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From detection to deflection: Mitigation techniques for hidden global threats of natural space objects with short warning time

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ABSTRACT

Throughout recorded history, hundreds of Earth impacts have been reported, with some catastrophic localized consequences. Based on the International Space University (ISU) Planetary Defense project named READI, we address the impact event problem by giving recommendations for the development of a planetary defense program. This paper reviews the current detection and tracking techniques and gives a set of recommendations for a better preparation to shield Earth from asteroid and cometary impacts. We also extend the use of current deflection techniques and propose a new compilation of those to deflect medium-sized potentially hazardous objects (PHOs). Using an array of techniques from high-energy lasers to defensive missiles, we present a set of protective layers to defend our planet. The paper focused on threats with a short warning period from discovery to impact with Earth, within few years.

Contents

1. Introduction

Earth is the cradle of life and generally does an incredible job protecting its inhabitants from external threats. Despite a robust atmosphere and magnetosphere, it cannot prevent all hazards from threatening the life it contains. Cosmic hazards come in many forms,

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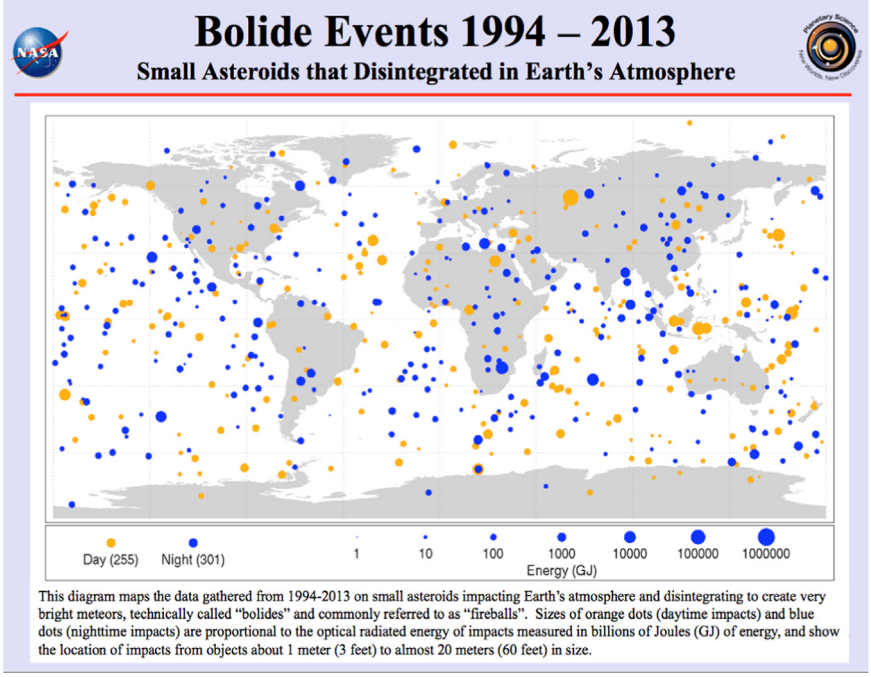

Fig. 1. Global map of bolide events 1994–2013 [2].

from solar flares to deadly gamma ray bursts, but the discussion of planetary defense focuses on the threats from asteroids and comets. The potential dangers associated with high energy impacts from these objects pose a real threat to life on Earth. At least one of the five major extinction events in the Earth's past was the result of an asteroid impact, approximately 65 million years ago [1], and smaller impacts occur more frequently. Fig. 1 demonstrates this by showing a map of the bolide events (meteors) recorded around the globe between 1994 and 2013 [2]. Earth is being constantly bombarded by objects of various sizes, but events such as Tunguska in 1908 [3] and Chelyabinsk in 2013 [4] demonstrate that impacts from larger threats are much more common than the public usually believes. Therefore, it is essential that systems and methods be developed to deal with such hazards, and ensure the habitability of Earth and the survival of the life that it contains.

Current technologies have reached the point where it is plausible for humans to take a proactive role in defending Earth. As such, it is critical for humanity to conduct studies and develop the necessary technologies to protect our planet.

In order to contribute to the discussion on planetary defense and to propose solutions to the problem, a thorough understanding of the threats, namely near-Earth objects (NEOs) and long-period comets (LPCs), must be achieved. NEOs are asteroids or comets that orbit the Sun with a closest approach distance to it (perihelion) of 1.3 astronomical units (AU) or less, while LPCs are comets with periods greater than 200 years. Asteroids and comets are thought to be relatively unchanged remnants of the primordial phase of the Solar System formation that failed to aggregate into planets about 4.6 billion years ago.

Most asteroids are rocky bodies, with a minority composed of metal, mainly nickel and iron. Ranging from few meters across to hundreds of kilometers in diameter. Most of them are generally orbit the Sun in a region between Mars and Jupiter. Asteroids classified as NEOs can be found in four types of orbits: the Atiras and Amors orbits come close to Earth but never cross its orbit, while the Atens and Apollos have Earth-crossing trajectories and have a higher chance of impacting the planet.

Comets on the other hand are made of ice, rock, and organic compounds, and are often only a few kilometers in diameter. They

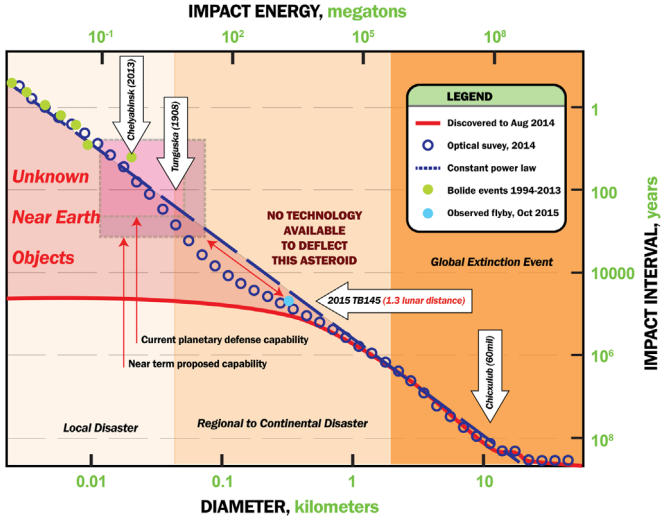

Fig. 2. Near Earth Asteroids (NEAs) impact intervals and impact energies as a function of the asteroid's diameter. Modified Harris chart [9] from [10].

mainly exist in the outer Solar System, in the region between Uranus and Neptune and in the Kuiper Belt, beyond Neptune's orbit. They can enter into an orbital course around the Sun with any inclination with respect to Earth's orbital plane. These are called LPCs because they orbit the Sun in elliptical trajectories with orbital periods ranging from 200 years to several million years. The short-period comets that exist in the Kuiper Belt periodically approach the Sun in orbits with periods of under 200 years with inclinations generally close to Earth's orbital plane [5] and they are included within the NEO category if they fulfill the perihelion criterion.

Almost all of the biggest objects, greater than 500 m in diameter, have already been discovered. An impact from any of these objects could create a global extinction event [6], but none of those detected currently threaten Earth, and their estimated time between impacts is in the millions of years. On the other hand, objects smaller than 20 m in diameter may disintegrate in the atmosphere and create no damage on the ground, but impact Earth at least once a century. The