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Overview of the 2019 Planetary Defense Conference Asteroid Impact Exercise

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Abstract

A realistic but fictional asteroid impact exercise was presented at the Planetary Defense Conference, (PDC) sponsored by the International Academy of Astronautics (IAA), in College Park, Maryland, April 29 to May 3, 2019. The week-long exercise was a realistic simulation of a hypothetical asteroid on a collision course with Earth, providing the opportunity to explore the decision-making processes that might be necessary to respond to such a threat. The time between discovery and the potential impact was set to 8 years, long enough to allow space missions to characterize the threat and carry out a deflection, but short enough to challenge the decision making. Detailed material was presented as "injects" on each day of the meeting, with the calendar advancing from the initial discovery stage, to the decision stage for development of space missions for asteroid characterization and deflection, to the execution of some of those missions, and then finally to the simulated impact of a small fragment of the original asteroid. This paper describes the sequence of steps in the exercise and summarizes some of the key challenges presented and issues discussed.

1. Introduction

Impact tabletop exercises have been presented at several recent IAA Planetary Defense Conferences. Each exercise is a realistic – but fictional – scenario of an asteroid on an impact trajectory with our planet. It provides an opportunity to practice and assess the decision-making processes that might be needed in the unlikely event that a sizeable asteroid is headed for Earth. In designing these exercises, efforts are made to expose issues and provide challenges for the different communities of experts working on planetary defense: astronomers working on discovery and follow-up, orbit modelers, mission designers, impact effects modelers, physical and infrastructure effects modelers, and emergency response managers. The 2019 PDC exercise was produced using high-fidelity orbit calculations, and the trajectory of the fictional asteroid was posted on the JPL Horizons ephemeris system. Impact probabilities were calculated using realistic simulated observations and operational orbit software. Impact effects were calculated using full physics-based models, and the suite of possible missions to the asteroid were computed using full-up mission design techniques. This paper summarizes the scenario and its evolution.

2. The 2019 PDC Impact Scenario

The 2019 PDC impact scenario was introduced on the first day of the Conference. The orbit of the fictional asteroid was designed so that discovery occurred 5 weeks earlier, and using a realistic set of simulated ground-based observations, the probability on the opening day of the conference was 1% for an impact exactly 8 years in the future, on April 29, 2027. The hypothetical asteroid was given the designation "2019 PDC". With an orbital period of 2.7 years, the object was close to an 8:3 resonance with Earth, making it essentially undiscoverable for the previous two decades. The asteroid's size was estimated at roughly 100 to 300 meters, based on its absolute magnitude. Two important concepts were introduced on Day 1: the "uncertainty region" around the future predicted asteroid positions, and the "risk corridor", the intersection of that region with the Earth's surface. Even with impact being very uncertain, the locations of the possible impact locations could already be constrained to lie along that risk corridor which stretched from Hawaii across the continental U.S. and through central Africa. The challenges discussed on Day 1 were simply observational: to track the asteroid as accurately as possible as it receded and faded through 2019 in order to obtain the best possible orbit estimate.

On Day 2, the calendar moved forward 3 months and the impact probability climbed to 10% due to the improved orbit estimated from an extensive observation campaign. NEOWISE observations now constrained the asteroid's size a bit better: 140 to 260 meters. The corresponding impact energy was in the range of 100 to 800 megatons, enough to produce serious devastation over a large region. A detailed statistical analysis of impact effects along the entire risk corridor was presented, but the exact impact location remained unknown. It was already known that the impact location could not be precisely predicted using only ground-based observations until mere months before the potential impact. Discussion turned to the set of possible space missions which could be deployed against the threat. Decision makers chose to proceed with rapid development of characterization missions, both flyby and rendezvous, and start work on deflection missions of two types: kinetic impactor (KI) and standoff nuclear detonation. The challenge on Day 2 was to decide on a robust campaign of missions to mitigate the impact threat. The decision to proceed with an early flyby reconnaissance mission turned out to provide early key situational awareness on the precise impact location, not only simplifying later mitigation decisions, but also increasing the chances of a successful deflection.

Day 3 moved the calendar to the day after the successful reconnaissance mission flyby. In situ imaging from the spacecraft led to a highly accurate orbit which pinpointed the impact location at Denver, Colorado. Imaging further revealed that 2019 PDC was a contact binary roughly 260 by 140 meters in size. A detailed briefing on the physical effects of the impact event was presented. The challenge for Day 3, was to decide on the specific set of missions to deflect the asteroid. While the flyby mission did not provide a precise mass estimate for the asteroid, pinpointing the impact location made the requirements on the deflection problem clearer. A set of six kinetic impactor missions was chosen as the primary deflection approach, and a rendezvous spacecraft with an optional nuclear device served as a backup deflection plan. Issues associated with each of these deflection approaches were discussed.

Day 4 advanced the scenario to the deflection itself. The rendezvous spacecraft had established a precise mass for the asteroid, and three kinetic impactor missions successfully deflected the asteroid off its impact trajectory, although a large 60-m fragment of the contact binary was seen in spacecraft images to break off after the first KI deflection and remain largely unaffected by the deflection, still on a collision course with Earth. Day 4 discussions focused on the challenges of using kinetic impactors against contact-binary rubble-pile asteroids, as well as legal and political challenges against the nuclear deflection option, which had been dropped from the rendezvous mission. In a final twist on Day 4, contact with the rendezvous spacecraft was lost due to debris hits, and the impact location of the fragment could not be determined.

Day 5 flipped the calendar ahead to just 10 days before impact, and a worst-case scenario was selected for discussion: ground-based observations had narrowed down the predicted impact location of the fragment to New York City. After the physical and infrastructure effects were presented, attendees discussed the logistics and lead time required for effective evacuation, as well as the financial and economic consequences of an impact over a large city.

3. Summary and Conclusions

An overview has been given of the hypothetical asteroid impact exercise carried out at the 2019 Planetary Defense Conference. Exercises such as this bring together the various disciplines working on planetary defense, and can lead not only to better understanding of the technical issues involved but also improved communications within the planetary defense community and with the public.

The presentations and detailed technical material for the 2019 PDC impact scenario are available online at https://cneos.jpl.nasa.gov/pd/cs/pdc19/.

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