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Planetary Defense

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Abstract

Planetary defense against asteroids should be a major concern for every government in the world. Millions of asteroids and comets cross our solar system, many of them coming dangerously close of Earth. The ones that approach Earth orbit are called Near-Earth Objects (NEOs), and come in various size and shape, from small ones that burn up completely when they enter Earth's atmosphere, to large ones that can do a great deal of damage and even threaten human race with extinction. Although extinction level impacts are extremely rare, statistically the chance still exists. While extinction is a concern, we should not disregard the smaller size asteroids because these can do extensive damage and wipe out entire regions on Earth. This article intends to provide a brief description of the current situation regarding Planetary Defense.

Chelyabinsk Event

In 2013, on February 15, local residents from Chelyabinsk region of Russia witnessed an extremely bright object in the sky. It was an asteroid, which penetrated the Earth atmosphere. Although it exploded in the atmosphere, it still did great damage. The meteor entered earth's atmosphere at a high velocity and shallow angle and exploded at a height of approximately 18 miles. The blast of the energy measured the equivalent of 500,000 tons of TNT, 10-30 times more powerful than the nuclear detonation at Hiroshima. The explosion was observed as a bright flash and produced a cloud of gas that reached around 15 miles, and a shock wave that went twice around the globe. Although the atmosphere absorbed the biggest part of the explosion, it damaged thousands of building and injured more than 1,000 people. The meteor was only about 20 meters in diameter with a mass of 12000-13000 metric tons. It is the largest asteroid to enter Earth atmosphere since the 1908 Tunguska event, which flattened thousands of square kilometers of forest, and would have destroyed an area the size of Washington DC.[1]

Significance

The Chelyabinsk event was both significant and important. It proved that the risk from asteroids below 150 m has been underestimated. The international community hoped that this event would serve as an incentive to initiate government-supported projects regarding planetary defense against NEOs. However, no significant international effort has been forthcoming. Although concepts for planetary defense exist within the scientific and international policy communities, the financial support required from governments to create a working capability is still missing.

Unlike most natural disasters, we currently possess the technology and knowledge to prevent nearly all major NEO strikes at very reasonable cost. We know how to build telescopes that can detect NEOs and we have identified a wide variety of approaches to nudging the offending rocks so they miss Earth.[2] Under the auspices of the United Nations, the International Asteroid Warning Network coordinates the search for asteroids and other space objects that threaten the Earth, and the Space Mission Planning Advisory Group (SMPAG) focuses on the space missions and technology needed to address the threat.[3]

Projects concerned with interception or destruction of NEOs have been around since the 70’s but the financial support was not. It appears it is extremely difficult to convince governments to invest significant capital in endeavors which will not have a palpable income return, not in the short term anyway. The sums required for developing the technology that will allow us to modify asteroids trajectory are substantial and no government to date has been willingto invest so much. Based on these facts, two paths were identified. First, it is argued by the international community, that a proper solution is to formalize the Space Mission Planning Advisory Group-SMPAG and a standing U.N. organization with appropriate staff and budget that has the sole purpose to defend our planet against extraterrestrial objects. Such an organization might be an efficient way to pool capital from the many governments of the world and perhaps even from the private sector. A second path would be the development of technology required for planetary defense for other objectives such as asteroid mining, which could also have a considerable return investment for governments or private business.

Space Mission Planning Advisory Group-SMPAG

SMPAG is a United Nations-mandated organization with the primary purpose to prepare an international response to a NEO threat through the exchange of information, development of options for collaborative research and mission opportunities, and to conduct NEO threat mitigation planning activities.[4] SMPAG has 15 members among who are NASA, ESA, JAXA, and ROSCOSMOS. All of the above are space agencies from countries with significant financial resources, and two of them, United States and Russia have extensive experience in the domain of space. Although the space agencies involved developed realistic projects for planetary defense, they still lack funding. The main reason for this is that all are government institutions, and for those governments an investment in countering asteroids has not been perceived as a priority. Significant Investment in an altruistic endeavor like planetary defense has not made it onto any governments agenda.

Development of Space Technologies

The development of space technologies for other purpose than planetary defense such as asteroid mining is very important because, indirectly, those technologies can be used in deflecting or destroying asteroids. A high financial return constitutes a good incentive for governments and especially for private business. Because the main goal of private companies is profit, the speed of developing and testing space related technologies could be significantly higher than a governmental led program and is very likely that they may develop a solution for planetary defense.

United States is leading in space private investments. SpaceX, for example, manufactures and launches advanced reusable rockets and spacecraft at low cost. The company was founded in 2002 to revolutionize space technology, with the ultimate goal of enabling people to live on other planets.[5] SpaceX is the only private company ever to return a spacecraft from low-Earth orbit and in May 2012 its Dragon spacecraft attached to the International Space Station, exchanged cargo payloads, and returned safely to Earth — a technically challenging feat previously accomplished only by governments.[6] Contracted by NASA and commercial companies, SpaceX already did 50 launches representing an impressive sum of $5 billion in contracts. In the future, the company will fly numerous cargo resupply for NASA and commercial satellites launches. SpaceX is the world's fastest-growing provider of launch services and has currently under development the Falcon Heavy, which will be the world's most powerful rocket.

Another example is the company Blue Origin that targets space as a new tourism opportunity. On November 23 2015, the company made history, by successfully flying and landing a reusable rocket. Powered by the company's own BE-3 engine, the rocket was launched carrying a space vehicle designed to take tourists 100 km above Earth. Shortly after liftoff, the rocket separated from the vehicle and for the first time it was guided toward a landing pad, where it re-ignited its engines, hovered briefly above the ground and finally touched down softly on the pad, remaining upright and intact.[7] This bears significant importance for space flight because it opens the era of reusable rockets, driving down the cost of space flight, and making asteroid wealth more accessible to private industry.

Space base solar power plant (SBSP), is another technology with high pay off. The idea is to put satellites on Earth's orbit, which will harvest solar energy and beam it to Earth. Experts calculate that the exploitable energy in orbit exceeds not just the electrical demand of the planet today, but also the total energy needs of a fully developed planet with over 10 billion people.[8] With the lure of a multi-trillion-dollar annual market for space energy, it is no wonder that the list of companies interested in SBSP is growing constantly. The need to move unprecedented mass flows to GEO to construct SBSP is also a powerful incentive to develop space lift technologies, like Falcon Heavy, technologies that can be very beneficial for Planetary Defense. Moreover, because it is far less energy intensive to source materials and propellant from space-based resources such as asteroids, SBSP may further encourage early private sector access and exploitation of asteroids, further advancing planetary defense related technologies.

Which brings us to the technical path, which is most likely to advance Planetary Defense: the concept of mining asteroids. Asteroids are a vast resource of minerals and water that are waiting for us to tap into. Although the development of technology to harvest asteroids comes at a high cost, the benefits are incalculably larger. Additionally, developing asteroid mining technologies assumes the ability to divert asteroids to suitable orbits and even capture and move them in Earth's vicinity where they can be mined. Fundamentally, it is the same technology that is required to divert an asteroid for mining and diverting it to save our planet. Clearly a good direction for developing Planetary Defense technologies would be asteroid mining.

All these technologies are important in themselves and represent a major step forward in space conquest, but their advantages for Planetary Defense are clear. Because of the immense benefits they bring, it is likely that space technologies will be developed towards these ends. Developing these capabilities for specific commercial applications helps make Planetary Defense viable because defending the Earth against asteroids benefits from all the above technologies. So if our planet security will not suffice to convince governments to take the required measures, maybe commercial benefit will.

Planetary Defense Challenges and Solutions

One of the most active organizations in space related subjects is The Planetary Society. It is a public organization founded by Carl Sagan, Bruce Murray and Louis Friedman in 1980 with the intent to inspire and involve the world's public in space exploration through advocacy, projects, and education.[9] In 2015, The Planetary Society sponsored the 2015 Planetary Defense Conference where participants identified five major issues that must be addressed when dealing with asteroid threats: 1. find potentially threatening asteroids and comets; 2. track them in order to see their orbit intersects with Earth; 3. characterize them to understand characteristics of dimension, composition, spin rate, if they are individual or binary; 4. deflect them (which implies the development and testing of various methods used to against potential dangerous asteroids); and finally 5.internationall collaboration, coordination and education referring to observation, planning, educating the public and building support for such an endeavor.[10] These five issues pose serious challenge for countering asteroids and an international involvement and funding is necessary for them to be solved.

Detection and Tracking

Detecting asteroids is the first major step in Planetary Defense. Currently there are a large number of asteroid detection and tracking programs. Some are ground based like SpaceWatch Camera, Catalina Sky Survey and Panoramic Survey Telescope, and Rapid Response, whereas others are satellite based like NASA WISE and Canada's NEOSat. Additionally other projects are also under development. For example, NASA's Near-Earth Object Camera (NEOCam) is a new mission proposal designed to discover and characterize most of the potentially hazardous asteroids that are near the Earth. NEOCam consists of an infrared telescope and a wide-field camera operating at thermal infrared wavelengths. NASA has recently funded the NEOCam proposal for technology development.[11]

Another example is the B612 Foundation, which is a private, nonprofit organization co-founded by astronauts in 2002 with the purpose of helping protect Earth from asteroid threats, plans to launch their own satellite, called Sentinel, to search for asteroids. The current plan is to launch The Sentinel on a Falcon 9 rocket in December 2016.

Physical Characteristics of Asteroids

However, discovering NEOs is not enough. In order to have a chance to divert or destroy asteroids that are on a collision trajectory with Earth, we need information about their physical characteristics so we can employ the right strategies. It is a crucial difference if asteroids are made up of metal or rock, or if they are made of a single object or a pile of rubble. Most asteroid compositions are determined using infrared spectroscopy from ground-based telescopes. In the infrared, different minerals absorb different wavelengths of light. By looking at the infrared spectral absorptions, and comparing them to spectra of minerals measured on Earth, it is possible to identify the composition.[12] Another way is through NASA NEAR spacecraft that orbited asteroid Eros and used infrared camera and x-ray/gamma ray spectrometer to look at the composition of the asteroid. Precise information about the composition of asteroids is very significant because will allow us to determine the best way to divert them.

Deflection

Two paths are considered, in the space community, when discussing deflection of dangerous asteroids: the first method is to use of a powerful kinetic impact, usually for small asteroids, and the second method requires the development of a spacecraft to attempt to alter bigger asteroids orbit. The first is used when the warning time is very short and does not allow extensive preparations. The second assumes that between threat discovery and actual impact, a sufficient amount of time to prepare exists.

Ground based technologies can provide the necessary means to deflect asteroids. Kinetic impact is a practical technique and the technologies are already available. The principle is the transfer of momentum to a NEO by impacting it with a rocket at high velocity. The impact would transfer momentum to the NEO and either will destroy it or cause a velocity change which, propagated in time, would cause the NEO to arrive later or sooner at the point of crossing the Earth's orbit.[13] If the point of impact is correctly calculated, the asteroid would be destroyed or a small change in position or speed would take place, enough to cause a complete miss of the Earth. This is easily achievable with some modifications of current ICBMs. They can be launched from the ground by adding extra rocket stages or various launch vehicle and spacecraft can deliver them.

This solution has some advantages and disadvantages. As stated, it has a short time requirement and can be accomplished with technologies that we already possess. The risk of undertaking such a mission is low because a kinetic deflection technique has already been demonstrated in space. Although not ground-based, NASA's Deep Impact mission successfully demonstrated the technologies for an intercept of the Tempel 1 comet.[14] However, the composition of the NEO should be known prior, so that the effects of a kinetic impact can be reliably calculated; additionally, there is great uncertainty in the effect of impact fragments which are sure to be ejected as a result of a high velocity collision.[15] The risk exists that the impact will shatter the asteroid in multiple pieces big enough to still represent a threat for Earth.

When it comes to altering the path of an asteroid or comet, to ensure it misses the Earth, various methods have been considered. These methods are often categorized into different types; for example, there are “slow-push-pull” methods, in which a small amount of force is exerted over a long period of time to slowly alter the path of the asteroid or comet, and there are “quick” methods, in which a large amount of force is applied over a short period of time.[16]

We have to keep in mind the fact that, when we refer at early warning we refer at several years. This long period is necessary for two reasons: it will provide time for planning, construction, and testing of spacecraft missions and secondly the slow push or pull concept needs time, because the force applied to the NEO, must be slow and gentle to avoid severe stress but enough to cause the desired change.[17] Additionally all these methods imply the use of manned or unmanned spaceships.

Steps are already made in this direction. Part of the official National Space Policy of the United States of America as of June 28, 2010, includes the goal of sending astronauts to an NEA in the 2025 timeframe. Required propulsive change in velocity (delta-V, or impulse for departure/return) and roundtrip mission duration (less than a year) are the most critical factors in planning human spaceflight endeavors. Therefore, the first human missions beyond the Earth-Moon system will necessarily target asteroids with orbits very similar to Earth’s. Not only are these asteroids close, but their velocity relative to Earth is small, facilitating round trip journeys. Robotic missions could capitalize on such favorable trajectories as well to minimize overall cost, but are not limited by such constraints otherwise. As a precursor to developing either type of mission, suitable candidates must be identified, and their physical properties defined to a level that constrains scientific and engineering risk.[18]

The advantages of this second path include a low risk of fragmenting NEOs, the ability to reuse of spaces vehicles developed for other purposes and the opportunity to have contingencies missions. The disadvantage, besides the lengthy period of time is the cost, which will certainly be much greater than a simple kinetic impactor.

International Collaboration

The threat posed by a pending asteroid impact is inherently international in scope. While the physical extent of an impact could range from local to regional to global, the entire world would be engaged in the unfolding drama from the announcement of a potential collision through either the successful mitigation or the disastrous consequences of impact.[19]

As shown previously, international organizations already exist and solutions are considered. However, a major problem regarding Planetary Defense that still needs to be addressed concerns international space treaties. The current regime of space related treaties is a big obstacle for space development. For example, Outer Space Treaty (OST), signed by all the relevant countries to the matter, is the basic legal framework of international space law and introduced the term *res communis*, which hinder space endeavors. OST states that space is not subject to national appropriation or sovereignty claims and the conduct of any military maneuvers on the Moon or celestial bodies is prohibited. Although these articles sound good in theory, in practice they are a major obstacle, and represent one of the main reason for lack of space exploration and of political motivation. While the interpretation of this ranges from absolutely no military activities in space to allowing activities that are military but do not constitute a kinetic attack, the result is that military activities are curtailed and limit space as a realm for employing national security activities and also prevents military force to act in support for Planetary Defense.[20] Additionally The Moon Treaty and The Agreement of Activities of States on the Moon and Other Celestial Bodies state that exploration of the Moon and other celestial bodies will be in interest and for benefit of all countries. Again, although noble in its intention, this article undermines competition in space exploration, which leads to stagnation.

Moreover, the international treaties regarding nuclear devices in space were formulated during the cold war and were intended to minimize the chance that they would be used by some nations against others--they were clearly not formulated with an extraterrestrial threat in mind. Thus, it is not unreasonable to address the amendment of these treaties to allow the employment of nuclear devices to mitigate extraterrestrial threats, even though such considerations would require extensive political and policy deliberations by the world's major powers in order to assure verifiable international safeguards and use agreements.[21] For example, Limited Test Ban Treaty between US and USSR prohibits the use of nuclear explosions in space, thus hindering a possibility of using ICBMs to defend our planet.

These treaties were conceived during the Cold War between the United States and the former Soviet Union and at that point in time, when space race was undergoing and weapons might be launched from orbit, made sense. However, today, when we really entered the space exploration age, these treaties are obsolete and deserve a reevaluation.

The United States appears to favor a liberal interpretation of the OST that might significantly advance the technologies required for planetary defense. An important step was achieved with the signing of the bill, which recognizes asteroid resources properties rights, by president Obama in November 2015. This bill opens the door for private endeavors in harvesting resource from asteroids and represents the most important law related to space, ever approved. Now the private companies have the necessary incentive to invest in asteroid mining, which means that technologies required for Planetary Defense will be developed. Even though these developments will not be governmental, they still represent a huge leap ahead and can give U.S. the push needed toward Planetary Defense.

National Approach

While international cooperation would in concept be the ideal way to tackle Earth's defense, little is done by governments to support Planetary Defense. The reasons were explained briefly above. In this light, maybe a national approach should be considered. United States (US) is the most developed country in space related missions and if it wishes to maintain a position of hegemony, should lead in Planetary Defense, both for reasons of legitimacy and the technological and economic benefits it would provide. With a vast experience and significant resources, the US can set the tone for Planetary Defense. Friendly nations look to the US as a global leader to provide public goods and provide for the common defense.

There are several reasons for which the US government should give more importance to Planetary Defense. First, as showed, developing Planetary Defense technology has important benefits for other space related missions. The US might is based on its economic power, and developing space technologies can maintain that power constant. For this, it is appropriate for the US to prioritize Planetary Defense projects and use its public and private capabilities to that end.

Second, it is important to know that the nation which will lead human kind in space, will be the hegemon of the world. While US has decreased its space budget on a yearly base, competitors has emerged. China has a strong space program, achieved rapid success, and has long term plans for deeper venturing in space, including Mars. Third, success in space remains a major source of national prestige and pride. Planetary Defense is a program that can make any country proud, but for US has a different meaning - an undeniable reaffirmation of the most powerful country and the protector of the world. Last, a significant U.S. investment in space will constitute an incentive for allies and partners to join or support it.

For all this, political backing is required to establish a national lead agency, similar with SMPAG, for handling mitigation procedures, creating lines of communication, and defining planetary-defense policy for the United States and perhaps for the United Nations.[22] Through this agency or through Department of Defense, U.S. government should devise the necessary budgetary, political, decision-making, and command and control mechanisms.

USAF Role

In the foreword of Future Operating Concept of the Air Force (A View of the Air Force in 2035), published in September 2015, General Mark A Welsh III, USAF Chief of Staff, states that for Air Force to continue to succeed in its purpose, it must consider both the challenges and the opportunities faced in air, space, and cyberspace, which is in accordance with one of USAF's core mission: air and space superiority. While air superiority is self-explanatory, let us examine what space means for USAF.

Throughout the above-mentioned document, space domain is used in conjunction with air or cyberspace capability and it is seen as 2035's USAF mission to assure capabilities, including the resilience to operate effectively in this important and increasingly contested, degraded, and *operationally limited domain*.[23]

The fact that in 2035 space is seen as an operationally limited domain by USAF is troubling. From the AF point of view, Space is only a battle domain, which at present does not include Planetary Defense or other deep space related activities. Apart from imagery and surveillance satellites, today's vision of Airmen about space is very narrow. All the problems presented in this article are considered closer to sci-fi than reality for most Airmen. Moreover, AF by collaborating with private companies, admits that access in space is often facilitated by multinational or commercial partners. If in the past, USAF was the only provider for NASA with astronauts and assets, which is not the case anymore. Partners around the world look to the USAF as the natural and logical choice to take leadership in Planetary Defense projects. The USAF nuclear capability makes it the ideal candidate to lead the national or international Planetary Defense missions. Additionally USAF had a tumultuous experience before it became independent and one expects that it can relate with the situation in which space issues are now.

This situation bears many similarities with the struggle that the Air Force had in its beginning years, when it was under the Army Corps. Space is not in the focus of Air Force leadership and space passionate Airmen are regarded more or less how aviators were regarded by the Army. As a logical conclusion maybe a separate force is appropriated, made of those passionate people who believe that space means more than satellites, in the same way that 90 years ago, Airmen believed that the airplane is more than a supportive instrument to the Army.

Conclusion

The problems of Planetary Defense are complex and challenging for both national and international institutions. It requires extensive development of technologies and support in order to provide viable short-term and long-term solutions. This article was intended to provide basic knowledge about Planetary Defense.

From the facts presented, it is clear that even a small asteroid, like Chelyabinsk, can unexpectedly do a lot of damage to property and human life. Although we possess the required technology to build an effective Planetary Defense system, the financial support does not exist. There are many paths that can lead to a viable defense program. Be it national or international, private or government endorsed the objective is to move forward and hope that for the next asteroid headed to Earth we will be prepared.

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