THE INTERNATIONAL CONFERENCE ON THE 120TH ANNIVERSARY OF THE BULNAY EARTHQUAKE: ADVANCES IN ASTRONOMY AND GEOPHYSICS

POTENTIALLY HAZARDOUS CELESTIAL OBJECTS AND THEIR CALCULATIONS

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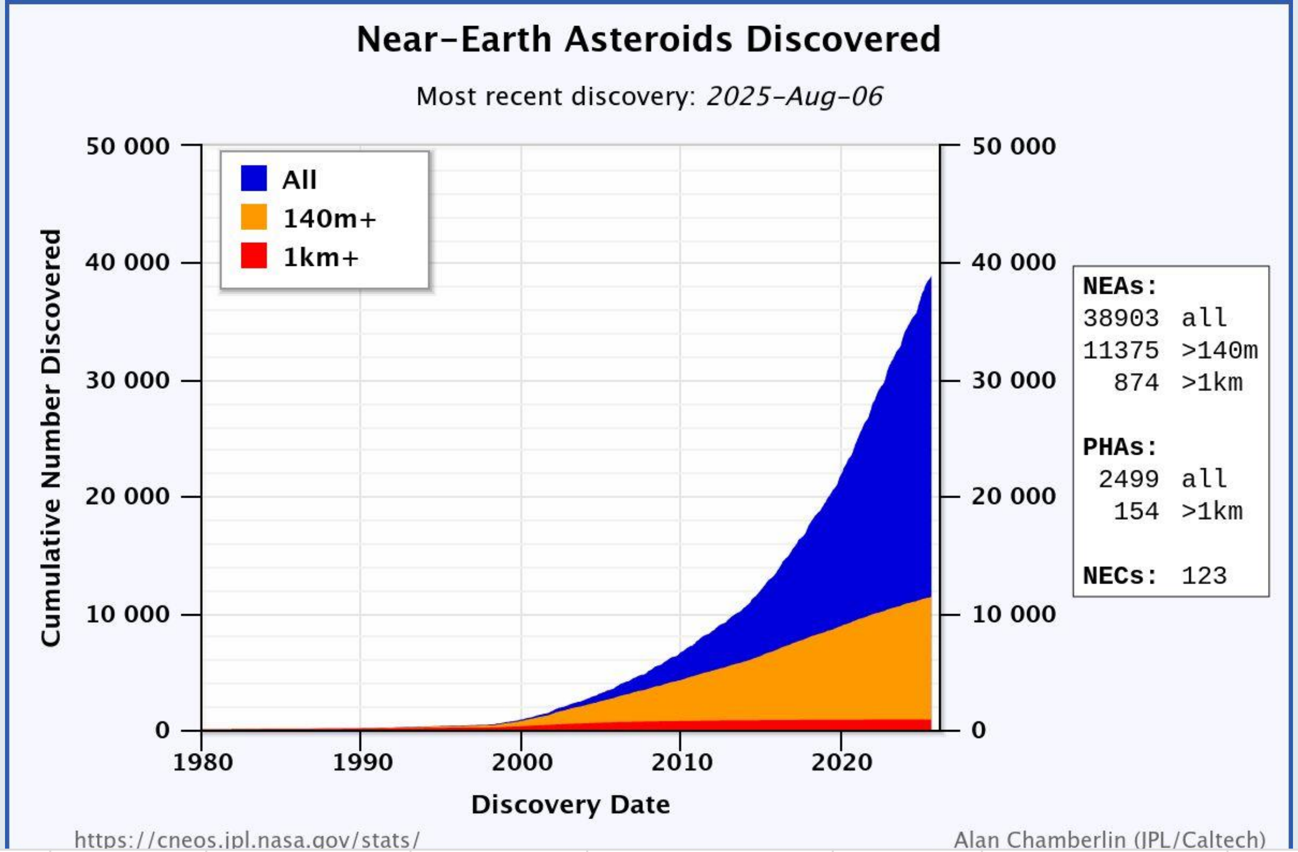
INTRODUCTION AND PROBLEM STATEMENT

A potentially hazardous object (PHO) is a Near-Earth object – either an asteroid or a comet – with an orbit that can make close approaches to the Earth and which is large enough to cause significant regional damage in the event of impact.

Most of these objects are potentially hazardous asteroids (PHAs), and a few are comets.

As of August 2025, just 33 of the known potentially hazardous objects listed on the Sentry Risk Table could not be excluded as potential threats over the next hundred years.



Date	NEC	Atira	Aten	Apollo	Amor	PHA-km	PHA	NEA-km	NEA-140m	NEA	NEO
2025-08-06	123	38	3139	22094	13632	154	2499	874	11375	38903	39026
2025-08-01	123	38	3136	22078	13621	154	2498	874	11370	38873	38996
2025-07-01	123	38	3114	21987	13531	154	2496	873	11344	38670	38793
2025-06-01	123	37	3101	21905	13487	154	2490	873	11313	38530	38653
2025-05-01	123	37	3086	21815	13429	154	2488	873	11293	38367	38490
2025-04-01	123	36	3070	21704	13379	154	2486	873	11277	38189	38312
2025-03-01	123	35	3034	21517	13299	154	2480	873	11244	37885	38008
2025-02-01	123	35	2998	21300	13218	154	2474	873	11219	37551	37674
2025-01-01	123	35	2979	21161	13174	154	2468	873	11191	37349	37472

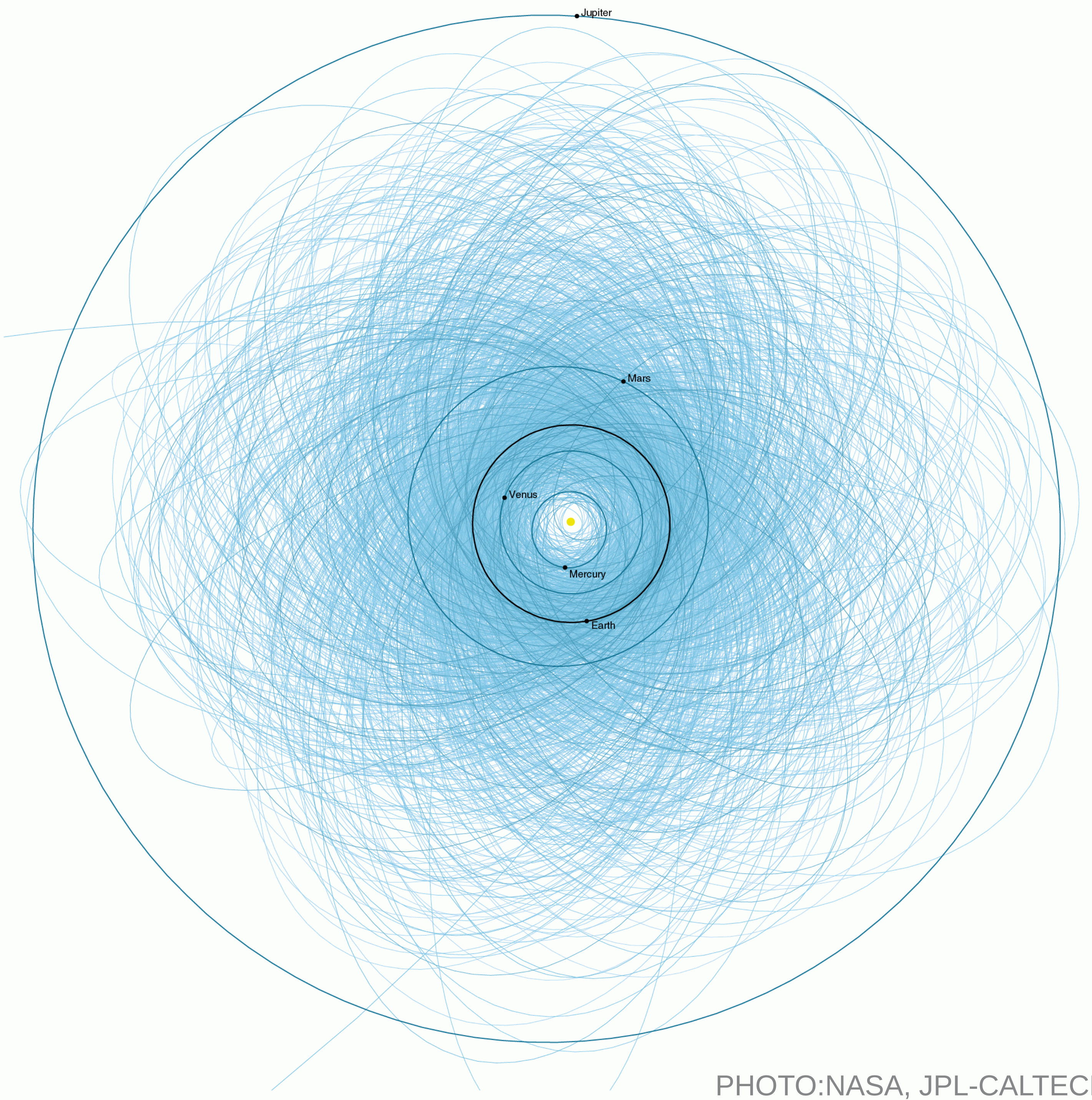


PHOTO:NASA, JPL-CALTECH

SOLUTION OF EQUATIONS IN MEAN ELEMENTS

Let the orbital elements ω, e, i, Ω, g ,M represent the mean motion, eccentricity, inclination, longitude of the ascending node, argument of pericenter, and mean anomaly, respectively.

The transition from osculating elements to mean elements is performed according to the formulas

$$\in_n = \overline{\in}_n + u_n \qquad (2)$$

Here, $\in_n$ denote the six osculating elements taken in the specified order, and $\overline{\in}_n$ denote the six mean elements. The quantities u_n are considered functions of the mean elements $\overline{\in}_k$, but in the first approximation, it is indifferent whether to consider the arguments u_n as mean or osculating.

$$u_1 = -\frac{3}{\omega a}\left[\left(e - \frac{1}{4}e^3 - \frac{3}{64}e^5\right)\sin E - \left(\frac{1}{8}e^2 + \frac{1}{32}e^4\right)\sin 2E - \frac{1}{256}e^4\sin 4E\right]\mathfrak{I},$$

$$u_2 = \frac{1}{\omega^2 a}\left[\left(2 - \frac{9}{4}e^2 + \frac{11}{32}e^4\right)\sin E + \left(-\frac{1}{2}e + \frac{1}{4}e^3 + \frac{19}{256}e^5\right)\sin 2E + \left(\frac{1}{12}e^2 - \frac{1}{192}e^4\right)\sin 3E - \left(\frac{1}{32}e^3 + \right.\right.$$
$$\left.\left. + \frac{1}{256}e^5\right)\sin 4E + \frac{3}{320}e^5\sin 5E - \frac{1}{256}e^5\sin 6E\right]\mathfrak{I},$$

$$u_3 = u_4 = 0, \qquad (3)$$

$$u_5 = \frac{1}{\omega^2 a}\left[\left(-1 + \frac{3}{8}e^2 + \frac{9}{64}e^4\right) + \left(-\frac{2}{e} + \frac{3}{4}e + \frac{9}{32}e^3 + \frac{79}{512}e^5\right)\cos E + \left(\frac{1}{2} - \frac{1}{8}e^2 - \frac{17}{256}e^4\right)\cos 2E + \left(-\frac{1}{12}e - \right.\right.$$
$$\left. - \frac{1}{192}e^3 + \frac{7}{1536}e^5\right)\cos 3E + \left(\frac{1}{32}e^2 + \frac{1}{128}e^4\right)\cos 4E - \left(\frac{3}{320}e^3 + \frac{13}{2560}e^5\right)\cos 5E + \frac{1}{256}e^4\cos 6E -$$
$$\left. - \frac{5}{3584}e^5\cos 7E\right]\mathfrak{I},$$

$$u_6 = \frac{1}{\omega^2 a}\left[\left(1 + \frac{13}{8}e^2 + \frac{1}{64}e^4\right) + \left(\frac{2}{e} + \frac{13}{4}e + \frac{1}{32}e^3 + \frac{41}{512}e^5\right)\cos E - \left(\frac{1}{2} + \frac{25}{16}e^2 + \frac{11}{256}e^4\right)\cos 2E + \left(\frac{1}{12}e + \frac{53}{192}e^3 + \right.\right.$$
$$\left.\left. \frac{7}{64}e^5\right)\cos 3E - \left(\frac{1}{32}e^2 + \frac{59}{1024}e^4\right)\cos 4E + \left(\frac{3}{320}e^3 + \frac{3}{128}e^5\right)\cos 5E - \frac{1}{256}e^4\cos 6E + \frac{5}{3584}e^5\cos 7E\right]\mathfrak{I},$$

$$u_7 = \frac{2}{\omega^2}\left[\left(e - \frac{1}{4}e^3 - \frac{3}{64}e^5\right)\sin E - \left(\frac{1}{8}e^2 + \frac{1}{32}e^4\right)\sin 2E - \frac{1}{256}e^4\sin 4E\right]\mathfrak{I}.$$

$$\begin{aligned}
\dot{\omega} &= -\frac{3}{a}\, F_1(e^2)\mathfrak{I}, \\
\dot{e} &= -\frac{e}{\omega a}\, F_2(e^2)\mathfrak{I}, \\
\dot{M} &= \omega, \\
\ddot{\imath} &= \dot{\Omega} = \dot{g} = 0,
\end{aligned} \tag{4}$$

$$F_1(e^2) = 1 - \frac{1}{4}e^2 - \frac{3}{64}e^4 + \cdots,$$

$$F_2(e^2) = 1 - \frac{5}{8}e^2 - \frac{9}{64}e^4 + \cdots,$$

$$F_3(e^2) = \frac{3}{8} + \frac{3}{32}e^2 + \cdots,$$

DISPLACEMENT NORM

$$\rho_k^2 = \frac{1}{2\pi}\int_{-\pi}^{\pi}(\Delta r_k)^2 dM, \qquad\qquad k = 1,2.$$

$$\rho_2 = \frac{4|\mathfrak{T}|}{\omega^2}\sqrt{1 - \frac{39}{128}e^2 + \frac{52505}{73728}e^4}$$

$$(\Delta r_3)^2 = \delta r^2 + r^2 \delta u^2$$

$$\rho_3^2 = \|\Delta r_3\|^2 = \frac{1}{2\pi}\int_0^{2\pi}(\Delta r_3)^2 dM,$$

RESULTS

PHA	d	m $\times 10^{-7}$	a, au	e	ω^2 $\times 10^{14}$	$\mathfrak{T}$ $\times 10^8$	t^* $\times 10^{-12}$	τ_1 $\times 10^6$	τ_2 $\times 10^5$	ρ_2 $\times 10^{-6}$	$\rho_3(\tau_1)$ $\times 10^{-5}$	$\rho_3(\tau_2)$ $\times 10^{-6}$
2002 JR100	28	2.87	0.924	0.299	5.03	3.48	0.890	2.91	3.54	2.74	8.78	52.3
2010 JJ3	32	4.29	2.23	0.578	0.356	2.33	0.855	3.03	3.69	25.9	20.7	41.6
2010 CO44	34	5.14	1.07	0.231	3.23	1.94	1.48	1.75	2.13	2.39	5.95	29.6
2010 JO71	37	6.63	1.17	0.387	2.46	1.51	1.82	1.42	1.73	2.41	5.23	22.9
2010 QG2	38	7.18	1.67	0.517	0.846	1.39	1.65	1.57	1.91	6.48	8.05	22.3
2010 JH3	39	7.76	1.76	0.470	0.731	1.29	1.74	1.49	1.81	6.93	7.99	21.0
2010 EX11	40	8.38	0.956	0.110	4.54	1.19	2.55	1.02	1.24	1.05	3.15	18.2
2010 UC7	43	10.4	1.88	0.567	0.593	0.961	2.26	1.15	1.40	6.40	6.62	15.9
2004 KH17	197	1000	0.712	0.499	11.0	0.00999	353	0.00734	0.00893	0.00358	0.0184	0.146
2010 CB55	198	1020	1.13	0.148	2.72	0.00984	284	0.00912	0.0111	0.0144	0.0325	0.151

CONCLUSIONS

- For all 8 asteroids with a diameter smaller than 45 m, $\rho_3(\tau_1)$ exceeded the Earth's radius. Thus, for small dangerous asteroids, deflection is possible in about a month.
- For all 10 asteroids with a diameter of up to 100 m, $\rho_3(\tau_2)$ exceeded the Earth's radius. For such asteroids, deflection is possible in about a year.
- For asteroids larger than 150 meters, deflection in a year is impossible.


THANK YOU FOR
YOUR
ATTENTION!
СПАСИБО ЗА ВНИМАНИЕ!