2002

NASA FACULTY FELLOWSHIP PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA

PROBABLE DISASTEROUS CONSEQUENCES OF COLLISION BETWEEN UNKNOWN SMALL (100M) ASTEROIDS AND KNOWN (~1 KM) NEAR EARTH ORBITING (NEOS) ASTEROIDS

Prepared By:	Larry Smalley
Academic Rank	Professor
Institution and Department	University of Alabama in Huntsville Physics
NASA/MSFC Directorate:	Advanced Projects
MSFC Colleague	Dr. Jonathan Campbell

The long-term stability of the Solar System is not well understood. Ironically its stability is taken for granted even though our knowledge of **all** the constituents [comets, asteroids. (The Asteroid Belt between Mars and Jupiter, Trojan Asteroids, Kuiper belt, Ort Cloud), planetoids, planets, moons, etc], and its long-term dynamics cannot be easily computed. At best one might say that the solar system is chaotic, but much of the time it seems to exists near a quasi-stationary state. An asteroid that passes near the Earth regularly returns with clock-like precision. Taking into account every *known* detail of its path through the solar system, its orbit is calculated forward thousands of years with no untoward calamity on the horizon. And then one day, this passive visitor slams into the Earth during a sunny afternoon picnic! Can this happen? Unfortunately, this is a real possibility in the ordinary history of the solar system. In fact our knowledge of the solar system in the small is sketchy, as will be pointed out. Events, which lie outside our awareness, can precipitate disasters that we **may** perceive when it's too late to launch effective counter measures. In this work, one such scenario is discribed and the direct consequences for the Earth are calculated.

It is estimated that The Asteroid Belt--the vast region of debris between Jupiter and Mars-- contains a million or so asteroids larger than 1 km, and it is suggested that with Earth Based Telescopes we might be able to "see" 100,000. More important are two groups of asteroids known as Near Earth Object (NEO) Asteroids (or NEOs for short) that are in nearly the same orbit as the Earth. The NEOs can be further classified as Earth Crossing (ECR) Asteroids that tend to have orbits *slightly* out of the plane of the ecliptic. These in turn can be described as (a) Earth Passing asteroid in which the Earth or the asteroid passes one another, and (b) Horseshoe orbits in which the Earth and the asteroid periodically draws "near" to one another and the separates and draws closer in the opposite direction. These latter Horseshoe orbits are well known in the Saturn rings in which a large moon shepherds smaller moonlets. It appears that around 1700 NEOs are known--estimates suggest that there may be 1800 of them; however, the faint albedo of asteroids makes it very difficult for Telescopes to see them without constant, full sky surveillance. Many have been discovered long after their closes approach to the Earth, a time which would be too late for protective efforts if it had been a threatening encounter. There should be a real fear! These ~1-km sized asteroids (or larger) are known as **Earth Busters** and are capable of destroying civilization, as we know it.

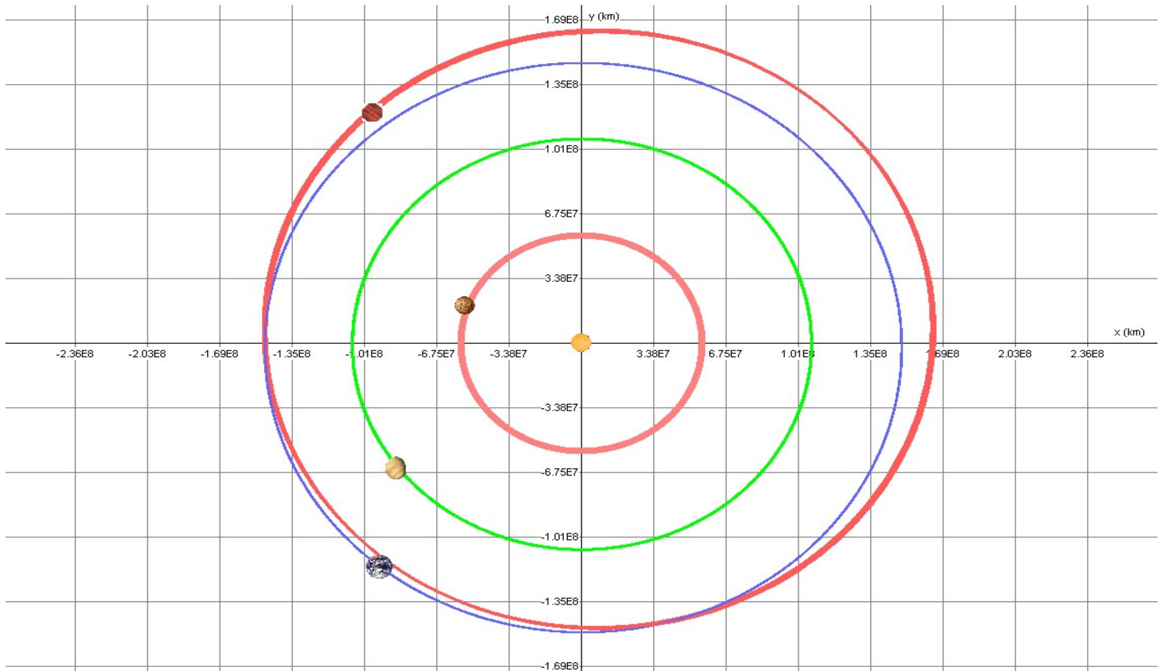
JPL maintains an orbital simulation for most of these known asteroids using an Orbit View applet [1]. The Ephemeras and the "Risk" pages for some NEOs are also found on the NEO pages. A sample is given for the recently *rediscovered* asteroid 1950DA [2], which **may** miss the Earth in 2880. The reacquisition of asteroids is extremely important since after leaving the vicinity of the Earth, the faintness of the asteroid makes it difficult to continue tracking. During this dark period, it is possible that the asteroid might encounter perturbations. This why it is now thought that 1950DA is now listed as a potential threat to the Earth in 2880. For amateur astronomers, there is a complete orbital package called Orbit Fit [3] that can accurately calculate the orbits. The orbital elements given at the NEODys Website are in a form that can be entered directly into the Orbit Fit. Package. [4]

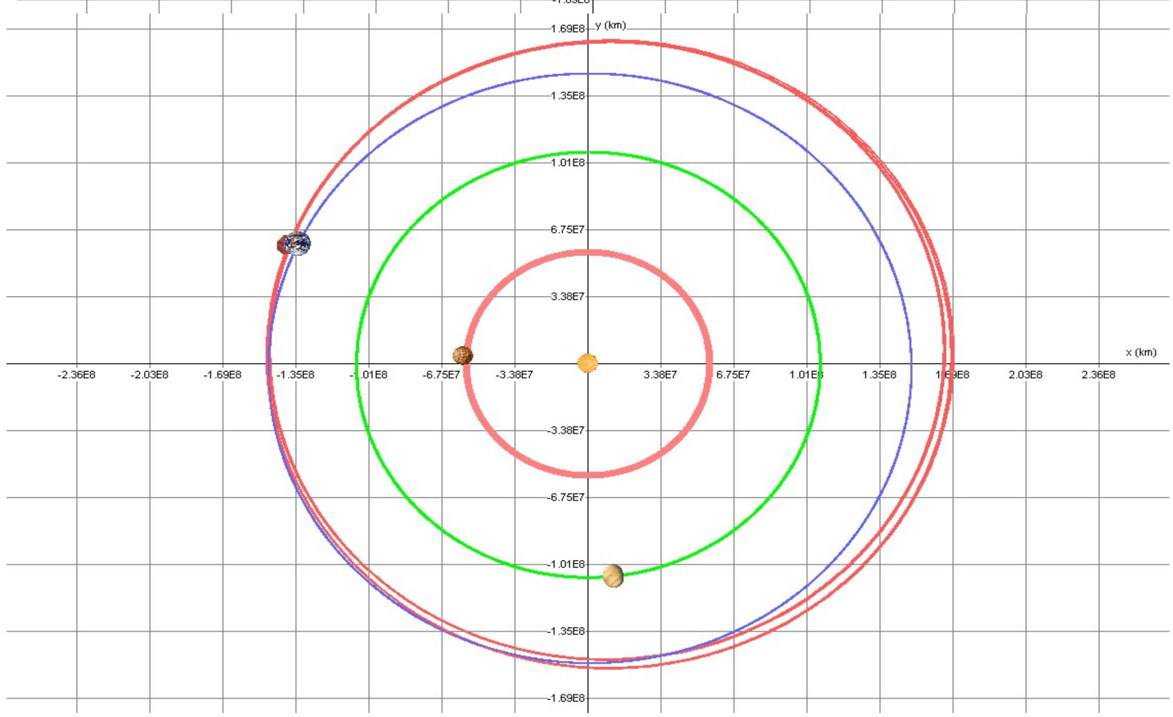
NASA's Near-Earth Object Program Office announced, March 12, 2002, an Automatic, Near-Earth Asteroid Collision Monitoring System, called SENTRY. The arrival of the SENTRY (in development for nearly two years) is a highly automated, accurate, and robust system for continually updating the orbits, future close Earth approaches, and Earth impact probabilities for all Near-Earth Asteroids. The system includes data from amateur astronomers, major telescope, and radar observations,

There is a limitation to the SENTRY Program: It cannot readily discover the smaller (and lower albedo) ≈ 100-m asteroids that could seriously damage the Earth. This blind spot in SENTRY was very evident when the "small," 100-m sized asteroid 2002 MN passed within 0.3 lunar distances of the Earth on June 14, 2002, **some three days prior** to its discovery. It is estimated that there are upwards to 200,000 of these ≈100-m class asteroids that visit the environs the Earth!

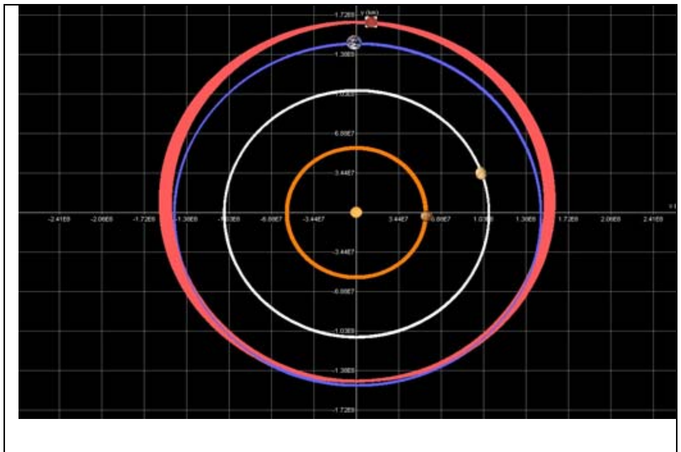
Although 100-meter-sized asteroids would pose direct, serious damage upon collision with the Earth, in this work, it is shown that their greatest potential threat to the Earth is instead due to the risk from colliding with the relatively stable NEOs. In this work, simulations of these orbital collisions are obtained using the package, Orbital Explorer [5]. Since this is an astronomical, simulation package, one needs only a simplified set of orbital elements for the 1-km asteroid to obtain the relevant stability information {mass, radius, x, y, z, v_x, v_y, v_z}. The data for the planets and the sun, plus the starting positions of the "bodies," are part of the simulation package. One can determine the parameter for an asteroid by iterating a "trial set" until the NEO's orbit is *stable*. On a PC, the calculation to determine stability to 100,000y takes about 12 hours. The task to find a wide range of stable orbits is straightforward but tedious. However, the result of these calculations shows that the stable orbits straddle **dense** bands of unstable orbits. Although it is not *obvious*, what this means is that if a stability calculations goes to ≈ 5000y, in all cases investigated, it will be stable to 100,000y, *assuming that there are no subsequent perturbations*—therein lies the danger!

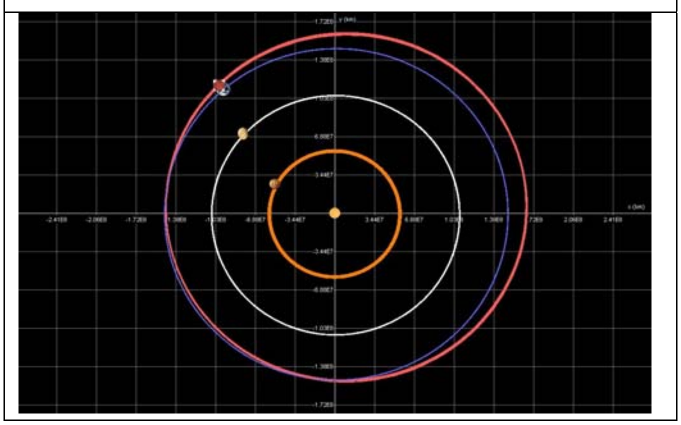
In our calculations, the average composition (and thereby their density) of asteroids is assumed to be a mixture of iron and stone. This fixes, for simplicity, the mass-density of all the asteroids in our simulations and thus the total mass of a 100-m asteroid. It is then easily shown that the collision between a 100-m and a 1-km asteroid could easily impart velocity increments up to 2 km/s to the 1-km asteroid. *But this is overkill!* Calculations show that relatively long-term, stable orbits of a NEOs are **easily** destabilized by a glancing collision with a 100-m asteroid that departs only a relatively small velocity increment of 0.25 km/s. It seems counter intuitive that such a small incremental nudge to an asteroid already moving 25-40 km/s would make much difference. In fact, orbital simulations show that the stability of the NEO's orbit rapidly degenerates and invariably **the NEO subsequently collides with the Earth within the timescale of human lifetimes**. The Orbital Explorer program has the useful feature that allows one to stop an orbital calculation in midstream and insert parameter changes, such as decreasing the velocity v_x of the NEO by 0.25 km/s. This is the mathematical equivalent of an impulse due to the collision of a 100-m asteroid with the 1-km NEO. [As an aside, it doesn't make much difference if the increment is positive or negative since the NEOs straddle bands of unstable orbits.] In the examples given below, the NEOs are described only by their velocity components, and the “impulse” is applied to the v_x component of NEO. Orbital diagram for the NEOs s are described by the reduced set of parameters: NEO{30326, 4595,1100}.The first figure below shows the relative orbital positions of the inner planets and the asteroid (red) at 8892y86d. Assuming that the orbit is stable, at this time v_x is decremented by -0.25 km/s to simulate a collision. The last second shows that the NEO collides with the Earth at 8943y358d for an elapsed time of 48y93d!





An interesting example is the NEO{30326,495, 1300}. The first figure shows the simulation stopped at 50109y74d and v_x is decremented by 0.25 km/s and runs until 56501y239d, at which time v_x is decremented by 0.25 km/s. and then runs until the NEO collides with the Earth at 56,542y159d shown in the second figure. One might conclude that an overall decrement of v_x of 0.5 km/s would have caused the asteroid to collide. To test this premise, the v_x parameter was changed to 29826. The asteroid collided with the Earth in 29y8d!





Taking into account all the close encounters of NEOs with planets and the known asteroids, the best calculations may predict that the Earth is safe from collision. But from our poor knowledge of the shear number and whereabouts of the small 100-m asteroids, it truly becomes impossible to calculate with certainty that we are safe from the collision with the NEOs. Thus it is important to develop advanced monitoring system and options for rapid defense. Options could be the use of space based lasers for ablative thrust, parasitic spacecraft that attach to the asteroid and use the engines in an ablative mode, etc. But if they fail as well, there is always nuclear energy to break up the NEO.

References

1. Orbit Viewer applet were originally written and kindly provided by Osamu Ajiki (AstroArts),and further modified by Ron Baalke (JPL).
2. http://neo.jpl.nasa.gov/news/news127.html .
3. **NEODys Near-Earth Objects** .
4. The ObFit package is also found on the NeoDys site**:** OrbFit **.**
5. Orbital Explorer shareware http://www.ottisoft.com/orbit_x.htm