

PLANETARY DEFENSE

Architecture for Mitigating Short-Term Warning Cosmic Threats: READI Project

Shrrirup Nambiar

Alaa Hussein

Jackelynnne Silva-Martinez

Jessica Reinert

Fernando Gonzalez

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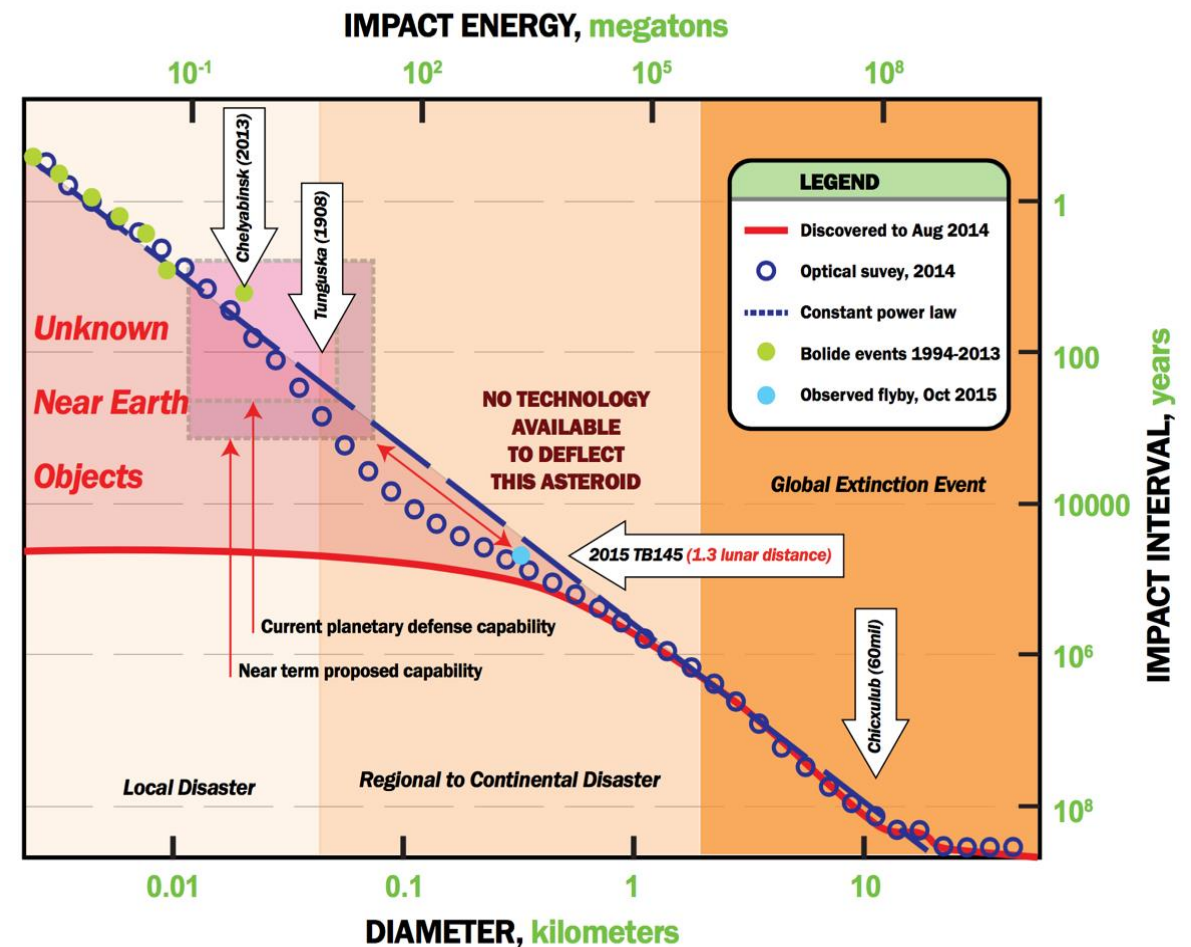
Outline

- Why do we want to defend our Planet?
- Background
- Problem Statement
- Key aspects of responding to a cosmic threat
- Conclusions & Recommendations

Why do we want to defend our Planet?

Identified Objects:

- Potentially Hazardous Objects (PHOs):
~1,590
- Near-Earth Objects (NEOs):
~12,500
- Comets:
~4,000 / ~1 trillion

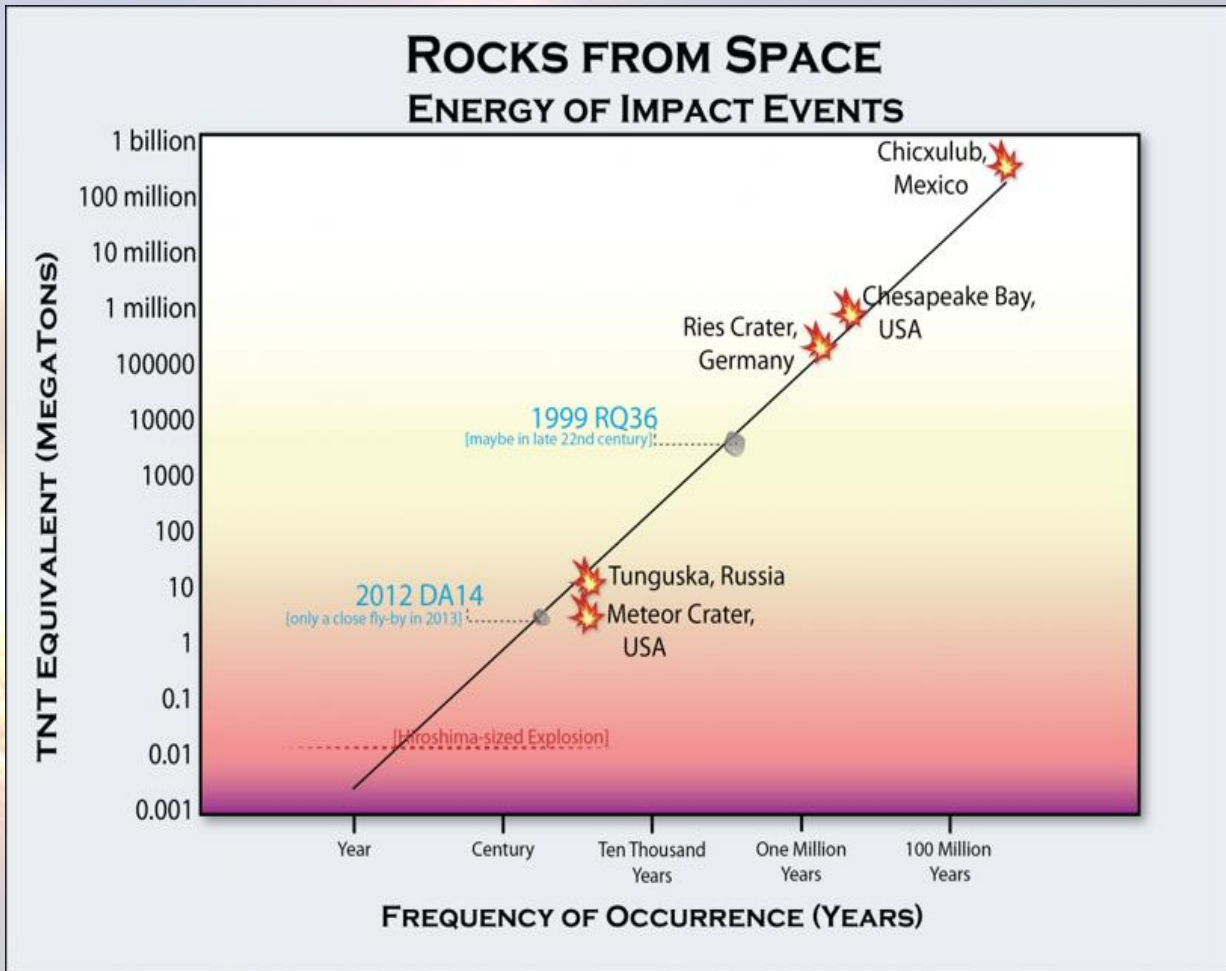
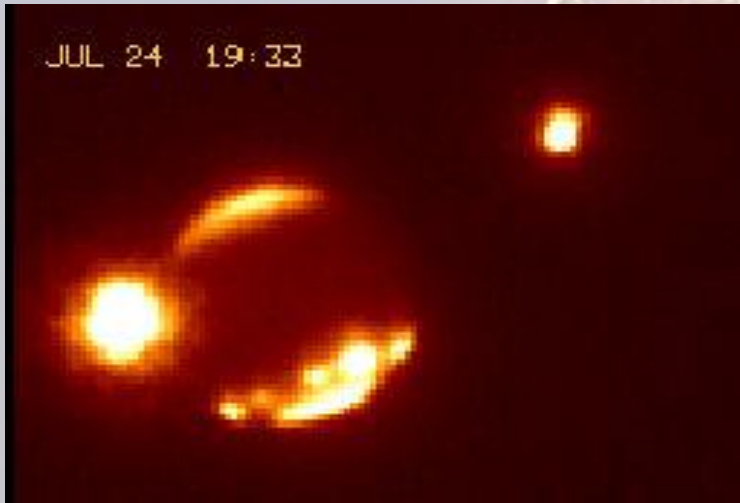


Plot redesigned and based on ref. no. 10 Harris, A.W.

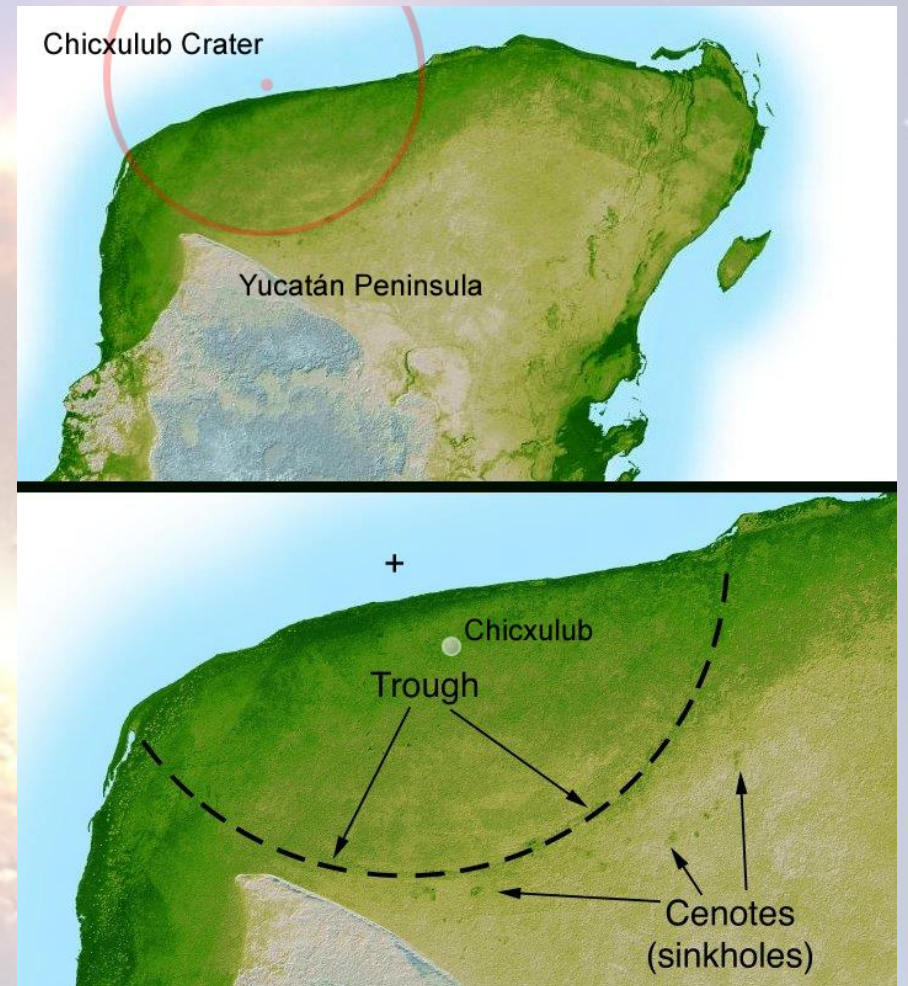
Background Information (Impact History)

Past Impacts (recorded):

- 1490 Ching-Yang Meteorite Shower
- 1908 Tunguska Event
- 1994 Shoemaker-Levy Comet
- 2013 Chelyabinsk Meteor



65 Million Years Ago...



2 Years Ago...



Why deal with this issue now?

- Chelyabinsk incident: temporary international attention
- Lack of attention to cosmic threats: limited funding
- Some potential solutions already exist: need to increase TRL and ORL of current technologies
- General public is sadly uninformed on cosmic threats

Threat Parameters

Threat Definition:

- Type: Comet
- Size: 800m diameter
- Composition: Ice dust
(water, methane, ammonia)
- Warning time: ~2 years
- Relative velocity: 36 km/s

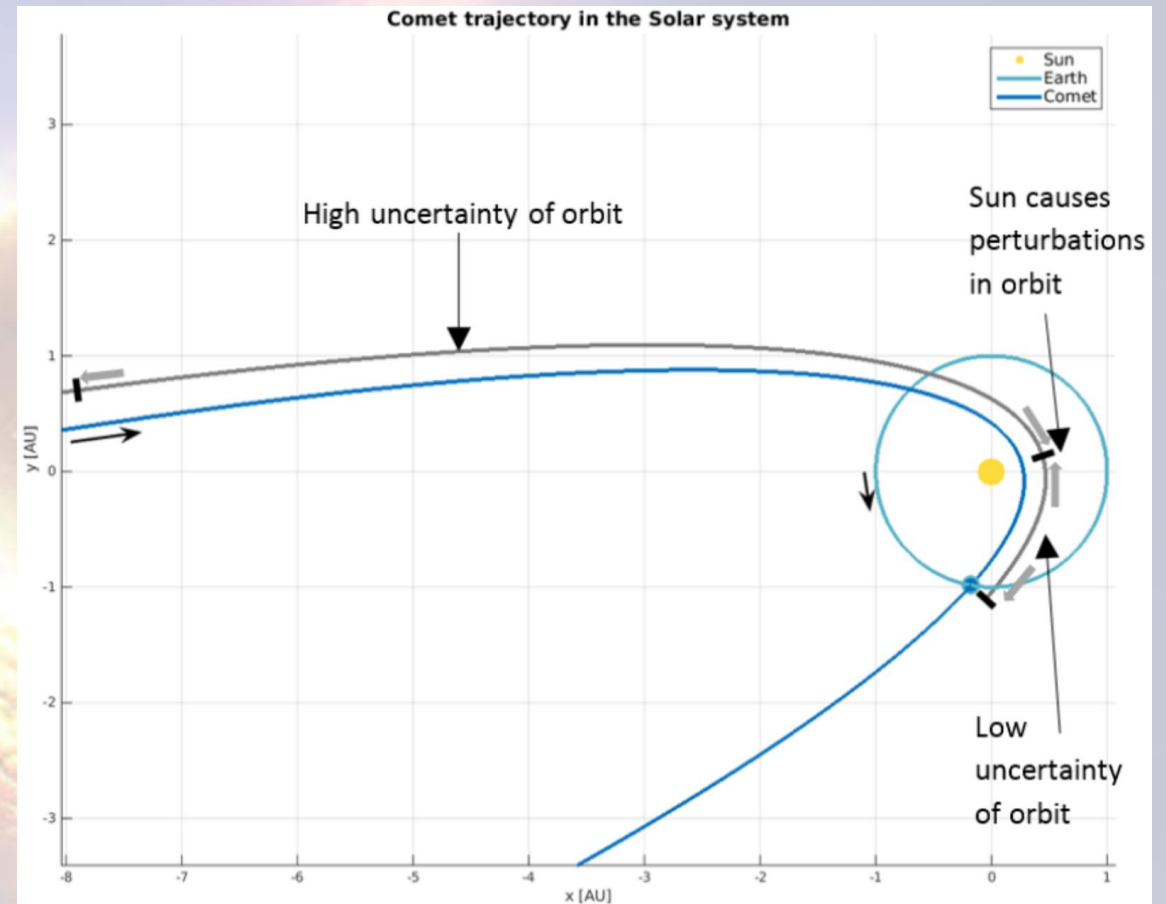
Orbital Parameters:

- Semi-major axis: 34.24 AU
- Eccentricity: 0.992
- Inclination: 174° to J2000 ecliptic
- Perihelion: 0.27 AU
- Aphelion: 68.15 AU
- Period: 200 years

Detection

Enable Advance warning

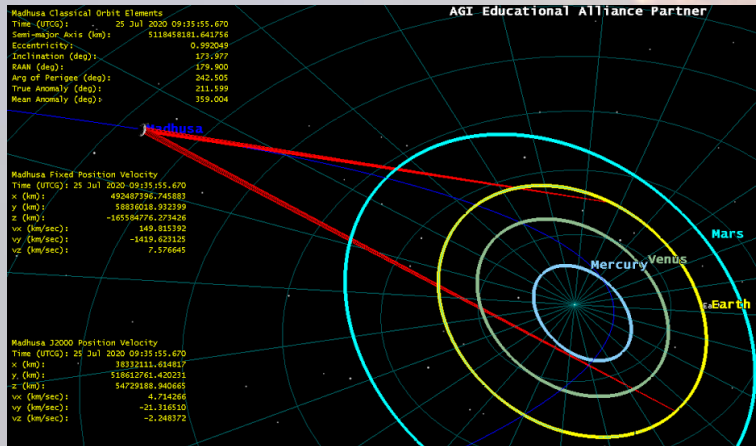
- Make space-based IR telescopes available
- More ground-based observations
- Increased sensitivity of detection
- Cover complete sky every night
- Increased Southern Hemisphere coverage
- Dedicated tracking network - amateur astronomers



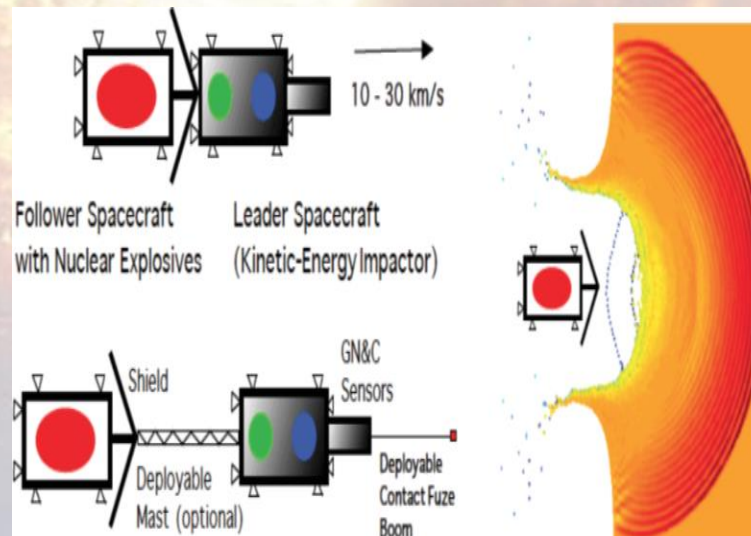
Comet trajectory simulation using initial orbital parameters on MATLAB

Deflection

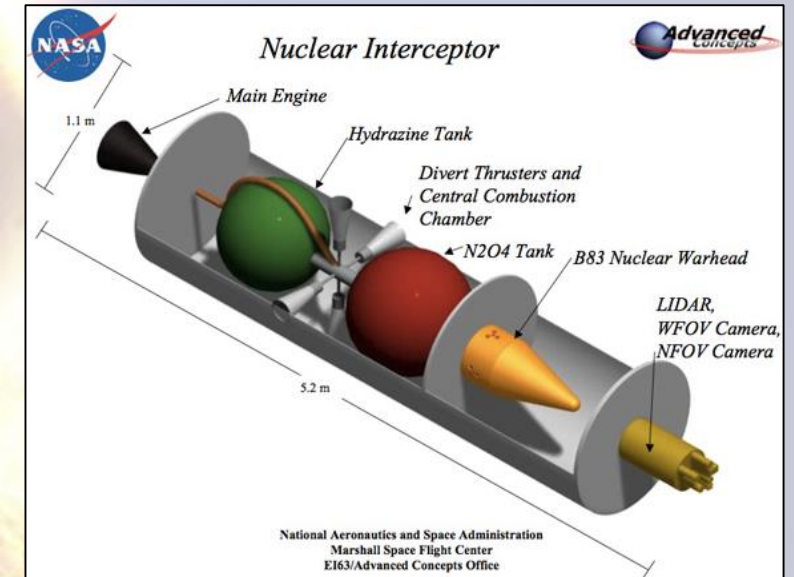
- Directed Energy Systems (DES): High power laser beams interacting with the comet from L4 and L5



- Hypervelocity Comet Impactor Vehicle (HCIV):



- Thermonuclear Energy Device (TED):



Policy Implications of a Cosmic Threat

- Planetary Defense technology is inherently dual use technology
- Responsibility to Protect (R2P)
 - Ground laid for R2P in UN report A/57/303, August 2002
 - Based on three elements
 - Responsibility to Prevent
 - Responsibility to React
 - Responsibility to Rebuild
- Responsibility to Defend (R2D)
 - Extension of R2P's elements to Planetary Defense
 - Responsibility to Detect cosmic threats
 - Responsibility to React to cosmic threats
 - Responsibility to Rebuild in the aftermath of a cosmic impact

Conclusions and Recommendations

- **Conclusions:**

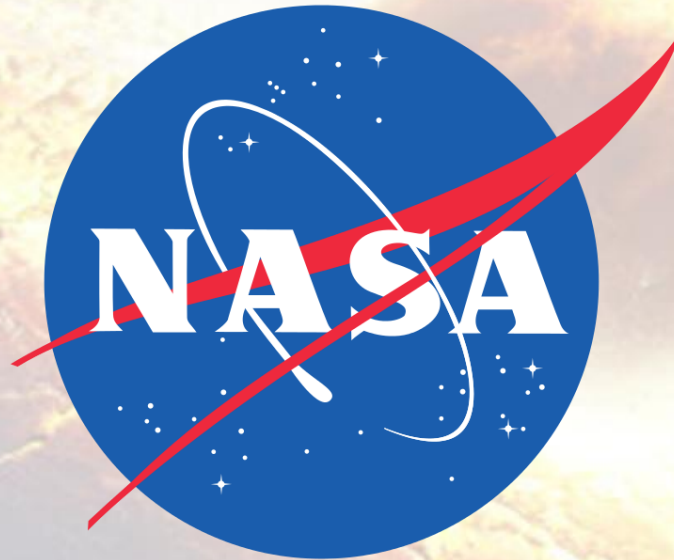
- Increase detection capabilities
- Develop, test, and validate deflection technologies such as:
 - DES
 - HCIV
 - TED
- Develop new policy norm: R2D

- **Recommendations:**

- Develop disaster preparedness strategies for cosmic impacts
- Increase public awareness



Acknowledgements



References

- [1] *Planetary Defense team project: READI (Roadmap for Earth Defense Initiatives)*, 2015. Project Report. International Space University (ISU), Ohio, USA.
- [2] Alvarez LW, Alvarez W, Asaro F, Michel HV (1980). "Extraterrestrial cause for the Cretaceous-Tertiary extinction". *Science* 208 (4448): 1095-1108
- [3] Napier, B. and Asher, D.: *The tunguska impact event and beyond*. *Astronomy and Geophysics*, 50(1), 2009
- [4] Brown, P. G., Assink, J.D., Astiz, L., Blaauw, R., Boslough, M.B., Borovička, J., Brachet, N., Brown, D., Campbell-Brown, M., Ceranna, L., Cooke, W., de Groot-Hedlin, C., Drob, D.P., Edwards, W., Evers, L.G., Garces, M., Gill, J., Hedlin, M., Kingery, A., Laske, G., Le Pichon, A., Mialle, P., Moser, D.E., Saffer, A., Silber, E., Smets, P., Spalding, R.E., Spurný, P., Tagliaferri, E., Uren, D., Weryk, R.J., Whitaker R., Krzeminski, Z. : *A 500-kiloton airburst over Chelyabinsk and an enhanced hazard from small impactors*, *Nature*, 2013.
- [5] Chodas, P. n.d. NEO Groups. *NASA, Near Earth Object Program*, [online] Available at: <<http://neo.jpl.nasa.gov/neo/groups.html>> [Accessed 24 October 2015].
- [6] Dones, L., Weissman, P. R., Levison, H. F. and Duncan, M. J.: Oort Cloud Formation and Dynamics. In *Star Formation in the Interstellar Medium: In Honor of David Hollenbach*. Vol. 323, p. 371, 2004
- [7] Schulte, P., Alegret, L., Arenillas, I., Arz, J.A., Barton, P.J., Bown, P.R., Bralower, T.J., Christeson, G.L., Claeys, P., Cockell, C.S., Collins, G.S., Deutsch, A., Goldin, T.J., Goto, K., Grajales-Nishimura, J.M., Grieve, R.A.F., Gulick, S.P.S., Johnson, K.R., Kiessling, W., Koeberl, C., Kring, D.A., MacLeod, K.G., Matsui, T., Melosh, J., Montanari, A., Morgan, J. V, Neal, C.R., Nichols, D.J., Norris, R.D., Pierazzo, E., Ravizza, G., Rebolledo-Vieyra, M., Reimold, W.U., Robin, E., Salge, T., Speijer, R.P., Sweet, A.R., Urrutia-Fucugauchi, J., Vajda, V., Whalen, M.T. and Willumsen, P.S.: *The Chicxulub asteroid impact and mass extinction at the Cretaceous-Paleogene boundary*. *Science (New York, N.Y.)*, 2010
- [8] Alger, J. 2009. *From nuclear energy to the bomb: the proliferation potential of new nuclear energy programs*. Centre pour l'innovation dans la gouvernance internationale. Nuclear Energy Futures Paper No. 6.
- [9] Bible, J., Johansson I., Hughes G. B. and Lubin P. M., 2013. *Relativistic Propulsion Using Directed Energy*. Proc. of SPIE, Vol. 8876, 887605-1.
- [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-asteroid-grand-challenge-seminar-al-harris/>> [accessed 24 October 2015].
- [11] Weissman, P. R.: *Terrestrial impact rates for long and short-period comets*. Geological Society of America Special Papers, 190, pp.15-24, 1982.
- [12] Balkans 1940s to 1999, 2000. *Washington Post*. [online] Available at: <<https://www.washingtonpost.com/wp-srv/inatl/longterm/balkans/timeline.htm>> [accessed 24 October 2015].
- [13] *A short history of the Rwanda Genocide*. About.com. [online] Available at: <<http://history1900s.about.com/od/rwandagenocide/a/Rwanda-Genocide.htm>> [accessed 24 October 2015]
- [14] Background Information on the Responsibility to Protect. *Outreach Programme on the Rwanda Genocide and the United Nations*. [online] Available at: <<http://www.un.org/en/preventgenocide/rwanda/about/bgresponsibility.shtml>> [accessed 24 October 2015].
- [15] UNGA Report by the international commission on intervention and state sovereignty. A/57/303, pp. XI; [online] <<http://responsibilitytoprotect.org/ICISS%20Report.pdf>> [accessed 24 October 2015].
- [16] Howley, K., Managan, R. and Wasem, J., 2014. *Blow-off momentum from melt and vapor in nuclear deflection scenarios*. *Acta Astronautica*, [online] 103, pp.376-381. Available at: <<http://linkinghub.elsevier.com/retrieve/pii/S0094576514002215>> [Accessed on 24 October 2015]
- [17] *Outer Space Treaty*, The United Nations Office of Outer Space Affairs; 1966.
- [18] *National Mitigation Framework*, 2013. Homeland Security. [online] <<http://www.fema.gov/media-library/assets/documents/32209?id=7363>> [accessed 24 October 2015]
- [19] *Near Earth Object (NEO) Mitigation Options Using Exploration Technologies*, Presentation to 2007 Planetary Defense Conference, Washington, DC. [online] <http://uavarese.altervista.org/CM_ACH-2009.pdf> [accessed 24 October 2015].
- [20] Gritzner, C., Dürfeld, K., Kasper, J., and Fasoulas, S. 2006. *The asteroid and comet impact hazard: risk assessment and mitigation options*. *Naturwissenschaften*, 93(8), pp.361-373.
- [21] JPL, 2015. *JPL Small-Body Database Browser*, JPL, [online]. Available at: <<http://ssd.jpl.nasa.gov/sbdb.cgi>>. [Accessed on 20 October 2015].
- [22] Mainzer, A., Bauer, J., Grav, T., Cutri, R., Masiero, J., McMillan, R.S. and Wright, E., 2015a. *Space-Based Infrared Discovery and Characterization of Minor Planets with NEOWISE*. In *Handbook of Cosmic Hazards and Planetary Defense*, pp. 583-611. Springer International Publishing.
- [23] Melosh, H., Nemchinov, I.V. and Zetzer, Y. I. 1994. *Non-nuclear strategies for deflecting comets and asteroids*. In *Hazards due to comets and asteroids*, Vol. 1, pp.1111-1132.
- [24] Pitz, A., Kaplinger, B., Wie, B., Dearborn, D., 2012. *Preliminary Design of a Hypervelocity Nuclear Interceptor System (HNIS) for Optimal Disruption of Near-Earth Objects*. In: 22nd Spaceflight mechanics 2012, 29 January-2 February 2012, Charleston, S.C., San Diego: Univelt.
- [25] Pelton, J.N., Allahdadi, F., ed. 2015. *Handbook of Cosmic Hazards and Planetary Defense*. Switzerland: Springer International Publishing. pp.569-581.
- [26] Thangavelu, M., McVicker, J.M., 2015. *QBOLT Directed Energy System Concepts For Asteroid Threat Mitigation*; The International Academy of Astronautics Planetary Defense Conference, 13-17 April 2015, Frascati, Italy.
- [27] Lubin, P., 2015. *Directed Energy for Planetary Defense*, Core Lectures Space Studies Program 2015. International Space University, unpublished.
- [28] Wie, B., 2013. *Hypervelocity nuclear interceptors for asteroid disruption*. *Acta Astronautica*, [online] 90(1), pp.146-155. Available at: <<http://dx.doi.org/10.1016/j.actaastro.2012.04.028>>. [accessed 17 October 2015]
- [29] Kaplinger, B., Wie, B., and Dearborn, D. 2013. "Nuclear Fragmentation/Dispersion Modeling and Simulation of Hazardous Near-Earth Objects," *Acta Astronautica*, Vol. 90, pp. 156164.
- [30] Kaplinger, B. and Wie, B. 2012. "GPU Accelerated 3-D Modeling and Simulation of a Blended Kinetic Impact and Nuclear Subsurface Explosion," IAA-PDC13-04-06, 2013 IAA Planetary Defense Conference.
- [31] Kaplinger, B., Setzer, C., Premaratne, P., Wie, B. 2013. "GPU-Accelerated 3D Modeling and Simulation of a Blended Kinetic Impact and Nuclear Subsurface Explosion," AIAA-2013-4548, presented at AIAA Guidance, Navigation, and Control Conference, Boston, MA, August 19-22.
- [32] Gourdon, R., Hussein, A., Soni, A., Aliaj, B., Manuel Entrena Utrilla, C., Sisaid, I., Reinert, J., Faull, J., Bettioli, L., Schmidt, N., Nambiar, S., Dimitrov, T., and Thangavelu, M., 2015. *The International Space University Space Studies Program 2015 Planetary Defense Project*. In: 66th International Astronautical Congress 2015 (IAC 2015) "Space - The Gateway for Mankind's Future", 12-16 Oct 2015.
- [33] Burke, J., Hussein, A., Soni, A., Thangavelu, M., Schmidt, N., and Wilson, T., 2015. *Planetary defence: a duty for world defenders*. In: American Geophysical Union (AGU) Fall Meeting, 14-18 Dec 2015, San Francisco, USA.
- [34] Lamy, P. L., Toth, I., Fernandez, Y. R. and Weaver, H. A: *The sizes, shapes, albedos, and colors of cometary nuclei. Comets II*, 1, pp.223-264, 2004.