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The Catastrophe We Can Prevent:

The Near Earth Object Problem[1]

Background

A near earth object (NEO) is a solar system object whose orbit brings it within close proximity of Earth. It is widely accepted that past collisions have had a significant roles in shaping the geological and biological history of Earth. Asteroids and comets comprise the NEO population. Two of the most often discussed asteroid events are the K-T extinction event that occurred 65 million years ago in the Yucatan Peninsula killing between 70 and 80% of all species including all the dinosaurs,[2] and the Tunguska impact of 1908, in which an asteroid fragment, just thirty or forty meters wide, flattened 2100 square kilometers of forest in Siberia. [3] It is predicted that Tunguska like events might occur every three hundred years or so.[4] The NEO population includes some "potentially hazardous asteroids" (PHAs) which closely approach Earth and may pose a future collision hazard. One well known PHA is Apophis which is the size of a sports arena:

> For a few days around Christmas 2004, this 250 - 300 m NEA was given an official probability… of about 3% of impacting Earth on 13 April 2029. The places on Earth that were at risk of being struck were central Europe, the Middle East, and populous regions in Asia such as the Ganges river valley. About a month later, radar echoes received by the Arecibo radar refined knowledge of Apophis' position and removed any chance of collision in 2029, although Apophis will still

> pass below the geosynchronous artificial satellites and will be visible to the unaided eye…. (There remains a 1-in-45,000 chance that Apophis will pass through a resonant-return "keyhole" in 2029, so that it impacts Earth on 13 April 2036.)[5]

Such impacts will certainly happen in the future unless we prevent them. A cosmic impact will cause tsunamis, volcanic eruptions, and earthquakes, dramatically and quickly change the weather, etc. The issue is not *if*, it's *when.* At the moment our detection capabilities are limited. Thus, a NEO that we aren't aware of could blindside us. As Apollo 9 astronaut, Rusty Schweickart says, "we're driving around the solar system uninsured (personal communication)."

Not so Fast

If we are to do anything about this problem detection must improve. So it will. Pan-STARRS (Panoramic Survey Telescope and Rapid Response System), on Mount Haleakala on Maui, saw first light in August 2007. It will usher in a new era in observational astronomy.[6] Some 300 scientists are lined up to take advantage of this new technology. Some will map the Milky Way and others will look for asteroids. LSST (Large Synoptic Survey Telescope) will have twenty four times more survey power than Pan-STARRS. Like its Hawaiian rival, this expensive project has broad scientific objectives, asteroid detection among them. Construction of LSST is expected to begin at Cerro Pachon, Chile in 2011 and be operational by 2014. When completed LSST will cover the entire available sky every four nights with a 3.2 billion pixel camera. [7]

By 2000 more than 1,272 NEOs had been identified. By 2007 the number had grown to 5,083. And after ten years of operation LSST should have plotted rough orbits for 82% of 20,000 NEOs larger than 140 meters. In 2005 the U.S. Congress ordered NASA to expand its search to detect 90% of NEOs at least 140 meters in diameter by 2020. A byproduct of this activity will be

the discovery of a large number of NEOs, some with the worrisome probability of striking Earth. NEOs.

An open question is what astronomers, engineers, politicians, etc., will do when several of these smaller NEOs appear to pose collision threats. It is estimated that several NEOs per year will have a non zero collision probability As former astronaut and planetary scientist Tom Jones writes, "The effects of a 1-km asteroid strike on today's fragile, interconnected human society would probably cause global climatic disruptions, widespread crop failures, and world famine." [8]

The Only Preventable Natural Disaster

Unlike tsunamis, earthquakes, volcano eruptions, hurricanes, etc., an asteroid strike is the only natural disaster we have the technologies to prevent. Several tools are available for deflection. The simple objective is to change the asteroid's speed so it arrives too early or too late to hit Earth.

How do we do this? The first step is to use a transponder-equipped spacecraft to determine the NEOs future orbit precisely and eliminate uncertainty surrounding most impact calculations. If deflection is necessary it is possible to use a "gravity tractor" spacecraft to hover near the asteroid and slightly change its velocity, if the required velocity change is small. Alternatively, if the required velocity change is large, it is possible to ram an incoming object with a high-speed projectile, transferring momentum and altering the object's velocity. A third solution, considered a last resort, is to use a nuclear explosion to vaporize the top layer of the NEO's bedrock, resulting in debris and gas nudging the asteroid off course.[9] The first two solutions require years of planning and deployment. The third solution is unlikely to be needed

except in cases of very late discovery or a large NEO. It is the only solution available if warning time is short.

The European Space Agency (ESA) has addressed one part of the deflection problem. Its project, Don Quijote, is a mission concept addressing the projectile proposal. A non threatening asteroid would be identified. A spacecraft would fly out and observe the asteroid for some period of time. A second spacecraft would then fly out and ram the asteroid and the first spacecraft would continue to measure changes in asteroid trajectory, etc. This program is as yet unfunded.

Compared to solving other gripping Earth problems, like world peace, world hunger, climate change, etc., the solution to the NEO problem is relatively clear and relatively inexpensive. The fact that it seems not to be high on the world's radar screen seems surprising, since it has the potential to collapse civilization or cause large disruptions to society.

Some Barriers to a Solution

There are a number of significant barriers to solution. The first and possibly the largest is that no national or international agency has been charged with preparing for asteroid deflection or mitigation of the effects of an asteroid Earth strike. And no local or national emergency response plan or training includes any planning about near earth objects.

If an international agency were charged with attending to this problem the myriad of decisions that need to be made is mind boggling. The large economic and behavioral science literatures on decision making attest to the fact that we really don't know how such decisions can or should be made. Rational models suggest one approach, behavioral models another,

garbage can models yet another and naturalistic approaches yet another. The list goes on and on.

Assuming an international agency were charged with addressing both the deflection and mitigation issues it would must necessarily farm part of the problem out to other agencies across nations. To address deflection manufacturers of launch vehicles, gravity tractors, etc., would have to work together. In turn they will would have to work with space experts. Space experts will have to work with local and international political figures. In the mitigation area emergency service planners and trainers will have to work across nations and cultures. As an example of the near impossibility of this, today in the wild land fire arena in Europe NATO wants cross nation responsibilities to be taken over by the European Community. It's difficult to imagine France working with Germany, much less Greece on this one, a far smaller problem than the asteroid problem.

Predicting a NEO impact site is another barrier. The orbit of a NEO with probability of striking Earth is imperfectly known due to tracking limitations. The set of possible impact points appears on Earth's surface as a corridor which is only a few miles wide, but passes over many countries. We may not know the actual impact point with precision until long after a decision to deflect must be made.

Any deflection attempt must necessarily take one or more countries out of the risk corridor while simultaneously exposing other countries to temporary risk. It's difficult to imagine countries agreeing to be placed in the risk zone without some international process for taking that decision.

Existing space law also provides challenges to problem solution. That body of law speaks more generally to the peaceful uses of outer space than it does specifically to such issues as the legal dimensions of detecting operations, the peaceful uses of nuclear propulsion, the issue of liability for damages, etc. For example, "UN GA Res (1962) (XVIII) of 13 December 1963 on the Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space demands that the exploration and use of outer space be carried on for the benefit and interest of all mankind."[10] Such broad provisions contain no guidelines for how NEO deflection activities might be approved or executed.

Challenges also occur at the level of the individual. One challenge is our usual inability to think and act long term. It is unlikely that world leaders or even local leaders will trade the solution of a low probability long term problem for a high probability short term problem. Citizen support depends on how well leaders can fix imminent problems before the next election or the next uprising. Closely associated with this problem is the fact that we think probabilistically rather than possiblistically.[11] The probability of an asteroid strike at any particular time is low but eventually one is inevitable and its consequences are far worse than the normal human understanding of disaster! If we think possiblistically we will come up with different solutions than if we think probabilistically.

In an interesting paper on the asteroid impact problem, Paul Slovic reminds us that the possibility of natural disasters elicits far less concern from people than the possibility of man-made disasters and that perceptions are heightened and then quickly drop after the occurrence of a disaster. Slovic doubts that any meaningful progress can be made toward understanding perceptions of risk from an asteroid impact in the absence of credible imminent threat. A more

achievable objective, he thinks, is to create realistic appraisals of risk. We are susceptible, Slovic notes, to bounded rationality and the availability heuristic. That is, we never have all the information we need to make decisions, and frequent or more visible events are easier to recall than infrequent or less visible events.[12]

Some Contributors to a Solution

Before discussing the contributors in place let me discuss a "what if." What if a credible international agency combined with national space agencies' convinced the world's governments and populations of the necessity to think about and act upon this issue – while we think it is still not imminent? What if possiblistic thinking worked? The only international agency one could appeal to is the United Nations. The UN or its appointees would then have to work in conjunction with national space agencies. This problem is tractable because there are only thirteen space-faring nations (this does not include nations able to launch sub orbital flights) and only three of those are capable of manned space flight. Space farers themselves are rather an international lot (see Association of Space Explorers web page); many of them know each other and they probably have a good deal of cultural similarity.

Another contributor to a solution is the fact that asteroids can potentially contribute to world economic benefit. Sonter reports that mining and metallurgical options exist that are robust and sound. Further he states, asteroid mining is very close to technical and economic feasibility.[13] The most valuable product to be found in space is water. One reason the ESA is interested in the asteroid problem is because of the economic potential of asteroid exploration and exploitation.[14]

And, finally at a more individual level of concern the risk of asteroid impact on Earth is demonstrable, and the potential consequences are catastrophic. The probability of impact in our lifetimes is small but not trivial. Chapman estimates that our odds of dying in a NEO impact are about the same as dying in a plane crash. Under these circumstances thinking in possiblistic terms may get us further than thinking in probabilistic terms. Unless action is taken the risks will be unknown and uncontrolled!

Is There Any Progress?

Yes. In 2005 the Association of Space Explorers (ASE - the international professional and educational organization whose members are over 320 space farers from thirty three nations) approved an open letter asking the world to take action to prevent future asteroid and comet collisions with Earth. The Association formed a committee to further this activity. In 2007 the ASE named an international panel of diplomats, scientists, engineers and legal experts, called the Panel on Asteroid Threat Mitigation. This panel convened to study the scope of the NEO hazard and to make recommendations on processes for moving forward. In 2008 the panel finalized and adopted its document and the ASE submitted it to the United Nations for its consideration.[15]

The report makes five major recommendations:

- It declares that international preparations, not unilateral action by a single space faring country are the only way society can counter impact threats.
- It states that a global, coordinated response to a NEO threat includes the execution of three functions: information gathering, analysis, and warning; mission planning and operations; and executive oversight.
- It calls for the international community to create and recognize a NEO information, analysis, and warning network. The network is to include a web of ground or space based telescopes for detecting and tracking NEOs. The network should then analyze NEO orbits to identify

potential impacts. And the network should establish criteria for issuing public NEO impact warnings.

- It calls for a mission planning and operations group to draw from the expertise of the world's space faring nations to determine the best means of mounting a successful deflection campaign.

- It calls on The United Nations to exercise oversight of the above functions through an intergovernmental Mission Authorization and Oversight Group (MOAG). The MOAG would authorize and oversee execution of a deflection campaign.

The ASE report was formally submitted to both the Scientific and Technical Subcommittee and the full committee of the Peaceful Uses of Outer Space (COPOUS) committee of the UN at their 2009 sessions. It is currently being integrated into formal UN documents as part of a COPOUS' 3-year work plan in anticipation of being transmitted to the UN General Assembly. Astronaut Tom Jones reports that at least five years of work lie ahead, and that the ASE continues to use its members' international influence to advise the UN and policy makers of the necessity to create a practical decision making framework.

We know the NEO hazard is a potentially lethal but solvable problem. Failure to address it seems irresponsible in light of the degree of potential catastrophe and the solution's relatively modest cost. A deflection mission might cost less than USD 500 million, while it is estimated that an impact by a NEO such as Apophis would result in more than USD 400 billion in damage. As we know from other catastrophes the cost of prevention is always lower than the cost of clean-up. Then, too, as someone said; "Gee, if we could solve this problem we might have a template for addressing world hunger, the H1N1 flu, world peace, etc."

[1] My thanks to astronauts Russell Schweickart and Thomas D. Jones who contributed much to this piece.
[2] Alvarez, W. (1997) *T. Rex and the Crater of Doom*. Princeton: Princeton University Press.
[3] Chapman, C.R. (submitted for publication) "Meteroids, Meteors, and Near-Earth Objects" *Earth, Moon, and Planets*
[4] Jones, T. (October, 2008) "Asteroid Deflection: Planning for the Inevitable," *Aerospace America*, 14-17.
[5] Chapman, Ibid
[6] Irion, R. (May, 2006)"A Hawaiian Upstart Prepares to Monitor the Starry Heavens: *Science*, 312, 840-841.
[7] Stone, R. (March, 2008) "Preparing for Doomsday," *Science*, 319, 1326-1329.
[8] Jones, Ibid.
[9] This solution is probably the only one known to most people and this is probably because they've been exposed to the movie *Armageddon* (1998). NASA uses this movie as a management training device. Prospective managers are asked to identify as many inaccuracies in the movie as they can. They've identified 168.
[10] Lichem, W.A. (2009) "International Legal and Institutional Implications of Asteroid Threat Mitigation Operations." Paper presented at the Conference on Near-Earth Objects: Risks, Responsibilities and Opportunities – Legal Aspects, College of Law, University of Nebraska, Lincoln, April 23-24.
[11] Clarke, L. (2006) *Worst Cases*. Chicago: University of Chicago Press.
[12] Slovic, P. (2007) "Perception of Risk and Asteroid Impact." In P.T. Bobrowsky and H. Rickman (Eds.) *Comet Impacts and Human Society*. New York: Springer, 369-381.
[13] Sonter, M. (1998) "The Technical Feasibility of Mining the Near-Earth Asteroids." Presentation to the 49th IAF Congress, Melbourne, Australia, Sept 28 – Oct 2.
[14] Andres Galvez, GSP manager, Strategic Studies and Institutional Matters Office, European Space Agency, personal communication.
[15] Schweickart, R., Jones, T., von der Dunk, F., Camaro-Lara, S. (2008) *Asteroid Threats: A Call for Global Response*. Association of Space Explorers.