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Space Mission & Campaign Design

Planetary Defense Mission Campaign Design for the 2023 PDC Hypothetical Asteroid Impact Scenario

Brent W. Barbee[1], Bill Benson[2], Mary Burkey[3], Paul Chodas[4], Jessie Dotson[5], Kathryn M. Kumamoto[6], Joshua R. Lyzhoft[7], Joseph A. Nuth[8], Catherine Plesko[9], Bruno Sarli[10], Joshua Schare[11], Megan Bruck Syal[12], Matthew A. Vavrina[13], and Lorien Wheeler[14]

[1] *NASA/Goddard Space Flight Center, Code 595, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA, 301-448-5681, brent.w.barbee@nasa.gov*

[2]*Flight Analysis - Dynamics, NASA Launch Services Program, Kennedy Space Center, Florida 32899, Mail Code: VA-H1, 321-867-9455, william.w.benson@nasa.gov*

[3]*Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA 94550, USA, burkey1@llnl.gov*

[4]*Jet Propulsion Laboratory, California Institute of Technology, Solar System Dynamics Group, 301-121, Pasadena, CA, 91109, USA, 818-354-7795, paul.w.chodas@jpl.nasa.gov*

[5]*NASA/ARC, MS 244-1, Moffett Field, CA 94035, (650) 604-2041, Jessie.Dotson@nasa.gov*

[6]*Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA 94550, USA, kumamoto3@llnl.gov*

[7] *NASA/Goddard Space Flight Center, Code 595, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA, 301-286-7527, joshua.r.lyzhoft@nasa.gov*

[8]*NASA/Goddard Space Flight Center, Code 690, Greenbelt MD 20771, 240-285-1022, joseph.a.nuth@NASA.gov*

[9]*ASC Program Manager for V&V, LANL PI for Planetary Defense, Applied Computational Physics, Materials and Data Group, Mail Stop A143, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM, 87545, 505-667-2345, plesko@lanl.gov*

[10]*Heliospace Corp., 2448 6th Street, Berkeley, CA 94710, 301-286-0353, bruno.victorinosarli@nasa.gov*

[11]*Nuclear Deterrence Transformation, Org-00521, Sandia National Laboratories, New Mexico, P.O. Box 5800, Albuquerque, NM 87185-00521, 505-284-3610, jmschar@sandia.gov*

[12]*Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA 94550, USA, syal1@llnl.gov*

[13]*a.i. solutions, 4500 Forbes Boulevard Suite 300, Lanham, MD 20706, 301-306-1756, matthew.a.vavrina@nasa.gov*

[14]*NASA/ARC, MS 258-5, Moffett Field, CA 94035, (650) 604-0785, Lorien.Wheeler@nasa.gov*

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ABSTRACT

In this paper, we describe analysis of the 2023 Planetary Defense Conference (PDC) hypothetical asteroid impact scenario[1] and a campaign of missions for responding to the threat. The hypothetical asteroid, designated "2023 PDC," is discovered on January 10, 2023. By April 3, 2023 its Earth impact probability reaches 1%, and the potential Earth impact date is October 22, 2036. Little is known about 2023 PDC's physical properties except its approximate size, inferred from its brightness to be between several hundred meters and several kilometers; the most likely size range is 220-660 m.

We present a scenario timeline for missions to reconnoiter 2023 PDC, deflect it away from Earth, and monitor the deflection attempt during and after. We show that 2023 PDC is likely too large for kinetic impact deflection, unless its impact point happened to be close to the Earth limb in the preferential kinetic impactor deflection direction. We also show that the asteroid is likely too large to be robustly disrupted via nuclear devices. Thus, deflection via standoff nuclear detonation is the most viable option.

Assessment of mission options would begin on April 3, 2023, when the asteroid's Earth impact probability reaches 1%. Two reconnaissance missions could be deployed: First, a rapid flyby reconnaissance mission could launch on October 23, 2024, ~18 months after mission assessments begin, and fly past the asteroid ~14 months after launch on December 1, 2025. The second reconnaissance mission would rendezvous and could launch on October 19, 2025, ~30 months after mission assessments begin, and shortly before the flyby mission encounters the asteroid. The rendezvous mission would arrive at the asteroid November 23, 2026, ~11 months before deflection mission launch. The rapid flyby mission would provide early information about whether the asteroid is indeed on an Earth-impacting trajectory and, if so, clarify the impact location and the amount of Δv needed for deflection. The rendezvous reconnaissance mission would survey the asteroid to measure its physical properties, which would inform deflection mission design, and could remain near the asteroid to provide ongoing situational awareness during and after deflection. Finally, a rendezvous mission for deflection via standoff nuclear detonation could launch on October 24, 2027, ~4.5 years after the start of mission assessments. It would arrive at the asteroid on January 4, 2030, ~26 months after launch, and perform the deflection detonations around the asteroid's perihelion passage during August-September of 2030, approximately 6 years before Earth encounter.

We will describe the risk-informed aspects of the mission design in terms of handling uncertainties in the asteroid's properties, spacecraft mission performance, nuclear device effects on the asteroid, and the asteroid's Earth impact effects. Holistic treatment of the end-to-end uncertainties in an iterative fashion produces robust mission designs aimed at maximizing reduction in the probabilistic risk associated with the asteroid threat. We will also discuss practical considerations including launch infrastructure to support planetary defense, rapid development of spacecraft,

[1] "Planetary Defense Conference Exercise - 2023," Center for Near-Earth Object Studies, https://cneos.jpl.nasa.gov/pd/cs/pdc23/, accessed 2022-12-21.

nuclear systems delivery and integration, general best practices for planetary defense missions, and recommended future steps towards improved preparedness.

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