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APPLICATION OF IOT IN PLANETARY DEFENSE

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Since the very first artificial object was launched into a Low Earth Orbit the technology surrounding space research has developed rapidly. Recent advancements let us fight against threats that were never thought of before resulting in the science of planetary defense. Our home planet Earth is continually barraged by numerous cosmic objects. Fortunately for the life on Earth most of these effects cause no harm because of the naturally formed protection built into the planet such as the relatively dense atmosphere or the surrounding magnetic field. Evidence shows that some asteroids or comets however can produce considerable damage. Although deflecting an incoming asteroid was considered science fiction a few decades ago, nowadays we are able to successfully modify a near-Earth object's orbit to miss a potential impact.

There are several documented methods for asteroid deflection, some of which are already in the testing phase such as the DART mission that provided recent successful results in modifying an asteroid's orbit with kinetic impact [1]. Other known methods include nuclear deflection and disruption that may cause controversy with the usage of nuclear technology in space, laser ablation being a theoretical method for vaporizing material away from the near-Earth objects (NEOs), and gravitational tractor that is a spacecraft with sufficient mass to tug the NEO away of its original path with gravitational force.

A new and interesting approach to planetary defense is the application of Internet of Things (IoT) technology. IoT can be conceivably used for the exploration of near-Earth objects as well as for performing defense schemes against potentially hazardous asteroid encounters. The use of IoT implies the application of numerous cheap devices that communicate with each other forming a larger network instead of a single complicated and costly apparatus. This network can be utilized as a complex system to help deep-space exploration and the discovery of potential threats as well as it can be a supportive tool for the modification of the orbit of near-Earth objects.

Mentioned ideas include distributed solar sail technology along with the description of how we can make use of Internet of Things technology to detect asteroids that may be dangerous to life on Earth.

IoT infrastructure in space

The everyday use of Internet of Things technology has gained extreme popularity in the recent decade. With an estimated number of IoT devices reaching 14.4 billion in 2023 the need for a strong network capable of handling the market demands emerges since current networks are not equipped to deal with the exponential growth in connected devices even only for Earth-based application. Not surprisingly there are recent ongoing projects aiming to enhance network capabilities while providing potential to extend IoT coverage to space.

In certain scenarios IoT devices are unable to connect to the internet using terrestrial and aerial networks due to limited infrastructure availability. In these cases, satellite communication becomes the only viable option as well as satellite networks have the ability to strategically augment the capabilities of terrestrial IoT networks [2]. Space IoT have the potential to extend planetary IoT coverage if appropriate communications standard and truly autonomous small mobile sensors capable of communications via satellites can be developed. A suitable opportunity for this purpose is the development of LPWA (Low Power Wide Area) satellites with multi connectivity chips. The LPWA network designed to allow long-range communications at low bitrate among connected devices is suitable for sensors operated on battery. The IoTEE (Internet of Things Everywhere on Earth) project proposes a receiver/emitter device with low energy consumption and a miniaturized design, enabling high autonomy and easy integration [3]. The solution provides backwards compatibility with existing and planned terrestrial and spaceborne systems leading to a space-based approach essential for a rapid rollout of worldwide IoT connectivity.

Besides theoretical initiatives functional schemes are in the works. Iridium Communications Inc. announced the service introduction of a two-way cloud-native networked data service named Iridium Messaging Transport (IMT) optimized for use over Iridium Certus – a broadband service based on the constellation of crosslinked satellites in Low Earth Orbit (LEO) – and designed to make it easier to add satellite connections to new and existing IoT solutions [4]. IMT provides IP data transport service designed for small-to-moderate-sized messages supporting satellite IoT applications. The new service offers integration with Iridium CloudConnect and Amazon Web Services (AWS) and can be used by any customer applications having small amounts of data traffic that do not require persistent connection between servers. Iridium confirms that LEO satellite constellation based IoT system is a realizable and powerful supplement to the terrestrial IoT networks.

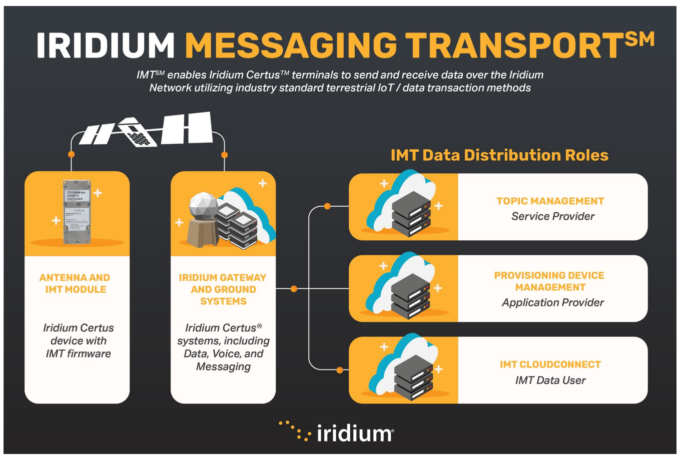

Figure 1. Iridium Messaging Transport (IMT) [4]

Asteroid detection aided with IoT

NEOs are discovered every day. To detect NEOs scientists must track their orbits and trajectories, which can be difficult to do from Earth. Since satellites provide a less disturbed vantage point to observe deep space, satellite communication enables a new level of accuracy in the detection of asteroids and comets. Earth-orbiting devices can allow for more frequent monitoring and space-based sensors can provide real-time data on NEOs' trajectories contributing to a better analysis of potential hazards in space.

The increasing number of LEO satellites reveals the potential to increase the number of active deep-space observation terminals. As mentioned before there already are IoT capable satellite networks orbiting Earth as well as there are other promising constellations under construction such the SpaceX developed Starlink with nearly 12,000 units planned to be deployed (with possible extension to 42,000). Extending their functionality, a number of these satellites could be installed a camera built with infrared-light detectors such as NEOCam that can discover and characterize most asteroids larger than 140 meters in diameter [5]. These camera modules could frequently monitor deep-space and transmit their data to the cloud using satellite IoT solutions or direct wired connections in case of the Starlink system. As the data is processed in the cloud the analysis of the images could be carried out using artificial intelligence (AI). Once correctly trained AI is good at looking at a lot of data and making fast analysis. More satellites equipped with asteroid-hunting cameras could provide greater detail and accuracy as complete spatial scans would be assembled from the data. With regular deep-space scans the AI could indicate areas worth of further investigation. In these scenarios the camera system could provide continuous real-time monitoring of space to characterize a possible threat. AI could also be utilized to optimize the frequency and detail of deep-space scans based on the motion of detected objects in order to save energy and operational costs [6].

Solar sail with IoT technology

Solar sails are spacecraft propulsion methods that are based on the radiation pressure exerted by sunlight. As the Sun radiates a total power of 3.85×10^{26} W, this energy can be used for modifying asteroid orbits as well. The foremost problem to overcome in solar sail deflection is the attachment and fastening of the sail to the NEO. An interesting solution was proposed in [7] using IoT inspired techniques. Instead of attaching one steady sail, many small sensors could be spread around the asteroid's surface where their carried panels of sail can open. Considering the weak gravitational conditions around NEOs, delivering the sensors from the carrier spacecraft to the asteroid could be carried out using several methods including electromagnets, rope with grappling hook or anchor, or methods similar to MINERVA mini-lander carried by Hayabusa spacecraft, where an internal flywheel assembly was used to hop across the asteroid's surface [8]. Though the original mission was unsuccessful the idea of hopping rover could be base for developing hopping sensors to spread solar sails across the surface since wheel-based motion is unfeasible due to the low gravity. Hopping sensors could jump with the help of an electromagnet and an iron ball. The positioning problem of the devices can be solved using LoRaWAN (Long Range Wide Area Network) implementing RSSI (Received Signal Strength Indicator). The efficiency of solar sail deflection can be enhanced using solar pumped lasers directed towards the sensor covered NEO.

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