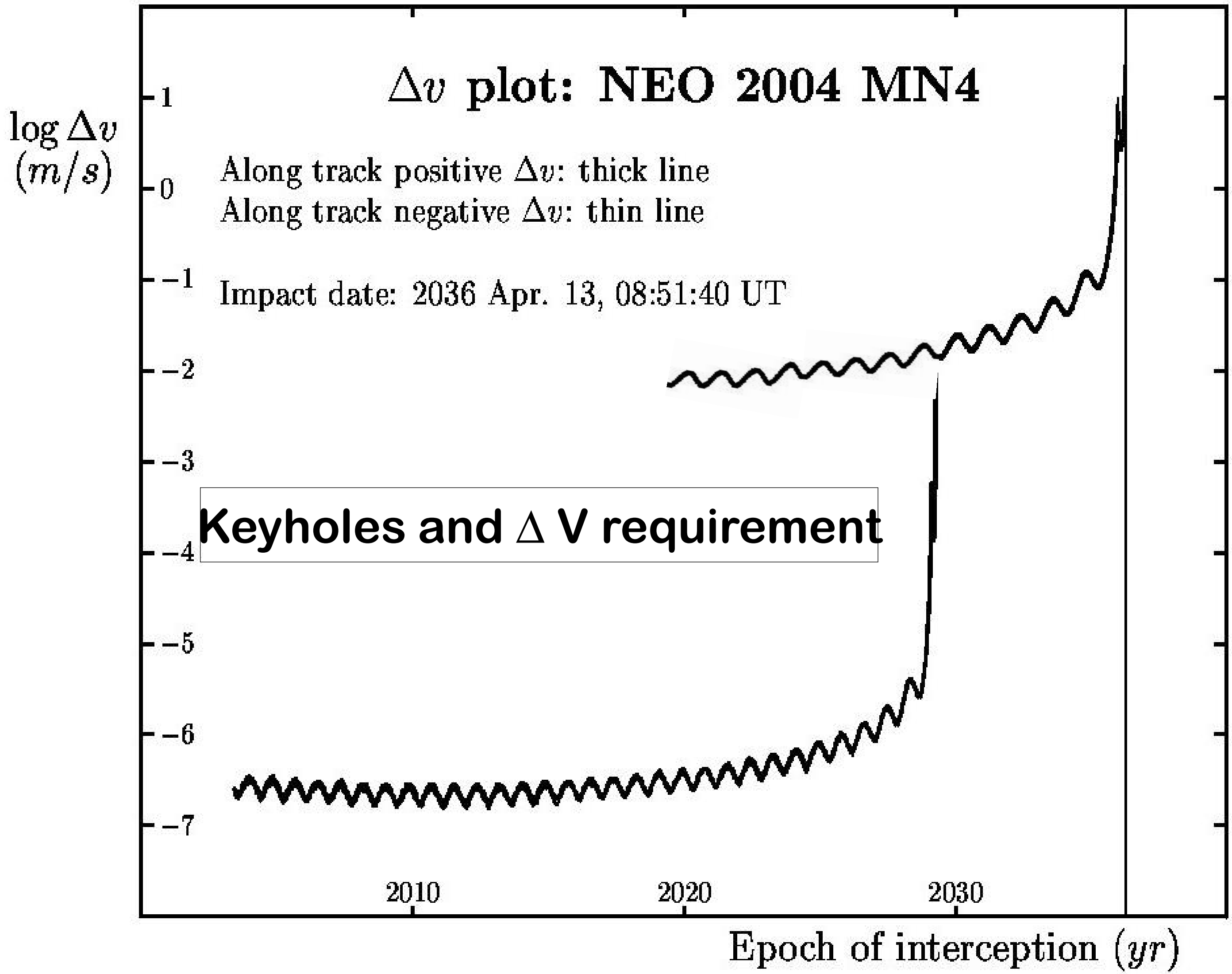


Current Deflection Capability

Kinetic Impact

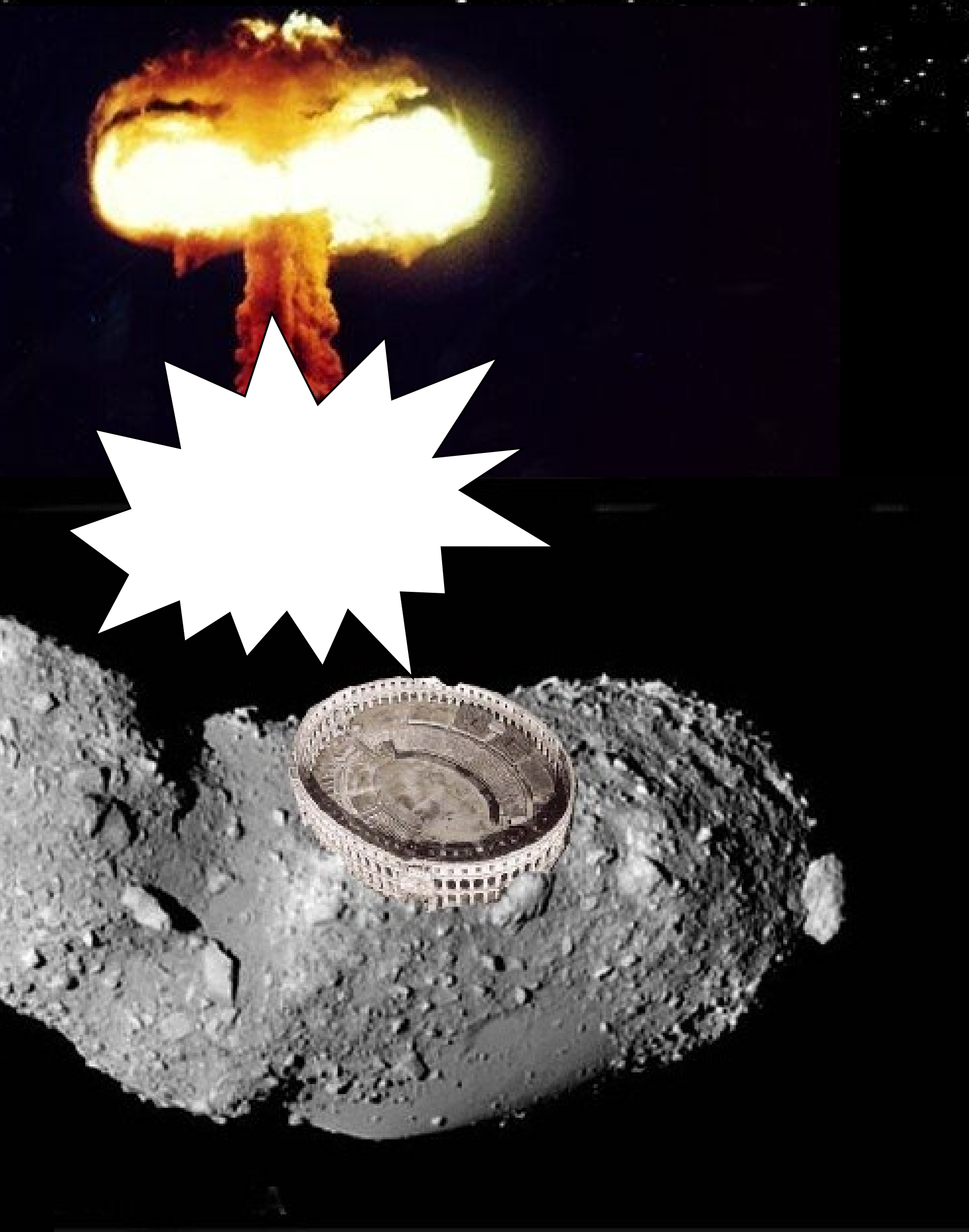
Pushes the asteroid via direct impact
(KI = robust but imprecise)

Gravity Tractor

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

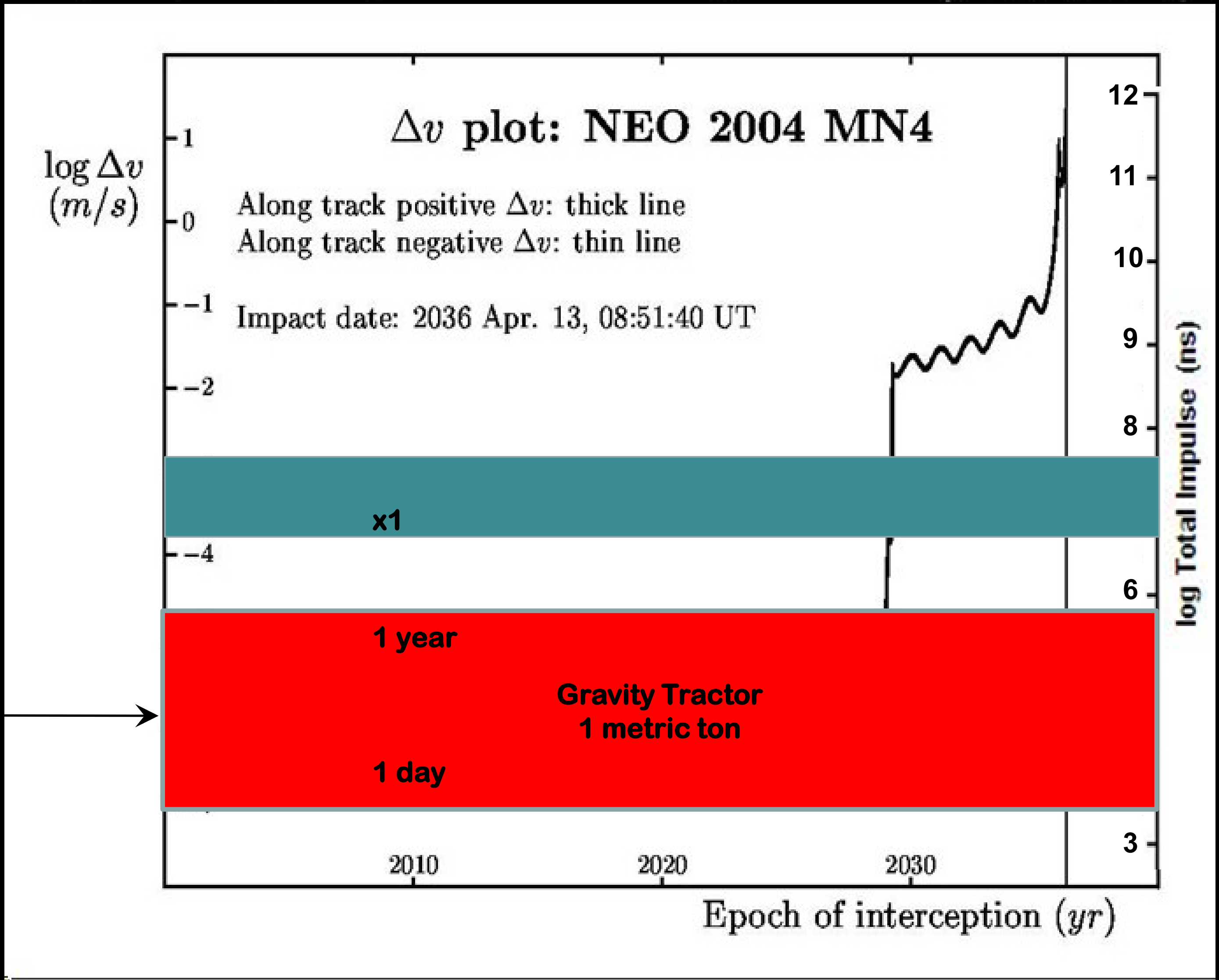
Nuclear Explosion

Explodes surface off NEO
to create impulsive push



Keyholes and Δ V requirement

12.4 days
@ 0.4n
= 42,160 ns



Key Parameter
– Total Impulse –

(= NEO momentum change)
(Units = n-sec or kg-m/sec)

<u>Kinetic Impact*</u>

$$M\Delta V_{NEO} = \beta m V_{IMP}$$
$$\Delta V_{NEO} = \beta (m/M) V_{IMP}$$
$$2 < \beta < 10$$

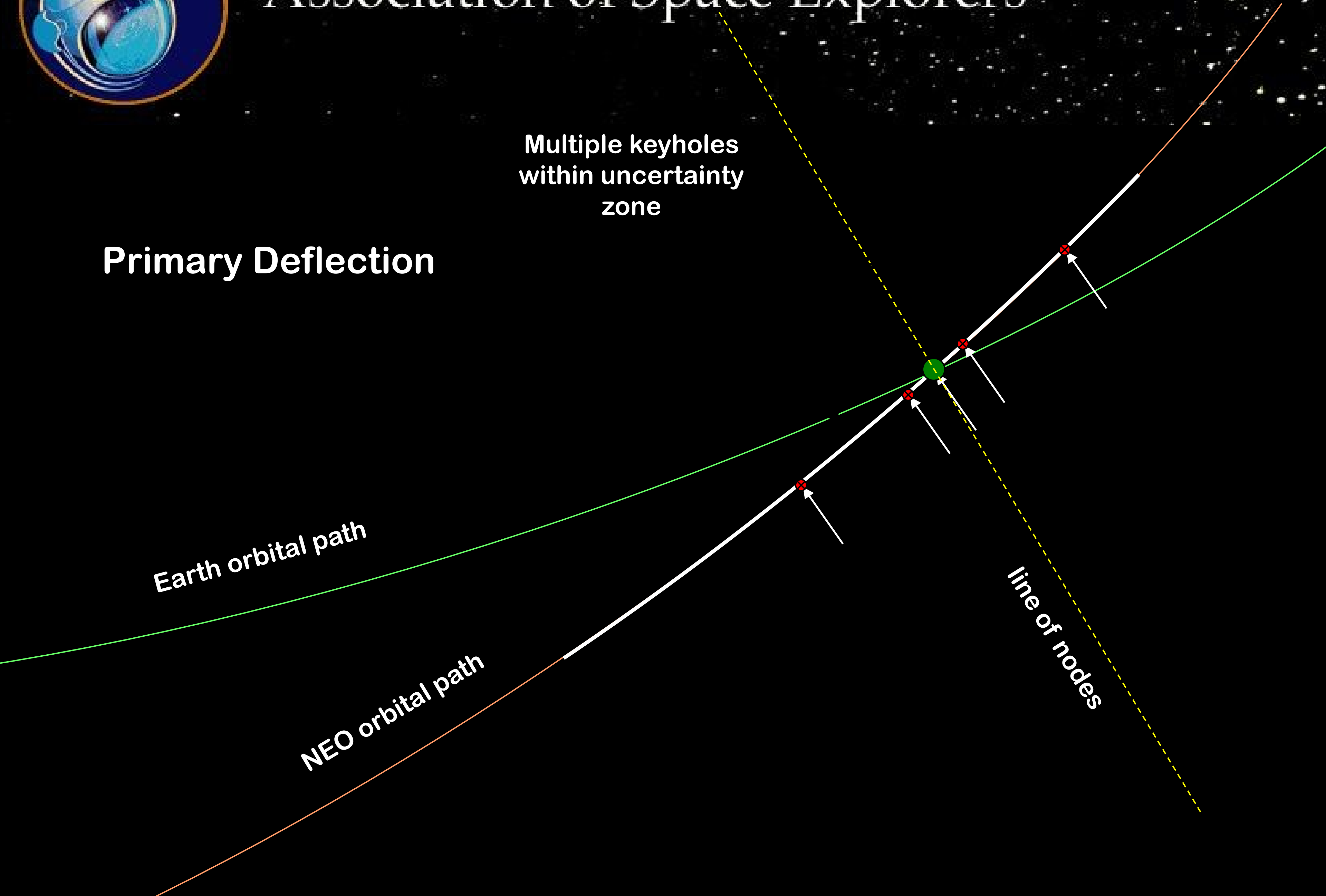
<u>Gravity Tractor</u>

$$F = GMm/r^2$$
$$\Delta V_{NEO} = tGm/r^2$$

Independent of M

* Nuclear standoff explosion subject to different but comparable uncertainties.

Primary Deflection



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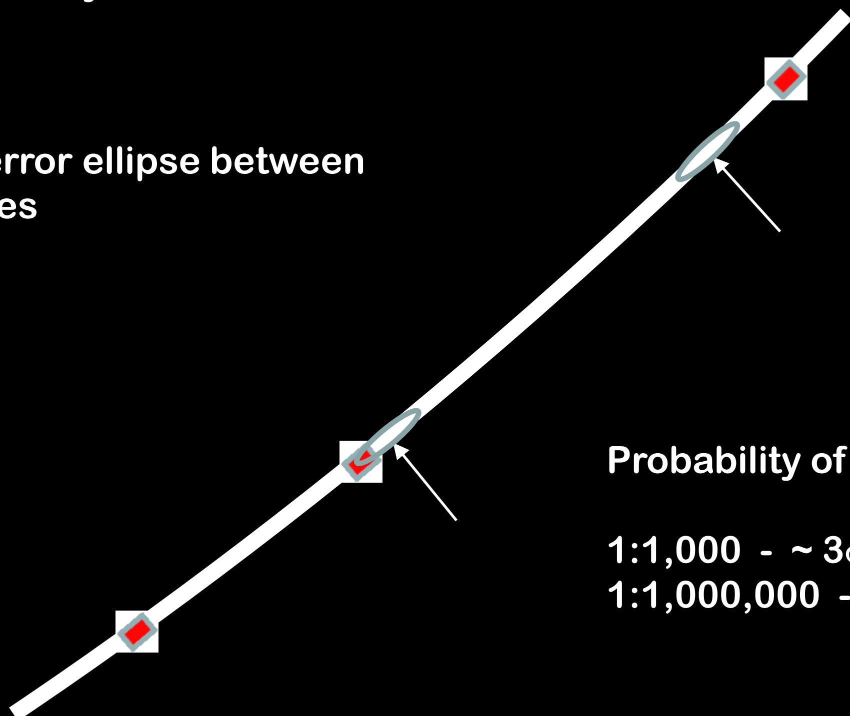
Secondary Deflection
or
Shepherding the NEO error ellipse

Step 1
- collapse the primary deflection error ellipse

Step 2
- shepherd the error ellipse between adjacent keyholes



Probability of success goal

1:1,000 - ~ 3σ error ellipse
1:1,000,000 - ~ 5σ error ellipse

Discussion

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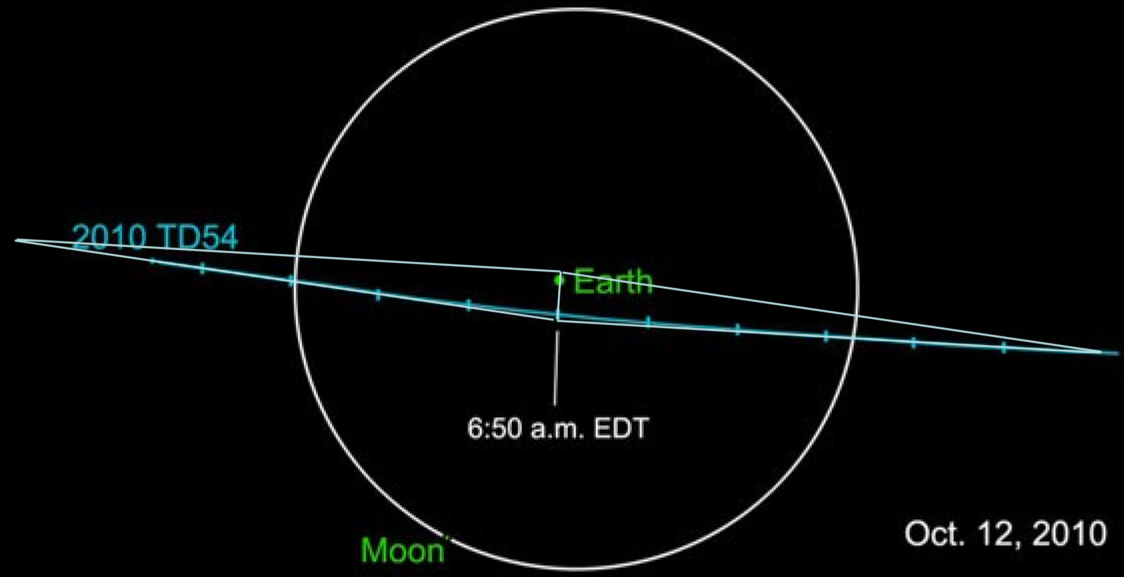

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