

## Near-Earth Objects – The United Nations International Conference: Twenty Years Later

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### Introduction

Natural history, interpreted through the geological and paleontological records, has taught us that impacts of near-Earth objects (NEOs) pose a serious threat to humankind. Astronomy tells us that it is practically inevitable that Earth will be struck by a globally or regionally civilization threatening NEO in the future. The good news is that given sufficient warning there's a good chance this threat could be mitigated if the people on Earth act collectively and decisively. The organization best suited to coordinate NEO mitigation efforts is the United Nations. That is why John L. Remo called for and organized the UN Conference on Near-Earth Objects in 1994. It's now time to look back and see what has been achieved in the past twenty years and where we should go in the future.

### The Need for Comprehensive NEO Observational Programs

The United Nations Near Earth Objects Conference at the UN Headquarters in New York in 1995 established a scientific basis and an international framework within which the NEO hazard can be discussed, minimized, or even, with sufficient warning, possibly averted. The proceedings contained basic papers outlining the critical scientific and engineering topics that must be addressed in the future to successfully meet the challenges of effective NEO mitigation. During the past 20 years there has been much to report on including research that extends NEO population surveys, space exploration activity, basic laboratory analytical studies, and observations of impact events. This paper will not attempt to catalog all the progress that has been made in the past two decades. However, some of the extraordinary activities and discoveries that have occurred since the publication of the ANYAS Volume 822 in 1997 (Figure 1; <http://onlinelibrary.wiley.com/doi/10.1111/nyas.1997.822.issue-1/issuetoc>) are highlighted and briefly outlined in an attempt to bring this volume up to date.

Regarding NEO population surveys, the NASA sponsored terrestrial based surveys dominate the field to date and have identified most of the kilometer-size asteroids that threaten society (NEAs) (<http://www.unoosa.org/pdf/pres/stsc2013/tech-33E.pdf>'s ground based NEO search program includes the Linear telescope in New Mexico, the Catalina sky survey in Arizona and Australia, the Pan-Starrs survey in Hawaii and the space based NEO Wide-field Infrared Survey Explorer (NEO-Wise) telescope which became operational in 2010. However, NASA's 2005 congressional directive to identify (and orbitally characterize) 90% of the extremely dangerous NEOs at least 140 m in diameter by 2020 is way behind schedule with only about 10% found as of July 2013 [1]. Furthermore, only about 1% of the estimated one million Earth threatening NEAs have been identified. As of 2/1/14 there were 10,591 known NEAs, 868 of which are large, and 155 which are Earth threatening. On the positive side, NASA's NEO program has rapidly increased its discovery rate.

Clearly, deploying orbital telescopes could substantially increase the discovery rate of NEOs. Especially critical would be utilizing of infra-red telescopes in inferior orbits, i.e. those orbiting the Sun near Venus. This will help achieve the goal of discovering about 90% of the NEOs > 140 m and about ½ of the 40 m objects. But this will only alleviate, though not eliminate, the NEO threat especially from the smaller Chelyabinsk sized NEOs (Figure 2) whose trajectory are consistent with an origin from the Flora family in the inner belt. Other space telescopes similar to NEO-Wise would also help in the discovery of smaller threatening objects by extending the NEO search to ever smaller limiting diameters [2]. The Russian Federation plans a new 1.6 m detection telescope in 2017 and to extend further the International Scientific Optical Network (ISON; <http://www.oosa.unvienna.org/pdf/pres/stsc2013/tech-07E.pdf>). Given the available telescope technologies one expects NEO survey issues such as size vs. number and Earth impact probability could be largely resolved within the coming decade.

Outstanding among several space explorations successfully carried out, is the sample recovery from the asteroid Itokawa in 2005 by the Hayabusa spacecraft which resolved a dilemma regarding the composition of the (most common inner belt) S-type asteroids and the most common meteorite type on Earth, the LL subclass of ordinary chondrites. Chemical, mineralogical, and isotopic analysis determined that Itokawa is composed of LL chondrite mineralogy that



**Figure 1:** Cover page of the proceedings of the United Nations Near Earth Objects Conference (Annals of the New York Academy of Sciences).

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**Received** April 04, 2014; **Accepted** April 05, 2014; **Published** April 07, 2014

**Citation:** Haubold HJ, Nadis S (2014) The Forgotten Remit of Astrobiology. Near-Earth Objects – The United Nations International Conference: Twenty Years Later. 2: e104. doi: 10.4172/2332-2519.1000e104

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**Figure 2:** Near Earth asteroid near the Russian city of Chelyabinsk on 15 February 2013.

was altered by “space-weathering” on its surface. This establishes an analogue relationship between (spectrographically) remotely sensed asteroids and their inner mineral composition as related to meteorite classes. There are also variations in structure, e. g. rubble piles, massive fracture, porosity, etc. that may be associated with asteroid types. Such relationships are critically important for estimating the effects on different target materials and their orbital response to high energy density interactive NEO threat mitigation missions. NASA’s Dawn spacecraft is expected to carry out a close inspection of the huge asteroid Ceres in 2015.

The very important and impressive Deep Impact space mission experiment on comet Tempel 1 in 2005 probed the structure and composition of the 6 km diameter comet nucleus using collision dynamics between a massive copper impactor and the comet [3]. A crater approximately 100-200 m in diameter and 30 m deep was excavated by the impact that ejected a complex array of icy, organic refractory, and inorganic fine dusty materials. The orbital displacement was a mere 10 to 20 m/y, inconsequential for mitigation purposes. But this is no surprise and underscores the need for developing high energy payloads for mitigation [4]. Tempel 1 was revisited by the Stardust (reconnaissance) mission in 2011. The Deep Impact mission serves as an important initial momentum transfer and orbital rendezvous model for NEO mitigation. Because of their population distribution, size, varying compositions and structures, highly active evolution and orbital uncertainties primarily due to non-gravitational interactions (i.e. jetting emissions of volatiles), NEO comet impact mitigation is an extremely difficult problem to characterize.

The Rosetta spacecraft launched in 2004 by ESA is expected to carry out landing and sampling on comet Churyumov-Gerasimenko in August 2014, which should provide new insights into the composition of comets. However, asteroid mitigation also has its own drawbacks given that high rotation rates may be present along with a rubble pile structure.

Since the 1995 UN NEO Conference there has been very little innovative computer modeling of high energy density (HED) interactions with NEOs, e.g. CTH hydrocode as applied to NEO interactions such as atmospheric entry, cratering and mitigation. A long term experimental analysis of the momentum and energy transfer effects of HED soft X-ray radiation on meteorites (as asteroid analogs) was concluded [4]. Simulations of and experimentation on HED mechanical and radiation interactions on putative NEO models is critical for a successful NEO mitigation mission. Current rocket technology, e.g. Ares 1 or 5, Atlas 5, Athena, or Delta IV heavy launch vehicle, could, with minor modifications, be up to the task of reliable

payload delivery, within an optimal rendezvous time frame depending on the mitigation system.

Standing out is the sudden, singular, and dramatic observed event of the entry and subsequent explosion into Earth’s atmosphere of an approximately 20 m near-Earth asteroid (NEA) near the Russian city of Chelyabinsk on 15 February 2013 (Popova [5]; Figure 2). With an explosive energy equivalent to about 1/2 MT of TNT, Chelyabinsk is thought to be the most energetic impact since Tunguska (~10-50 MT) in 1908. Because of the ubiquity of consumer video devices and timely and well-managed damage assessments, the Chelyabinsk impact event was well recorded allowing quantitative evaluations of key parameters; (shallow) entry angle (~18 d), speed (~20 km/s), airburst altitude (~27 km), and debris path ~ 100 km. Mineralogical analysis of recovered meteorite fragments indicate a strongly shocked LL chondrite with a density of 3.3 g/cm<sup>3</sup> and an entry body mass of ~ 1.3 x 10<sup>7</sup> kg. Although many injuries and substantial ground damage were sustained, fortunately there were no fatalities.

That the Chelyabinsk impact occurred without warning should come as no surprise according to work by Isobe and Yoshikawa [6], presented at the 1995 UN NEO Conference, showing that with ground based telescopes there is a blind celestial area surrounding the sun at about 30 degrees elongation in which an asteroid approaching the Earth cannot be detected optically because of the bright sky background. The number of NEOs coming from this area to within a minimum distance less than 0.01AU of the Earth comprise more than 30% of the total. One way to detect these NEOs is to deploy infra-red sensitive survey telescopes in inferior orbits as discussed above. It shall be highlighted here that Syuzo Isobe [6] organized an IAU NEO Conference as a follow up to the UN NEO Conference as part of the 23rd General Assembly of the International Astronomical Union (IAU), held at Kyoto, Japan, in 1997.

## UN Agenda Item NEOs

Since the 1995 UN NEO Conference, there have been numerous meetings, workshops, and topical conferences, sponsored by Member States of the UN Committee on the Peaceful Uses of Outer Space (COPUOS), whose purpose was to recommend, initiate, or develop further original scientific initiatives and topics laid out in 1995 at the Conference (Isobe and Hirayama 1998; Remo and Haubold 2001; Wamsteker, Albrecht and Haubold 2004). The Conference was also an important international meeting in the United Nations Basic Space Science Initiative, implemented for the development of astronomy and space science worldwide in the period of time 1991-2012 (Haubold [7]; <http://aas.org/posts/news/2013/08/united-nations-basic-space-science-initiative>).

An Action Team on Near-Earth Objects was established in 2001 by COPUOS in response to recommendations of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space [8-10], held at the United Nations Office at Vienna and charged with the following tasks: (a) review the content, structure, and organization of ongoing efforts in the field of Near-Earth Objects; (b) identify any gaps in the ongoing work where additional coordination is required and/or where other countries or organizations could make contributions; and (c) propose steps for the improvement of international coordination in collaboration with specialized bodies [11]. Since 2001, the Action Team has considered annual reports submitted by the Member States active in NEO work, as well as recommendations concerning an international response to the NEO impact threat made by workshops and conferences conducted by the international community.

The Action Team identified three primary components of threat mitigation: (a) discovering hazardous asteroids and comets and identifying those objects requiring action; (b) planning a mitigation campaign that includes deflection and/or disruption actions and civil defense activities; and (c) implementing a mitigation campaign, if the threat warrants. The Action Team emphasized the value of finding hazardous NEOs as soon as possible in order to avoid unnecessary delays in NEO threat mitigation missions. Recommendations of the Action Team are meant to: (a) ensure that all nations are aware of potential threats and (b) ensure the design and coordination of mitigation activities among nations that could be affected by an impact and those that might play an active role in any eventual deflection or disruption campaign [12].

At its sixty-eighth session, the General Assembly of the United Nations, on 11 December 2013, welcomed with satisfaction the recommendations for an international response to the near-Earth object impact threat endorsed by the Scientific and Technical Subcommittee of COPUOS at its fiftieth session and by COPUOS at its fifty-sixth Session [13].

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