

NEAR-EARTH OBJECTS IMPACT HAZARD ASSESSMENT SCALES

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Introduction: As demonstrated by the 2013 Chelyabinsk event, asteroids pose a threat to safety of lives and are a critical consideration for overall planetary defense. They are a constant reminder of the significance of identifying, assessing, monitoring, and classifying near-Earth objects (NEOs), which may frequently have no effect and critically, though scarcely, help us identify cataclysmic effects. Here, we consider assessment scales, namely the Torino and Palermo Technical Impact Hazard Scales their utility and limitations for impact hazard assessment.

Hazard assessment scales: Over the years, several impact hazard risk and probability models have emerged to quantify the likelihood, severity, and level of impact based on multiple variables including velocity, mass, magnetic fields, etc. Alternatively, impact hazard risk assessment scales assess the predicted severity of collisions based on probabilistic parameters and calculated kinetic damage potentials into a single value on an integer scale.

Torino Scale: The Torino Scale is currently recognized as the gold standard for the impact hazard risk assessment scale due to its simplicity and accessibility for members of the general public [1]. With an easy-to-use color coded system, the level of devastation and seriousness of the impact can be communicated to inform scientific response, evacuations and larger public responses. Collision probability and the estimated kinetic energy are both major variables for the Torino Scale and as such, other parameters are not applied. This means impact predictions are uni-dimensional and do not consider multiple factors such as orbital parameters and other NEO properties.

Palermo Technical Impact Hazard Scale: In contrast, the Palermo Technical Impact Hazard Scale is a logarithmic scale much more complex than the Torino Scale [2]. In this scale, a more comprehensive consideration of impact probability and estimated kinetic yield is included. As a result of its inclusion of additional orbital parameters and NEO properties in its calculations, the Palermo Technical Impact Hazard Scale can also be prone to more error. In 2002, for example, the NEO (89959) 2002 NT7 and asteroid (29075) 1950 DA gave a positive reading suggesting a higher than background risk – both of which was reduced after subsequent measurements.

Future avenues: While both scales offer estimates, advancing probability models will help us to more effectively classify the likelihood, severity, and level of the impact. With brief positive readings for NEOs such as 99942 Apophis, novel probe designs may help enable sampling for further parametric assessments and modeling required for predicting future impact [3,4].

References:

[1] Chapman, C. R. and Mulligan, B. M., “NEO Impact Hazard Scales in the Context of Other Hazard Scales”, vol. 34, 2002. [2] Remo, J. L. (2004). A quantitative NEO hazard mitigation scale. *Acta Astronautica*, 54(10), 755-762. [3] Johnson P.A., et al. (2020) *Asteroid Science in the Age of Hayabusa2 and OSIRIS-Rex*, Tucson AZ, Abstract# 2011. [4] Johnson P. A. et al. (2020) Considerations for the Application of Probes for Mineral Sampling on Apophis. *Apophis T-9 Years: Knowledge of Opportunities for the Science of Planetary Defense* (2020), Abstract #2001