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CONCEPTUAL DESIGN OF A FLIGHT VALIDATION MISSION FOR A HYPERVELOCITY ASTEROID INTERCEPT VEHICLE

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ABSTRACT

Earth has been struck in the past by near-Earth objects (NEOs) that were sufficiently energetic, in terms of mass and impact velocity, to cause signficant damge ranging from local or regional devastation to mass extinctions. Such impact events will occur again in the future and humanity is beginning to see the wisdom in planning ahead to be ready to respond to the next incoming NEO so that we will have the opportunity to mount an effective defense.

Some of the key factors in designing planetary defense systems include the size of the incoming NEO and the amount of warning time. The size of the NEO determines how much damage it would cause and places limits on our response options, while the warning time further constrains our options for dealing with the NEO. Opportunities to rendezvous with NEOs at a reasonable propellant mass cost tend to occur infrequently, so for scenarios in which the NEO impact event is known less than 10 years in advance, the most viable option will likely be hypervelocity intercept in which our mitigation system is delivered to the NEO at high relative velocity

because the propellant cost to match the NEO's orbital velocity would be prohibitive. Although larger NEOs are capable of causing more damage than small NEOs, the small NEOs are far more numerous and thus a small NEO impact scenario is more likely within a given time frame, all else being equal. Unfortunately, small NEOs are fainter in the night sky and therefore harder to discover and track with ground-based telescopes in advance of when they would collide with Earth. Additionally, small NEOs are more difficult for a spacecraft to target, especially at high relative velocity. Thus the most challenging NEO mitigation scenario involves a small NEO with relatively short warning time requiring a hypervelocity intercept for deflection or destruction of the NEO. A spacecraft system capable of reliably handling that scenario would of course be able to handle less stressing cases, i.e., more warning time, lower intercept velocities, and larger NEOs.

Work was recently performed towards the design of such a spacecraft system by the Mission Design Laboratory (MDL) of NASA Goddard Space Flight Center's Integrated Design Center (IDC) to assess the technical feasibility of reliably performing hypervelocity interception of a 50 m diameter NEO and design a spacecraft and mission operations support architecture for flight validation of the system. This research was funded by and in support of the recently awarded NASA Innovative Advanced Concepts (NIAC) Phase II study entitled "An Innovative Solution to NASA's NEO Impact Threat Mitigation Grand Challenge and Flight Validation Mission Architecture Development." The goals of this research project include designing a two-body Hypervelocity Asteroid Intercept Vehicle (HAIV) to deliver a kinetic impactor to the target NEO that will excavate a shallow crater in which the second portion of the spacecraft will detonate a Nuclear Explosive Device (NED) immediately thereafter to effect a powerful subsurface detonation capable of disrupting the NEO. The flight validation mission will carry an inert dummy payload with the same mass properties as a NED. Flight validation of this system is crucial because any NEO mitigation system must be thoroughly flight tested before it can be relied upon during a true emergency and to date no such flight validations have been performed.

In this paper we provide a detailed overview and summary of the MDL study results including the conceptual configuration of the HAIV and all of its subsystems; guidance, navigation, and control (GNC) analysis results regarding the ability of the HAIV to reliably target and intercept small (50 m) NEOs at hypervelocity (typically > 10 km/s); the mission scenario and trajectory design for the notional flight validation mission to a selected candidate target NEO chosen for safety and mission affordability; the launch vehicle, operations concept, and cost estimate for the flight validation mission; and important research topics identified by the MDL study to be addressed in ongoing research.