Part 3. Reminiscences from past IAU General Secretaries

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The IAU and the Impact Hazard

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Abstract. A brief history of research concerning the risk of impacts by asteroids or comets onto the Earth is presented with attention to the role played by the IAU. Special focus is placed on the events that occurred about 20 years ago, which caused the IAU to become seriously involved in dealing with the impact hazard and to take a leading role in international coordination of these activities.

Keywords. impact hazard, asteroids, comets

1. Introduction

A Near-Earth Asteroid (NEA) is an asteroid with a perihelion distance less than 1.3 au, implying that it is either on an Earth-crossing orbit or may enter such an orbit within $\sim 10^4$ y due to planetary perturbations. When the IAU was founded in 1919, only three NEAs were known. The first one, (433) Eros, was discovered in 1898.

With asteroids known to move on Earth-crossing orbits, the risk of asteroidal impacts onto the Earth could not be denied. Indeed, the impact risk had already been realized since centuries as far as comets were concerned. However, the magnitude of the impact risk posed by NEAs was unknown, since it was not possible to estimate the number of undiscovered NEAs from the few discoveries thus far made.

The dominating hypothesis on the formation of the lunar craters at the time in question was that these are of volcanic origin. Large circular structures on the Earth were also considered as volcanic. Thus, the frequency of impacts appeared to be very low, and what we now call the impact hazard was not an issue. This situation would remain unchanged for a long time, since new chance discoveries of NEAs took place only rarely.

There was only one occasion that led to some concern. This happened near the end of October 1937 with the discovery of (69230) Hermes, which was due to a very close approach to the Earth. With a mere four days of observations, no orbit could be calculated, but the closeness to the Earth was undisputed. The object remained lost until 2003, and in the meantime there was no guarantee against a second, even closer approach with a possible impact. Even so, it would still take a few decades before such worries came to the fore in news media.

From 1947, a Minor Planet Center (MPC) operated under the *aegis* of the IAU, first at the University of Cincinnati and then, since 1978, at the Smithsonian Astrophysical Observatory. This has made essential contributions to the international coordination of orbital and astrometric work on asteroids and comets. However, the MPC deals with all kinds of asteroids, not only NEAs, and its initial mandate was independent of the impact hazard.

2. Realization of the impact hazard

The route toward the realization of the impact hazard started in earnest during the 1950s with the work of several geologists on a possible impact origin of terrestrial craters. Perhaps the most notable of these was Eugene M. Shoemaker, whose work on the Barringer Crater in northern Arizona proved that this is an impact crater (Shoemaker 1963) and, moreover, a rather recent one. Other evidence for impact craters tended to concern much larger and older structures.

With this development, the debate on the possible impact nature of the lunar craters (Baldwin 1949) was revitalized. However, no consensus was yet within reach. At the end of the 1960s the number of NEAs was 27, and 13 of these had perihelion distances less than the Earth's aphelion distance (so-called Apollo asteroids). A few more close approaches to the Earth had also been identified. An interesting case was that of (1566) Icarus, discovered in 1949, which flew by the Earth at a distance of 0.04 au on June 14, 1968. This predicted flyby caused some alarmist newspaper headlines.

The following progress has been characterized by several great strides at intervals of roughly ten years. First of these came the lunar sample return missions of the Apollo and Luna programs, which proved that the surface regolith of the Moon is formed by layers of impact ejecta. This clarified the nature of the lunar craters and demonstrated that impact cratering has been an important process shaping the surfaces of planets and satellites in the solar system. The same time also saw the start of organized NEA search efforts using Schmidt telescopes.

The second important event was the discovery of a worldwide iridium-enriched clay deposit in the Cretacious-Tertiary boundary layer (65 Ma), suggesting a major impact at that time and a causal link between this impact and the associated biological mass extinction (Alvarez *et al.* 1980). The ensuing debate over possible relations between major impacts and the evolution of life on Earth took many directions, and a few consequences stand out. One is that the world was made aware that cosmic impacts not only form craters but may punctuate biological evolution and threaten the survival of species like mankind. Another is that much was learned about the physico-chemical mechanisms that cause the hazard to human lives.

About 100 NEAs larger than 1 km in diameter were known at the end of the 1980s, and the estimates of the total population size were converging. Together with other scientific progress, like the one just mentioned, this could be used to pin down the impact hazard in terms of mortality rate, which in turn led to the third major stride. With a total number of km-sized NEAs of $\sim$1000, the average impact rate onto the Earth would be about one per million years, and if one of the undiscovered objects would strike the Earth in a near future, the likely, global fatality was $\sim 10^9$ people. The estimated, average annual death rate is thus $\sim$1000 per year over a period of 1 My. Clark Chapman and David Morrison (Chapman & Morrison 1989) published numbers like this in the book Cosmic Catastrophes.

Thus, the impact hazard was made known and in some sense quantified. The similarity of the above death rate to that of airplane crashes over a period of ten years indeed made an impact, and there were several important consequences. The first IAU initiative specifically related to the impact hazard was the setting up of the Working Group on Near-Earth Objects at the XXIst GA in Buenos Aires, 1991. Simultaneous to this, on request by the US Congress, NASA was studying ways to deal with the hazard, one of which was the Spaceguard Survey (Morrison 1992) aiming to discover 90% of the km-sized NEAs within a decade.

3. The IAU involvement

The work done in the WG notwithstanding, the impact hazard was not immediately of high priority within the IAU. The study of NEAs dwelt within the quiet backwaters of the scientific ocean, and in 1994 even the symbolic financial support to the MPC was withdrawn. However, the Spaceguard Survey worked flawlessly and with it came new NEA orbits and ephemerides in large numbers. It was just a matter of time, when the first NEA ephemeris would involve the risk of an upcoming impact with the Earth.

This materialized with the discovery of the km-sized Apollo asteroid 1997 XF11. Based on observations available after a few months and the projected orbit at a close encounter with the Earth in 2028, calculated by MPC Director Brian G. Marsden, IAU Circular No 6837 of March 11, 1998, contained the words "*not entirely out of the question*" concerning an actual impact. Other astronomers, particularly the team at NASA's Jet Propulsion Laboratory, came to the opposite result, denying the possibility of such an impact.

Thus, the world was facing the awkward situation of two contradictory statements on the possibility of an imminent destruction of human civilization around the globe. The IAU found itself in the midst of the resulting turmoil. In retrospect, the reaction of our Union has to be judged admirable, largely thanks to the prompt and wise actions by General Secretary Johannes Andersen. The same year, an IAU policy statement on NEO research was issued. The financial support to the MPC was reinstated and doubled, and MPC Terms of Reference were negotiated and accepted. A central part of these was to secure quick and unrestricted data dissemination as a non-negotiable duty of the MPC. The role of the MPC as an international facility to serve scientific work on the impact hazard was also promoted within wider, both political and scientific circles in order to raise awareness and attract further funding.

In my roles as AGS and GS during 1997–2003, I dealt with these issues as one of my top priorities, and I am happy to see that they have remained a high priority for the Union ever since. Detailed accounts of the early IAU activities in this area can be found in (Rickman 2002, 2006). In addition, the IAU initiated and became a leader of a project funded by ICSU, whereby the impact hazard was studied on a multi-disciplinary basis covering most aspects of society's preparedness to this particular kind of natural disaster (Bobrowsky & Rickman 2007).

4. Scientific risk assessment

The ultimate rationale of the Spaceguard Survey was not the discovery of remaining NEAs but, first, to make sure that these did not pose an imminent threat of impact, and then to put in place a strategy of mitigation for the case that this should prove necessary. Meeting the first goal was a matter for scientific research, and the great progress made in this field around the turn of the millennium can be regarded as the fourth in the above-described series of milestones. The idea is as follows.

Consider an NEA, whose future motion involves the possibility of a collision with the Earth. At the time its ephemeris is computed, the observations constrain its osculating orbit to a certain domain in phase space. Inside this domain there is a small region, where all the orbits lead to a collision. The relative measure of that region compared to the whole domain indicates the likelihood of impact. Further observations will shrink the domain of "compatible orbits" but not necessarily remove the hazardous region. Hence, the likelihood of impact may at first increase but will eventually tend to zero, unless a real impact will occur. If each compatible orbit is associated with a virtual NEA, the goal is thus to kill the virtual impactors by optimally planned observations (Milani *et al.* 2000).

There have been a number of cases, where such a scheme has been put into real practice. As a consequence, astronomers have sometimes appeared in the media as doomsday prophets by stating that some asteroid presents a certain, minimal likelihood of colliding with the Earth at a certain time in the future. We may then have appeared incompetent or, worse, as having cried wolf when the impact risk dropped to zero due to planned observations. While this was initially perceived as an issue, it only took a few years

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before our scientific pursuit stopped raising unnecessary alarm. Of great significance were coordinating activities, like the efficient work of the IAU MPC and the setting up of independent, automatic computing facilities at the University of Pisa and at JPL (CLOMON2 and Sentry, respectively), whose results are continually checked against each other.

Thus, at present the NEA impact hazard has been recognized, and appropriate measures have been put in place. Non-zero impact risks exist but none of concern in the present century, and these are dealt with in a routine manner. The IAU has been actively cooperating in this development and continues to do so.

References

Alvarez, L. W., Alvarez, W., Asaro, F., Michel, H. V. 1980, *Extraterrestrial Cause for the Cretacious-Tertiary Extinction*, *Science*, 208, 1095–1108

Baldwin, R. B. 1949, *The Face of the Moon*, Univ. of Chicago Press

Bobrowsky, P. T., Rickman, H. (eds.) 2007, *Comet/Asteroid Impacts and Human Society*, Springer (Berlin, Heidelberg, New York)

Chapman, C. R., Morrison, D. 1989, *Cosmic Catastrophes*, Plenum Press (New York)

Milani, A., Chesley, S. R., Boattini, A., Valsecchi, G. B. 2000, *Virtual Impactors: Search and Destroy*, *Icarus* 145, 12–24

Morrison, D. 1992, *The Spaceguard Survey Report of the NASA International Near-Earth-Object Detection Workshop*, NASA Publ.

Rickman, H. 2002, *NEO Research and the IAU*, in *Proc. Intern. Workshop on Collaboration and Coordination among NEO Observers and Orbital Computers* (eds. S. Isobe & Y. Asakura), Japan Spaceguard Assoc., pp. 97–102

Rickman, H. 2006, *IAU Initiatives Relating to the Near-Earth Object Impact Hazard*, in *Organizations and Strategies in Astronomy*, Vol. 6 (ed. A. Heck), Springer, pp. 225–241

Shoemaker, E. M. 1963, *Impact Mechanics at Meteor Crater, Arizona*, in *The Moon, Meteorites and Comets* (eds. B. M. Middlehurst & G. P. Kuiper), Univ. Chicago Press (Chicago), pp. 301–336

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