CONFERENCE REPORT: 2011 IAA PLANETARY DEFENSE CONFERENCE, 09-12 May 2011, Bucharest, Romania

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The International Academy of Astronautics (IAA) has held its second conference on protecting our planet from impacts by asteroids and comets from 9–12 May 2011 in Bucharest, Romania. The website of this 2011 IAA Planetary Defense Conference is:

http://www.pdc2011.org/

The abstracts of all presentations are available on this website (see "Programme").

The sessions of the conference were organized as follows:
- Session 1: History & Current Status;
- Session 2: Discovery & Tracking Resources and Plans;
- Session 3: Potentially Hazardous Objects – Recent Progress;
- Session 4: Impact Consequences & Education;
- Session 5: Campaign Planning;
- Session 6: Mission Planning & Technologies;
- Session 7: Student Session;
- Session 8: Legal Policy, Political Framework for Planetary Defense;
- Poster Session.

The conference started with a *Historical Overview of the Cosmic Impact Hazard*, presented by David Morrison from NASA, USA. He reminded that our planet is vulnerable even to relatively small impacts with near-Earth objects (NEOs, which are mainly asteroids and comets). In order to protect our planet from such global environmental damaging impacts, a first issue is to correctly estimate the impact hazard. NASA started in 1998 the program called Spaceguard Survey, in order to discover and track most of the potentially dangerous near-Earth asteroids (NEAs). From the defense point of view, two solutions were considered so far: 1) the use of the nuclear propulsion and of nuclear explosives to deflect or disrupt the threatening NEAs; 2) telescopic surveys in order to be warned of dangerous NEAs years or decades before the possible impact. In what concerns the use of the nuclear technology, several questions have been raised: "Are nuclear

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options acceptable? If so, could they be tested?", or "How do we ensure that asteroid defense systems are not misused for military purposes?"

Still in Session 1, Lindley Johnson from NASA presented the *US/NASA NEO Program Status and Plans*, while Detlef Koschny from the European Space Agency (ESA) spoke about *The Near-Earth Objects Segment of the European Space Situational Awareness Programme*. In such serious issues for science and public policy, which obviously concern all mankind, the collaboration of all main space agencies, such as NASA, ESA, or the Japan Aerospace Exploration Agency (JAXA), is extremely important. In fact, Richard Crowther from the United Kingdom Space Agency presented the involvement of the United Nations, in his speech entitled *Introduction to UN COPUOS and NEOs*. He outlined the strategy and approach for dealing with near-Earth objects (NEOs) within the UN framework, ranging from the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), in 1999, to current discussions within Action Team 14 and the Working Group on NEOs.

Session 2 concerned the *Discovery & Tracking Resources and Plans*, since detecting and then tracking NEOs is the first stage of the planetary defense strategy. Using a method of evaluating the "re-detection ratio" of the survey (fraction of detections that are already-known objects), Alan Harris estimated the number of NEAs of diameter > 1 km to be 996 ± 45, from which a number of 821 such large NEAs have already been discovered until January 27, 2011. In what concerns *Comparing the Earth Impact Flux from Comets and Near-Earth Asteroids*, Donald Yeomans *et al.* drawn the attention on Long-period comets (LPCs, *i.e.*, active comets with orbital periods greater than 200 years), more precisely on the fact that these LPCs are the most difficult NEOs to mitigate, since their "impact warning time would be measured in only a few months- not years".

Two telescope systems currently in use were presented: the Catalina Sky Survey, located at the Mount Lemmon Observatory in Arizona, respectively the Pan-STARRS 1 (PS1) telescope, located atop Haleakala volcano in Hawaii. As for the next-generation of telescopes, the following future projects were presented: the Large Synoptic Survey Telescope (LSST, chosen site Cerro Pachon, Chile); the astrometry of the Gaia mission; the "Near Earth Object Surveillance Satellite (NEOSSat) which will search near-Sun along the ecliptic plane to efficiently discover objects of the Aten and Atira orbital classes" (A. Hildebrand *et al.*); finally "a Space-Based Near-Earth Object Survey Telescope in support of human exploration, solar system science, and planetary defense" (P.A. Abell *et al.*).

Session 3 was focused on *Potentially Hazardous Objects*. Patrick Michel spoke about the *Physical Properties of NEOs* (*e.g.*, size, shape and mass of an asteroid, or knowledge of the NEO's surface, composition and internal properties), which are relevant for mitigation strategy designs. By using the Wide-Field Infrared Survey Explorer (WISE), NEOs diameters and albedos can be determined, thus obtaining a more precise calculation of mass and impact hazard (A. Mainzer *et al.*). By using radars such as Arecibo (Puerto Rico) and Goldstone (California),

the provided images can reveal sizes, shapes, spin rates of NEAs, features on their surface such as craters and valleys, masses of binary NEAs, etc. Radar tracking can also significantly refine collision probability estimates based on optical astrometry alone (L. Benner). Several presentations focused on predicting possible impacts, *e.g.*, Steve Chesley spoke about "asteroid impact hazard assessment over long time intervals".

Impact Consequences & Education was the topics of Session 4. Giuseppe Longo opened this session speaking about the Tunguska impact, "the best-known historical cosmic impact on our Planet, which took place in Siberia on June 30, 1908. A huge explosion, equivalent to 1000 Hiroshima nuclear bombs, devastated 2000 square km of Siberian taiga". G. Longo pointed out that no meteorite fragments were found, speaking about the hypothesis that "the Tunguska bolide underwent fragmentation or was one of the 20% of NEAs that have satellites or are double bodies". Since small asteroids are far more likely to hit the Earth, Galen Gisler performed a detailed *Calculation of the Impact of a Small Asteroid on a Continental Shelf*. He simulated the ground shock and the sediment-laden splash wave generated by the impact of a 200-meter-diameter stony sphere, as well as the associated atmospheric thermal effects (high temperatures) and the sediment transport and inundation consequences. The conclusion of G. Gisler was that "the atmospheric effects from continental shelf impacts are worse than the impact tsunami". Three Romanian researchers from University Politehnica of Bucharest, D. Isvoranu, S. Danaila and V. Badescu, presented the *Dynamics of tsunamis generated by asteroid impact in the Black Sea*. Using the TsunamiClaw software, their simulation considered a 250 m asteroid and a distance between the impact point and the coast of about 150 km. Finally, J.-L. Venant *et al.* gave the audience some hope by underlining *The protective role of the Earth's atmosphere against the threat of asteroids*, by ablation and disruption.

In what concerns the educational issues, M. Mueller spoke about *Creating Awareness – The impact hazard in public education curricula content, students' interests and concepts and educational implementation*.

Session 5 was dedicated to *Campaign Planning*, *e.g.*, A. Zimmer and E. Messerschmid spoke about *Target selection and mission analysis of human exploration missions to Near-Earth Asteroids*. As an example of mission, J.-T. Grundmann *et al.* presented the AsteroidSQUADS/iSSB mission scenario, which "employs a flotilla of simple multi-role spacecraft directed at a suitable sub-PHO size practice target for a brief but intense integrated deflection campaign exercise in real space". Another example is the *Robotic and Human Exploration/Deflection Mission Design for Asteroid 99942 Apophis* (S. Wagner and B. Wie). In fact, "the asteroid 99942 Apophis appears to be the most likely to impact Earth" on April 13, 2036, but "an impact from Apophis appears unlikely, with an estimated impact probability of approximately four-in-a-million".

Different deflection strategies can be considered: nuclear interceptor (*e.g.*, nuclear thermal rocket, as a propulsion device for delivery of thermonuclear

payloads – S. Howe *et al.*), kinetic impactor, low-thrust propulsion, solar or laser ablation, gravity tractor (C. Foster *et al.* proposed multiple gravity tractors), etc. The choice of the deflection methodology depends on the NEO composition, for example Y. Sugimoto *et al.* have "modified the chemical composition of a set of virtual impactors to investigate how NEO composition affects a change in deflection methodologies". In order to integrate all campaign planning factors, the Aerospace Corporation, USA, is *developing a handbook and an on-line tool on defending Earth against potentially hazardous objects* (N. Melamed).

Session 6 concerned *Mission Planning & Technologies*, in close connection with the previous session. Thus, the "Gravity tractor strategies for deflecting a binary asteroid system" were further investigated by J. Bellerose *et al*. As announced in the previous session, "for realistic worst-case mission campaigns with a warning time of less than 10 years, a direct intercept mission employing nuclear explosives becomes the only viable option" (Bong Wie). The same nuclear option is the aim of the *Numerical models of hazard mitigation by nuclear stand-off burst* presented by C. Plesko *et al*., while D. Dearborn and M. Bruck warned about the *Limits on the use of nuclear explosives for asteroid deflection*. An ingenious solution was presented by C. Bombardelli *et al.*: the *Ion beam shepherd new concept for asteroid deflection*.

Design options for NEO and NEA missions were outlined by J. Gil-Fernandez *et al.* (GMV, Spain), V. Friedensen *et al.* (NASA) and M. Yoshikawa *et al.* (JAXA, Hayabusa mission). Again one can remark that space agencies from all over the world are involved in planetary defense. Specific mission planning technologies were also presented: *Measuring the momentum transfer for asteroid deflections* (K. Housen and K.A. Holsapple); *Influence of intermediate-scale structures on Yarkovsky and YORP effects* (O. Golubov and Y.N. Krugly); *Improved navigation techniques for asteroid landers and impactors* (A. Klesh *et al.*).

The Student Session 7 was aimed to encourage the involvement on young researchers in planetary defense, while Session 8 concerned the complex legal and political aspects of this serious defense issue for all mankind.

The 2011 IAA Planetary Defense Conference had also a Poster Session. From the applied mechanics point of view, let us remark the following paper: *Computational Fluid Dynamics simulations of infrasound generation process by meteorites*, presented by M. Henneton, Ph. Delorme, O. Gainville and F. Coulouvrat.

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