IAA-PDC-17-09-P01 Findings and Recommendations of the 2015 International Space University Road Map for Earth Defense Initiatives(READI) Project

Madhu Thangavelu, Team Project Chair, International Space University and the Department of Astronautical Engineering, Viterbi School of Engineering and the School of Architecture, University of Southern California, Los Angeles, CA 90089-1191 mthangav@usc.edu
J.D.Burke, Team Project Adviser, International Space University and The Planetary Society, Pasadena, California, jdburke@caltech.edu
T.Wilson, Team Project Assistant, International Space University and University College London, UK

Project Participants from Seventeen Nations
Alaa Hussein(UK), Anushree Soni(Canada/India), Bora Aliaj(Albania), Carlos Entrena(Spain), Chanwoo Lee(S.Korea), Doron Shterman(Israel), Fernando Gonzalez(Spain), High Byrne(Ireland), Idriss Sisaid(Morocco), Jackelynne Silva(USA/Peru), James McCreight(Ireland), Jessica Reinhert(USA), Jonathan Faull(Ireland), Lars Hoving(Sweden), Laura Bettiol(France), Louis Neophytou(UK), Marianne Girard(Canada), Naama Glauber(Israel), Nicholas Strzalkowski(Canada), Nikola Schmidt(Czech Republic), Oshri Rozenheck(Israel), Parker Stratton(USA), Remi Gourdon(France), Shajiha Meeran(India), Shangrong Ouyang(China), Shitao Ji(China), Toby Call(UK), Susanne Peters(Germany), Tihomir Dimitrov(Bulgaria), Shrrirup Nambiar(India), Umang Parikh(India), Yunjun Yang(China), Yuxian Jia(China), Zheng Fang(China)

ABSTRACT

Keywords: Planetary Defense, Directed Energy, Solar System Situational Awareness, Asteroid Deflection, Asteroid Disintegration, Nuclear Weapon Engagement, Natural Disaster Mitigation

Planetary Defense is a complex problem, not well articulated by policy makers and the general public need to be made more aware of and educated about this extraterrestrial threat. The recent Chelyabinsk incident in Russia created temporary international attention but has failed to effectively stimulate public action. To realistically address this challenge and achieve the high test and operational readiness needed for an effective Planetary Defense strategy, this READI Project created a set of recommendations for the development of a Planetary Defense Program, for the purpose of contributing to the protection of Earth from asteroids and comets. The SSP15 READI Project focused on threats for which there is only a short-term warning, specifically a warning of two years or less from detection of the object on a terminal Earth impact approach trajectory. Recommendations are offered in five areas of Planetary Defense including detection and tracking, mitigation techniques, global collaboration, outreach and education, and in the aftermath of an impact, evacuation and recovery. The findings and recommendations that are identified constitute a roadmap for planetary defense, and we believe they should be taken seriously and implemented swiftly with the consensus of all nations.

Foreword

In this Anthropocene era, where we have bestowed upon ourselves the title of “stewards of planet Earth”, in a world of many cutting-edge technologies, it is humbling to know that the power of nature still vastly exceeds all that we can bring to bear to prevent or avert natural upheavals and disasters.

For the first time in our evolution, as a progressive technology wielding species, space and other allied advanced technologies allow us to ameliorate the effects of some of these large scale calamities. We feel we are at the threshold of mastering the tools that will allow us to thwart asteroid and cometary impacts that play a critical role in shaping our planet and in the evolution of species. Transcending space situational awareness that allows us to monitor space weather routinely, an expanded solar system situational awareness is making us a more refined species, sensitive to changes more distant, where denizens of deep space like asteroids and comets lurk.

Far from just possibilities or imaginative conjectures, we continue to observe close encounters and study the effects of these impacts in our solar system neighborhood. The 2013 Chelyabinsk asteroid airburst that caused citywide damage and injury proved yet again that this natural phenomenon can disrupt lives and has to be dealt with. As our population grows, asteroids and comet impacts can cause untold misery for Earth’s flora and fauna alike, and depending on the energy release of the impact, the swift damage to physical infrastructure can be many times that of entire nuclear arsenals of the world’s greatest armies.

ISU SSP team projects have looked at NEOs and comets in the past. This latest edition is the third in the series after Cassandra in 2005 and Phoenix in 2007. The 2015 Planetary Defense team project: READI, looked at the potential for humanity as a whole to join forces to avert a cometary impact with a very short warning period, using current technologies and strategies. Employing a “more eyes on the skies” approach, and by crafting agile global networks for communications to execute a globally coordinated threat response, this truly international team from 17 countries, offers a unique global view of how to cooperate on this vital project to defend Earth from these hazardous deep space objects.

Introduction

The READI Project is a team project done by an international group of students at the 2015 summer studies program(SSP). The SSP is an annual program conducted by the International Space University(ISU) at various leading educational institutions that was inaugurated at MIT in 1988. Ohio University was the venue for the ISU SSP in the summer of 2015. The READI Project is the third team project done by ISU on this topic. An outline of the team project was presented as a poster at the 2015 Planetary Defense Conference in Italy.

While it is well established that the first and most critical pillar of an economic and reliable Planetary Defense architecture is timely detection, it is clear that until such observatories and a network with enough capability and redundancies are fully functional, the threat of a small, short warning period “city killer” type impactor appearing along a terminal trajectory is still possible. This is also a reason the IAA/PDC group continues to build awareness and refine the impactor exercise.

The question posed to the ISU team project participants was : ***What can we do if a threat is detected very late ?i.e., the object is on a terminal trajectory with only months to weeks before impact.***

The report which surveyed the literature and proposed concepts may be accessed at :

https://isulibrary.isunet.edu/opac/doc_num.php?explnum_id=722

Several papers have been published in the literature in the proceedings of AGU[Burke etal., 2015] IEEE[Nambiar etal., 2016], INCOSE[Silva-Martinez etal., 2016] and including one in Acta Astronautica[Hussein etal., 2016] that detail complex aspects of the READI Project.

This paper presents key findings in the READI Project, and highlights areas in Planetary Defense, both technical and policy related, that could accelerate forward-looking projects in Planetary Defense, specifically those that address short period warning threat based on current actionable intelligence.

The seminal work being done systematically and diligently by the IAA/PDC group as well as recent progressive activities by the world's space agencies and the evolving global Planetary Defense community being spurred on by the United Nations are all noted as vital to addressing this very real threat to our species and civilization, not to mention the havoc such an event, if not thwarted in a timely manner, poses to our fragile biosphere.

The READI Project Findings

The READI Project identified five elements of Planetary Defense and looked in depth at potential solutions for each. The topics covered are detection and tracking, mitigation techniques, global collaboration, outreach and education, and evacuation and recovery. Each of the groups analyzed current and future technologies and methods to develop solutions.

1. Detection: The detection of NEOs and LPCs is the first fundamental step in preventing hazardous objects from impacting Earth. After detection, the tracking phase becomes the most important, since a precise orbital determination is fundamental for implementing a successful defense strategy. This is pursued through professional ground and space-based telescopes that observe the sky in the visible and infrared bands. Amateur astronomers also play an important role supporting professional observations. In addition to these, radar observations are performed, enabling very precise orbit determination and characterization of asteroids and comets.

2. Deflection: We selected innovative but feasible technical ideas inspired by an extensive literature review of existing concepts. These mainly revolve around the use of thermonuclear devices, and Directed Energy Systems (DES). The need for a highly redundant and robust mitigation architecture led the group to also investigate ground-based solutions that would act as a last line of defense. We emphasized the need to overcome numerous political and economic hurdles to increase the TRL of the proposed solutions. This would allow better preparation and higher confidence when designing Planetary Defense missions. Even though further analyses are required to assess the technical feasibility of the proposed scenarios, we highlight the main needs to increase the chances of success in such missions.

3. Global Collaboration: The most important challenge is the establishment of new norms and a legal basis for action in the case of an imminent impact threat. The second challenge would be the creation of an advisory body that would oversee the implementation of a Planetary Defense Program and provide advice to the United Nations Security Council (UNSC). We recommend taking immediate action in these areas because a long time might be required to establish international consensus, and that time is needed for the internalization of our newly proposed norms as a moral obligation.

4. Outreach and Education: We aimed to increase interest in Planetary Defense among children and students. Targeting this demographic provides access to future active members of society, and will likely involve their parents indirectly. We believe that having a mascot and using it across different media would be a good way to actively involve children. We took inspiration from the United States' (US) famous "Smokey Bear," used for 70 years to make people aware of fire safety. We also developed two video game ideas using current and potential software to involve children and other age groups to convey basic knowledge of asteroids and comets through an interactive and entertaining activity. We considered an educational campaign as being twofold. First, it brings the threat of cosmic impacts to the general public in a way that provides scientifically accurate information to decrease the risk of misunderstanding and opposition when actions are needed. Second, it contributes to the Science, Technology, Engineering, Arts and Mathematics (STEAM) movement by bringing science and engineering to the youth through the arts, which could in return lead to new creative and innovative approaches to Planetary Defense.

5. Evacuation and Recovery: According to the threat characteristics, asteroid and comet impact responses will differ from typical disaster response techniques. In the case of small impacts where the damage will only be local, the response for evacuation or recovery will be similar to the existing strategy for an earthquake or hurricane. A similar method can be used in case of a small to medium-sized threat. With most asteroid or comet threats however, the timely identification of the point of impact seriously affects the successful implementation of evacuation and shelter allocation. The best scenario for saving as many citizens as possible is to start evacuation days prior to the impact. To minimize loss of life and ecosystems, disaster preparations must be developed at different scales, and global collaboration can be useful in the case of large city-killer threats. New techniques for shelter design and remote sensing are also required to assist with recovery efforts. Our investigation of evacuation and recovery shows that this is a critical element of Planetary Defense that does not get enough focus to see significant improvements.

The READI Project recommendations to tackle short warning PD threat :

1. PD can be a peaceful globally inclusive endeavor
2. Like Climate Change effort, or CDC response to global pandemic, PD must have top priority
3. Humanity's obligation as stewards of Earth and biosphere - Extend Responsibility to Defend(R2D) to Responsibility to Defend Earth(R2DE)
4. Improve Detection and Warning Networks
5. Increase Public Awareness and Education
6. Close range Nuclear Intervention may not be possible because of policy issues

7. Advance new technologies like High Energy Lasers(HEL)
8. Coordinate action plan globally including aftermath activity in the event of failed attempt
9. Moon may offer location for HEL complex
10. Spiritual dimension needs more attention

Debated issues that were not highlighted in the report:

1. Global threat requires global response
2. Can militaries of the world extend joint exercises to coordinate a global PD response ?
3. Who will coordinate and control assets for PD ?
4. Spiritual dimension of threat and response

Conclusion

Comet and asteroid impacts on Earth are a concerning reality and have occurred many times in the past. Small asteroids usually burn up when they enter the atmosphere, but large asteroids and comets could potentially destroy cities. Even worse, an impact by a large comet could end all life on Earth. This is a very unlikely event, but the high impact of it make it necessary to dedicate more efforts to study and research this matter. The READI Project has aimed to tackle these issues during the nine weeks of SSP15.

Detection, deflection, and mitigation strategies are the only way to protect our planet from such threats. Achieving that is a huge challenge, and requires fundamental studies and global preparation well before impact. . The warning time between detection and impact is not always sufficient for successful deflection and mitigation. Major developments for detection are essential especially for detecting large objects that are traveling at very high velocities far from Earth.

We examined and proposed the potential effectiveness of different mitigation strategies for the deflection of comets and asteroids before impact with Earth. We looked at the problem of Planetary Defense from different angles by taking into account the legal, economic, political, and business perspectives, in addition to the engineering and scientific aspects. We need to understand the policy and legal considerations related to a Planetary Defense Program, and analyze the responsibilities of governments and their reaction if an asteroid or comet is on a collision course with Earth. The concern then is not only limited to the technical and scientific aspects, but it expands to the political, legal, and even social and ethical aspects. Therefore, the sooner we start thinking about solutions, the more prepared humanity will be for any impact.

We built a scenario for a given comet threat to give the project a sense of reality, describing two different scenarios: one in which there is insufficient effort and planning, also known as the pessimistic case; and one with a very well planned response, also known as the optimistic case. We decided to take these two extreme situations to generate recommendations that can be applied to other situations. We did this by taking into consideration risks, necessary technology developments, public awareness, and global cooperation efforts. The most feasible solution proposed to deflect Madhusa in our scenario was a combination of three different deflection techniques. We proposed to use DES, TND, and BMD technologies. Time in such a protection program is crucial. Thus, we developed a timeline for the given

scenario and responses for detection, deflection, global collaboration, outreach and education, and evacuation and recovery.

The READI Project presents main elements for a complete Planetary Defense Program. We believe that the implementation of such a Planetary Defense Program should be a priority for humanity. As an obligation to future generations, we must act now.

Selected References

[01] Ailor, W., etal.,(2015) Planetary Defense Conference, Frascati, Italy www.pdc2015.org

[02] Air University, Spacecast 2020(1994) Preparing for Planetary Defense: Detection and Interception of Asteroids on Collision Course with Earth Spacecast 2020, Air University White Paper, Maxwell Air Force Base, http://fas.org/spp/military/docops/usaf/2020/app-r.htm

[03] Ben-Ami, H. (2015) SamePage: Preparing to Defend Our Home – Earth. IAC Jerusalem

[04] Burke, J. et al. (2015) Space Assets for Mitigating and Managing Impact Disasters. IAC Jerusalem

[04] Burke, J., Hussein, A., Soni, A., Thangavelu, M., Schmidt, N., & Wilson, T. (2015). Planetary defence: a duty for world defenders.

[05] Boslough, M., Brown, P., Harris, A., (2015) Updated Population and Risk Assessment for Airbursts from Near-Earth Objects (NEOs), IEEE Aerospace Conference, Big Sky MT

[06] http://sentinelmission.org/sentinel-mission/the-mission/ - program cancelled by NASA

[07] Chodas P.W etal.(2015) NASA/JPL NEO Deflection app: http://neo.jpl.nasa.gov/nda

[08] Chodas, P.W etal.,(2015)Asteroid Impact Scenario PDC 2015 http://neo.jpl.nasa.gov/pdc15

[09] Garretson, P.,USAF(2008) Natural Impact Hazard (Asteroid Strike), Interagency Deliberate Planning Exercise After Action Report, AF/A8XC, Directorate of Strategic Planning, Headquarters, United States Air Force December 2008, http://neo.jpl.nasa.gov/neo/Natural_Impact_After_Action_Report.pdf

[10] Harris, A.W.(2014) NEA Populations and Impact Frequency, Asteroid Grand Challenge Seminar Series, NASA Asteroid Grand Challenge Seminar, NASA SSERVI. http://sservi.nasa.gov/event/nasa-asteroidgrand-challenge-seminar-al-harris/

[11]Hussein, A., Rozenheck, O., & Utrilla, C. M. E. (2016). From Detection to Deflection: Mitigation techniques for hidden global threats of natural space objects with short warning time. Acta Astronautica, 126, 488-496.

[12] ISU(2005) CASSANDRA ISU team project, https://isulibrary.isunet.edu/opac/doc_num.php?explnum_id=123

[13] ISU(2007) Phoenix ISU Team Project, https://isulibrary.isunet.edu/opac/doc_num.php?explnum_id=103

[14] ISU(2015) READI:Roadmap for Earth Defense Initiatives, IAC-15,B5,1,10,x31370 Jerusalem

[15] Johnson, L., Drolshagen G.,(2015) Status of the International Asteroid Warning Network, IAWN/SMPAG Report,(IAWN) http://www.unoosa.org/pdf/pres/stsc2015/tech-12E.pdf

[16] Landis, Geoffrey(2013), Asteroid Repositioning for Planetary Defense, NASA Glen Research Center http://spice.ikiweb.ru/PHSRM/asolopchuk/05%20VIRTUAL-Landis_Asteroid-Repositioning.pdf

[17] Lubin, P.M., etal.,(2013) http://www.deepspace.ucsb.edu/projects/directed-energy-planetary-defense

[18] Mainzer, A., (2015) etal., http://neocam.ipac.caltech.edu/page/mission

[19] Morrison, D.,(2014) NASA Asteroid Grand Challenge Seminar, The Asteroid Impact Hazard: Historical Perspective, SSERVI http://sservi.nasa.gov/event/nasa-asteroid-grand-challenge-seminar/

[20]Nambiar, s., etal(2016)Architecture for Mitigating Short Term Warning Cosmic Threats:READI Project, 978-1-4673-7676-1/16 ©2016 IEEE

[21] National Research Council(2010) Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies , ISBN: 978-0-309-14968-6 http://www.nap.edu/openbook.php?record_id=12842&page=R1

[22] Pelton, J. N., Allahdadi, F., (2015) Eds. Handbook of Cosmic Hazards and Planetary Defense, http://www.springer.com/us/book/9783319039510

[23] Phipps, C.R.,(1997) “Laser Deflection of Near-Earth Asteroids and Comet Nuclei”, Proc. International Conference on Lasers 96, STS Press, McLean, VA (1997) pp. 580-7

Silva-Martinez, J., Hussein, A., & Wilson, T. (2016, July). Implementation of a Systems Engineering Approach to the Management of a Planetary Defense Team Project in an Intensive Space Studies Program Using IPPD. In INCOSE International Symposium (Vol. 26, No. 1, pp. 614-629).

[24] Thangavelu, M., McVicker, J.M.,(2015) QBOLT:Directed Energy System Concepts for Asteroid Threat Mitigation, IAA Planetary Defense Conference, Frascati, Italy. IAA-PDC-15-03-11

[25]Thangavelu, M., & Vasmate, V. (2016). LUNAR SENTINEL: Planetary Defense from the Moon. In AIAA SPACE 2016 (p. 5475).

[26] Urias, H. et al. (1996) Planetary Defense: Catastrophic Health Insurance for Planet Earth. A research paper presented to Air Force 2025, Maxwell Air Force Base, USAF http://fas.org/spp/military/docops/usaf/2025/v3c16/v3c16-1.htm#Disclaimer

[27] The White House(2010) Report to Congress on Near Earth Objects, Office of Science and TechnologyPolicy(OSTP), Executive Office of the President, http://www.whitehouse.gov/sites/default/files/microsites/ostp/ostp-letter-neo-senate.pdf

[28] Wie, B., etal.,(2013) Hypervelocity nuclear interceptors for asteroid disruption, Acta Astronautica 90(2013) 146–155 http://www.adrc.iastate.edu/resources-and-publications/publications/

[29] Worden, S.P., (2002) Statement Before the House Science Committee, Space and Aeronautics SubCommittee, U.S. House of Representatives, October 3, 2002, “Near Earth Object Threat.

[30] Worden,S.P.(2002) “Military Perspectives on the Near-Earth Object (NEO) Threat”, Deputy Director for Operations, United States Space Command, http://www.spaceref.com/news/viewpr.html?pid=8834

[31] Yeomans, D., Chodas, P., etal., NASA JPL Near Earth Object Program - http://neo.jpl.nasa.gov/

[32] Yeomans, D.,(2012) Near-Earth Objects: Finding Them Before They Find Us

[33] National Near-Earth Object Preparedness Strategy(2016) Product Of The Interagency Working Group For Detecting And Mitigating The Impact Of Earth-Bound Near Earth Objects (Neos) (Damien) Of The National Science And Technology Council, Washington DC.

[34] Wall, M.(2106) How to Stop An Incoming Comet, Scientific American

[35] Lubin, Philip, Gary B. Hughes, Mike Eskenazi, Kelly Kosmo, Isabella E. Johansson, Janelle Griswold, Mark Pryor et al. (2016)."Directed Energy Missions for Planetary Defense." Advances in Space Research, Pergamon Press