PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

AFTER-ACTION REPORT

NASA Planetary Defense Coordination Office
PD TTX5
2-3 April 2024

NASA | Johns Hopkins Applied Physics Laboratory | Ames Research Center

FEMA | JPL Jet Propulsion Laboratory California Institute of Technology | Lawrence Livermore National Laboratory

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Planetary Defense Interagency Tabletop Exercise 5

After-Action Report

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Executive Summary

Planetary Defense Interagency Tabletop Exercise 5 (PD TTX5) provided opportunities for participants to better understand the preparedness and response challenges associated with the threat of an asteroid impact. PD TTX5 was sponsored jointly by the National Aeronautics and Space Administration (NASA) Planetary Defense Coordination Office (PDCO) and the Federal Emergency Management Agency (FEMA), with the assistance of the U.S. Department of State Office of Space Affairs. The exercise incorporated both national and international considerations to improve preparedness for an asteroid impact. It emphasized coordination and collaboration and included participants from many federal departments and agencies, as well as international partners.

In the PD TTX5 scenario, a hypothetical asteroid had a significant chance of impacting Earth in approximately 14 years. The asteroid's size and impact energy as well as the potential damage it could cause were reported to be highly uncertain (Figure ES-1), and no asteroid observations would be possible for the next seven months. The entire exercise scenario took place during this single moment in time.

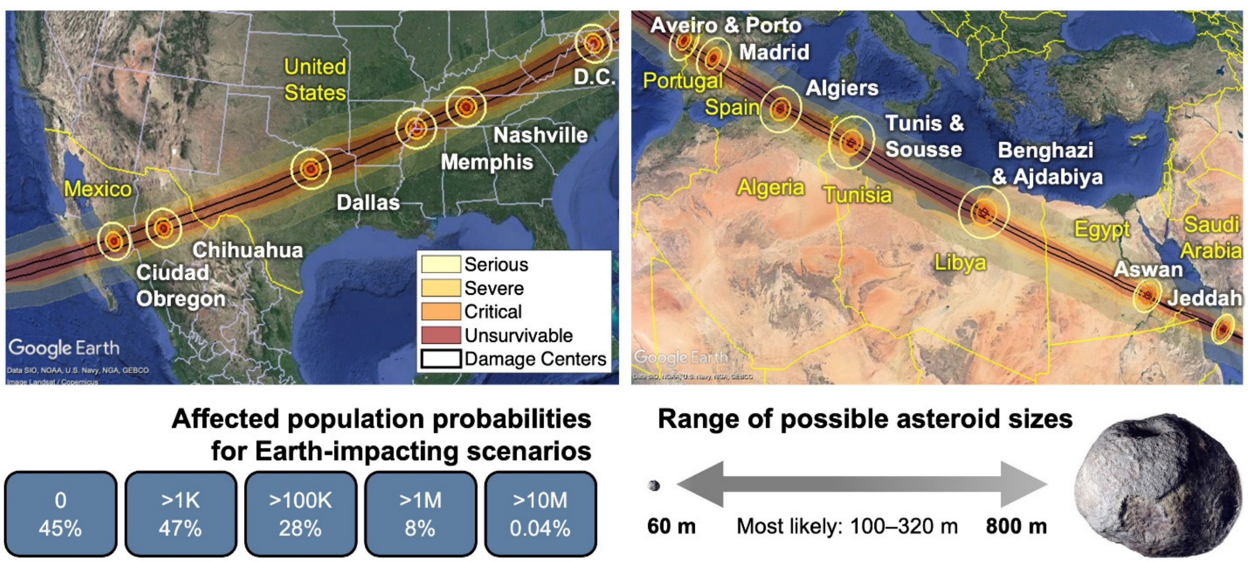

Figure ES-1. EXERCISE ONLY Impact damage risk corridor, potentially affected population probabilities, and range of asteroid sizes.

The four high-level objectives for PD TTX5 were to:

1. Raise awareness of the nature of asteroid threats and the challenges related to preparing an effective international response
2. Explore potential in-space responses to an asteroid threat with greater than 10 years of warning time, including through international cooperation
3. Assess the challenges of and readiness for planning an international, ground-based emergency response to an asteroid impact that would be large enough to devastate entire regions
4. Identify current mechanisms for and barriers to international near-Earth object (NEO) threat-related information sharing and communications, including public messaging strategies

During the exercise's facilitated discussions about various challenges associated with, preparing for, and responding to the hypothetical asteroid impact in the exercise, notetakers with varied subject-matter expertise (see Appendix B) gathered data. After TTX5, the data were assessed, which resulted in common key takeaways that summarized the event and identified gaps and associated recommendations. Overall, the exercise increased awareness of the nature of asteroid threats and the challenges related to preparing for an effective international response, and 91% of participants who completed feedback forms agreed or strongly agreed that they left the exercise feeling better prepared to deal with the capabilities and challenges associated with preparing for an asteroid impact threat.

A common takeaway from TTX5 was that the large and varied uncertainties about the potential impact and its consequences posed unique challenges. The 14-year timeline prompted discussion about preparedness over a longer time frame than many other hazards and raised a variety of concerns for different stakeholders. Improved information about the asteroid's orbit and properties would reduce uncertainties in the potential consequences of an impact, thereby enabling better decision-making about how to respond and underscoring the need to gather more information about the asteroid. Many stakeholders indicated they would want as much information about the asteroid as soon as possible but expressed skepticism that funding would be forthcoming to obtain such information without a more definitive understanding of the risk.

During the exercise, three perspectives were woven into the facilitated discussions: (1) international space responses, (2) disaster preparedness planning, and (3) public information messaging. Overall, the exercise participants concluded that development of best practices, common approaches, and procedures at the bilateral and multilateral level (including the United Nations [UN]) could facilitate international collaboration and, as appropriate, coordination of space missions, disaster management, and communication in the context of a possible asteroid impact response. It was also recognized that the timelines of space mission planning, disaster management, information sharing, and communications are intertwined in ways that were not fully appreciated before the exercise. Participants acknowledged that misinformation and disinformation would need to be addressed to achieve effective public information messaging. Although specific disaster management plans for a NEO impact do not currently exist, participants stated that preparedness and response plans for other more common critical events may provide suitable starting points, and it would be worthwhile to begin identifying plans that could be adapted for NEO impact disaster management.

From the exercise, a set of high-level gaps and actionable recommendations were identified and are summarized in Table ES-1 below. Addressing these gaps will advance planetary defense preparedness and make progress toward furthering existing planetary defense capabilities. Future tabletop exercises should continue to assess current planetary defense readiness, both for U.S. agencies and for international cooperation efforts.

Table ES-1. Gaps and recommendations identified in PD TTX5.

Gap	Recommendations
Awareness of the Role of SMPAG. The role of the UN-endorsed Space Mission Planning Advisory Group (SMPAG) in an asteroid impact threat scenario is not fully understood by all participants.	Raise awareness among U.S. and international organizations about SMPAG's role as a coordination and advisory group for in-space responses. Emphasize that UN member states determine whether or not to pursue space mission(s) recommended by SMPAG.
Process for Space Mission Decisions. The process for making decisions about space missions in an asteroid impact threat scenario remains unclear. The process has not been adequately discussed in the U.S. or internationally.	Clarify a process for how decisions to select space mission options to pursue in various planetary defense scenarios could be made. Exercise the process and continue to update based on future exercise outcomes.
Risk Tolerance and Decision Criteria for Space Missions. The risk tolerance and decision criteria for undertaking a space-based response in a planetary defense scenario are not sufficiently codified.	Establish a decision criteria framework for a space-based response by considering benefits versus cost and associated risks to guide choices about response options and funding needs.
Go/No-Go Decision Points for Space Missions. Information about the timeline for go/no-go decision points for space missions is not adequately infused into discussions about courses of action in response to an asteroid impact threat.	Identify relevant decision points for pursuit of planetary defense mission options and the timing of decisions needed to preserve future response options, and compile approximate costs associated with those decision points. Codify criteria for determining when a mission option is no longer considered viable.
Spacecraft Reconnaissance. The ability to use a spacecraft to quickly gather information about the asteroid, via flyby or rendezvous, is limited because of spacecraft and launch availability.	Develop the capability to rapidly implement a NEO reconnaissance mission. Determine information required and processes for repurposing existing spacecraft and/or instruments to rapidly gather information about an asteroid threat, and mechanisms for timely launch options.
Earth-Impact-Prevention Capabilities. Only one technology for Earth impact prevention—kinetic impact—has been demonstrated in flight, and it has only been demonstrated once.	Conduct additional Earth-impact-prevention flight demonstration(s) to increase their maturity and reliability (e.g., multiple kinetic impactors as well as gravity tractor, ion beam, or other "slow push" techniques). Continue to study efficacy of versus concerns regarding nuclear explosive devices.
Commercial Space Industry. The role of the commercial space industry in planetary defense missions has not been fully explored.	Identify appropriate and effective ways of engaging with commercial industry in a planetary defense scenario.
Legal and Policy Issues. Several legal and policy issues associated with planetary defense remain.	Conduct a workshop or exercise specifically focused on further identifying and discussing legal and policy issues related to planetary defense, using the basis of the work done by the SMPAG Ad-Hoc Working Group on Legal Issues.
International Coordination of Public Messaging. Approaches to timely international consultation/coordination regarding public messaging about asteroid impact threats have yet to be fully developed and exercised.	Expand existing efforts that take advantage of asteroid close approaches, planetary defense exercises, and other opportunities to consult or coordinate regarding national and international public information messaging strategies.
Public Messaging Content Development. The rare nature of an asteroid impact threat and the need to develop new public messaging content may delay the timely release of accurate information to the public.	Develop templates for preapproved holding statements for several different planetary defense scenarios (e.g., long warning, short warning, impact without warning).
Sustainment over a Long Timeline. Sustaining the space mission, disaster preparedness, and communications efforts across a 14-year timeline would be challenging because of budget cycles, warning fatigue, changes in political leadership, changes to personnel, and ever-changing world events.	Continue use of periodic briefings and exercises to continue to raise and sustain awareness of planetary defense. The natural cycle of changes in exercise participants emulates real-world changes in leadership and personnel that would likely occur during a long-warning scenario.
International Disaster Preparedness for a NEO Impact. There is no analogue to the International Asteroid Warning Network (IAWN) or SMPAG for international disaster preparedness for a NEO impact.	Identify an appropriate forum for discussing legal, policy, and operational aspects of international NEO impact disaster preparedness and planning, potentially through existing organizations at the UN or elsewhere.
Interconnected Timelines. The interconnectedness of timelines for space mission planning, disaster preparedness, and communications is not fully understood; an increased understanding of these needs would enhance planning and preparedness.	Engage in cross-agency dialogue to identify interagency dependencies and the means to share needed information with the relevant agencies at the right times.

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Chapter 1. Introduction and Background

In fall 2023, the National Aeronautics and Space Administration (NASA) Planetary Defense Coordination Office (PDCO) and the Federal Emergency Management Agency (FEMA) jointly sponsored Planetary Defense Interagency Tabletop Exercise 5 (PD TTX5), with the assistance of the U.S. Department of State (DoS) Office of Space Affairs. The event was held on 2–3 April 2024 at the Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland, with an option for virtual participation. PD TTX5 was a dynamic, multimedia-facilitated event.

Over the course of the two-day exercise, approximately 95 attendees participated. Most participated in-person at APL (Figure 1-1). Key U.S. participants came from NASA, FEMA, DoS, the National Space Council, U.S. Space Command (USSPACECOM), and the White House Office of Science and Technology Policy (OSTP), among others. Key international organizations represented included the United Nations Office for Outer Space Affairs (UNOOSA), the European Space Agency (ESA), the U.K. Space Agency (UKSA), the International Asteroid Warning Network (IAWN), and the Space Mission Planning Advisory Group (SMPAG). Appendix C provides a complete list of participating organizations.

Figure 1-1. PD TTX5 participants in Laurel, Maryland.

1.1. Exercise Overview

Exercise Name	Planetary Defense Interagency Tabletop Exercise 5 (PD TTX5)
Exercise Dates	2–3 April 2024
Location	Hybrid event hosted at the Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland
Scope	Two-day tabletop exercise (TTX) to improve preparedness and planning for an asteroid impact with an emphasis on international coordination and collaboration
Objectives	Raise awareness of the nature of asteroid threats and the challenges related to preparing an effective international response Explore potential in-space responses to an asteroid threat with >10 years of warning time, including international collaboration and contributions Assess the challenges of and readiness for planning an international, ground-based emergency response to an asteroid impact that would be large enough to devastate entire regions Identify current mechanisms for and barriers to international near-Earth object (NEO) threat-related information sharing and communications, including public messaging strategies
Threat/Hazard	Asteroid impact
Scenario	A hypothetical asteroid has been discovered that has a significant chance of impacting Earth in about 14 years. The asteroid's size and impact energy, and the potential damage it could cause, remain highly uncertain; therefore, the requirements for preventing its impact also have large uncertainties. Data indicate the asteroid could devastate a regional- to country-scale area, if it should impact.
Sponsor	NASA Planetary Defense Coordination Office (PDCO), in partnership with the Federal Emergency Management Agency (FEMA) and U.S. Department of State Office of Space Affairs
Point of Contact	Leviticus A. "L.A." Lewis FEMA Liaison/NASA Planetary Defense Program Officer Leviticus.lewis@fema.dhs.gov Leviticus.a.lewis@nasa.gov

1.2. Background

PD TTX5 continues a series of joint NASA–FEMA planetary defense exercises dating back to 2013. Each TTX has addressed a different type of asteroid impact scenario and focused on different aspects of the planning considerations associated with each respective impact scenario (Figure 1-2). Notably, PD TTX5 was the first U.S. interagency planetary defense exercise to include participation from the international planetary defense community and the first to be held since NASA's Double Asteroid Redirection Test (DART) mission successfully demonstrated that kinetic impactor technology could be used to potentially prevent an asteroid impact.

TTX1 (2013)	TTX2 (2014)	TTX3 (2016)	TTX4 (2022)	TTX5 (2024)
Time to impact: 1 month	Time to impact: 7 years	Time to impact: 4 years	Time to impact: 6 months	Time to impact: 14 years

Aims:	Aims:	Aims:	Aims:	Aims:
Acquaint FEMA with the nature of an asteroid impact and how warning of an impact might evolve if the object were detected a short time before possible impact	Acquaint agencies with the nature and evolution of impending asteroid impact; assess whether and how processes and procedures for disaster warning and response might be employed	Acquaint disaster response planners with the nature and evolution of information available for, and the inherent challenges of, a potential impact emergency	Increase understanding of agencies' roles in mitigating near-Earth object (NEO) impact threats; exercise postimpact protocols, including at the state and local level; test communication methods	Raise awareness of NEO threats and their challenges; inform preparedness and response capabilities, including international coordination and involvement

Figure 1-2. Planetary defense interagency tabletop exercises over time.

PD TTX5 was also the first such interagency exercise since the 2023 release of an updated U.S. *National Preparedness Strategy & Action Plan for Near-Earth Object Hazards and Planetary Defense* and the release of the *NASA Planetary Defense Strategy and Action Plan*. PD TTX5 supported specific goals from both of these plans, as noted below.

- *National Preparedness Strategy & Action Plan for Near-Earth Object Hazards and Planetary Defense* (2023)[1]
  - Goal 4: *Increase International Cooperation on NEO Preparedness*
  - Goal 5: *Strengthen and Routinely Exercise NEO Impact Emergency Procedures and Action Protocols*
  - Goal 6: *Improve U.S. Management of Planetary Defense through Enhanced Interagency Collaboration*
- *NASA Planetary Defense Strategy and Action Plan* (2023)[2]
  - Goal 4: *Increase NASA Contributions to International Cooperation on NEO Preparation*
  - Goal 5: *Coordinate with FEMA and Other Agencies to Strengthen and Routinely Exercise NEO Impact Emergency Procedures and Action Protocols*

[1] National Science and Technology Council Planetary Defense Interagency Working Group, *National Preparedness Strategy & Action Plan for Near-Earth Object Hazards and Planetary Defense*, April 2023, https://www.whitehouse.gov/wp-content/uploads/2023/04/2023-NSTC-National-Preparedness-Strategy-and-Action-Plan-for-Near-Earth-Object-Hazards-and-Planetary-Defense.pdf.

[2] National Aeronautics and Space Administration, *NASA Planetary Defense Strategy and Action Plan*, April 2023, https://www.nasa.gov/wp-content/uploads/2023/06/nasa_-_planetary_defense_strategy_-_final-508.pdf.

- Goal 6: *Improve NASA Contributions to Ongoing Interagency Coordination on Planetary Defense*
- Goal 8: *Enhance Strategic Communications Related to Planetary Defense*

The two most recent exercises, TTX4 and TTX5, share both similarities and differences (Figure 1-3). Both exercises were low-stress, no-fault environments using a facilitated discussion and a structured data-collection approach. Both strived to raise awareness of asteroid impact threats as well as the various response options. While TTX4 focused on engagement among domestic federal, state, and local organizations, TTX5 emphasized international collaboration. The scenarios in the two exercises were also quite different: TTX4 involved a short-warning scenario with only six months until a potential impact, whereas TTX5 involved a long-warning scenario with slightly more than 14 years until a potential, but not definitively known, impact.

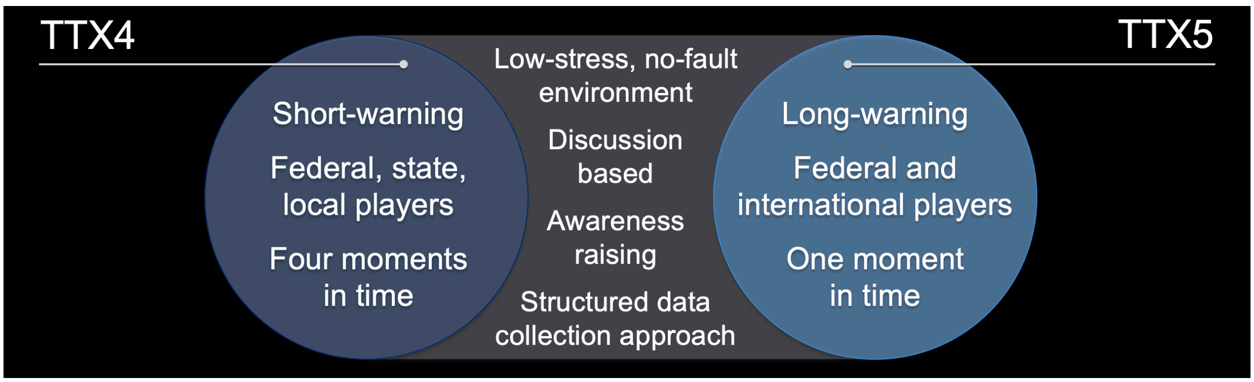

Figure 1-3. Similarities and differences between TTX4 and TTX5.

TTX4 identified 11 high-level gaps and vulnerabilities. In the intervening two years between TTX4 and TTX5, progress has been made on some, but not all, of those gaps, as summarized in Table 1-1.

Table 1-1. PD TTX4 capability gaps and progress since.

Gaps from PD TTX4	Progress to Date
Need for capabilities for earlier asteroid detection and characterization	NASA's NEO Surveyor mission, which is a dedicated space-based infrared survey telescope for planetary defense, was confirmed and is on track to launch in late 2027. The Vera C. Rubin Observatory will contribute detections and become operational in 2025. The NASA Infrared Telescope Facility (IRTF) continues to operate.
Limited radar capabilities for imaging small, rapidly moving asteroids	Radar for planetary defense remains a gap. A Cross-Disciplinary Deep Space Radar Needs Study[3] was released in June 2023. Upgrades are being studied to increase the Green Bank Observatory's capabilities for planetary radar.
Limited ability to rapidly launch a NEO reconnaissance mission	Three "Near-Earth Object Workshops to Assess Reconnaissance for Planetary Defense" were held to address requirements for NEO reconnaissance missions, as well as technology capabilities and gaps. The workshop report was delivered to PDCO.

[3] Matthew F. Marshall, Scott L. Schnee, Veronica Cruz-Klueber, Josefina Salazar Morales, Eliana Nossa, Thomas J. Fagan, Joseph J. Crossin, et al., *Cross-Disciplinary Deep Space Radar Needs Study*, July 17, 2023, https://www.nasa.gov/wp-content/uploads/2023/10/atr-2023-01267.pdf.

Gaps from PD TTX4	Progress to Date
Government and public unfamiliar with asteroid threat	DART's success, asteroid close approaches, small asteroid impacts, and Hollywood movies raised awareness of planetary defense in the years between TTX4 and TTX5.
Only nascent strategies exist to address misinformation	Per the existing "NASA Policy on the Release of Information to News and Information Media,"[4] all agency public affairs officers are expected to act promptly to correct mistakes or erroneous information, either internally or externally. The strategy to do so has not been further refined.
Format and structure of visuals makes them difficult to use without subject-matter experts	A tailored approach to creating visuals was implemented for TTX5 based on lessons learned during TTX4 and at other venues. TTX5 included for the first time an interactive risk dashboard.
Processes that populate Center for Near Earth Object Studies (CNEOS) fireballs webpages are neither designed for quick reporting nor used definitively to distinguish a natural bolide event from foreign-state action; the page is too detailed for broad consumption	Discussions have been held to define an improved pipeline for receiving data collected by U.S. government sensors. Once that is in place, there may be a redesign of the webpages based on inputs from PDCO and others.
Minimal redundancy currently exists for NASA CNEOS and NASA Asteroid Threat Assessment Project (ATAP) NEO modeling capabilities/expertise	ATAP has trained additional personnel to run impact damage models.
Limited awareness/understanding of the National Incident Management System (NIMS)	For the domestic science community, a quick review of how NIMS works in relation to the National Response Framework would be of importance to the planetary defense science community.
Limited understanding of the international legal and policy implications of the potential use of nuclear explosive devices (NEDs) for planetary defense.	The 2023 Planetary Defense Conference included a legal panel that addressed aspects of this issue. The SMPAG Ad-Hoc Working Group on Legal Issues released a report that addresses issues with NEDs.
Limited understanding of capabilities offered by a NED-equipped intercontinental ballistic missile disruption option	A study has been completed at APL and a report has been submitted to PDCO.

[4] Brian Dunbar, "NASA Policy on the Release of Information to News and Information Media," August 24, 2016, https://www.nasa.gov/general/nasa-policy-on-the-release-of-information-to-news-and-information-media/.

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Chapter 2. Exercise Objectives and Planning

The exercise was planned using a modified version of the Department of Homeland Security's (DHS) Homeland Security Exercise and Evaluation Program (HSEEP). The HSEEP approach allows for tracking and comparison of current capabilities and assessment of overall preparedness. It also supports the following improvement-related processes:

- Alignment with a common planning structure and nomenclature
- Collection and analysis of both quantitative and qualitative data
- Documentation of baseline data to track improvement planning efforts

Planning for this event took place over a period of approximately six months and included hybrid, virtual, and in-person meetings and module "deep dives"; initial, midterm, and final planning conferences; a slide flip through; a dry-run; and a tech rehearsal. Planning efforts also included analysis of information from previous relevant events and exercises as well as relevant national and international documents. In addition to the U.S. national and NASA strategy and action plans from 2023, other key documents included the following:

- U.S. *Report on Near-Earth Object Impact Threat Emergency Protocols* (NITEP)[5]
- NASA Policy Directive 8740.1 ("Notification and Communications Regarding Potential Near-Earth Object Threats")[6]
- *After Action Report from Planetary Defense Interagency Tabletop Exercise 4*[7]
- "Statement of Intent for Participation in the International Asteroid Warning Network"[8]
- "Terms of Reference for the Near-Earth Object Threat Mitigation Space Mission Planning Advisory Group"[9]
- SMPAG's "Work Plan," Issue 2, Revision 2[10]
- SMPAG's *Planetary Defense Roadmap: Current Mitigation-Related Research and Priorities for Future Actions*[11]

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[5] National Science and Technology Council, *Report on Near-Earth Object Impact Threat Emergency Protocols*, January 2021, https://trumpwhitehouse.archives.gov/wp-content/uploads/2021/01/NEO-Impact-Threat-Protocols-Jan2021.pdf.

[6] National Aeronautics and Space Administration, "Notification and Communications Regarding Potential Near-Earth Object Threats," NASA Policy Directive NPD 8740.1, https://nodis3.gsfc.nasa.gov/npg_img/N_PD_8740_0001_/N_PD_8740_0001__main.pdf.

[7] National Aeronautics and Space Administration Planetary Defense Coordination Office, *Planetary Defense Interagency Tabletop Exercise 4 After Action Report*, August 2022, https://cneos.jpl.nasa.gov/pd/cs/ttx22/PD-TTX4-AAR-master-05August2022_final.pdf.

[8] "Statement of Intent for Participation in the International Asteroid Warning Network," March 9, 2014, https://iawn.net/documents/iawn_statement_of_intent.pdf.

[9] United Nations Office for Outer Space Affairs Space Mission Planning Advisory Group, "Terms of Reference for the Near-Earth Object Threat Mitigation Space Mission Planning Advisory Group," September 13, 2019, https://www.cosmos.esa.int/web/smpag/terms_of_reference_v2.

[10] United Nations Office for Outer Space Affairs Space Mission Planning Advisory Group, "Work Plan," Issue 2, Revision 2, SMPAG-PL-001, September 2019, https://www.cosmos.esa.int/documents/336356/336472/SMPAG-PL-002_2_0_Workplan_2019_09-01+%283%29.pdf/a117c9aa-27c1-788c-7d30-513fb7c06367?t=1590414041069.

[11] United Nations Office for Outer Space Affairs Space Mission Planning Advisory Group, *Planetary Defense Roadmap: Current Mitigation-Related Research and Priorities for Future Actions*, SMPAG-RP-001, Version 4.0, March 2023, https://www.cosmos.esa.int/documents/336356/336472/SMPAG-RP-001_4_0_Roadmap_2023-03-02.pdf/7a95c347-f749-1615-2b5f-5a89ef57f242?t=1692603843886.

- SMPAG's *Planetary Defense Action Plan* (draft report on work package 5.5)[12]
- SMPAG's "Recommended Criteria & Thresholds for Action for a Potential NEO Impact Threat"[13]
- SMPAG Ad-Hoc Working Group on Legal Issues' *Planetary Defence Legal Overview and Assessment*[14]
- The United Nations Committee on the Peaceful Uses of Outer Space's (COPUOS) "Recommendations of the Action Team on Near-Earth Objects for an international response to the near-Earth object impact threat"[15]

2.1. TTX5 Objectives

The aim of PD TTX5 was to improve long-term preparedness and planning for an asteroid impact with an emphasis on international coordination and collaboration. Part of the exercise examined how to proceed effectively—in the face of large uncertainties—to obtain better information about the asteroid and reduce the risks in the final outcomes of the scenario. The TTX had four top-level objectives, each with measurable sub-objectives to ensure meaningful outcomes (Table 2-1).

Table 2-1. PD TTX5 objectives.

Objective	Objective Statements
1 – Raise awareness of the nature of asteroid threats and the challenges related to preparing an effective international response	1.1. Inform participants on the nature of and process for NEO impact threats, to include discovery, tracking, characterization, and explicit quantification of uncertainties associated with a NEO impact
	1.2. Explore participating organizations' high-level understanding of and procedures for preparedness and response efforts involving a NEO impact threat
	1.3. Provide information-sharing opportunities that support participants' efforts to assess and improve existing plans and policies
2 – Explore potential in-space responses to an asteroid threat with >10 years of warning time, including international collaboration and contributions	2.1. Explore processes by which decisions could be made about collaborative space-based missions in response to a NEO threat
	2.2. Identify vulnerabilities or gaps in current readiness that pose challenges to preparing a timely and effective in-space response
	2.3. Assess potential roles, responsibilities, priorities, and contributions of domestic and international entities for planetary defense missions
	2.4. Identify international coordination needs for determining and implementing an in-space response and document opportunities for improvement

[12] United Nations Office for Outer Space Affairs Space Mission Planning Advisory Group, *SMPAG 5.5 – Planetary Defense Action Plan*, October 2018, https://www.cosmos.esa.int/documents/336356/336472/SMPAG-RP-002_D_0_WP5.5_2018-10-10.pdf/9913d489-72ca-5d0f-a067-7702ab26c0ee?t=1568377077297.

[13] United Nations Office for Outer Space Affairs Space Mission Planning Advisory Group, "Recommended Criteria & Thresholds for Action for a Potential NEO Impact Threat," SMPAG-RP-003/1.0, https://www.cosmos.esa.int/documents/336356/1879207/SMPAG-RP-003_01_0_Thresholds%26Criterion_2018-10-18.pdf/58eb84ae-e3b6-1b08-9465-d25c548c5c9b.

[14] United Nations Office for Outer Space Affairs Space Mission Planning Advisory Group Ad-Hoc Working Group on Legal Issues, *Planetary Defence Legal Overview and Assessment*, SMPAG-RP-004, April 8, 2020, 60df8a3a-b081-4533-6008-5b6da5ee2a98 (esa.int).

[15] United Nations Committee on the Peaceful Uses of Outer Space Scientific and Technical Subcommittee, "Recommendations of the Action Team on Near-Earth Objects for an international response to the near-Earth object impact threat," A/AC.105/C.1/L.329, December 21, 2012, https://www.unoosa.org/pdf/limited/c1/AC105_C1_L329E.pdf.

Objective	Objective Statements
3 – Assess the challenges of and readiness for planning an international, ground-based emergency response to an asteroid impact that would be large enough to devastate entire regions	3.1. Improve collaboration between nations, departments, agencies, and organizations responsible for preparedness planning for a NEO impact threat
	3.2. Identify and document challenges and uncertainties associated with information sharing and needed decision-making for ground-based NEO impact response operations in a long-warning scenario
	3.3. Understand priorities and considerations of stakeholders related to civil defense plans, including critical infrastructure protection
	3.4. Explore differences and their effects among international partners related to response planning
4 – Identify current mechanisms for and barriers to international NEO threat-related information sharing and communications, including public messaging strategies	4.1. Increase participants' understanding of information-sharing needs and timelines to ensure consistency and continuity of public messaging to diverse communities across the globe
	4.2. Identify and document gaps in international policies and procedures related to critical information sharing for planetary defense
	4.3. Assess need for tailoring of messages based on location, culture, language, and common terminology in an international context
	4.4. Determine the extent to which information presented, including visual aids, is sufficient for and well understood by key international decision-makers

2.2. Exercise Planning Team

The planning team comprised individuals from several organizations working under the guidance of NASA and FEMA sponsors. APL led TTX planning, execution, and assessment and also provided subject-matter expertise. The exercise was successful as a result of contributions from many additional organizations, including the Center for Near Earth Object Studies (CNEOS) at NASA's Jet Propulsion Laboratory (JPL), the Asteroid Threat Assessment Project (ATAP) at NASA's Ames Research Center, NASA Goddard Space Flight Center (GSFC), Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), the DoS Office of Space Affairs, UNOOSA, and SMPAG. Table 2-2 summarizes the roles of the various organizations on the planning team. See Appendix B for a complete list of planning team members.

Table 2-2. Exercise planning team.

Organization	Role
NASA Planetary Defense Coordination Office (PDCO), including Federal Emergency Management Agency (FEMA) Detailee	TTX direction and management
Department of State Office of Space Affairs	International collaboration and coordination guidance/expertise
Johns Hopkins Applied Physics Laboratory (APL)	TTX planning, execution, assessment; space mission option development
Center for Near Earth Object Studies (CNEOS) at NASA's Jet Propulsion Laboratory (JPL)	Asteroid impact threat scenario design
Asteroid Threat Assessment Project (ATAP) at NASA Ames Research Center	Development of asteroid properties; asteroid impact risks and damage effects
NASA Goddard Space Flight Center (GSFC)	Space mission option development
Lawrence Livermore National Laboratory (LLNL)	Asteroid deflection modeling

Organization	Role
Los Alamos National Laboratory (LANL)	Asteroid deflection modeling
United Nations Office for Outer Space Affairs (UNOOSA)	Utilize unique convening ability for international coordination and public messaging guidance/expertise
Space Mission Planning Advisory Group (SMPAG)	Recommendation of space mission options
International Asteroid Warning Network (IAWN)	Asteroid impact threat notification

2.3. Data Collection and Evaluation

Effective, accurate data collection during the exercise was essential in order to identify meaningful outcomes, including capability gaps and recommendations. Data collectors were responsible for recording information to evaluate the exercise and implementation of the protocols defined in the *National Preparedness Strategy & Action Plan for Near-Earth Object Hazards and Planetary Defense* and other documents identified earlier in this section. This included the technical, logistical, and/or operational challenges associated with planetary defense activities. Additional data were collected via participant feedback forms and through the digital platform used for the exercise.

In general, the primary objective of data collection was to document participant discussions, including how they weighed options and recommendations. At least four data collectors were assigned per module, and these individuals were located throughout the room to take detailed discussion notes without interfering with exercise activities using exercise evaluation forms. Before the TTX, the data collectors were provided with key information and instructions on how to use the exercise evaluation forms, which provided a structured tool to guide data collection and were aligned to the modules, injects, discussion questions, and exercise objectives. The data collectors' documentation was vital for an effective evaluation of the technical, logistical, and operational challenges associated with planetary defense activities and planning of future exercises.

Chapter 3. Modules

The TTX was divided into five modules (see Table 3-1). Each module explored different aspects of preparing for and responding to a potential asteroid impact. One of these modules, Module 3, was divided into two parts that spanned both days of the TTX. On Day 1, facilitators guided participants to identify a set of recommended courses of action, or COAs (Module 3a), that were shared with senior leaders on Day 2 (Module 3b). To engage participants from various backgrounds for the duration of the exercise, each module wove together the core themes of information sharing and public messaging, international in-space response, and disaster preparedness planning.

Table 3-1. Modules in PD TTX5.

Module	Description
1	Scene Setting and Initial International Coordination
2	Space Mission Options
3a	Recommended Courses of Action
3b	Senior Leader Briefing
4	Public Information Messaging
5	Disaster Preparedness

Each module consisted of four components: injects (new information provided by the facilitators or by another subject-matter expert [SME]); facilitated discussion wherein participants were presented with a series of questions to jumpstart dialogue about factors they would consider, decisions they would make, and actions they would take given the situation; a hotwash; and participant feedback forms. Injects and facilitated discussion were interwoven throughout a module, whereas the hotwash and feedback forms occurred at the end of a module. During the hotwashes, facilitators asked participants to share lessons learned and best practices identified during the discussion. In the participant feedback forms, participants answered a series of Likert scale and free-response questions via Qualtrics. On average, 41 attendees[16] completed each of the various participant feedback forms. A final hotwash (accompanied by a closing feedback form) took place as the exercise wrapped up on Day 2. The final hotwash offered selected participants an additional opportunity to speak freely, offer potential improvements, and share key insights.

The injects, facilitated discussion, hotwashes, and feedback forms during each module aligned with the exercise's objectives as described in Appendix A. Note that this chapter focuses on the content presented to participants in each of the modules. Appendix A includes summaries of the discussion focus areas and identified needs from each module.

3.1. Module 1: Scene Setting and Initial International Coordination

Module 1 emphasized two TTX objectives: "raise awareness of the nature of asteroid threats and the challenges related to preparing an effective international response" and "identify current mechanisms

[16] While participant feedback forms were available for everyone in attendance during the exercise, 38 participants seated in the central area were provided with a laptop computer to follow presentations and complete feedback forms.

for, and barriers to, international asteroid threat-related information sharing and communications, including public messaging strategies." Discussions in Module 1 focused on notification of, comprehension of, and information sharing about the asteroid threat; notification pathways and processes; international coordination; and policies to guide decision-making.

Module 1 included four injects. In inject 1.1, IAWN notified UNOOSA and SMPAG that there was a 72% probability that an asteroid would hit Earth on 12 July 2038 (14 years, 3 months in the future). The time to impact, probability of impact, and estimated asteroid size met the criteria for IAWN to provide such official notification. In-person participants opened an envelope containing the notification memo (see Appendix D). SMEs from IAWN, including NASA JPL CNEOS and NASA ATAP, briefed participants on the current knowledge of the asteroid and the impact risk assessment:

- The asteroid had been discovered six months earlier, and observations were then taken to more accurately determine its future orbit. It would now be seven months until astronomers would be able to resume tracking the asteroid. Because the asteroid was now too close to the Sun, as seen from Earth, and too far away from Earth, telescopic observations ended for the time being.
- The asteroid's size was still highly uncertain but was most likely ~100–320 meters (330–1,050 feet) in diameter based on brightness and typical asteroid properties. However, the SMEs indicated the size could range from 60 meters (200 feet) to as high as 800 meters (2,600 feet), over a larger range of asteroid properties.
- If the asteroid was positioned for Earth impact, then the exact location of that impact was highly uncertain (Figure 3-1). Potential impact locations spanned a corridor from the South Pacific, across North America, the Atlantic, the Iberian Peninsula, the Mediterranean coast of Africa, Egypt, and to the coast of Saudi Arabia.
- If impact were to occur, then the damage severity near the impact would likely reach non-survivable levels, extending out to larger areas of structural damage, fires, and shattered windows (see Appendix D). Damage areas were expected to be between ~80 and 180 kilometers (~50 and 110 miles) in radius. The largest damage areas could extend out ~300 kilometers (~180 miles) or more in radius.
- The number of people potentially affected was highly uncertain because of the large uncertainties in potential impact locations, asteroid size, and resulting damage. If impact occurred, the number of potentially affected people ranged from 0 to 20 million, with an average of ~270,000 people among all the potential Earth-impact cases (Figure 3-1).

After the SMEs from IAWN, NASA JPL CNEOS, and NASA ATAP concluded their briefings, exercise participants took part in a facilitated discussion.

The maps in Figure 3-2 show regions potentially at risk for ground damage (extending out to the 95th percentile of estimated damage size ranges). Rings show median (50th percentile) damage footprints at sample locations. The colors of the rings correspond to the severity of damage that extends out to that point. The damage severities range from un-survivable to serious, as indicated by the legend in the bottom right corner of the left panel of the figure.

THE ASTEROID THREAT SCENARIO

Current Date	Asteroid name	Potential Earth impact date	Impact probability	Approximate asteroid size
2 April 2024	2023 TTX	12 July 2038	72%	Highly uncertain. Mostly likely ~100–320 m in diameter. Full range of ~60–800 m.

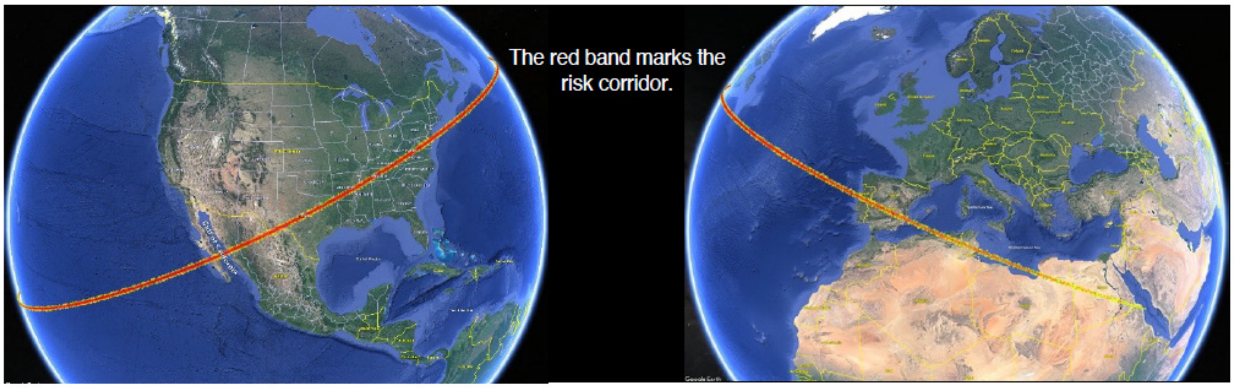

Figure 3-1. EXERCISE ONLY – Key information about asteroid threat and impact risk corridor.

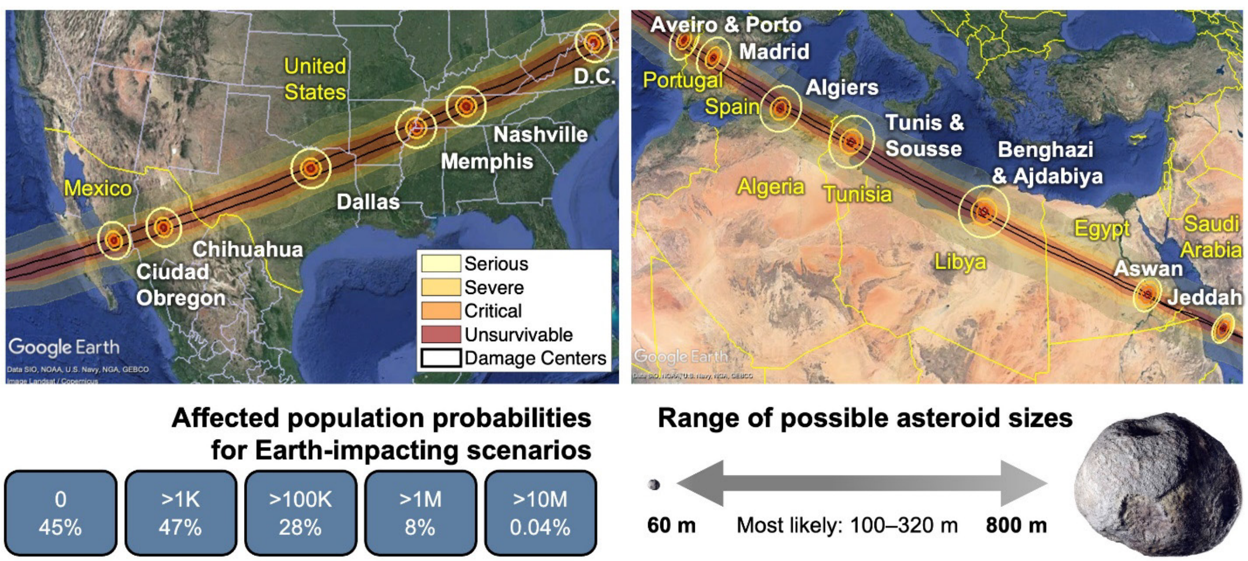

Figure 3-2. EXERCISE ONLY – Selected portions of the damage risk corridor.

In inject 1.2, the facilitators summarized the U.S. impact notification protocol as defined in NASA Policy Directive 8740.1 ("Notification and Communications Regarding Potential Near-Earth Object Threats"). This information was intended to prompt discussion of how other countries manage information and notifications of potential NEO impacts. A period of facilitated discussion ensued.

Inject 1.3 began with the facilitators reminding participants of the current state of knowledge about the impact threat, including the probability of impact, time to potential impact, risk corridor, range of affected people, and key milestones associated with future telescopic observations. The intent of this inject was twofold: First, it brought key facts back to the forefront of participants' minds to help seed further discussion. Second, it introduced an impact risk dashboard format that would be built upon throughout the exercise to summarize key information about the scenario for participants (Figure 3-3). The single chart below summarizes the asteroid and impact properties, impact risk swath, impact hazards, and population risks. Many of the quantities shown on the dashboard have large uncertainties because of the high level of uncertainties associated with impact location, asteroid size, and additional properties. Facilitated discussion followed.

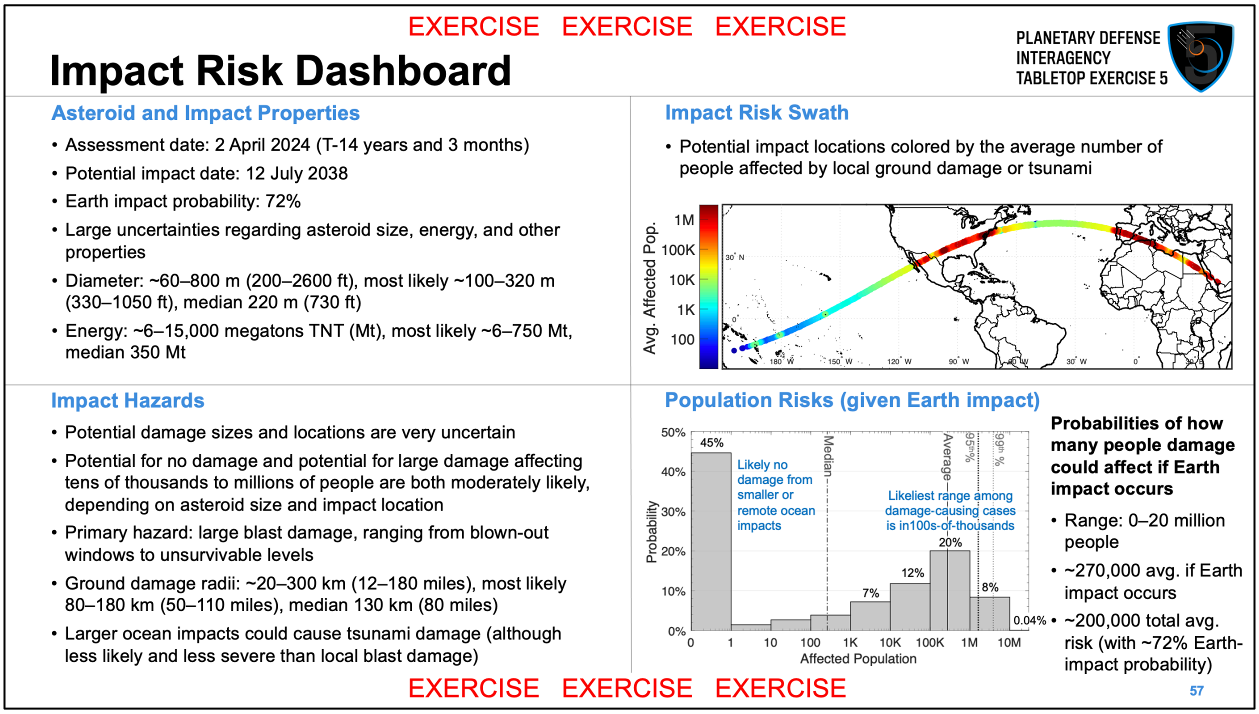

Figure 3-3. EXERCISE ONLY – Impact risk dashboard.

Finally, in inject 1.4 the facilitators emphasized the areas potentially at risk for damage (Figure 3-2) to prompt discussion about protection of critical infrastructure. The facilitators then led a hotwash to gather additional thoughts, and participants completed their feedback forms, concluding Module 1.

3.2. Module 2: Space Mission Options

Module 2 centered on the second TTX objective: "explore potential in-space responses to an asteroid threat with greater than 10 years of warning time, including international collaboration and contributions." Discussions in Module 2 focused on current readiness and challenges for a timely and effective in-space response, policy considerations, international coordination on space mission options, and implications of space mission options on emergency preparedness and public messaging.

This module included four injects. In inject 2.1, the facilitators reminded participants about the expectations for future information from telescopes (Figure 3-4). The uncertainty in the impact location would decrease in coming years as a result of additional information from telescopic data. However, the uncertainties in the asteroid's properties, and, therefore, the uncertainties in potential consequences should the asteroid impact Earth, would remain large. The facilitators then immediately presented inject 2.2, which explained that thresholds for estimated asteroid size, impact probability, and warning time had been crossed, triggering the planning of space mission options, based on the criteria recommended by SMPAG and NITEP. As a part of inject 2.2, a SME from APL explained the space mission options available for asteroid reconnaissance.

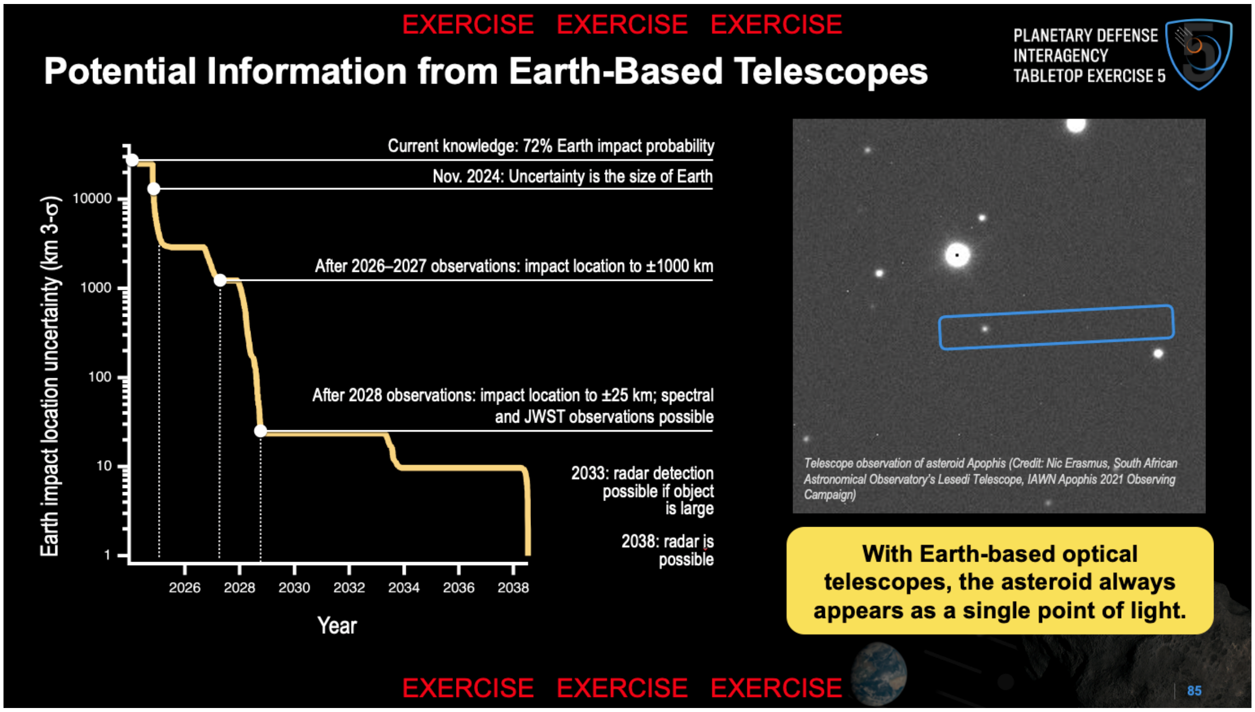

Figure 3-4. EXERCISE ONLY – Expectations for future observations.

As explained in the briefing, asteroid reconnaissance missions are critical for reducing uncertainties in asteroid properties so that effective missions can be designed to prevent an Earth impact and so emergency management organizations can better understand the potential consequences of impact.

The briefing also explained that reconnaissance missions can be broadly divided into two categories: flyby missions and rendezvous missions. In a flyby mission, a spacecraft flies past the asteroid at high speed while gathering information on the asteroid's position, size, and other properties. Such a mission would also obtain some surface images and a preliminary composition classification. The typical development time from build to launch for a flyby mission is three years. Alternatively, in a rendezvous reconnaissance mission, a spacecraft arrives at the asteroid and observes it up close for an extended period of time. This proximity allows the spacecraft to monitor the asteroid and make measurements over days, months, or even years, including a precise measurement of the asteroid's mass. Such a mission would also obtain extensive surface imaging and detailed composition mapping. The typical development time from build to launch for a rendezvous mission is five years. Rendezvous missions might also be flown as hybrid reconnaissance and Earth-impact-prevention missions.

Figure 3-5 below shows a timeline of reconnaissance mission options presented during the briefing. Participants were shown several options for both flyby and rendezvous reconnaissance missions based on possible launch windows, which were determined by the asteroid's orbit. The mission options presented to participants included the earliest possible launch for flyby and rendezvous missions, the very latest launch opportunity for each mission type, and several options in between. From a schedule perspective, some of the mission options were consistent with historical development timelines for space missions. Other missions, however, would only be possible with an accelerated development schedule. The development schedule feasibility was indicated by red, yellow, and green shading. Red missions would require a development timeline that would be at least two years shorter than typical, yellow missions could be developed one year shorter than typical, and green missions could be developed on the typical schedule, or approximately three years for a flyby mission and approximately five years for a rendezvous mission. The slide also included milestones for when major updates to impact threat information would be available based on expected data from telescopes.

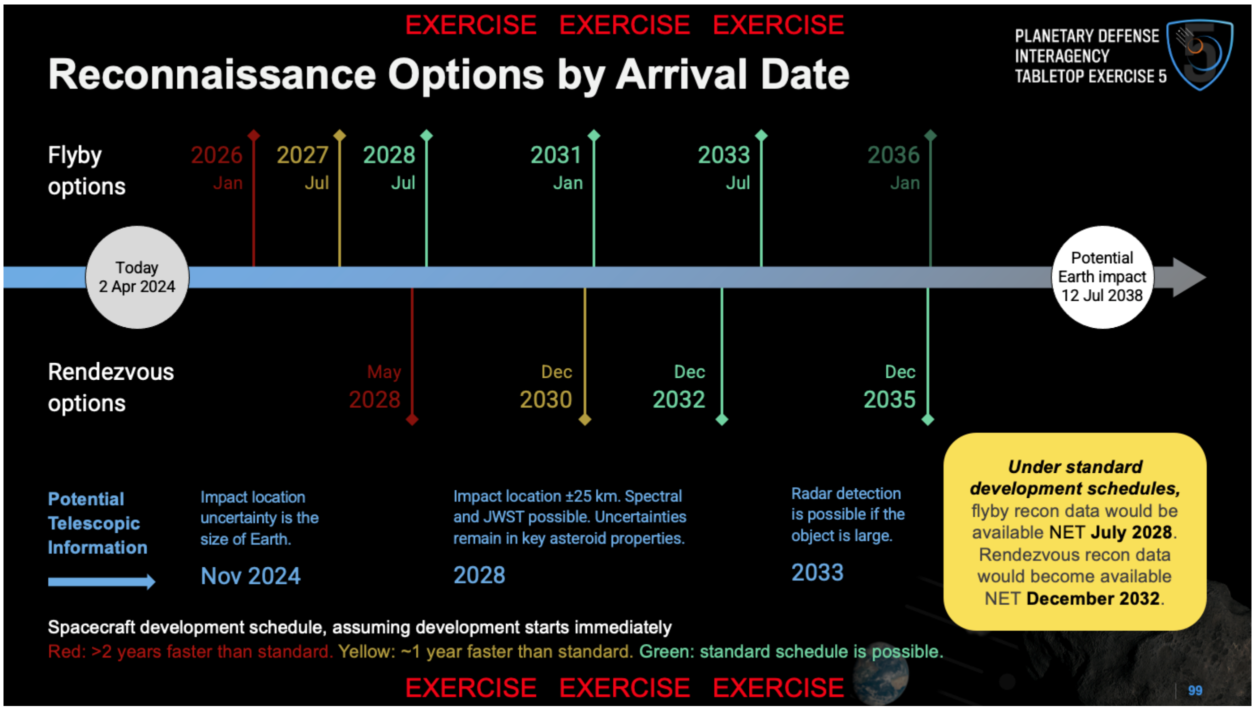

Figure 3-5. EXERCISE ONLY – Timeline of reconnaissance mission options.

The potential for repurposing existing spacecraft for asteroid reconnaissance was noted during the briefing. Some spacecraft currently flying or being developed could be redirected for an asteroid flyby. However, the SME noted that repurposing spacecraft for activities they were not designed for increases the risk that necessary measurements of the asteroid may not be successfully acquired. After the conclusion of the APL SME's briefing, the facilitators led a period of discussion.

Next, in inject 2.3 the facilitators explained to participants that the U.S. benchmarks to consider impact prevention missions outlined as in the NITEP report had been crossed. A SME from NASA GSFC then briefed participants on the space mission options available for Earth impact prevention.

As explained in the NASA GSFC brief, asteroid deflection (slowing down or speeding up the asteroid in its orbit) was preferred over asteroid disruption (breaking it into many pieces) in this scenario. Although various impact mitigation approaches are possible, three types of Earth-impact-prevention missions were presented: kinetic impact, ion beam, and nuclear explosive device (NED) deflection.

1. Kinetic impact deflection: A spacecraft intercepts and collides with the asteroid at high speed, creating ejecta that provides an additional push to change the asteroid's path through space. This method for asteroid deflection was demonstrated by NASA's DART mission in September 2022.
2. Ion beam deflection: A rendezvous spacecraft fires its ion beam engines at the asteroid for many months or years to slowly push the asteroid into a new orbit. At this time, this approach has not been demonstrated in flight.
3. NED deflection: A spacecraft deploys a NED, which is detonated near the asteroid to vaporize surface material and cause blowoff-induced recoil. This method has not been demonstrated for asteroid deflection. Additionally, there are concerns regarding violations of international law, treaty, and other considerations associated with its use.

Figure 3-6 shows a timeline of Earth-impact-prevention mission options. The briefing SME noted that it would be beneficial to receive reconnaissance data early enough in the impact prevention mission life cycle to make adjustments based on those reconnaissance data. However, they also noted that with standard space mission development timelines, getting the data early enough to make adjustments may prove challenging in this scenario. The color coding of mission opportunities matched the color coding used in the timeline of reconnaissance mission options. All the deflection options presented were intended to move the asteroid off an Earth-impact course before the asteroid's potential impact in 2038. The participants then engaged in a period of facilitated discussion.

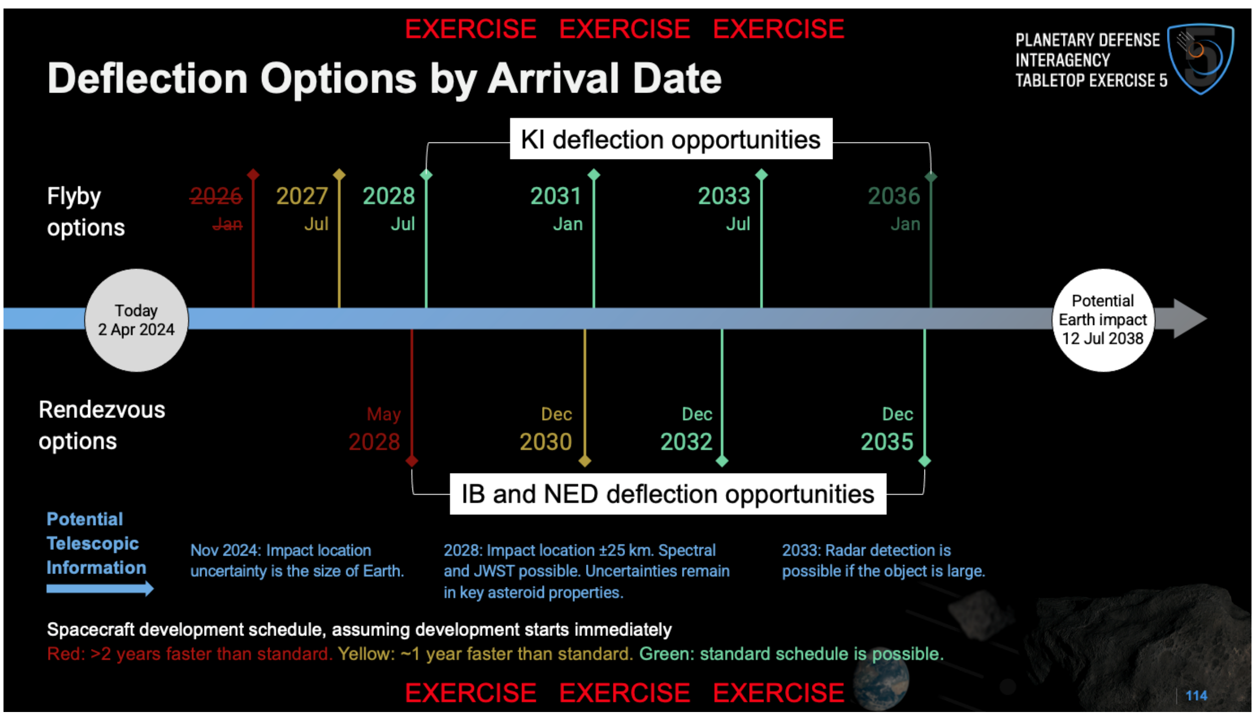

Figure 3-6. EXERCISE ONLY – Earth-impact-prevention mission options presented.

Finally, in inject 2.4 the facilitators summarized the current state of knowledge about the impact threat and mission options, including the probability of impact, time to potential impact, risk corridor, range of affected people, key milestones associated with future telescopic observations, and a timeline of arrival dates for reconnaissance and Earth-impact-prevention missions. Participants discussed a final set of questions before completing the Module 2 hotwash and participant feedback forms.

3.3. Module 3: Recommended Courses of Action

Module 3 included two parts. Module 3a, Recommended Courses of Action, took place on the afternoon of Day 1, and Module 3b, Senior Leader Briefing, took place on the morning of Day 2. Module 3 addressed all four of the top-level TTX objectives, with the discussion mainly focusing on the second objective: “explore potential in-space responses to an asteroid threat with greater than 10 years of warning time, including international collaboration and contributions.” Discussions during Module 3 focused on international collaboration and coordination, decision-making in the face of uncertainties, and processes for identifying recommended COAs.

In inject 3.1, the facilitators reminded participants of the current state of knowledge on the impact threat and mission options, including the probability of impact, time to potential impact, risk corridor, range of affected people, key milestones associated with future telescopic observations, and a timeline of arrival dates for reconnaissance and Earth-impact-prevention missions. Inject 3.2 presented a notional flowchart for international coordination on planetary defense missions based on the IAWN statement of intent, SMPAG terms of reference, and SMPAG roadmap (Figure 3-7). Under the SMPAG terms of reference,[9] “SMPAG would propose mitigation options and implementation plans for consideration by the international community.” SMPAG would also “recommend viable concepts for a possible mitigation campaign and directly inform those governments that would coordinate and fund space mission activities and request that they in turn inform UN COPUOS, via the UN Office for Outer Space Affairs if necessary.” After inject 3.2, participants took part in facilitated discussion.

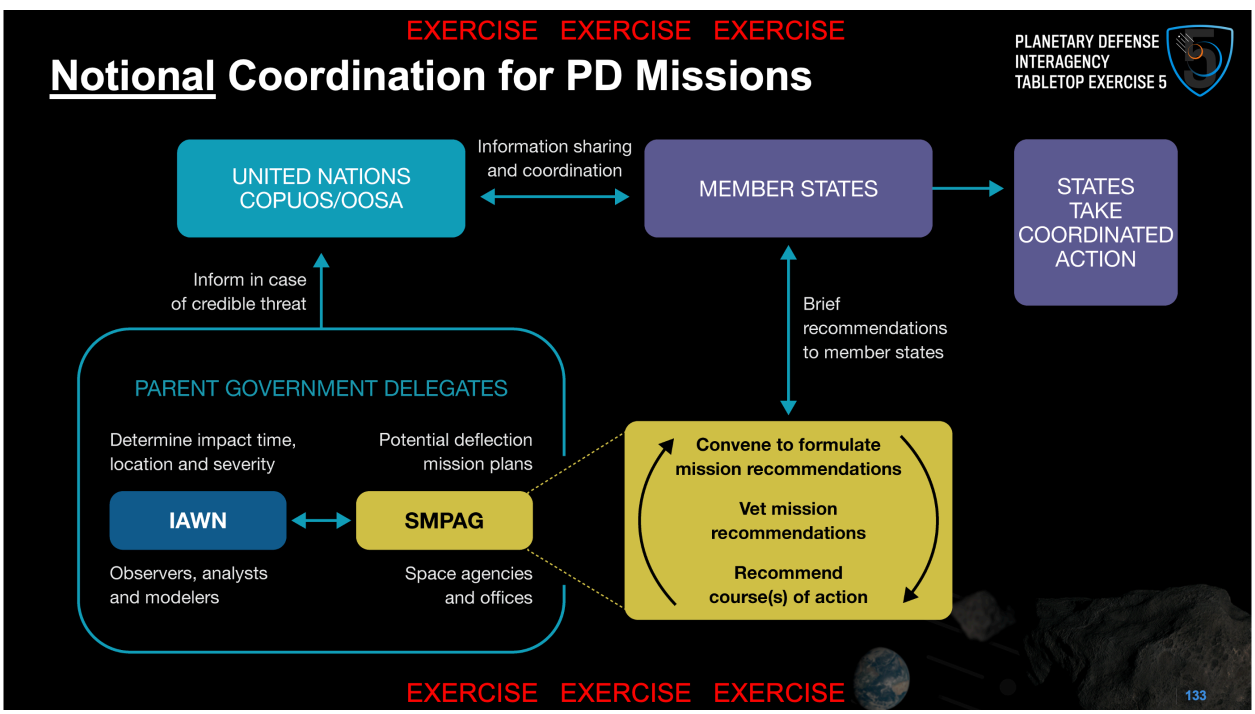

Figure 3-7. EXERCISE ONLY – Notional coordination for planetary defense missions.

During inject 3.3, the facilitators informed participants that senior leaders requested a briefing about recommended COAs for this scenario, primarily in terms of space missions but also in regard to disaster preparedness. This inject precipitated a robust discussion of the space mission options that were presented during Module 2. In-person participants received a mission options handout summarizing the reconnaissance missions and Earth-impact-prevention missions presented in Module 2. The handout (section D.1) included information on launch and arrival dates, relative cost, years to launch from the time of the exercise, and, for Earth-impact-prevention missions only, the number of launches that would be needed for successful asteroid deflection under different assumptions related to the asteroid's mass. The facilitators instructed participants to discuss the various mission options with individuals seated near them. After giving participants some time to discuss, the facilitators led a discussion to synthesize the small-group discussions.

For inject 3.4, the FEMA Liaison to the NASA PDCO led a briefing that included images of earthquakes, volcanic eruptions, floods, hurricanes, and wildfires to prompt discussion about potential COAs related to disaster preparedness for NEO impact threats, including international collaboration needs. This was the final inject on Day 1 followed by the module hotwash and distribution of the participant feedback form.

Immediately after the conclusion of Day 1, a small group met to codify the potential COAs that would be presented to senior leaders on Day 2. Recommendations were based on the discussions that had just taken place.

The recommended COAs were as follows:

1. Wait until additional telescopic observations of the asteroid become available in November 2024.
2. Immediately begin development of a U.S.-sponsored flyby mission. Work toward a November 2025 launch (accelerated development timeline) for a July 2027 asteroid encounter, with the option to fall back to a September 2027 launch (typical development timeline) with a July 2028 asteroid encounter. The rough order-of-magnitude (ROM) life-cycle cost (LCC) would likely be between ~$200 million and $400 million.

   2a. Encourage international partners to develop their own asteroid flyby mission(s), for redundancy and robust international response.
3. Start development today of a purpose-built rendezvous reconnaissance spacecraft to provide more detailed and precise information about the asteroid threat. The ROM LCC would likely be between $800 million and $1 billion.

   3a. Decide at a later time to develop the rendezvous mission as a hybrid (reconnaissance + Earth impact prevention) mission for an additional $200–300 million.

Module 3b began on the morning of Day 2 with additional senior leaders participating. The senior leaders were briefed with three injects:

- Inject 3.5 – IAWN notified senior leaders about the potential asteroid impact (a condensed version of inject 1.1 without additional detail from SMEs).

- Inject 3.6 – The chair of SMPAG briefly described the role of SMPAG.
- Inject 3.7 – A NASA GSFC SME presented background on space mission options (a condensed version of injects 2.2 and 2.3) as well as the three recommended COAs above.

After this briefing, senior leaders discussed the recommended space mission options. After a lively discussion about the recommended COAs, which was truncated for the sake of time, the exercise proceeded to the final inject of Module 3. In inject 3.8, the FEMA Liaison to the NASA PDCO provided information about disaster preparedness needs for asteroid impacts. Because of time constraints, there was no hotwash at the conclusion of Module 3. However, participants were still given time to fill out the Module 3b participant feedback forms.

3.4. Module 4: Public Information Messaging

Module 4 emphasized the TTX objective to "identify current mechanisms for, and barriers to, international asteroid threat-related information sharing and communications, including public messaging strategies." Discussions in Module 4 focused on public messaging approaches, information sharing and international cooperation, messaging consistency over a long time period of time, handling of misinformation and disinformation, and lessons learned from other public information experiences.

Inject 4.1 was an emulated news piece used to prompt discussions about crisis communication, international coordination, and trusted sources. The facilitators revealed that news outlets around the world are clamoring for information and that the public wants to know what to do. Participants then engaged in a period of facilitated discussion. In inject 4.2, the facilitators informed participants that international news sources are releasing messages that vary in meaningful ways (Figure 3-8). This inject emphasized the need for international coordination of public messaging.

Inject 4.2 was immediately followed by a briefing from UNOOSA about United Nations (UN) mechanisms for crisis communications and public messaging. The presenter shared that UNOOSA is the substantive office for space affairs at the UN and provides the UN secretary general with inputs on all space-related topics upon request. The UN has a communications group with standard operating procedures for crisis communications. In addition, the UN has a Department of Global Communications with centers in 60 countries that engage audiences in more than 80 languages. The option also exists within the UN to convene an emergency platform in response to a complex global shock, such as a major outer space event. Such an emergency platform would include strategic communications efforts. The presenter also discussed the *Joint Radiation Emergency Management Plan of the International Organizations* (JPLAN)[17] as an example that might have lessons that could be applied to a strategy for an asteroid impact emergency. A period of facilitated discussion followed the briefing from UNOOSA.

Finally, inject 4.3 imitated an influx of social media posts to prompt discussions about crisis communication, international coordination, and trusted sources. The facilitators noted that many of the posts about the potential asteroid impact were inaccurate (Figure 3-8). A third period of facilitated discussion ensued, followed by a hotwash and participant feedback forms, concluding Module 4.

[17] International Atomic Energy Agency, *Joint Radiation Emergency Management Plan of the International Organizations*, March 1, 2017, https://www-pub.iaea.org/MTCD/Publications/PDF/EPR-JPLAN-2017_web.pdf.

Figure 3-8. EXERCISE ONLY – Simulated social media posts.

3.5. Module 5: Disaster Preparedness

Module 5 emphasized the top-level TTX objective to "assess the challenges of, and readiness for, international emergency preparedness and response to an asteroid impact that would be large enough to devastate entire regions." Discussions in Module 5 focused on policy-related issues for disaster preparedness, preparedness and preparation for response, and lessons learned from other disasters.

In inject 5.1, the facilitators again reminded participants of the key details of the scenario. A NASA ATAP SME reminded participants of the range of potential outcomes if impact should occur, including the uncertainty in the resulting ground damage given the asteroid's highly uncertain properties (Figure 3-9) and the impact risk dashboard (Figure 3-3).

Figure 3-9 displays the extent of damage that would occur around Washington, DC, if the asteroid were to make Earth impact in that location. For different realizations of the asteroid, the median damage case is shown on the left and the 95th-percentile damage case is shown on the right. The colors of the circles correspond to the damage levels described in the table at the far right of the figure. A period of facilitated discussion followed the NASA ATAP briefing.

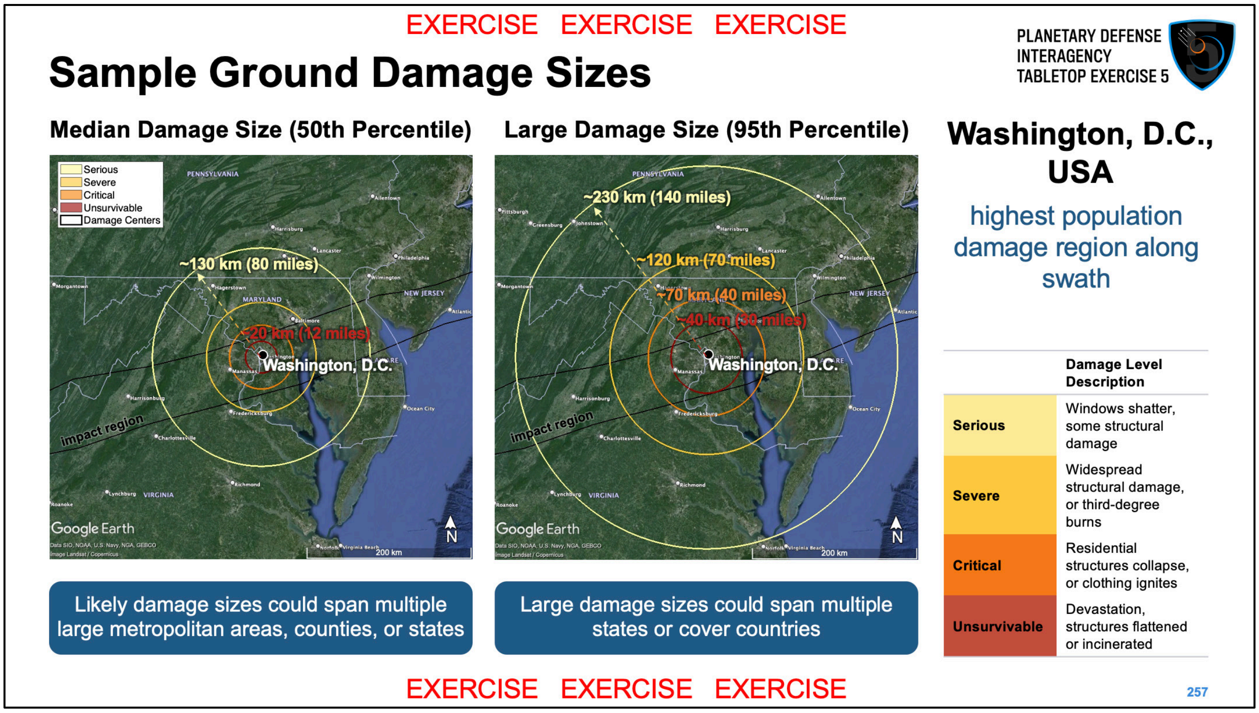

Figure 3-9. EXERCISE ONLY – Sample ground damage around Washington, DC.

Next, the FEMA Liaison to the NASA PDCO briefed participants on disaster preparedness needs for asteroid impacts. This presenter identified several possible international organizations that could potentially be relevant to asteroid impact response coordination and planning, including the International Charter Space and Major Disasters, the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), the United Nations Office for Disaster Risk Reduction (UNDRR), the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), and the UN-led "Early Warnings for All" initiative.[18] None of these groups are specifically focused on asteroid impact disasters at this time, but they could potentially be leveraged for collaboration on preparedness for NEO impact disasters. Additional facilitated discussion then took place. Finally, in inject 5.2, the facilitators reminded participants of key details of the scenario one last time. Additional facilitated discussion took place, followed by the Module 5 hotwash and participant feedback form.

[18] "Early Warnings for All," United Nations, accessed July 28, 2024, https://www.un.org/en/climatechange/early-warnings-for-all.

Chapter 4. Takeaways, Gaps, and Recommendations

This chapter summarizes the takeaways and gaps that resulted from the exercise. These items were identified over the course of analyzing the data collected, which came from the observations made by data collectors in the room, the written comments made by participants on exercise material, and the information reported in participant feedback forms (Figure 4-1). The exercise evaluation team distilled these data and traced discussions back to the exercise objectives (see Appendix A).

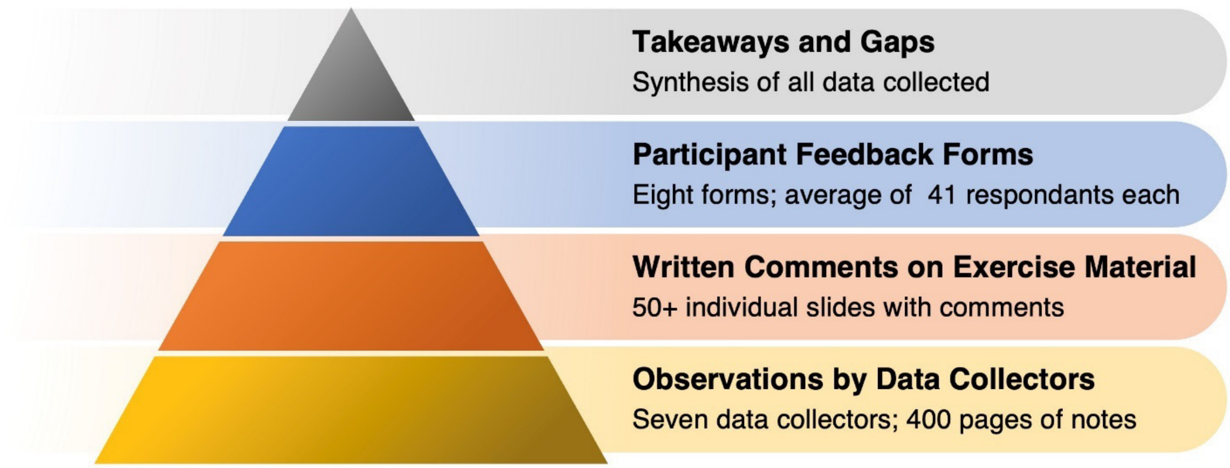

Figure 4-1. Data analysis approach.

The evaluation team then condensed the themes and needs identified in Appendix A into the key takeaways and gaps reported in this chapter, as well as recommendations about how to remedy the identified gaps. In addition, Appendix F summarizes lessons learned for briefing decision-makers on an asteroid threat scenario and response options. See Appendix G for the quantitative results from participant feedback forms.

4.1. Key Takeaways

The key takeaways identified from PD TTX5 discussions are identified below.

- **The large and varied uncertainties about the potential impact and its consequences posed challenges as participants discussed the scenario and possible responses.**

  Participants wrestled with the large uncertainties in potential Earth-impact consequences and what it would take to deflect the asteroid. Would the impact affect zero people? Or one million people? Affecting large numbers of people or no people were both relatively likely. Would it take one kinetic impactor to deflect the asteroid? Or 12 of them? Some participants noted in feedback forms that without more certainty, they found it difficult to know whether to pursue *any* concrete COA. Participants needed clarification from SMEs about the uncertainties in the scenario and their implications, as well as information about when more data about the aster-oid were going to be acquired and what those data could provide.

- **The 14-year timeline prompted discussion about preparedness over a longer time frame than many other hazards and raised varied concerns for different stakeholders.**

  Fourteen years could be unusually long or rather short, depending on the perspective and concerns of different agencies. For example, participants from the United States Agency for International Development (USAID) and FEMA noted that they often work to much shorter time frames and would continue to deal with everyday disasters across the 14 years. However, participants from space agencies felt that 14 years does not leave much leeway for a space mission campaign. Many participants noted that the long lead time would cross multiple political cycles.

  At the onset of the exercise, many participants remarked that 14 years was a significant amount of time to address this potential disaster because many challenging situations come with much less warning. As the scenario progressed, however, participants started to express that 14 years was not that long to accomplish everything needed for a planetary defense emergency.

- **Better information about the asteroid would reduce uncertainties regarding the potential consequences of an impact, thereby enabling better decision-making about how to respond.**

  Participants recognized that in order to make effective decisions about how to act, they needed to reduce the uncertainties in whether the asteroid would hit Earth, what the consequences of the impact would be, and what it would take to prevent the asteroid from hitting Earth. Narrowing down the impact location was a priority for participants. Observations from telescopes would refine the impact location, but substantial uncertainties in the asteroid's properties—and hence asteroid deflection requirements and the Earth-impact consequences—would remain without a spacecraft reconnaissance mission. No participants expressed opposition to reconnaissance missions, but some did question funding availability and readiness for a rapid-response characterization mission.

- **Many stakeholders expressed that they would want as much information about the asteroid as soon as possible but expressed skepticism that funding would be forthcoming to obtain such information without more definitive knowledge of the risk.**

  While participants broadly endorsed reconnaissance missions to gather information about the asteroid as quickly as possible, senior leaders in the U.S. predicted that Congress would be unlikely to fund such a mission until the probability of the asteroid impacting Earth was 100%. In the meantime, senior NASA leaders indicated they would recommend that NASA conduct an assessment of all space assets already in space or in development that could be re-vectored. They would also recommend that NASA immediately begin studies for flyby and rendezvous missions that strongly leverage existing missions in order to be ready to begin work should funding become available. An OSTP participant noted that because funding cycles and constraints would be factors, the identification of on/off ramps for mission options would be important.

- **Development of best practices, common approaches, and procedures at the bilateral and multilateral (including UN) levels could facilitate international cooperation and, as appropriate, coordination of space missions, disaster management, and communication.**

  Participants expressed the view that international cooperation would be not only positive but also necessary. International collaboration, whether between two countries or many, could facilitate rapid space mission planning, would help control the spread of misinformation and disinformation, and would generally build trust globally. Existing mechanisms such as UN COPUOS, IAWN, and SMPAG were identified as avenues for international cooperation and coordination. The IAWN collaboration is an effective means of enabling international collaboration for planetary defense observations and risk assessment, as well as issuing notifications for potential NEO impacts, when appropriate. Similarly, SMPAG is a vehicle for international cooperation and coordination on space mission options. However, a process for developing recommended options has yet to be fully fleshed out. Participants noted that the United States engages in bilateral and multilateral space cooperation with several international partners. Participants also recognized that some spacefaring nations currently have tenuous or strained international relationships. It was suggested that countries work to open lines of communication in advance of an emergency and that planetary defense could be a unifying cause.

- **The timelines of space mission planning, disaster management, information sharing, and communications are intertwined in ways that were not fully appreciated at first.**

  Participants frequently returned to the importance of timelines. At the start, the timelines for space mission options were considered in somewhat of a vacuum. However, during Module 2 a FEMA participant succinctly identified the intertwining of the timelines for space missions and disaster preparedness: the information gathered by these missions affects deliberative planning for consequence management planning and preparedness, which means the timing of these missions defines time markers for ground preparedness efforts. Similarly, public messaging needs to be responsive to when new information will be available, which is affected by the timing of space missions. On the other hand, public sentiment can sway the decisions being made about space missions, so concerted public messaging may need to take place ahead of space missions, too.

- **Misinformation and disinformation would have to be dealt with.**

  Given the long lead time, the potential for global effects, and the “sci-fi” aspect of an asteroid threat, misinformation and disinformation will occur and will need to be addressed and mitigated. A NASA participant noted the value of “pre-bunking” expected misconceptions ahead of time, rather than trying to correct them afterward. Robust communication plans paired with scheduled and recurrent information dissemination will be critical to addressing misinformation and disinformation. International collaboration will also be essential so it does not appear that one nation or entity is controlling the narrative. Engaging with community leaders and other trusted partners who deliver information will be crucial in establishing trust between the scientific community and the public. Ensuring that materials are available in a wide range of languages and formats to broaden distribution will further enable outreach to minimize misinformation and disinformation.

- **Although specific disaster management plans for a NEO impact threat do not currently exist, plans for response to other catastrophes may be a suitable starting point.**

  Participants noted that an asteroid impact emergency is not significantly different from many other natural disasters. Developing a plan within the standard National Response Framework (NRF) and National Incident Management System (NIMS) framework for an asteroid impact event would be useful. A reasonable starting point would be building off an existing plan for a comparable-scale natural catastrophe. This planning effort should go beyond the U.S. and include international (including UN-led emergency preparedness and response) groups as well, to broaden the applicability of the plans. Continuing to exercise responses to planetary-defense-relevant emergencies further helps identify shortfalls or discrepancies for emergency response groups. It is also important to understand how disaster preparedness coordination would be carried out internationally and how existing UN entities could facilitate this process.

4.2. Identified Gaps and Recommendations

This section summarizes the gaps identified as a result of the exercise and recommendations to address them. Many of these gaps and recommendations echo points that have been made in other documents, such as the U.S. national and NASA strategy and action plans, the after-action report from PD TTX4,[7] and the National Academies report *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023–2032*.[19]

- **The role of the UN-endorsed Space Mission Planning Advisory Group (SMPAG) in an asteroid impact threat scenario is not fully understood by all participants.**

  > **Recommendation:** Raise awareness among U.S. and international organizations about SMPAG's role as a coordination and advisory group for in-space mission responses. Emphasize that UN member states determine whether or not to pursue space mission(s) recommended by SMPAG.

  During the exercise, some participants thought the role of SMPAG was to decide which mission should be pursued. But SMPAG's actual role is to advise on the potential viable mission options. This distinction, once explained, was understood by participants, but the misconception demonstrated the need to strengthen understanding of SMPAG's roles and responsibilities.

- **The process for making decisions about space missions in an asteroid impact threat scenario remains unclear. The process has not been adequately discussed in the U.S. or internationally.**

  > **Recommendation:** Clarify a process for how decisions to select space mission options in various planetary defense scenarios could be made. Exercise the process and continue to update based on future exercise outcomes.

[19] National Academy of Sciences, *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023–2032*, 2023, https://nap.nationalacademies.org/read/26522/chapter/1.

The guidance in the U.S. NITEP report and the SMPAG report on benchmarks for space missions primarily specifies a "when": when certain thresholds are met, then mission options planning should begin for SMPAG or, in the case of the U.S. protocols, the U.S. should consider executing a reconnaissance and/or an Earth-impact-prevention mission, depending on the thresholds crossed. Neither document, however, adequately describes a framework for deciding what specific missions to do. Participants noted that the topic will be contentious and complicated, political implications aside, because of challenges with budgets and timing.

While discussing the various COAs for asteroid reconnaissance and mitigation, both participants and senior leaders noted there was no easy decision tree to follow, especially given the high uncertainties in the scenario. Participants from FEMA strongly recommended that making a plan for how to proceed and exercising against it would help make progress.

One of the actions associated with Goal 5 of the U.S. national and NASA planetary defense strategy and action plans is to "establish protocols for recommending space-based reconnaissance and mitigation missions." Making progress on that action of Goal 5 would benefit the first part of the above recommendation. Goal 4.7 in both the national and NASA plans pertains to encouraging international participation in planetary defense exercises, which would address the second part of the above recommendation.

- **The risk tolerance and decision criteria for undertaking a space-based response in a planetary defense scenario are not sufficiently codified.**

    Recommendation: Establish a decision criteria framework for a space-based response by considering the benefits versus costs and associated risks to guide choices about response options and funding needs.

A NASA participant explained that, to date, planetary defense has typically looked at what options exist to respond to a given asteroid scenario and then determined the residual risk. A participant from USSPACECOM suggested an alternative approach: set criteria for how much risk we are willing to tolerate and for the desired end state for planetary defense. Then, use that risk tolerance and end state to drive the decisions that get made about missions. A NASA participant noted that the approach had not been used before for planetary defense but could be considered.

Routinely incorporating costs of space mission(s) versus cost of consequence management into briefings about mission options and risk assessments would add useful context to the discussions. FEMA and other disaster response organizations' capabilities to conduct cost estimates for consequence management actions could be leveraged. Having a general consensus among those organizations will provide a more accurate figure for deliberation by international leadership.

- **Information about the timeline of go/no-go decision points for space missions is not adequately infused into discussions about courses of action in response to an asteroid impact threat.**

Recommendation: Identify relevant decision points for pursuit of planetary defense mission options and the timing of decisions needed to preserve future response options, and compile approximate costs associated with those decision points. Codify criteria for determining when a mission option is no longer considered viable.

Throughout the exercise, participants homed in on timelines, and timelines were frequently called out in feedback forms as effective. However, participants distinguished a need for the timelines to convey when *decisions* about specific mission options would need to be made in order for the mission to be viable. Information about when decisions would need to be made to preserve future options is critical in a scenario where senior leaders anticipated that they may be directed to wait for more certainty.

Costs loomed large as a factor in the discussions. None of the participants predicted having "blank checks" at this point in the scenario, and most senior leaders expected funding to be a challenge. Senior leaders were interested not only in the total costs of mission options but also in the phasing of those costs. Clarifying what resources would need to be committed now versus the ROM LCC will better communicate the initial funding ask and show where offramps exist to pause or end development, if appropriate, based on updated information.

The relevant go/no-go points can probably be tied to the key decision points that are part of NASA missions. Notional mission development timelines are known from past missions, as is the distribution of mission costs across Phases A–F. Recent NASA missions to small bodies, such as DART (similar to a NEO flyby) and OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer [NEO rendezvous]), would be useful points of reference. This information could be compiled in a digestible way for ease of sharing and used to show, for example, the level of investment required to a keep a mission option on the table in order to preserve option space in the future.

Making progress on this recommendation would benefit Goal 5.4 in the U.S. national and NASA plans ("improve procedures and timeline for conducting a risk/benefit analysis for space-based mitigation mission options following a NEO threat assessment").[1,2]

- **The ability to use a spacecraft to quickly gather information about the asteroid, via flyby or rendezvous, is limited because of spacecraft and launch availability.**

Recommendation: Develop the capability to rapidly implement a NEO reconnaissance mission. Determine information required and processes for repurposing existing spacecraft and/or instruments to rapidly gather information about an asteroid threat, and mechanisms for timely launch options.

During discussions of the reconnaissance missions, participants identified that the abilities to rapidly build and launch spacecraft are lacking. That limitation is a problem because substantial uncertainty in the consequences of Earth impact will remain until the spacecraft arrives at the asteroid and returns data. The sooner reconnaissance data are available, the sooner the uncertainties faced by disaster managers and Earth-impact-prevention mission designers will decrease, and the more effectively decision-makers can act. The TTX4 after-action report also noted that the U.S. has a limited ability to rapidly launch a reconnaissance mission.

Senior leaders were quite interested in whether existing spacecraft could be repurposed for asteroid reconnaissance. Developing a robust process for identifying spacecraft that could be repurposed for asteroid reconnaissance, to include mission design/navigation, spacecraft capabilities, and payload perspectives, would be a step forward. There is no guarantee that a suitable existing spacecraft would be able to be repurposed for any given asteroid, which underscores the need to develop a robust rapid-response characterization capability.

When asked to rate the overall readiness for planning and implementation of space missions, 19% of participants who responded said they either somewhat or strongly disagreed that readiness was adequate (Figure 4-2). This concern underscores the urgent need to develop a robust rapid-response reconnaissance capability.

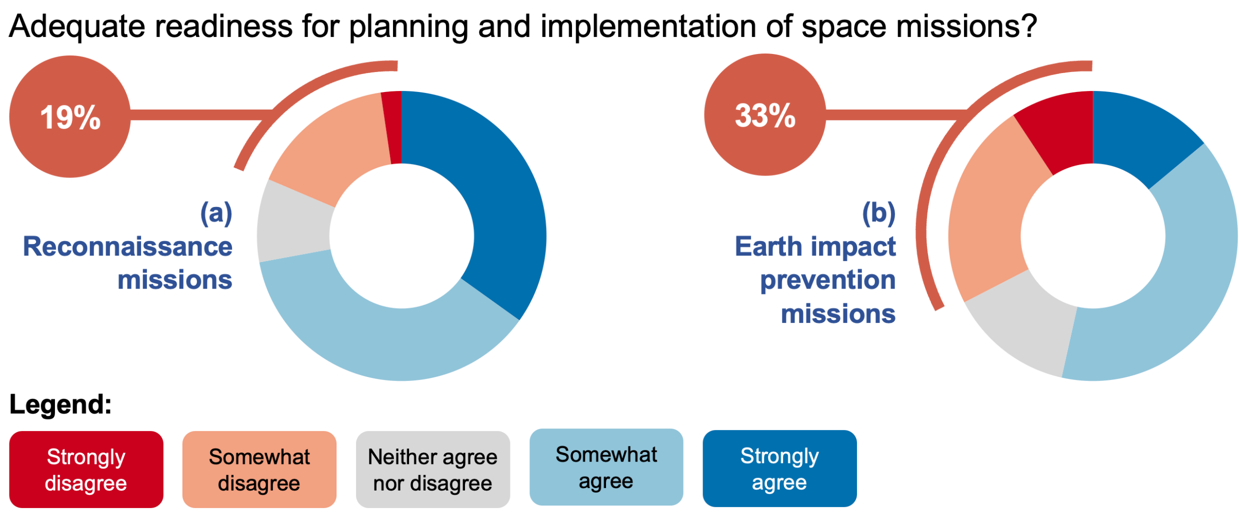

Figure 4-2. Participant assessment of readiness.

The above recommendation echoes the first action associated with Goal 3 of the U.S. national and NASA planetary defense strategy and action plans, which is to "develop technologies and designs for rapid-response NEO reconnaissance missions." Development of a rapid-response, flyby reconnaissance mission targeted to a challenging NEO (~50–100 meters [~160–330 feet] in diameter) as recommended by the recent decadal survey as the highest-priority planetary defense demonstration mission after NEO Surveyor would align with this recommendation.

- **Only one technology for Earth impact prevention—kinetic impact—has been demonstrated in flight, and it has only been demonstrated once.**

  Recommendation: Conduct additional Earth-impact-prevention flight demonstration(s) to increase their maturity and reliability (e.g., multiple kinetic impactors as well as gravity tractor, ion beam, or other "slow push" techniques). Continue to study efficacy of versus concerns regarding NEDs.

Participants avidly engaged in discussions about Earth-impact-prevention missions. The reliability of Earth-impact-prevention missions loomed large in the discussions. NASA participants noted that because only a kinetic impactor has been demonstrated in flight, the reliability of other mitigation technologies such as ion beam deflection is lower than that of kinetic impact, even though the physics is sound. The participant from ESA stated that ESA aims to do an ion beam deflection demonstration within the next 10 years. The level of risk people were willing to tolerate when relying on an Earth-impact-prevention mission was not definitively established.

Missions that would use NEDs to deflect the asteroid were discussed. The briefer in Module 3 noted that only one NED would be needed to deflect the asteroid, even if the asteroid were in the 90th percentile for mass. Participants from DoS noted that the U.S. has international obligations concerning the placement and use of NEDs in space and that there are many concerns with the use of NEDs. One participant asked, "How would the U.S. feel if an antagonistic nation were in the risk swath and decided unilaterally to pursue a NED mission?" They also emphasized that the use of NEDs comes with legal, policy, political, proliferation, and other considerations; that the United States takes its treaty obligations seriously; and that the use of NEDs should be considered only as a last resort to save humanity. Senior leaders noted that the final decision about whether to use NEDs would be made at the highest levels and in consultation with the international community.

The above recommendation echoes the second action associated with Goal 3 of the U.S. national and NASA planetary defense strategy and action plans, which is to develop technologies and designs for NEO deflection and disruption missions and specifically Goal 3.5, "continue flight demonstrations to validate NEO deflection and disruption system concepts."[1,2] The recent decadal survey also supported additional Earth-impact-prevention flight demonstrations.

- **The role of the commercial space industry in planetary defense missions has not been fully explored.**

  Recommendation: Identify appropriate and effective ways of engaging with commercial industry in a planetary defense scenario.

Participants identified that the burgeoning capabilities of commercial space companies may make them a useful part of a space-based response to an asteroid impact threat. Participants also noted that NASA has recently been expanding its use of commercial services through, for example, the Commercial Lunar Payload Services (CLPS) initiative and that novel approaches to rapid contracting mechanisms may enable an expeditious response to an asteroid impact threat.

- **Several legal and policy issues associated with planetary defense remain.**

  Recommendation: Conduct a workshop or exercise specifically focused on further identifying and discussing legal and policy issues related to planetary defense, using the basis of the work done by the SMPAG Ad-Hoc Working Group on Legal Issues.

Participants identified several legal and policy issues, including the potential implications of shifting the risk swath from one country to another as a result of multiple kinetic impactors or slow-push asteroid deflection (e.g., ion beam deflection). Participants also raised questions about international responsibility and liability as well as whether considerations exist that would encourage a capable country to not take action and, if so, what options exist that might address such considerations. Finally, issues associated with the potential use of NEDs for planetary defense were raised, including considerations about U.S. international obligations and proliferation, among others. This gap is similar to one identified in the PD TTX4 after-action report, which noted that, "Understanding of the international legal and policy implications of using nuclear explosive devices (NEDs) for planetary defense in deep space or near-Earth space remains limited."[7] The SMPAG Ad-Hoc Working Group on Legal Issues addressed some of these issues in its report, *Planetary Defence Legal Overview and Assessment: Report by the SMPAG Ad-Hoc Working Group on Legal Issues to SMPAG*[14]; however, more work is needed.

- **Approaches to timely international consultation/coordination regarding public messaging about asteroid impact threats have yet to be fully developed and exercised.**

  Recommendation: Expand existing efforts that take advantage of asteroid close approaches, planetary defense exercises, and other opportunities to consult regarding or coordinate national and international public information messaging strategies.

Appropriate messaging around the potential impact of an asteroid is crucial for trust among the general public. Participants noted that in order to ensure worldwide public trust, coordinated international messaging would be crucial. As a clear indication of the need for coordinated and timely communications, after TTX5 was held, misleading headlines and incorrect statements about the lack of preparedness demonstrated at the exercise itself appeared in the news.[20]

Acting on the above recommendation would advance Goal 8.1 of NASA's planetary defense strategy and action plan,[2] which is to "prepare a strategic communications plan related to planetary defense," as well as Goal 5.3 of the national plan, which is to "develop and share informational material for different audiences providing basic education, information on uncertainties, and emergency response plans."

- **The rare nature of an asteroid impact threat and the need to develop new public messaging content may delay the timely release of accurate information to the public.**

  Recommendation: Develop templates for preapproved holding statements for several different planetary defense scenarios (e.g., long warning, short warning, impact without warning).

Participants noted that delays in public messaging could lead to significant distrust. It was recommended that lessons learned from the messaging related to the COVID-19 pandemic be taken into account to develop strategies for planetary defense messaging. Finally, there

[20] Harry Baker, "No, NASA hasn't warned of an impending asteroid strike in 2038. Here's what really happened." *Live Science*, June 26, 2024, https://www.livescience.com/space/asteroids/no-nasa-hasnt-warned-of-an-impending-asteroid-strike-in-2038-heres-what-really-happened.

was discussion about the risk of public content being ignored or misunderstood given the inability to visualize unfamiliar concepts such as a long-warning NEO. Taking opportunities to familiarize the public with long-warning threats could help minimize those effects. For such an unprecedented threat, public statements by trusted voices are needed and should include community-based spokespeople.

Acting on the above recommendation would advance Goal 8.1 of NASA's planetary defense strategy and action plan,[2] which is to "prepare a strategic communications plan related to planetary defense," as well as Goal 5.3 of the national plan, which is to "develop and share informational material for different audiences providing basic education, information on uncertainties, and emergency response plans."[1]

- **Sustaining the space mission, disaster preparedness, and communications efforts across a 14-year timeline would be challenging because of budget cycles, warning fatigue, changes in political leadership, changes to personnel, and ever-changing world events.**

  Recommendation: Continue use of periodic briefings and exercises to continue to raise and sustain awareness of planetary defense. The natural cycle of changes in exercise participants emulates real-world changes in leadership and personnel that would likely occur during a long-warning scenario.

Decision-makers in the U.S. are often bound by political cycles, with staff coming and going based on elections. Participants noted that this turnover highlights the need for a consistent point of contact to deliver messages and updates over time. An asteroid on an impact trajectory with Earth is also competing with daily, emerging events (e.g., PD TTX4 occurred during the early days of the Russian invasion of Ukraine). Working to ensure continuity will be of the upmost importance in a long-warning scenario.

Ongoing efforts to implement Goals 5.2, 5.3, 6.1, and 6.2 in the U.S. national and NASA planetary defense strategy and action plans, as well as Goals 8.1 and 8.2 in the NASA plan, will also help address this gap.

- **There is no analogue to the International Asteroid Warning Network (IAWN) or SMPAG for international disaster preparedness for a NEO impact.**

  Recommendation: Identify an appropriate forum for discussing legal, policy, and operational aspects of international NEO impact disaster preparedness and planning, potentially through existing organizations at the UN or elsewhere.

While not all participants were initially clear on the role of SMPAG, all expressed the view that the work performed by SMPAG and IAWN is vital. Many felt that having a similar mechanism that brought together disaster preparedness experts and agencies from around the world for purposes of NEO impact disaster planning and preparedness could be valuable.

- **The interconnectedness of timelines for space mission planning, disaster preparedness, and communications is not fully understood; an increased understanding of these needs would enhance planning and preparedness.**

  Recommendation: Engage in cross-agency dialogue to identify interagency dependencies and the means to share needed information with the relevant agencies at the right times.

Disasters not caused by asteroid impact happen routinely and use space-based assets on a daily basis. A unique space-based mission is not required for hurricane season, for example. Emergency managers are preparing for and responding to emergencies every day. While preparedness plans are somewhat agnostic of the threat type, building long-term resilience to maximize effectiveness in the event of a NEO threat necessitates better understanding of potential impact locations, but that information does not exist without complex space mission planning. Timelines for planning a successful response to a planetary defense emergency across a range of agencies and, potentially, countries will require a robust logistical planning aspect. As such, identifying how different groups work together both domestically and internationally will allow for a smooth, coordinated response that removes duplication of efforts and enables synergism.

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Chapter 5. Conclusions

The U.S. Planetary Defense Interagency Tabletop Exercise 5 (PD TTX5) brought together participants from a wide range of U.S. departments and agencies and—for the first time—international partners to better understand the challenges posed by asteroid threats and improve international efforts to prepare for the potential low-probability, high-consequence natural disaster (Figure 5-1). Addressing the gaps will involve work on a number of fronts, including space mission technology development and demonstrations, space- and disaster-related policies, international coordination and collaboration on an array of fronts, development of messaging strategies, and further discussions of emergency preparedness efforts. Progress will be made most efficiently through appropriate collaboration among agencies and international partners.

Figure 5-1. In-person participants in the Planetary Defense Interagency Tabletop Exercise.

The takeaways and gaps identified as a result of PD TTX5 highlight the importance of continuing to conduct regular planetary defense tabletop exercises, as recommended by Goal 5 of the U.S. *National Preparedness Strategy & Action Plan for Near-Earth Object Hazards and Planetary Defense* (2023).[1] Future exercises will benefit from feedback received on the implementation of this exercise, including a need to better incorporate online participants and to allow additional time for free-flowing discussions as opposed to pre-scripted questions.

The exercise increased overall awareness of the nature of asteroid threats and the challenges related to preparing an effective international response; the large majority of participants reported that they left the exercise with a better understanding of how to deal with an asteroid impact threat. Responses to a selection of the prompts posed on participant feedback forms illustrate this point; see Figure 5-2.

As mentioned previously, participants were able to provide candid responses to the exercise team via the participant feedback forms. Figure 5-3 provides direct quotes from participant feedback forms that further highlight the importance of planetary defense tabletop exercises.

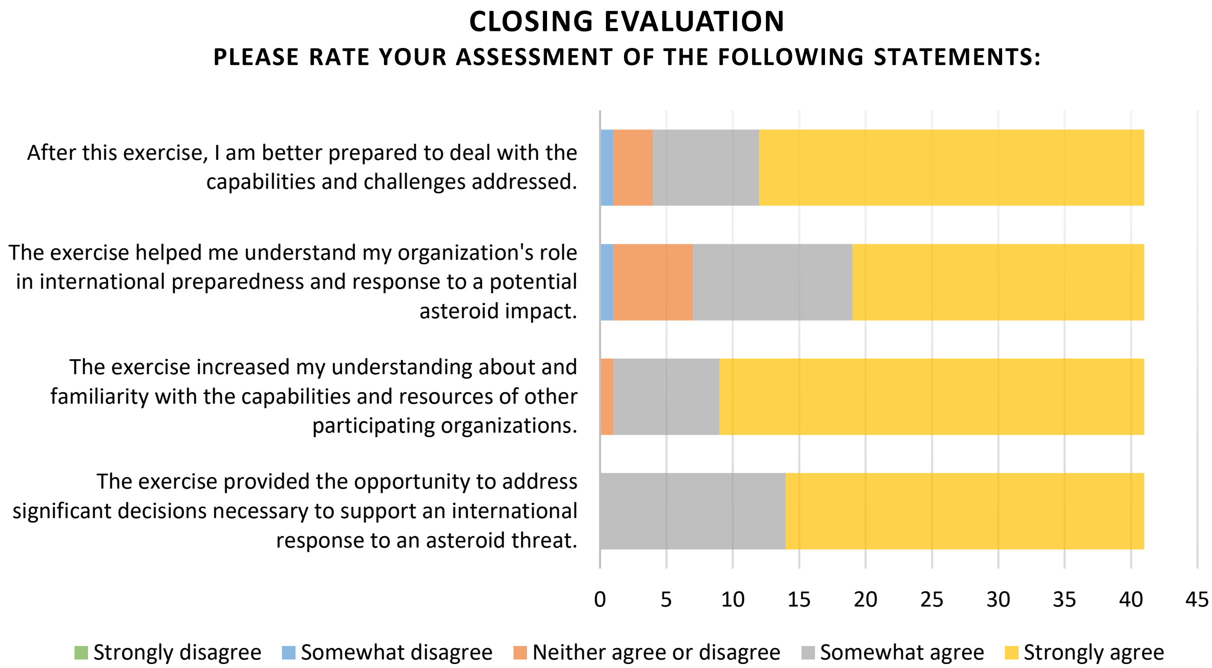

Figure 5-2. Selected results from the final participant feedback form.

"International involvement early will be critical. That credibility is essential and must be established now."

"This is a complex decision to be made, and I'm not sure we fully understand how that will happen. I think it will be an informed trial-and-error process, and exercising it more than a couple of times will be useful to at least document what doesn't work."

"I know what I would prefer [to do], but Congress will tell us to wait."

"The most important item of the morning was the discussion involving the political nature of the decision-making."

"Maintaining trust at the start of this event is critical, and that means talking early—probably earlier than the scientists and lawyers are comfortable with."

"Overall a great discussion about the challenges. I think people will go back to their organizations [with] a lot of questions to improve the next TTX."

Figure 5-3. Selected feedback from TTX5 participants.

Regular exercises keep planetary defense on the radar for various agencies and strengthen relationships both within the U.S. and internationally by bringing people together for a period of intense focus on potential responses to an asteroid impact threat. To paraphrase a participant, sometimes the greatest benefit lies in coming together. As the lessons learned from one exercise feed into the planning of the next, sustained progress will be made toward achieving an operational planetary defense capability.

Appendix A. Objectives and Discussion Tracing

A.1. Module 1

Inject 1.1 – Potential Asteroid Impact Notification: Hypothetical Scenario	Sub-Objectives Addressed
Discussion focus: • Adequacy and clarity of information provided	1.3, 3.2, 4.1, 4.3, 4.4

- SMPAG reported that the notification from IAWN provided sufficient information needed for SMPAG to start working on space mission options.
- Multiple participants noted that timelines of what information will be available when are critical to decision-making. In the participant feedback forms, several participants noted that the slide showing the expected improvement in impact location knowledge from telescopes was particularly effective at conveying useful information.
- There was a desire on the part of participants to know more clearly what information will be known and when in order to help with decision-making. A NASA participant recommended that in the future, the information provided by IAWN and SMEs should not only indicate when more data will become available and when predictions about the potential impact might change but also explain how the range of the uncertainties will change.
  - **Need noted:** Revise IAWN notification and SME briefs to include information about when updated information will be available and how that information is expected to change key uncertainties.
- Several participants noted that although the information provided in the IAWN notification and SME briefings from CNEOS and ATAP was useful, they felt that the level of information was not well suited for sharing with senior leadership (a topic discussed at greater length shortly after inject 1.2).
  - **Need noted:** Clarify with senior leadership what information they would want to know at this early stage of an asteroid impact threat.

Inject 1.2 – U.S. Impact Notification Process	Sub-Objectives Addressed
Discussion focus: • Notification processes in other countries • Notification systems • Policies to influence or guide decisions	1.2, 1.3, 2.2, 3.1, 3.2, 3.4, 4.1, 4.2, 4.3, 4.4
Discussion focus: • Communication and coordination among U.S. federal agencies • Mechanisms for international collaboration and coordination • Information sharing and coordination internationally • Laws, treaties, or other agreements for responding to a multinational emergency	1.2., 1.3, 2.1, 3.1, 3.2, 3.4, 4.1, 4.2

- Comments from international participants revealed that most of the participating countries do not have a notification process specifically for NEO impact threats. Existing procedures for other disasters or events (e.g., uncontrolled reentries) would likely be adapted for this scenario. A UN representative explained that COPUOS would inform member states and provide them with the best-available information at the time.

- Participants indicated that existing notification systems would likely be used. Using existing capabilities would lend familiarity to an unfamiliar threat. USAID noted that they have experience pushing notifications to people in less-developed nations that lack national notification systems, which may be relevant for some parts of the risk swath.
- A U.S. participant noted that the U.S. *National Preparedness Strategy & Action Plan for Near-Earth Object Hazards and Planetary Defense* (2023)[1] would be in play, as would a recent U.S. interagency "domestic response playbook" for major events. FEMA stated that they would apply appropriate parts of existing policies.
- Participants expressed that strong connectivity needs to exist between disaster response, planetary defense, and diplomatic communities to clarify priorities and communicate effectively. A participant from the National Space Council (NSpC) noted that this scenario could lead to evolving lines of integration for civil, commercial, and national security that may not be fully reflected in the U.S. National Space Policy.
  - **Need noted:** Practice communicating across planetary defense, emergency management, and diplomatic communities.
  - **Need noted:** Review the U.S. National Space Policy and assess whether it sufficiently covers planetary defense.
- Participants extensively discussed how to distill key points from SME briefings and augment them with further information that would make the problem clear and actionable for their senior leadership. Several participants noted that senior leaders will likely not be experts on this topic, and it will take effort to get and maintain their attention because this threat will be competing with other, more immediate concerns.
- A DHS participant asserted that senior leaders need to know when we will know more about the asteroid and its potential impact, what the possible COAs are for preventing the asteroid's impact and/or reducing risk, how much time it will take to implement those COAs, the level of confidence in predictions of impact effects, and what cascading effects might occur. The participant recommended that the information include the pros and cons of response options, rather than specific recommendations to leadership.
- Several participants noted that the message for senior leaders needs to be succinct and present possible COAs so that leadership knows what decisions they need to make, when they need to make those decisions, and how much the response options will cost.
  - **Need noted:** Distill key information from IAWN notification and SME briefs into a format well suited for sharing with decision-makers.

  - **Need noted:** Update briefings to provide additional information that participants expected senior leaders to want, such as possible COAs, timelines for needed decision, and estimated costs.

- A NASA participant noted that the commercial space industry is innovative and may be able to react quickly and contribute meaningfully in this scenario. However, participants questioned whether existing notification processes and communication channels would be adequate for sparking engagement with commercial space companies. Questions arose about the potential role the U.S. Department of Commerce might play, but no determination was made about what that department's specific role would be in this scenario.

  - **Need noted:** Examine notification processes and communication channels to assess whether they are adequate for engaging with commercial providers for planetary defense needs.

- A USSPACECOM participant explained that, from the U.S.'s perspective, there are sensitivities around associating the U.S. military with the response; however, the participant noted that the military would want to be aware early in the process and would help with space situational awareness if possible. The representative from the Canadian Space Agency (CSA) expected that the Canadian military would be engaging heavily with the U.S. military. A participant from a defense-related agency pointed out that many countries do not have a clear line between civil and national security space.

- A representative from the UN explained that UN COPUOS, IAWN, and SMPAG would play important roles in this scenario. Specifically, the UNOOSA director could bring information to the UN secretary general (UNSG), who could then convene the Security Council or General Assembly. The UNSG could also share information at their daily noon briefing.

- A participant wondered whether the Artemis Accords could be an avenue for collaboration and coordination. A NASA participant noted that the signatories of the Artemis Accords are a group with whom the U.S. has regular contact. Planetary defense is not part of the Artemis Accords, but the signatories could perhaps be leveraged in an emergency.

- A participant from DoS noted that that identifying the appropriate international forum to coordinate a response could be difficult, and it would be useful to establish those procedures now before an actual crisis.

- In term of information sharing, a participant from the UN explained that the UN Department of Global Communications could help coordinate messaging. The Department has a presence in 60 countries and procedures in many languages. The UN has a standard operating procedure on how to communicate during disasters. In addition, IAWN, SMPAG, and UN COPUOS would be vehicles for information sharing and coordination of messaging. Finally, a USSPACECOM participant stated that while the U.S. Department of Defense (DoD) may have relevant information, work is needed to figure out how to share that information with outside agencies. The participant asserted that paranoia could emerge without transparency.

  - **Need noted:** Identify approaches for sharing of relevant information from USSPACECOM with NASA about asteroid impact threats.

- Participants from emergency management organizations noted that there are international response plans for a range of emergencies but no specific policy for asteroid impact disaster planning, preparedness, or response. Participants felt that it is unclear who would be in charge of that effort. One option would be to add planning for NEO impact disasters to the scope of an existing disaster-preparedness-focused entity. A FEMA/NASA participant predicted that a small working group could be assigned to this problem full time for the next 14 years to make sure this threat is adequately addressed even as other disasters unfold. The facilitators noted that a more detailed discussion of this topic would occur on Day 2.

Inject 1.3 – Scenario Summary	**Sub-Objectives Addressed**
Discussion focus: • Planning over a 14-year timeline • Coordination of public messaging domestically and internationally	1.1, 1.3, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2, 4.3

- Participating agencies expressed a range of feelings about the 14-year timeline. It could be very long or very short, depending on the perspective and concerns of different agencies. Participants from USAID and FEMA noted that they usually work to much shorter time frames. Participants from space agencies explained that for interplanetary space missions, 14 years does not leave much wiggle room. Many agencies felt that the 14-year timeline would provide many opportunities for collaboration. However, it also would mean multiple changes in U.S. administrations and that attention paid to the potential impact threat may wax and wane, potentially affecting funding. A DHS participant noted that technology will evolve over the course of the 14-year timeline and that this evolution needs to be considered. A FEMA participant stated that the long warning time would give the agency the ability to update guidance (e.g., for shelters) and potentially change the way they offer grants. The U.S. Geological Survey (USGS) mentioned they are in the process of incorporating planetary defense into one of their survey manuals.
    - **Need noted:** Identify ways to break the timeline of a long-warning NEO impact threat scenario into operational "chunks" for purposes of phased planning.
- Multiple participants identified a need to develop a deliberate communication strategy for this scenario, both toward the highest levels of leadership and toward the public. Participants were unclear about when the potential asteroid impact would go from a scientific curiosity to a political problem. A participant from NSpC proffered that once that transition happens, the first message released by the White House would set the tone for subsequent messaging. The participant emphasized that the first message cannot be retracted, so it is important to craft it carefully. Participants expected that the public would want to know why we don't know more about the asteroid now and why we cannot get better answers until specific, later times.
    - **Need noted:** Develop a holding-statement-style communications strategy for a long-warning NEO impact threat, including the key points that should be made in an initial statement to the public.
    - **Need noted:** Develop responses to frequently asked questions that might arise in a long-warning NEO impact threat scenario.

Inject 1.4 – What Is at Risk?	Sub-Objectives Addressed
Discussion focus: • Critical infrastructure protection	3.3

- A FEMA participant predicted that once their agency sees the risk corridor, it would engage with other agencies (e.g., the Cybersecurity and Infrastructure Security Agency) and the National Risk Management Center to assess what critical infrastructure could be affected and what single-point failures might exist along the risk swath. That assessment would rely on geographic information systems (GISs).
  - **Need noted:** Develop a seamless process for delivering the impact risk corridor in GIS formats to an appropriate repository for disaster planning and preparedness use.[21]
- A FEMA/North Atlantic Treaty Organization (NATO) participant noted that with a 14-year timeline, it is possible to create infrastructure that is more resilient in order to reduce the disruptive effects of an impact. As the risk corridor shrinks, more focused changes could be made in the areas that remain at risk. The participant pointed out that ongoing efforts to increase the resilience of infrastructure to other risks will improve resilience against this risk as well.

A.2. Module 2

Inject 2.1 – Future Information from Earth-Based Telescopes **Inject 2.2 – Recommended Thresholds for Action Have Been Crossed** Educational Opportunity – Reconnaissance Mission Options	Sub-Objectives Addressed
Discussion focus: • Adequacy and clarity of information	4.4
Discussion focus: • Pros and cons of reconnaissance mission options • Readiness for implementation of reconnaissance missions	2.1, 2.2, 2.3, 2.4

- Many participants expressed an interest in getting reconnaissance information as quickly as was feasible.
- Participants identified no cons to doing a reconnaissance mission. It was generally agreed that data from reconnaissance missions lay the groundwork for the technical and diplomatic work that would need to be done to lay a path for Earth-impact-prevention missions and to inform disaster preparedness planning. A participant from the UN stated that describing reconnaissance missions as "information gathering" could galvanize international collaboration and support. Many participants expressed a strong desire to keep as many options open as possible for as long as possible. Moving ahead early will keep opportunities open because time will only decrease the available options and increase costs of response.

[21] ATAP did successfully demonstrate the handoff of geographic shape files of the risk swath to emergency response teams for this purpose during PD TTX4. They still maintain that capability, although there is not an official repository process for the delivery.

- A FEMA participant noted that emergency managers deal with uncertainty all the time, so they would rather have some information and know when it will change than wait for improved information at a later time.
- The possibility of repurposing existing spacecraft for asteroid reconnaissance resulted in a lot of discussion among participants, even though SMEs cautioned that relying on existing spacecraft isn't always a robust option. A participant from ESA stated that their agency would take the Gaia spacecraft and send it to fly by the asteroid and that ESA would study all missions currently operating or in development to see what could be repurposed.
  - **Need noted:** Develop a robust process for identifying spacecraft that could be repurposed for asteroid reconnaissance, to include mission design/navigation, spacecraft capabilities, and payload perspectives.
- A NASA participant expressed substantial interest in doing an inventory of sensor suites that could be quickly used for a reconnaissance mission; the SMPAG participant responded that SMPAG has already begun a similar inventory.
  - **Need noted:** Expand the SMPAG inventory of potential payloads and keep that information up to date.
- Participants discussed at length the timelines showing launch and arrival dates for flyby and rendezvous missions. Participants felt these were valuable because they helped to communicate which options would be possible at what times. However, participants distinguished an additional need for the timelines to convey when *decisions* about specific mission options would need to be made in order for the mission to be viable. Multiple participants pointed out that decision-makers need to understand decision-making timelines.
  - **Need noted:** Information about the timing of key decision points needs to be infused into discussions about mission options.
- Participants were interested in the costs of mission options. A NASA participant explained that flyby missions are less complex, less expensive, and faster to develop. They noted that DART is a good analogy to a flyby reconnaissance mission. It had a four-year development schedule, less than one year of flight time before reaching its target, and a $325 million total cost. The same participant noted that the OSIRIS-REx asteroid rendezvous mission had about a $1 billion LCC but was perhaps more complicated than what would be needed here. A different NASA participant mentioned the CLPS initiative as another point of cost reference; CLPS awards are in the $75–400 million range, with a cumulative maximum contract value of $2.6 billion through 2028.
  - **Need noted:** Include ROM costs of reconnaissance missions, including the phasing of funding relative to key decision points, when presenting mission options.
- Participants expressed the desire to better understand what information each of these reconnaissance mission types would provide. SMEs clarified that although ground observations will refine where the asteroid will hit, large uncertainties about the severity of the impact would remain without a reconnaissance mission. SMEs explained that impact location and asteroid

size and mass are the most important asteroid properties to characterize. SMEs noted, however, that there are open questions about how well those things need to be known in order to plan an effective Earth-impact-prevention mission.

- **Need noted:** Assess the fidelity of information from asteroid flyby and rendezvous reconnaissance missions and how residual uncertainties about asteroid properties propagate into disaster preparedness efforts and Earth-impact-prevention mission planning.

- Based on the discussions, the technology to do purpose-built flyby and rendezvous reconnaissance missions for NEOs largely exists already. However, the capability of bringing that technology together to quickly build and launch such a mission is limited.
- Participants were interested in shooting for the "yellow" opportunities on the timeline of mission options, which corresponded to missions that would require a one-year acceleration of the development timeline. Participants felt that the "red" opportunities, which would require a two-year acceleration of the development timeline, would be too risky. Participants identified a variety of means to achieve a rapid-response capability, such as stockpiling spacecraft, identifying spacecraft that could be repurposed, a sustained cadence of reconnaissance mission launches, and responsive launch. A participant from USSPACECOM noted that the U.S. military is interested in rapid-response launch, and there may be opportunities for learning and sharing between NASA and USSPACECOM on that front.
  - **Need noted:** Develop a rapid-response reconnaissance capability. Do a trade study of possible paths to achieving such a capability and identify which paths are realistic given the low-likelihood, high-consequence threat of an asteroid impact.
- It will be a challenge to gain political momentum for reconnaissance and maintain it through time.

Inject 2.3 – U.S. Benchmarks to Consider Impact Prevention Missions Have Been Crossed Educational Opportunity – Earth-Impact-Prevention Mission Options	**Sub-Objectives Addressed**
Discussion focus: • Adequacy and clarity of information	4.4
Discussion focus: • Pros and cons of Earth-impact-prevention mission options • Readiness for implementation of Earth-impact-prevention missions • Policy, funding, and resource considerations for missions	2.1, 2.2, 2.3, 2.4

- Participants were keen to discuss the reliability of Earth-impact-prevention options. A SME pointed out that kinetic impactor technology has been demonstrated in flight by the DART mission, but no other method for Earth impact prevention has been demonstrated in flight (although they should work in principle). A participant from ESA stated that ESA aims to develop and launch an ion beam deflection demonstration mission within the next 10 years. A NASA participant pointed out that next-generation launch vehicle capabilities such as Starship with low Earth orbit (LEO) refueling would change some of the options that are viable.
  - **Need noted:** Increase the reliability of Earth-impact-prevention technologies via additional flight demonstrations (e.g., ion beam, additional kinetic impact tests). Note that the NED

method comes with substantial legal, policy, political, and proliferation concerns discussed later in this section.

- Space agency participants noted that the same challenges discussed for rapid-response reconnaissance missions, in terms of getting a mission up into space quickly, are also relevant to Earth-impact-prevention missions.
- As with reconnaissance mission options, participants weighed cost as a prominent factor in discussions. Several participants predicted that space missions are probably cheaper than consequence management. A participant from FEMA stated that their agency could use the risk analysis shown during the TTX and estimate the costs of the consequence management, should impact occur.
  - **Need noted:** Include analysis of cost of consequence management versus space missions in discussions about COAs.
- Some participants asked about Earth-impact-prevention methods that were not presented in SME briefings, including gravity tractor and lasers. A SME noted that gravity tractor performance is enveloped by ion beam deflection and therefore was not shown separately. A NASA participant explained that lasers have been studied but the power levels and time needed to achieve asteroid deflection are factors currently limited by technology. In addition, a participant from a U.S. space agency noted that space-based lasers can just as easily be viewed as anti-satellite weapons.
- A USSPACECOM participant asserted that U.S. military entitles would want to keep a low profile given various sensitivities but that the military would want to maintain awareness and monitor activities so that nefarious actors do not exploit the situation.
- A participant asked if it would be possible to accidentally knock the asteroid on a path that would make it collide with another country. A SME clarified that such a thing could happen: Certain Earth-impact-prevention mission options (e.g., multiple kinetic impactors or ion beam defection) would move the impact point across other countries before moving the asteroid off Earth entirely.
  - **Need noted:** Continue to explore the legal/policy implications of shifting the risk swath to other countries in the course of deflecting the asteroid based on previous work done by the SMPAG Ad-Hoc Working Group on Legal Issues.
- The potential use of NEDs for Earth-impact-prevention missions generated a highly engaged discussion. NED missions led by the U.S. would be a joint effort between NASA, the Department of Energy (DOE)/National Nuclear Security Administration (NNSA), and other agencies. The DoS noted that the U.S. has international obligations concerning the placement or use of NEDs in space and that there are policy, geopolitical, and proliferation concerns associated with the use of NEDs. One participant asked, “How would the U.S. feel if an antagonist nation were in the risk swath and decided unilaterally to pursue a NED mission?”
  - **Need noted:** Better understand the legal/policy/proliferation factors associated with NEDs and the liability question in general, including nuances of gradual or partial deflection.
- Attorneys from DoS and NASA noted there are ways to deal with treaty obligations and international law in an emergency where use of NEDs for planetary defense might be required, such

as going to the UN Security Council or building a coalition of countries to legitimize the action and mitigate the political fallout. A participant from DoD suggested the possibility of revising the Outer Space Treaty, but DoS strongly discouraged that approach because values the treaty enshrines are technology neutral, and an updated treaty might never be ratified.

- The decision about which, if any, Earth-impact-prevention missions to pursue would be a political one, so there is a need to identify and appropriately message the decisions that senior leaders would need to make and when they would need to make them.
  - **Need noted:** Determine the key decision points for senior leaders and when those decisions would need to be made to enable various mission options.

Inject 2.4 – Scenario Summary	Sub-Objectives Addressed
Discussion focus: • Perspectives of emergency management organizations on mission options discussions	2.1, 2.2, 2.3, 2.4, 3.1, 3.2, 3.4
Discussion focus: • Perspectives of public information officers on mission options discussions	2.1, 2.2, 2.3, 2.4, 4.1, 4.2, 4.3

- A participant from FEMA viewed a reconnaissance mission as critical because the data from it might change the planning assumptions used by emergency managers. A FEMA participant also said they would want to understand the levels of confidence in the missions being undertaken.
- A public messaging and communications participant from FEMA noted that, from a public messaging perspective, kinetic impact is a great option because DART proved it could work. Several participants felt that ion beam deflection sounded like science fiction and that people would likely be skeptical of it as a result. People from multiple agencies stated that the NED option raises a variety of concerns regarding public messaging and geopolitics.
- Participants once again identified timelines as an important factor to convey in public messaging. A participant from FEMA noted that because the probability of impact is <100%, it would be important to talk about the other benefits a reconnaissance mission might have to build support for such a mission. Calling out those other benefits would also help deal with turnover in U.S. administrations and funding cycles.
  - **Need noted:** Identify messaging themes about the “side benefits” of doing a reconnaissance mission, even if it turns out the asteroid would miss the Earth.
  - **Need noted:** Raise public awareness of planetary defense and hone public messaging.
- The IAWN coordinating officer noted that the asteroid information would be public because the databases like the Minor Planet Center (MPC) are public. NASA’s policy is to be transparent to maintain public trust and to prioritize being accurate over being first to disclose information. A participant from ESA shared an example where an asteroid was improperly flagged, and internet trolls popped up trying to incite panic. The participant reported that once aggressive, corrective messaging went out, the trolls’ accounts rolled back and disappeared.

A.3. Module 3

Inject 3.1 – Scenario Summary Inject 3.2 – Notional Coordination for Planetary Defense Missions	Sub-Objectives Addressed
Discussion focus: • Processes for decision-making about mission options • International agreements for cooperation on mission options • Factors to weigh in making recommendations • Processes for resolving disagreements about recommendations • Role of geographic proximity to the risk corridor • Risk posture for planetary defense missions	1.2, 1.3, 2.1, 2.2, 2.3, 2.4, 4.2

- Participants noted that counties outside the risk corridor may still be affected by the potential impact (e.g., by financial market instability). A participant from NSpC felt that all countries should be encouraged to contribute in some way to preparedness efforts because they might be in the risk corridor the next time.
- No participants categorically removed any of the mission options from the table.
- The SMPAG chair clarified that SMPAG's purpose is to coordinate mission options planning and information sharing among its member agencies and then make recommendations to COPUOS. COPUOS would note the mission options from SMPAG and pass the planning information along to UN member states. The SMPAG chair emphasized that the "A" in SMPAG stands for "advisory." The SMPAG chair felt that SMPAG is a technical forum suited to tackling many of the issues pertaining to Earth-impact-prevention missions at a level below the inevitable political debates. The SMPAG chair explained that the group operates by building consensus, so SMPAG will have dialogue about disagreements. The SMPAG chair noted that although SMPAG mostly focuses on technical questions, it has an ad hoc legal working group that can provide international legal and treaty opinions. Participants noted that ultimately nations will decide to proceed as they choose, and those actions may or may not be coordinated.
    - **Need noted:** Understand potential contributions by various space agencies to build intuition for areas of likely collaboration, competition, or redundancy through independent missions.
- Some participants thought SMPAG would decide which missions to do, thereby revealing that role was not fully understood by all participants at the outset of the exercise.
    - **Need noted:** Consistently communicate the role of SMPAG as a coordinated advisory body composed of national space agencies and offices.
- A representative from the UN emphasized that COPUOS is a useful forum to build consensus and share information. Attorneys from NASA and DoS pointed out that bilateral and multilateral agreements could be used in lieu of, or in addition to, the UN Security Council and UN General Assembly, and that such agreements are done routinely. Participants with legal backgrounds noted that the UN Security Council may need to be involved for discussions about NED missions but also that a single Security Council veto by one of the permanent members could doom an action.

- A participant noted that they would not want a country to not take action to prevent an impact because of concerns about being liable if the attempt should fail.
    - **Need noted:** Continue the work of the SMPAG Ad-Hoc Working Group on Legal Issues to determine whether unresolved concerns about liability might lead a state to not take action and, if so, identify a path for developing agreements to remove that barrier to action.
- A representative from USSPACECOM suggested defining the risk tolerance and desired end state for planetary defense and then using that risk tolerance to drive decisions about how to act. A NASA participant responded that it is unclear what the appropriate risk tolerance is for planetary defense. The NASA participant explained that, to date, PDCO has worked to determine what actions could be taken in response to an asteroid impact threat and then looked at the risk associated with those actions. The USSPACECOM participant suggested taking a different approach to set criteria for how much risk we are willing to accept and then use those criteria to drive what mission options are recommended. The NASA participant said that the approach hadn't been taken before but that it could be considered.
    - **Need noted:** Assess whether setting a risk tolerance for NEO impact threats, and then using that tolerance to decide which actions to take, is a viable approach for planetary defense and determine risk tolerance levels.
- Many participants agreed that the risk of failure for space missions needs to be considered. Participants from NASA and ESA suggested that to hedge against mission failure, different countries should pursue their own reconnaissance missions for redundancy. Another NASA participant noted that using multiple commercial providers for these missions would be another way to build in redundancy and hedge against failure.
- Discussions occurred about how extensively Earth-impact-prevention technologies would need to be demonstrated before agencies would trust relying on them. A NASA participant stated that there is a lot of confidence in kinetic impactor technology because of DART and less confidence in methods that have not yet been proven in flight.

Inject 3.3 – Email from Senior Leaders Requesting Briefing on Recommended Courses of Action	Sub-Objectives Addressed
Discussion focus: • Which mission options should be presented to senior leadership? • Resources that might be committed to reconnaissance or Earth-impact-prevention missions • International coordination of resources • Barriers to international cooperation • Reliance on international partners	1.2, 1.3, 2.1, 2.2, 2.3, 2.4, 4.2
Discussion focus: • Public messaging challenges for space mission options	4.1, 4.2, 4.3, 4.4

- Several participants predicted that it would be tempting for senior leaders to wait for seven months until more information becomes available before taking action. The challenge would be to convince decision-makers of the need to act now, rather than waiting until the asteroid becomes observable again. There was general recognition that waiting until November is a legitimate COA available to senior leaders.

- Participants generally supported taking immediate, credible steps to preserve the decision space in the future. Reconnaissance missions are that immediate action, particularly those missions that would improve situational awareness as quickly as possible. In this scenario, those missions were flybys.
  - **Need noted:** Develop a rapid-response flyby reconnaissance capability.
- The discussion turned again to timelines for decision-making. Participants sought to understand the specific decisions that would need to be made for different mission options and when those decisions would need to be made for a mission to be feasible. Several participants deemed mission options that would require a two-year schedule compression unfeasible, but there was desire to try to push for the mission options that would require a one-year schedule compression.
  - **Need noted:** Better infuse information about decision points and time frames into discussions of mission options.
- Another discussion took place about using NEDs for Earth impact prevention. A SME pointed out that using a NED would mean that only one spacecraft would be needed to potentially prevent Earth impact. However, several participants from DoS emphasized that the use of NEDs is accompanied by legal, policy, political proliferation, and other issues. DoS noted that the U.S. takes treaty obligations seriously and that the use of NEDs would be a last resort to save humanity. A FEMA participant who focuses on external affairs pointed out that public sentiment can play a big role in holding or forcing a decision. A NASA participant reminded people that there was opposition to the nuclear power source on NASA's Cassini mission and prompted participants to imagine what that might look like for a NED mission.
  - **Need noted:** Revise messaging to emphasize that response options will fall off the table if decisions are delayed and the consequences of losing those options may leave NEDs as the only viable option for Earth impact prevention.
- A NASA participant stated that NASA would want to show leadership—and would likely pursue development of—a reconnaissance mission. However, the participant cautioned that senior leaders may want more certainty before proceeding. The ESA participant supported doing a reconnaissance mission. There was a preference for individual countries to pursue independent missions, rather than multiple countries contributing payloads, the bus, or the rocket to a single mission.
- A NASA participant expected that their agency would coordinate with other countries via SMPAG as well as bilateral and multilateral agreements on reconnaissance missions but would want a U.S.-only backup plan. A UN participant predicted that international participation in reconnaissance missions would increase the sense that this potential impact is a global issue. A USSPACECOM participant noted that the geostrategic environment could also be a barrier to international cooperation among some countries, but that perhaps with appropriate messaging, this scenario could be an opportunity to lower the temperature around the world.

- Some participants expected that International Traffic in Arms Regulations (ITAR) would be a potential barrier to international collaboration. However, a NASA participant said that ITAR would likely not be as much of an issue for reconnaissance missions because such missions have been done before by a variety of countries.
- Participants quickly identified budget as a likely limitation: NASA would need an appropriation to start something new, which could not be done under a continuing resolution.
- For briefing this information to senior leaders, a participant from DHS suggested starting with the potential consequences of the impact, then working on a reverse timeline that lays out COAs, decisions that would need to be made, and implications of those decisions, including when particular missions would no longer be possible in order to show what you lose if you do not act.
  - **Need noted:** Prototype different ways of briefing information about COAs to senior leaders and learn from each iteration.
- A FEMA participant emphasized that we need to message to politicians, to international partners, and to the public in the right order at the right time to make the right things happen. Knowing what the desired outcome is will help overall alignment on COAs. This strategy for all of this messaging needs to be developed in advance and should include messages about the benefits that a COA will bring.
  - **Need noted:** Develop a messaging strategy for a long-warning planetary defense scenario, including both to the public and to interagency leadership.
- A NASA participant noted that mis/dis/mal-information will be a challenge, and suggested that “pre-bunking” likely misconceptions now will help reduce the influence of mis/dis/mal-information.
  - **Need noted:** Identify likely misconceptions in a long-warning scenario, develop content to pre-bunk those misconceptions, and begin using that content.
- A participant from the UN pointed out that the close encounter between the Earth and asteroid Apophis in 2029 is an opportunity to raise awareness about planetary defense in general.
  - **Need noted:** Take advantage of Apophis’ close encounter with Earth in 2029 to raise awareness of planetary defense, as is being done by the proposal to designate through the UN that 2029 be an International Year of Asteroid Awareness and Planetary Defense.

Inject 3.4 – Preparedness Planning for Disasters	**Sub-Objectives Addressed**
Discussion focus: • Immediate courses of action for disaster preparedness	1.3, 3.1, 3.4

- A FEMA participant noted that FEMA would look to NASA as the lead authority. The participant predicted that emergency managers would have a lot of questions and will need a background brief to better understand the risk analysis product and its uncertainties in order to do deliberative planning. FEMA participants felt it would be hard to do planning at the federal, state, or local level at this time given the large uncertainties without a better understanding of them.

- **Need noted:** NASA ATAP to work with emergency managers to better understand what sort of information emergency managers would want in order to aid deliberative planning.

- Participants from several agencies noted that any steps people take to increase resilience will be a benefit in this scenario and for all other disasters.
- In the course of discussions between FEMA participants and a participant from the UN, it was noted that a new network specifically for asteroid impact disasters may not be needed, but connections would need to be made between asteroid impacts and other natural disasters. The UN secretary general's Early Warnings for All initiative[18] is focused on extreme weather, but a similar pathway could be used for asteroid impact disasters.
  - **Need noted:** Examine existing international collaborations related to disaster preparedness and determine which, if any, of those existing bodies might be a forum for also discussing asteroid impact disaster preparedness and planning.

Inject 3.5 – Senior Leader Briefing – Simulated Impact Threat Scenario Notification by IAWN **Inject 3.6 – Senior Leader Briefing – Space Mission Options/SMPAG** **Inject 3.7 – Senior Leader Briefing – Space Mission Options**	**Sub-Objectives Addressed**
Discussion focus: • Information in support of decision-making • Processes for identifying which courses of action to pursue • Next steps for a given organization • Prioritization of resources for this risk versus other efforts • International coordination	1.1, 1.3, 2.1, 2.2, 2.3, 2.4, 4.1, 4.4

- Senior leaders engaged in a much more extensive discussion of repurposing of existing assets than the other participants did on Day 1. Repurposing spacecraft was of interest to senior leaders in part because it could potentially get information about the object more quickly than a new spacecraft mission could. SMEs emphasized that more analysis would be needed to determine whether repurposed spacecraft could collect the needed data (e.g., Lucy was designed for asteroid flybys; OSIRIS-REx was designed to rendezvous).
  - **Need noted:** Call out specific practical repurposing possibilities for the senior leaders up front.
  - **Need noted:** Develop a robust process for identifying spacecraft that could be repurposed for asteroid reconnaissance, to include mission design/navigation, spacecraft capabilities, and payload perspectives (see also Module 2).
- Senior leaders wanted to better understand how long it would take the new asteroid observations from November 2024 to lead to updated impact probabilities. SMEs reported that information about the asteroid's trajectory would be updated within a day or two of getting new observations but that the asteroid's size would remain highly uncertain. A SME noted that when observations resume in November 2024, the impact probability may still not rise to 100% or drop to 0%.
  - **Need noted:** Better convey how uncertainties in impact probability and location are likely to change so that information can be better understood in the context of decision-making.

- Senior leaders also wanted to know when we would need to decide whether to use a NED or a kinetic impactor. A SME shared that if a reconnaissance mission were sent soon enough, we could know the asteroid size well enough in the 2027/2028 time frame to know whether a NED would be required to prevent Earth impact. That result underscores the need for rapid-response reconnaissance missions.
  - **Need noted:** Develop a rapid-response reconnaissance capability (see also Module 2).
- Senior leaders discussed the NED option. They noted that the final decision about whether to use a NED for this purpose would be made at the highest levels and in consultation with the international community. A participant from the National Science Foundation (NSF) asked about doing a demonstration with a dummy NED. However, a participant from DoS stated that developing that capability in advance is ill-advised for policy and proliferation reasons. A senior leader from NSpC postulated that the issue might come into play relatively early in the timeline if a purpose-build hybrid NED + reconnaissance spacecraft were contemplated. That perspective differed from a DoS participant's preference on Day 1, which was to push discussions about the potential use of NEDs to as late a time as possible. A participant from the Office of the Secretary of Defense suggested establishing a set of protocols related to the potential use of NEDs for planetary defense.
  - **Need noted:** Assess the pros and cons of planting seeds for a policy framework for potential use of NEDs for planetary defense.
- Senior leaders were very interested in the reliability of different Earth-impact-prevention methods. This topic was discussed on Day 1 by the participants who attended both days, and the points raised by senior leaders about reliability echoed those raised on Day 1. See earlier discussion in Modules 2 and 3.
  - **Need noted:** Conduct additional demonstrations of non-NED Earth-impact-prevention technologies while being mindful of the sensitivities associated with the potential use of NEDs for planetary defense.
  - **Need noted:** Revise messaging packages to convey the timelines more clearly for decision-making, where go/no-go points are located, and the phasing of investments (nearly identical points were raised during discussions on Day 1 by the participants who were in attendance on Day 1).
- Senior leaders were interested in redundancy to ensure mission success. A NASA senior leader noted that the ability of the U.S. to send redundant missions would depend on funding. Alternatively, redundancy could be achieved by having different countries develop their own missions. This approach to redundancy aligned with the preference from Day 1 participants to have different countries pursue independent missions.
- NASA senior leaders would support the U.S.-led flyby and rendezvous missions and design those options, but they expected that Congress would wait to provide funding until additional telescopic observations of the asteroid become available in November 2024. In the meantime, NASA might choose to retarget the Lucy mission for a flyby. NASA would also want a complete inventory of existing spacecraft in space and in development and a survey of optical sensors

in the U.S., to have an industry day to get ideas from commercial companies and build congressional support, and to look at rapid contracting approaches.

  - **Need noted:** Figure out compelling ways to illustrate which mission options fall off the table if the decision is made to wait until the asteroid is observable once more by telescopes and to illustrate the consequences of losing the information the mission would have provided.
  - **Need noted:** Update the SMPAG inventory of potential assets for planetary defense missions and establish a process for keeping it current (see also Module 2).

- Next steps for Earth-impact-prevention missions from senior leaders were less concrete, but a NASA participant noted that this scenario could be an opportunity to fast-track a technology demonstration that we would want to do anyway, such as ion beam deflection.
- NASA participants noted that the budget is a zero-sum game without a specific appropriation. Money could potentially be reallocated for initial mission concept studies but only at the expense of something else, which could create backlash from the projects whose funding would be reduced to keep the budget balanced.
  - **Need noted:** Clarify what resources would need to be committed now versus the ROM LCC to better communicate the initial funding ask and where offramps exist to pause or end development.
- Senior leaders were strongly in favor of international collaboration on space missions. They noted that having separate missions from different counties builds trust, provides more data, and increases the chance that at least one mission will be successful. In addition, they felt people would be more likely to believe the asteroid is real if multiple missions from different countries all indicated that was the case. A participant from the Office of the Secretary of Defense suggested potentially reaching out to China quietly in this scenario at this tense geopolitical time to see whether they wanted to talk about Earth impact prevention.
- Finally, a NASA participant noted for others that if another asteroid were a potential threat in the future, new missions may be needed, depending on the risk posed by the asteroid, because every asteroid is different. A USSPACECOM participant commented that defining a risk tolerance for planetary defense would stave off a lengthy discussion about what missions to potentially pursue in every new asteroid scenario, thereby potentially enabling a faster response.

Inject 3.8 – Senior Leader Briefing – Initial Emergency Preparedness Actions	Sub-Objectives Addressed
Discussion focus: • Disaster preparedness actions 14 years out from impact	1.2, 1.3, 3.1, 3.2, 3.3, 3.4

- A FEMA participant said their agency would start building a small team to provide guidance to emergency managers. The participant said memorandums of understanding exist between FEMA and many other countries, so the communication channels are open. The participant noted that there are things, such as pushing for improved building codes, that will increase overall resilience for a range of potential disasters; the NRF is designed to be scalable, but not everything has been solved.

- A UN participant noted that the JPLAN[17] may be another potential point of reference related to disaster preparedness planning. Alternatively, consequence management plans for atmospheric reentries may be a starting point.
  - **Need noted:** Review existing disaster or catastrophe plans and identify the plan closest to what is needed for an asteroid impact disaster; then tailor that plan for an asteroid impact scenario.

A.4. Module 4

Inject 4.1 – Global News Outlets Are Clamoring for Information and the Public Wants to Know What to Do	Sub-Objectives Addressed
Discussion focus: • Existing crisis communication plan(s) and potential adaptation • Additional considerations regarding public information messaging • Trusted persons to provide updates to the public • Analogous crisis communications and prior lessons learned • Positive and negative impacts on trust of agencies	1.1, 1.2, 1.3, 3.1, 3.2, 3.3, 3.4, 4.1, 4.2, 4.3, 4.4

- Participants from NASA, FEMA, and UNOOSA noted that they have existing crisis communication plans that could be scaled up. For NASA, the closest is likely space weather communications options. FEMA has a national response framework and Emergency Support Function (ESF) 15 (Public Affairs) with interagency coordination around communication. It was later mentioned by a NASA representative that figuring out how to share data should be addressed now and that this is bigger than just ESA and NASA and also involves citizen scientists, other nations, etc.
  - **Need noted:** Develop a more formal method to share data across many entities, including NASA, ESA, IAWN, and beyond.
- A representative from DoS stated they would leverage their experience addressing other types of global crises and they could issue rapid communications to embassies in the impact corridor. They would also leverage COPUOS, IAWN, and SMPAG to coordinate dialogue with other member states and rely on the UN to aid with communications to member states. UNOOSA would prepare the UN secretary general to present at a noon briefing by working with relevant bodies and aligning with the SMPAG chair.
- ESA stated they would be activating communications, working in collaboration with partners (e.g., NASA), relaying information to IAWN and SMPAG, and facilitating their technical analysis. They have a draft communications plan that mostly focuses on debunking false information and providing stages of information regularly to the public to ensure they are recognized as a credible agency and to build trust.
- A FEMA representative expressed that communications challenges will be immediate when the data are publicly available and amateur astronomers begin communicating. FEMA noted that it would be useful to have a plan in place ahead of time for specific people to make initial statements, even if they are boilerplate statements to wait for further information.

- **Need noted:** Develop a communication flow process that is vetted and that people are comfortable with releasing very quickly (both a drafted statement and a plan of who is going to put messages out).

- There have been lessons learned about regularly communicating, even if the message is "we're still working on this and have the brightest people finding more information." An example was given of Astrobotic's public-facing messaging review process for Peregrine Mission One, which only involved two people, noting that NASA could work on streamlining their approval and release process. The communications world is good at making teams that work well together and would be part of that group for establishing processes for quick turnaround. From a legal perspective, there needs to be appropriate management of leadership expectations.
- A representative from DHS stated that from a homeland security perspective, there will be unintended consequences from initial communications, such as a spike in asylum claims in and out of the U.S. Initial messaging would be to stay in place. The point was made that eventually there might be sanctioned migration from places in danger, but early on the message would be not to migrate. Additionally, they expressed concern for a potential increase in malicious information and lawlessness (e.g., "asteroid insurance") as others take advantage of the situation.
- The National Reconnaissance Office (NRO) confirmed that communicating with the public on a regular basis is important and gave the example of how DoD's regular communications after 9/11 helped. They suggested having a set schedule for regular briefings (even if there is nothing to report) so everyone knows when the brief is coming. Another participant suggested flooding the public with facts.
- The U.K. Space Agency noted that while they don't have NEO-specific communications, for satellite reentry risks they give a date and time for when their next update will happen and can rapidly deploy that. If the U.K. were directly affected, the decision would go up to the prime minister. They also have an academic lead in SMPAG who they collaborate with for communications. There was a lesson from the COVID-19 pandemic to have the SMEs lead communications because politicians are not always trusted.
- NASA mentioned that IAWN and SMPAG are collaborations and do not have a formal structure. Technical information would be flowing between them, but the signatories would communicate according their country's and agency's policies.
- A representative from NASA stated that the communications strategy starts before identifying any asteroid of concern, so PDCO is working to build trust now and become a trusted source of information. They are already working with CNEOS and ESA's Near-Earth Object Coordination Centre (NEOCC) to put out information about close approaches of smaller asteroids given that they happen frequently and can help build public confidence. Another participant later noted that the public is familiar with ESA and NASA coordination and that they are a growing trusted source of information. This is important because trust is developed during calm times. The U.K. Space Agency mentioned that a partnership with NASA and/or the UN would help provide more trust/credibility. Additionally, the U.K. is planning to stand up a national space operation to coordinate military and civil response for planetary defense.

- UNOOSA pointed out that there should be multiple sources of information and speakers saying essentially the same thing. FEMA suggested thinking beyond the government sector to trusted public figures (i.e., Bill Nye the Science Guy, Neil deGrasse Tyson, etc.) to reach a variety of people. Another representative from FEMA noted the big difference between a trusted person and a government spokesperson. Trusted persons (e.g., faith-based or community leaders) are needed in a community. This is why FEMA emphasizes a whole-of-community approach and does not rely on one nationally trusted individual.
- DHS posed the question of "how does public affairs maintain consistent messaging as the timeline moves along?" The timeline involves at least three presidential cycles and as many as five different presidential administrations. Another participant later commented that consistency is already important when doing technical analysis and there needs to be a goal to achieve. Communications will be different depending on whether it is to protect or inform.
- NASA has had success working with churches as one of the main messengers about solar eclipse safety. They suggested making trusted groups Solar System Ambassadors who put information out into the communities and creating lists of who those trusted groups are.
- A FEMA representative suggested figuring out a timeline of points of high interest and communicating accordingly. From their perspective, a sense of control changes people's risk perception, so there will be a need to overcome the perception that there is no individual control over the situation. They noted that even with daily risks, getting people to take precautions is very challenging. Focusing as locally as possible and getting community leaders up to speed is of critical importance when action is needed. A representative from NASA stated that the timeline and various options presented earlier gave them a sense that there *was* some control, even if not theirs specifically.
- NASA emphasized that with an asteroid, it would be very difficult to correct bad first impressions or mistakes, so it would be critical to get it right with communications. As the asteroid gets closer local people can be mobilized, but localization is not as important in the beginning, when the threat it is a global issue. At that early stage, it is important to internationally collaborate, share the data, and avoid publishing different information.
- NRO stated that, in their experience, acknowledging that something took place, even if it hasn't been determined whether it was good or bad, is important; updates with more information can then be provided later.
- USSPACECOM stated they will be ready to help. NASA noted the importance of global communications at the beginning to help initiate a reconnaissance or rendezvous mission and get congressional support. There needs to be an early sense for spending needs, otherwise taxpayer dollars will fund something else instead.

Inject 4.2 – International News Sources Are Releasing Varying Messages Educational Opportunity – UN Mechanisms for Public Messaging	Sub-Objectives Addressed
Discussion focus: • International laws, treaties, or other agreements in place • Steps to avoid information being lost in translation? • Lack of enforceability impacts on messaging consistency • Considerations for message consistency and customization across nations and cultures • Balancing expediency and accuracy • Format and frequency of communications • Avoiding "asteroid panic" or "asteroid fatigue" • Examples that might serve as a model for information sharing and coordination for planetary defense	1.1, 4.1, 4.2, 4.3, 4.4

- DoS pointed out that there are notification requirements in the Outer Space Treaty, including several provisions for information sharing that may be relevant in the case of a NEO disaster threat. These are a good starting point for understanding how information sharing is already supposed to work under the treaty. In the UN context, technical briefings and information sharing will be important for building communication given that this threat has a long time frame. It was also stated that strategy and diplomacy are required because there are certain political and legal implications regarding what is shared. It was suggested that setting up forums that might prematurely constrain NASA's options later should be avoided and that it is important to understand that the threat can affect everyone equally.

- NASA noted that the more than 1,000 bilateral/multilateral international agreements and treaties with coordination clauses for public messaging and communications agreements are relevant. While the Artemis Accords do not directly mention planetary defense, parties commit to transparency about space operations and prompt responses. A legal representative noted that they would want to review all communications before release to avoid limiting later options as a result of unintended legal implication. A participant noted that enforceability is often an issue with international agreements. Enforceability is largely based on countries' reputations and reputation for trustworthiness.

- UNOOSA stated that the UN has the ability to handle messaging in multiple languages and that it is important to have global networks in place up front to put forward trustworthy information. There are culturally significant locations and cultural sensitivities of partners to consider as well (e.g., trying to stop a potential natural disaster could be seen as denying fate/defying God's will). A representative from the UN cautioned the group about losing credibility if people feel that the threat is not real and pointed out the tension between what is seen to make a difference in lives now and the future. It was suggested to use Apophis as an opportunity given that it is real and could be an opportunity to show global collaboration.

- A NASA representative stated that it might be helpful to minimize the number of people making choices about what is said. Another representative noted that reaching out to scientific organizations and enabling scientists to share their discoveries and collaborate will be important (e.g., the international astronomical community).

Inject 4.3 – Social Media Posts Are Abundant, and Many Are Inaccurate	Sub-Objectives Addressed
Discussion focus: • Current methods used to address and monitor misinformation • Current response to misinformation when aware of it • Response change if disinformation is purposefully disseminated to cause a crisis • Messaging via social media versus traditional news outlets • Messaging quickly and frequently, with limited time for review and coordination • Top three concerns about public messaging and coordination	1.1, 1.2, 1.3, 3.1, 3.2, 3.3, 3.4, 4.1, 4.2, 4.3, 4.4

- FEMA has a social listening report to track misinformation and disinformation on social media. They look at what is becoming popular on social media to determine whether a misinformation issue is growing in public interest and needs to be officially addressed. Because they cannot confront everything, FEMA addresses topics that could threaten safety or their missions. Once something is identified on social media that is dangerous, the agency takes a disciplined approach to get the right information out.
- ESA reiterated an experience they had in 2023 when a small delay in correcting inaccurate information was picked up by malicious actors who used targeted terms and hashtags like "city killer" and "#citykiller" to alarm the public. ESA was able to publish the real information, explained the delay, and aggressively tamped down the activity until it subsided.
- DoS mentioned there is a global engagement center headed by a special envoy as a center for countering misinformation from state actors. They have capabilities and international partners that could be another avenue for addressing misinformation and disinformation. DHS noted that they also have counterterrorism operations and have successfully stopped attacks but that the details are classified. Often their successes are not seen, and there needs to be a way to visually maximize social impact because otherwise "it didn't happen if you didn't see it." NASA noted that this reasoning is why they livestreamed the images from DART's kinetic impact with Dimorphos.
- There were several mentions of comparisons to messaging during the COVID-19 pandemic. USAID struggled at first but was successful when using local leaders to convey the message. Keeping people safe and alive was the broad message. Another participant noted that they learned to be proactive not reactive, and not to leave a void where others can take control of the narrative.

A.5. Module 5

Inject 5.1 – Scenario Summary Educational Opportunity – Recap: PD TTX5 Impact Risk Assessment	Sub-Objectives Addressed
Discussion focus: • Risk assessments provided by countries or organizations • Useful information for disaster preparedness and response planning • Risk assessment comparisons and sharing	1.2, 1.3, 3.1, 3.2, 3.3, 3.4, 4.1, 4.4

- One of the opening questions from a participant inquired about the time window for determining the impact location. JPL responded that with current capabilities, they will be able to pinpoint down to ~10 kilometers (~6,200 miles) or, with radar, down to 1 kilometer (~620 miles) in 2028. NASA stated that as the impact location uncertainty decreased, models of impact risks would be updated to provide focused information about the specific areas at risk. Later in discussion, there was a question as to when more information about the trajectory and where impact would happen would be available, including whether or not an intercept was successful. A representative from JPL stated that if an observer spacecraft were there, the success could be determined in days. If not, it would take about a month. JPL also pointed out that there are two years between the last deflection opportunity and impact.
- It was stated that NASA's asteroid threat modeling team does not have direct integration with defense modeling groups; however, they do work with DOE labs on determining the mitigation and impact effects. A participant noted that FEMA has formalized mechanisms for working with federal entities such as the National Oceanic and Atmospheric Administration (NOAA), U.S. Environmental Protection Agency (EPA), U.S. Department of Health and Human Services (HHS), and Defense Threat Reduction Agency (DTRA) for interagency modeling and that they engage with other entities as needed. It was discussed that while the NASA team works on determining impact effects, how to react to those effects is a responsibility of FEMA. The question was posed as to whether risk modeling outside of the ground damage risk swaths is available to inform recommendations for residents outside of that area to prepare. NASA representatives commented that they have a modeling working group that is looking toward developing evacuation thresholds. However, this type of modeling crosses into the emergency response community, so there would need to be collaboration with FEMA. NASA focuses on determining effects, and FEMA determines how to react to the effects.
    - **Need noted:** NASA should establish formal relationships with the federal entities that FEMA has formalized mechanisms with for modeling and engagement. Enable collaborative effort between NASA and FEMA to (1) determine effects and (2) determine appropriate response.
- There was a suggestion from an online participant that a global systemic risk assessment be conducted on the various impact scenarios to better understand the potential cascading impacts on global systems and infrastructures from the perspective of a worst-case scenario. Further online discussion suggested that the risk assessment include effects related to climate, global food security, radiation exposure, etc., and that the assessment would help identify where to build resilience while there is time. Considerations of data collaboration, access to computational resources, and use of novel tools to assist in analysis were mentioned as well. Later in discussion, the need to be cautious in consistency of messaging (i.e., 270,000 *people affected* is not the same as 270,000 *deaths*) and potential damage to other things (i.e., ocean impact may affect zero people but does not have zero consequences) was mentioned. It was noted that current models only include effects on people.
    - **Need noted:** Conduct a systematic risk assessment of potential cascading impacts from an event of this kind (i.e., risk models that include marine life, wildlife, or other damages).

- Another online suggestion was to draw from U.S. interagency activities for other disaster responses. This resulted in other questions including: Would there be government-backed insurance or buyouts for the area(s) that are potentially going to be impacted? Would the U.S. grant refugee status (asylum or temporary protected status) for non-U.S. citizens in the U.S. already? There were no attempts to answer these questions.
- A representative from ESA stated that they have long-standing expertise in astronomy and that their main focus would be to boost the specificity of the predicted effects from an impact by providing measurements to inform modeling tools. ESA is also working on a National Fire Protection Association (NFPA) hazard-diamond-type communication tool for first responders.
- A NASA representative commented that, hopefully, PDCO would take the lead in delivering messaging because they have communication strategies already in operation. Others suggested use of the hazard diamond for emergency responders. The Torino (designed for public audiences) and Palermo (designed for technical audiences) scales were also brought up as potential tools for communications. A FEMA representative highlighted that from the disaster preparedness perspective, everything comes down to population protection and mitigation. They ultimately would want to know three basic categories of information: asteroid mass, Earth impact location, and time to impact.
  - **Need noted:** Determine who will take the lead in developing, packaging, and delivering messages to various audiences (public, first responders, etc.) about impact risks.

Inject 5.1 – Scenario Summary (continued) Educational Opportunity 5.2 – Relevant International Policies for Disaster Preparedness	**Sub-Objectives Addressed**
Discussion focus: • Effect of novel scenario on public safety planning and preparations • Existing disaster emergency operations plans (EOPs) that could be applied • Lessons learned from other large-scale disasters to inform multinational preparedness and response • Emergency management perspective of relevant international laws, treaties, etc., that could be adapted • Determining preparations lead(s) and means for international coordination	1.2, 1.3, 3.1, 3.2, 3.3, 3.4

- A FEMA representative stated that there are a lot of good efforts going on now for preparedness and early warning for disasters but that there needs to be a documented inventory of them that can be filtered to identify the efforts that have appropriate planetary defense applications. Similarly to the diagram that IAWN showed that indicated how they and SMPAG are aligned under the UN (referring to an earlier slide in Module 3b), there should be a comparable group for emergency preparedness as a starting point for international collaboration on NEO impact disasters. A representative from FEMA stated that they are working to break down barriers with international affairs and are planning to release a document about international coordination but did not offer further details in this discussion.

- **Need noted:** Conduct an inventory of international efforts pertaining to preparedness and early-warning systems that can then be reviewed for application to NEO impact disaster preparedness.

- FEMA noted that they are always planning for and dealing with various disasters on scale (massive earthquakes, volcanoes, etc.), learning from every event, and then refining plans. A FEMA representative noted that they have years of expertise in planning, which includes U.S. and international aid, that could be used as a template for planning for a NEO impact disaster. It was also stated that depending on the size of the asteroid, which is poorly known, the required response might strip the U.S. of resources.
- FEMA continued the discussion, stating there is an assumption that NASA would be the lead federal agency with others (i.e., FEMA) supporting but that this might change if an emergency is declared because dealing with natural disasters is not part of NASA's mission. Ultimately, determination of the lead agency is subject to presidential decisions, and while FEMA has occasionally deployed internationally, they are a domestic response agency. However, it was noted that this type of event would affect the U.S., regardless of where it occurs.
- A representative from NASA asked how to prepare a community for something they should be concerned about but can't see and don't have context for; how much more can we be doing now to start talking about what the possibilities are? It was stated that this is something to take seriously, fund, and generate conversations about. FEMA's response to this discussion emphasized a lesson learned from TTX4 related to the emergency management and emergency response community; how the information was presented determined whether it was understood, including the scale, and how soon to reach out to FEMA for assistance. A NASA representative suggested the close approach of asteroid Apophis in 2029 should be used as a catalyst for educating the public and creating public discussion around planetary defense. The representative noted that discussions have begun about potentially making 2029 an international year of planetary defense, similar to the international year of astronomy.
- Regarding bilateral and multilateral agreements, a representative from FEMA/NATO mentioned the Vanguard leadership forum (in the U.K.) as an example of a crisis leadership network that was created to be able to reach out at the appropriate leadership level. That network includes other countries but also DoD and DoS. The European Union has their own emergency response coordination center, so foundations for a larger-scale platform exist.
- A representative from UNOOSA cited UN-SPIDER as an aim to breach the gap between space and humanitarian aid. UN-SPIDER works in developing countries and has technical advisory commissions with small regional offices that feed best practices for mitigation and on-the-ground assistance into an international knowledge portal. A FEMA representative noted that last year's planetary defense conference (PDC) included a UN-SPIDER representative, but the partnership should be solidified. It was also mentioned that the UN General Assembly established the Central Emergency Response Fund, which has contingency funds reevaluated every year for assisting countries.

Inject 5.2 – Scenario Summary	Sub-Objectives Addressed
Discussion focus: • Preparations by international emergency management communities • Impact of recommended space mission COAs on preparedness activities and timelines • Impact of emergency declarations on allocation of resources • Contingency planning • Public information strategy for emergency preparedness over 14 years • Challenges to developing and sustaining a state of preparedness	3.1, 3.2, 3.3, 3.4

- Discussion began with FEMA reiterating that they would work in coordination with NASA. Also, there was general consensus that, internationally, expectation setting is going to be essential to ensure everyone stays on the same message to help lift up messaging and interagency coordination.
- A participant made the point that players should remember that going through the process of putting together the next steps for preparedness might also require planning adjustment to the mission approach. This was followed up by a question about whether or not the risk corridor shifts from one location to another and with what degree of confidence that shift can be predicted. A point was made that progressive updates may be needed as to what locations are (and are not) safe if the asteroid were deflected gradually.
- The JPL team addressed the previous question with a response that the shift in risk corridor depends on the type of Earth-impact-prevention mission. Assuming an execution of a deflection mission, such a mission could gradually move the impact location across the Earth (depending on the method used to achieve deflection) over a period of years. JPL could generate data products to project what the Delta-V might be, but there would still be uncertainties as it pertains to disaster preparedness.
- A representative from USGS noted that they thought 14 years was a long time until seeing the timing for missions. They stated that there is a lot more that needs to be done for modeling additional cascading impact consequences and pointed out that this scenario is occurring in a period of climate change too. There are a lot of unknowns, and 14 years is a short amount of time to work it out. The U.K. Space Agency stated that despite the U.K. not being in the direct line of impact, they may need to work on predicting what secondary effects could occur (i.e., climate and migration).
    - **Need noted:** Progressive updates to the risk corridor prediction based on results of Earth-impact-prevention mission(s). Note: This capability exists but was not represented in TTX5 because the exercise only represented one moment in time.
- Discussion continued about potential consequences to action, such as if the risk swath was moved over another country at a period of time, which would be of concern. There was general recognition that while Earth-impact-prevention missions may be operating, the message still may not be “we’re all safe now,” especially if a stepwise approach to asteroid deflection were used that would bring one place out of danger but put another one in it (although it was unclear whether this is a realistic scenario from a scientific perspective). A point was made that this

speaks to the value of an international coalition providing continuous monitoring of the asteroid through various rendezvous missions to meet critical information requirements. Additionally, there was mention of a need for cross-agency liaisons to coordinate about ongoing missions and associated timelines, which are important for the emergency preparedness activities.

- **Need noted:** Better understanding of policy/political aspects of gradual asteroid deflection.
- **Need noted:** Cross-agency (and international) liaisons to communicate/coordinate ongoing missions and their associated timelines.

- A participant suggested that all of this conversation be captured as critical mission requirements: When am I going to know whether Earth impact prevention is going to work or not? They noted that at each key point, something will happen to either increase or reduce urgency and/or concerns, so there will be a need to rely on SMEs to understand what is needed. This could also be used to help improve capacity around the world.
- FEMA noted that administrations and discussions (e.g., climate) will change over the extended time period, which is not something they typically deal with in acute emergencies. FEMA would rely on the SMEs and industry to let them know when additional information is available. There is a need to be connected, both internationally and domestically (i.e., between agencies), and for sustainability with partners. The representative emphasized that many senior leaders will be retired in 14 years, so the sustainability cannot reside with changing leadership, budgets, and political climate. The challenge is to maintain the energy and talent pool to keep the effort alive and not be distracted by the disaster of the day or warning fatigue. NASA participants expressed high value in hearing about disaster planning, how to work best with emergency experts, and what is important from their perspective given that emergency experts are closest to the response.
- USSPACECOM commented that they would be providing anything they can for disaster response. They mentioned international partnerships with Five Eyes and security cooperation with countries without space capabilities. These could be used to communicate to combatant command that there is a nexus with USSPACECOM working with other countries that do not have space capabilities.
- UNOOSA pointed out that at the Space Resources Conference in Luxembourg, statements were made about the need to include non-space-faring communities when having these types of discussions and setting standards. At that conference, statements were made by developing countries that situations should not be controlled only by those who can do the mission.
    - **Need noted:** Develop a response sustainability plan that is not subject to leadership changes and that includes recruitment and retention of associated skills, knowledge, and abilities.
- A suggestion was made to have a long-term point of contact be a consistent public face for the effect, with the example of OSIRIS-Rex's principal investigator (PI) being the same person for 12 years. It was helpful that the PI role was funded at the outset, and it may be a lesson for consistency on mission leadership. ESA reiterated the likelihood that the duration of the potential threat will overpower the public consciousness and provoke disaster fatigue and therefore that public and frequent reports that are "boring but consistent" are important. There was

a suggestion by an online participant that disaster fatigue could be thought of as a long-term marketing plan, such as in terms of a 14-year TV show and the various “seasons” of the show.

- **Need noted:** A long-term point of contact that can cross multiple administrations and be a consistent, ongoing, and familiar face of the situation for ongoing updates.

- A participant suggested looking at the basics of logistics and project management in support of coordination and communication. They noted there would be value in having superb administrative, program management, and knowledge management support. A suggestion was made to look to institutes that can manage longer-term initiatives (e.g., nonprofits devoted to long-term disease eradication, etc.).
  - **Need noted:** Administrative, program, and knowledge management to support a long-term initiative.

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Appendix B. Planning Team and Contributing Subject-Matter Experts

The TTX5 Planning Team was led by the exercise sponsors, Lindley Johnson (NASA PDCO Planetary Defense Officer) and L.A. Lewis (FEMA Liaison to NASA PDCO). The planning team included:

- NASA Planetary Defense Coordination Office, including FEMA Liaison and International Asteroid Warning Network Coordinating Officer
  - Kelly Fast
  - Josh Handal
  - Lindley Johnson
  - Rob Landis
  - Leviticus A. “L.A.” Lewis
  - Andrea Riley
  - Charlotte Davis
- Department of State Office of Outer Space Affairs
  - Ryan Guglietta
- NASA Office of International and Interagency Relations Mission
  - Rebecca Levy
- United Nations Office for Outer Space Affairs
  - Romana Kofler
- Space Mission Planning Advisory Group
  - Detlef Koschny
- Planetary Defense Office, European Space Agency
  - Richard Moissl
- Johns Hopkins Applied Physics Laboratory
  - Justin Atchison
  - Rylie Bull
  - Nancy Chabot
  - R. Terik Daly
  - Patrick King
  - Julee Rendon
  - Andrew Rivkin
  - Anne Roberts-Smith

- Ben Sheppard
  - Dipak Srinivasan
  - Angela Stickle
  - Megan Toms
  - Lisa Turner
  - Ruth Vogel
  - Scott Weinberg
- JPL Center for Near Earth Object Studies
  - Paul Chodas
  - Davide Farnocchia
  - Ryan Park
- NASA Ames Asteroid Threat Assessment Project
  - Michael Aftosmis
  - Ashley Coates
  - Jessie Dotson
  - Donovan Mathias
  - Lorien Wheeler
- NASA Goddard Space Flight Center
  - Brent Barbee
  - Josh Lyzhoft
  - Matt Vavrina
- NASA Langley
  - Daniel Mazanek
- National Science Foundation
  - Edward Ajhar
  - Bevin Ashley Vanderley
- Lawrence Livermore National Laboratory
  - Mary Burkey, SME
  - Kathryn Kumamoto, SME
  - Isaiah Santistevan, SME
  - Megan Syal, SME

- Los Alamos National Laboratory
  - Wendy Caldwell, SME
  - Catherine Plesko, SME

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Appendix C. Participating Organizations

Organizations of Exercise Participants

- Canadian Space Agency (CSA)
- Department of Defense (DoD)
- Department of Energy (DOE), National Nuclear Security Administration (NNSA)
- Department of Homeland Security (DHS)
- Department of State (DoS)
- European Space Agency (ESA)
- Federal Emergency Management Agency (FEMA)
- German Aerospace Center (DLR)
- International Asteroid Warning Network (IAWN)
- International Astronomical Union (IAU) Minor Planet Center (MPC)
- Japan Aerospace Exploration Agency (JAXA)
- Johns Hopkins University School of Advanced International Studies (SAIS)
- Lawrence Livermore National Laboratory (LLNL)
- Los Alamos National Laboratory (LANL)
- National Aeronautics and Space Administration (NASA)
- NASA Jet Propulsion Laboratory (JPL)/California Institute of Technology (Caltech)
- NASA Planetary Defense Coordination Office (PDCO)
- National Geospatial-Intelligence Agency (NGA)
- National Oceanic and Atmospheric Administration (NOAA)
- National Reconnaissance Office (NRO)
- National Science Foundation (NSF)
- National Space Council (NSpC) – Office of the Vice President
- Office of Science and Technology Policy (OSTP) – Executive Office of the President
- Rand Corporation
- Space Mission Planning Advisory Group (SMPAG)
- The Aerospace Corporation
- United Kingdom Space Agency (UKSA)
- United Nations Office for Outer Space Affairs (UNOOSA)

- United States Agency for International Development (USAID)
- United States Geological Survey (USGS)
- United States Space Command (USSPACECOM)
- United States Space Force (USSF)
- University of Cambridge
- University of Maryland (UMD)

Appendix D. Exercise Handouts – EXERCISE

D.1. IAWN Notification Memo – EXERCISE

EXERCISE **EXERCISE** **EXERCISE**

INTERNATIONAL ASTEROID WARNING NETWORK

Potential Asteroid Impact Notification: Hypothetical Scenario

Date: 2 April 2024

From: International Asteroid Warning Network (IAWN)

To: Chair, Space Mission Planning Advisory Group (SMPAG); United Nations Office of Outer Space Affairs (UNOOSA)

Title: Potential for the Impact of Near-Earth Asteroid 2023 TTX

Impact Probability	72% as calculated by NASA JPL CNEOS & ESA NEOCC
Impact Date:	12 July 2038
Impact Risk Corridor:	Potential impact locations span a corridor from the South Pacific across North America, the Atlantic, Iberian Peninsula, Mediterranean coast of Africa, Egypt, to the coast of Saudi Arabia.
Approximate Size:	Highly uncertain based on brightness and unknown surface reflectivity: most likely ~100–320 m (350–1000 ft), but potentially ~60–800 m in diameter.
Expected Damage Level if Impact Occurs:	Uncertain, but regional- to country-scale. Energy release most likely to be in the range of 6 to 750 megatons TNT, but potentially up to 15 gigatons TNT.

Additional details:

- There is a 72% probability that asteroid 2023 TTX will impact Earth on 12 July 2038, as calculated by the NASA JPL Center for Near-Earth Object Studies (CNEOS) and the ESA Near-Earth Objects Coordination Centre (NEOCC). While there is uncertainty in whether the asteroid will impact Earth, if an impact occurs it will be on this date.
- The impact risk corridor includes Mexico, United States of America, Portugal, Spain, Algeria, Tunisia, Libya, Egypt; a slight chance of very edges of Sudan and Saudi Arabia; and small chances of Vanuatu, Tuvalu, Kiribati in Melanesia/Polynesia. Figure 1 shows the risk corridor.
- There is a high probability that if the impact occurs, tens of thousands to millions of people could be affected by the potential damage from the impact based on the latest predicted impact corridor and risk modeling.
- The potential impact effects are highly dependent on the size of the asteroid and impact location. Nearly all cases cause large blast damage areas, likely reaching unsurvivable levels near the impact/airburst with larger outlying areas of structural damage, fires, and shattered windows. For the most likely size range, serious damage (including shattering windows, some structure damage) will occur over an area between 80–180 km (50–110 mi) in radius. The largest outer damage areas could extend over a region of 300 km (180 mi) or larger in radius. An impact in coastal waters could result in a tsunami that would inundate coastline areas, though tsunami risk and damage estimates are lower than local ground damage. Figure 2 summarizes the full impact risk, including damage assessments.

EXERCISE **EXERCISE** **EXERCISE**

- The asteroid 2023 TTX was discovered on 4 October 2023 by an Earth-based telescope in the southern hemisphere. The asteroid's absolute magnitude is 21.5 ± 0.3. Telescopes observed the asteroid almost daily between its discovery and 31 March 2024, when the asteroid became too close to the Sun to observe from the ground. The asteroid was identified in archival data, which helped refine the impact probability.
- Further observations will reduce the uncertainty in the asteroid's trajectory and impact probability. However, further ground-based observations will be impossible for the next seven months as the asteroid is too distant and appears too close to the Sun in the sky for telescopes to observe. Earth-based telescopes will be able to observe the asteroid again starting on 29 October 2024.
- The size of the asteroid cannot be estimated with further precision without radar observations or images from a spacecraft reconnaissance mission. The asteroid may come within radar range in July 2033 (5 years before potential impact). But, a successful detection depends on the asteroid's size and rotation period, both of which are highly uncertain at this time.

This notification is issued by the International Asteroid Warning Network (IAWN) in accordance with report SMPAG-RP-003 on "Recommended Criteria & Thresholds for Action for Potential NEO Impact Threat" that defines the threshold for issuing warnings of possible impact effects, which is a probability of impact is greater than 1% and a rough size estimated to be greater than 10 meters (33 feet).

IAWN is a worldwide collaboration of asteroid observers and modelers that was recommended by the United Nations (iawn.net)

Point of Contact: IAWN Coordinating Officer for the IAWN Steering Committee [email]

Graphics:

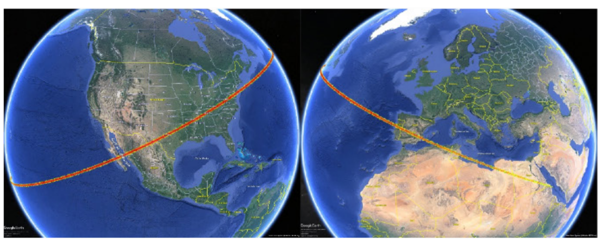


FIGURE 1. The impact risk corridor. If the asteroid is on track to impact Earth, the impact will occur at a point somewhere along the red swath. Potential impact locations span a corridor from the South Pacific across North America, the Atlantic, Iberian Peninsula, Mediterranean coast of Africa, Egypt, to the coast of Saudi Arabia.

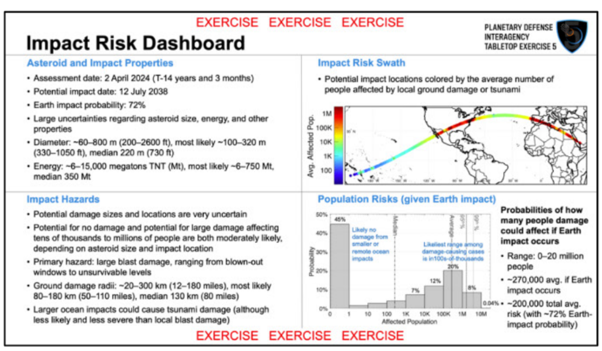


FIGURE 2. Impact risk summary, which provides a high-level overview of the asteroid threat and associated risks of impact.

D.2. Space Mission Options Handout – EXERCISE

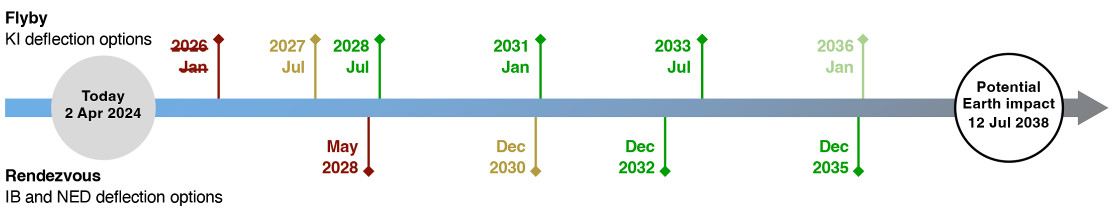
EXERCISE EXERCISE EXERCISE

SPACE MISSION OPTIONS

Hypothetical Scenario

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

MISSION OPTIONS BY ARRIVAL DATE



RECONNAISSANCE MISSION OPTIONS

FLYBY OPTIONS

Launch Date	Arrival Date	Relative Cost	Launch: Years from April 2024
~~Aug 2024~~	~~Jan 2026~~	~~$$~~	~~0.5~~
Nov 2025	Jul 2027	$$$	1.5
Sep 2027	Jul 2028	$	3.5
May 2029	Jan 2031	$ – $$	5
Jul 2032	Jul 2033	$ – $$	8
Aug 2034	Jan 2036	$	10

RENDEZVOUS OPTIONS

Launch Date	Arrival Date	Relative Cost	Launch: Years from April 2024
Jun 2026	May 2028	$$$$	2
Jul 2028	Dec 2030	$$$$	4
Jul 2029	Dec 2032	$$$	5
Jul 2033	Dec 2035	$$$	10

EARTH IMPACT PREVENTION MISSION OPTIONS

Mission	Time Frame			Date of			# of Launches for Deflection					
							50th Percentile			90th Percentile		
	Launch	Years from April 2024	Arrival	KI Deflection	NED Deflection	IB Deflection	KI	NED	IB	KI	NED	IB
IB or NED	Jun 2026	2	May 2028	-	Aug 2028	April 2036	-	1	3	-	1	18
KI	Sep 2027	3.5	Jul 2028	Jul 2028	-	-	1–2	-	-	7	-	-
IB or NED	Jul 2028	4	Dec 2030	-	Feb 2031	April 2036	-	1	4	-	1	>20
KI	May 2029	5	Jan 2031	Jan 2031	-	-	1–2	-	-	8	-	-
IB or NED	Jul 2029	5	Dec 2032	-	Aug 2033	April 2036	-	1	11	-	1	>20
KI	Jul 2032	8	Jul 2033	Jul 2033	-	-	1–2	-	-	7	-	-
NED	Jul 2033	9	Dec 2035	-	Feb 2036	*not feasible*	-	1	>20	-	1	>20
KI	Aug 2034	10	Jan 2036	Jan 2036	-	-	2	-	-	12	-	-

KI: Kinetic Impactor; IB: Ion Beam; NED: Nuclear Explosive Device

Spacecraft development schedule, assuming development starts immediately:
Red: >2 years faster than standard. Yellow: ~1 year faster than standard. Green: standard schedule is possible.

EXERCISE EXERCISE EXERCISE

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Appendix E. Abbreviations and Acronyms

APL	Johns Hopkins Applied Physics Laboratory
ATAP	Asteroid Threat Assessment Project (at NASA Ames Research Center)
C3	Command, Control, and Communications
CLPS	Commercial Lunar Payload Services
CNEOS	Center for Near Earth Object Studies (at NASA's Jet Propulsion Laboratory)
COA	Course of Action
COPUOS	UN Committee on the Peaceful Uses of Outer Space
CSA	Canadian Space Agency
DART	Double Asteroid Redirection Test
DHS	U.S. Department of Homeland Security
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DoS	U.S. Department of State
DTRA	Defense Threat Reduction Agency
EOP	Emergency Operations Plan
ESA	European Space Agency
ESF	Emergency Support Function
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GSFC	NASA Goddard Space Flight Center
HHS	U.S. Department of Health and Human Services
HSEEP	Homeland Security Exercise and Evaluation Program
IAU	International Astronomical Union
IAWN	International Asteroid Warning Network
IRTF	NASA Infrared Telescope Facility

ITAR	International Traffic in Arms Regulations
JPL	NASA Jet Propulsion Laboratory
JPLAN	*Joint Radiation Emergency Management Plan of the International Organizations*
LANL	Los Alamos National Laboratory
LCC	Life-Cycle Cost
LEO	Low Earth Orbit
LLNL	Lawrence Livermore National Laboratory
MPC	Minor Planet Center
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NED	Nuclear Explosive Device (*for NEO deflection*)
NEO	Near-Earth Object
NEOCC	ESA Near-Earth Object Coordination Centre
NFPA	National Fire Protection Association
NIMS	National Incident Management System
NITEP	U.S. Report on Near-Earth Object Impact Threat Emergency Protocols
NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NRF	National Response Framework
NRO	National Reconnaissance Office
NSF	National Science Foundation
NSpC	National Space Council
OCHA	UN Office for the Coordination of Humanitarian Affairs
OSIRIS-REx	Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer
OSTP	Office of Science and Technology Policy
PD	Planetary Defense

PDC	Planetary Defense Conference
PDCO	NASA Planetary Defense Coordination Office
PI	Principal Investigator
ROM	Rough Order of Magnitude
SME	Subject-Matter Expert
SMPAG	Space Mission Planning Advisory Group
TTX	Tabletop Exercise
UKSA	United Kingdom Space Agency
UN	United Nations
UNDRR	United Nations Office for Disaster Risk Reduction
UNOOSA	United Nations Office for Outer Space Affairs
UNSG	United Nations Secretary General
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
USAID	United States Agency for International Development
USGS	United States Geological Survey
USSPACECOM	United States Space Command

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Appendix F. Lessons Learned for Briefing Decision-Makers on NEO Threats

Participants provided feedback on the briefs and notifications provided during the exercise. Based on the data collected during the exercise, here are some ways to communicate more effectively on these topics and provide decision-makers with information that these participants would have found helpful but were not included in briefs.

- Update IAWN notification and SME briefs to include information about when updated information will be available and how that information is expected to change key uncertainties.
- Better convey in SME briefs how uncertainties in impact location and impact probability are likely to change so that information can be better understood in the context of decision-making.
- Update briefings to provide additional information participants expected senior leaders to want, such as possible COAs, timelines for needed decision, and estimated costs.
- Incorporate key decisions and timelines for those decisions into briefings about COAs.
- Include ROM costs of reconnaissance missions, including the phasing of funding relative to key decision points, when presenting mission options.
- Include analysis of cost of consequence management versus space missions in briefings about COAs.
- Call out specific practical repurposing possibilities for the senior leaders up front. Revise messaging packages to convey the timelines more clearly for decision-making, where go/no-go points are located, and the phasing of investments.
- Revise mission options timelines to show when decisions about whether to proceed with a particular mission need to be made in order for it to remain viable.
- Figure out compelling ways to illustrate which mission options fall off the table if you wait until a certain point and to illustrate what the impacts of that would be of delaying the reconnaissance data.
- Integrate timelines about mission options with expectations for what we will know from telescopes.
- Clarify with senior leadership what information they would want to know at this early stage of an asteroid impact threat.
- Prototype different ways of briefing information about COAs to senior leaders and learn from each iteration.

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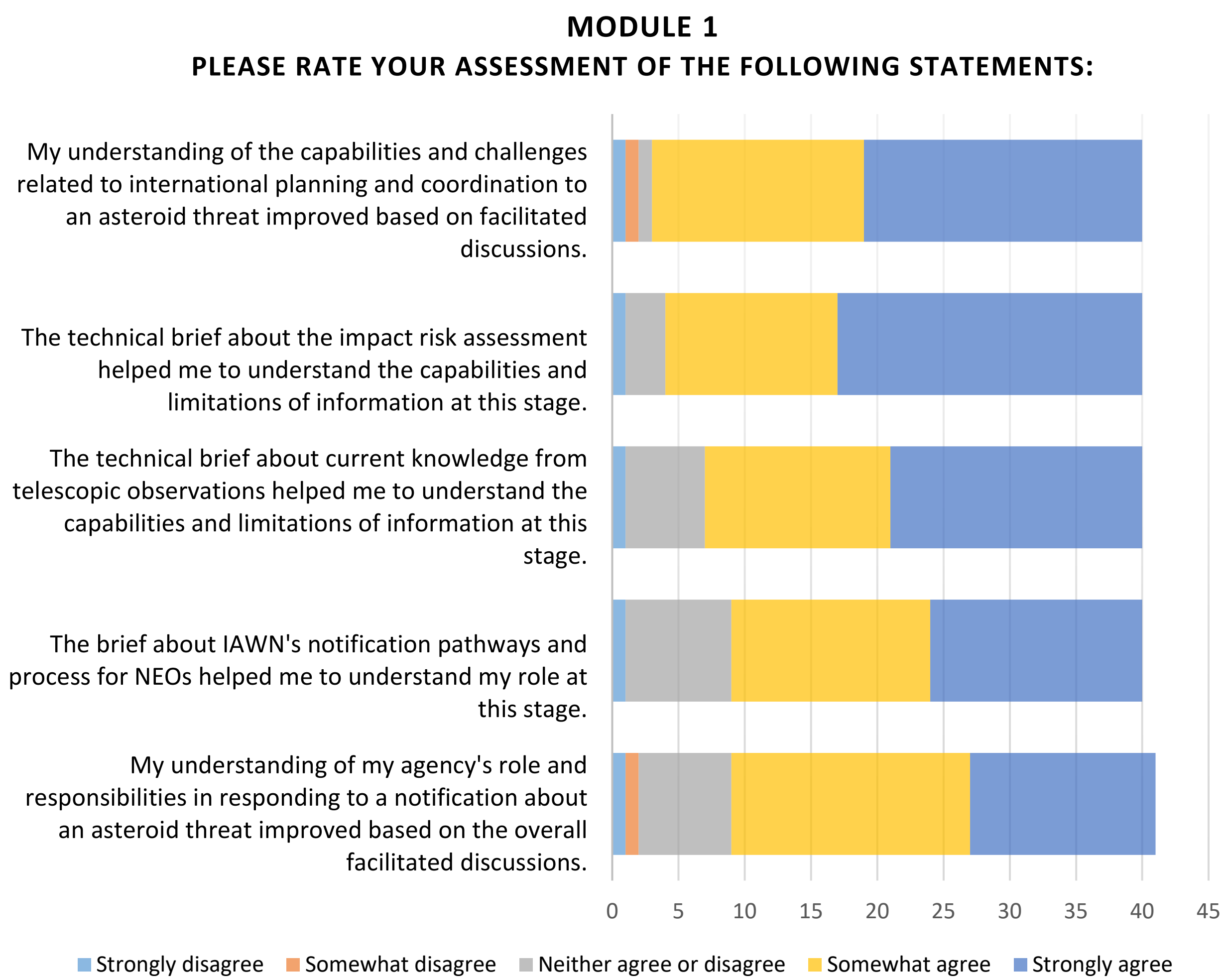
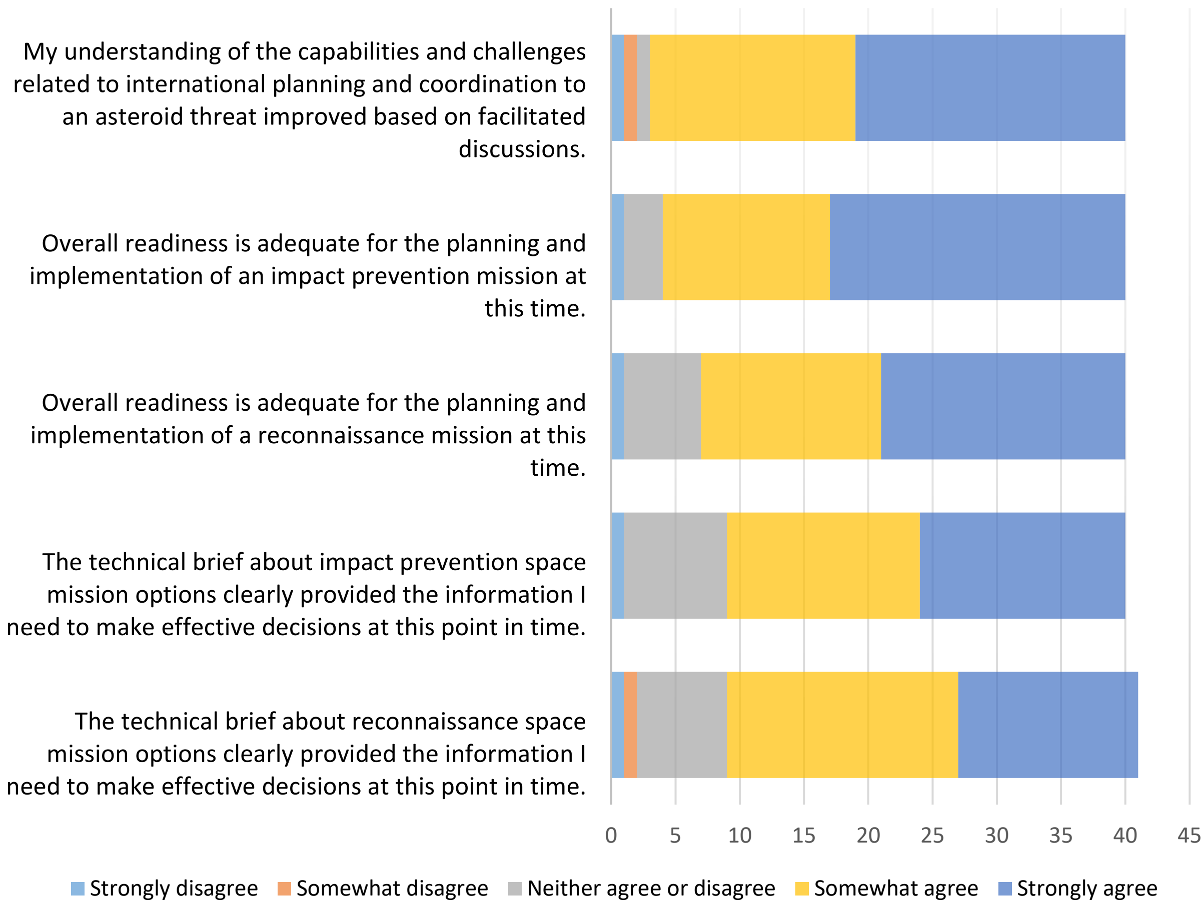
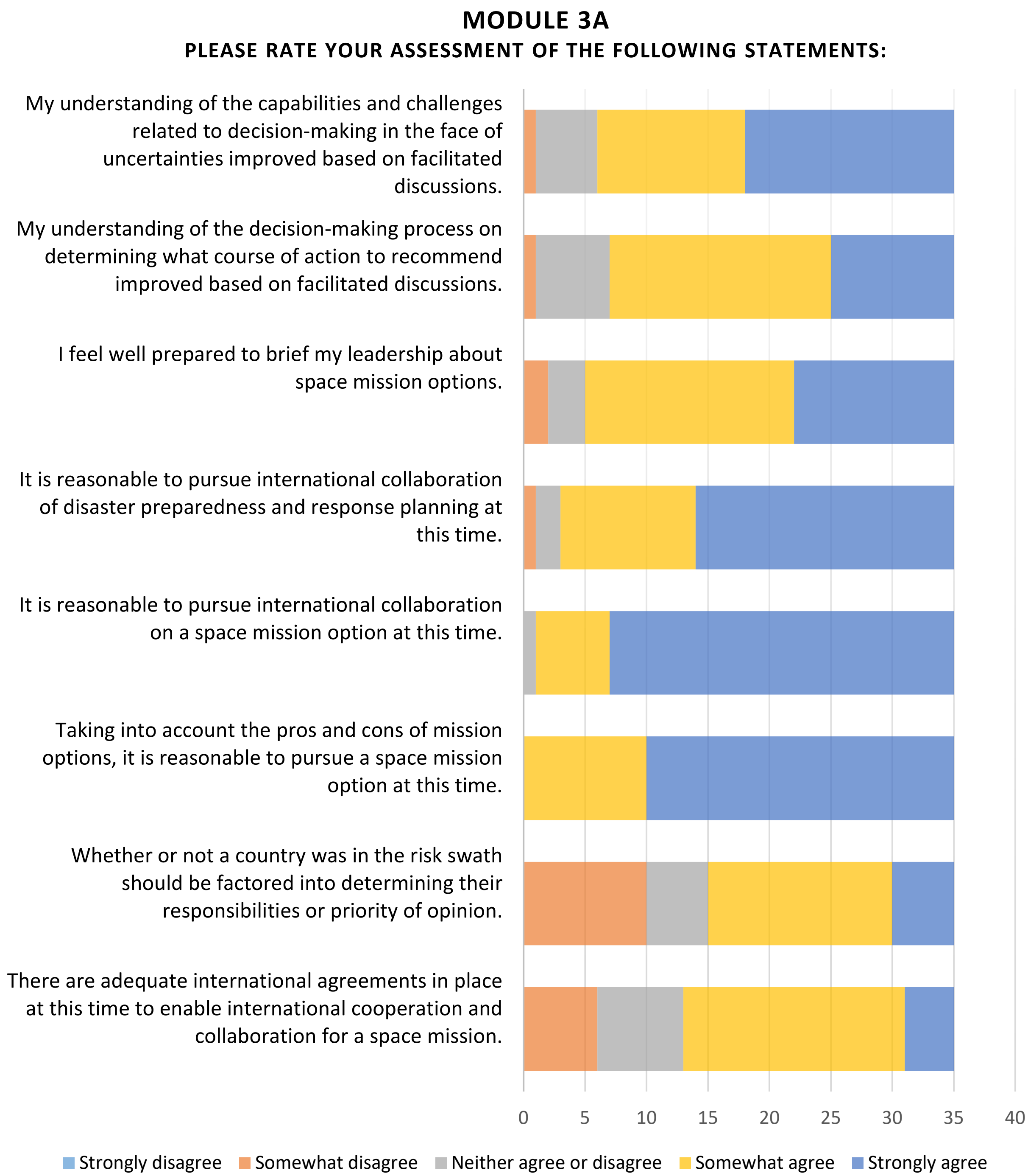
Appendix G. Participant Feedback



MODULE 2

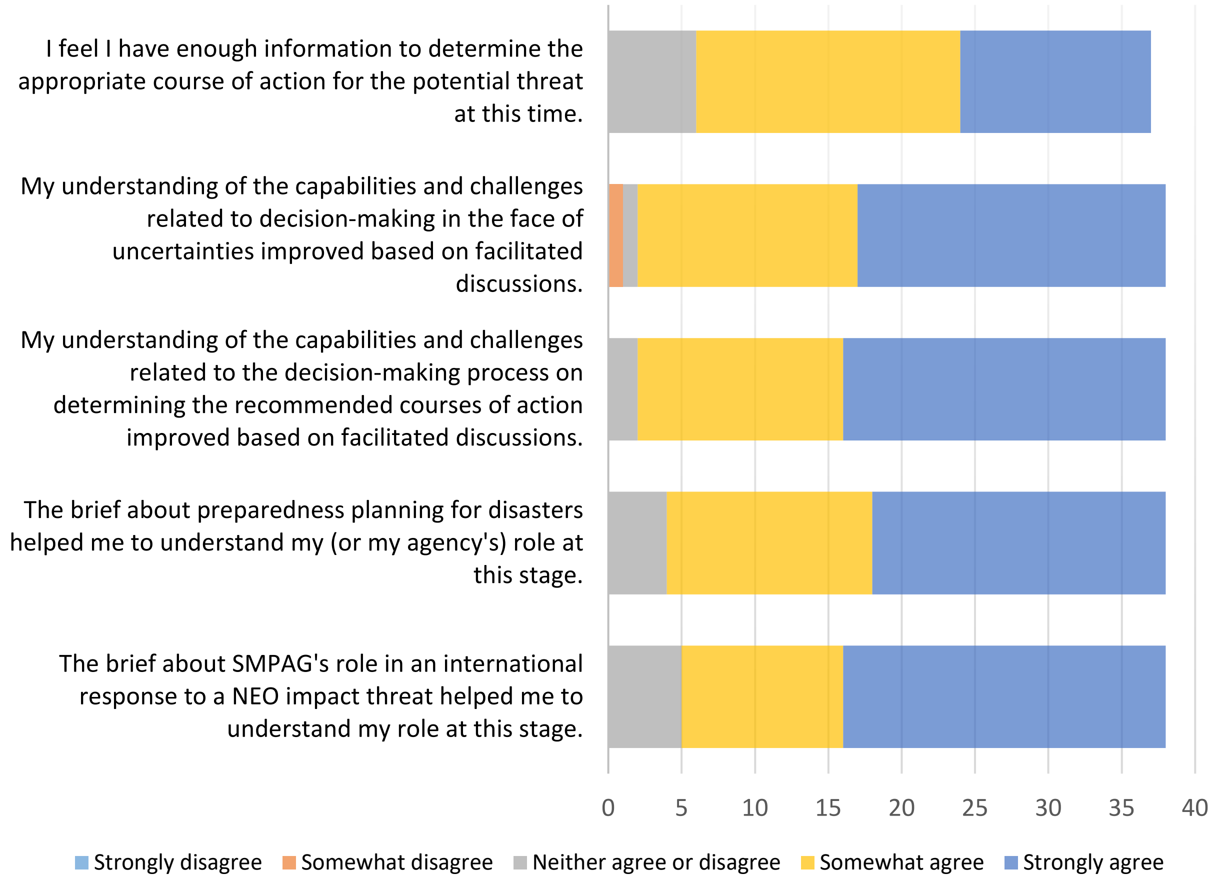
PLEASE RATE YOUR ASSESSMENT OF THE FOLLOWING STATEMENTS:




MODULE 3A
PLEASE RATE YOUR ASSESSMENT OF THE FOLLOWING STATEMENTS:
My understanding of the capabilities and challenges related to decision-making in the face of uncertainties improved based on facilitated discussions.
My understanding of the decision-making process on determining what course of action to recommend improved based on facilitated discussions.
I feel well prepared to brief my leadership about space mission options.
It is reasonable to pursue international collaboration of disaster preparedness and response planning at this time.
It is reasonable to pursue international collaboration on a space mission option at this time.
Taking into account the pros and cons of mission options, it is reasonable to pursue a space mission option at this time.
Whether or not a country was in the risk swath should be factored into determining their responsibilities or priority of opinion.
There are adequate international agreements in place at this time to enable international cooperation and collaboration for a space mission.
0
5
10
15
20
25
30
35
40
Strongly disagree
Somewhat disagree
Neither agree or disagree
Somewhat agree
Strongly agree

MODULE 3B - ALL PARTICIPANTS

PLEASE RATE YOUR ASSESSMENT OF THE FOLLOWING STATEMENTS:

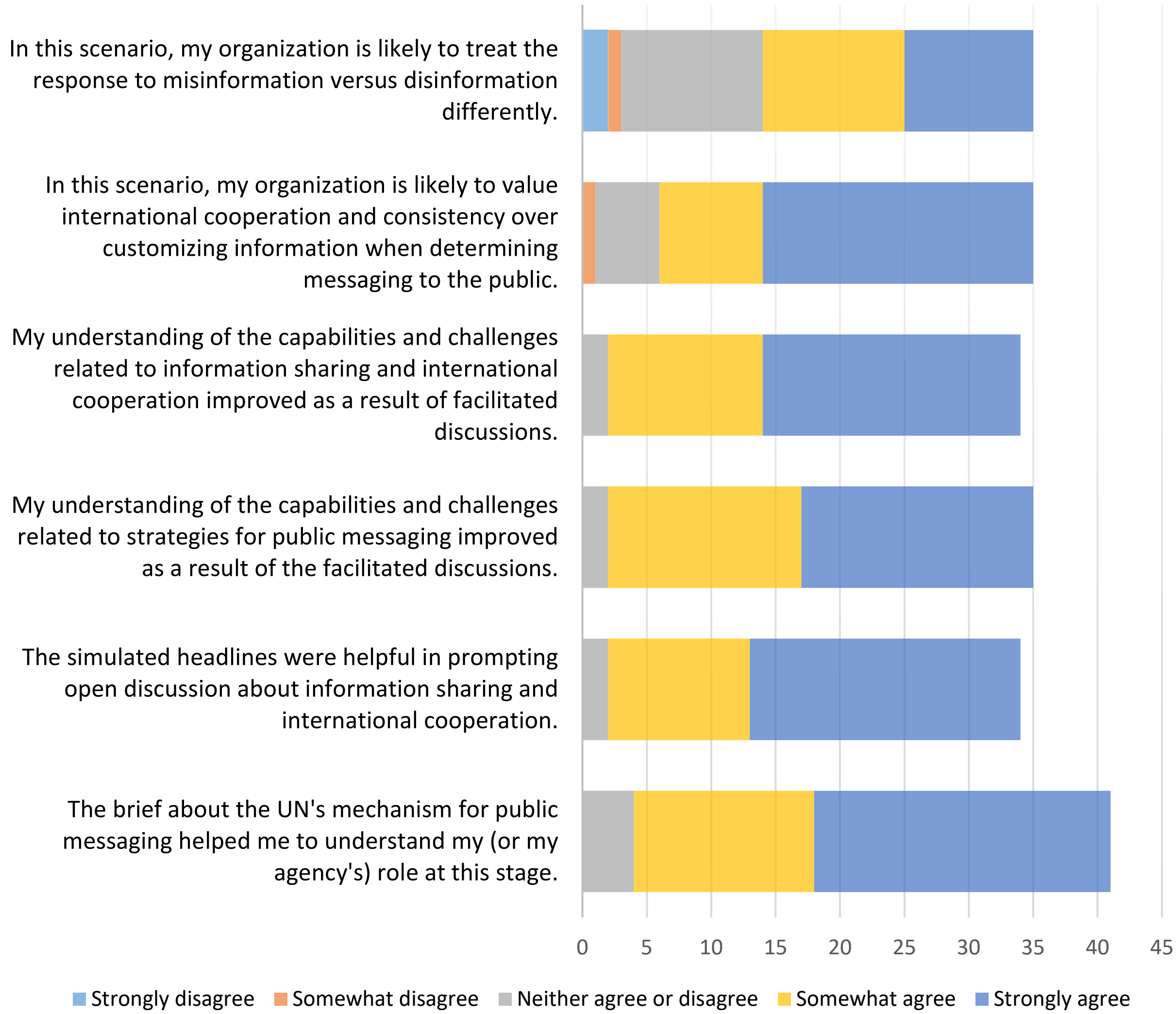


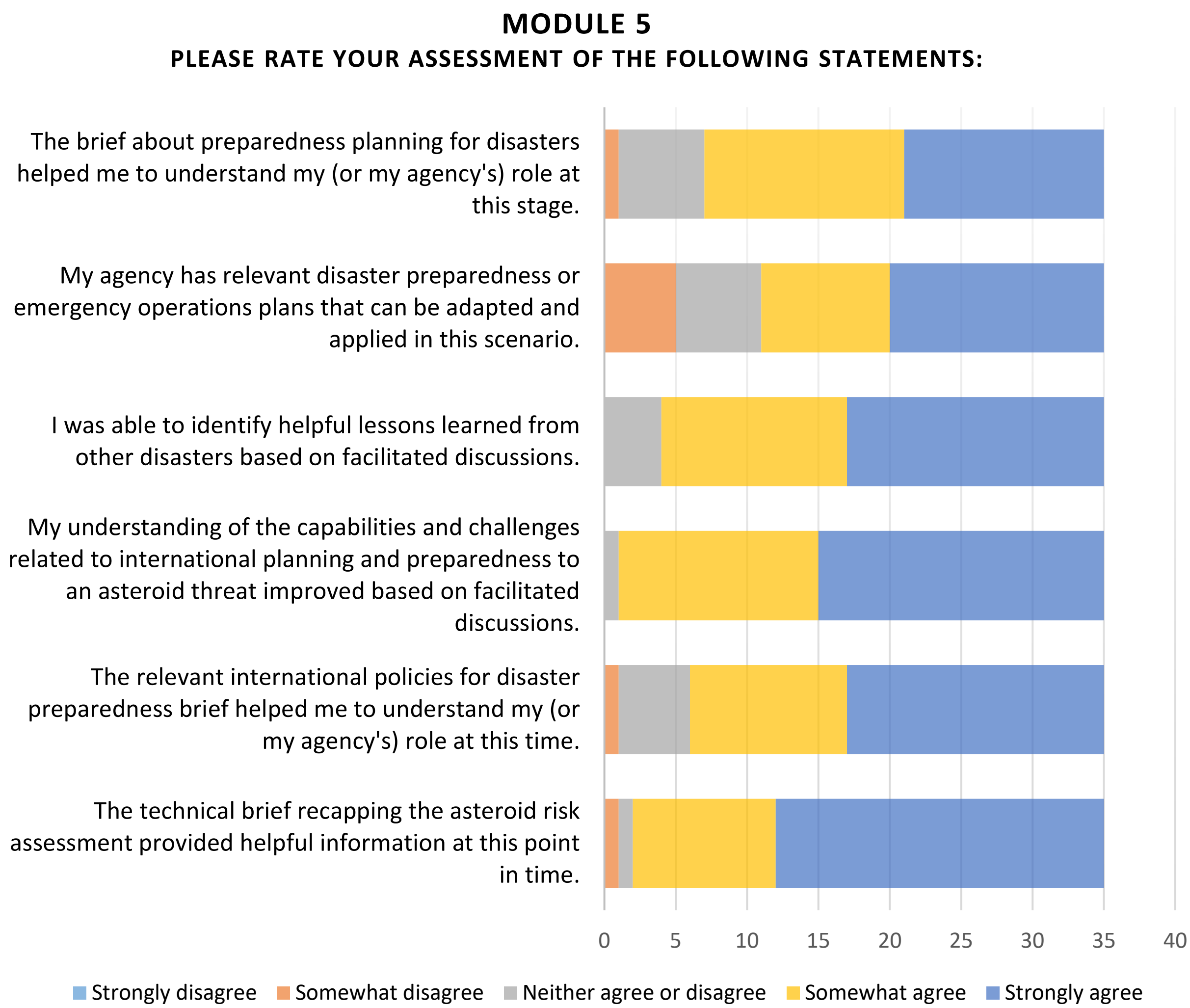
MODULE 3B - NEW PARTICIPANTS ONLY

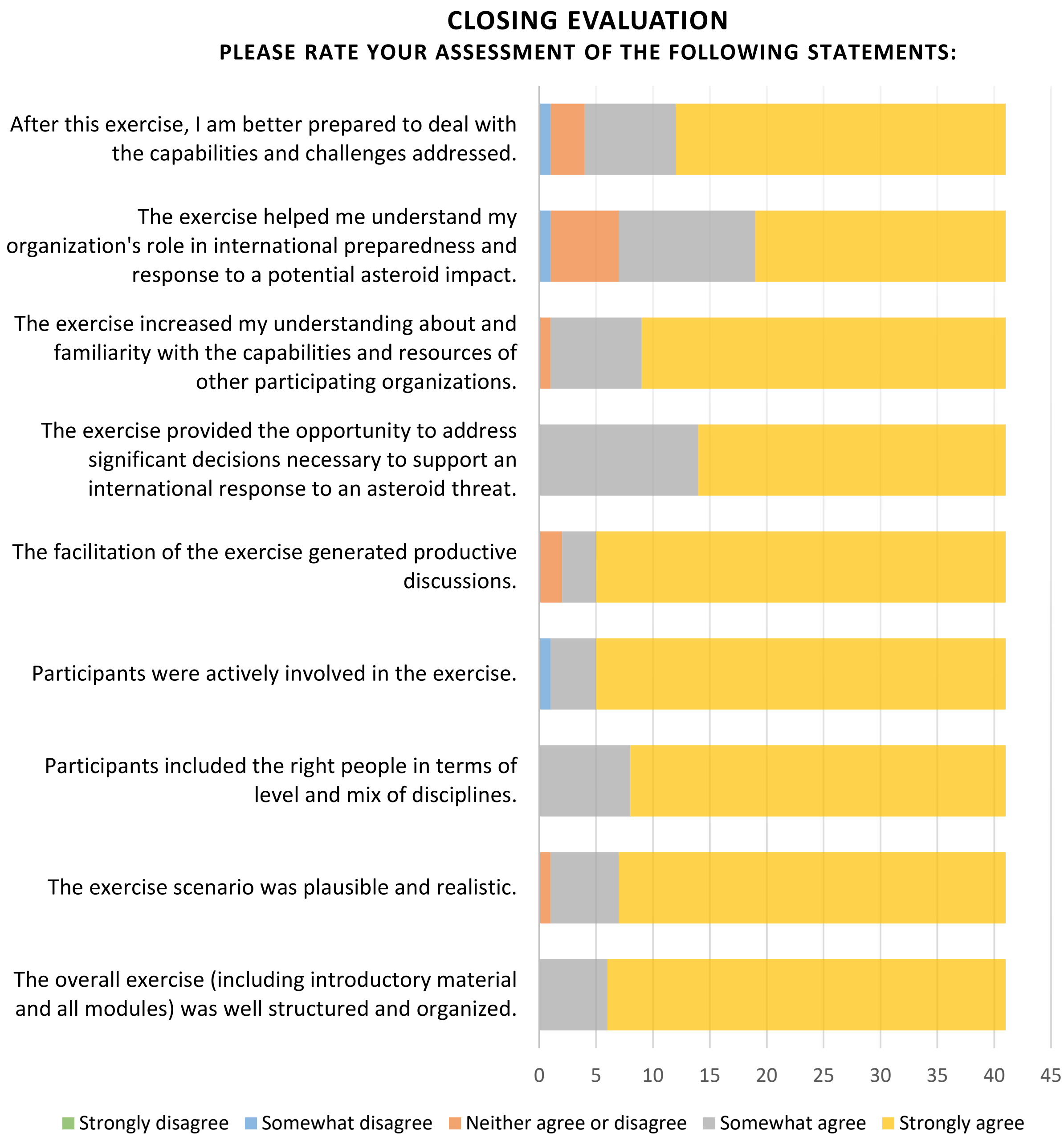
PLEASE RATE YOUR ASSESSMENT OF THE FOLLOWING STATEMENTS:

MODULE 4

PLEASE RATE YOUR ASSESSMENT OF THE FOLLOWING STATEMENTS:




MODULE 5
PLEASE RATE YOUR ASSESSMENT OF THE FOLLOWING STATEMENTS:
The brief about preparedness planning for disasters helped me to understand my (or my agency's) role at this stage.
My agency has relevant disaster preparedness or emergency operations plans that can be adapted and applied in this scenario.
I was able to identify helpful lessons learned from other disasters based on facilitated discussions.
My understanding of the capabilities and challenges related to international planning and preparedness to an asteroid threat improved based on facilitated discussions.
The relevant international policies for disaster preparedness brief helped me to understand my (or my agency's) role at this time.
The technical brief recapping the asteroid risk assessment provided helpful information at this point in time.
0
5
10
15
20
25
30
35
40
Strongly disagree
Somewhat disagree
Neither agree or disagree
Somewhat agree
Strongly agree



CLOSING EVALUATION
PLEASE RATE YOUR ASSESSMENT OF THE FOLLOWING STATEMENTS:
After this exercise, I am better prepared to deal with the capabilities and challenges addressed.
The exercise helped me understand my organization's role in international preparedness and response to a potential asteroid impact.
The exercise increased my understanding about and familiarity with the capabilities and resources of other participating organizations.
The exercise provided the opportunity to address significant decisions necessary to support an international response to an asteroid threat.
The facilitation of the exercise generated productive discussions.
Participants were actively involved in the exercise.
Participants included the right people in terms of level and mix of disciplines.
The exercise scenario was plausible and realistic.
The overall exercise (including introductory material and all modules) was well structured and organized.
0
5
10
15
20
25
30
35
40
45
Strongly disagree
Somewhat disagree
Neither agree or disagree
Somewhat agree
Strongly agree

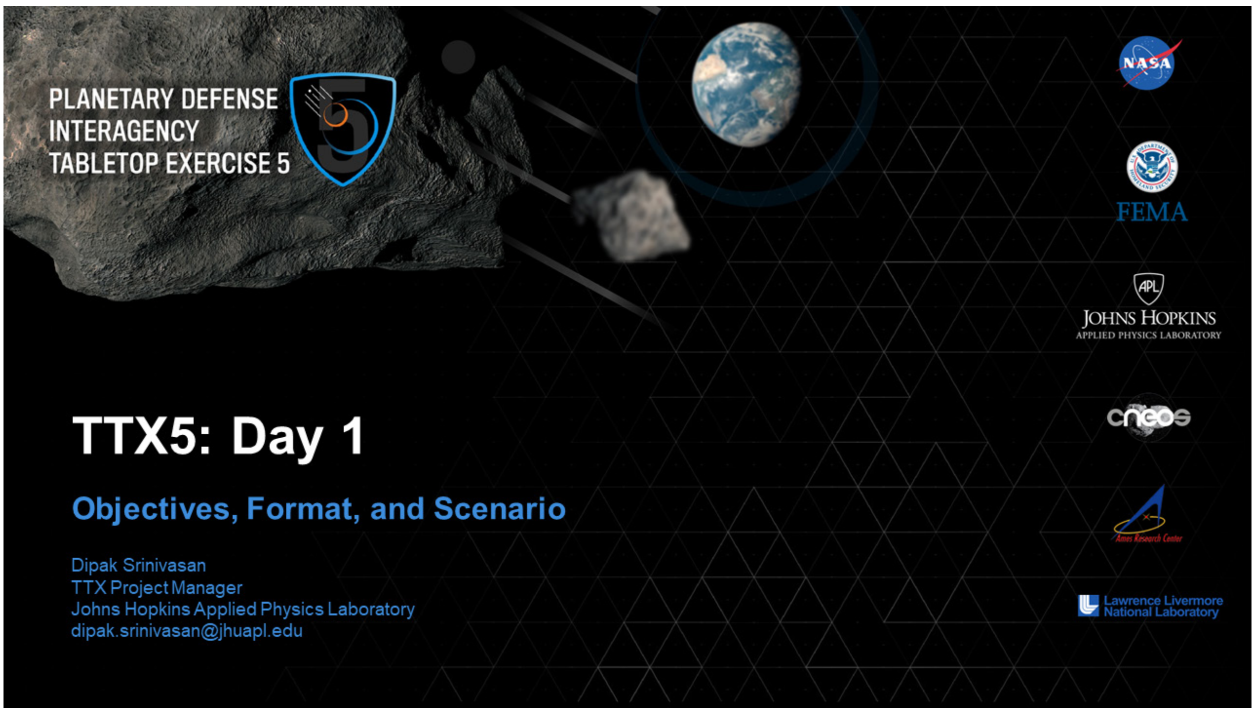
Appendix H. PD TTX5 Slides

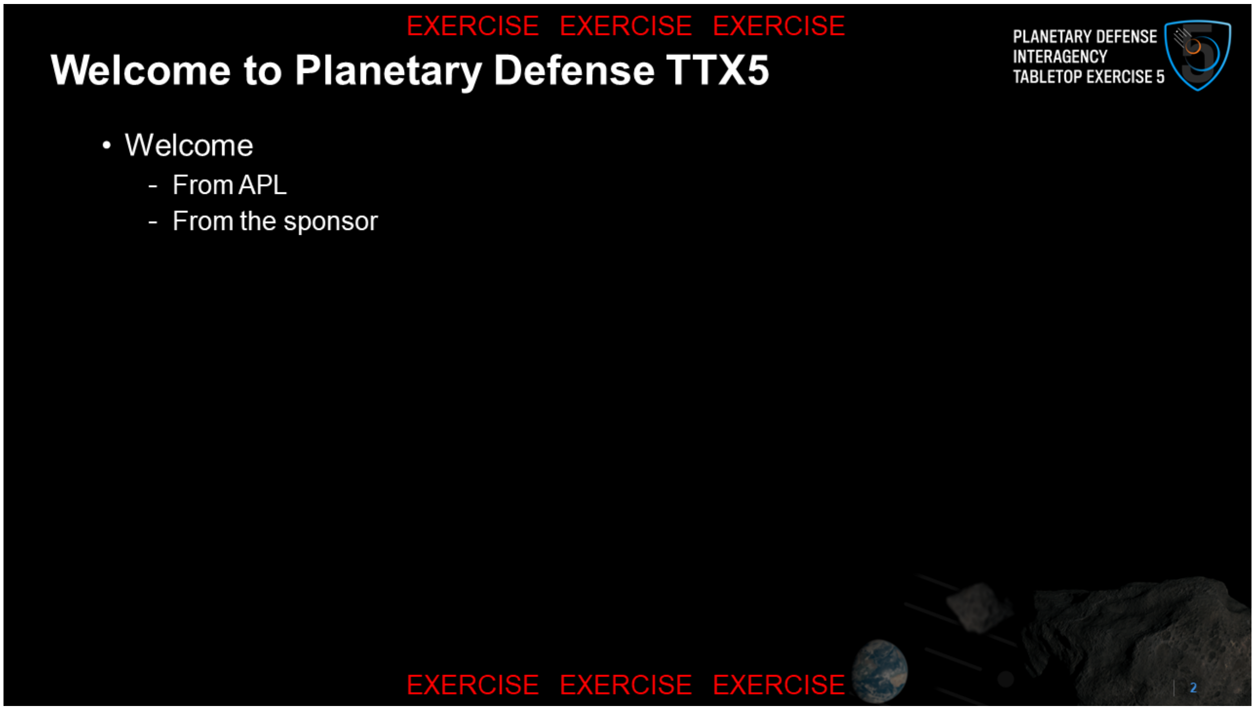
This appendix contains static versions of the as-presented slides from the 5th Planetary Defense (PD) Interagency Tabletop Exercise (TTX). The actual slides in some cases contained animations to better inform or describe the scenario.

These presentation materials are also available at https://cneos.jpl.nasa.gov/pd/cs/ttx24/.

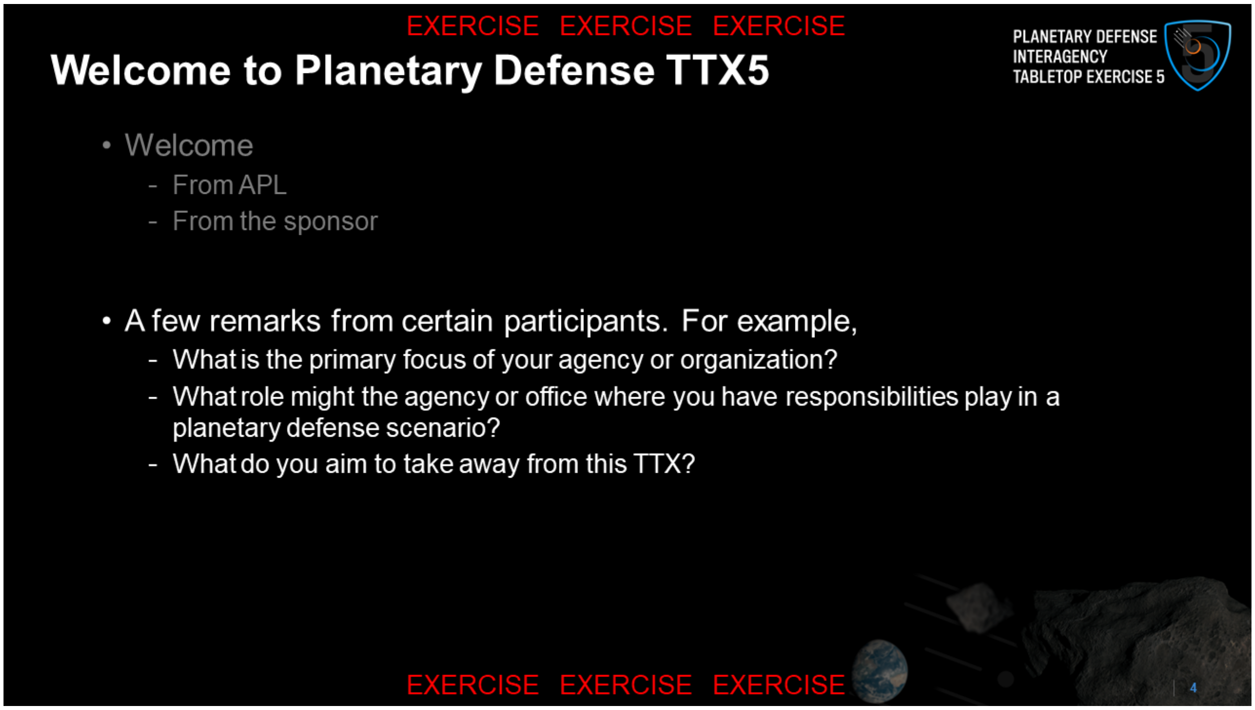
H.1. TTX5 Day 1

H.1.1. Introductory Material




EXERCISE EXERCISE EXERCISE
Welcome to Planetary Defense TTX5
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Welcome
- From APL
- From the sponsor
EXERCISE EXERCISE EXERCISE
2


ASSESS
Determine NEO population survey completeness and hazard from NEOs that pose the highest risk
CENTER FOR NEAR-EARTH OBJECT STUDIES (CNEOS)
PLANETARY DEFENSE COORDINATION OFFICE
SEARCH, DETECT & TRACK
Find the natural near-Earth objects – asteroids and comets – and track to determine those whose orbits create an impact hazard to Earth
GROUND & SPACE-BASED OBSERVATORIES, MINOR PLANET CENTER (MPC), INTERNATIONAL ASTEROID WARNING NETWORK
PLANETARY DEFENSE
MITIGATE
Demonstrate technologies and techniques to divert or disrupt asteroids in space or inform emergency response activities on the ground
DOUBLE ASTEROID REDIRECTION TEST (DART), FEMA EXERCISES
CHARACTERIZE
Determine physical characteristics of NEOs (size, shape, composition, rotation) to understand their natural state
INFRARED TELESCOPE FACIITY, GOLDSTONE SOLAR SYSTEM RADAR, NEOWISE
PLAN & COORDINATE
Work with the U.S. interagency and international collaborations on effective actions for impact threat response
SPACE MISSION PLANNING ADVISORY GROUP, PLANETARY IMPACT EMERGENCY RESPONSE WG, PLANETARY DEFENSE IWG


EXERCISE EXERCISE EXERCISE
Welcome to Planetary Defense TTX5
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Welcome
- From APL
- From the sponsor
• A few remarks from certain participants. For example,
- What is the primary focus of your agency or organization?
- What role might the agency or office where you have responsibilities play in a planetary defense scenario?
- What do you aim to take away from this TTX?
EXERCISE EXERCISE EXERCISE
4


2013/02/15 09:26:23
13 February 2013 near Chelyabinsk, Russia
5

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

An Excerpt from Asteroid Hunters

EXERCISE EXERCISE EXERCISE

6

EXERCISE EXERCISE EXERCISE

A Series of Planetary Defense Interagency TTXs

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

2013: TTX1

Acquaint FEMA with the nature of an asteroid impact and how warning of an impact might evolve if the object were detected a short time before possible impact

Time to impact:
1 month

2014: TTX2

Acquaint agencies with the nature and evolution of impending asteroid impact; assess whether and how processes and procedures for disaster warning and response might be employed

Time to impact:
7 years

2016: TTX3

Acquaint disaster response planners with the nature and evolution of information available for, and the inherent challenges of, a potential impact emergency

Time to impact:
4 years

2022: TTX4

Increase understanding of agencies' roles in mitigating near-Earth object (NEO) impact threats; exercise postimpact protocols, including at the state and local level; test communication methods

Time to impact:
6 months

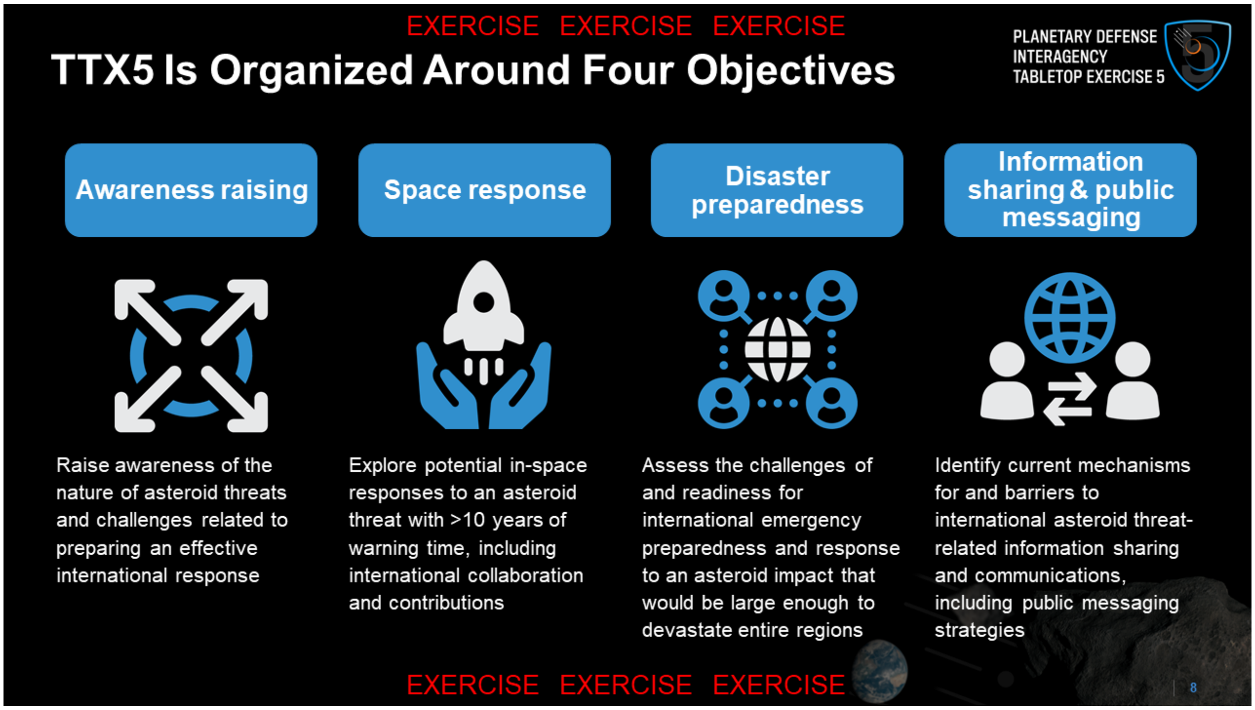
2024: TTX5

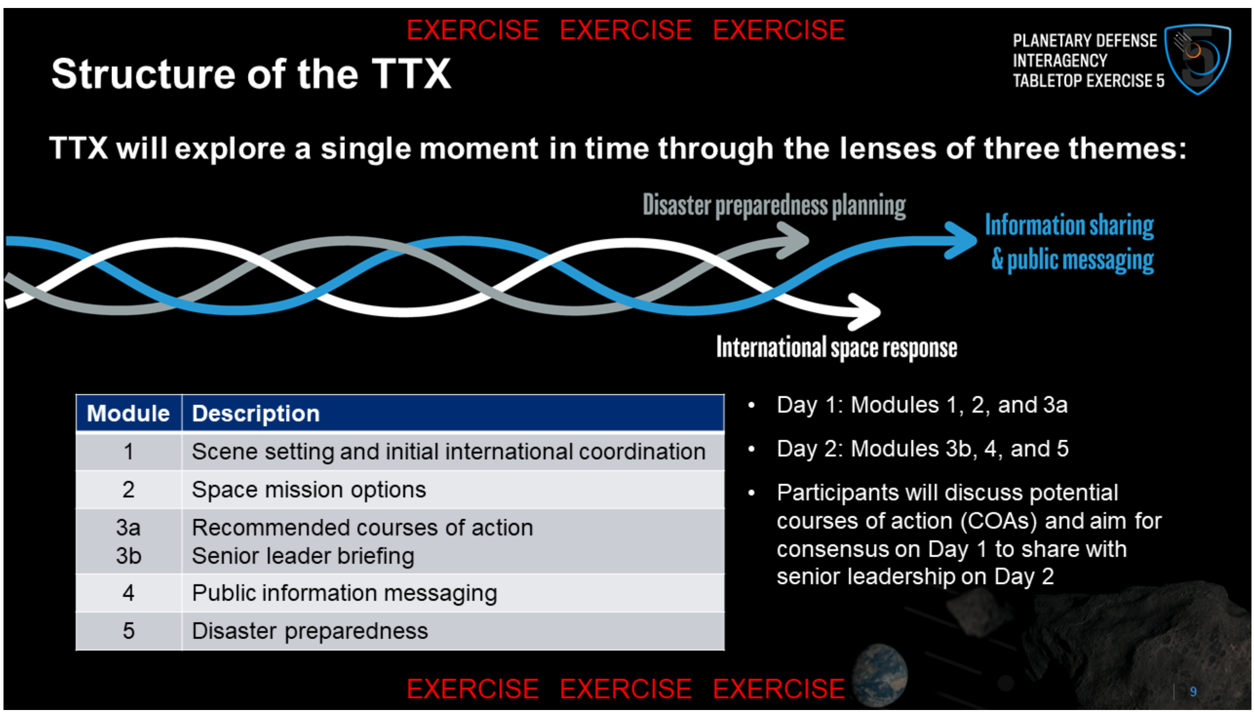
Raise awareness of NEO threats and their challenges; inform preparedness and response capabilities, including international coordination and involvement

Time to impact:
14 years

EXERCISE EXERCISE EXERCISE

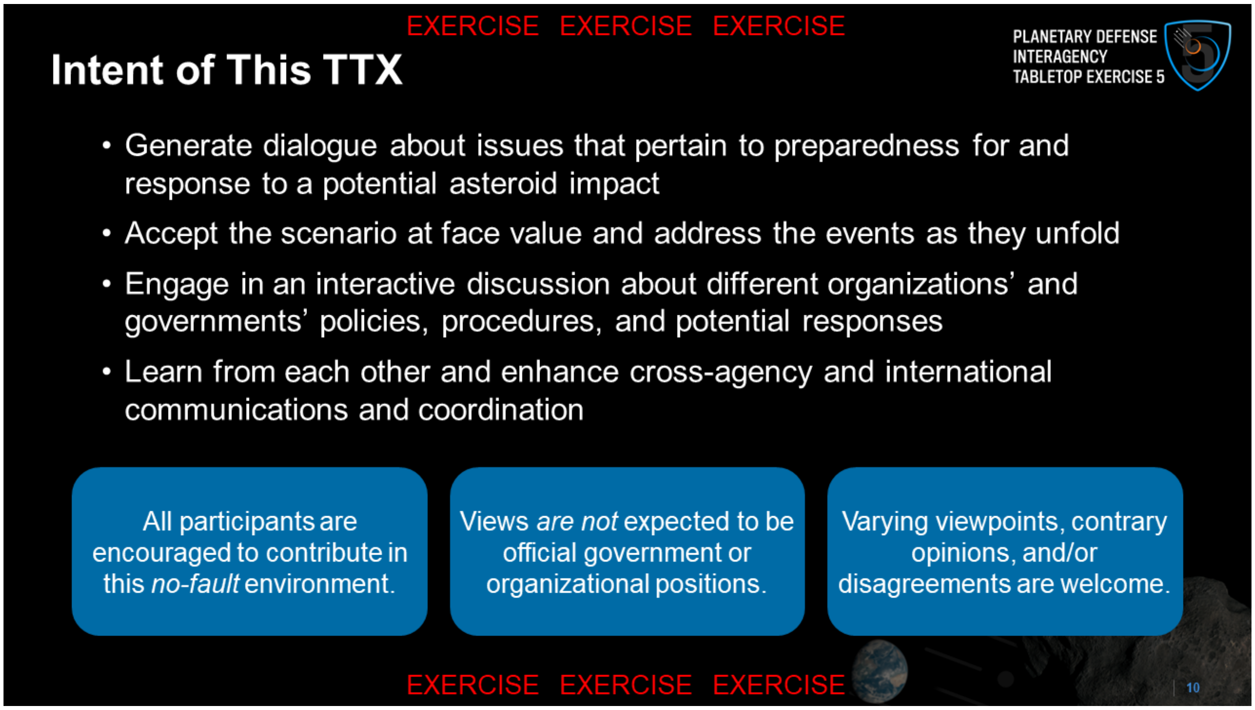
7

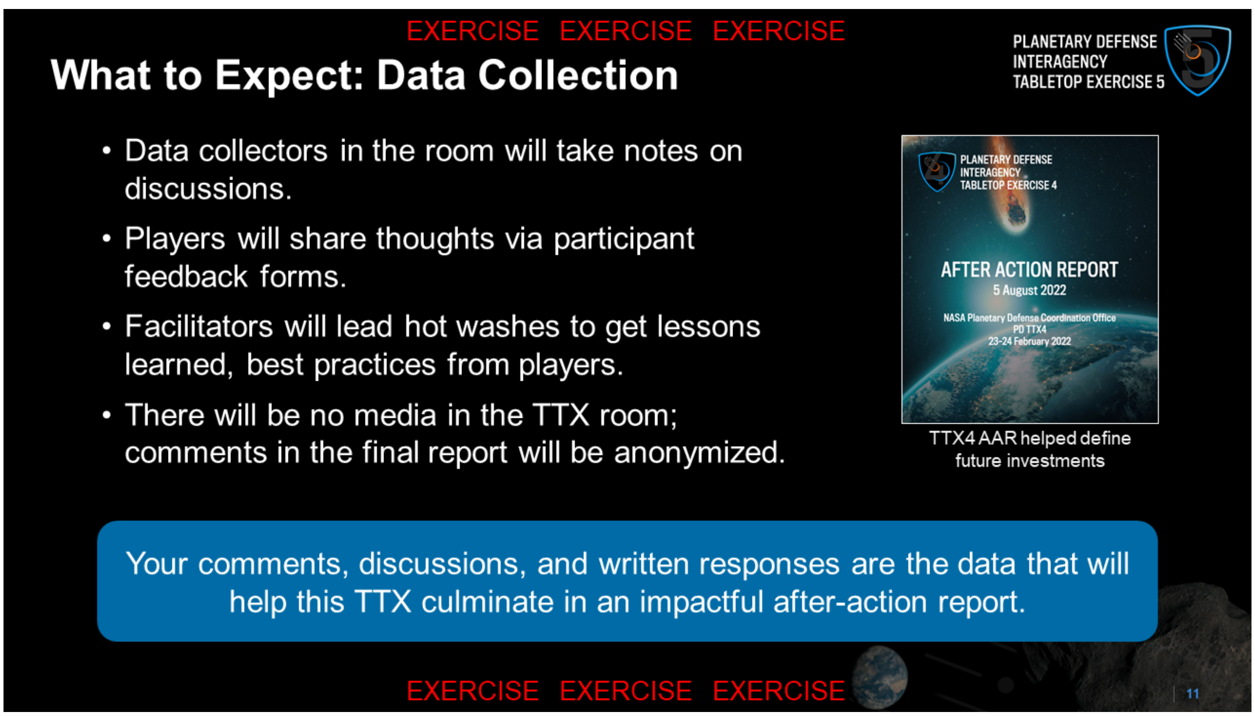

EXERCISE EXERCISE EXERCISE
TTX5 Is Organized Around Four Objectives
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Awareness raising
Space response
Disaster preparedness
Information sharing & public messaging
Raise awareness of the nature of asteroid threats and challenges related to preparing an effective international response
Explore potential in-space responses to an asteroid threat with >10 years of warning time, including international collaboration and contributions
Assess the challenges of and readiness for international emergency preparedness and response to an asteroid impact that would be large enough to devastate entire regions
Identify current mechanisms for and barriers to international asteroid threat-related information sharing and communications, including public messaging strategies
EXERCISE EXERCISE EXERCISE
8

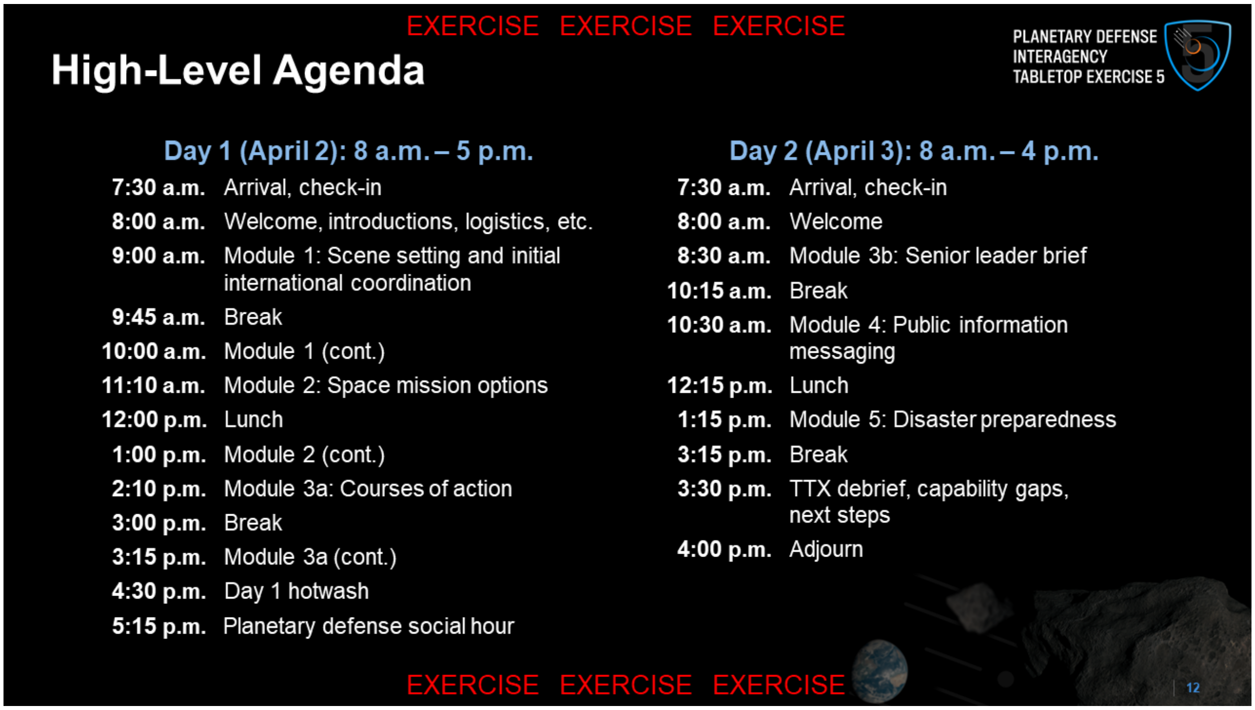

EXERCISE EXERCISE EXERCISE
Structure of the TTX
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
TTX will explore a single moment in time through the lenses of three themes:
Disaster preparedness planning
Information sharing & public messaging
International space response

Module	Description
1	Scene setting and initial international coordination
2	Space mission options
3a 3b	Recommended courses of action Senior leader briefing
4	Public information messaging
5	Disaster preparedness

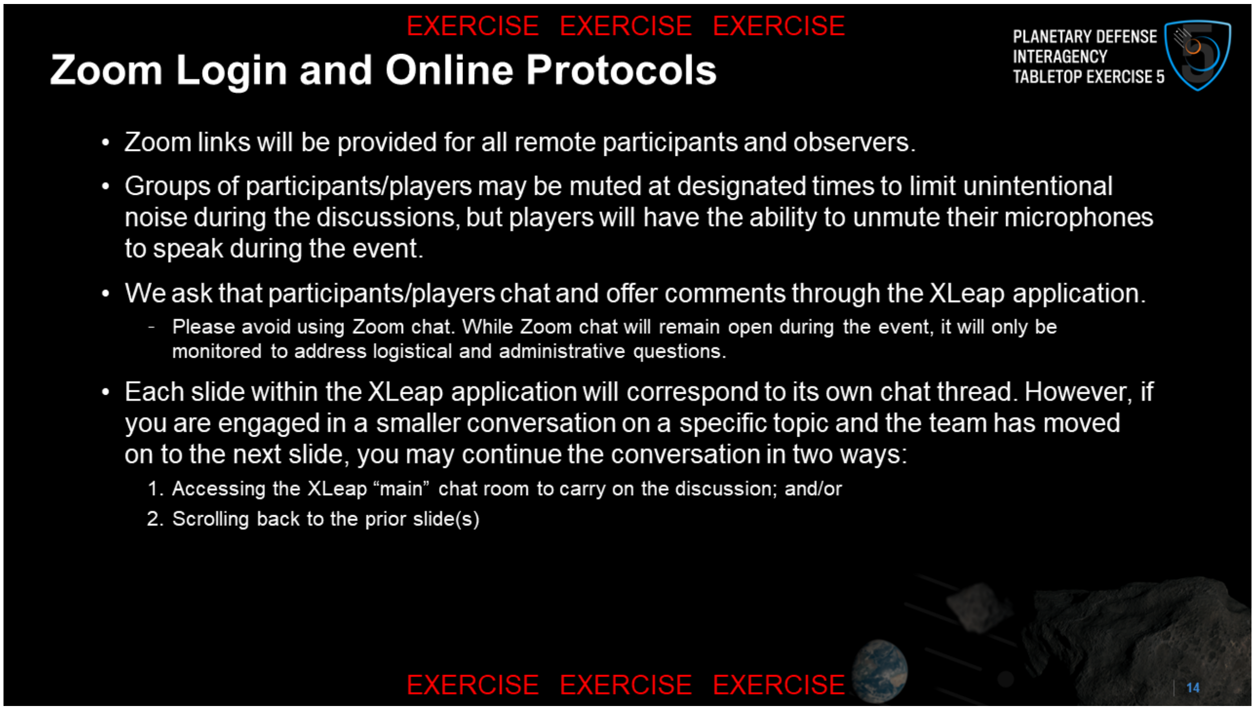
• Day 1: Modules 1, 2, and 3a
• Day 2: Modules 3b, 4, and 5
• Participants will discuss potential courses of action (COAs) and aim for consensus on Day 1 to share with senior leadership on Day 2
EXERCISE EXERCISE EXERCISE
9

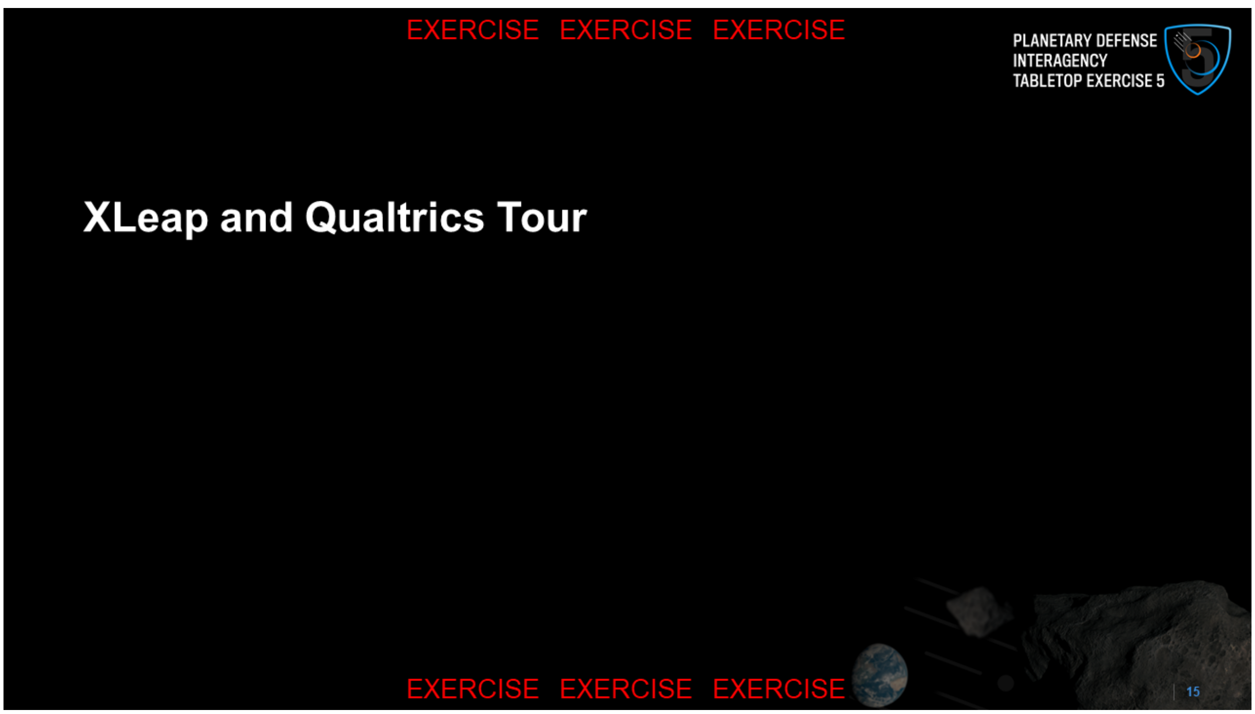

EXERCISE EXERCISE EXERCISE
Intent of This TTX
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Generate dialogue about issues that pertain to preparedness for and response to a potential asteroid impact
• Accept the scenario at face value and address the events as they unfold
• Engage in an interactive discussion about different organizations' and governments' policies, procedures, and potential responses
• Learn from each other and enhance cross-agency and international communications and coordination
All participants are encouraged to contribute in this no-fault environment.
Views are not expected to be official government or organizational positions.
Varying viewpoints, contrary opinions, and/or disagreements are welcome.
EXERCISE EXERCISE EXERCISE
10


EXERCISE EXERCISE EXERCISE
What to Expect: Data Collection
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Data collectors in the room will take notes on discussions.
• Players will share thoughts via participant feedback forms.
• Facilitators will lead hot washes to get lessons learned, best practices from players.
• There will be no media in the TTX room; comments in the final report will be anonymized.
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4
AFTER ACTION REPORT
5 August 2022
NASA Planetary Defense Coordination Office
PD TTX4
23-24 February 2022
TTX4 AAR helped define future investments
Your comments, discussions, and written responses are the data that will help this TTX culminate in an impactful after-action report.
EXERCISE EXERCISE EXERCISE
11

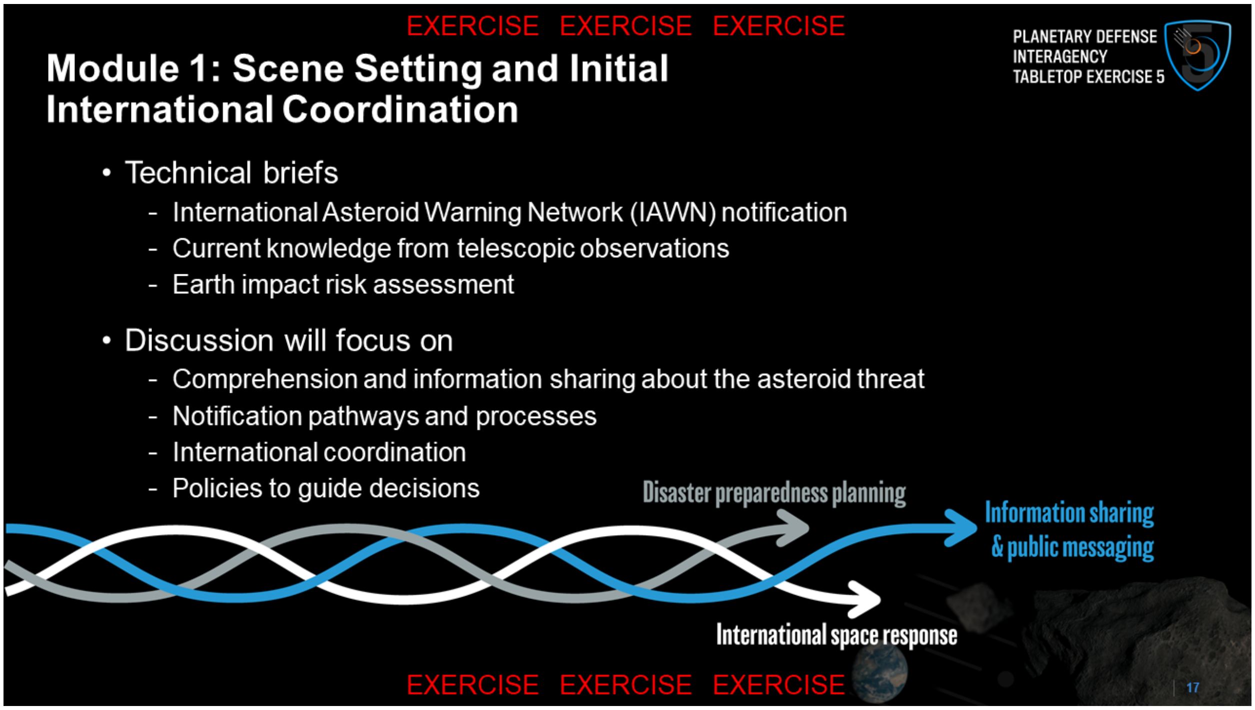

EXERCISE EXERCISE EXERCISE
High-Level Agenda
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Day 1 (April 2): 8 a.m. – 5 p.m.
7:30 a.m. Arrival, check-in
8:00 a.m. Welcome, introductions, logistics, etc.
9:00 a.m. Module 1: Scene setting and initial international coordination
9:45 a.m. Break
10:00 a.m. Module 1 (cont.)
11:10 a.m. Module 2: Space mission options
12:00 p.m. Lunch
1:00 p.m. Module 2 (cont.)
2:10 p.m. Module 3a: Courses of action
3:00 p.m. Break
3:15 p.m. Module 3a (cont.)
4:30 p.m. Day 1 hotwash
5:15 p.m. Planetary defense social hour
Day 2 (April 3): 8 a.m. – 4 p.m.
7:30 a.m. Arrival, check-in
8:00 a.m. Welcome
8:30 a.m. Module 3b: Senior leader brief
10:15 a.m. Break
10:30 a.m. Module 4: Public information messaging
12:15 p.m. Lunch
1:15 p.m. Module 5: Disaster preparedness
3:15 p.m. Break
3:30 p.m. TTX debrief, capability gaps, next steps
4:00 p.m. Adjourn
EXERCISE EXERCISE EXERCISE
12

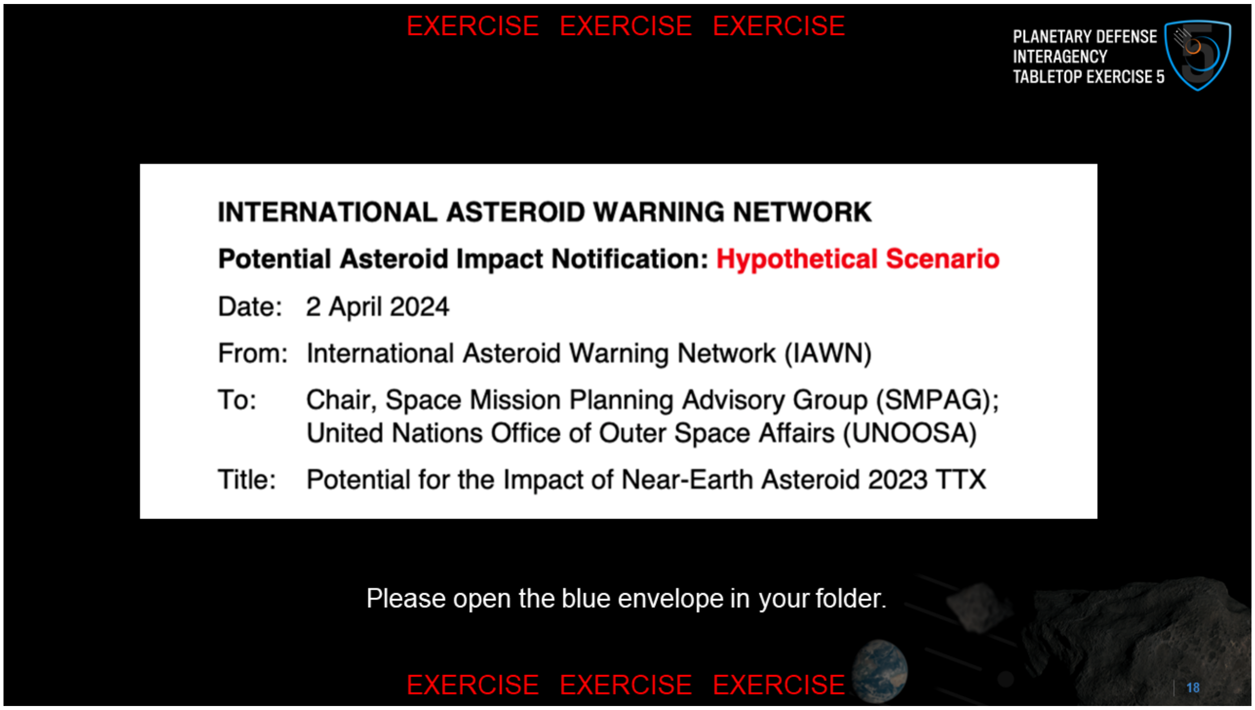

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Zoom, XLeap, and Qualtrics "How to" and Login
Online Protocols
Aaron Chrietzberg
Johns Hopkins Applied Physics Laboratory
Aaron.Chrietzberg@jhuapl.edu
240-228-9405
NASA
FEMA
APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
cneos
Lawrence Livermore National Laboratory


EXERCISE EXERCISE EXERCISE
Zoom Login and Online Protocols
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• Zoom links will be provided for all remote participants and observers.
• Groups of participants/players may be muted at designated times to limit unintentional noise during the discussions, but players will have the ability to unmute their microphones to speak during the event.
• We ask that participants/players chat and offer comments through the XLeap application.
- Please avoid using Zoom chat. While Zoom chat will remain open during the event, it will only be monitored to address logistical and administrative questions.
• Each slide within the XLeap application will correspond to its own chat thread. However, if you are engaged in a smaller conversation on a specific topic and the team has moved on to the next slide, you may continue the conversation in two ways:
1. Accessing the XLeap "main" chat room to carry on the discussion; and/or
2. Scrolling back to the prior slide(s)
EXERCISE EXERCISE EXERCISE
14

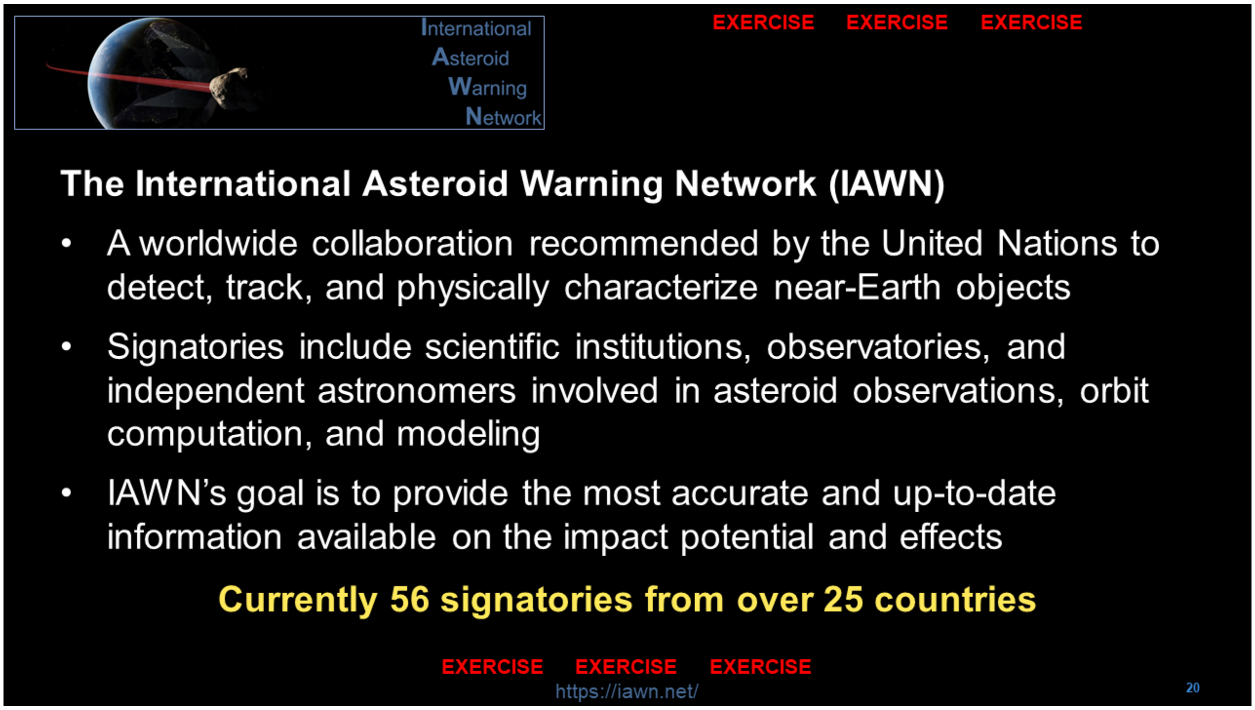

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
XLeap and Qualtrics Tour
EXERCISE EXERCISE EXERCISE
15

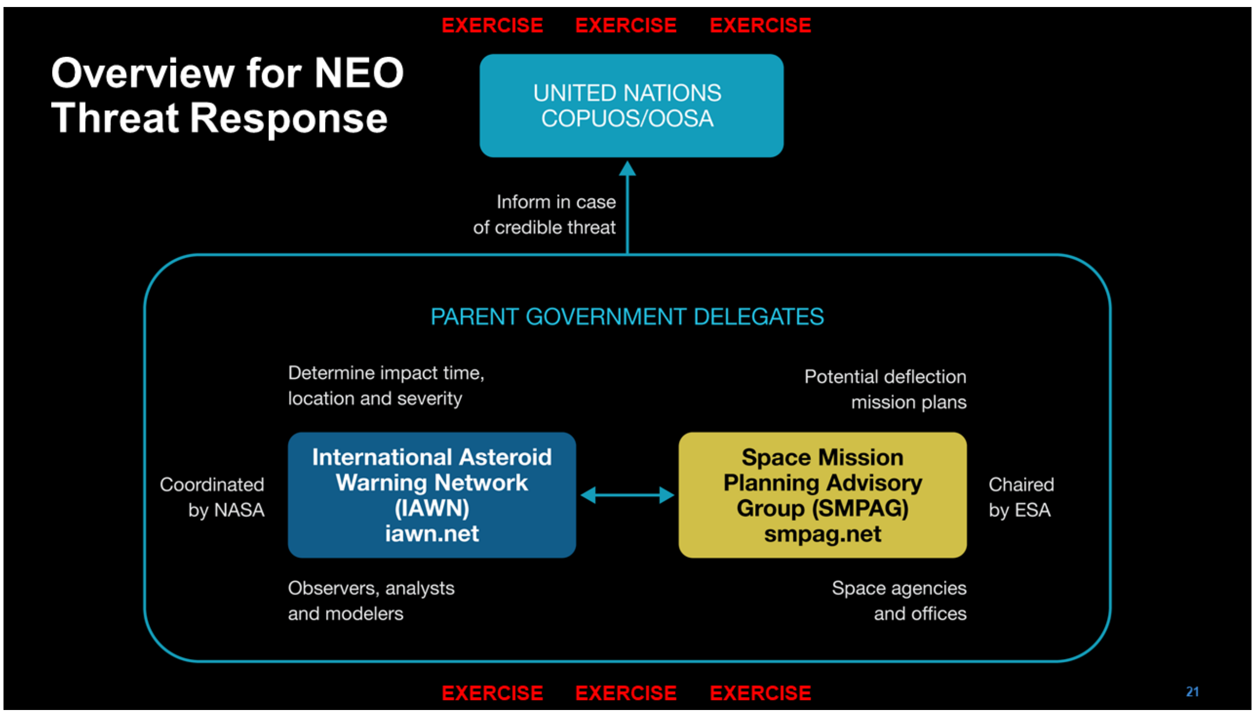
H.1.2. Module 1: Scene Setting and Initial International Coordination

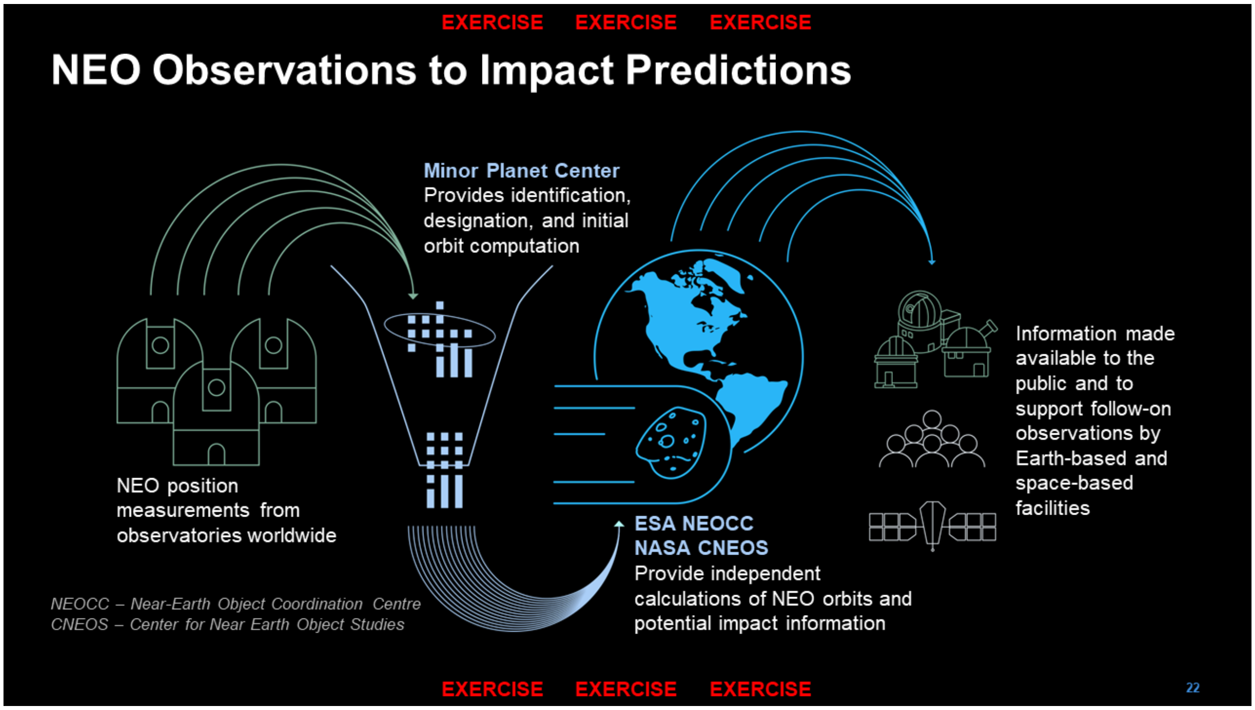


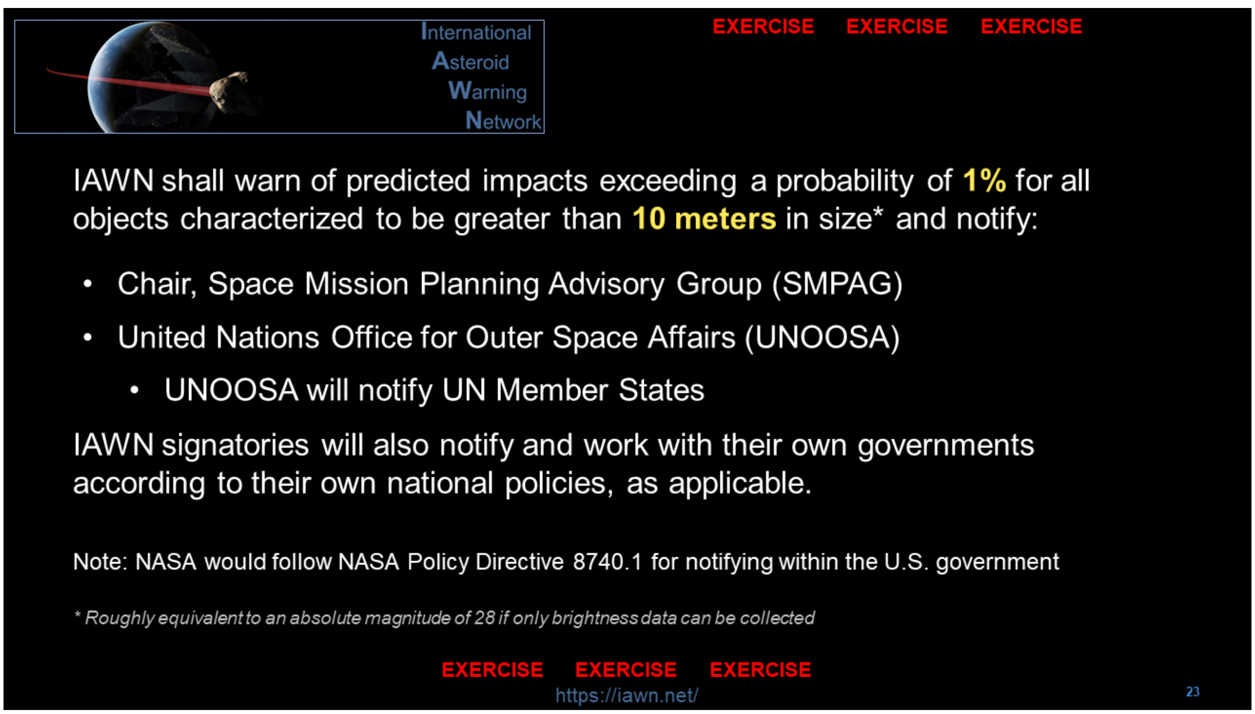

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
INTERNATIONAL ASTEROID WARNING NETWORK
Potential Asteroid Impact Notification: Hypothetical Scenario
Date: 2 April 2024
From: International Asteroid Warning Network (IAWN)
To: Chair, Space Mission Planning Advisory Group (SMPAG); United Nations Office of Outer Space Affairs (UNOOSA)
Title: Potential for the Impact of Near-Earth Asteroid 2023 TTX
Please open the blue envelope in your folder.
EXERCISE EXERCISE EXERCISE
18

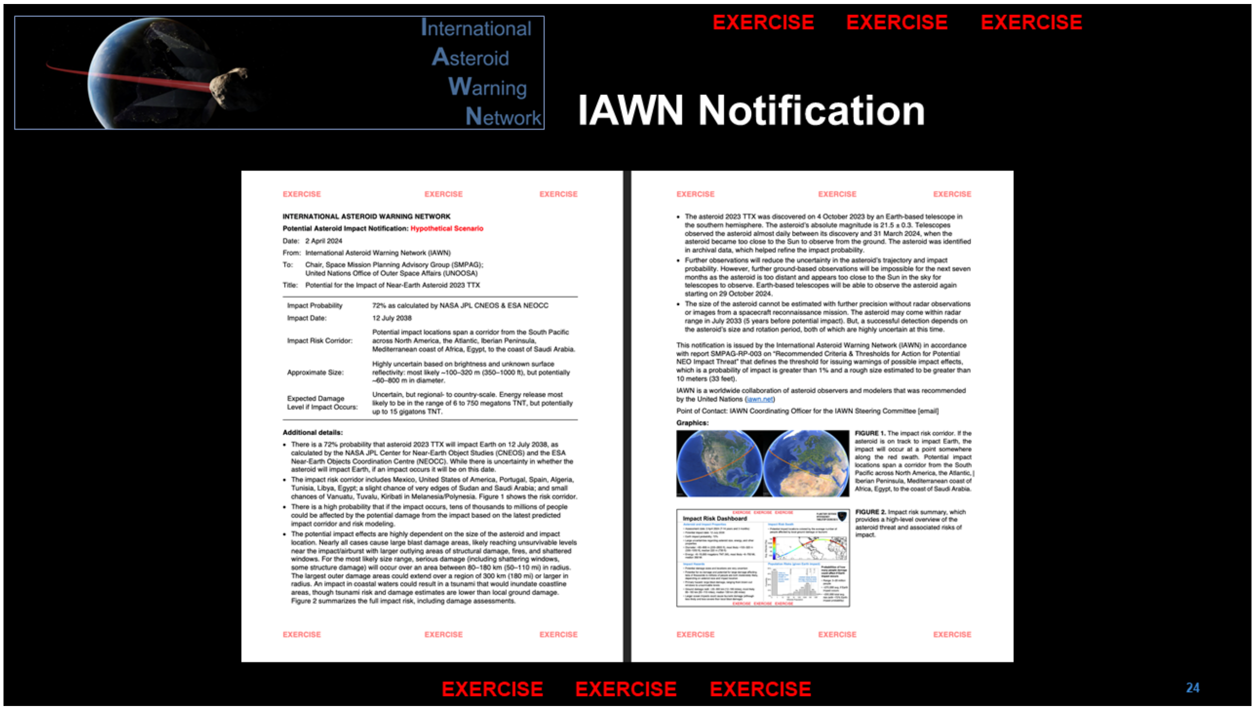

International Asteroid Warning Network
EXERCISE EXERCISE EXERCISE
Simulated Impact Threat Scenario
Notification by the International Asteroid Warning Network (IAWN)
Kelly Fast, NASA
IAWN Coordinating Officer
5th Interagency Planetary Defense Tabletop Exercise
April 2024
EXERCISE EXERCISE EXERCISE
https://iawn.net/

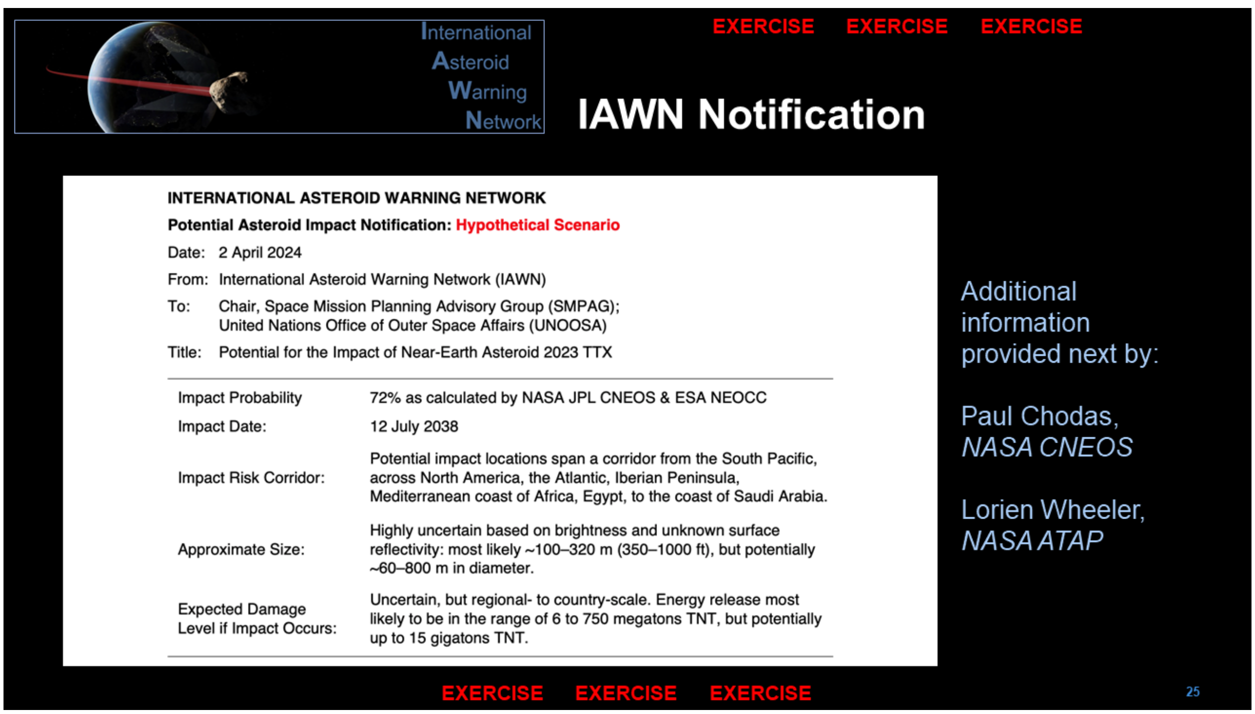

EXERCISE EXERCISE EXERCISE
International
Asteroid
Warning
Network
The International Asteroid Warning Network (IAWN)
• A worldwide collaboration recommended by the United Nations to detect, track, and physically characterize near-Earth objects
• Signatories include scientific institutions, observatories, and independent astronomers involved in asteroid observations, orbit computation, and modeling
• IAWN's goal is to provide the most accurate and up-to-date information available on the impact potential and effects
Currently 56 signatories from over 25 countries
EXERCISE EXERCISE EXERCISE
https://iawn.net/
20

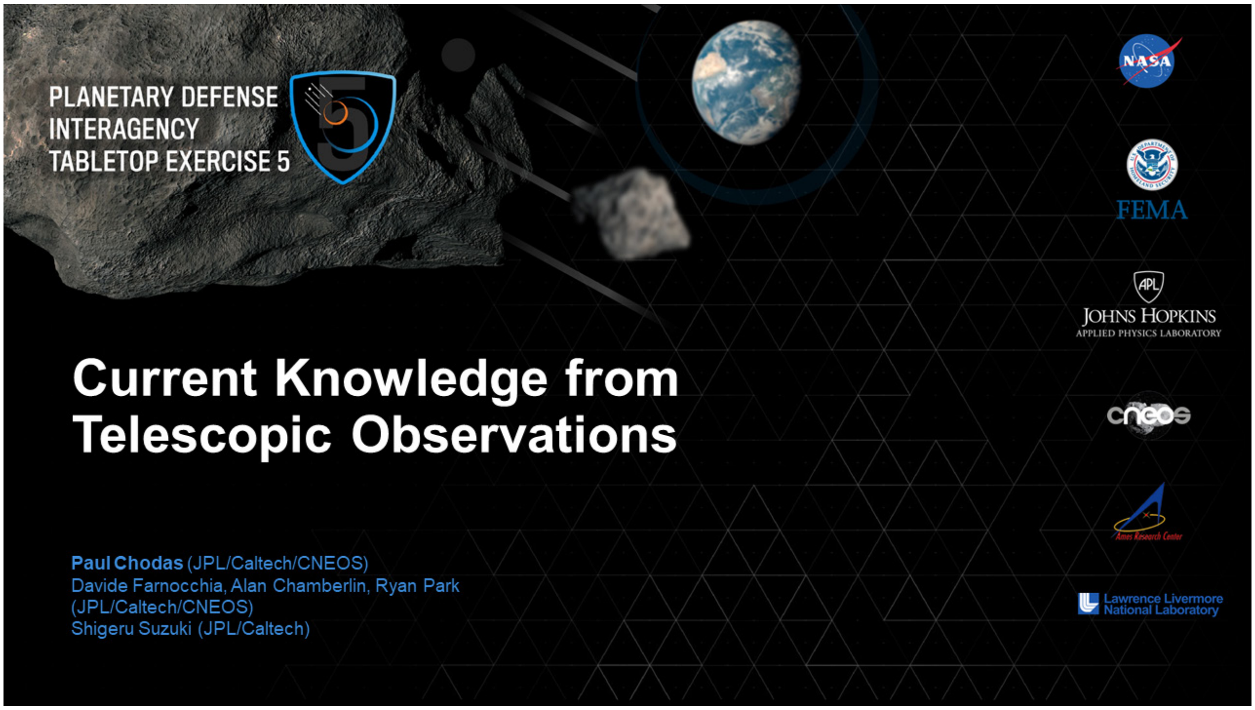

EXERCISE EXERCISE EXERCISE
Overview for NEO Threat Response
UNITED NATIONS COPUOS/OOSA
Inform in case of credible threat
PARENT GOVERNMENT DELEGATES
Determine impact time, location and severity
Potential deflection mission plans
Coordinated by NASA
International Asteroid Warning Network (IAWN) iawn.net
Space Mission Planning Advisory Group (SMPAG) smpag.net
Chaired by ESA
Observers, analysts and modelers
Space agencies and offices
EXERCISE EXERCISE EXERCISE
21

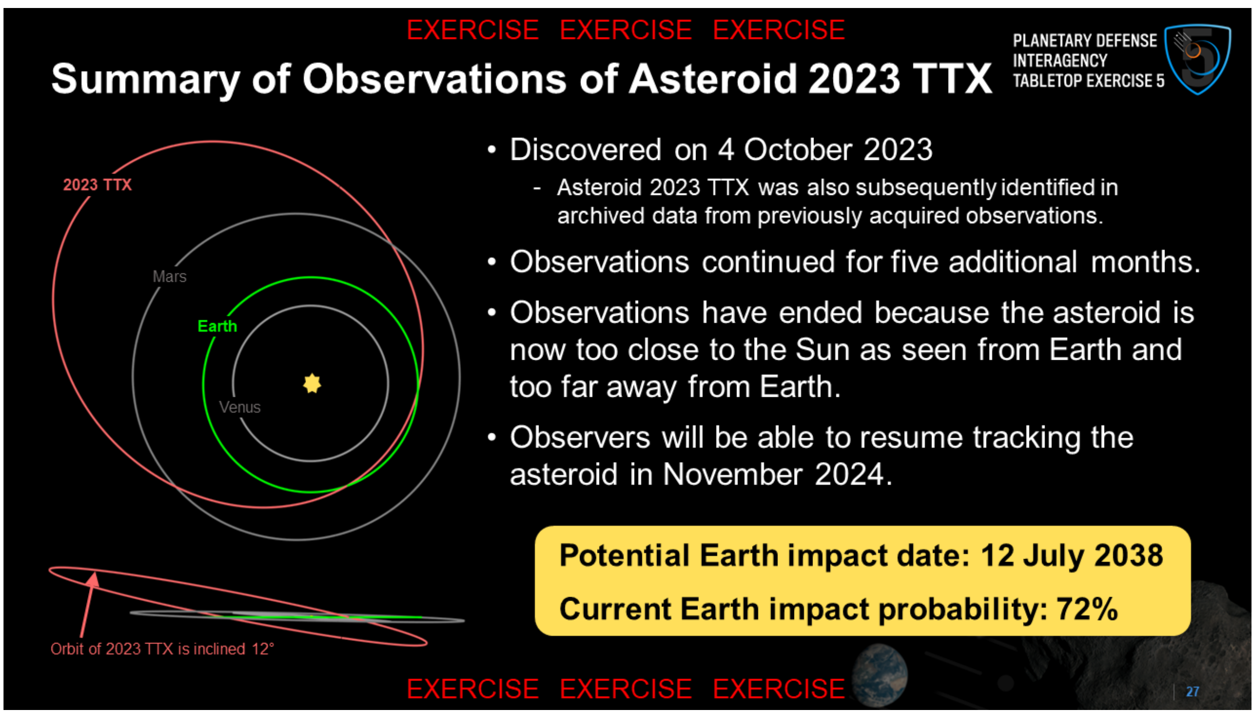

EXERCISE EXERCISE EXERCISE
NEO Observations to Impact Predictions
Minor Planet Center
Provides identification, designation, and initial orbit computation
NEO position measurements from observatories worldwide
ESA NEOCC
NASA CNEOS
Provide independent calculations of NEO orbits and potential impact information
Information made available to the public and to support follow-on observations by Earth-based and space-based facilities
NEOCC – Near-Earth Object Coordination Centre
CNEOS – Center for Near Earth Object Studies
EXERCISE EXERCISE EXERCISE
22

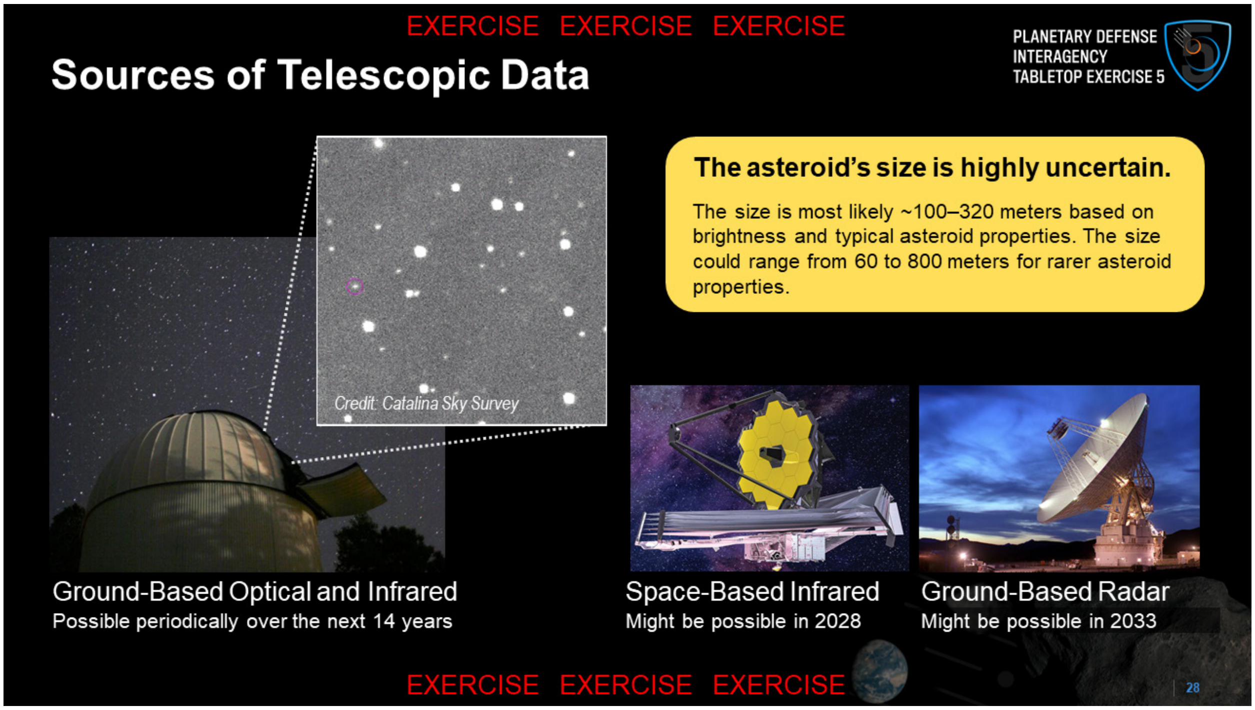

International Asteroid Warning Network
EXERCISE EXERCISE EXERCISE
IAWN shall warn of predicted impacts exceeding a probability of 1% for all objects characterized to be greater than 10 meters in size* and notify:
• Chair, Space Mission Planning Advisory Group (SMPAG)
• United Nations Office for Outer Space Affairs (UNOOSA)
• UNOOSA will notify UN Member States
IAWN signatories will also notify and work with their own governments according to their own national policies, as applicable.
Note: NASA would follow NASA Policy Directive 8740.1 for notifying within the U.S. government
* Roughly equivalent to an absolute magnitude of 28 if only brightness data can be collected
EXERCISE EXERCISE EXERCISE
https://iawn.net/
23

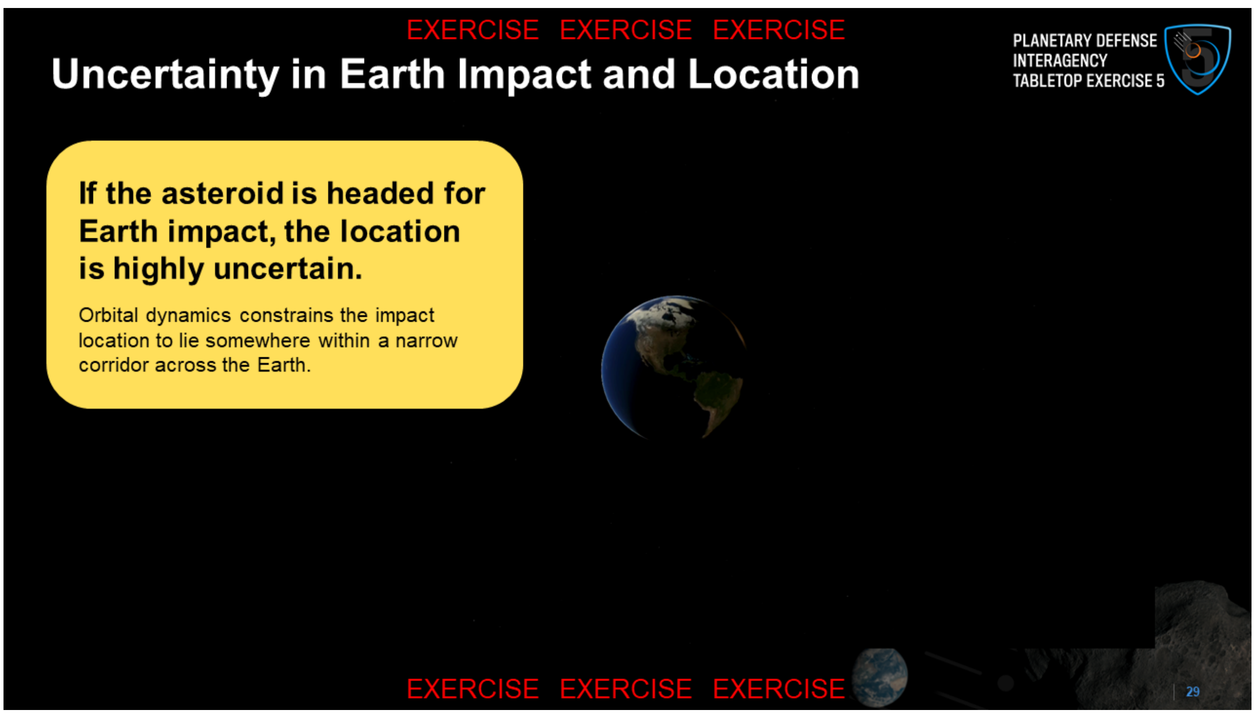

International
Asteroid
Warning
Network
EXERCISE EXERCISE EXERCISE
IAWN Notification
EXERCISE EXERCISE EXERCISE
24

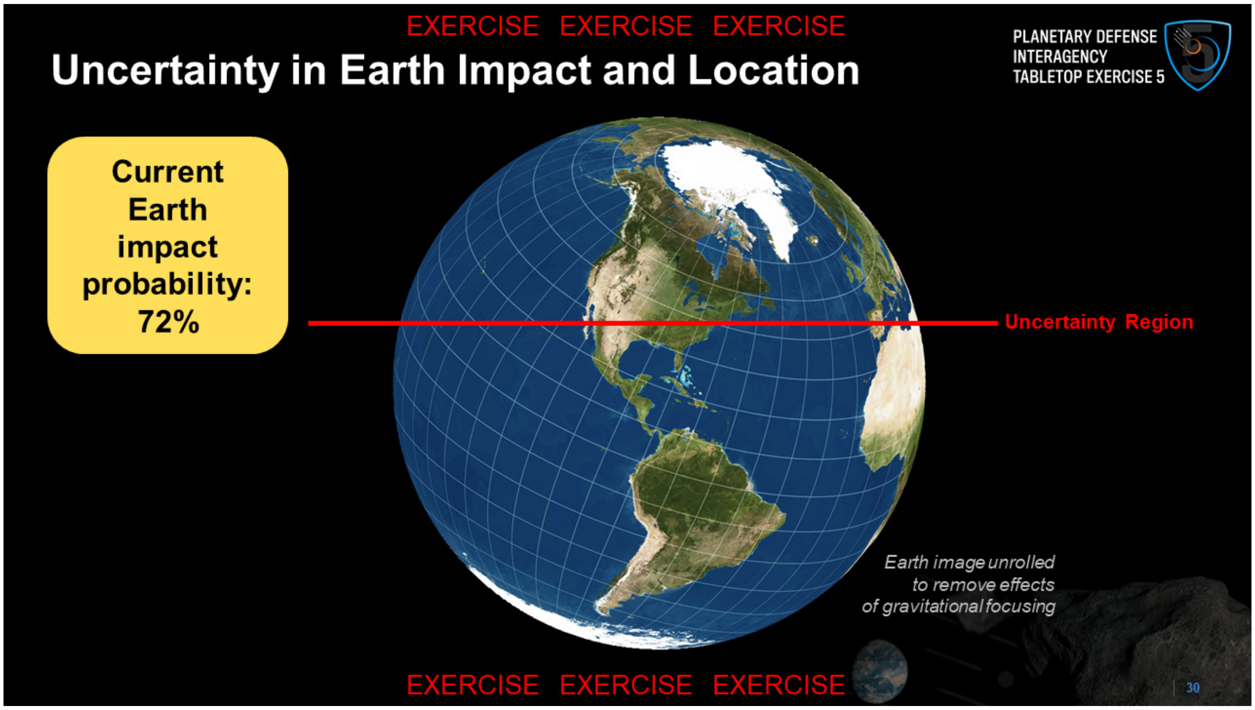

International
Asteroid
Warning
Network
EXERCISE EXERCISE EXERCISE
IAWN Notification
INTERNATIONAL ASTEROID WARNING NETWORK
Potential Asteroid Impact Notification: Hypothetical Scenario
Date: 2 April 2024
From: International Asteroid Warning Network (IAWN)
To: Chair, Space Mission Planning Advisory Group (SMPAG); United Nations Office of Outer Space Affairs (UNOOSA)
Title: Potential for the Impact of Near-Earth Asteroid 2023 TTX
Impact Probability
72% as calculated by NASA JPL CNEOS & ESA NEOCC
Impact Date:
12 July 2038
Impact Risk Corridor:
Potential impact locations span a corridor from the South Pacific, across North America, the Atlantic, Iberian Peninsula, Mediterranean coast of Africa, Egypt, to the coast of Saudi Arabia.
Approximate Size:
Highly uncertain based on brightness and unknown surface reflectivity: most likely ~100–320 m (350–1000 ft), but potentially ~60–800 m in diameter.
Expected Damage Level if Impact Occurs:
Uncertain, but regional- to country-scale. Energy release most likely to be in the range of 6 to 750 megatons TNT, but potentially up to 15 gigatons TNT.
Additional information provided next by:
Paul Chodas, NASA CNEOS
Lorien Wheeler, NASA ATAP
EXERCISE EXERCISE EXERCISE
25

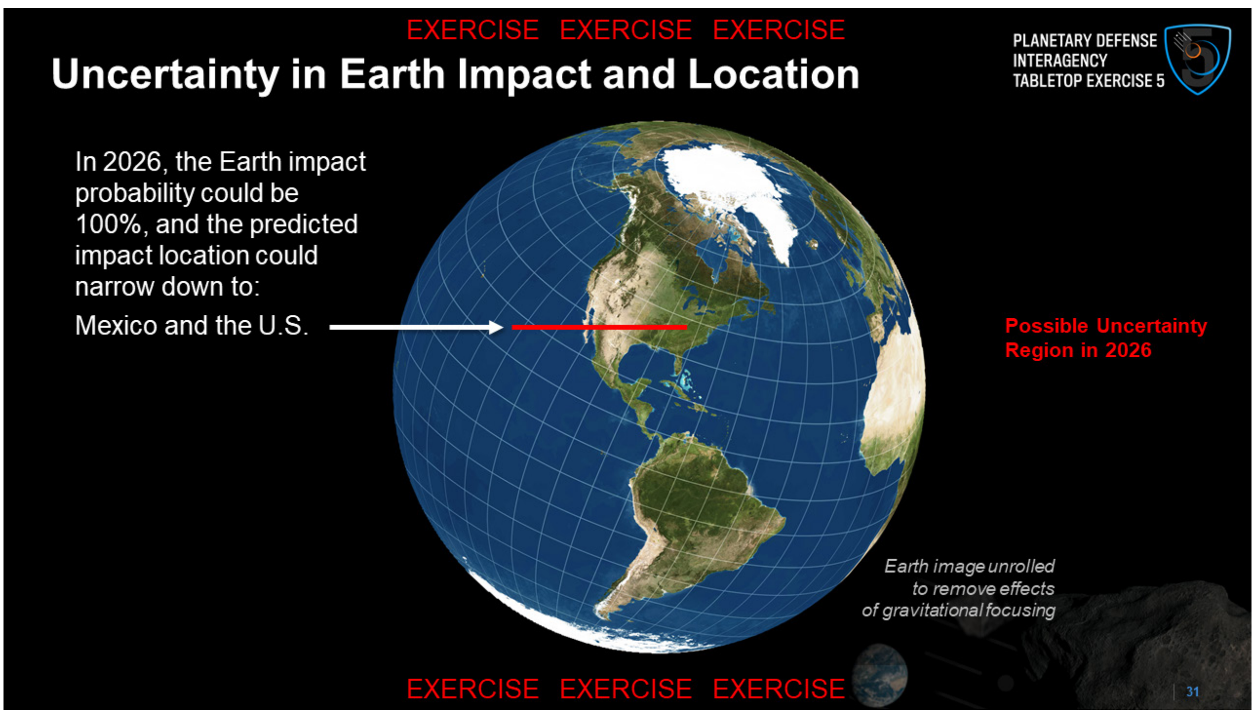

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Current Knowledge from Telescopic Observations
Paul Chodas (JPL/Caltech/CNEOS)
Davide Farnocchia, Alan Chamberlin, Ryan Park (JPL/Caltech/CNEOS)
Shigeru Suzuki (JPL/Caltech)
NASA
FEMA
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
cneos
Lawrence Livermore National Laboratory

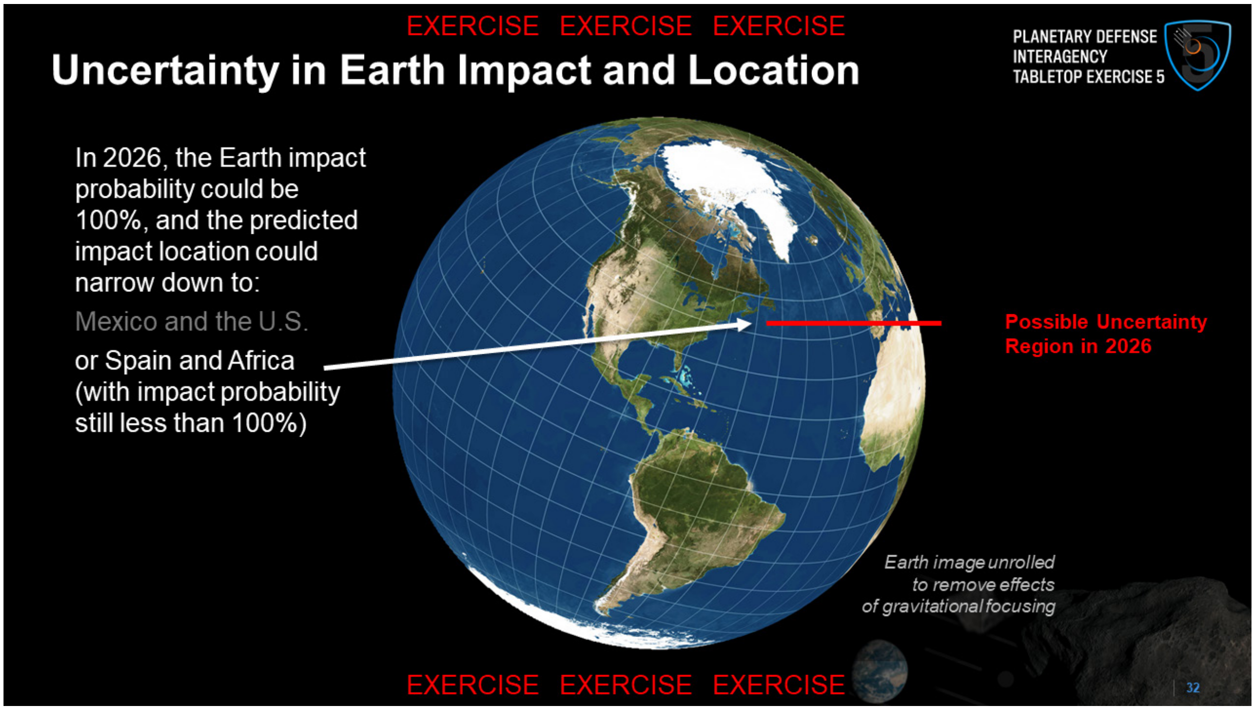

EXERCISE EXERCISE EXERCISE
Summary of Observations of Asteroid 2023 TTX
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
2023 TTX
Mars
Earth
Venus
Orbit of 2023 TTX is inclined 12°
• Discovered on 4 October 2023
- Asteroid 2023 TTX was also subsequently identified in archived data from previously acquired observations.
• Observations continued for five additional months.
• Observations have ended because the asteroid is now too close to the Sun as seen from Earth and too far away from Earth.
• Observers will be able to resume tracking the asteroid in November 2024.
Potential Earth impact date: 12 July 2038
Current Earth impact probability: 72%
EXERCISE EXERCISE EXERCISE
27

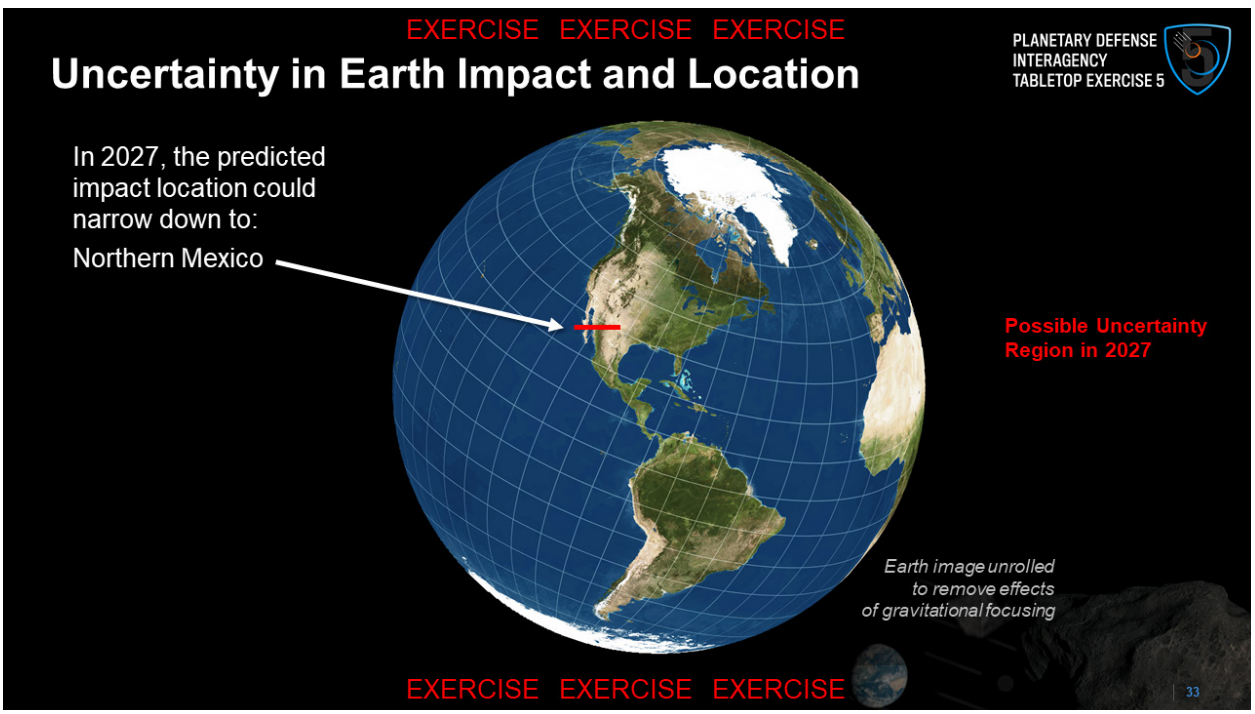

EXERCISE EXERCISE EXERCISE
Sources of Telescopic Data
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
The asteroid's size is highly uncertain.
The size is most likely ~100–320 meters based on brightness and typical asteroid properties. The size could range from 60 to 800 meters for rarer asteroid properties.
Credit: Catalina Sky Survey
Ground-Based Optical and Infrared
Possible periodically over the next 14 years
Space-Based Infrared
Might be possible in 2028
Ground-Based Radar
Might be possible in 2033
EXERCISE EXERCISE EXERCISE
28

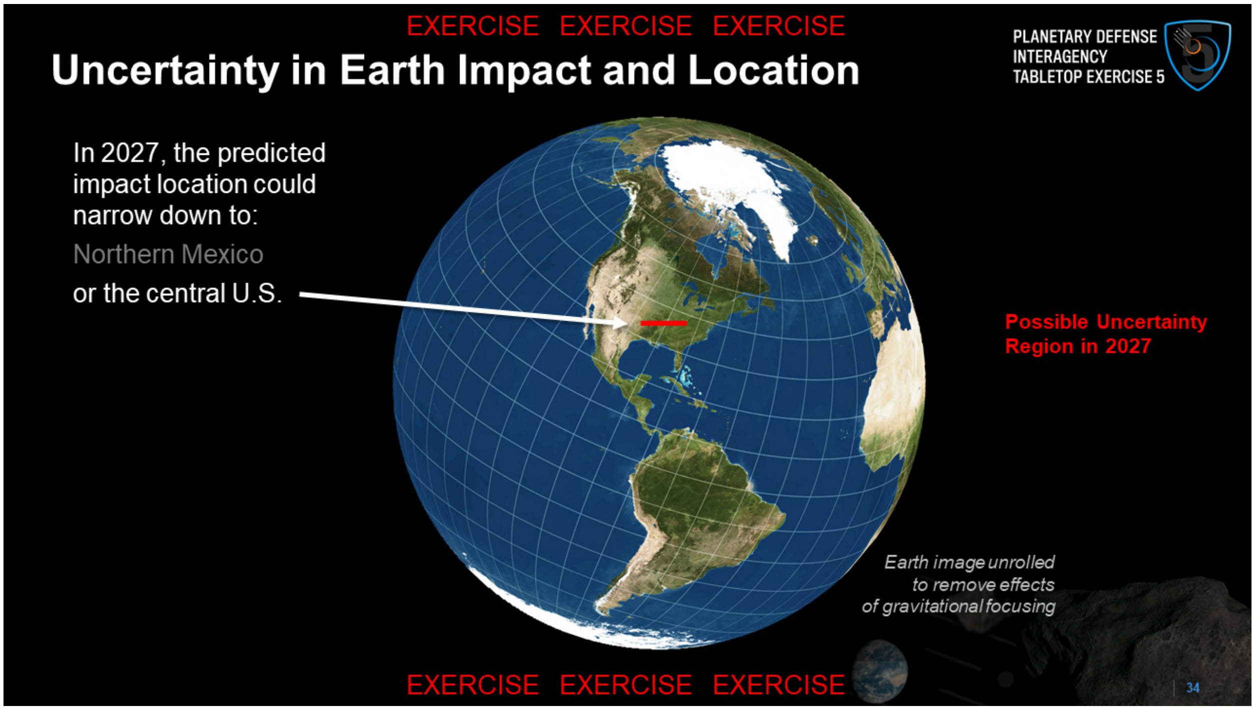

EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
If the asteroid is headed for Earth impact, the location is highly uncertain.
Orbital dynamics constrains the impact location to lie somewhere within a narrow corridor across the Earth.
EXERCISE EXERCISE EXERCISE
29

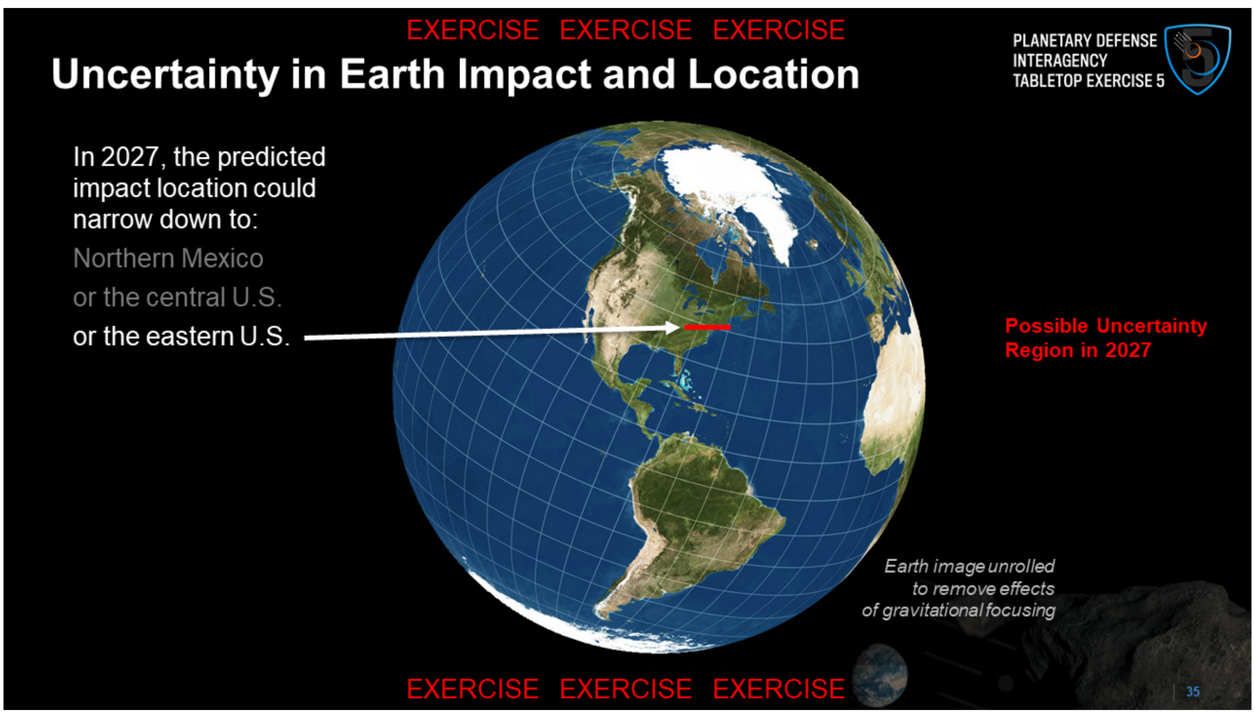

EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Current Earth impact probability: 72%
Uncertainty Region
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
30

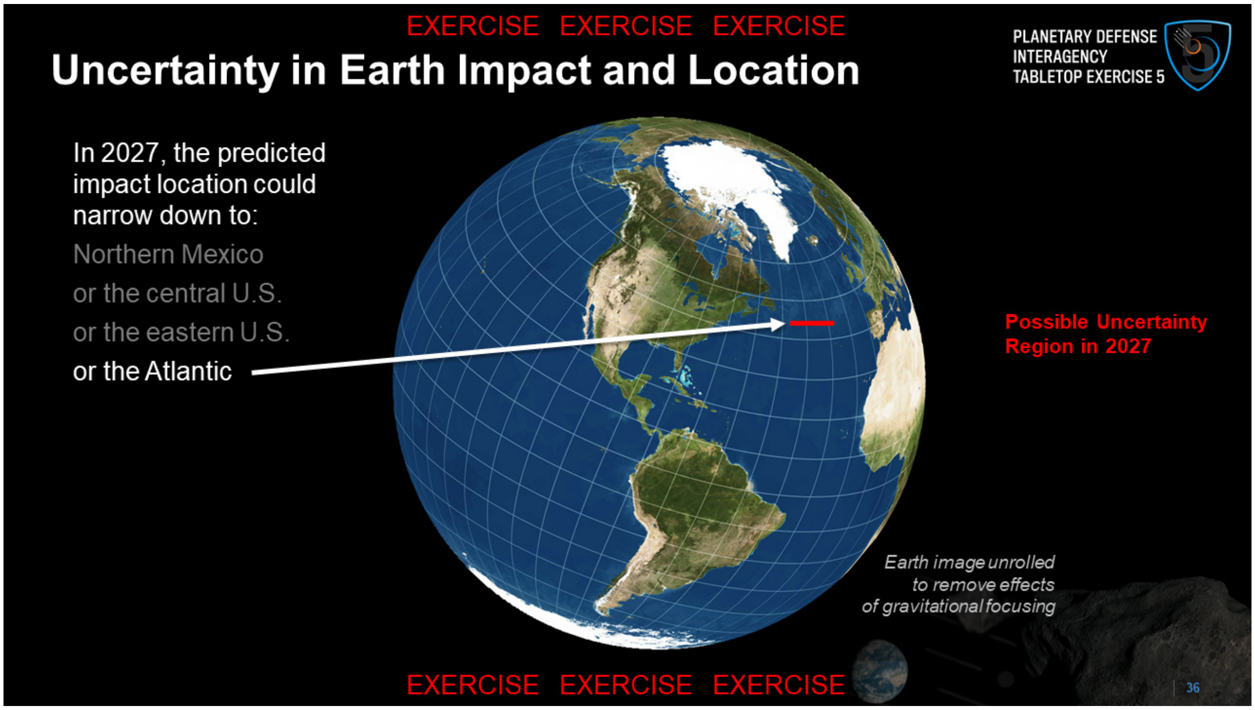

EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
In 2026, the Earth impact probability could be 100%, and the predicted impact location could narrow down to:
Mexico and the U.S.
Possible Uncertainty Region in 2026
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
31

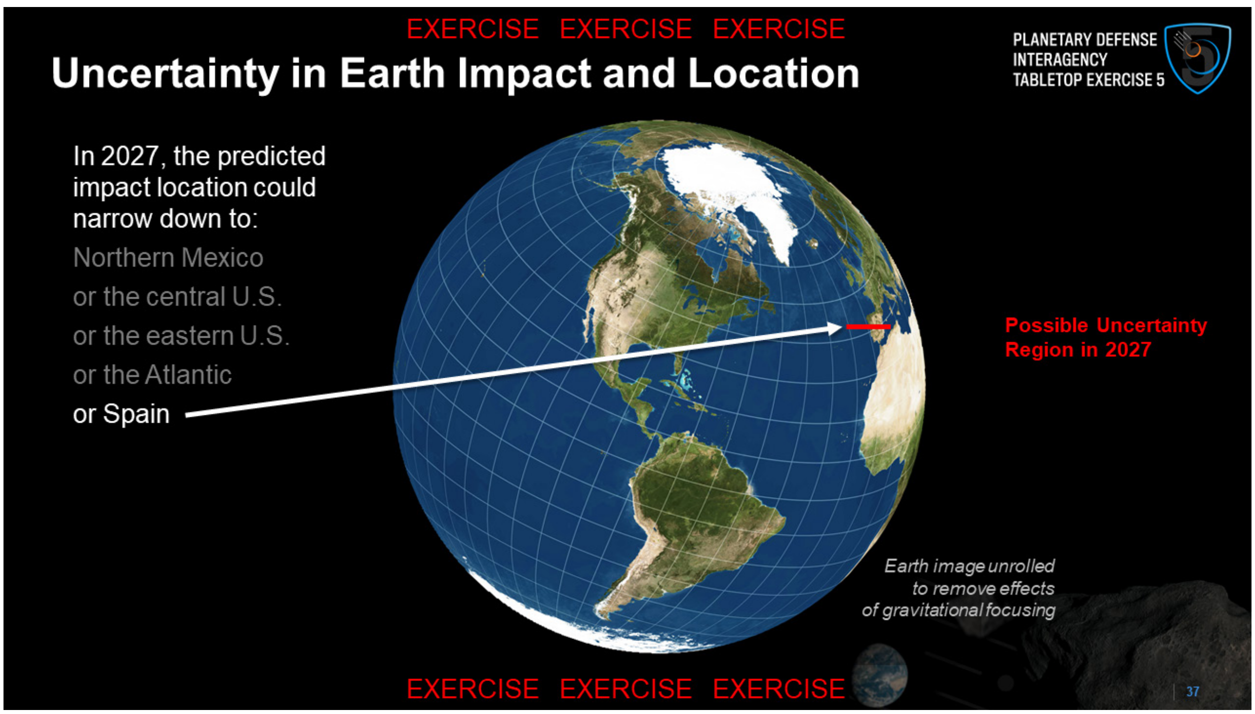

EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
In 2026, the Earth impact probability could be 100%, and the predicted impact location could narrow down to:
Mexico and the U.S.
or Spain and Africa (with impact probability still less than 100%)
Possible Uncertainty Region in 2026
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
32

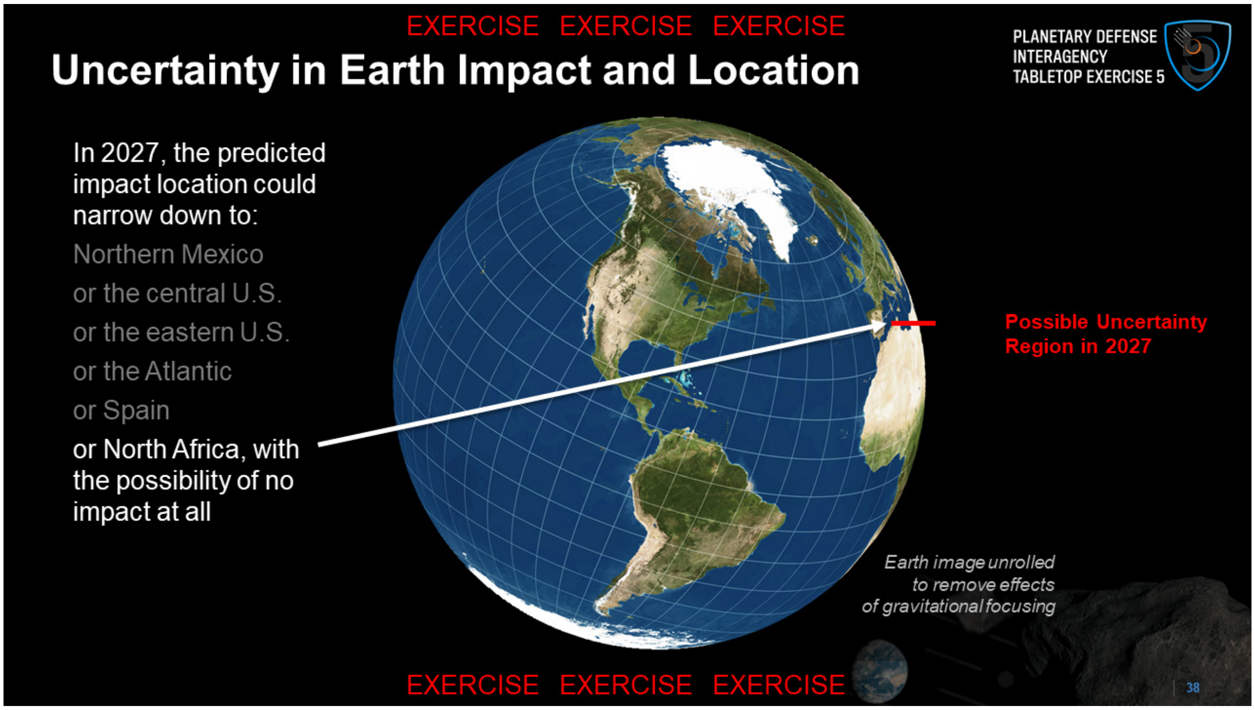

EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
In 2027, the predicted impact location could narrow down to:
Northern Mexico
Possible Uncertainty Region in 2027
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
33

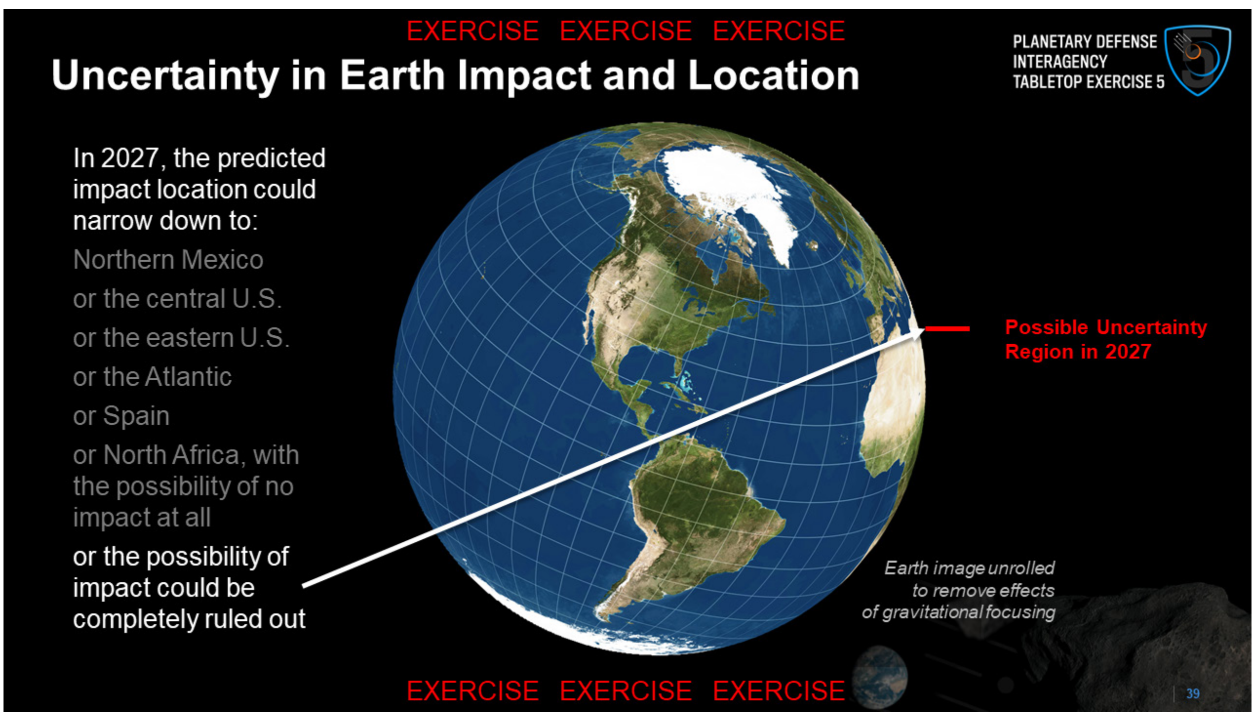

EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
In 2027, the predicted impact location could narrow down to:
Northern Mexico
or the central U.S.
Possible Uncertainty Region in 2027
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
34

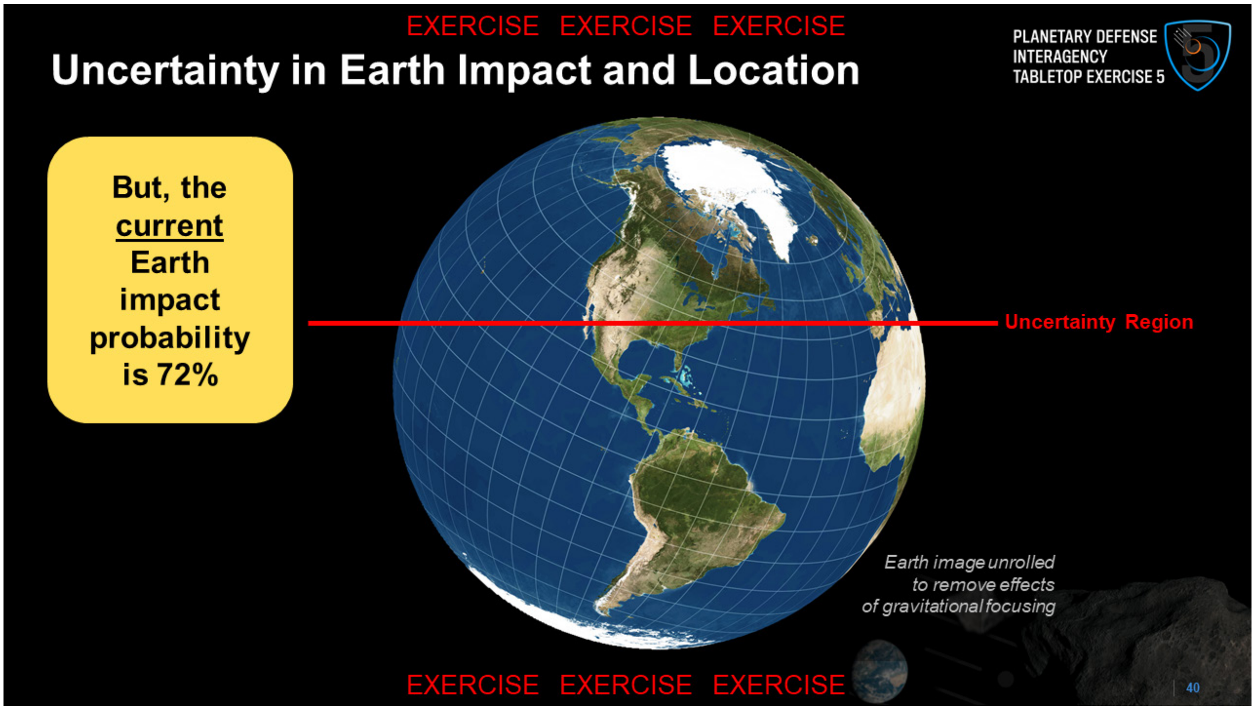

EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
In 2027, the predicted impact location could narrow down to:
Northern Mexico
or the central U.S.
or the eastern U.S.
Possible Uncertainty Region in 2027
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
35


EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
In 2027, the predicted impact location could narrow down to:
Northern Mexico
or the central U.S.
or the eastern U.S.
or the Atlantic
Possible Uncertainty Region in 2027
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
36


EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
In 2027, the predicted impact location could narrow down to:
Northern Mexico
or the central U.S.
or the eastern U.S.
or the Atlantic
or Spain
Possible Uncertainty Region in 2027
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
37

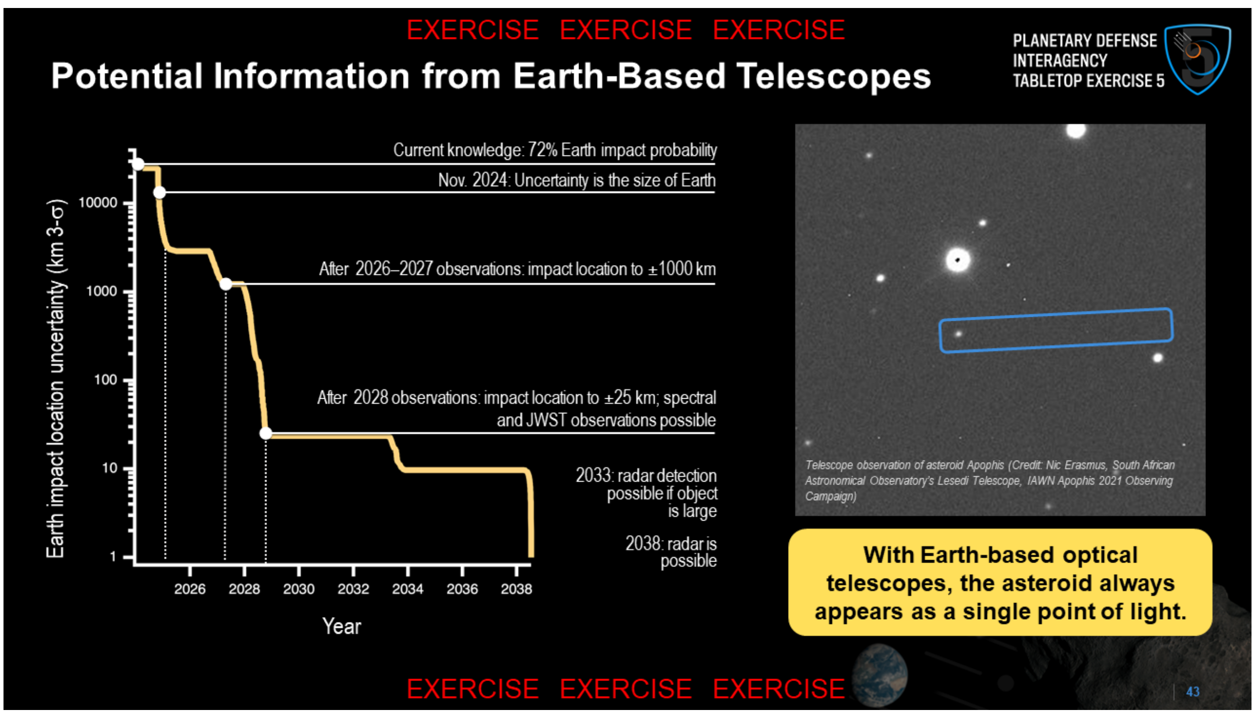

EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
In 2027, the predicted impact location could narrow down to:
Northern Mexico
or the central U.S.
or the eastern U.S.
or the Atlantic
or Spain
or North Africa, with the possibility of no impact at all
Possible Uncertainty Region in 2027
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
38


EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
In 2027, the predicted impact location could narrow down to:
Northern Mexico
or the central U.S.
or the eastern U.S.
or the Atlantic
or Spain
or North Africa, with the possibility of no impact at all
or the possibility of impact could be completely ruled out
Possible Uncertainty Region in 2027
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
39


EXERCISE EXERCISE EXERCISE
Uncertainty in Earth Impact and Location
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
But, the current Earth impact probability is 72%
Uncertainty Region
Earth image unrolled to remove effects of gravitational focusing
EXERCISE EXERCISE EXERCISE
40


EXERCISE EXERCISE EXERCISE
Impact Risk Corridor: Western Part
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Gulf of California
Google Earth
EXERCISE EXERCISE EXERCISE
41

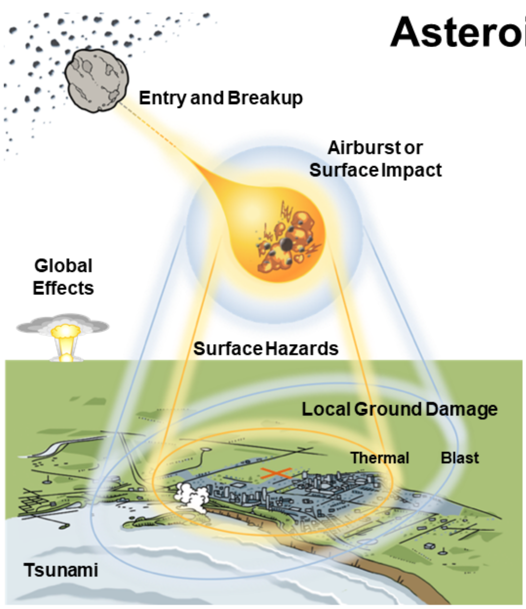

EXERCISE EXERCISE EXERCISE
Impact Risk Corridor: Eastern Part
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
EXERCISE EXERCISE EXERCISE
42


EXERCISE EXERCISE EXERCISE
Potential Information from Earth-Based Telescopes
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Current knowledge: 72% Earth impact probability
Nov. 2024: Uncertainty is the size of Earth
After 2026–2027 observations: impact location to ±1000 km
After 2028 observations: impact location to ±25 km; spectral and JWST observations possible
2033: radar detection possible if object is large
2038: radar is possible
Earth impact location uncertainty (km 3-σ)
10000
1000
100
10
1
2026
2028
2030
2032
2034
2036
2038
Year
Telescope observation of asteroid Apophis (Credit: Nic Erasmus, South African Astronomical Observatory's Lesedi Telescope, IAWN Apophis 2021 Observing Campaign)
With Earth-based optical telescopes, the asteroid always appears as a single point of light.
EXERCISE EXERCISE EXERCISE
43

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Asteroid Hazards



Damage depends on asteroid properties, atmospheric entry, and impact location.

- Asteroids can cause damage by disrupting explosively in the atmosphere or by impacting Earth's surface.
- Primary hazards include: local ground damage from destructive blast waves or thermal fireballs, tsunamis, and/or global climate effects.

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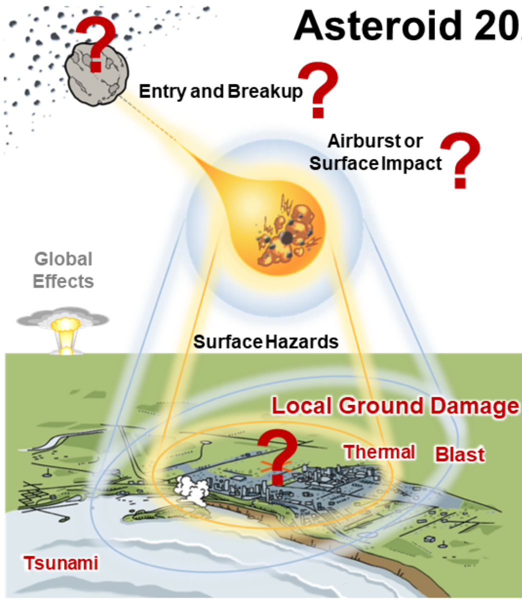
45

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Asteroid 2023 TTX Hazards

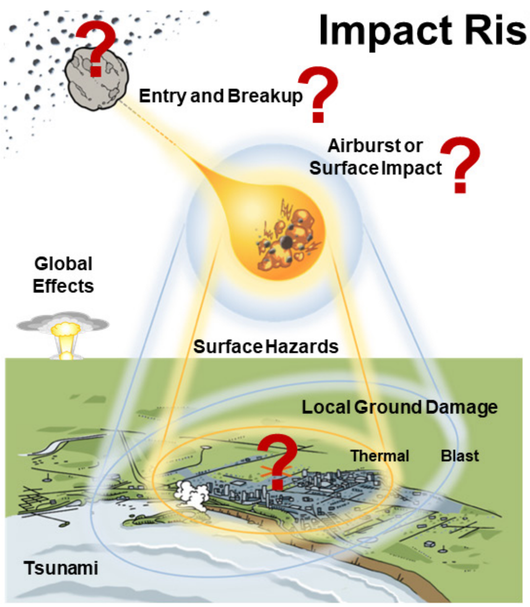


2023 TTX properties and impact location are highly uncertain, so the potential damage is highly uncertain.

- Primary hazard is a low airburst or ground impact causing a highly destructive blast wave and fireball.
- Larger ocean impacts could cause tsunami damage.
- Largest sizes could cause other extended regional environmental effects.

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Impact Risk Assessment

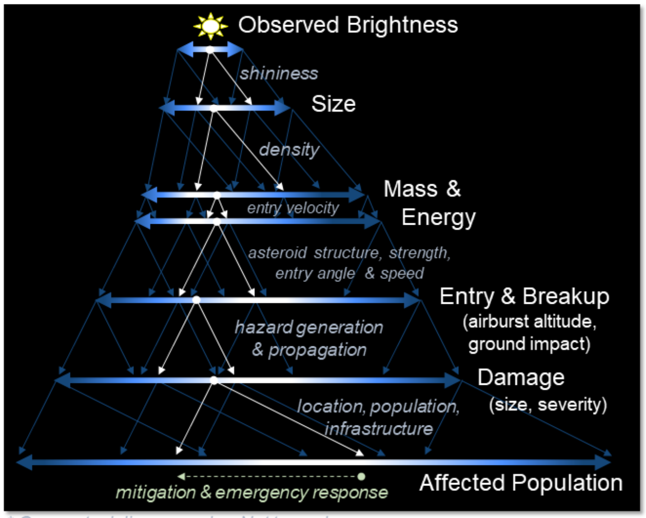


Risk assessment models millions of impact cases to evaluate the range and likelihood of potential damage.

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Asteroid and Damage Uncertainties



* Conceptual diagram only – Not to scale

Uncertainties in asteroid properties, impact location, and damage models…

…cascade into huge uncertainties in potential damage.

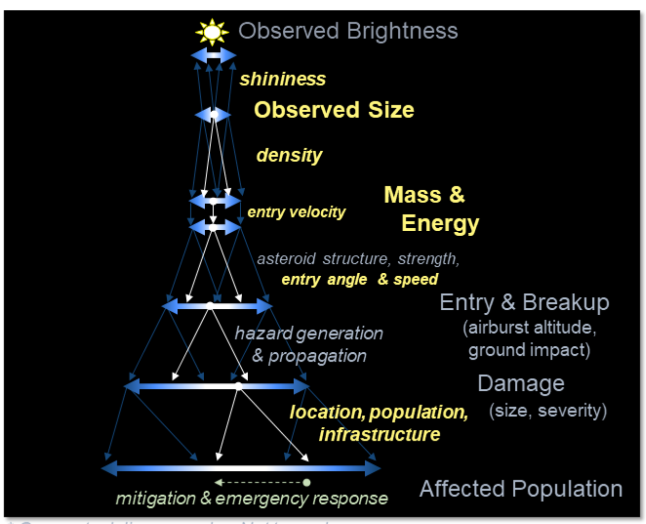
EXERCISE EXERCISE EXERCISE

48

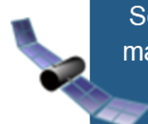
EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Asteroid and Damage Uncertainties



* Conceptual diagram only – Not to scale



Some key uncertainties may shrink or shift as we gain data.

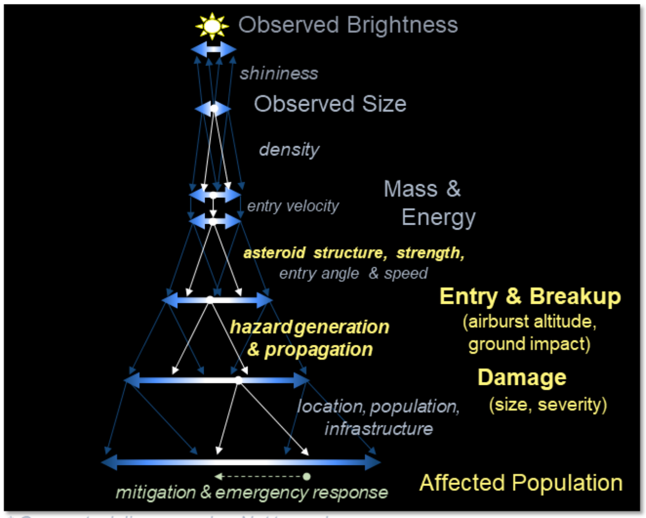
EXERCISE EXERCISE EXERCISE

49

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Asteroid and Damage Uncertainties



* Conceptual diagram only – Not to scale

?

Some factors will remain uncertain through impact.

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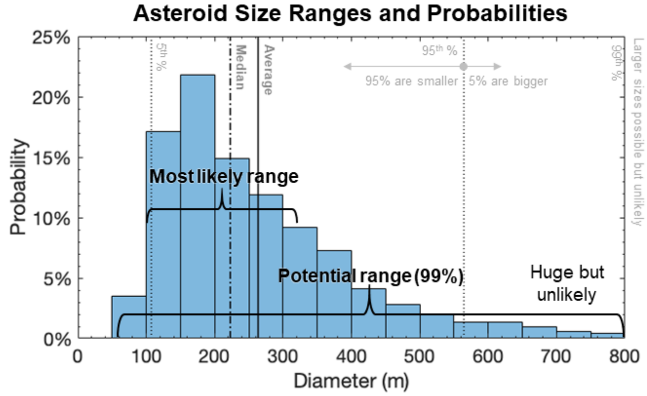
EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Asteroid and Impact Properties

	Asteroid Diameter	Impact Energy (megatons TNT)
Median	220 m (730 ft)	350 Mt
Most Likely	100–320 m (330–1100 ft)	6–750 Mt
Range	60–800 m (200–2600 ft)	6–15,000 Mt

Asteroid Size Ranges and Probabilities



Asteroid size, type, and properties are uncertain,
resulting in **very large ranges of mass and impact energy**.

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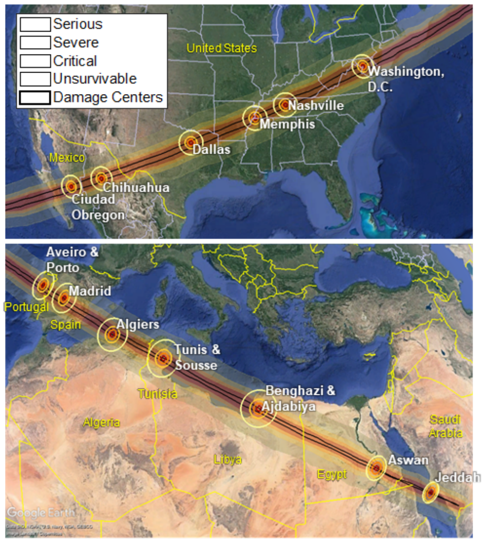
51

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Ground Damage Risk Swath



Damage risk swath: Extent of regions *potentially* at risk for ground damage, given ranges of potential impact locations and damage sizes (out to 95th percentile). Rings show median (50th percentile) damage footprints at sample locations.

- Damage severities are likely to reach **unsurvivable levels**, extending to larger areas of structural damage, fires, and shattered windows.
- Damage areas are most likely between **~80 and 180 km (50 and 110 miles) in radius**.
- Largest damage areas could extend out ~**300 km (180 miles) or more in radius**.

	Damage Level Description
Serious	Windows shatter, some structure damage
Severe	Widespread structure damage, or third-degree burns
Critical	Residential structures collapse, or clothing ignites
Unsurvivable	Devastation, structures flattened or burned

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52

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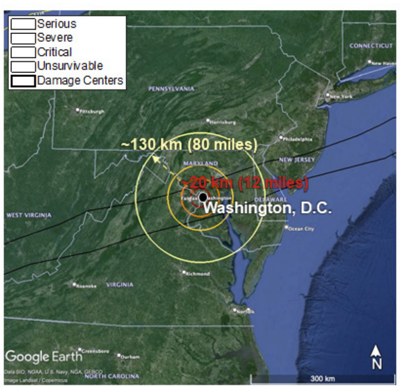
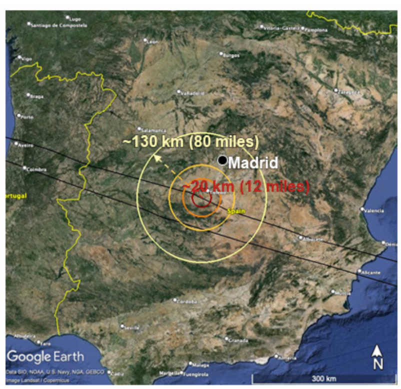
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Median Damage Size Examples



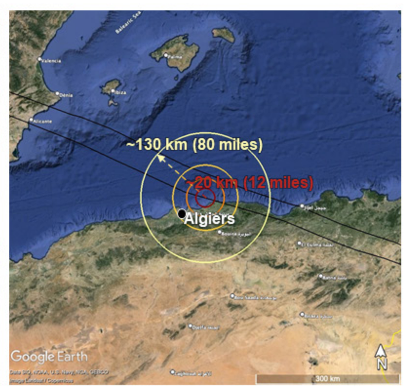
Washington, D.C., USA

highest population damage region along swath



Madrid, Spain

highest population damage region in Europe



Algiers, Algeria

highest population damage region in Africa

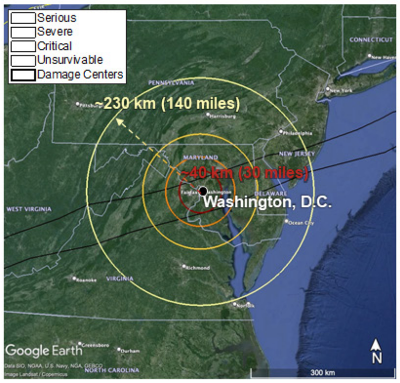
EXERCISE EXERCISE EXERCISE

53

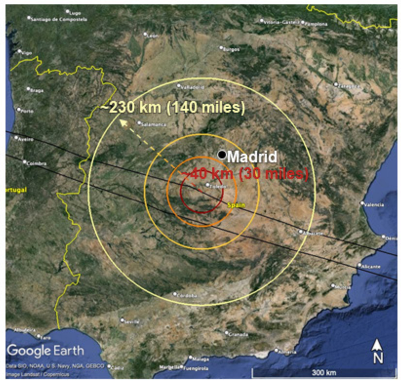
EXERCISE EXERCISE EXERCISE

Large (95th Percentile) Damage Size Examples

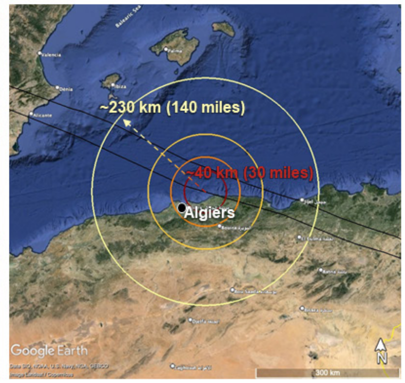
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5



Washington, D.C., USA
highest population damage region along swath



Madrid, Spain
highest population damage region in Europe



Algiers, Algeria
highest population damage region in Africa

EXERCISE EXERCISE EXERCISE

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EXERCISE EXERCISE EXERCISE

Affected Population Ranges Along Swath

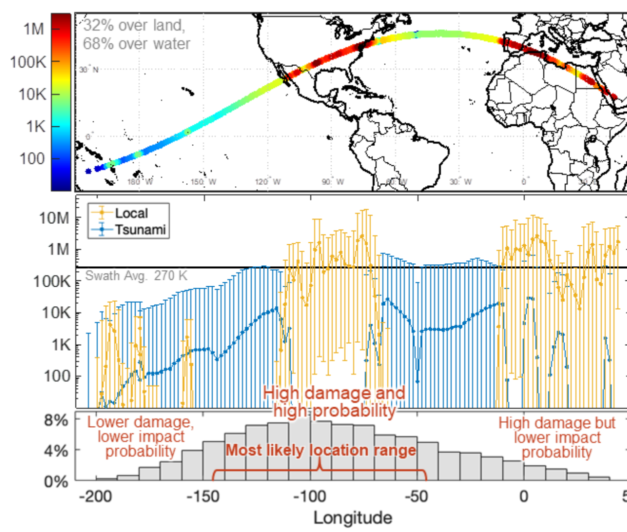
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Large affected population ranges due to both location and asteroid size & damage uncertainties

Impacts over land cause large population damage

Tsunami damage could be significant if impact is large or near coasts, or minor for smaller mid-ocean impacts

Likeliest impact locations are over North America (mid-Pacific to mid-Atlantic)



Average affected population along swath locations

Affected population ranges

Relative probability

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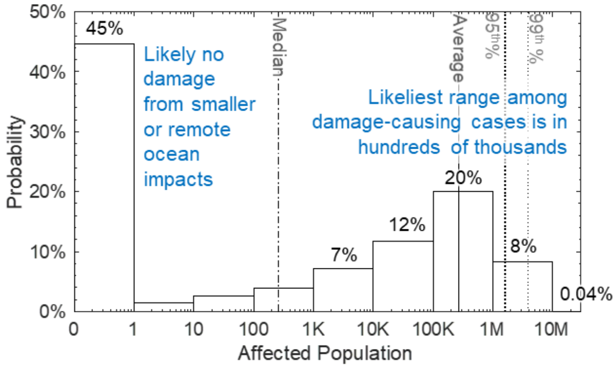
Population Risks

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Damage Probabilities *among Earth-Impacting Cases*



Chance of no damage and chance of large damage are both fairly likely

Affected Population Threshold	Chance of Damage Exceeding Threshold
Any	55%
>1K	47%
>10K	40%
>100K	28%
>1M	8%
>10M	0.04%

Range: 0–20 million people
~270,000 people affected, on average, if Earth impact occurs (72% chance of Earth impact)

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EXERCISE EXERCISE EXERCISE

Impact Risk Dashboard

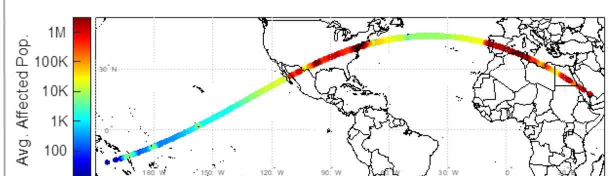
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Asteroid and Impact Properties

- Assessment date: 2 April 2024 (T-14 years and 3 months)
- Potential impact date: 12 July 2038
- Earth impact probability: 72%
- Large uncertainties regarding asteroid size, energy, and other properties
- Diameter: ~60–800 m (200–2600 ft), most likely ~100–320 m (330–1050 ft), median 220 m (730 ft)
- Energy: ~6–15,000 megatons TNT (Mt), most likely ~6–750 Mt, median 350 Mt

Impact Risk Swath

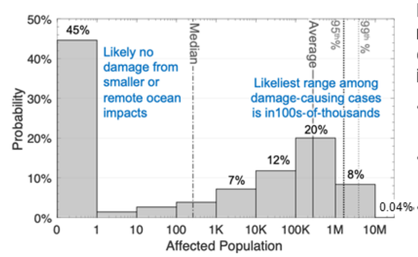
- Potential impact locations colored by the average number of people affected by local ground damage or tsunami



Impact Hazards

- Potential damage sizes and locations are very uncertain
- Potential for no damage and potential for large damage affecting tens of thousands to millions of people are both moderately likely, depending on asteroid size and impact location
- Primary hazard: large blast damage, ranging from blown-out windows to unsurvivable levels
- Ground damage radii: ~20–300 km (12–180 miles), most likely 80–180 km (50–110 miles), median 130 km (80 miles)
- Larger ocean impacts could cause tsunami damage (although less likely and less severe than local blast damage)

Population Risks (given Earth impact)



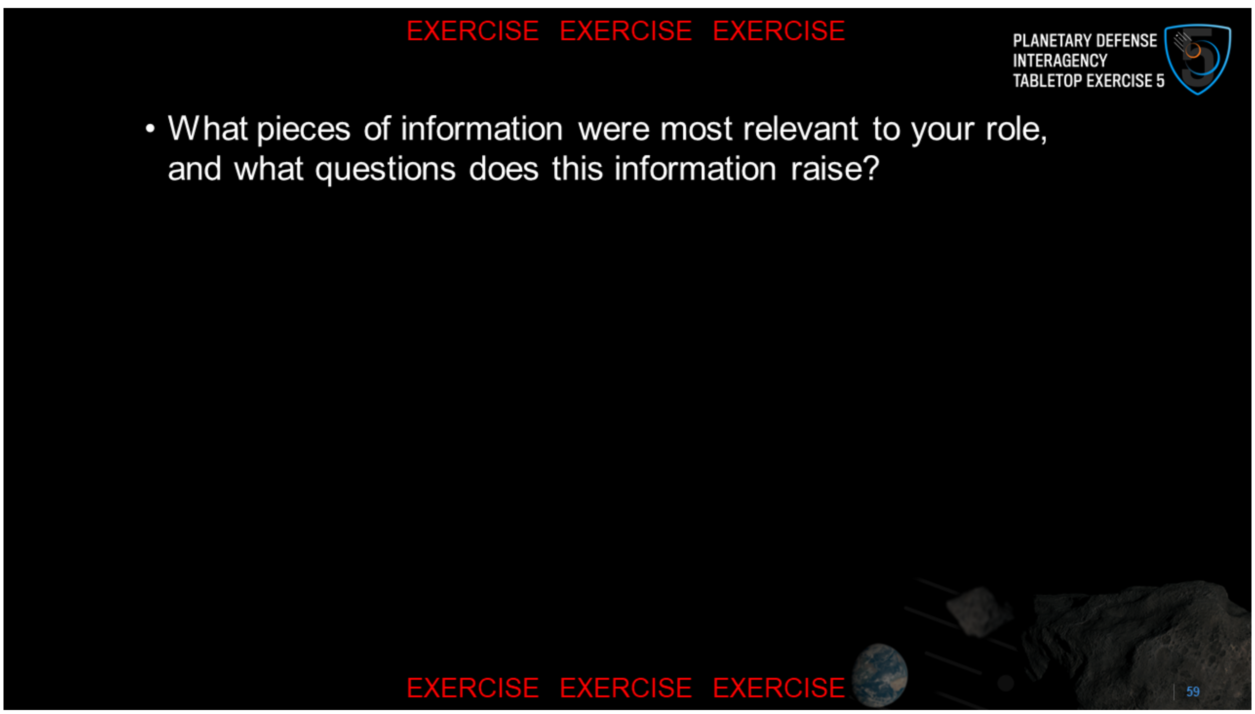
Probabilities of how many people damage could affect if Earth impact occurs

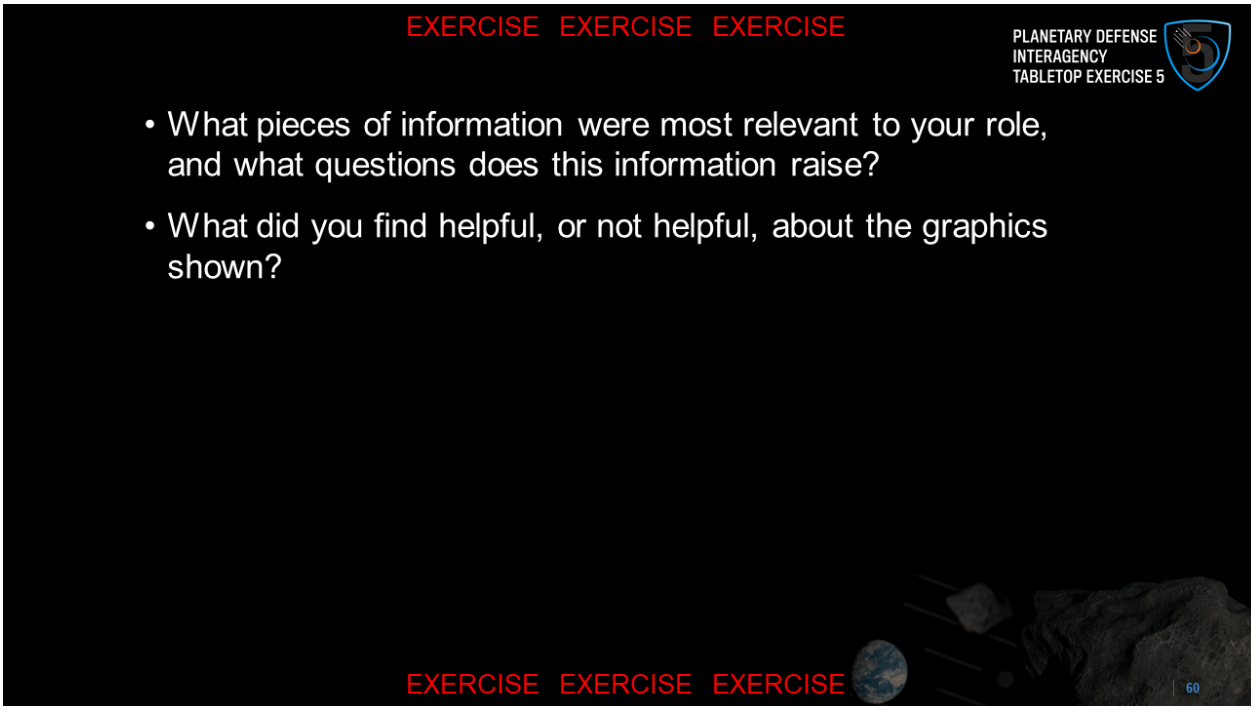
- Range: 0–20 million people
- ~270,000 avg. if Earth impact occurs
- ~200,000 total avg. risk (with ~72% Earth-impact probability)

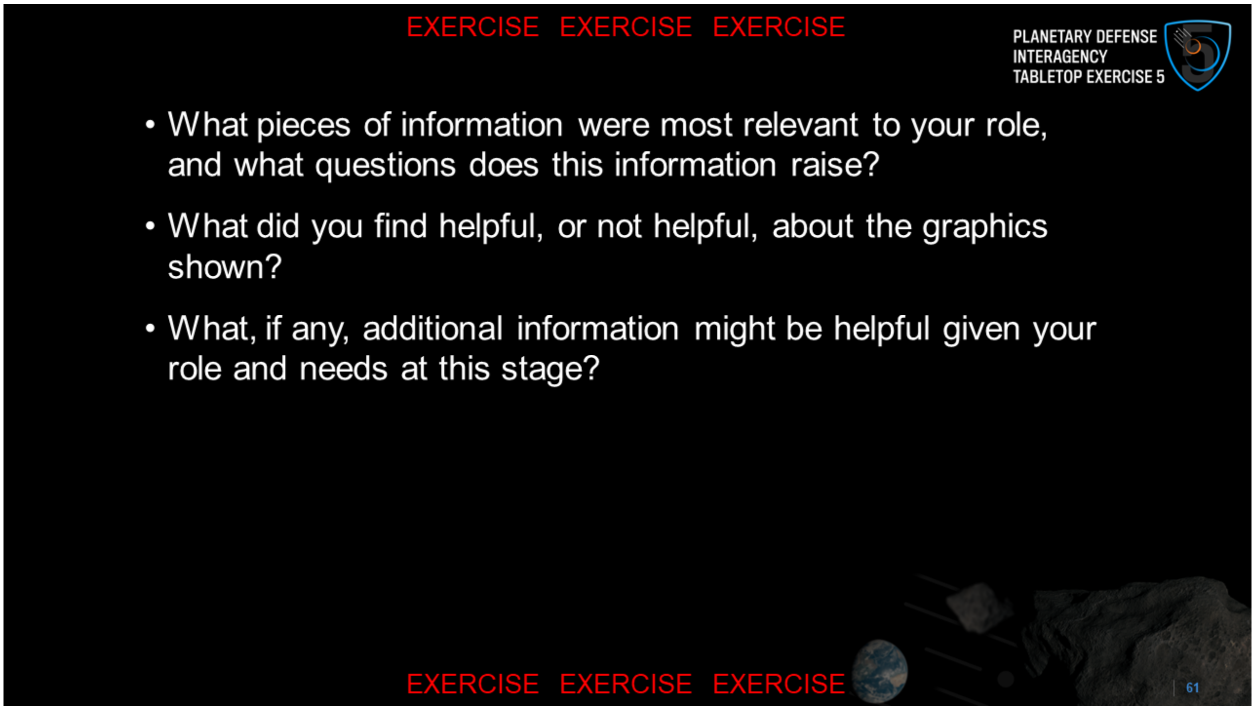
EXERCISE EXERCISE EXERCISE

57

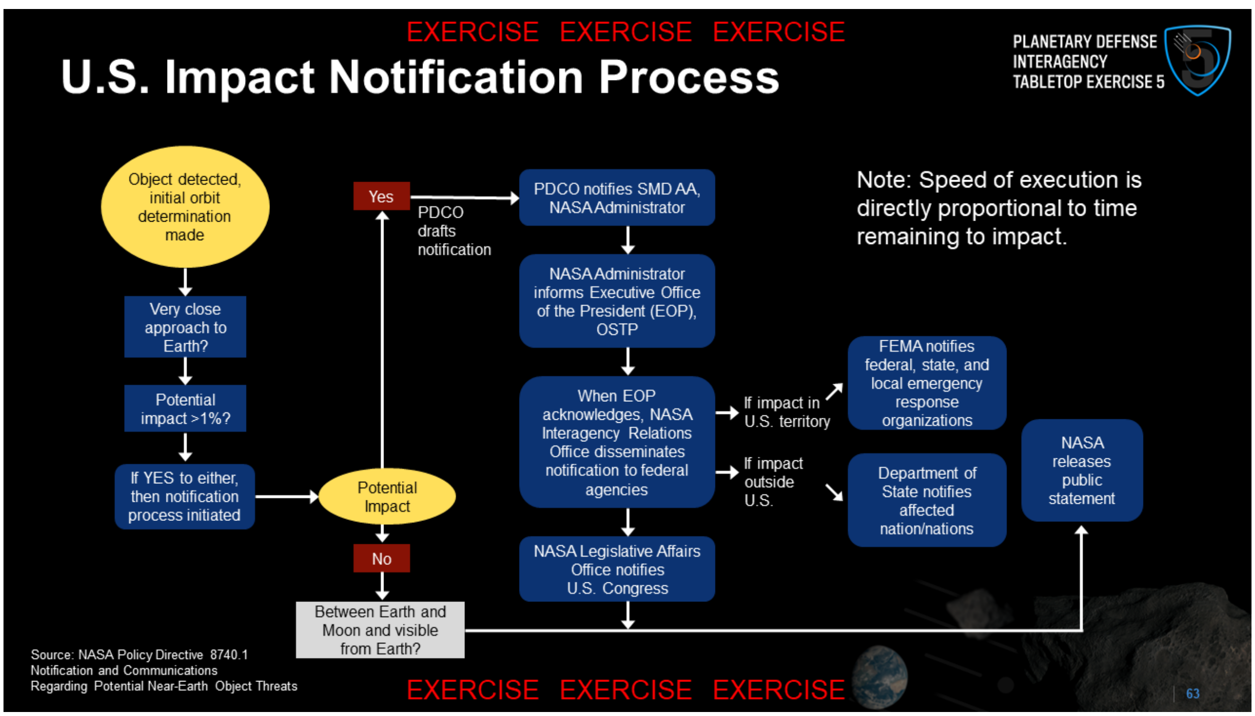

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
EXERCISE EXERCISE EXERCISE
58

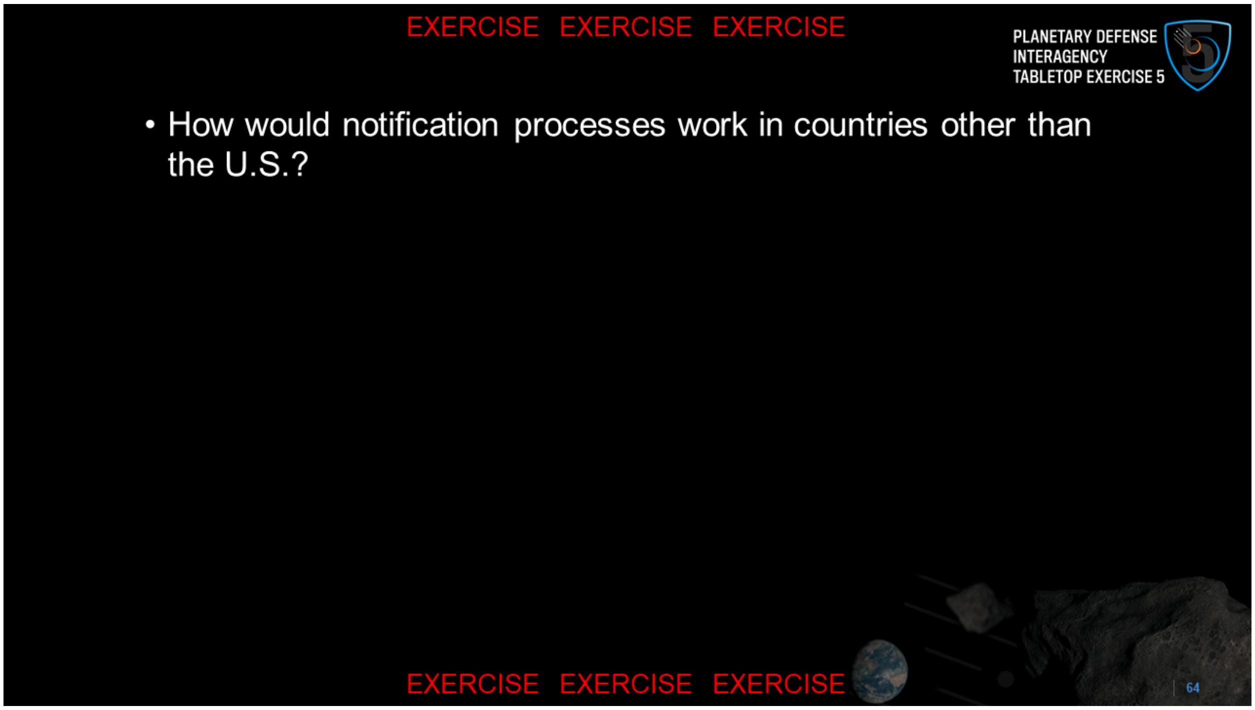

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What pieces of information were most relevant to your role, and what questions does this information raise?
EXERCISE EXERCISE EXERCISE
59

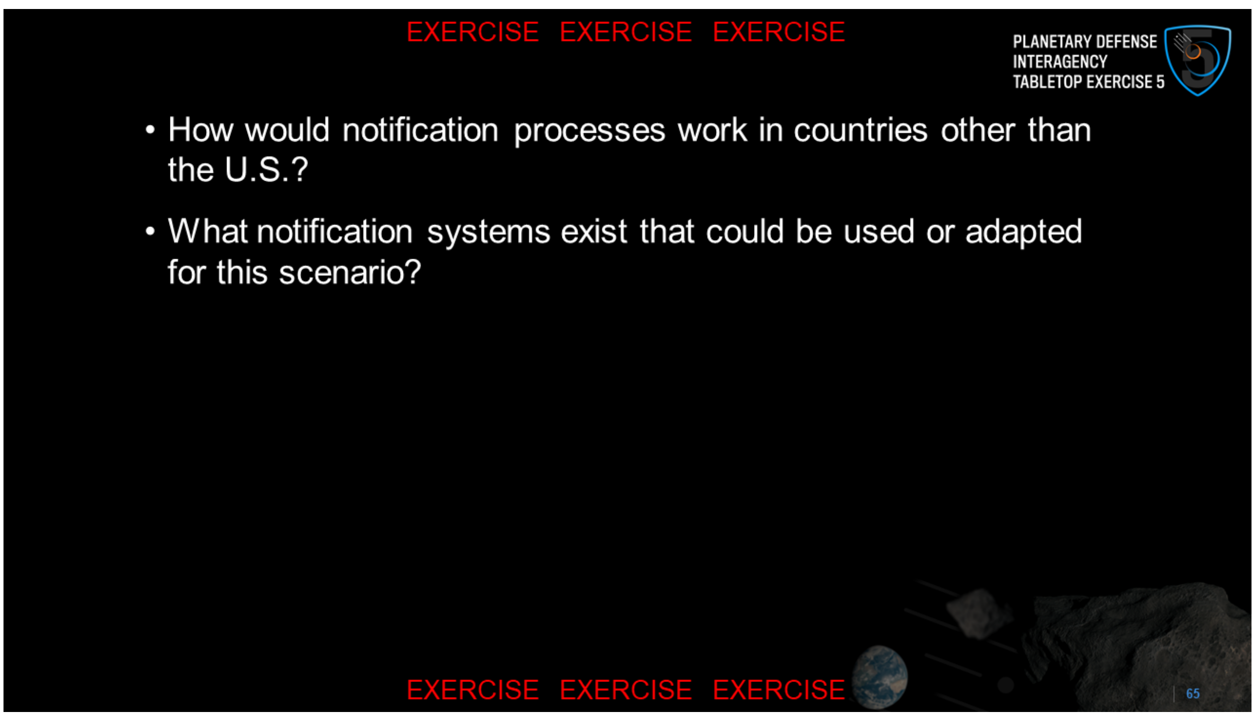

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What pieces of information were most relevant to your role, and what questions does this information raise?
• What did you find helpful, or not helpful, about the graphics shown?
EXERCISE EXERCISE EXERCISE
60

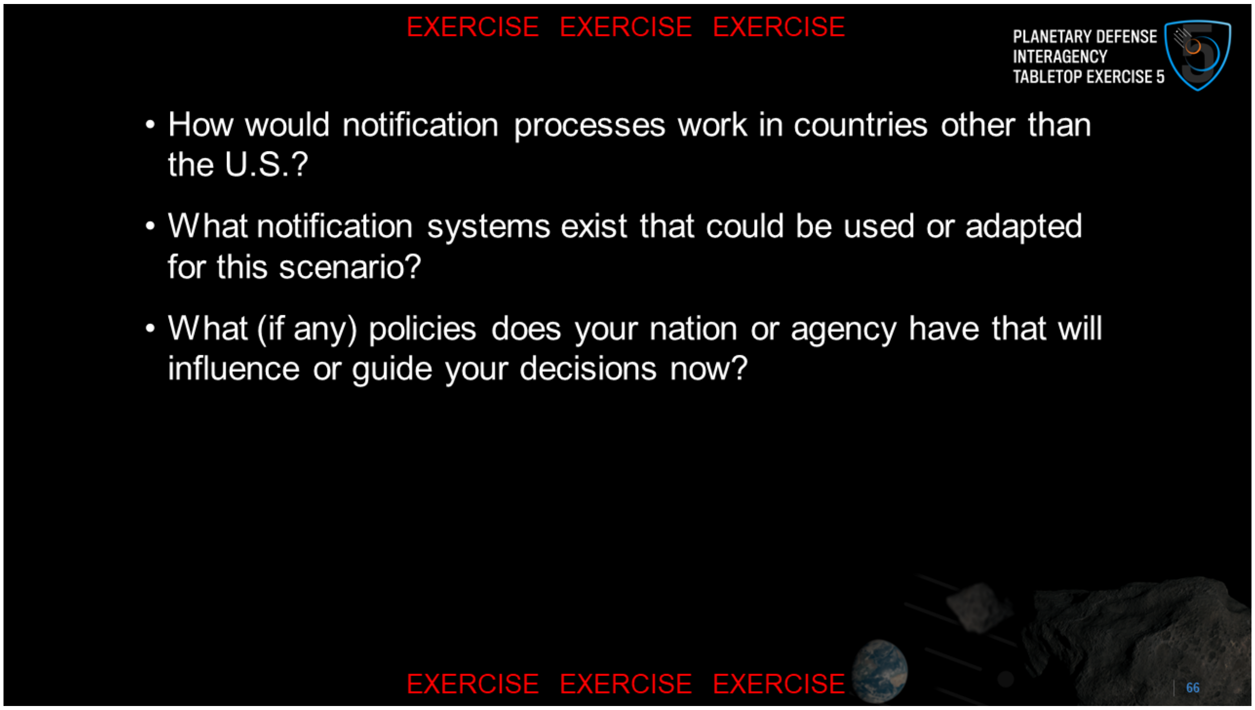

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What pieces of information were most relevant to your role, and what questions does this information raise?
• What did you find helpful, or not helpful, about the graphics shown?
• What, if any, additional information might be helpful given your role and needs at this stage?
EXERCISE EXERCISE EXERCISE
61

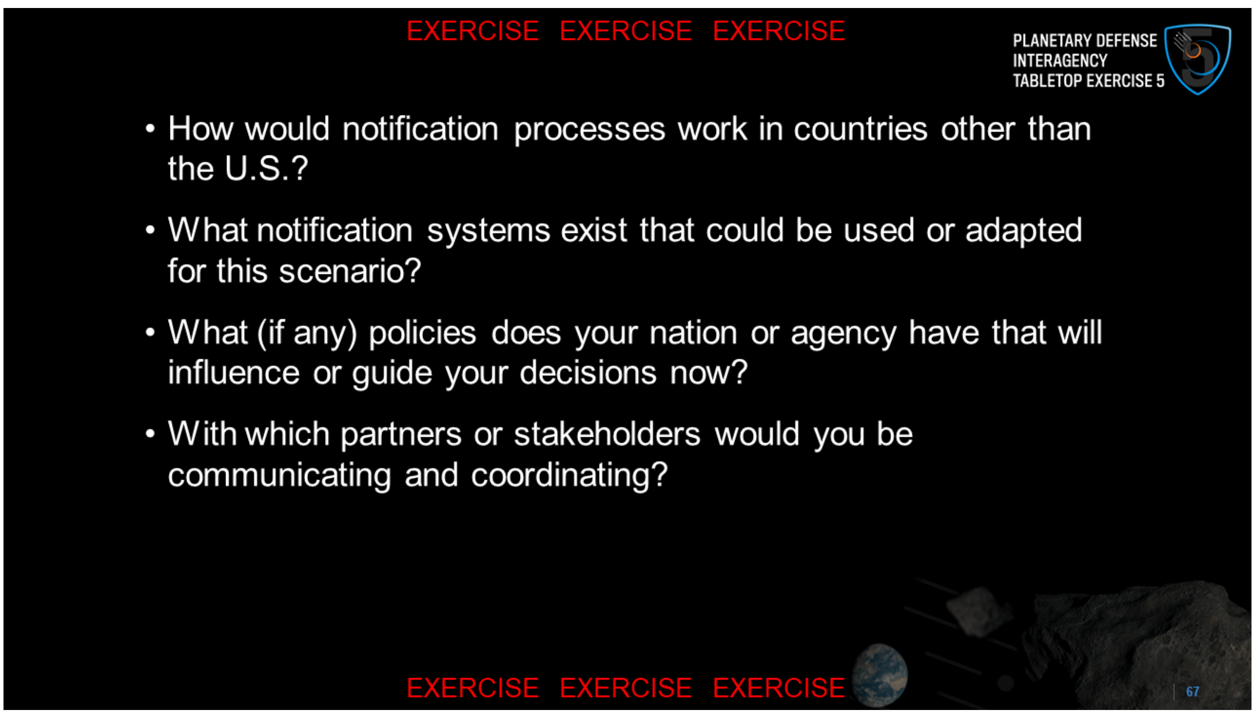

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Break
EXERCISE EXERCISE EXERCISE
62

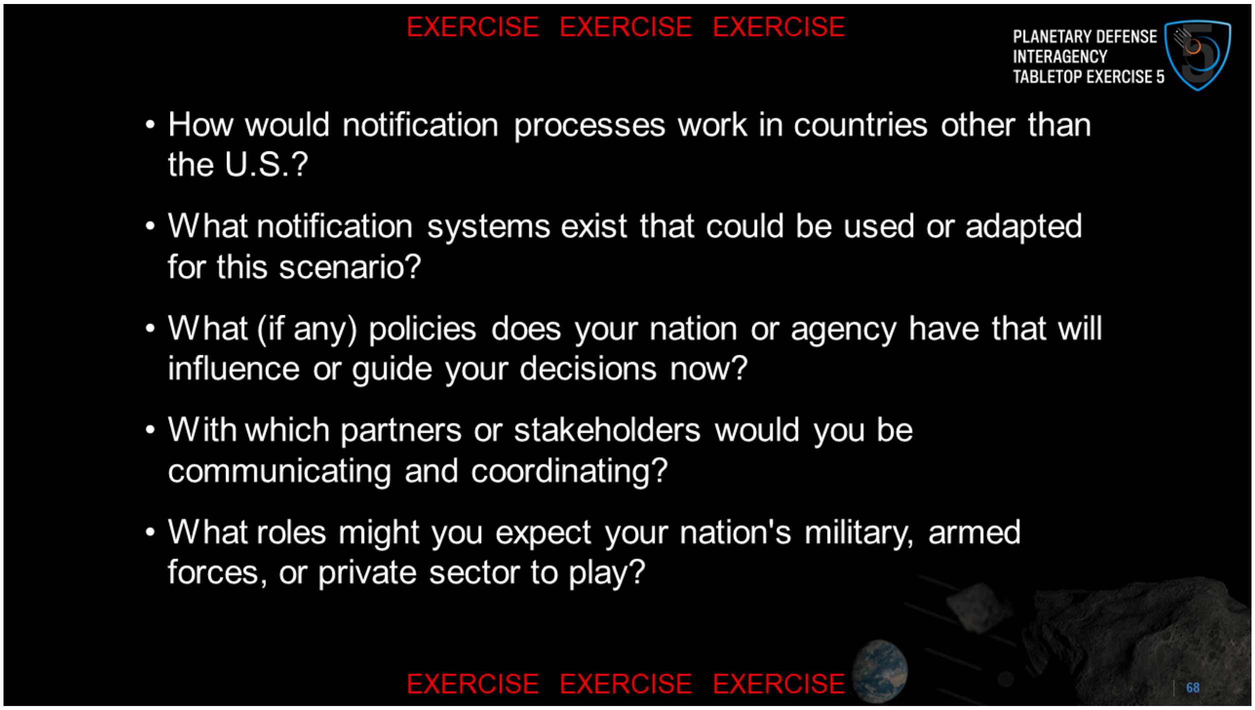

EXERCISE EXERCISE EXERCISE
U.S. Impact Notification Process
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Object detected, initial orbit determination made
Very close approach to Earth?
Potential impact >1%?
If YES to either, then notification process initiated
Potential Impact
Yes
PDCO drafts notification
No
Between Earth and Moon and visible from Earth?
PDCO notifies SMD AA, NASA Administrator
NASA Administrator informs Executive Office of the President (EOP), OSTP
When EOP acknowledges, NASA Interagency Relations Office disseminates notification to federal agencies
NASA Legislative Affairs Office notifies U.S. Congress
If impact in U.S. territory
If impact outside U.S.
FEMA notifies federal, state, and local emergency response organizations
Department of State notifies affected nation/nations
NASA releases public statement
Note: Speed of execution is directly proportional to time remaining to impact.
Source: NASA Policy Directive 8740.1 Notification and Communications Regarding Potential Near-Earth Object Threats
EXERCISE EXERCISE EXERCISE
63

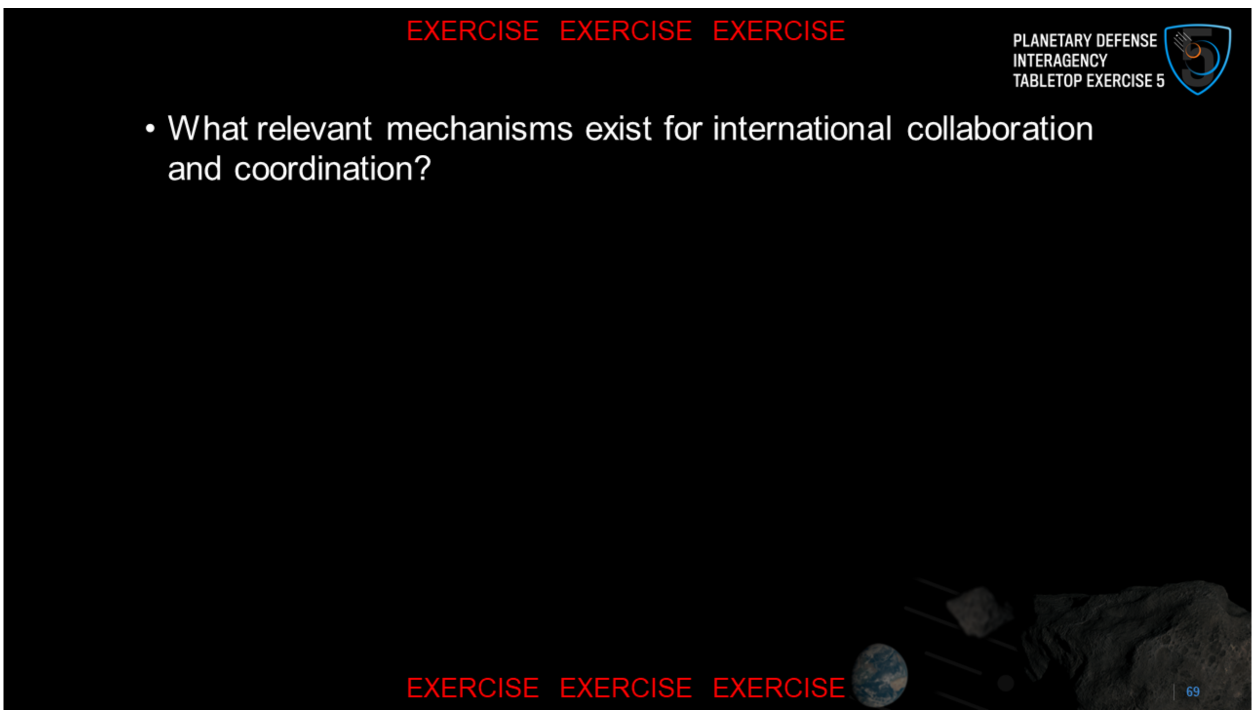

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• How would notification processes work in countries other than the U.S.?
EXERCISE EXERCISE EXERCISE
64

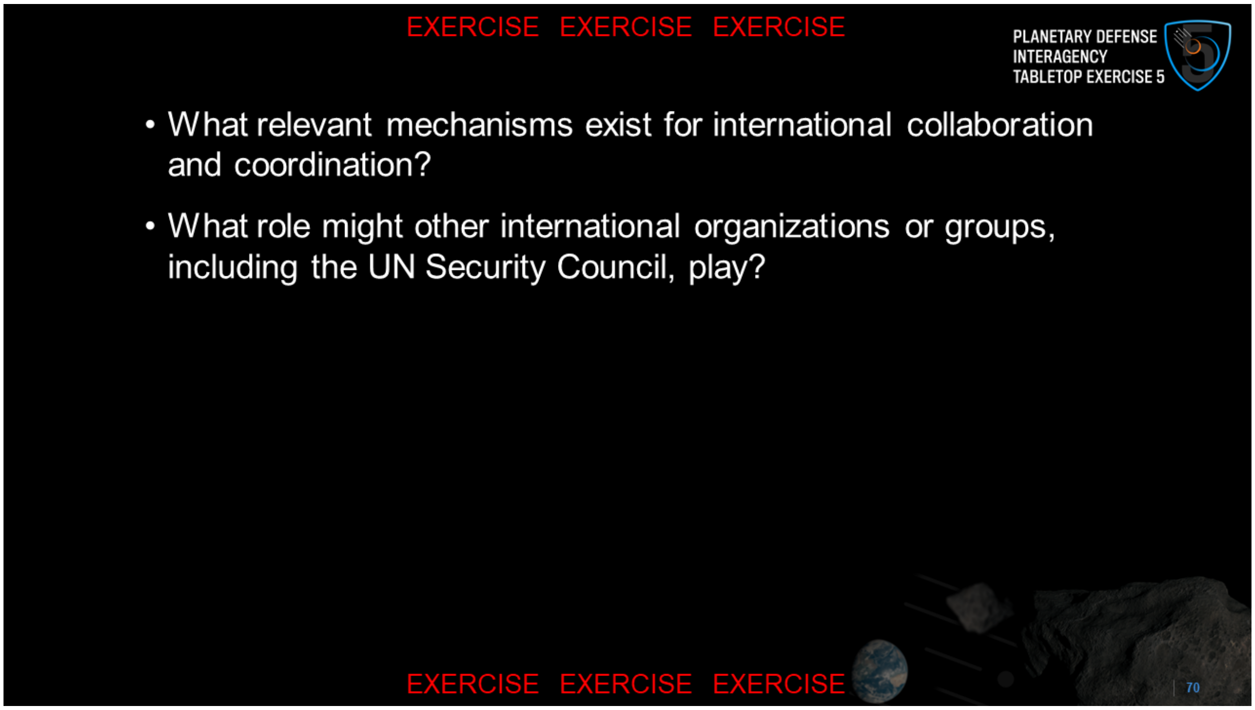

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• How would notification processes work in countries other than the U.S.?
• What notification systems exist that could be used or adapted for this scenario?
EXERCISE EXERCISE EXERCISE
65

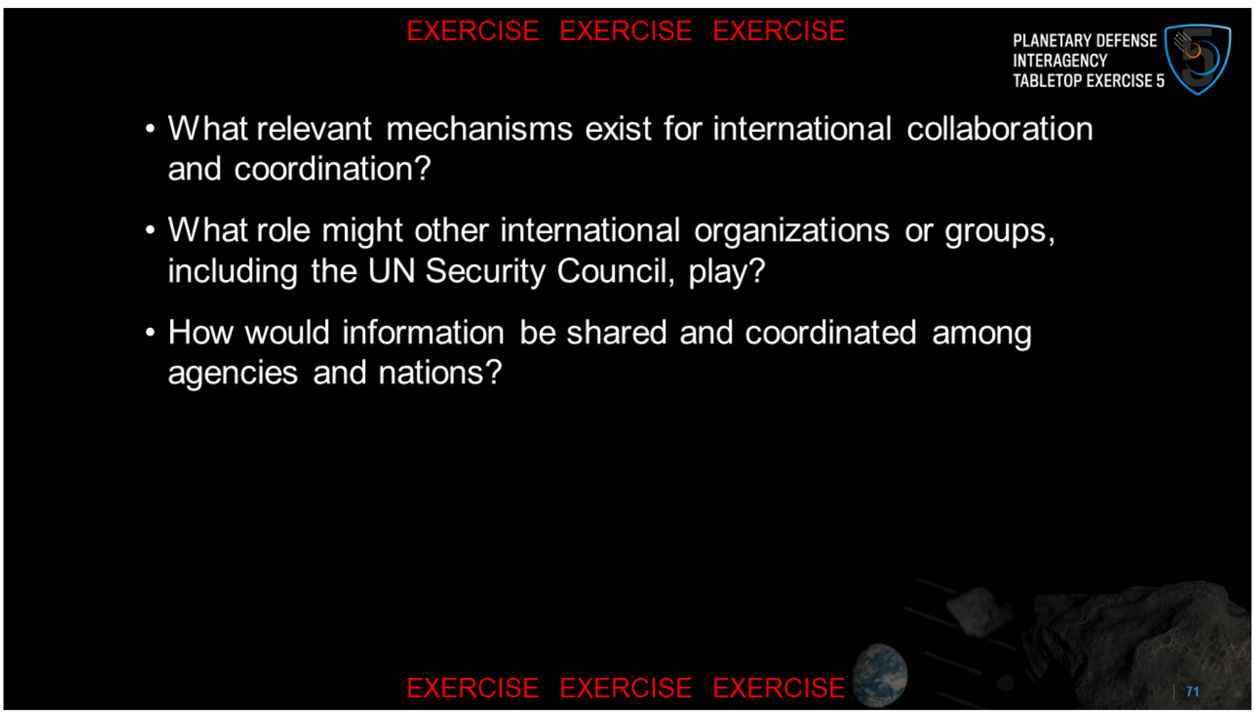

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• How would notification processes work in countries other than the U.S.?
• What notification systems exist that could be used or adapted for this scenario?
• What (if any) policies does your nation or agency have that will influence or guide your decisions now?
EXERCISE EXERCISE EXERCISE
66

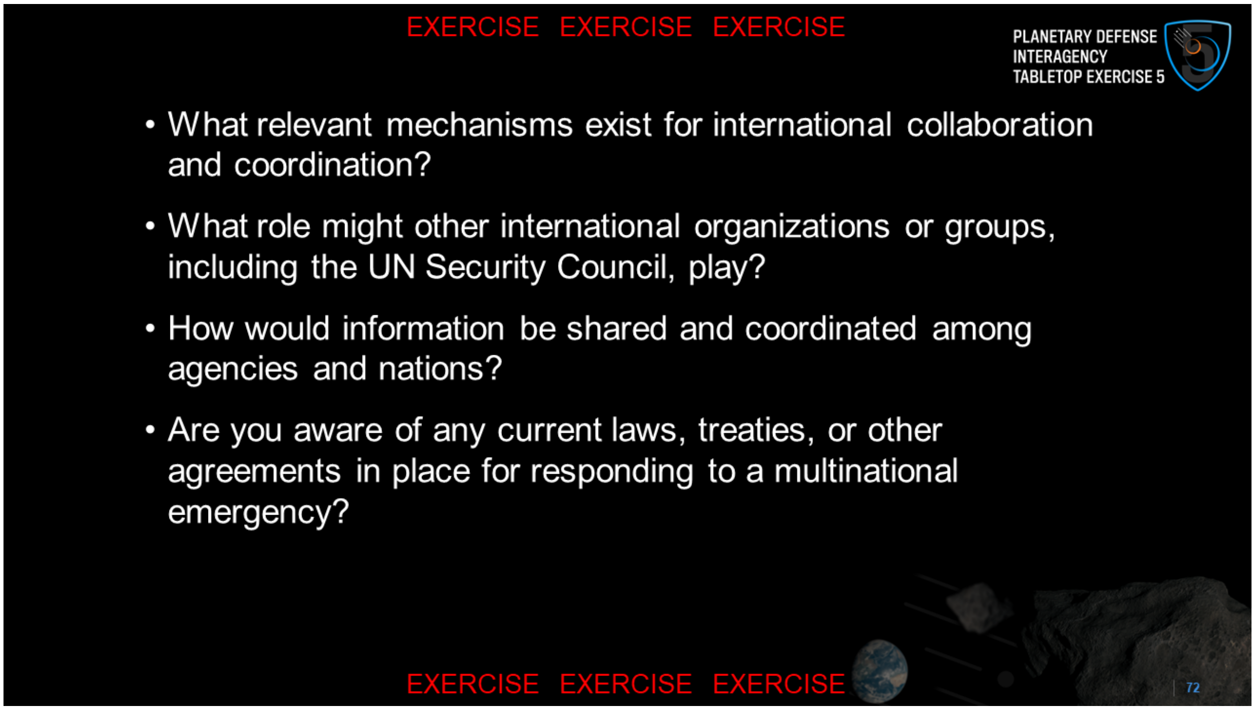

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• How would notification processes work in countries other than the U.S.?
• What notification systems exist that could be used or adapted for this scenario?
• What (if any) policies does your nation or agency have that will influence or guide your decisions now?
• With which partners or stakeholders would you be communicating and coordinating?
EXERCISE EXERCISE EXERCISE
67


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• How would notification processes work in countries other than the U.S.?
• What notification systems exist that could be used or adapted for this scenario?
• What (if any) policies does your nation or agency have that will influence or guide your decisions now?
• With which partners or stakeholders would you be communicating and coordinating?
• What roles might you expect your nation's military, armed forces, or private sector to play?
EXERCISE EXERCISE EXERCISE
68

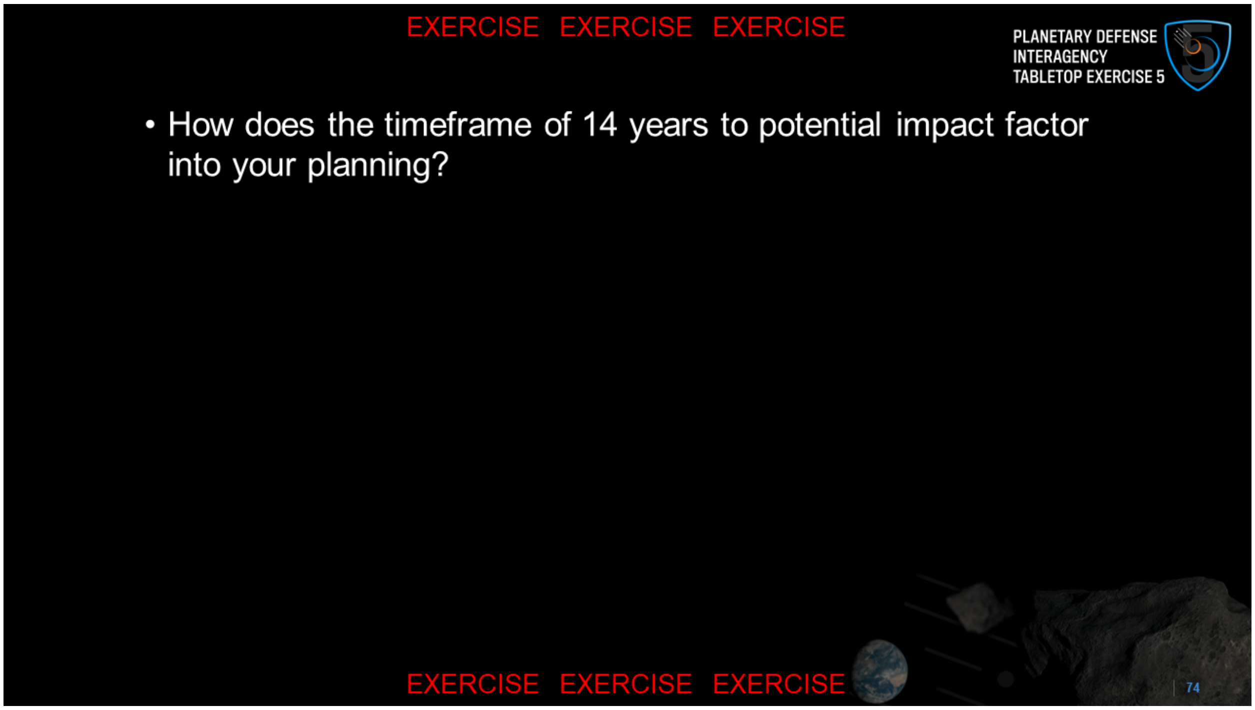

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What relevant mechanisms exist for international collaboration and coordination?
EXERCISE EXERCISE EXERCISE
69

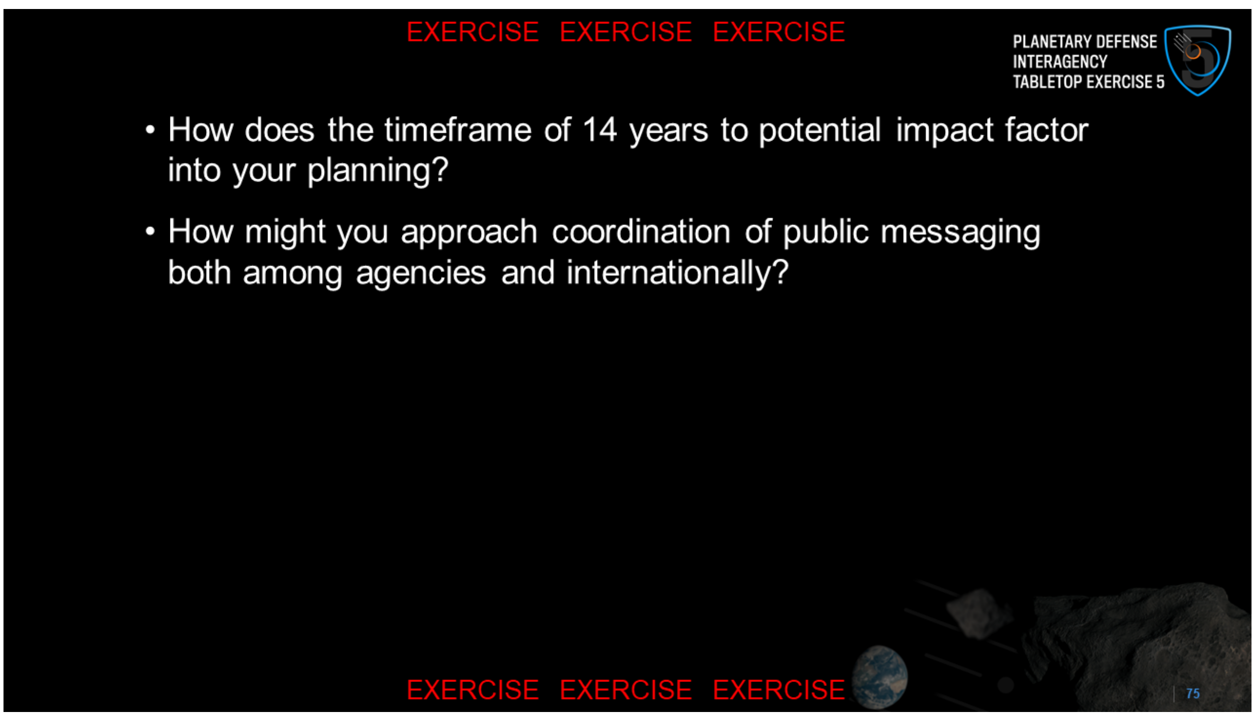

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What relevant mechanisms exist for international collaboration and coordination?
• What role might other international organizations or groups, including the UN Security Council, play?
EXERCISE EXERCISE EXERCISE
70


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What relevant mechanisms exist for international collaboration and coordination?
• What role might other international organizations or groups, including the UN Security Council, play?
• How would information be shared and coordinated among agencies and nations?
EXERCISE EXERCISE EXERCISE
71


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What relevant mechanisms exist for international collaboration and coordination?
• What role might other international organizations or groups, including the UN Security Council, play?
• How would information be shared and coordinated among agencies and nations?
• Are you aware of any current laws, treaties, or other agreements in place for responding to a multinational emergency?
EXERCISE EXERCISE EXERCISE
72


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
NORTH AMERICA
ASIA
AFRICA
SOUTH AMERICA
Indian Ocean
OCEAN
0 people 45%
>1K people 47%
>100K people 28%
>1M people 8%
>10M people 0.04%
Affected people among Earth-impacting scenarios
72%
probability of Earth impact
14.25 years
from today
Many
uncertainties
Potential Telescopic Information
2024 Nov
2028
2033
Today 2 Apr 2024
Impact location uncertainty is the size of Earth.
Earth impact location ±25 km. Spectral and JWST observations possible. Uncertainties remain in key asteroid properties.
Radar detection is possible if the object is large.
Potential Earth impact 12 Jul 2038
EXERCISE EXERCISE EXERCISE
73


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• How does the timeframe of 14 years to potential impact factor into your planning?
EXERCISE EXERCISE EXERCISE
74


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• How does the timeframe of 14 years to potential impact factor into your planning?
• How might you approach coordination of public messaging both among agencies and internationally?
EXERCISE EXERCISE EXERCISE
75

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- How does the timeframe of 14 years to potential impact factor into your planning?
- How might you approach coordination of public messaging both among agencies and internationally?
- How might you approach public safety preparedness planning?

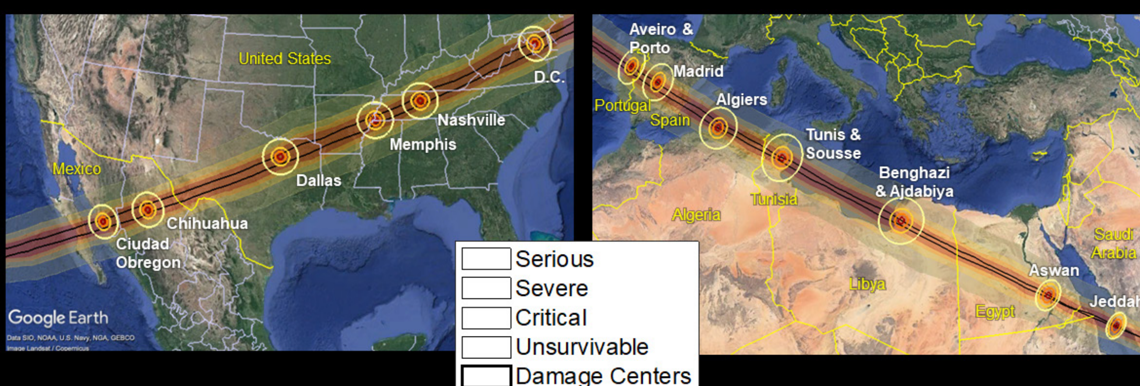
EXERCISE EXERCISE EXERCISE

76

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

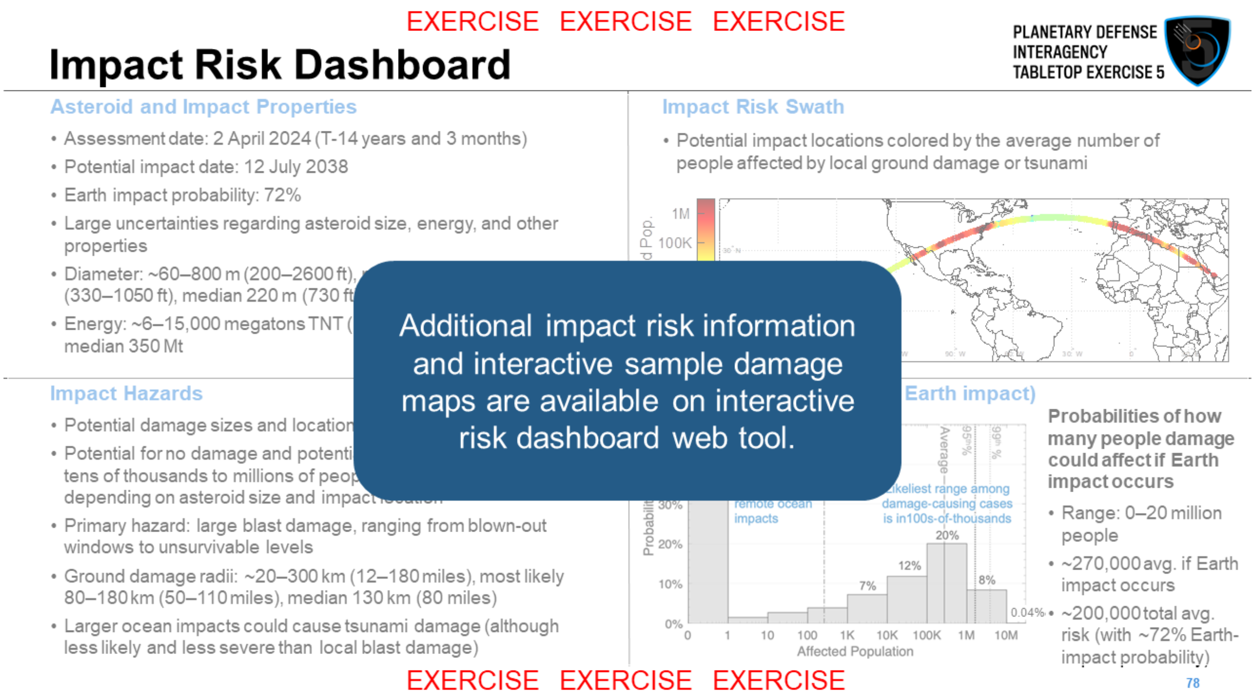
What's at Risk?

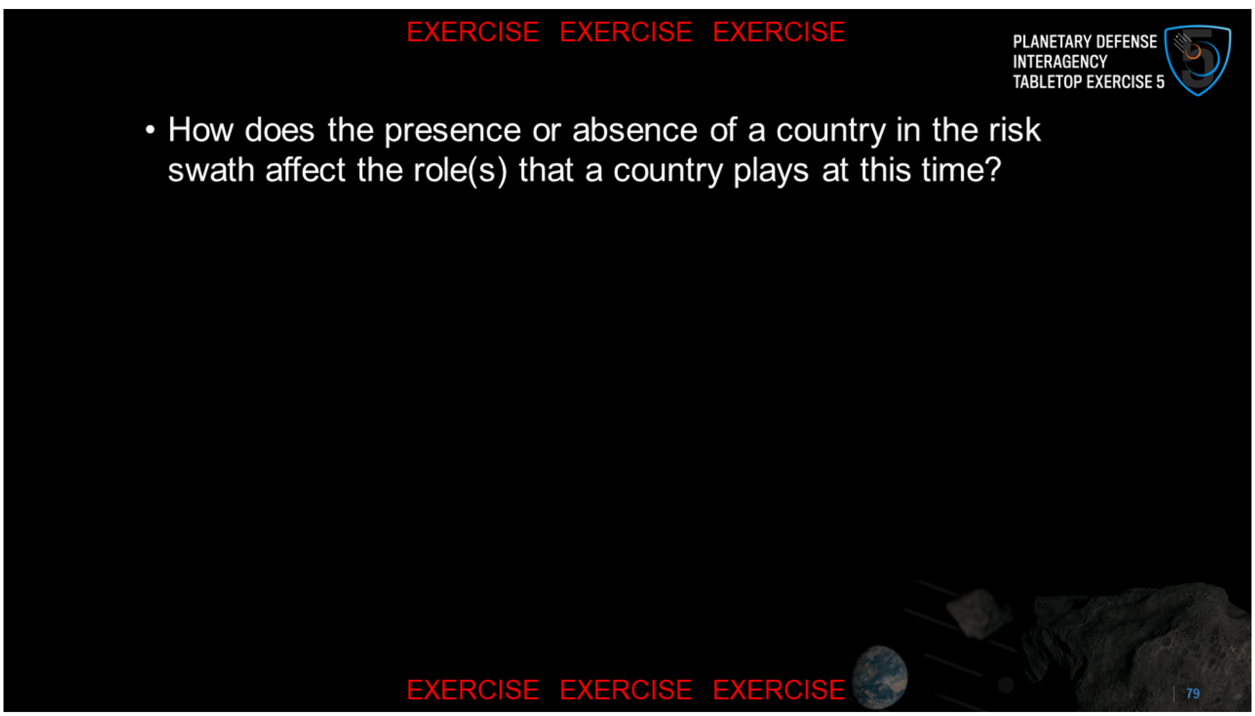


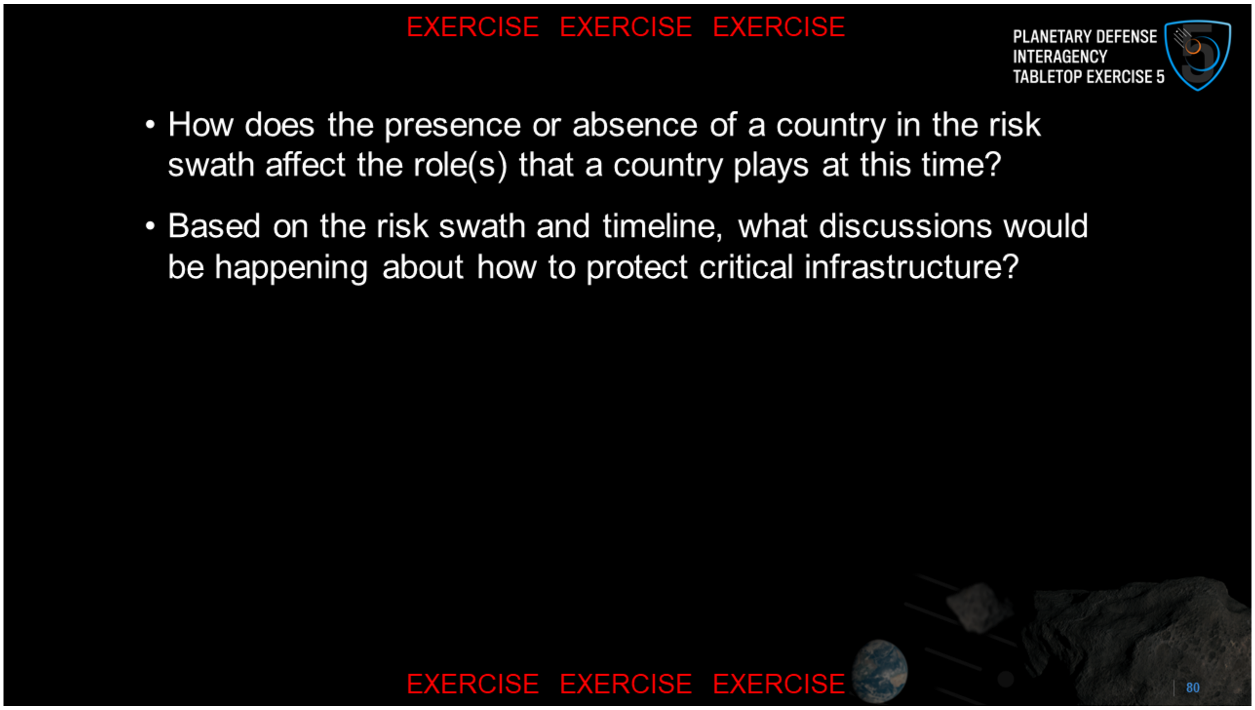
Damage risk swath: Regions that are *potentially* at risk for ground damage, given ranges of potential impact locations and damage sizes (out to 95th percentile). Rings show median (50th percentile) damage footprints at sample locations.

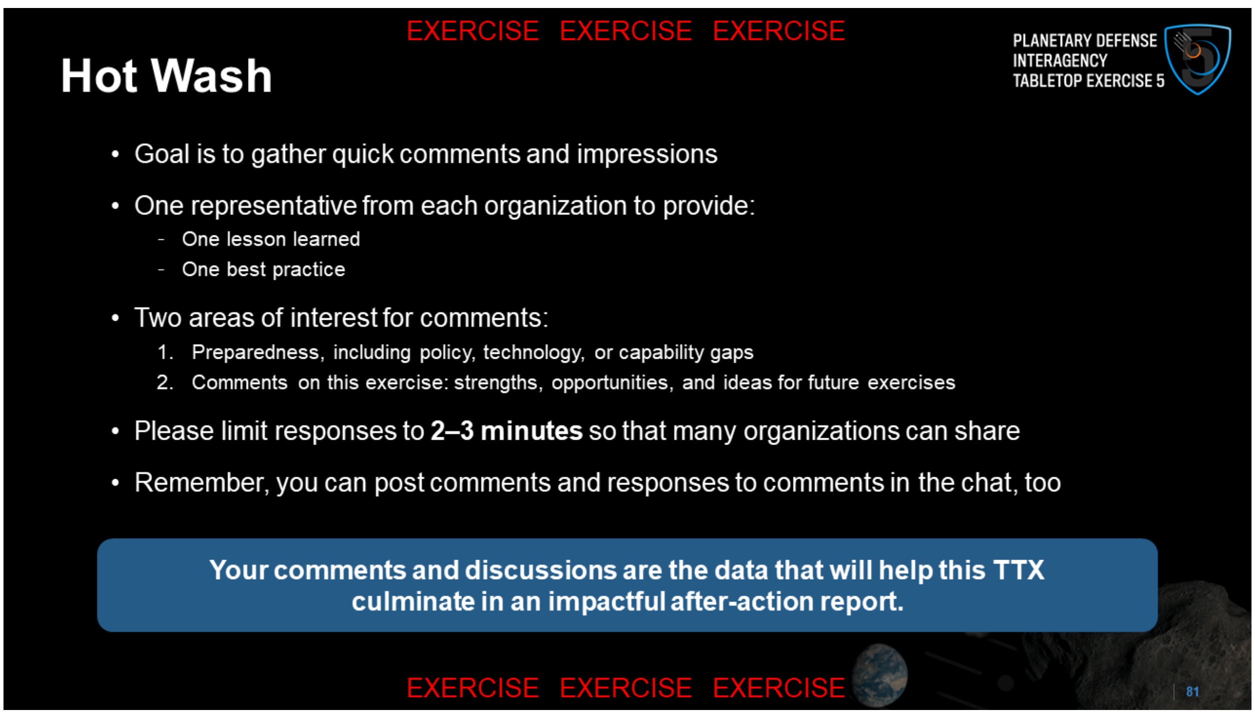
EXERCISE EXERCISE EXERCISE

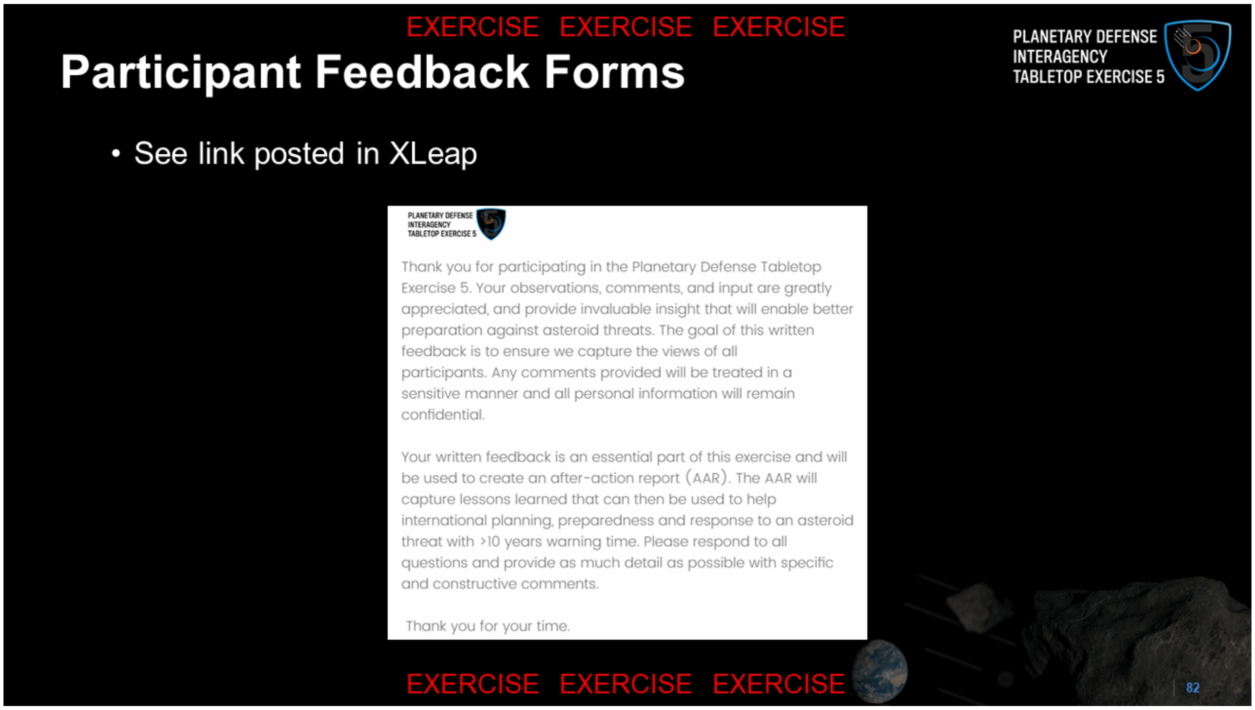
77


EXERCISE EXERCISE EXERCISE
Impact Risk Dashboard
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Asteroid and Impact Properties
• Assessment date: 2 April 2024 (T-14 years and 3 months)
• Potential impact date: 12 July 2038
• Earth impact probability: 72%
• Large uncertainties regarding asteroid size, energy, and other properties
• Diameter: ~60–800 m (200–2600 ft),
(330–1050 ft), median 220 m (730 ft
• Energy: ~6–15,000 megatons TNT (
median 350 Mt
Impact Risk Swath
• Potential impact locations colored by the average number of people affected by local ground damage or tsunami
1M
100K
Additional impact risk information and interactive sample damage maps are available on interactive risk dashboard web tool.
Impact Hazards
• Potential damage sizes and location
• Potential for no damage and potenti
tens of thousands to millions of peop
depending on asteroid size and impact
• Primary hazard: large blast damage, ranging from blown-out windows to unsurvivable levels
• Ground damage radii: ~20–300 km (12–180 miles), most likely 80–180 km (50–110 miles), median 130 km (80 miles)
• Larger ocean impacts could cause tsunami damage (although less likely and less severe than local blast damage)
Earth impact)
remote ocean impacts
Likeliest range among damage-causing cases is in100s-of-thousands
Average
95th%
99th %
30%
20%
10%
0%
20%
12%
7%
8%
0.04%
0
1
10
100
1K
10K
100K
1M
10M
Affected Population
Probability
Probabilities of how many people damage could affect if Earth impact occurs
• Range: 0–20 million people
• ~270,000 avg. if Earth impact occurs
• ~200,000 total avg. risk (with ~72% Earth-impact probability)
EXERCISE EXERCISE EXERCISE
78


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• How does the presence or absence of a country in the risk swath affect the role(s) that a country plays at this time?
EXERCISE EXERCISE EXERCISE
79

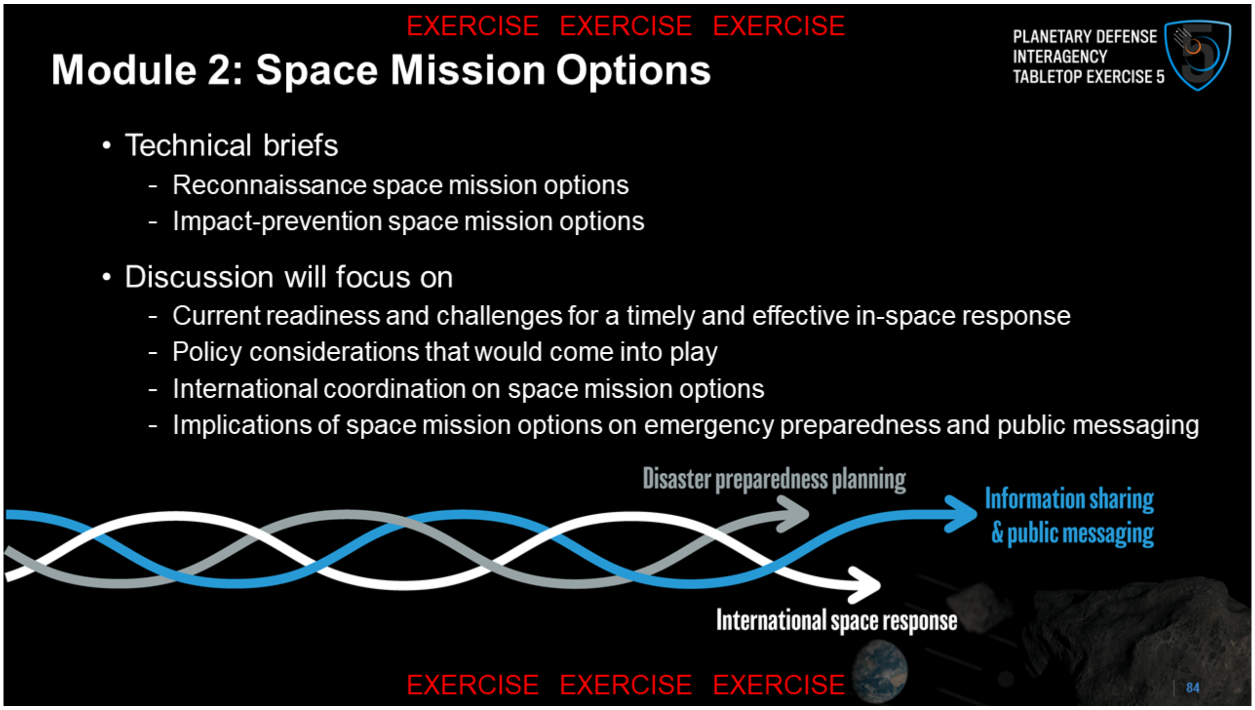

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• How does the presence or absence of a country in the risk swath affect the role(s) that a country plays at this time?
• Based on the risk swath and timeline, what discussions would be happening about how to protect critical infrastructure?
EXERCISE EXERCISE EXERCISE
80

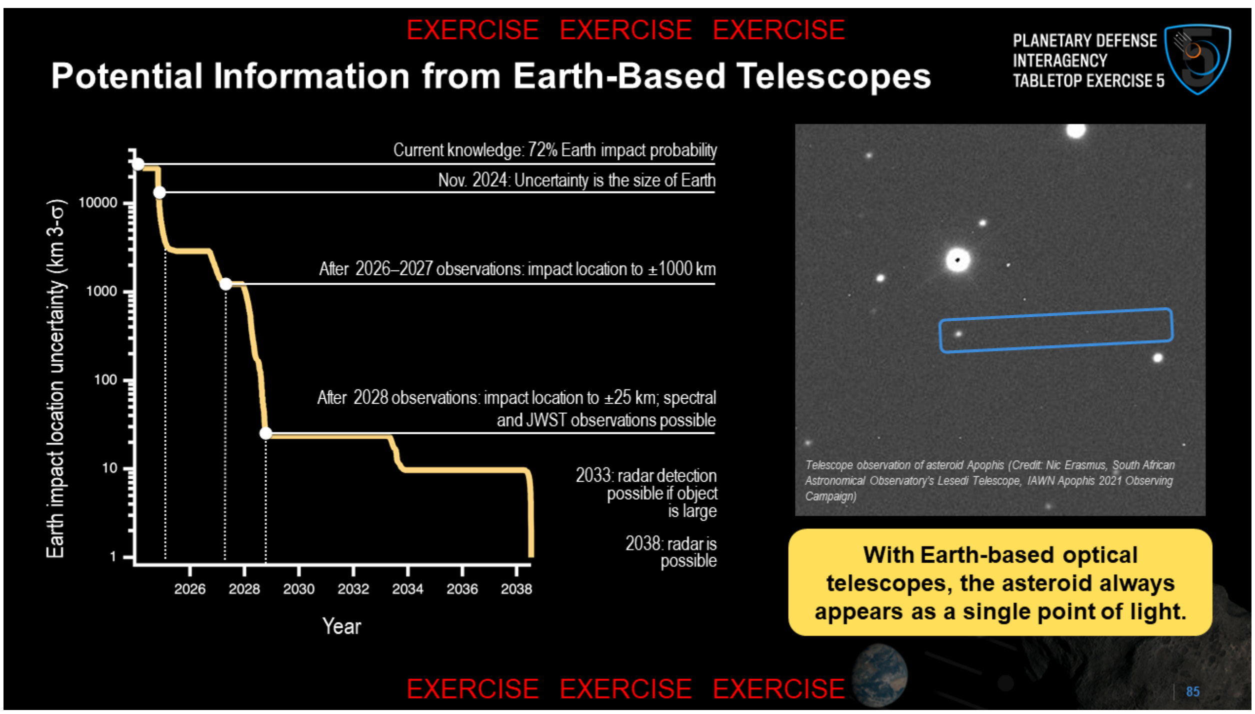

EXERCISE EXERCISE EXERCISE
Hot Wash
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Goal is to gather quick comments and impressions
• One representative from each organization to provide:
- One lesson learned
- One best practice
• Two areas of interest for comments:
1. Preparedness, including policy, technology, or capability gaps
2. Comments on this exercise: strengths, opportunities, and ideas for future exercises
• Please limit responses to 2–3 minutes so that many organizations can share
• Remember, you can post comments and responses to comments in the chat, too
Your comments and discussions are the data that will help this TTX culminate in an impactful after-action report.
EXERCISE EXERCISE EXERCISE
81

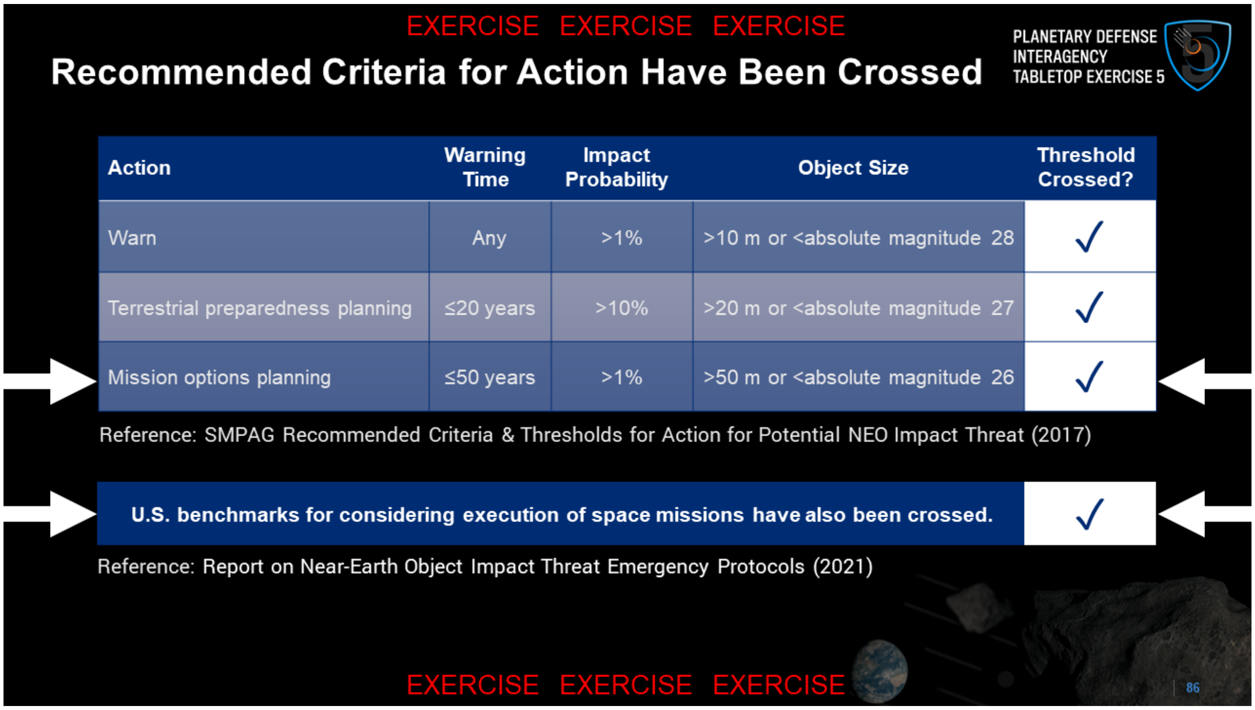

EXERCISE EXERCISE EXERCISE
Participant Feedback Forms
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• See link posted in XLeap
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Thank you for participating in the Planetary Defense Tabletop Exercise 5. Your observations, comments, and input are greatly appreciated, and provide invaluable insight that will enable better preparation against asteroid threats. The goal of this written feedback is to ensure we capture the views of all participants. Any comments provided will be treated in a sensitive manner and all personal information will remain confidential.
Your written feedback is an essential part of this exercise and will be used to create an after-action report (AAR). The AAR will capture lessons learned that can then be used to help international planning, preparedness and response to an asteroid threat with >10 years warning time. Please respond to all questions and provide as much detail as possible with specific and constructive comments.
Thank you for your time.
EXERCISE EXERCISE EXERCISE
82


PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
NASA
FEMA
APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
cneos
Ames Research Center
Lawrence Livermore National Laboratory
83

H.1.3. Module 2: Space Mission Options

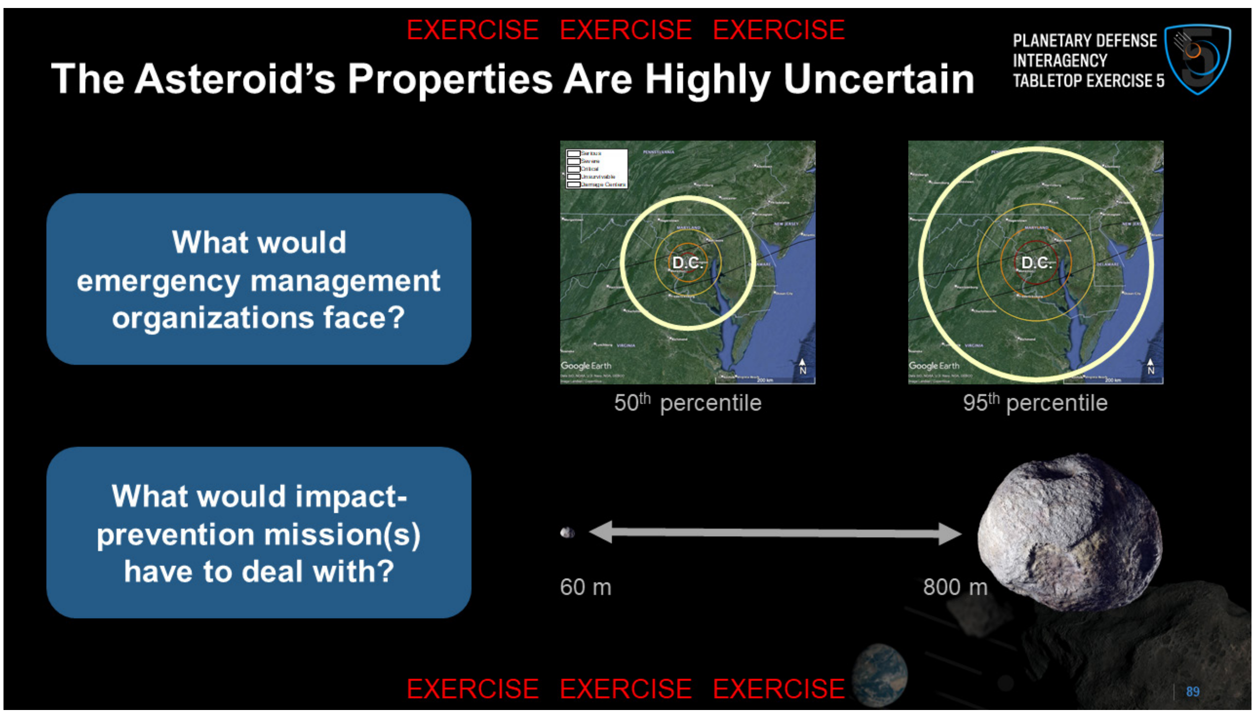


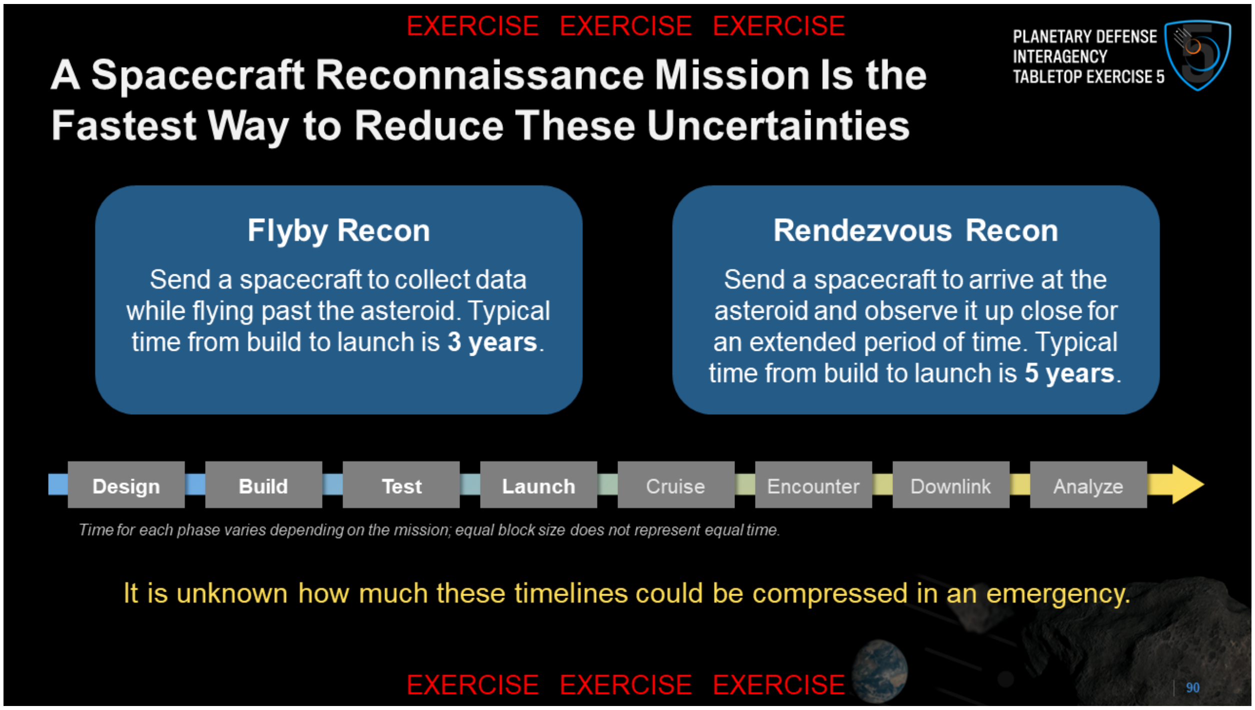


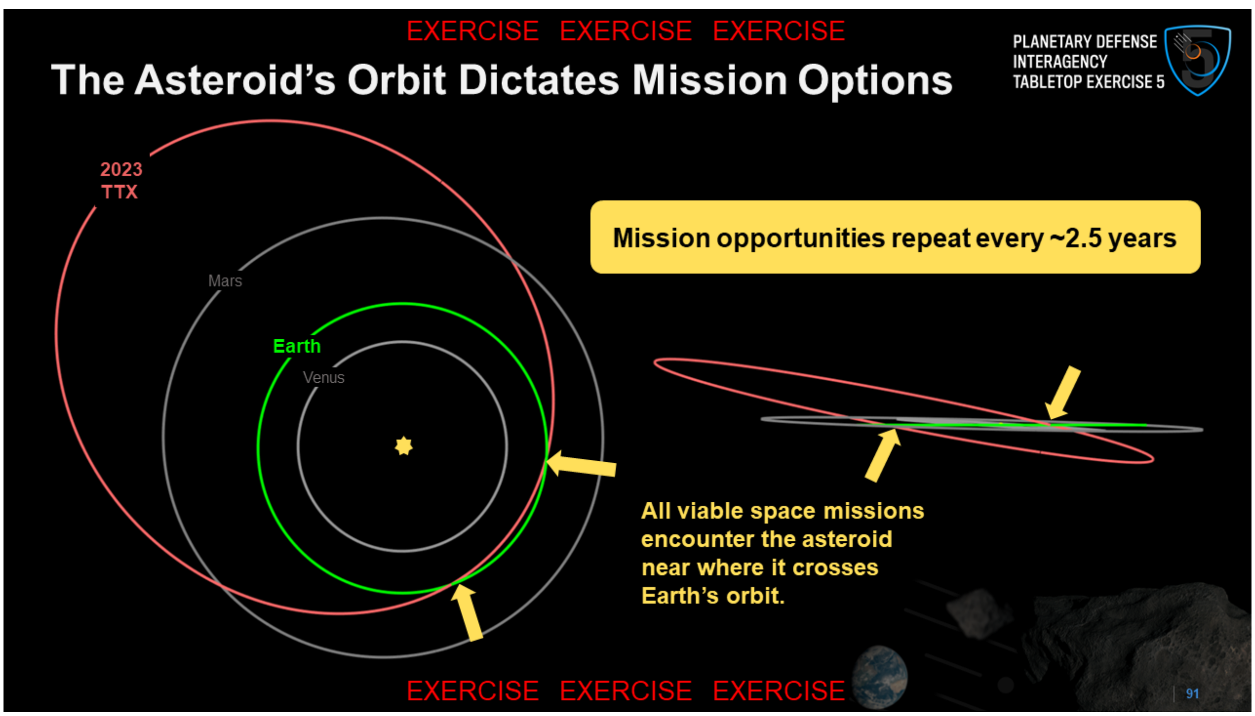

EXERCISE EXERCISE EXERCISE
Recommended Criteria for Action Have Been Crossed
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Action | Warning Time | Impact Probability | Object Size | Threshold Crossed?
Warn | Any | >1% | >10 m or <absolute magnitude 28 | ✓
Terrestrial preparedness planning | ≤20 years | >10% | >20 m or <absolute magnitude 27 | ✓
Mission options planning | ≤50 years | >1% | >50 m or <absolute magnitude 26 | ✓
Reference: SMPAG Recommended Criteria & Thresholds for Action for Potential NEO Impact Threat (2017)
U.S. benchmarks for considering execution of space missions have also been crossed. ✓
Reference: Report on Near-Earth Object Impact Threat Emergency Protocols (2021)
EXERCISE EXERCISE EXERCISE
86

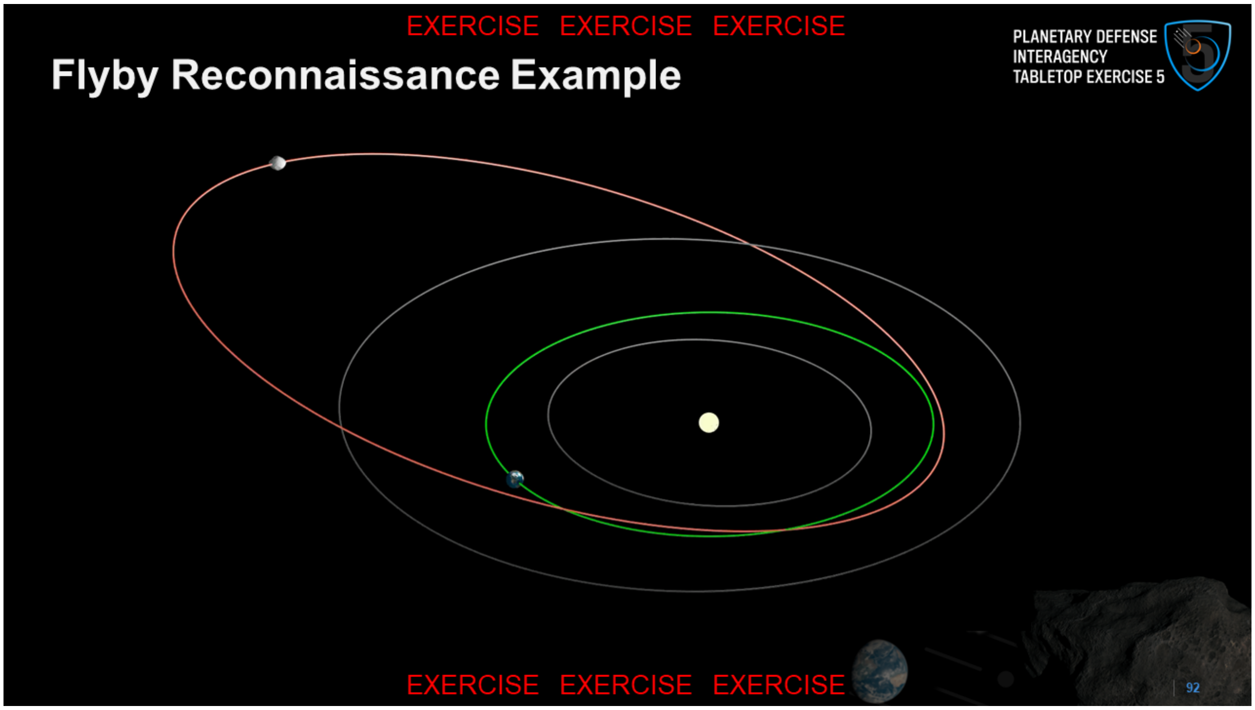

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Reconnaissance Mission Options
Justin Atchison (Johns Hopkins Applied Physics Laboratory)
Brent Barbee (NASA Goddard Space Flight Center)
Rylie Bull (Johns Hopkins Applied Physics Laboratory)
Davide Farnocchia (Jet Propulsion Laboratory/Center for Near Earth Object Studies)
Matt Vavrina (NASA Goddard Space Flight Center)
NASA
FEMA
APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
cneos
Ames Research Center
Lawrence Livermore National Laboratory


EXERCISE EXERCISE EXERCISE
Asteroid Impacts May Be Preventable
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Kinetic Impact
Ion Beam
Nuclear Explosive Devices
Successful impact prevention requires adequate warning time
and information about key asteroid properties.
EXERCISE EXERCISE EXERCISE
88


EXERCISE EXERCISE EXERCISE
The Asteroid's Properties Are Highly Uncertain
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
What would
emergency management
organizations face?
D.C.
50th percentile
D.C.
95th percentile
What would impact-
prevention mission(s)
have to deal with?
60 m
800 m
EXERCISE EXERCISE EXERCISE
89


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
A Spacecraft Reconnaissance Mission Is the Fastest Way to Reduce These Uncertainties
Flyby Recon
Send a spacecraft to collect data while flying past the asteroid. Typical time from build to launch is 3 years.
Rendezvous Recon
Send a spacecraft to arrive at the asteroid and observe it up close for an extended period of time. Typical time from build to launch is 5 years.
Design
Build
Test
Launch
Cruise
Encounter
Downlink
Analyze
Time for each phase varies depending on the mission; equal block size does not represent equal time.
It is unknown how much these timelines could be compressed in an emergency.
EXERCISE EXERCISE EXERCISE
90


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
The Asteroid's Orbit Dictates Mission Options
2023 TTX
Mars
Earth
Venus
Mission opportunities repeat every ~2.5 years
All viable space missions encounter the asteroid near where it crosses Earth's orbit.
EXERCISE EXERCISE EXERCISE
91



EXERCISE EXERCISE EXERCISE

Flyby Reconnaissance Example

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Mission type	Earth impact location uncertainty	Asteroid size uncertainty	Asteroid mass uncertainty	Other asteroid information gained
Flyby recon	~100 km	~10%	~50%	Some surface images and high-level composition classification
Rendezvous recon	<10 km	<1%	<1%	Extensive surface imaging and detailed composition mapping

From analyses of previous planetary defense exercises and data from asteroid missions. Specific information gained would depend on the specific mission.

EXERCISE EXERCISE EXERCISE

93

EXERCISE EXERCISE EXERCISE

Flyby Recon Mission Options

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Launch Date	Arrival Date	Relative Cost	Launch: Years from April 2024	
~~Aug 2024~~	~~Jan 2026~~	~~$$~~	~~0.5~~	← Requires a spacecraft ready to go
Nov 2025	Jul 2027	$$$	1.5	← Aggressive development schedule (~3 years historically)
Sep 2027	Jul 2028	$	3.5	
May 2029	Jan 2031	$ – $$	5	
Jul 2032	Jul 2033	$ – $$	8	
Aug 2034	Jan 2036	$	10	← Not possible to send a follow-on mitigation mission

Many flyby options are available for other arrival windows.

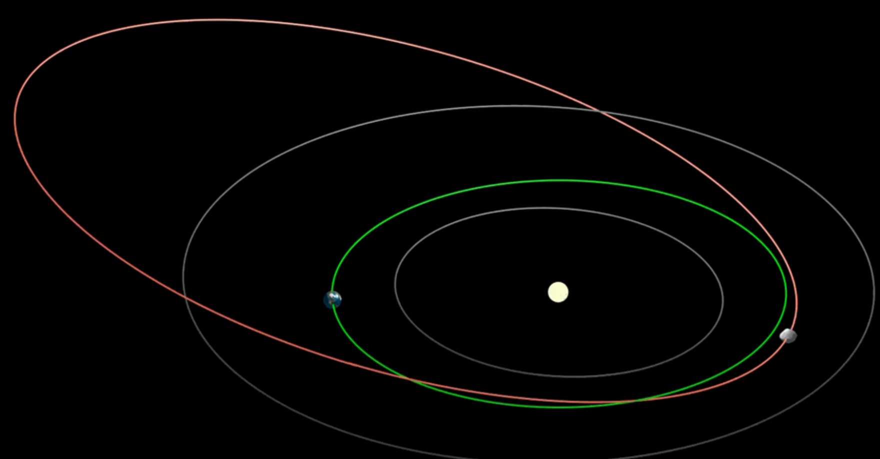
EXERCISE EXERCISE EXERCISE

94

EXERCISE EXERCISE EXERCISE

Rendezvous Reconnaissance Example

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5



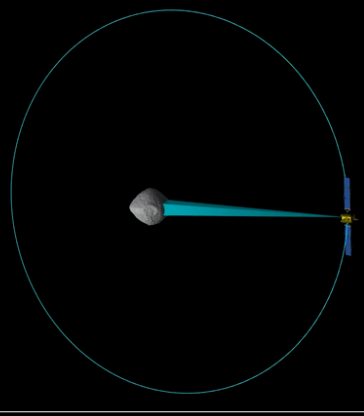
EXERCISE EXERCISE EXERCISE

95

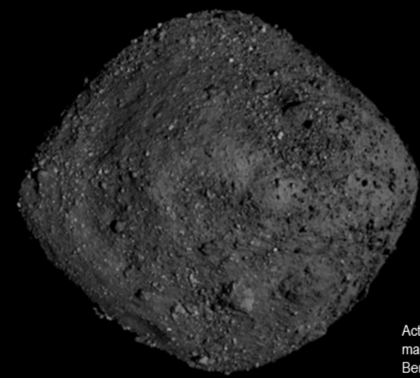
EXERCISE EXERCISE EXERCISE

Rendezvous Reconnaissance Example

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5



Simulated rendezvous operations



Actual OSIRIS-REx map of asteroid Bennu (2019)

Mission type	Earth impact location uncertainty	Asteroid size uncertainty	Asteroid mass uncertainty	Other asteroid information gained
Flyby recon	~100 km	~10%	~50%	Some surface images and high-level composition classification
Rendezvous recon	<10 km	<1%	<1%	Extensive surface imaging and detailed composition mapping

From analyses of previous planetary defense exercises and data from asteroid missions. Specific information gained would depend on the specific mission.

EXERCISE EXERCISE EXERCISE

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EXERCISE EXERCISE EXERCISE

Rendezvous Reconnaissance Mission Options

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

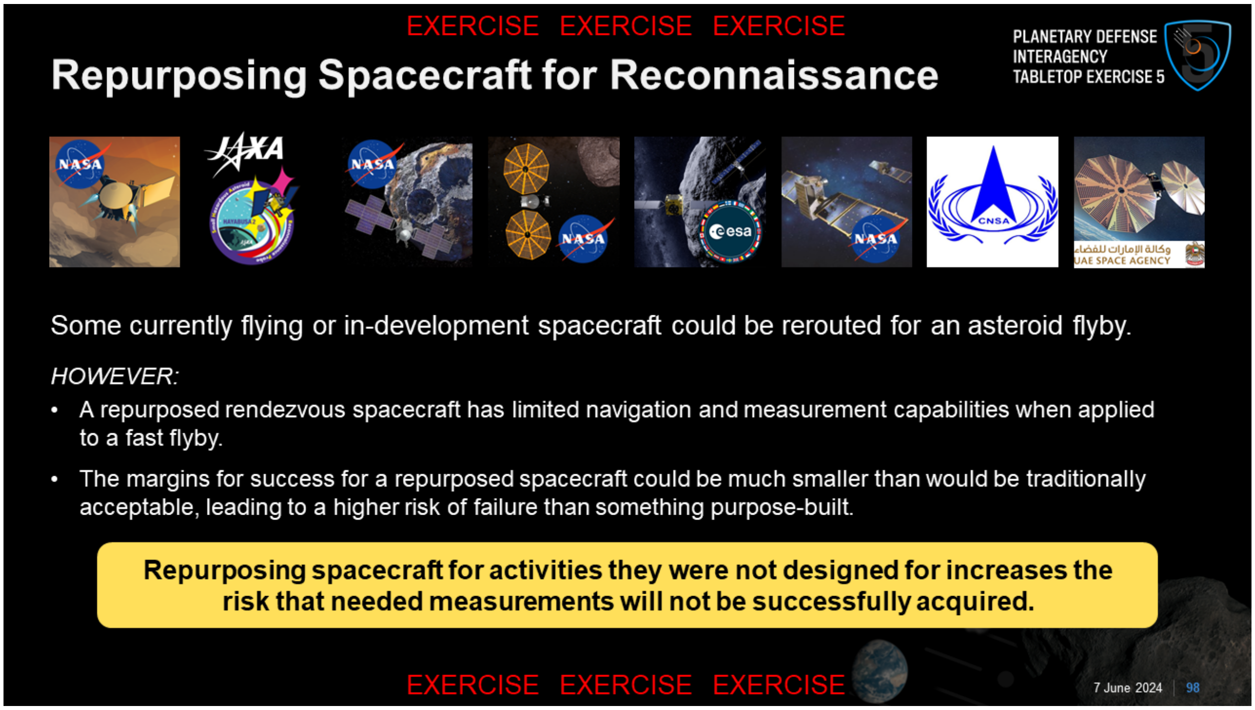
Launch Date	Arrival Date	Relative Cost	Launch, Years from April 2024	
Jun 2026	May 2028	$$$$	2	← Extremely aggressive development schedule (~5 years historically)
Jul 2028	Dec 2030	$$$$	4	← Aggressive development schedule (~5 years historically)
Jul 2029	Dec 2032	$$$	5	
Jul 2033	Dec 2035	$$$	10	

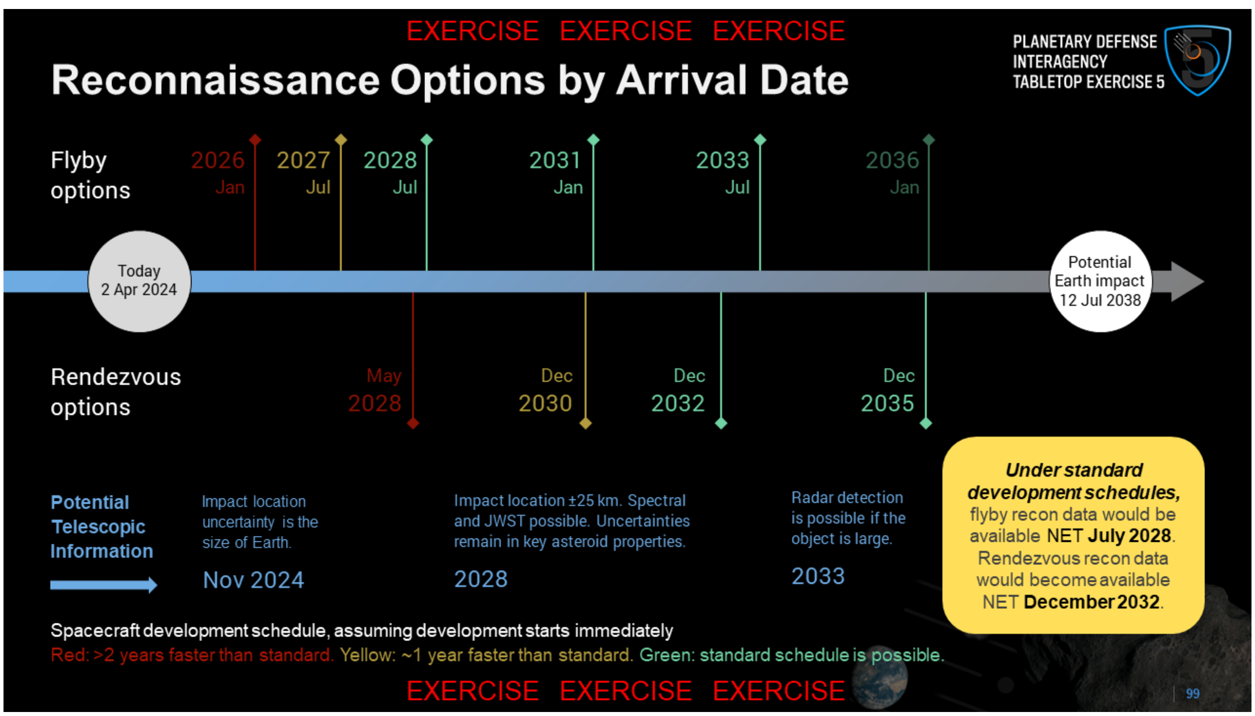
Rendezvous options assume a spacecraft mass and propulsion capabilities similar to NASA's Psyche mission.

Rendezvous requires a more complex spacecraft.
Rendezvous missions could be flown as combined recon and impact prevention missions.

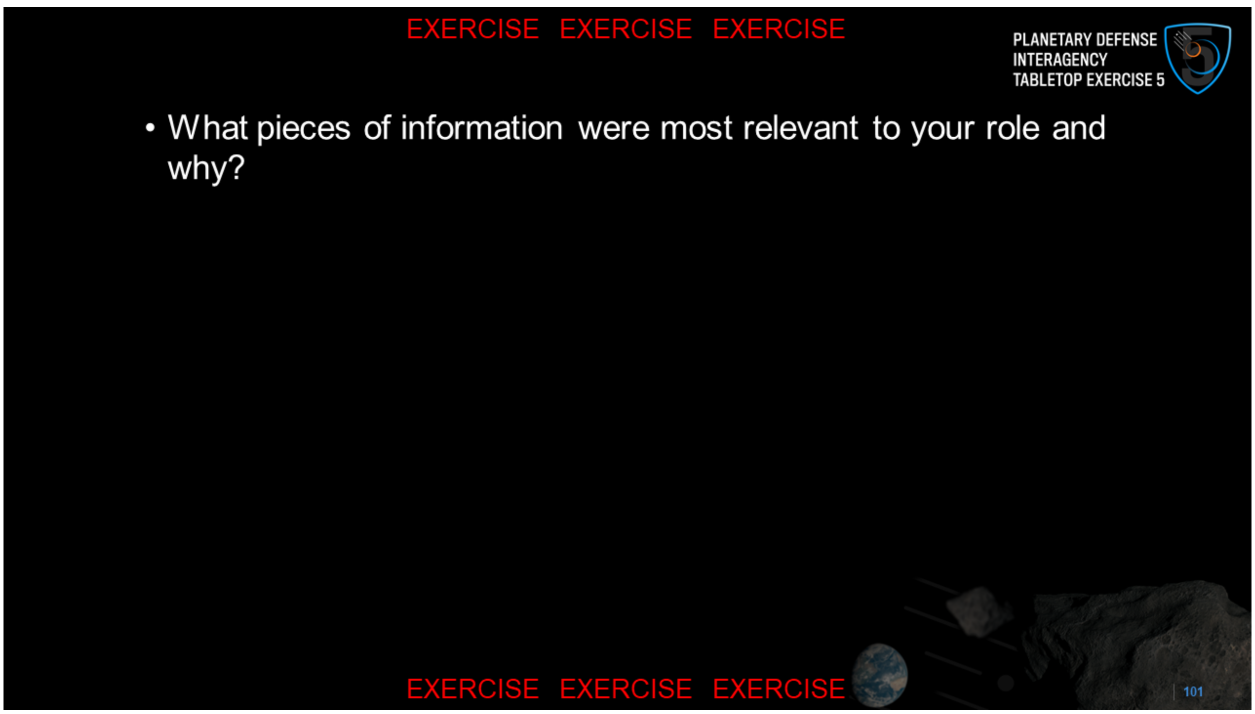
EXERCISE EXERCISE EXERCISE

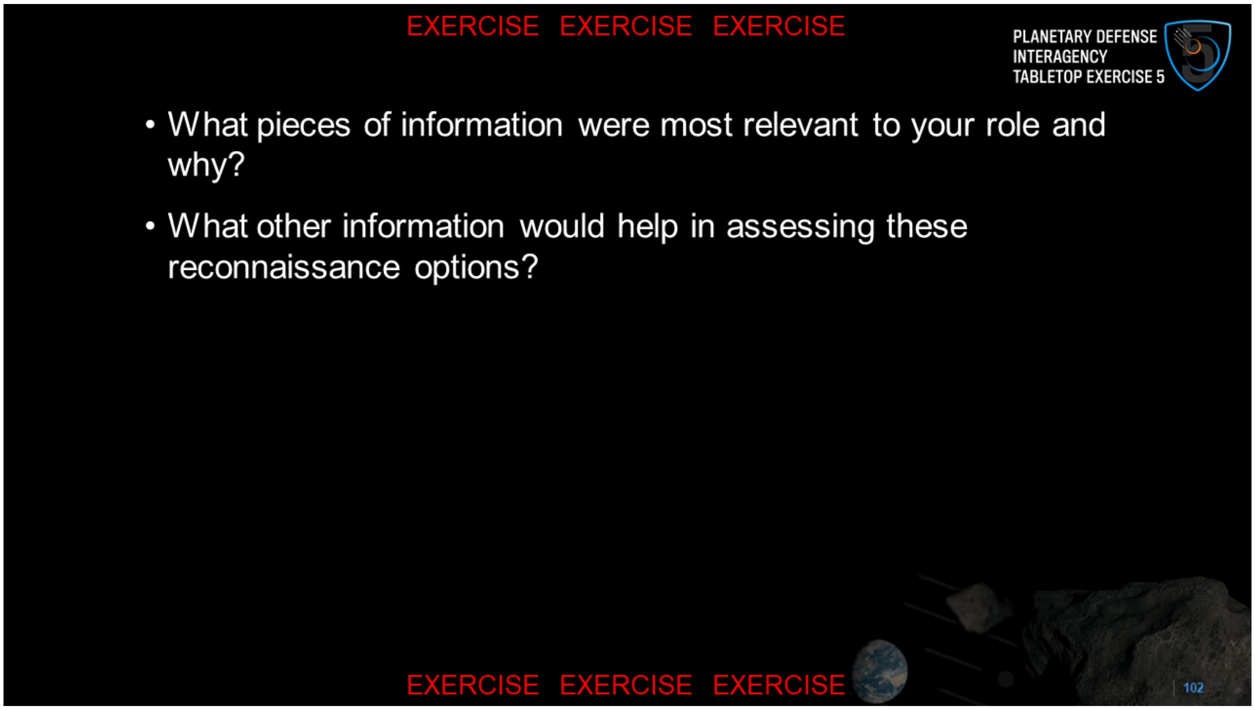
97

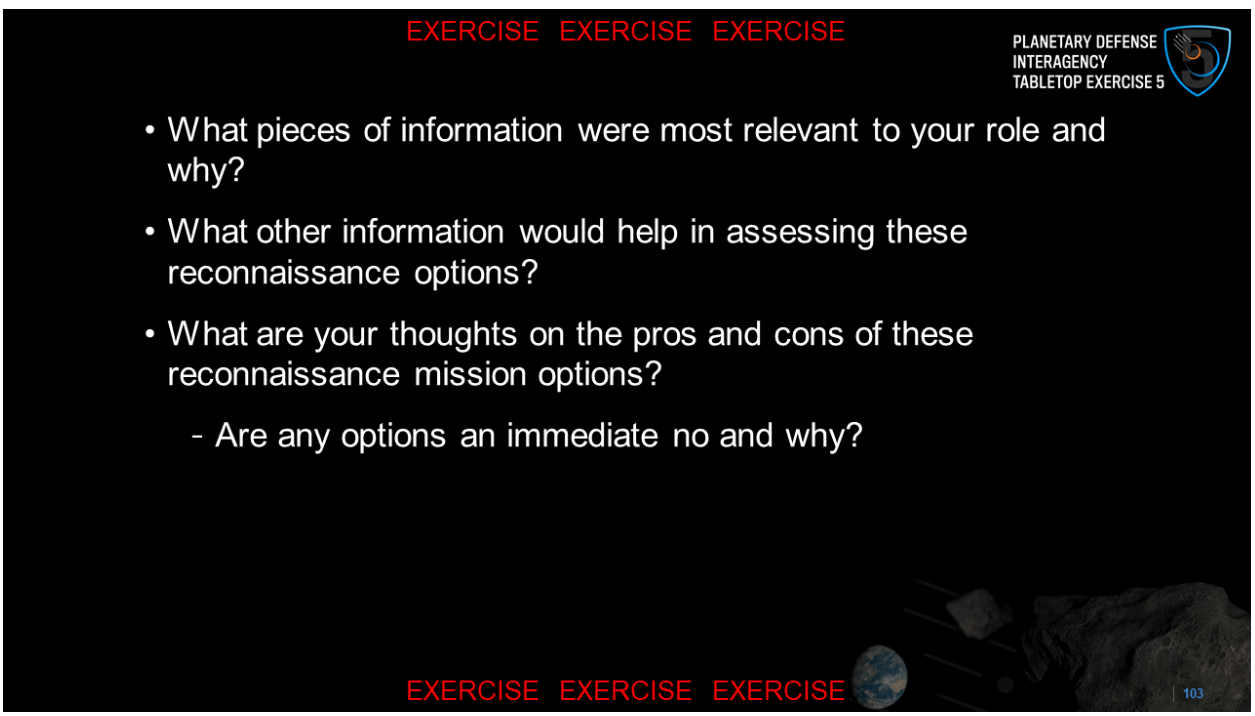

EXERCISE EXERCISE EXERCISE
Repurposing Spacecraft for Reconnaissance
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Some currently flying or in-development spacecraft could be rerouted for an asteroid flyby.
HOWEVER:
• A repurposed rendezvous spacecraft has limited navigation and measurement capabilities when applied to a fast flyby.
• The margins for success for a repurposed spacecraft could be much smaller than would be traditionally acceptable, leading to a higher risk of failure than something purpose-built.
Repurposing spacecraft for activities they were not designed for increases the risk that needed measurements will not be successfully acquired.
EXERCISE EXERCISE EXERCISE
7 June 2024 | 98

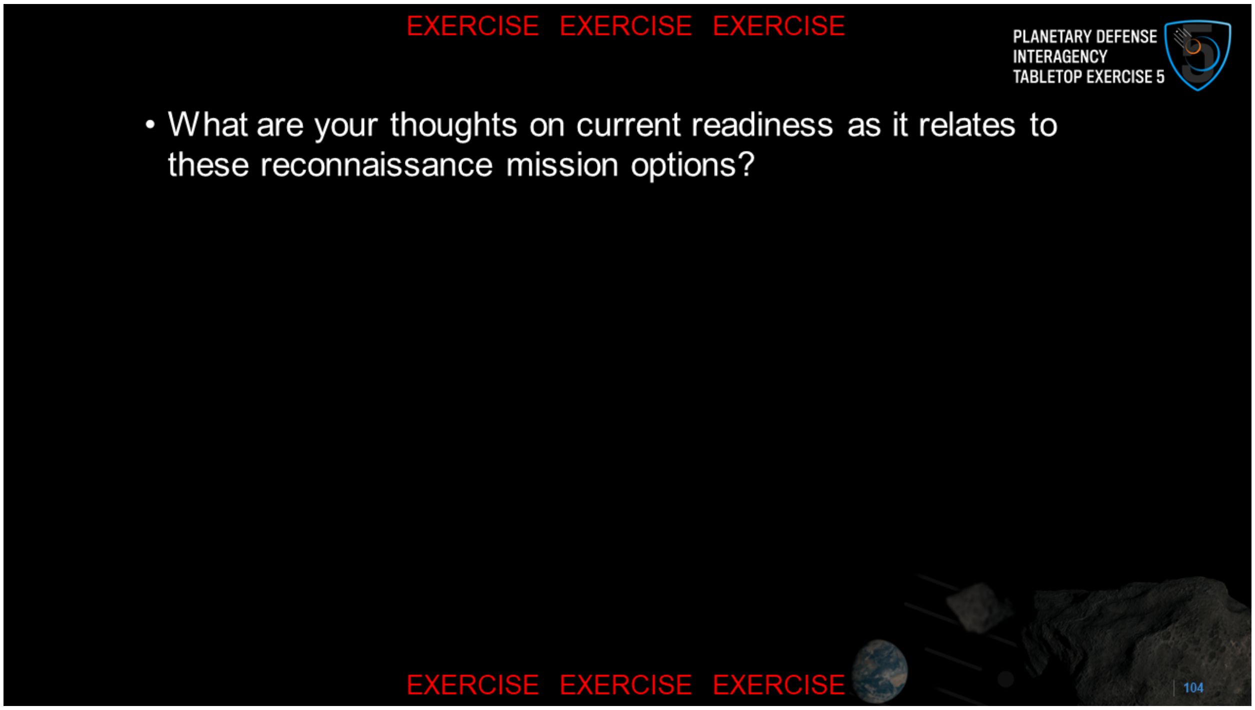

EXERCISE EXERCISE EXERCISE
Reconnaissance Options by Arrival Date
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Flyby options
2026 Jan
2027 Jul
2028 Jul
2031 Jan
2033 Jul
2036 Jan
Today 2 Apr 2024
Potential Earth impact 12 Jul 2038
Rendezvous options
May 2028
Dec 2030
Dec 2032
Dec 2035
Potential Telescopic Information
Impact location uncertainty is the size of Earth.
Nov 2024
Impact location ±25 km. Spectral and JWST possible. Uncertainties remain in key asteroid properties.
2028
Radar detection is possible if the object is large.
2033
Under standard development schedules, flyby recon data would be available NET July 2028. Rendezvous recon data would become available NET December 2032.
Spacecraft development schedule, assuming development starts immediately
Red: >2 years faster than standard. Yellow: ~1 year faster than standard. Green: standard schedule is possible.
EXERCISE EXERCISE EXERCISE
99

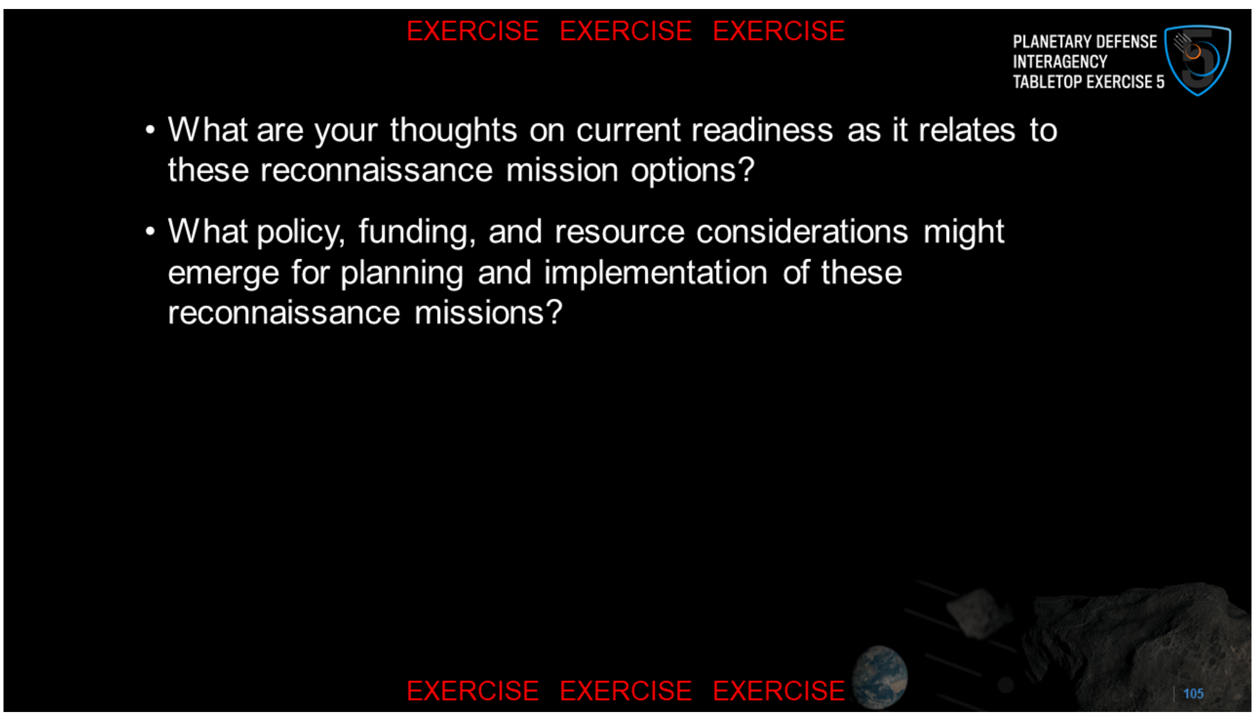

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
EXERCISE EXERCISE EXERCISE
100


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What pieces of information were most relevant to your role and why?
EXERCISE EXERCISE EXERCISE
101


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What pieces of information were most relevant to your role and why?
• What other information would help in assessing these reconnaissance options?
EXERCISE EXERCISE EXERCISE
102


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What pieces of information were most relevant to your role and why?
• What other information would help in assessing these reconnaissance options?
• What are your thoughts on the pros and cons of these reconnaissance mission options?
- Are any options an immediate no and why?
EXERCISE EXERCISE EXERCISE
103


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What are your thoughts on current readiness as it relates to these reconnaissance mission options?
EXERCISE EXERCISE EXERCISE
104


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What are your thoughts on current readiness as it relates to these reconnaissance mission options?
• What policy, funding, and resource considerations might emerge for planning and implementation of these reconnaissance missions?
EXERCISE EXERCISE EXERCISE
105

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Lunch

EXERCISE EXERCISE EXERCISE

106

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Recommended Criteria to Consider Impact Prevention Missions Have Been Crossed

Action	Warning Time	Impact Probability	Object Size	Threshold Crossed?
Mission options planning	≤50 years	>1%	>50 m or <absolute magnitude 26	✓

Reference: SMPAG Recommended Criteria & Thresholds for Action for Potential NEO Impact Threat (2017)

Action	Warning Time	Impact Probability	Object Size	Threshold Crossed?
Consider executing space-based impact-prevention mission	≤50 years	>10%	>50 m or <absolute magnitude 26	✓
Feasibility benchmarks	• Technically feasible • More likely to decrease impact probability than increase it • Waiting longer to improve confidence in impact prediction would substantially decrease likelihood of successful prevention			
Hazard benchmarks	• Impact would likely result in loss of many lives within the U.S. (of order 100 or more*) **OR** would likely result in U.S. economic cost exceeding the financial cost of prevention			

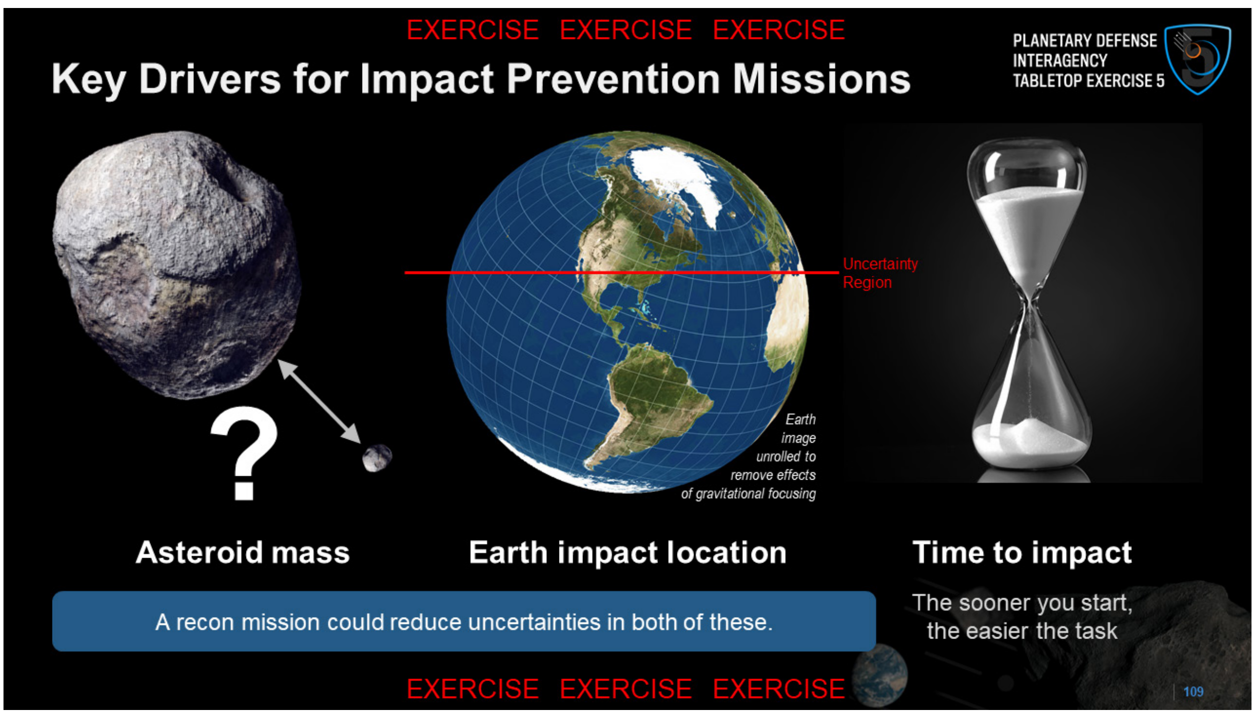
Reference: Report on Near-Earth Object Impact Threat Emergency Protocols (2021)

** Refers to assessed loss of life that evacuation cannot prevent, either because some cannot evacuate or the risk corridor is too large to organize an effective evacuation.*

EXERCISE EXERCISE EXERCISE

107


PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Earth Impact Prevention
Mission Options
Brent Barbee and Analysis Team
NASA Goddard Space Flight Center
Analysis Team: Justin Atchison (APL), Brent Barbee (NASA/GSFC), Rylie Bull (APL), Mary Burkey (LLNL), Wendy K. Caldwell (LANL), Paul Chodas (JPL/CNEOS), Jessie Dotson (NASA/ARC/ATAP), Davide Farnocchia (JPL/CNEOS), Kathryn Kumamoto (LLNL), Josh Lyzhoft (NASA/GSFC), Catherine Plesko (LANL), Isaiah Santistevan (LLNL), Bruno Sarli (NASA/GSFC), Megan Syal (LLNL), Matt Vavrina (NASA/GSFC)
FEMA
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
Lawrence Livermore National Laboratory


EXERCISE EXERCISE EXERCISE
Key Drivers for Impact Prevention Missions
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Uncertainty
Region
Earth
image
unrolled to
remove effects
of gravitational focusing
Asteroid mass
Earth impact location
Time to impact
A recon mission could reduce uncertainties in both of these.
The sooner you start,
the easier the task
EXERCISE EXERCISE EXERCISE
109

EXERCISE EXERCISE EXERCISE

In This Scenario, Deflection Is Preferred

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- Given what we know at this time in the scenario, disruption (breaking the asteroid into multiple smaller pieces) is impractical for ~80% of the potential asteroid masses.
- To avoid Earth impact, an asteroid can be **deflected** by changing its speed (slowing it down or speeding it up) but leaving the asteroid largely intact.
- Deflection analysis assumes the **highest deflection energy requirements** and considers up to the **90th-percentile asteroid mass** to provide high probability of mission success.

EXERCISE EXERCISE EXERCISE

110

EXERCISE EXERCISE EXERCISE

Kinetic Impact (KI) Deflection

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

A spacecraft intercepts and rams into the asteroid at high speed, creating ejecta that provides an additional push.

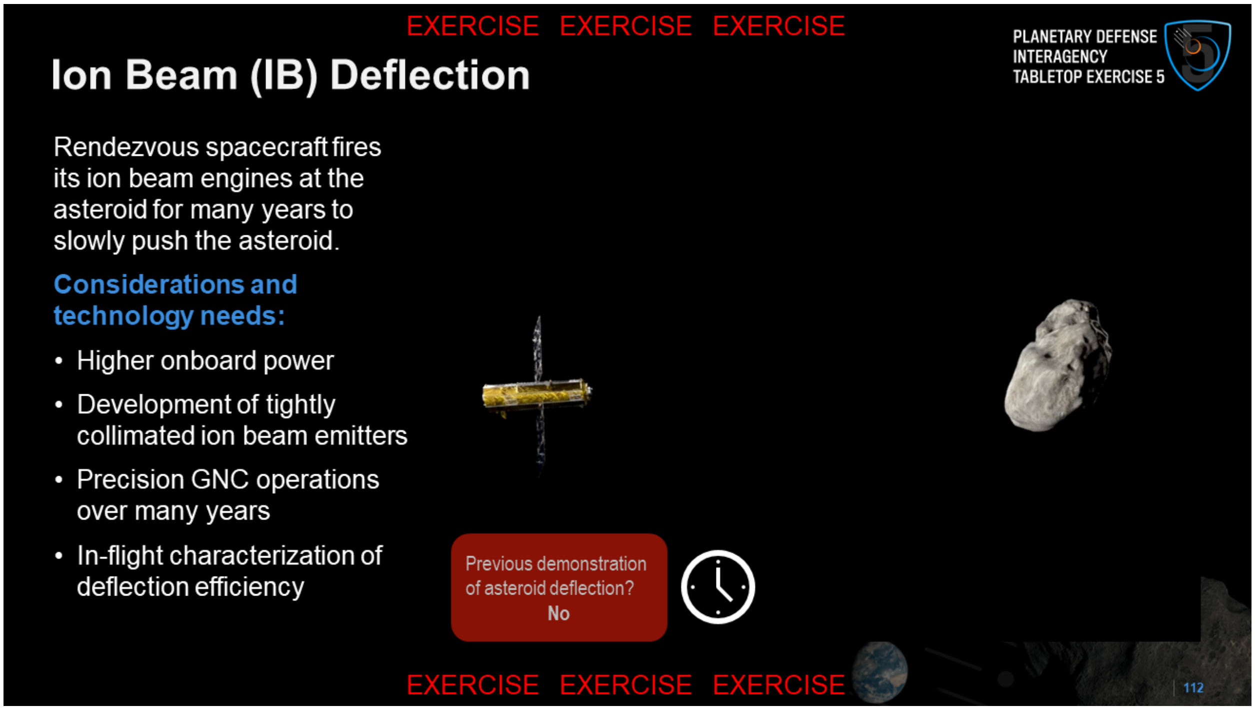
Considerations and technology needs:

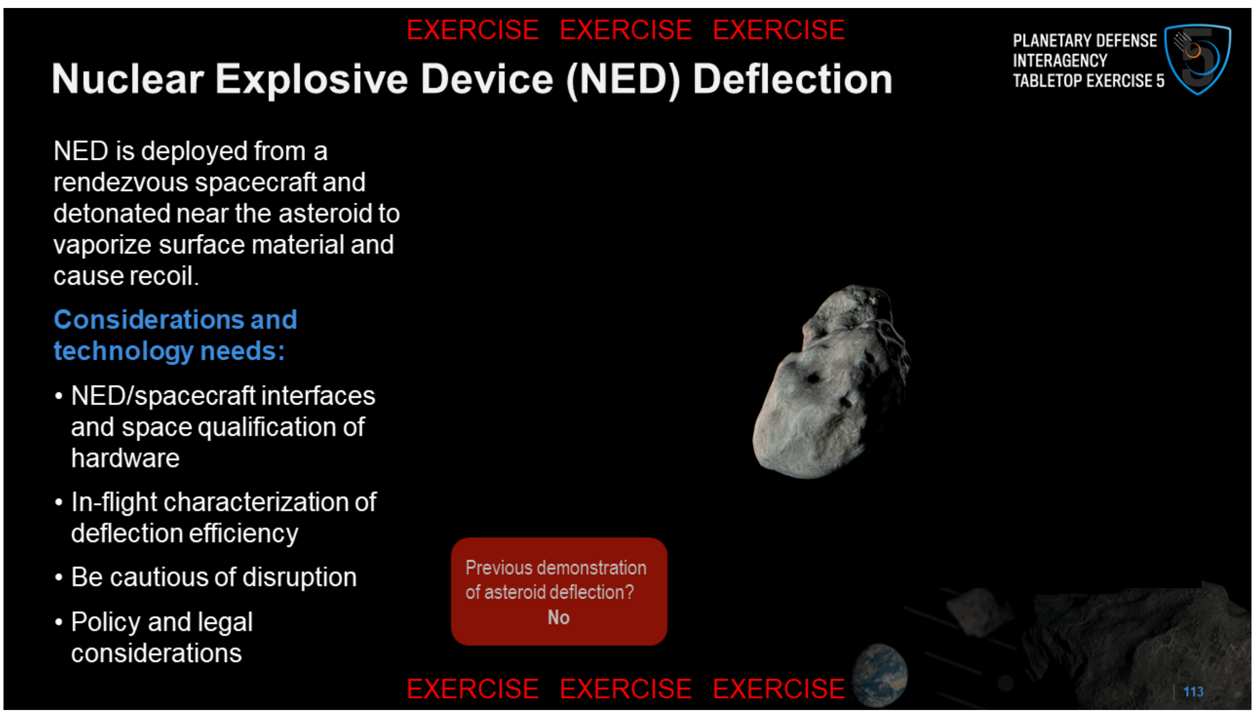
- Need to be cautious of disruption. Multiple, smaller impactors co-manifested on a single launch may be needed.
- Larger and faster spacecraft than DART demonstration are useful to achieve deflection.

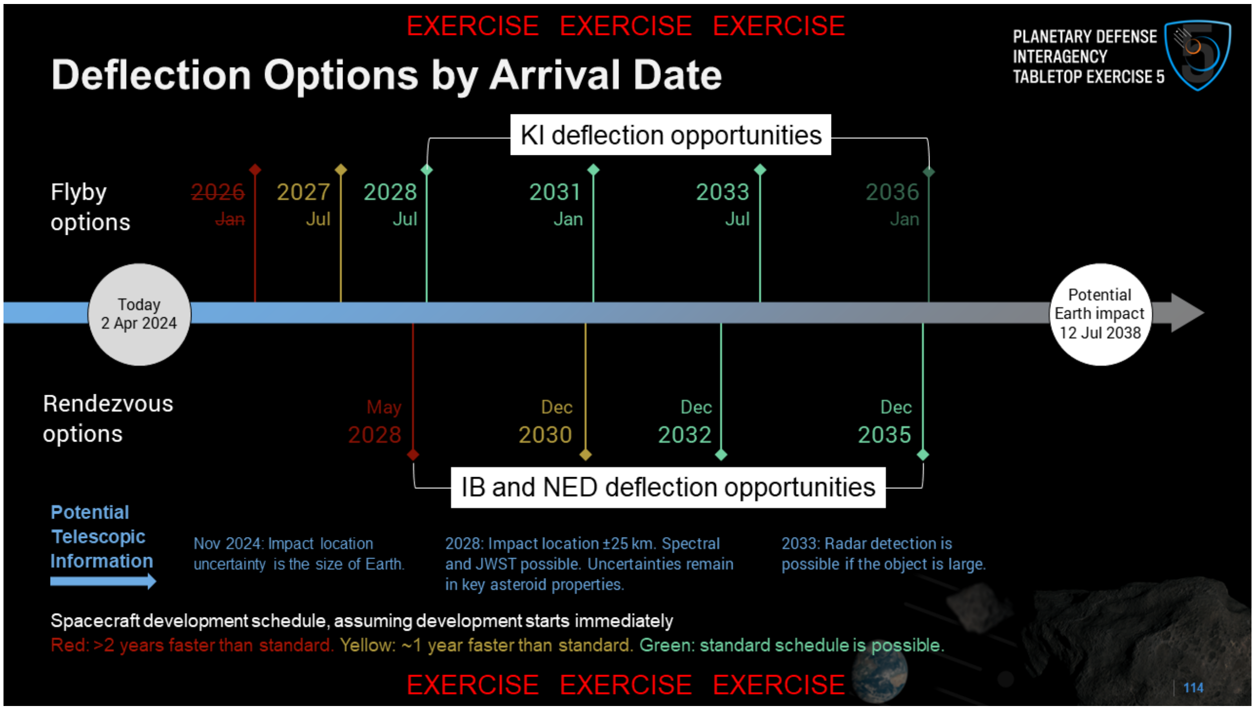
Previous demonstration of asteroid deflection? **Yes – with NASA's DART mission (2022)**

EXERCISE EXERCISE EXERCISE

111


EXERCISE EXERCISE EXERCISE
Ion Beam (IB) Deflection
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Rendezvous spacecraft fires its ion beam engines at the asteroid for many years to slowly push the asteroid.
Considerations and technology needs:
• Higher onboard power
• Development of tightly collimated ion beam emitters
• Precision GNC operations over many years
• In-flight characterization of deflection efficiency
Previous demonstration of asteroid deflection? No
EXERCISE EXERCISE EXERCISE
112


EXERCISE EXERCISE EXERCISE
Nuclear Explosive Device (NED) Deflection
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
NED is deployed from a rendezvous spacecraft and detonated near the asteroid to vaporize surface material and cause recoil.
Considerations and technology needs:
• NED/spacecraft interfaces and space qualification of hardware
• In-flight characterization of deflection efficiency
• Be cautious of disruption
• Policy and legal considerations
Previous demonstration of asteroid deflection? No
EXERCISE EXERCISE EXERCISE
113



EXERCISE EXERCISE EXERCISE
Deflection Options by Arrival Date
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
KI deflection opportunities
Flyby options
2026 Jan
2027 Jul
2028 Jul
2031 Jan
2033 Jul
2036 Jan
Today 2 Apr 2024
Potential Earth impact 12 Jul 2038
Rendezvous options
May 2028
Dec 2030
Dec 2032
Dec 2035
IB and NED deflection opportunities
Potential Telescopic Information
Nov 2024: Impact location uncertainty is the size of Earth.
2028: Impact location ±25 km. Spectral and JWST possible. Uncertainties remain in key asteroid properties.
2033: Radar detection is possible if the object is large.
Spacecraft development schedule, assuming development starts immediately
Red: >2 years faster than standard. Yellow: ~1 year faster than standard. Green: standard schedule is possible.
EXERCISE EXERCISE EXERCISE
114

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Earth Impact Prevention Mission Options

Data from recon missions could provide crucial information for planning Earth-impact-prevention missions.

Mission	Time Frame: Launch	Time Frame: Years from April 2024	Time Frame: Arrival	Date of: KI Deflection	Date of: NED Deflection	Date of: IB Deflection	# of Launches for Deflection, 50th Percentile: KI	50th Percentile: NED	50th Percentile: IB	90th Percentile: KI	90th Percentile: NED	90th Percentile: IB
Rendezvous	Jun 2026	2	May 2028	-	Aug 2028	April 2036	-	1	3	-	1	18
Flyby/KI	Sep 2027	3.5	Jul 2028	Jul 2028	-	-	1–2	-	-	7	-	-
Rendezvous	Jul 2028	4	Dec 2030	-	Feb 2031	April 2036	-	1	4	-	1	>20
Flyby/KI	May 2029	5	Jan 2031	Jan 2031	-	-	1–2	-	-	8	-	-
Rendezvous	Jul 2029	5	Dec 2032	-	Aug 2033	April 2036	-	1	11	-	1	>20
Flyby/KI	Jul 2032	8	Jul 2033	Jul 2033	-	-	1–2	-	-	7	-	-
Rendezvous	Jul 2033	9	Dec 2035	-	Feb 2036	*not feasible*	-	1	>20	-	1	>20
Flyby/KI	Aug 2034	10	Jan 2036	Jan 2036	-	-	2	-	-	12	-	-

Spacecraft development schedule, assuming development starts immediately

Red: >2 years faster than standard. Yellow: ~1 year faster than standard. Green: standard schedule is possible.

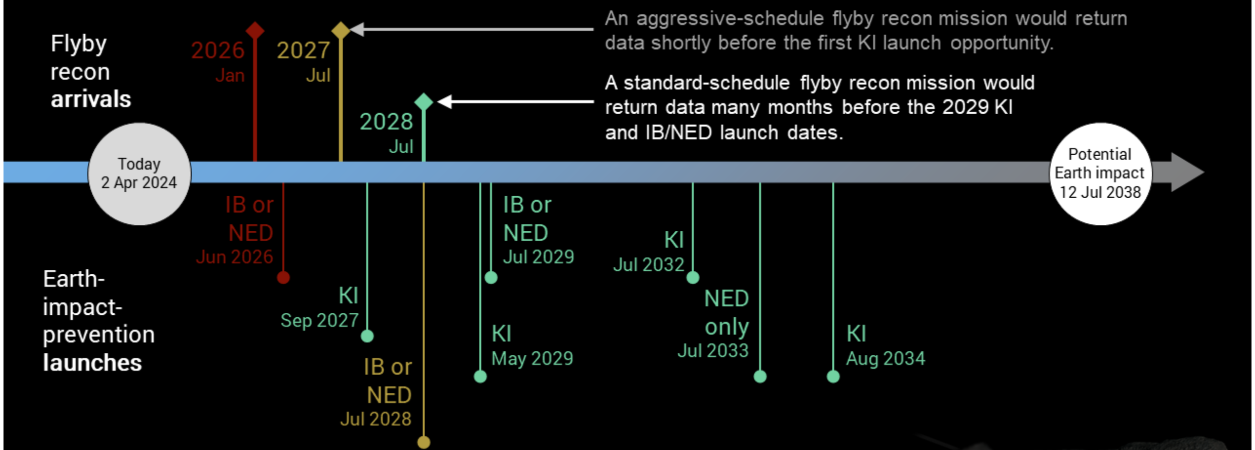
EXERCISE EXERCISE EXERCISE

115

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Could Flyby Recon Data Inform Earth-Impact-Prevention Missions?

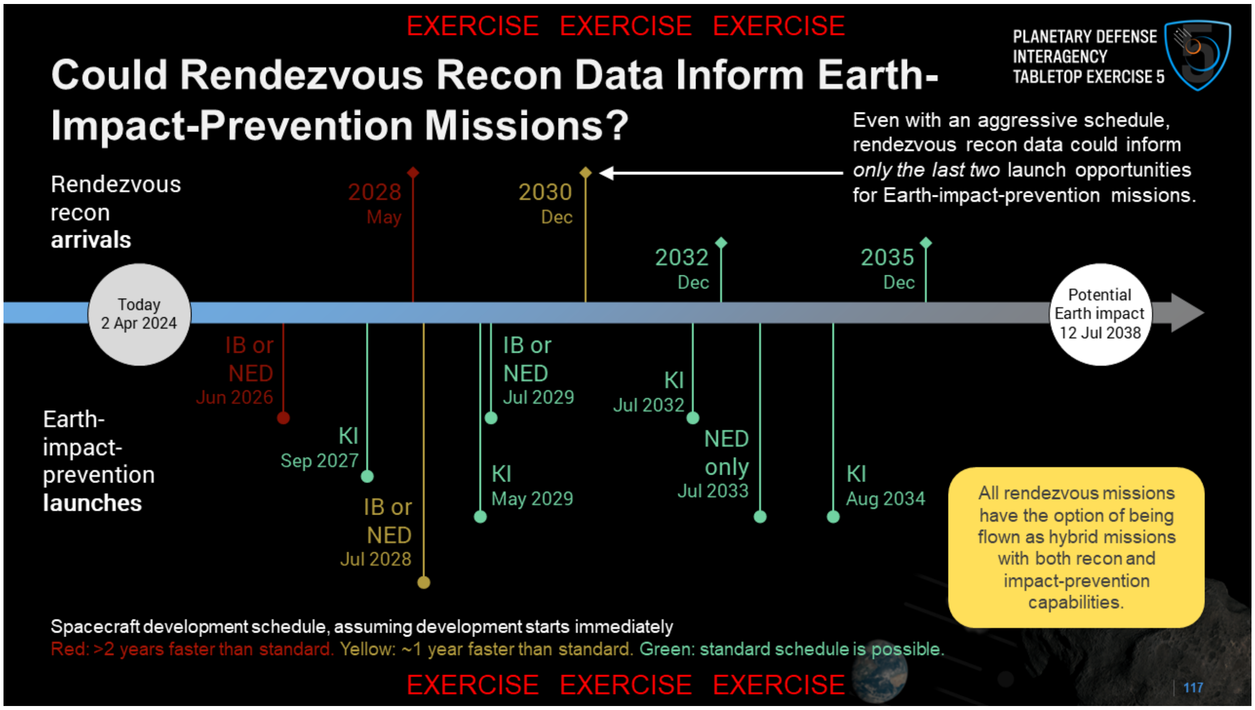


Spacecraft development schedule, assuming development starts immediately

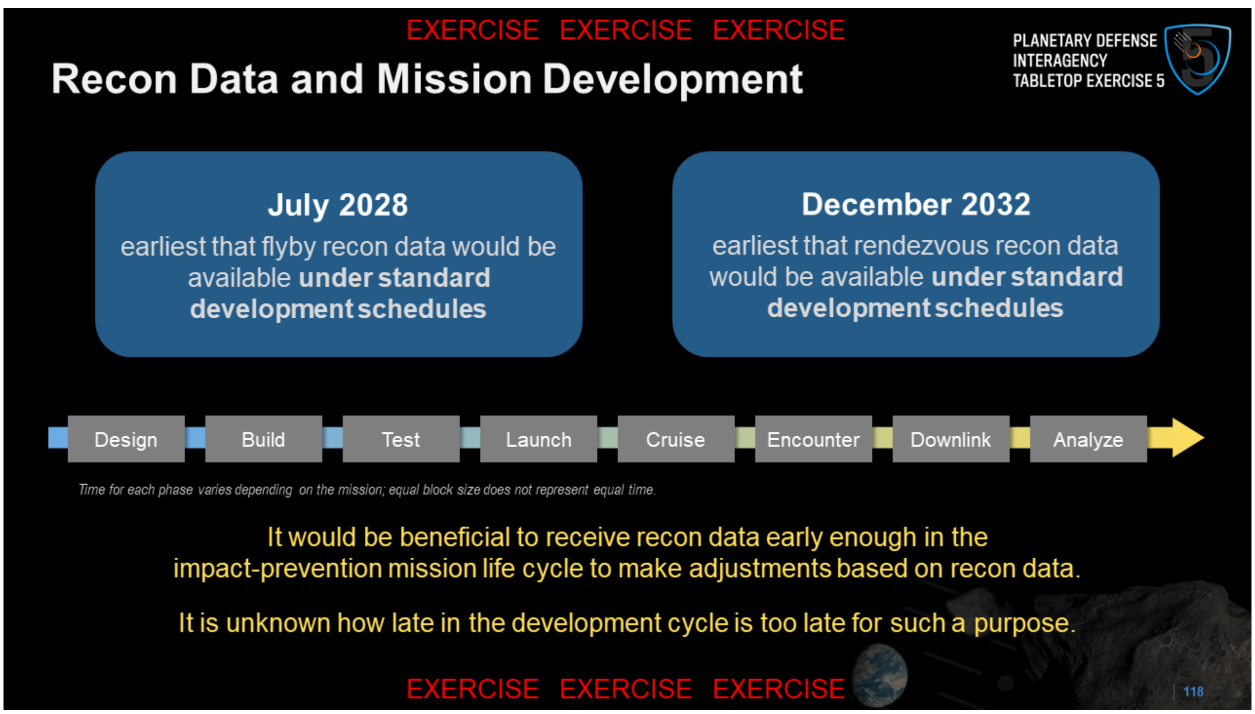
Red: >2 years faster than standard. Yellow: ~1 year faster than standard. Green: standard schedule is possible.

EXERCISE EXERCISE EXERCISE

116

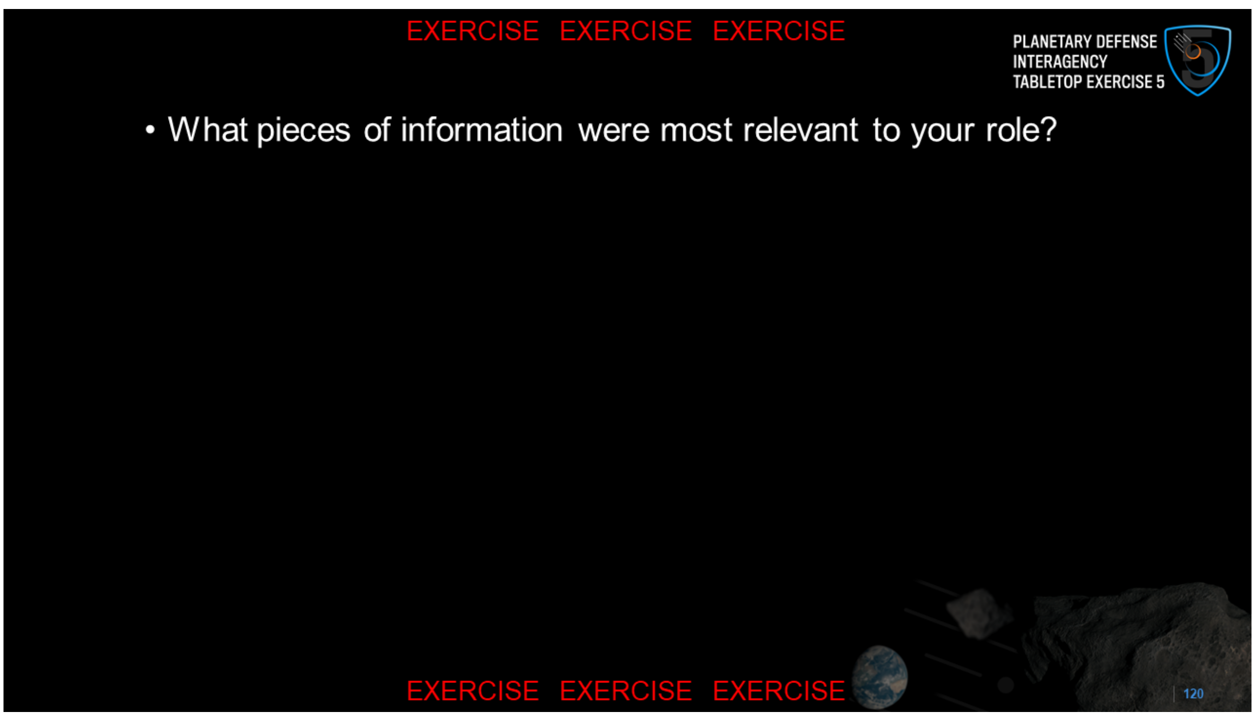


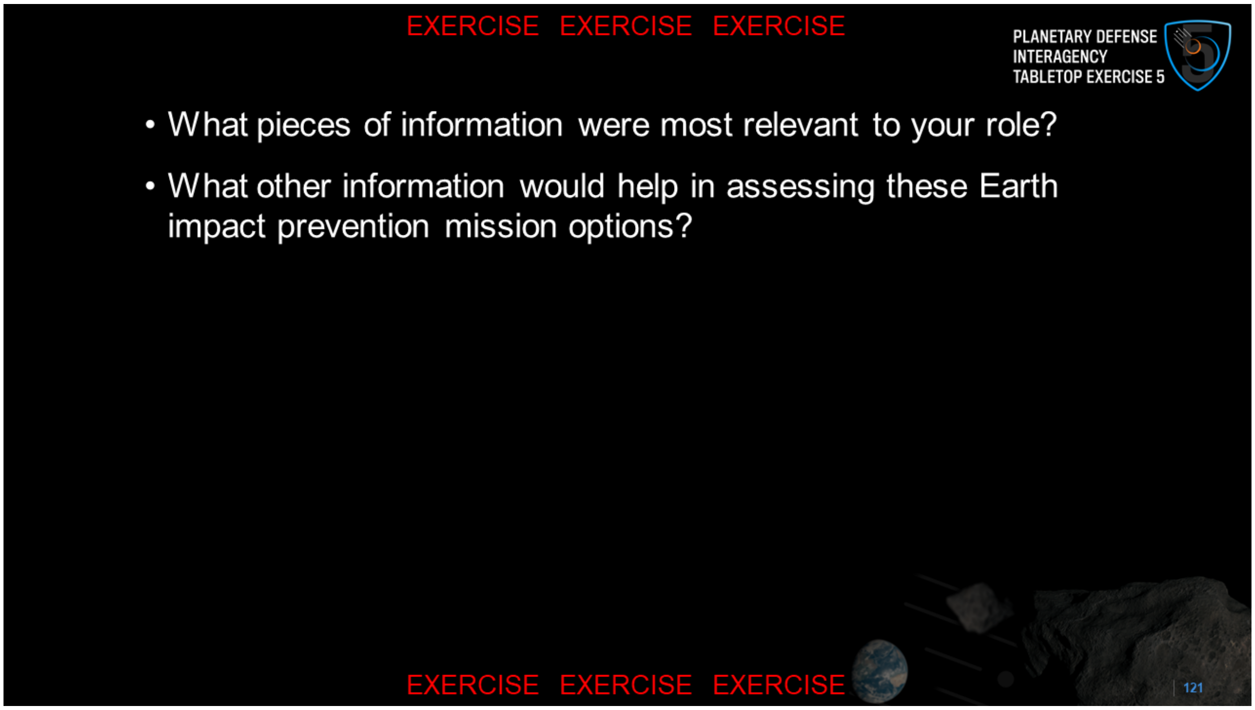
EXERCISE EXERCISE EXERCISE
Could Rendezvous Recon Data Inform Earth-Impact-Prevention Missions?
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Even with an aggressive schedule, rendezvous recon data could inform only the last two launch opportunities for Earth-impact-prevention missions.
Rendezvous recon arrivals
2028 May
2030 Dec
2032 Dec
2035 Dec
Today 2 Apr 2024
Potential Earth impact 12 Jul 2038
IB or NED Jun 2026
KI Sep 2027
IB or NED Jul 2028
KI May 2029
IB or NED Jul 2029
KI Jul 2032
NED only Jul 2033
KI Aug 2034
Earth-impact-prevention launches
All rendezvous missions have the option of being flown as hybrid missions with both recon and impact-prevention capabilities.
Spacecraft development schedule, assuming development starts immediately
Red: >2 years faster than standard. Yellow: ~1 year faster than standard. Green: standard schedule is possible.
EXERCISE EXERCISE EXERCISE
117

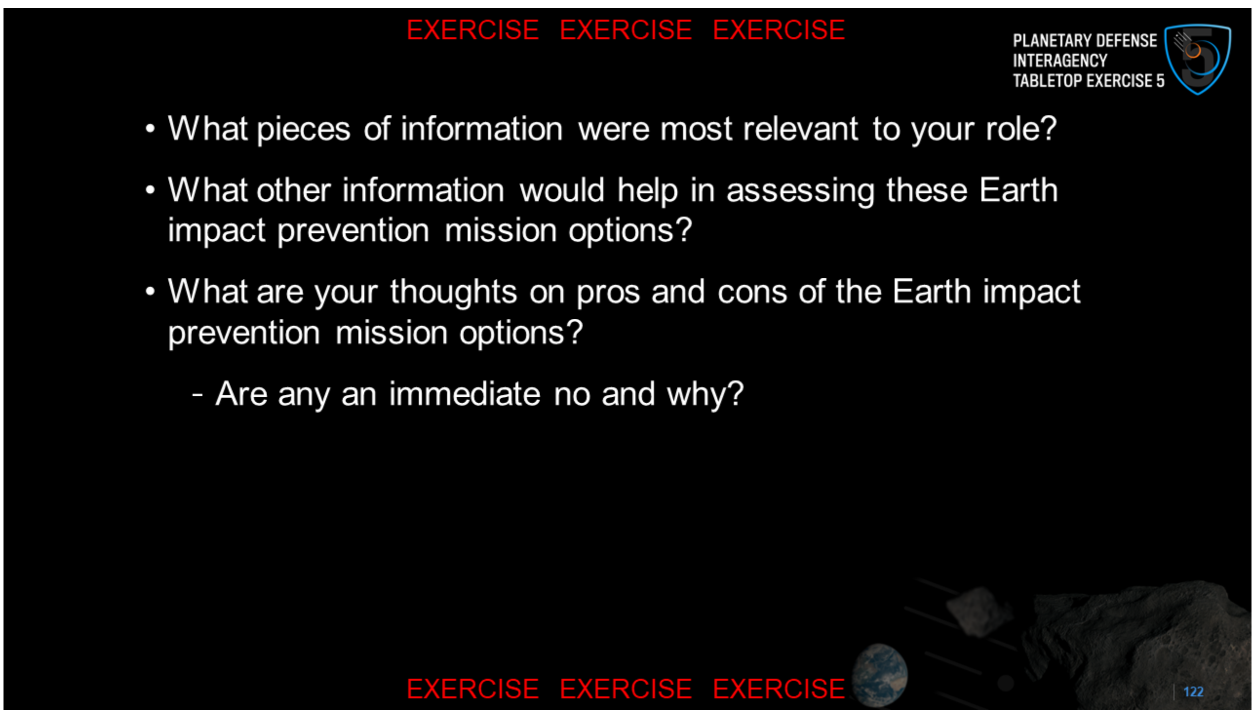


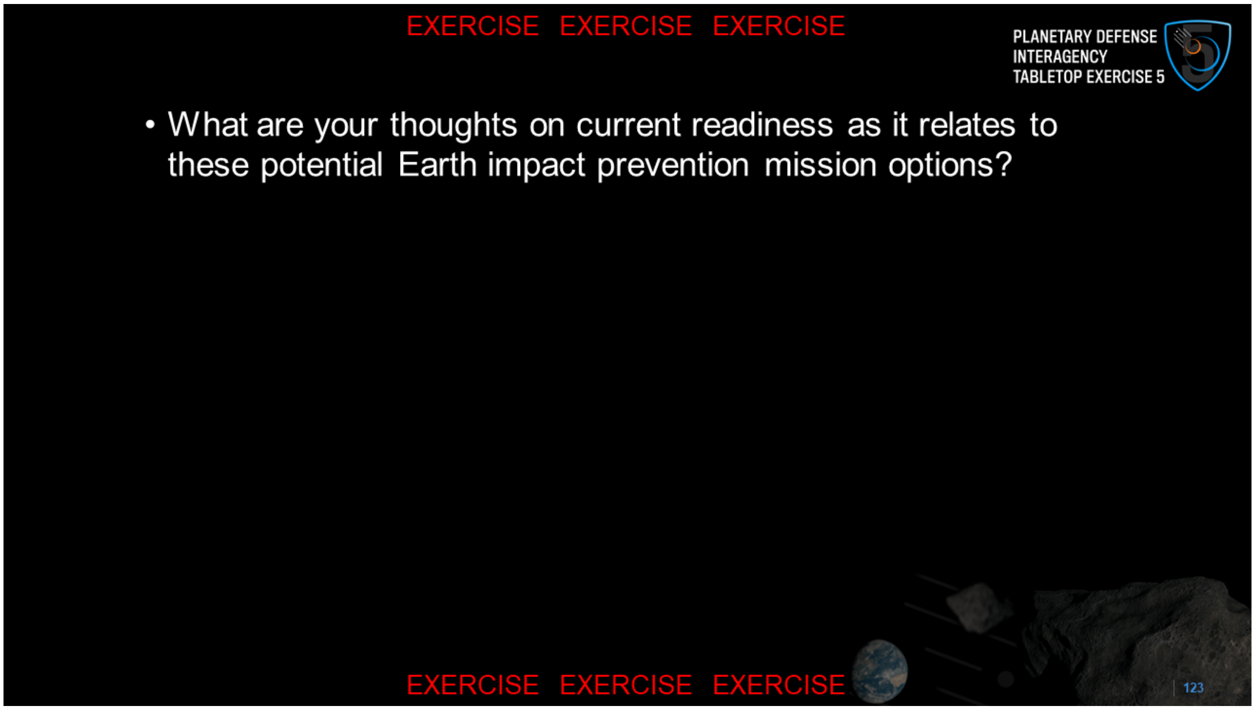
EXERCISE EXERCISE EXERCISE
Recon Data and Mission Development
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
July 2028
earliest that flyby recon data would be available under standard development schedules
December 2032
earliest that rendezvous recon data would be available under standard development schedules
Design
Build
Test
Launch
Cruise
Encounter
Downlink
Analyze
Time for each phase varies depending on the mission; equal block size does not represent equal time.
It would be beneficial to receive recon data early enough in the impact-prevention mission life cycle to make adjustments based on recon data.
It is unknown how late in the development cycle is too late for such a purpose.
EXERCISE EXERCISE EXERCISE
118

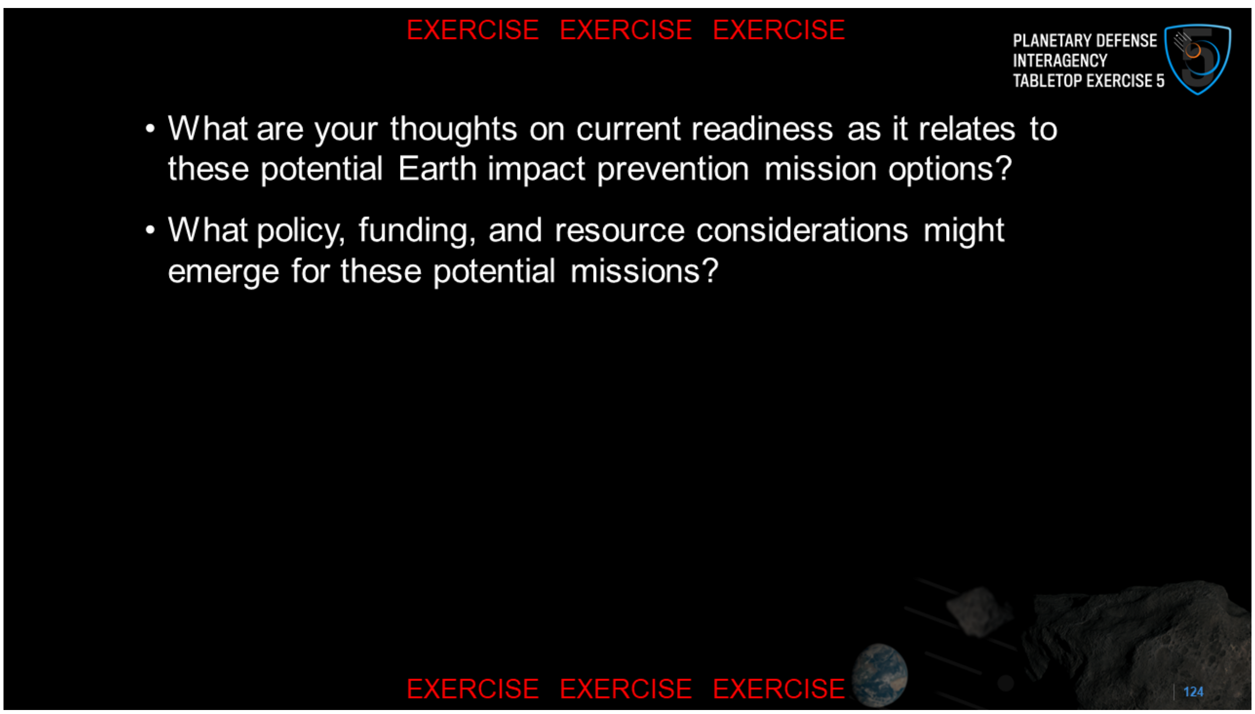

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
EXERCISE EXERCISE EXERCISE
119

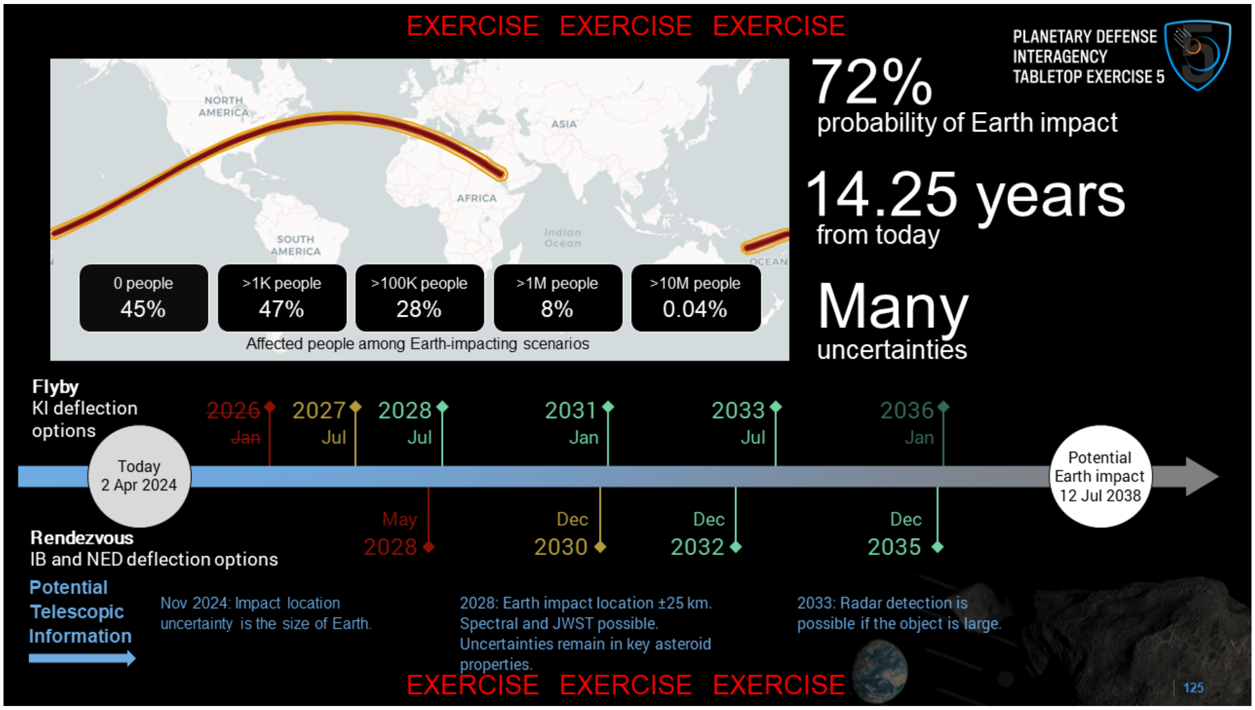

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What pieces of information were most relevant to your role?
EXERCISE EXERCISE EXERCISE
120

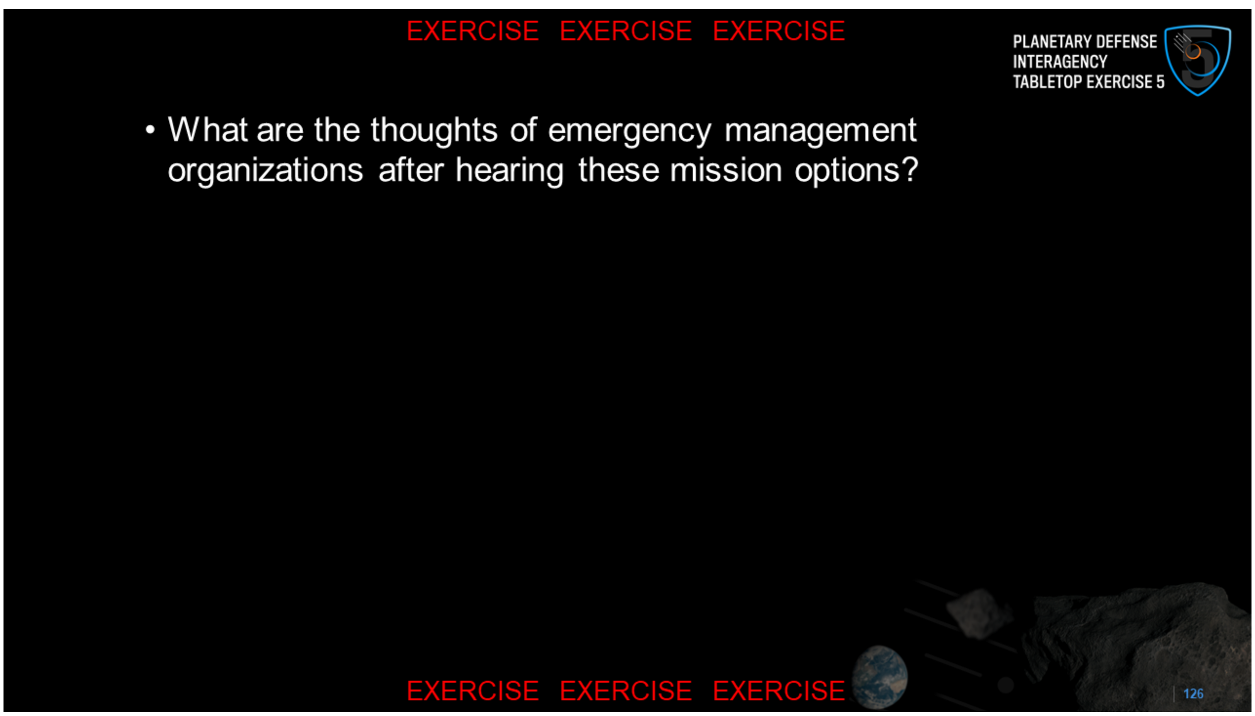

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What pieces of information were most relevant to your role?
• What other information would help in assessing these Earth impact prevention mission options?
EXERCISE EXERCISE EXERCISE
121


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What pieces of information were most relevant to your role?
• What other information would help in assessing these Earth impact prevention mission options?
• What are your thoughts on pros and cons of the Earth impact prevention mission options?
- Are any an immediate no and why?
EXERCISE EXERCISE EXERCISE
122


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What are your thoughts on current readiness as it relates to these potential Earth impact prevention mission options?
EXERCISE EXERCISE EXERCISE
123


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What are your thoughts on current readiness as it relates to these potential Earth impact prevention mission options?
• What policy, funding, and resource considerations might emerge for these potential missions?
EXERCISE EXERCISE EXERCISE
124


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
NORTH AMERICA
ASIA
AFRICA
SOUTH AMERICA
Indian Ocean
0 people 45%
>1K people 47%
>100K people 28%
>1M people 8%
>10M people 0.04%
Affected people among Earth-impacting scenarios
72%
probability of Earth impact
14.25 years
from today
Many
uncertainties
Flyby
KI deflection options
Today 2 Apr 2024
2026 Jan
2027 Jul
2028 Jul
2031 Jan
2033 Jul
2036 Jan
Potential Earth impact 12 Jul 2038
May 2028
Dec 2030
Dec 2032
Dec 2035
Rendezvous
IB and NED deflection options
Potential Telescopic Information
Nov 2024: Impact location uncertainty is the size of Earth.
2028: Earth impact location ±25 km. Spectral and JWST possible. Uncertainties remain in key asteroid properties.
2033: Radar detection is possible if the object is large.
EXERCISE EXERCISE EXERCISE
125


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What are the thoughts of emergency management organizations after hearing these mission options?
EXERCISE EXERCISE EXERCISE
126

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- What are the thoughts of emergency management organizations after hearing these mission options?
- What are the thoughts of public information officers after hearing these mission options?

EXERCISE EXERCISE EXERCISE

127

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

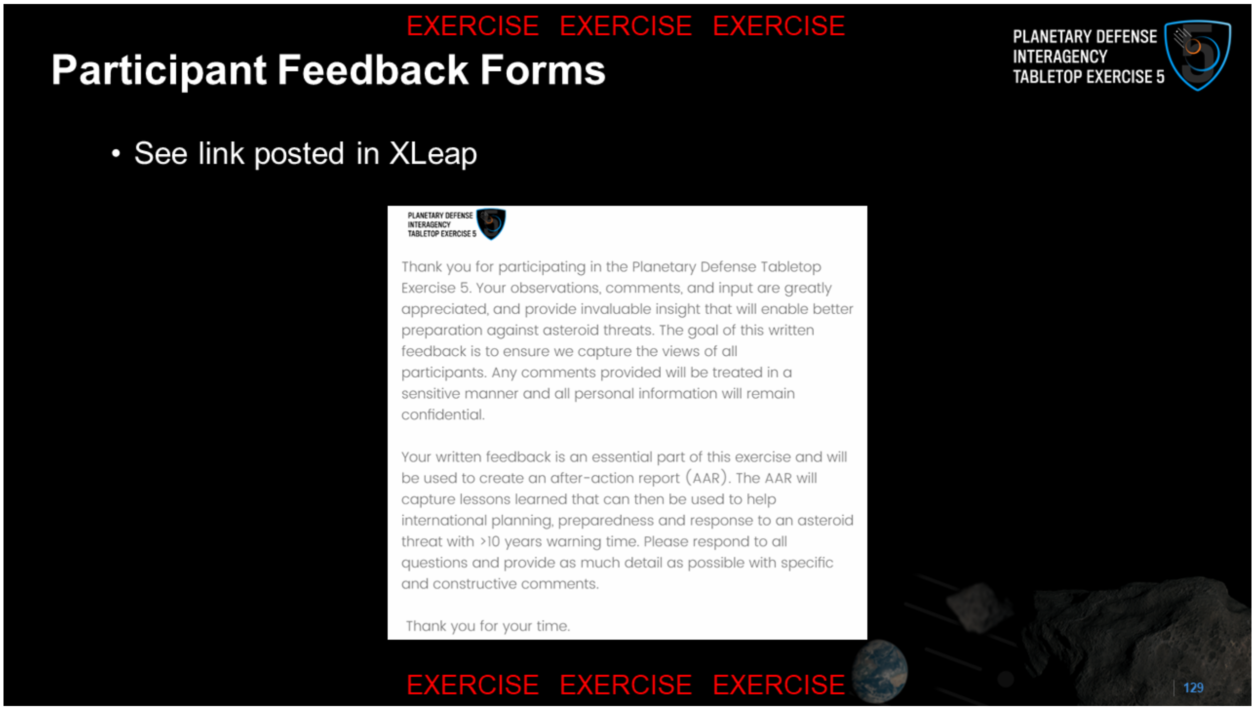
Hot Wash

- Goal is to gather quick comments and impressions
- One representative from each organization to provide:
  - One lesson learned
  - One best practice
- Two areas of interest for comments:
  1. Preparedness, including policy, technology, or capability gaps
  2. Comments on this exercise: strengths, opportunities, and ideas for future exercises
- Please limit responses to **2–3 minutes** so that many organizations can share
- Remember, you can post comments and responses to comments in the chat, too

Your comments and discussions are the data that will help this TTX culminate in an impactful after-action report.

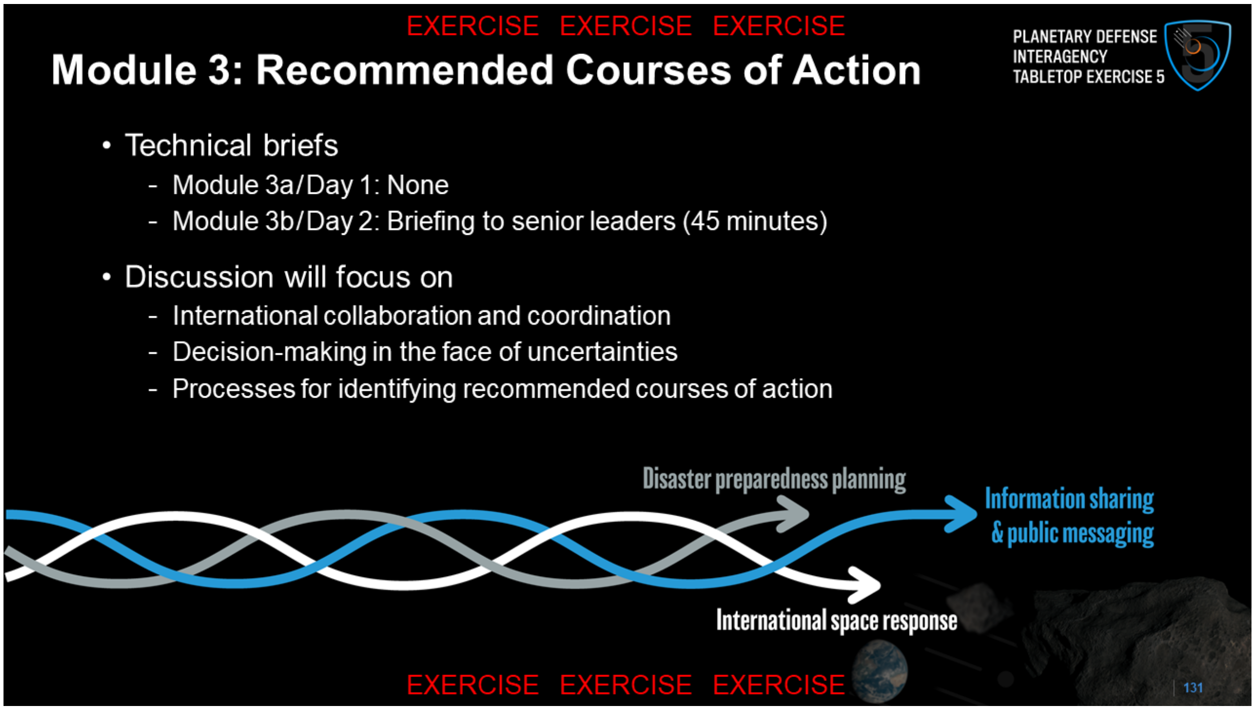
EXERCISE EXERCISE EXERCISE

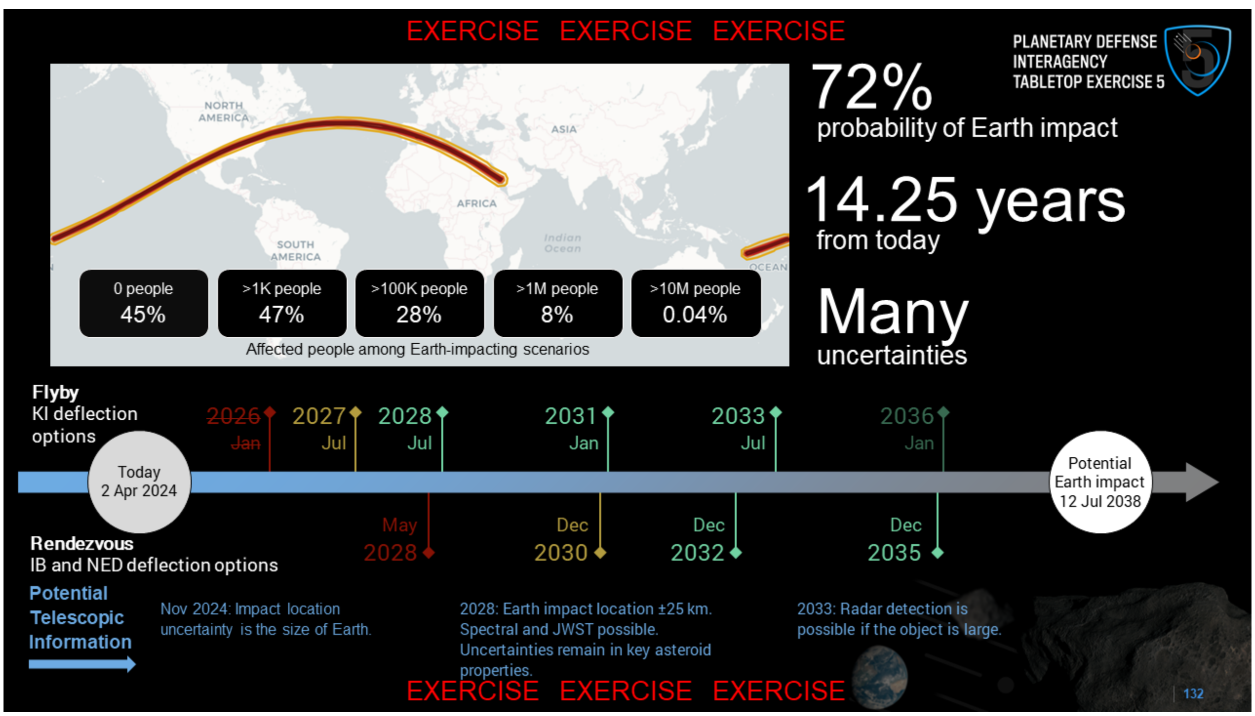
128

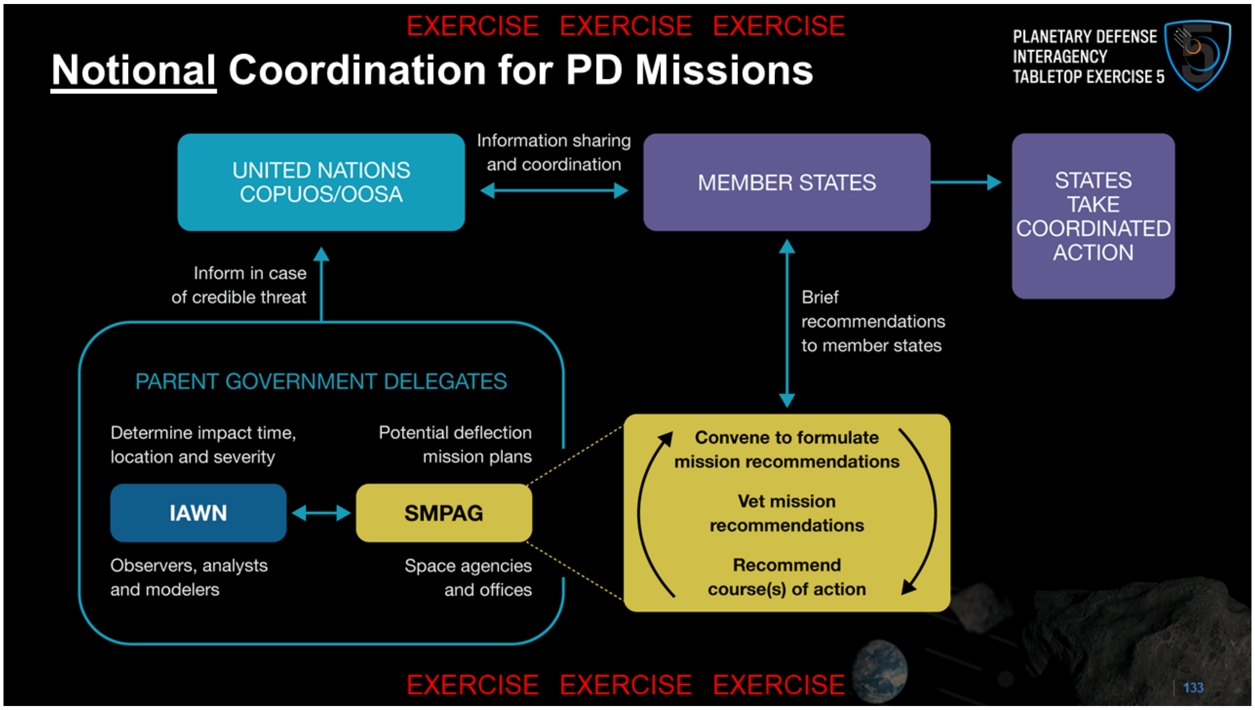

EXERCISE EXERCISE EXERCISE
Participant Feedback Forms
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• See link posted in XLeap
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Thank you for participating in the Planetary Defense Tabletop Exercise 5. Your observations, comments, and input are greatly appreciated, and provide invaluable insight that will enable better preparation against asteroid threats. The goal of this written feedback is to ensure we capture the views of all participants. Any comments provided will be treated in a sensitive manner and all personal information will remain confidential.
Your written feedback is an essential part of this exercise and will be used to create an after-action report (AAR). The AAR will capture lessons learned that can then be used to help international planning, preparedness and response to an asteroid threat with >10 years warning time. Please respond to all questions and provide as much detail as possible with specific and constructive comments.
Thank you for your time.
EXERCISE EXERCISE EXERCISE
129

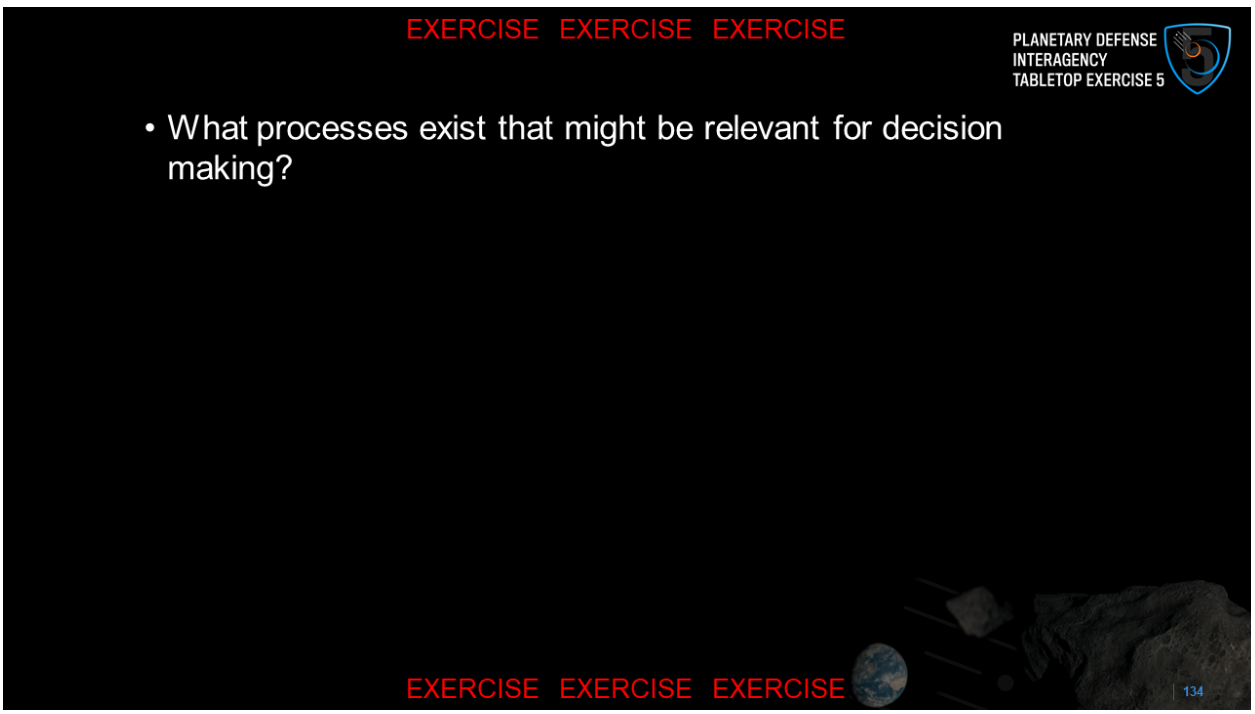

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
NASA
FEMA
APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
cneos
Ames Research Center
Lawrence Livermore National Laboratory
130

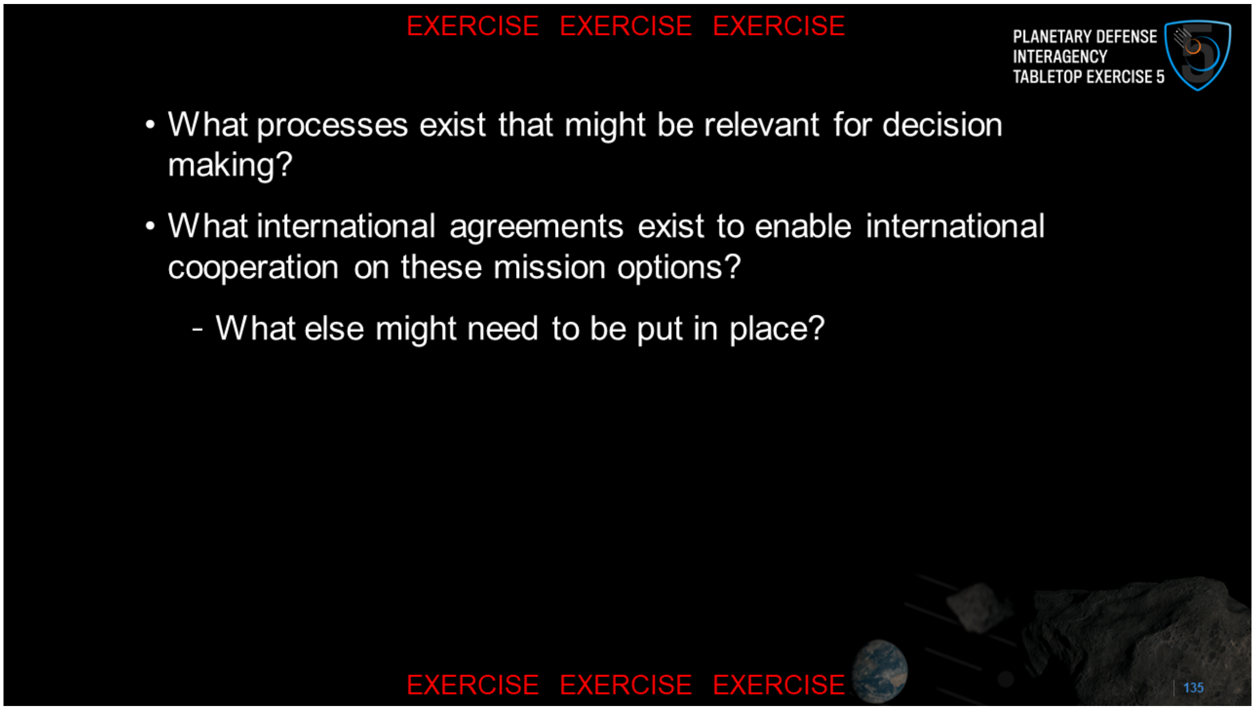
H.1.4. Module 3: Recommended Courses of Action

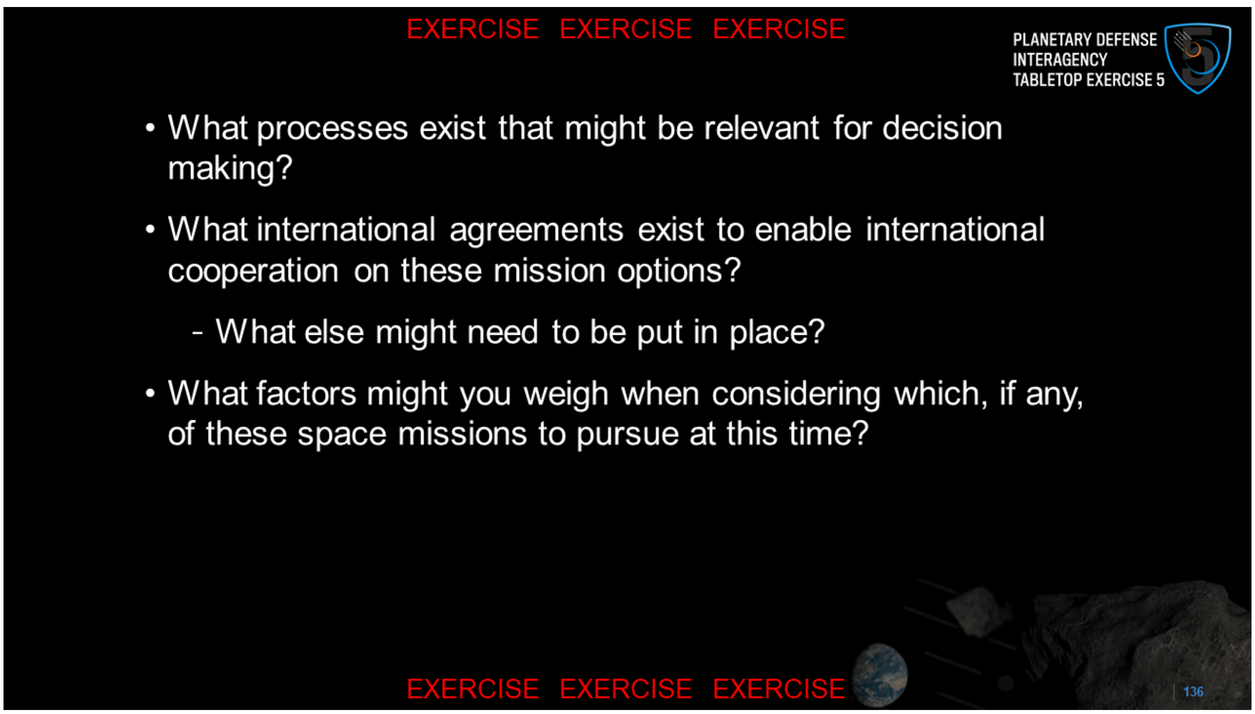


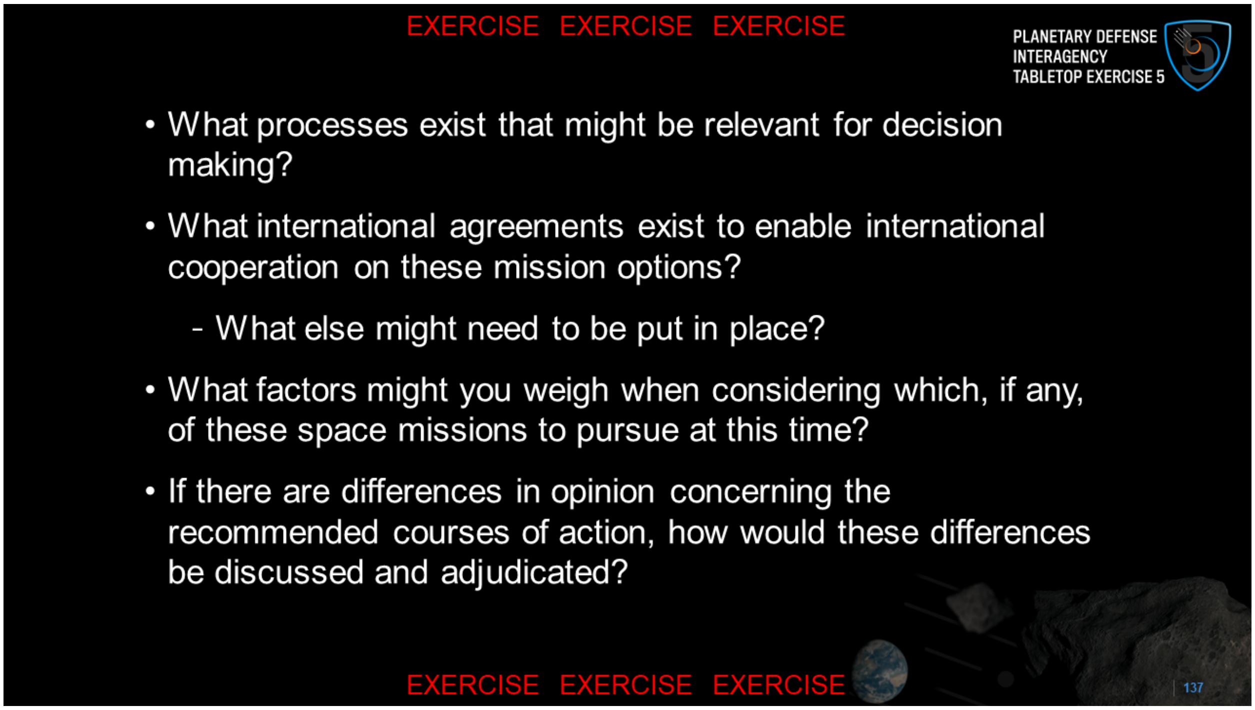


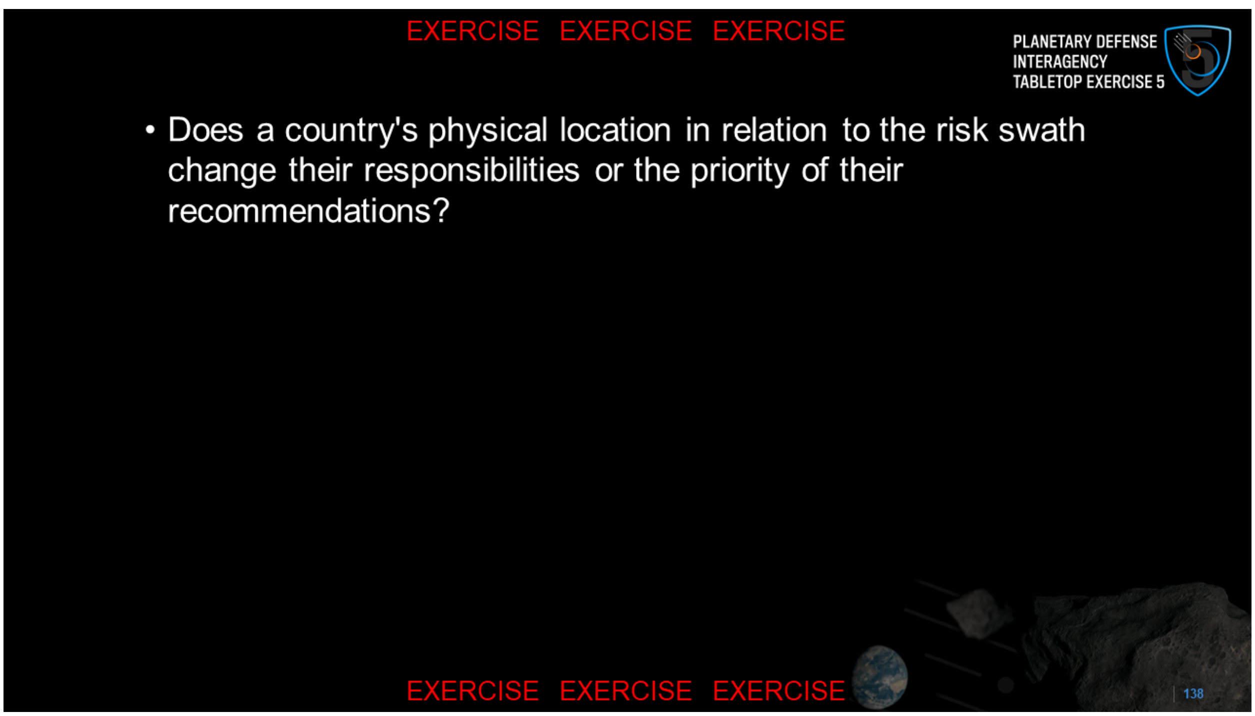

EXERCISE EXERCISE EXERCISE
Notional Coordination for PD Missions
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
UNITED NATIONS
COPUOS/OOSA
Information sharing
and coordination
MEMBER STATES
STATES
TAKE
COORDINATED
ACTION
Inform in case
of credible threat
Brief
recommendations
to member states
PARENT GOVERNMENT DELEGATES
Determine impact time,
location and severity
Potential deflection
mission plans
IAWN
SMPAG
Observers, analysts
and modelers
Space agencies
and offices
Convene to formulate
mission recommendations
Vet mission
recommendations
Recommend
course(s) of action
EXERCISE EXERCISE EXERCISE
133

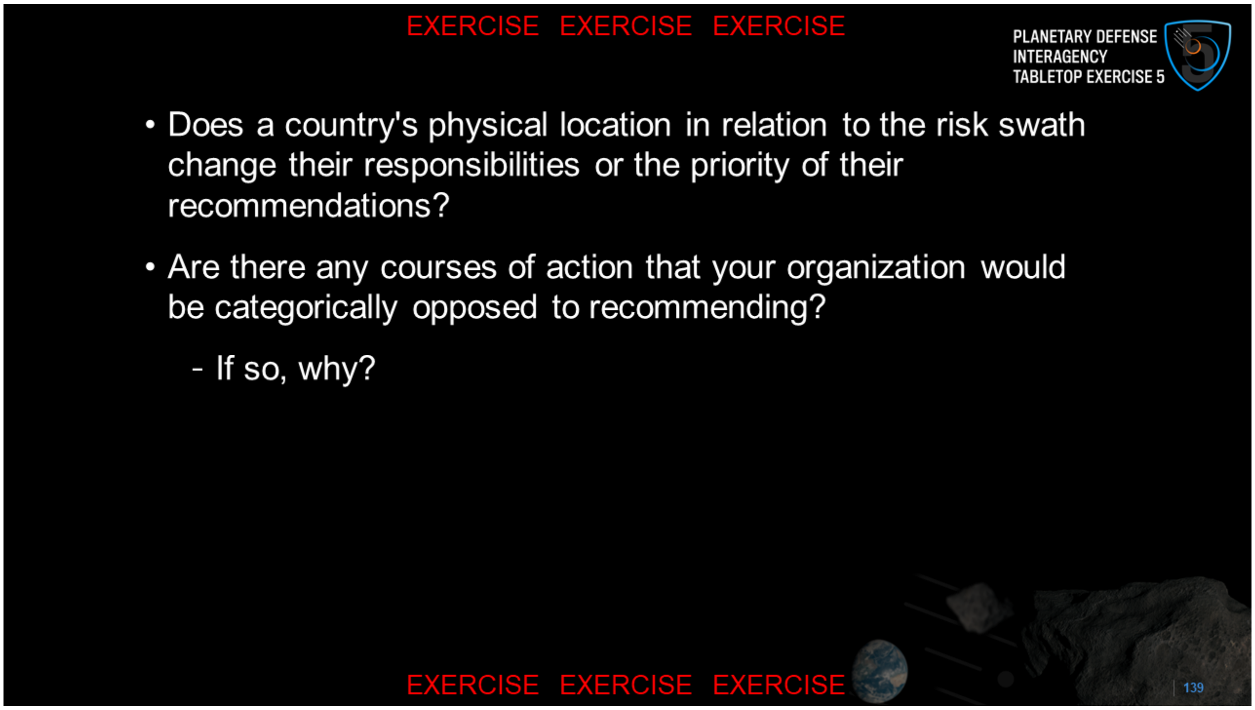

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What processes exist that might be relevant for decision making?
EXERCISE EXERCISE EXERCISE
134

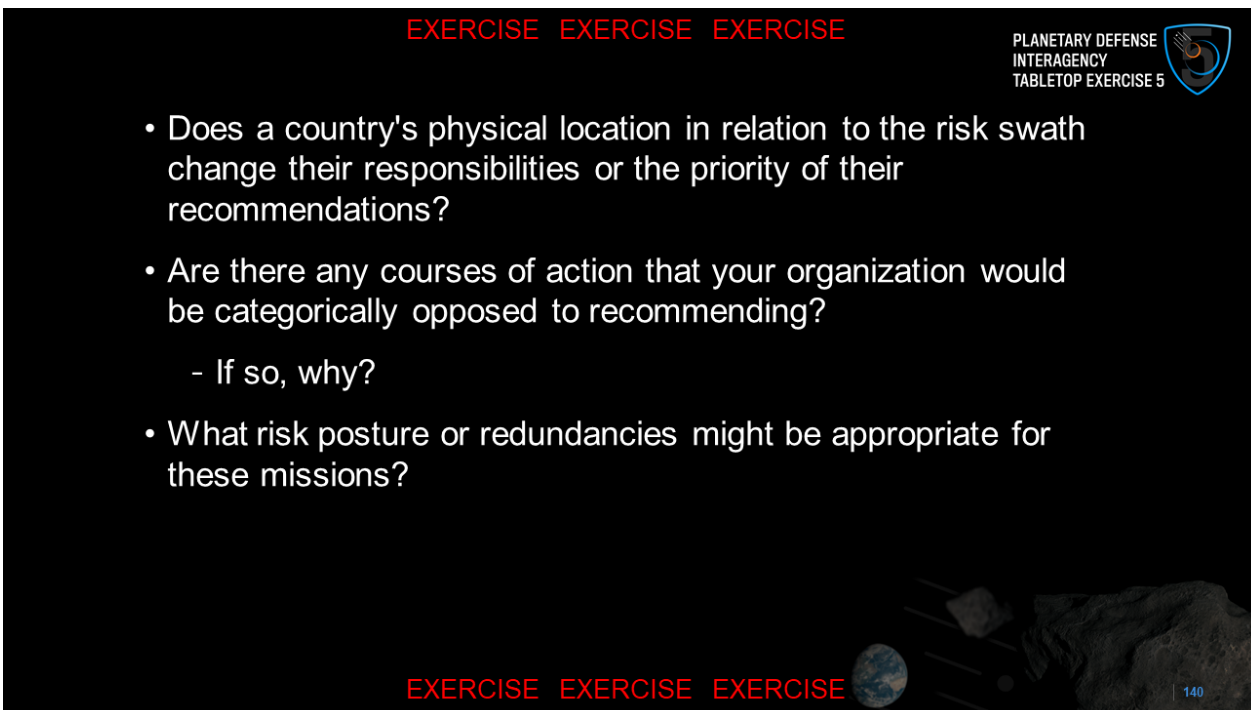

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What processes exist that might be relevant for decision making?
• What international agreements exist to enable international cooperation on these mission options?
- What else might need to be put in place?
EXERCISE EXERCISE EXERCISE
135

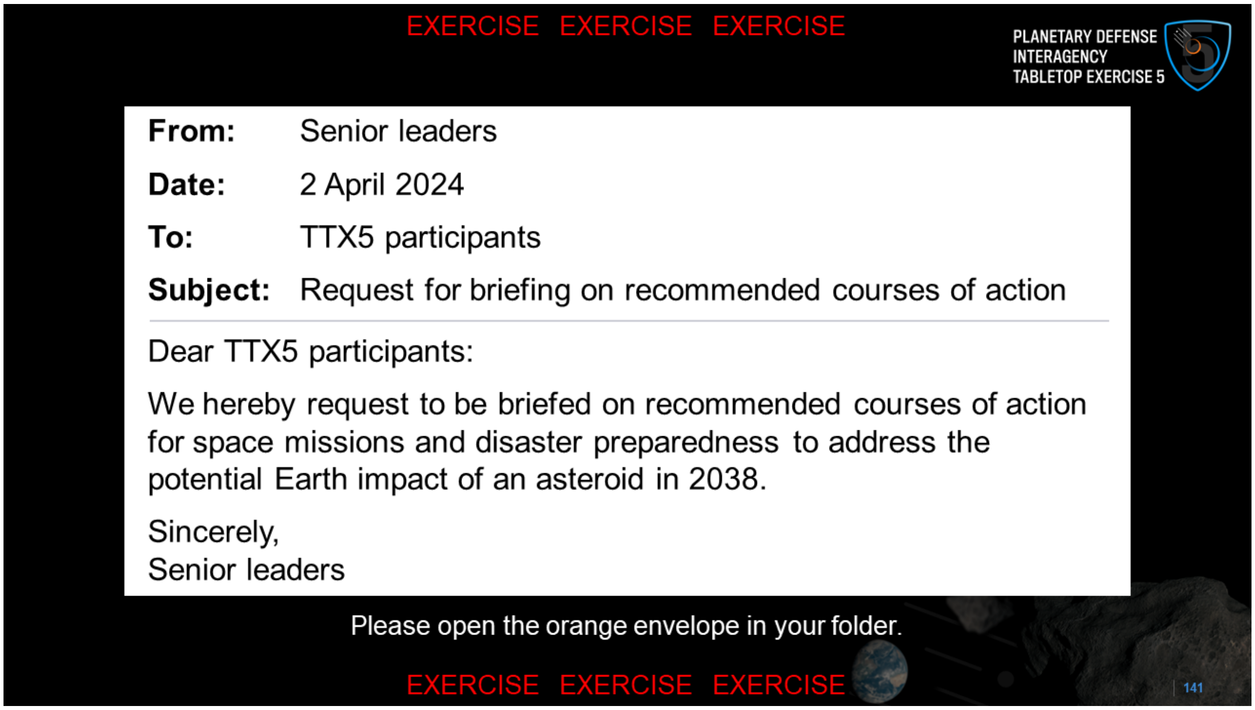

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What processes exist that might be relevant for decision making?
• What international agreements exist to enable international cooperation on these mission options?
- What else might need to be put in place?
• What factors might you weigh when considering which, if any, of these space missions to pursue at this time?
EXERCISE EXERCISE EXERCISE
136


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What processes exist that might be relevant for decision making?
• What international agreements exist to enable international cooperation on these mission options?
- What else might need to be put in place?
• What factors might you weigh when considering which, if any, of these space missions to pursue at this time?
• If there are differences in opinion concerning the recommended courses of action, how would these differences be discussed and adjudicated?
EXERCISE EXERCISE EXERCISE
137

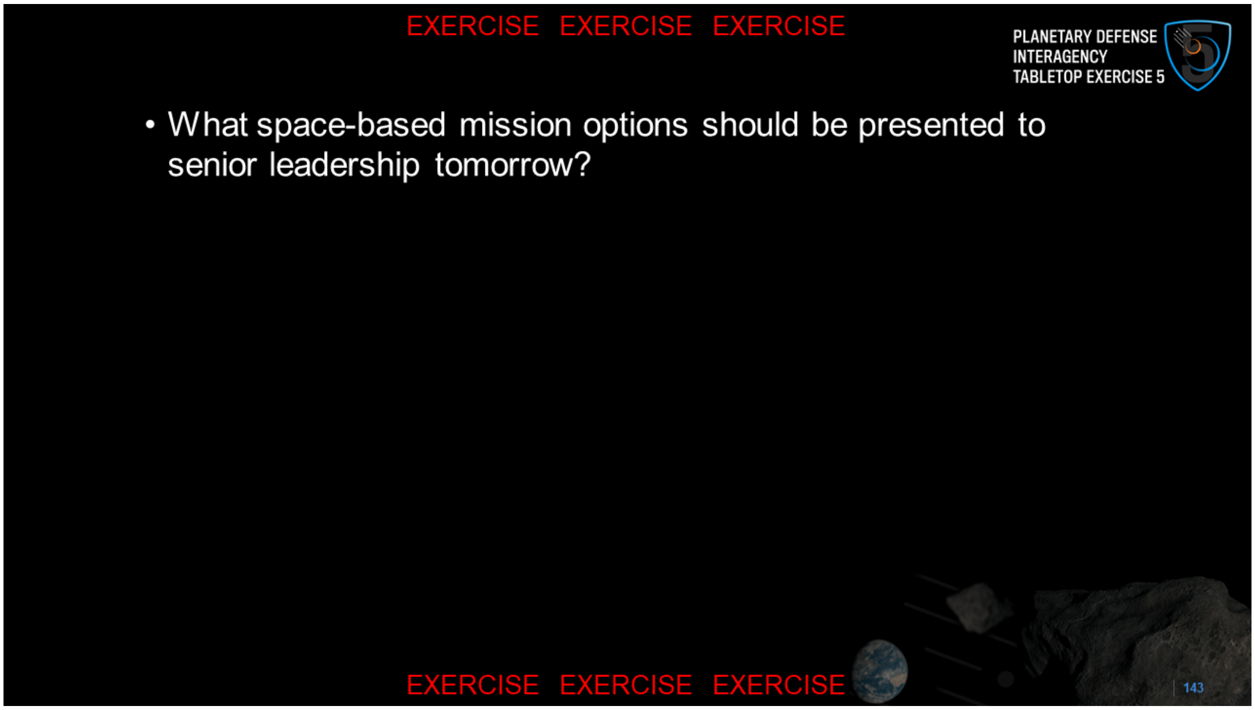

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Does a country's physical location in relation to the risk swath change their responsibilities or the priority of their recommendations?
EXERCISE EXERCISE EXERCISE
138

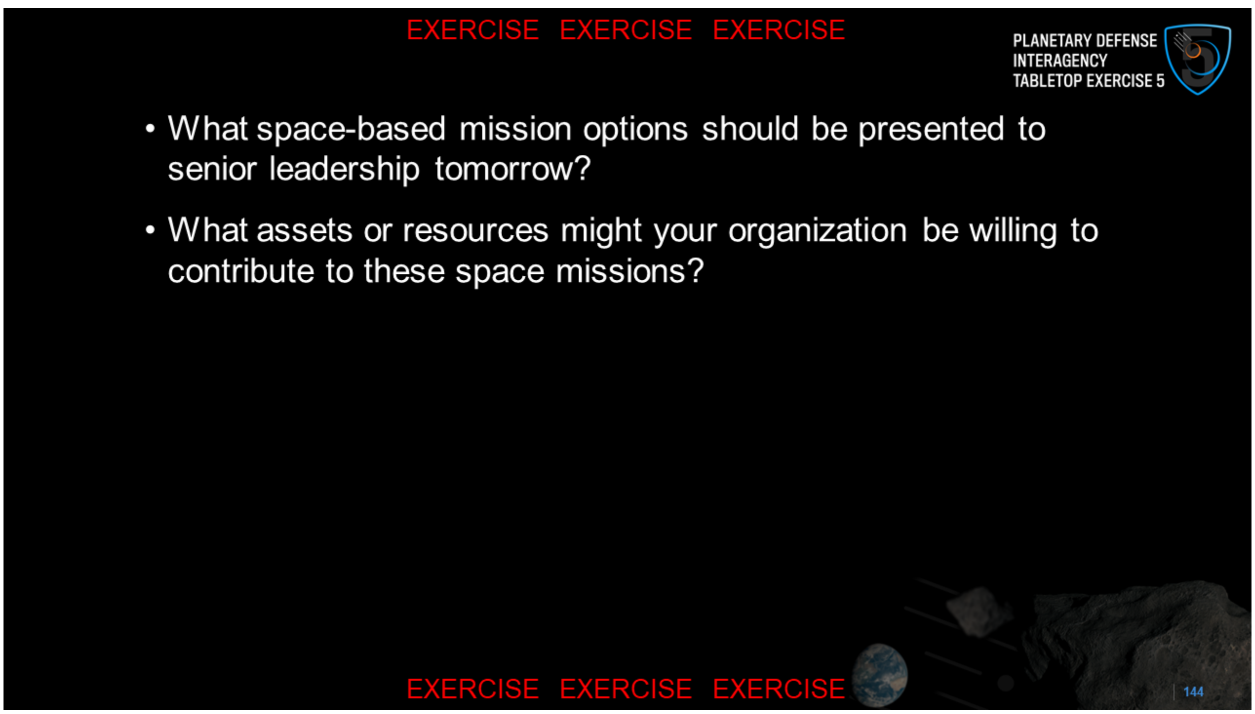

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Does a country's physical location in relation to the risk swath change their responsibilities or the priority of their recommendations?
• Are there any courses of action that your organization would be categorically opposed to recommending?
- If so, why?
EXERCISE EXERCISE EXERCISE
139

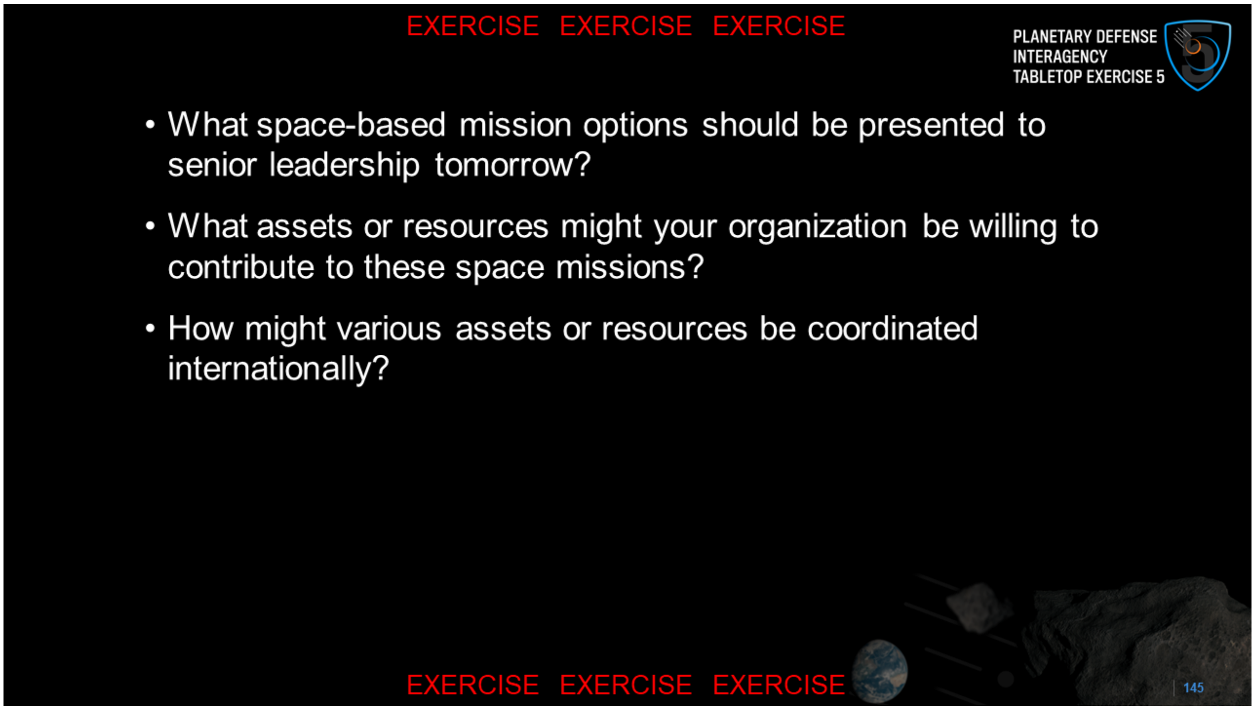

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Does a country's physical location in relation to the risk swath change their responsibilities or the priority of their recommendations?
• Are there any courses of action that your organization would be categorically opposed to recommending?
- If so, why?
• What risk posture or redundancies might be appropriate for these missions?
EXERCISE EXERCISE EXERCISE
140

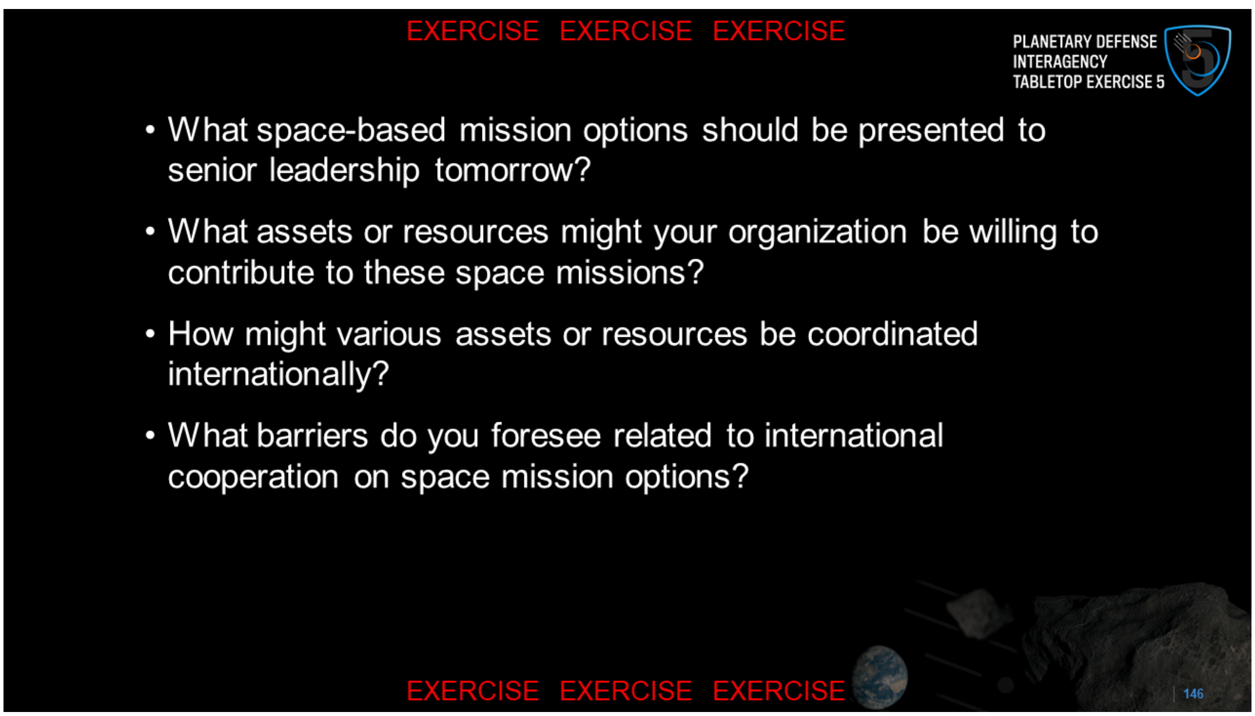

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
From: Senior leaders
Date: 2 April 2024
To: TTX5 participants
Subject: Request for briefing on recommended courses of action
Dear TTX5 participants:
We hereby request to be briefed on recommended courses of action for space missions and disaster preparedness to address the potential Earth impact of an asteroid in 2038.
Sincerely,
Senior leaders
Please open the orange envelope in your folder.
EXERCISE EXERCISE EXERCISE
141

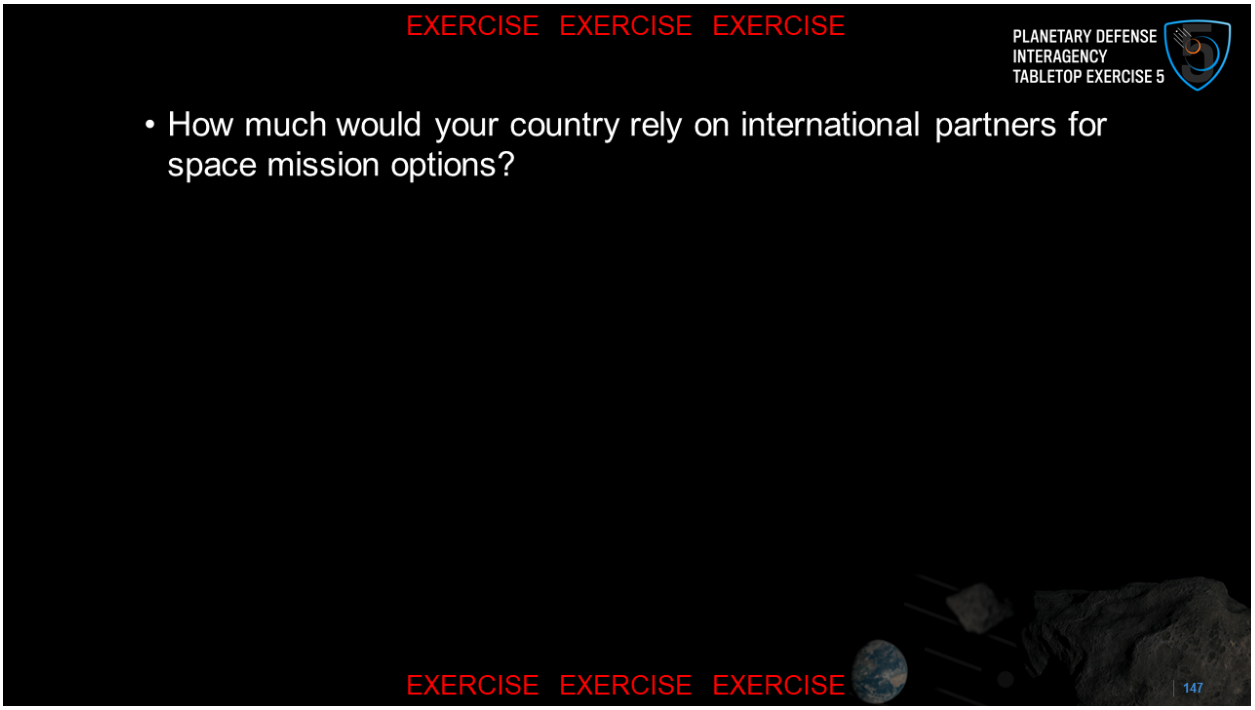

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Break
EXERCISE EXERCISE EXERCISE
142

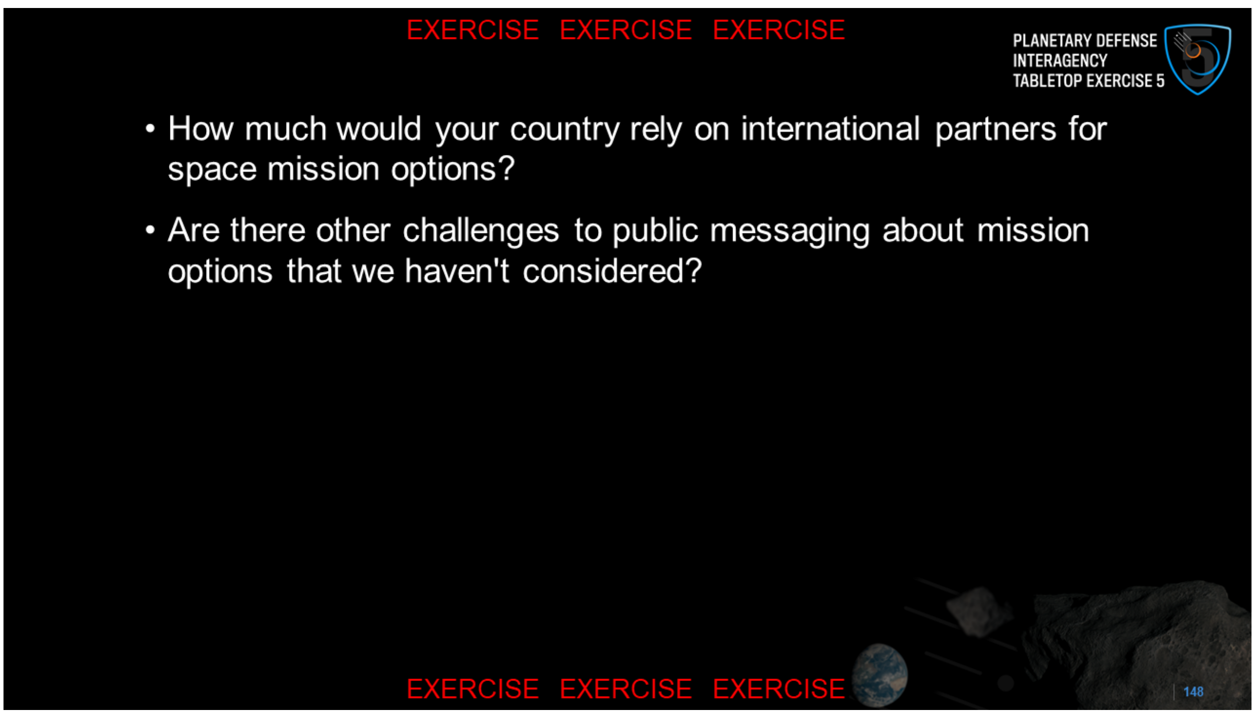

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What space-based mission options should be presented to senior leadership tomorrow?
EXERCISE EXERCISE EXERCISE
143


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What space-based mission options should be presented to senior leadership tomorrow?
• What assets or resources might your organization be willing to contribute to these space missions?
EXERCISE EXERCISE EXERCISE
144

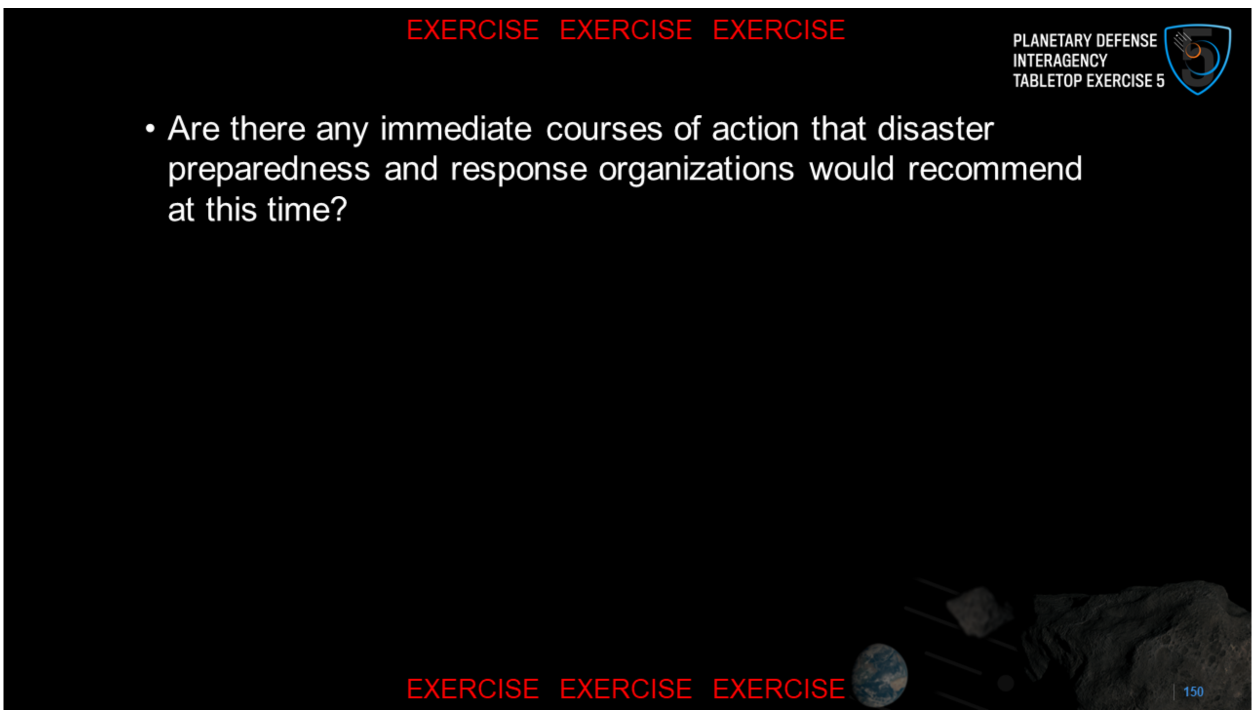

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What space-based mission options should be presented to senior leadership tomorrow?
• What assets or resources might your organization be willing to contribute to these space missions?
• How might various assets or resources be coordinated internationally?
EXERCISE EXERCISE EXERCISE
145

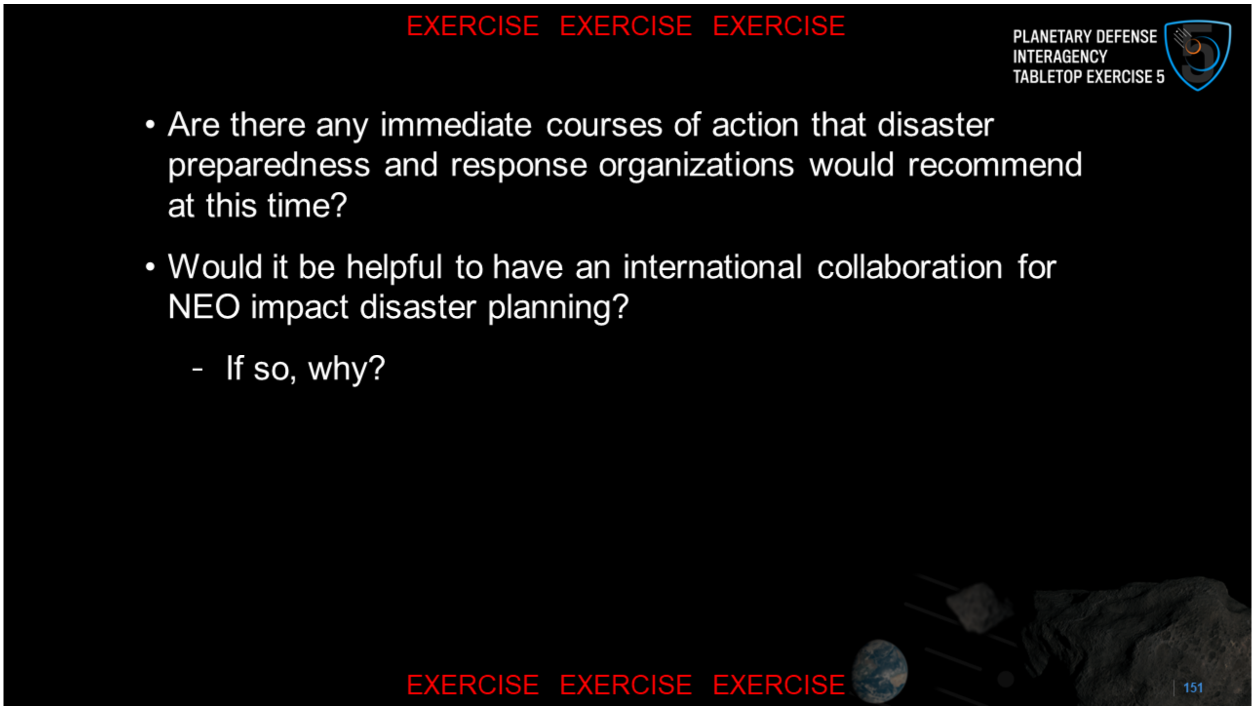

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What space-based mission options should be presented to senior leadership tomorrow?
• What assets or resources might your organization be willing to contribute to these space missions?
• How might various assets or resources be coordinated internationally?
• What barriers do you foresee related to international cooperation on space mission options?
EXERCISE EXERCISE EXERCISE
146

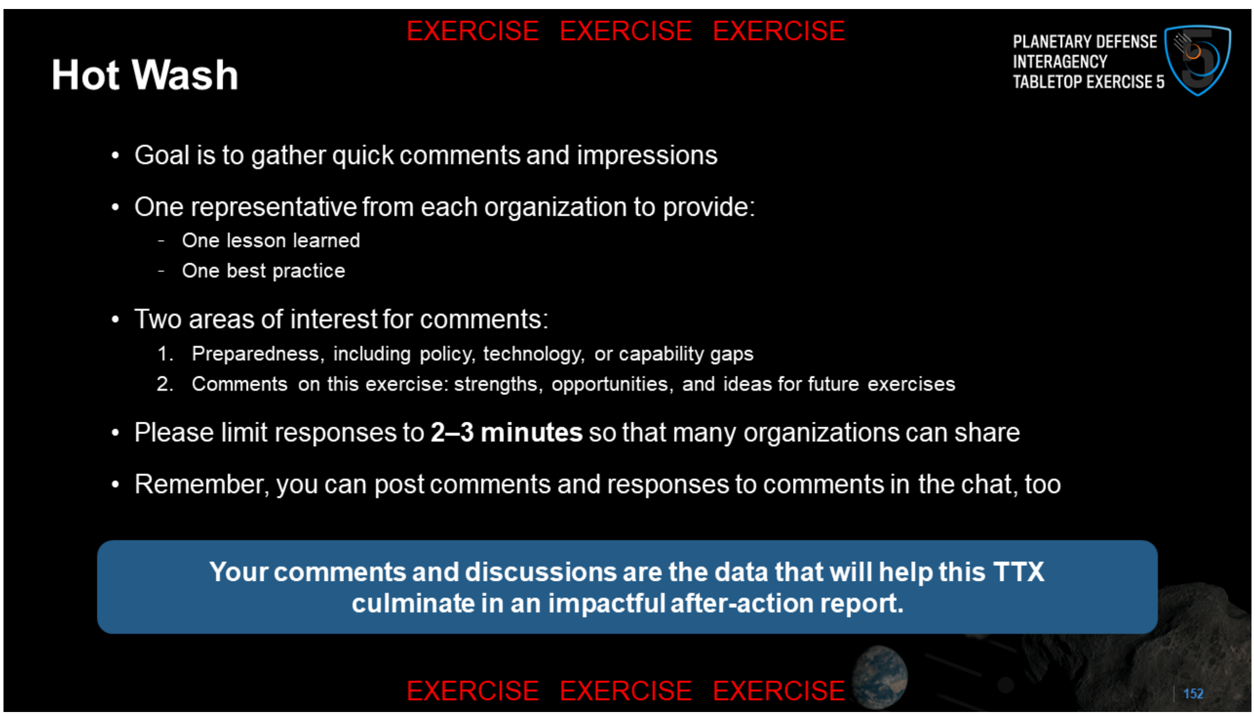

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• How much would your country rely on international partners for space mission options?
EXERCISE EXERCISE EXERCISE
147


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• How much would your country rely on international partners for space mission options?
• Are there other challenges to public messaging about mission options that we haven't considered?
EXERCISE EXERCISE EXERCISE
148


EXERCISE EXERCISE EXERCISE
Disaster Preparedness for Asteroid Impacts
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Earthquake
Volcanic eruption
Flood
Hurricane
Wildfire
?
Asteroid impact
EXERCISE EXERCISE EXERCISE
149


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• Are there any immediate courses of action that disaster preparedness and response organizations would recommend at this time?
EXERCISE EXERCISE EXERCISE
150


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Are there any immediate courses of action that disaster preparedness and response organizations would recommend at this time?
• Would it be helpful to have an international collaboration for NEO impact disaster planning?
- If so, why?
EXERCISE EXERCISE EXERCISE
151


EXERCISE EXERCISE EXERCISE
Hot Wash
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Goal is to gather quick comments and impressions
• One representative from each organization to provide:
- One lesson learned
- One best practice
• Two areas of interest for comments:
1. Preparedness, including policy, technology, or capability gaps
2. Comments on this exercise: strengths, opportunities, and ideas for future exercises
• Please limit responses to 2–3 minutes so that many organizations can share
• Remember, you can post comments and responses to comments in the chat, too
Your comments and discussions are the data that will help this TTX culminate in an impactful after-action report.
EXERCISE EXERCISE EXERCISE
152

EXERCISE EXERCISE EXERCISE

Participant Feedback Forms

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- See link posted in XLeap

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Thank you for participating in the Planetary Defense Tabletop Exercise 5. Your observations, comments, and input are greatly appreciated, and provide invaluable insight that will enable better preparation against asteroid threats. The goal of this written feedback is to ensure we capture the views of all participants. Any comments provided will be treated in a sensitive manner and all personal information will remain confidential.

Your written feedback is an essential part of this exercise and will be used to create an after-action report (AAR). The AAR will capture lessons learned that can then be used to help international planning, preparedness and response to an asteroid threat with >10 years warning time. Please respond to all questions and provide as much detail as possible with specific and constructive comments.

Thank you for your time.

EXERCISE EXERCISE EXERCISE

153

EXERCISE EXERCISE EXERCISE

Revisit the Parking Lot & Day 1 Hotwash

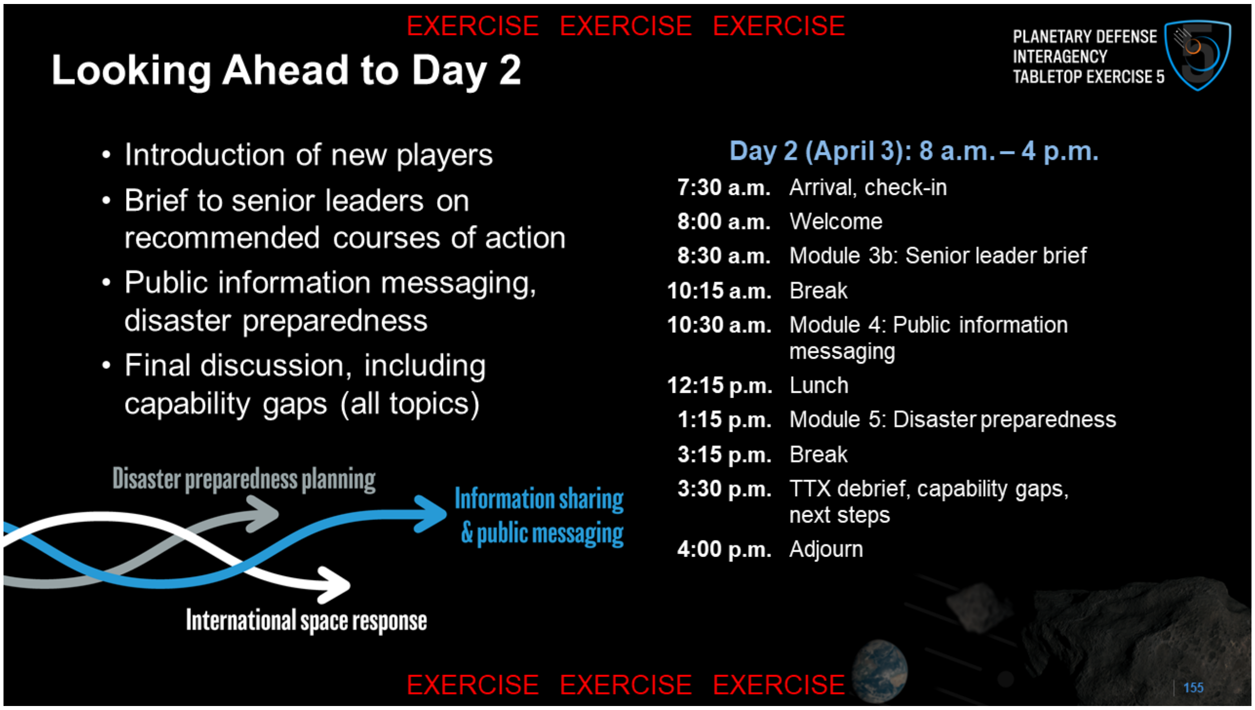
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- Revisit key discussions from earlier modules that might have been cut short

Module	Description
1	Scene setting and international coordination
2	Space mission options
3a	Recommended courses of action

EXERCISE EXERCISE EXERCISE

154



H.2. TTX5 Day 2

H.2.1. Introductory Material

EXERCISE EXERCISE EXERCISE

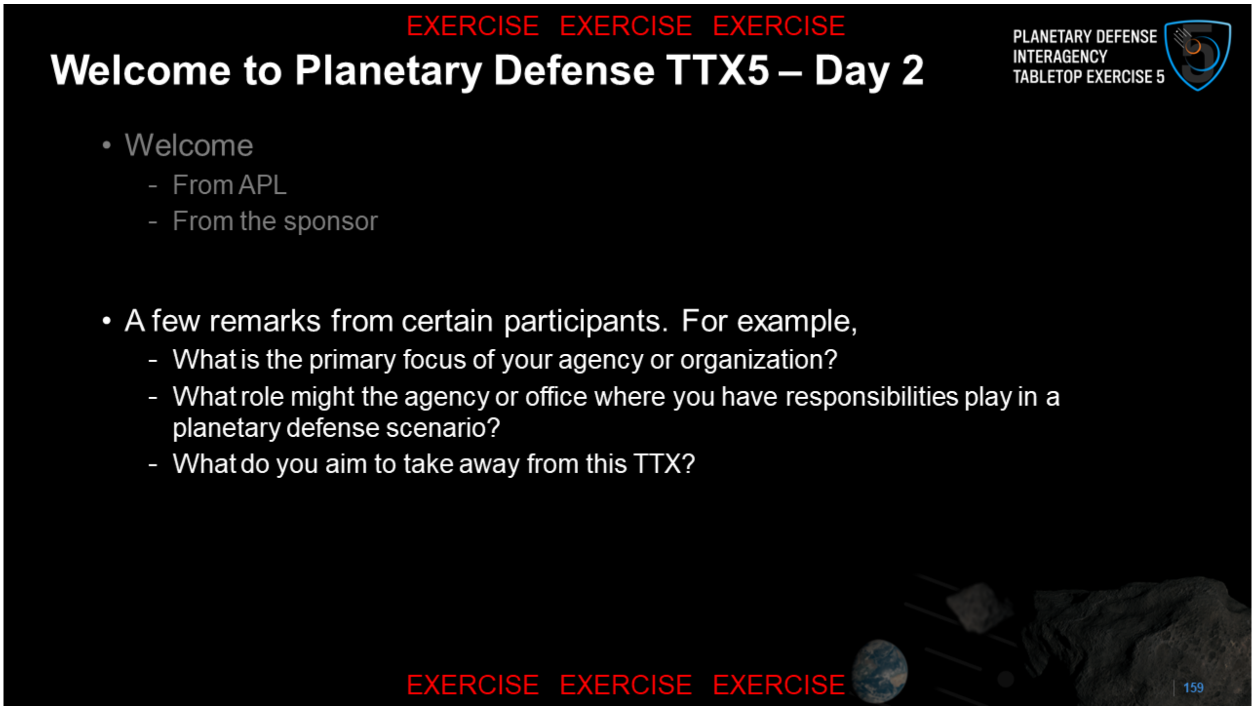
Welcome to Planetary Defense TTX5 – Day 2

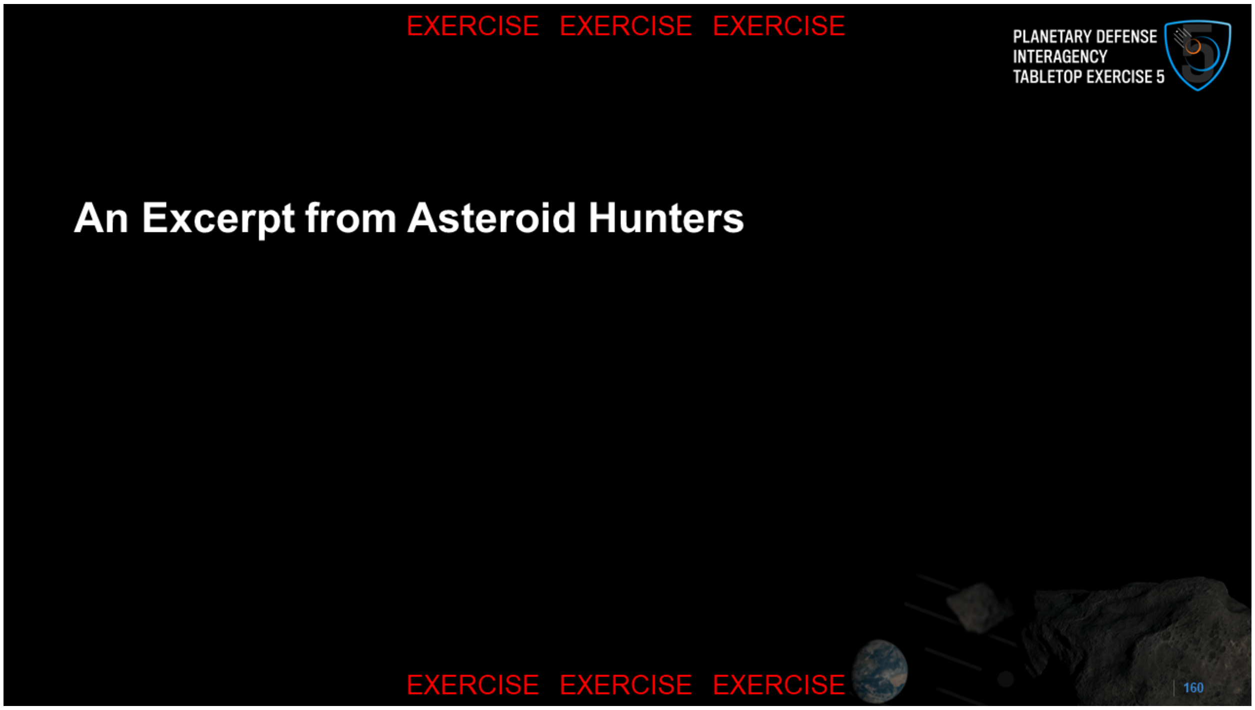
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

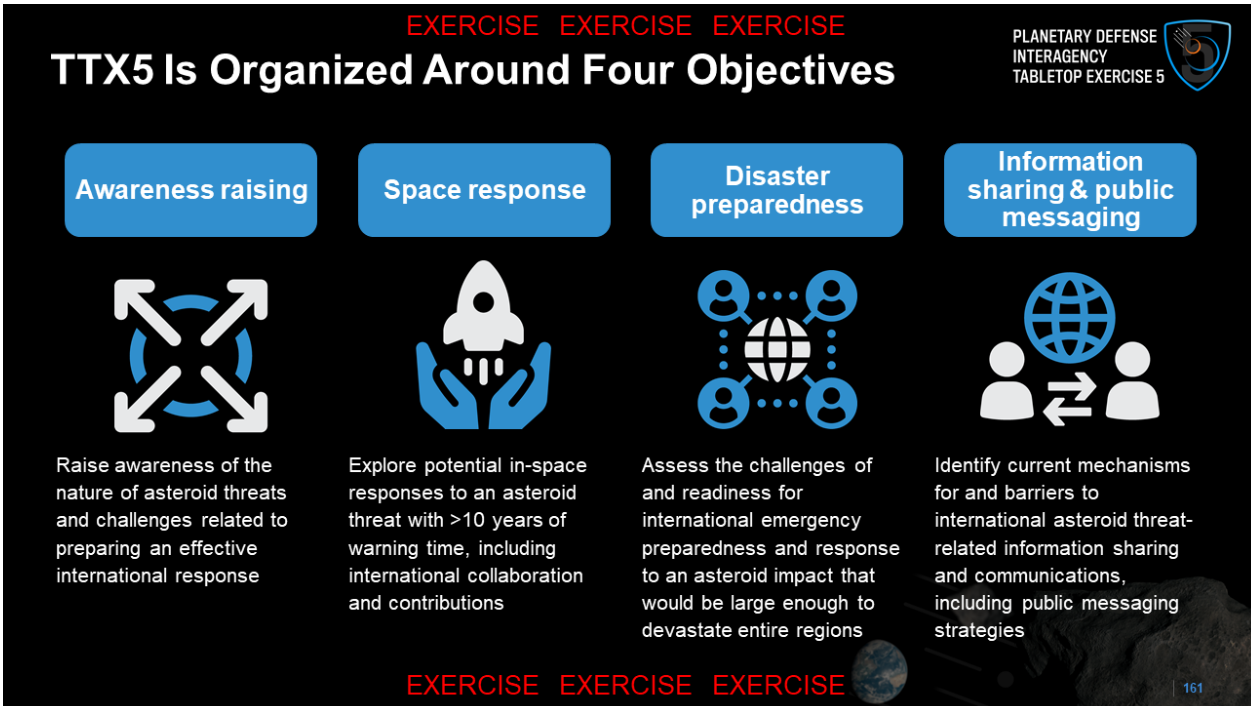
- Welcome
  - From APL
  - From the sponsor

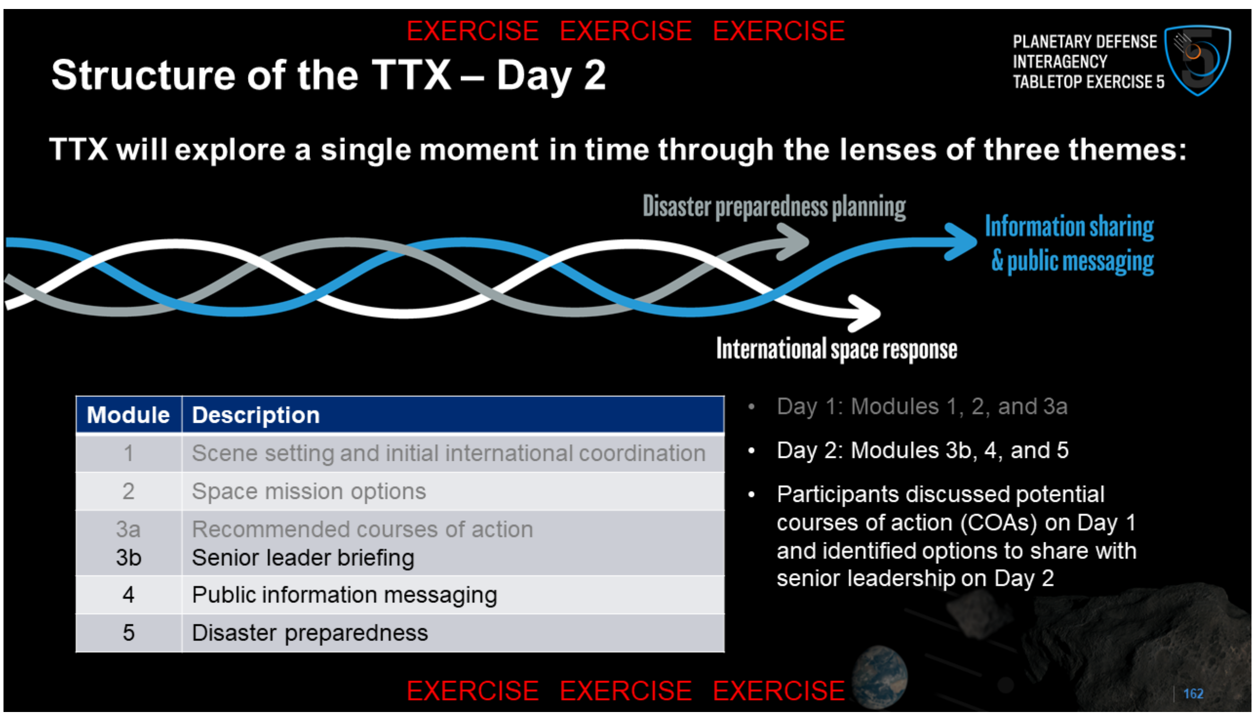
EXERCISE EXERCISE EXERCISE

157

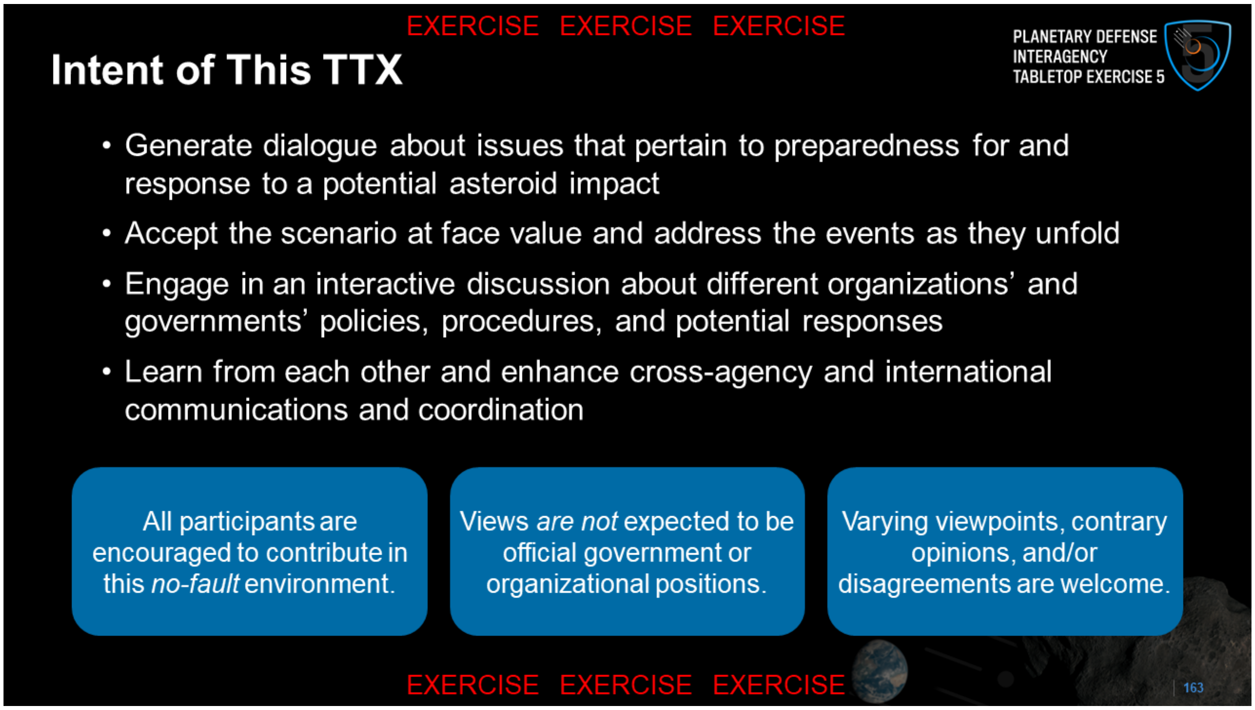

EXERCISE EXERCISE EXERCISE
Welcome to Planetary Defense TTX5 – Day 2
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Welcome
- From APL
- From the sponsor
• A few remarks from certain participants. For example,
- What is the primary focus of your agency or organization?
- What role might the agency or office where you have responsibilities play in a planetary defense scenario?
- What do you aim to take away from this TTX?
EXERCISE EXERCISE EXERCISE
159

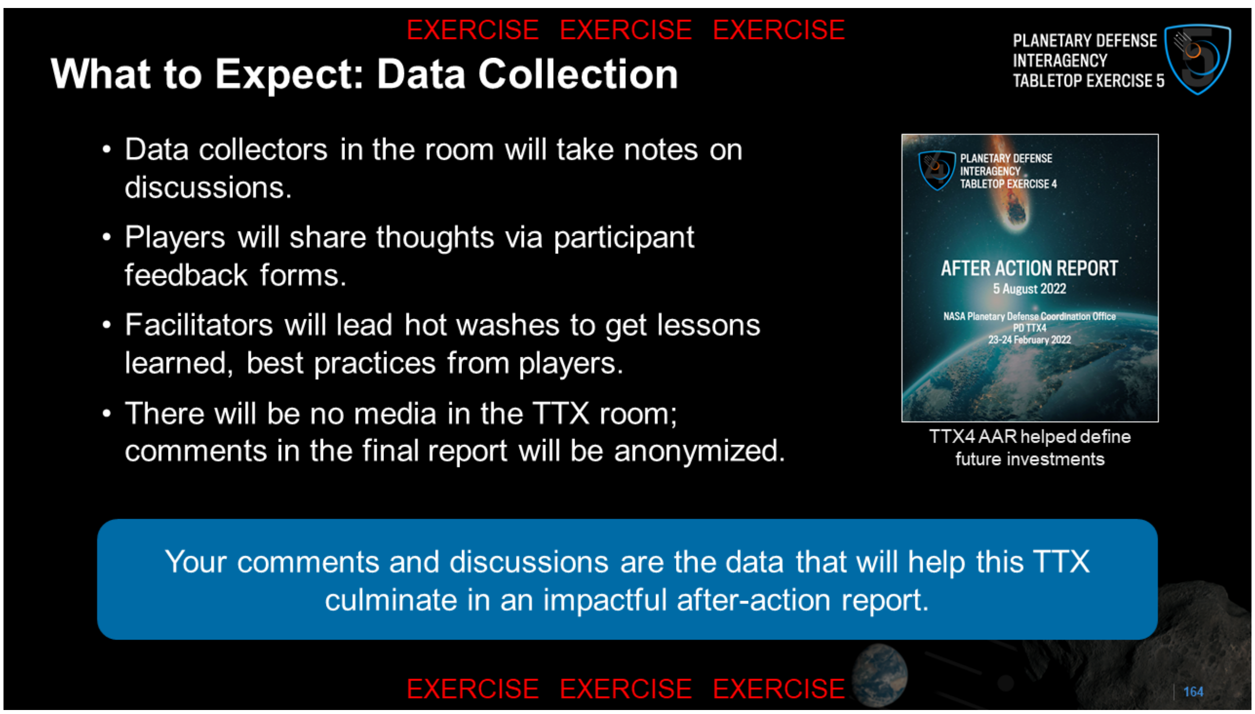

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
An Excerpt from Asteroid Hunters
EXERCISE EXERCISE EXERCISE
160



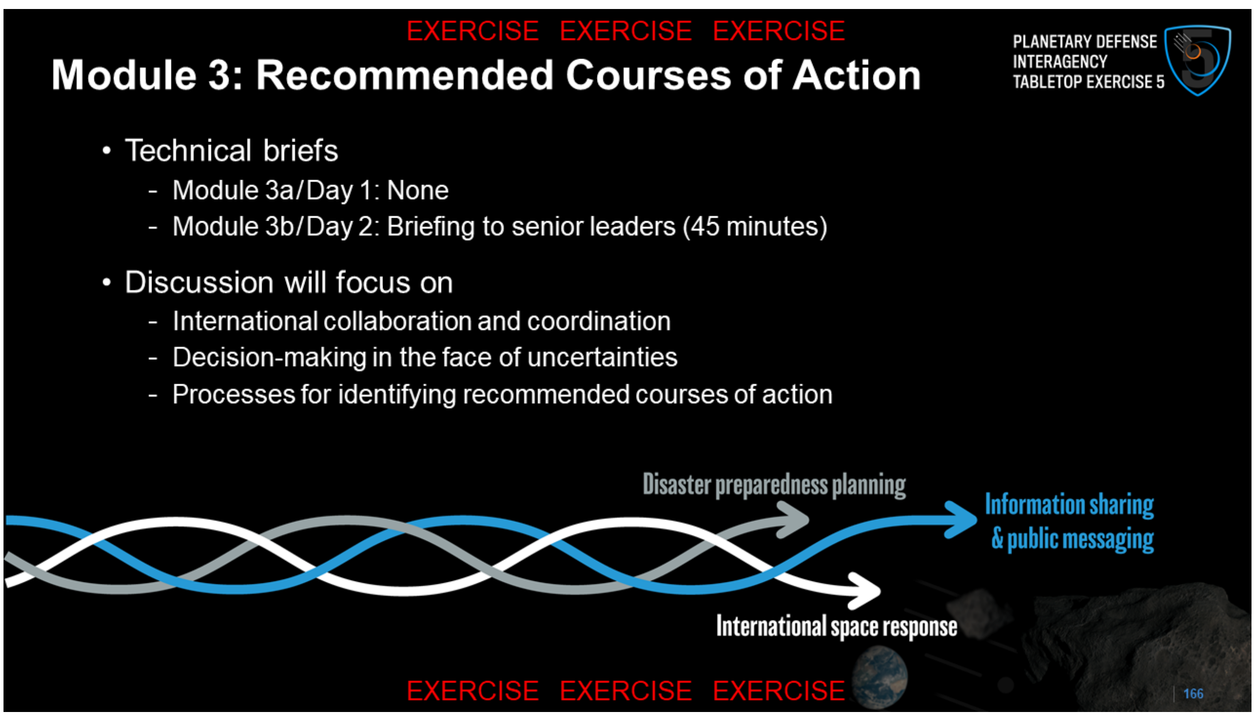


Module	Description
1	Scene setting and initial international coordination
2	Space mission options
3a 3b	Recommended courses of action Senior leader briefing
4	Public information messaging
5	Disaster preparedness

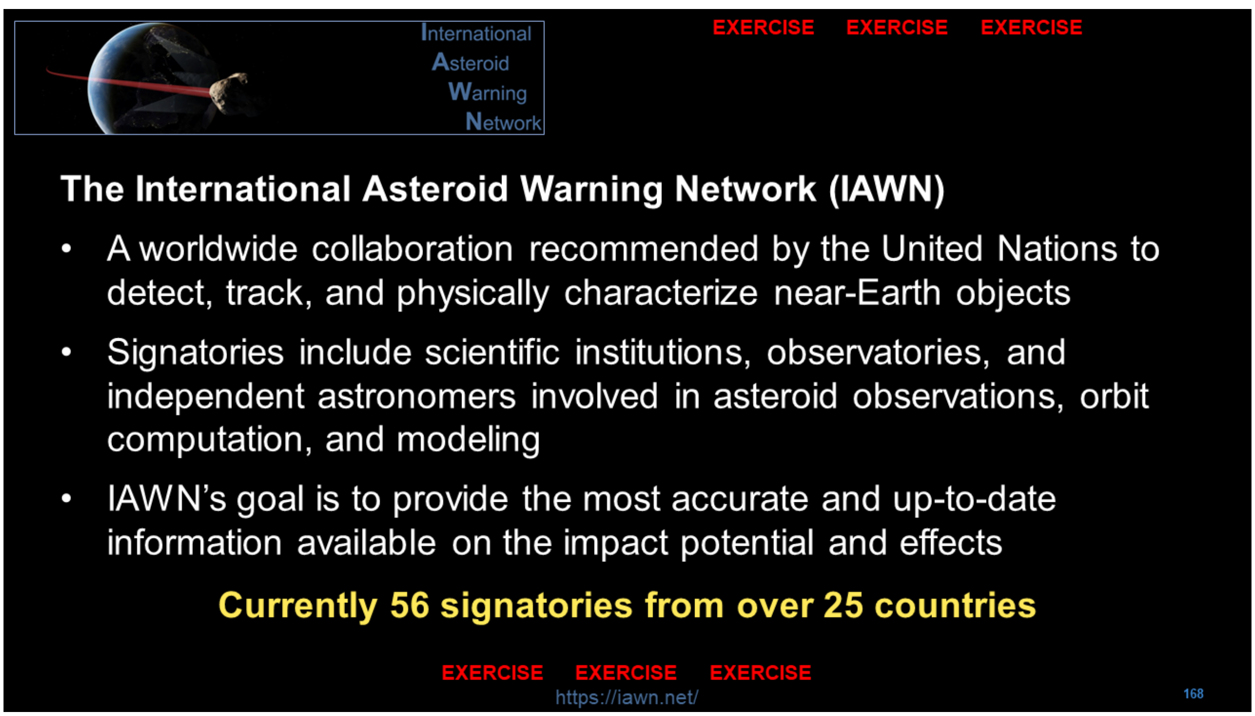

EXERCISE EXERCISE EXERCISE
Intent of This TTX
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• Generate dialogue about issues that pertain to preparedness for and response to a potential asteroid impact
• Accept the scenario at face value and address the events as they unfold
• Engage in an interactive discussion about different organizations' and governments' policies, procedures, and potential responses
• Learn from each other and enhance cross-agency and international communications and coordination
All participants are encouraged to contribute in this *no-fault* environment.
Views *are not* expected to be official government or organizational positions.
Varying viewpoints, contrary opinions, and/or disagreements are welcome.
EXERCISE EXERCISE EXERCISE
163

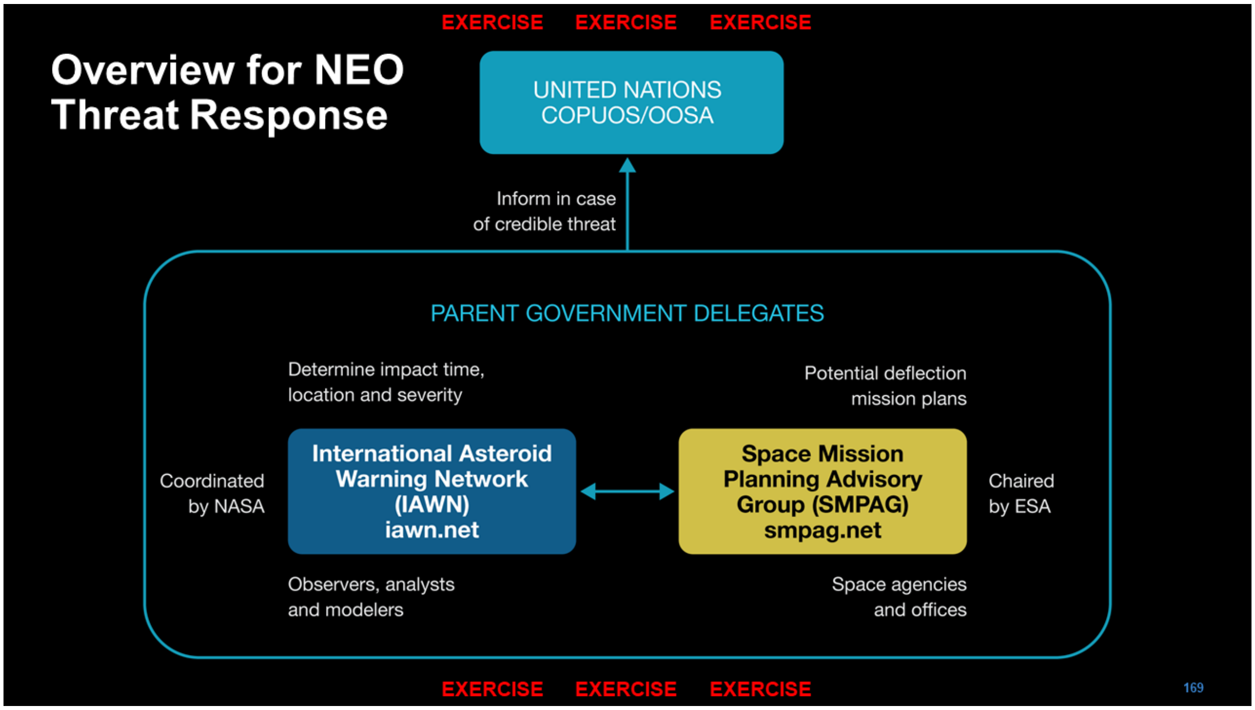

EXERCISE EXERCISE EXERCISE
What to Expect: Data Collection
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• Data collectors in the room will take notes on discussions.
• Players will share thoughts via participant feedback forms.
• Facilitators will lead hot washes to get lessons learned, best practices from players.
• There will be no media in the TTX room; comments in the final report will be anonymized.
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4
AFTER ACTION REPORT
5 August 2022
NASA Planetary Defense Coordination Office
PD TTX4
23-24 February 2022
TTX4 AAR helped define future investments
Your comments and discussions are the data that will help this TTX culminate in an impactful after-action report.
EXERCISE EXERCISE EXERCISE
164

H.2.2. Module 3: Recommended Courses of Action, Continued




International
Asteroid
Warning
Network
EXERCISE EXERCISE EXERCISE
Simulated Impact Threat Scenario
Notification by the International Asteroid Warning Network (IAWN)
Kelly Fast, NASA
IAWN Coordinating Officer
5th Interagency Planetary Defense Tabletop Exercise
April 2024
EXERCISE EXERCISE EXERCISE
https://iawn.net/


International
Asteroid
Warning
Network
EXERCISE EXERCISE EXERCISE
The International Asteroid Warning Network (IAWN)
• A worldwide collaboration recommended by the United Nations to detect, track, and physically characterize near-Earth objects
• Signatories include scientific institutions, observatories, and independent astronomers involved in asteroid observations, orbit computation, and modeling
• IAWN's goal is to provide the most accurate and up-to-date information available on the impact potential and effects
Currently 56 signatories from over 25 countries
EXERCISE EXERCISE EXERCISE
https://iawn.net/
168



EXERCISE EXERCISE EXERCISE

IAWN shall warn of predicted impacts exceeding a probability of **1%** for all objects characterized to be greater than **10 meters** in size* and notify:

- Chair, Space Mission Planning Advisory Group (SMPAG)
- United Nations Office for Outer Space Affairs (UNOOSA)
  - UNOOSA will notify UN Member States

IAWN signatories will also notify and work with their own governments according to their own national policies, as applicable.

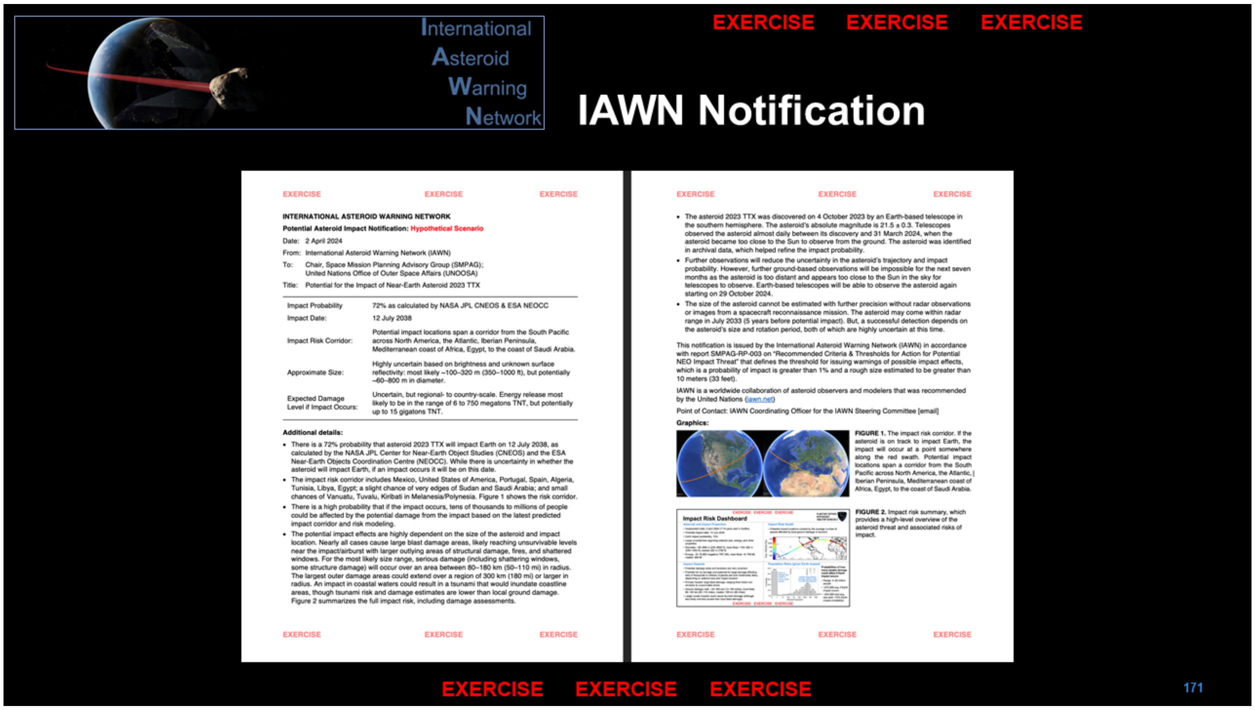
Note: NASA would follow NASA Policy Directive 8740.1 for notifying within the U.S. government

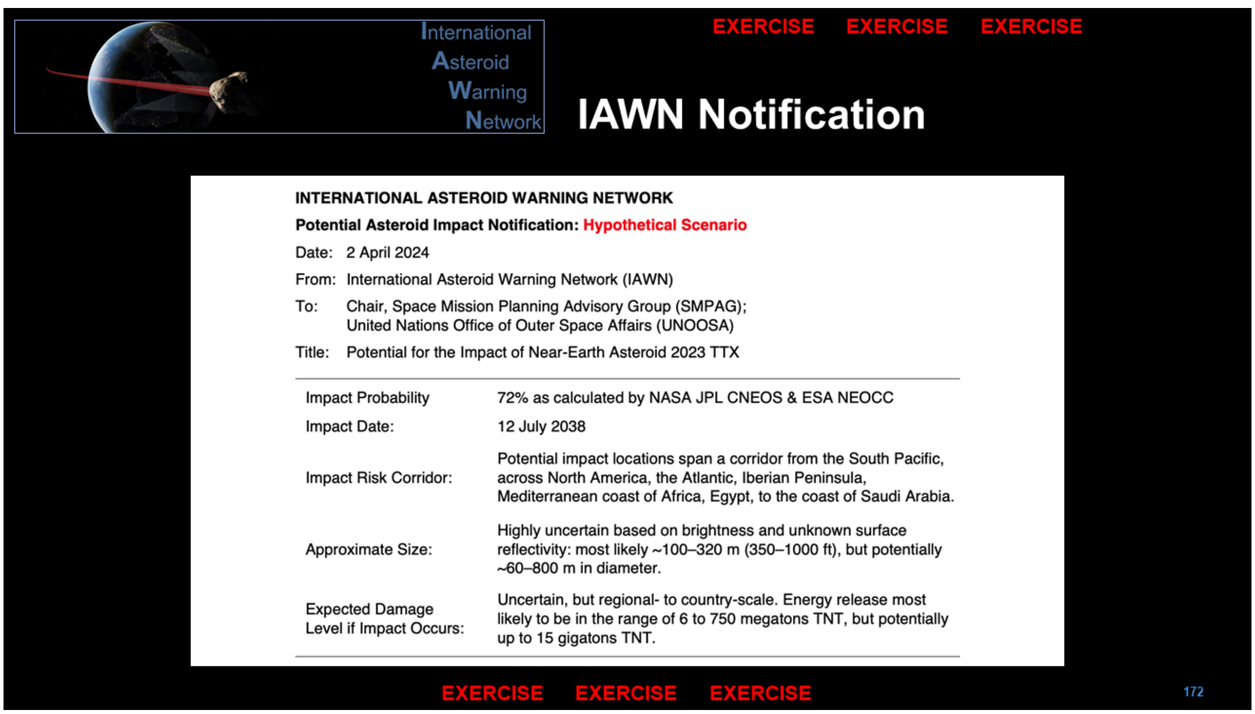
** Roughly equivalent to an absolute magnitude of 28 if only brightness data can be collected*

EXERCISE EXERCISE EXERCISE

https://iawn.net/

170

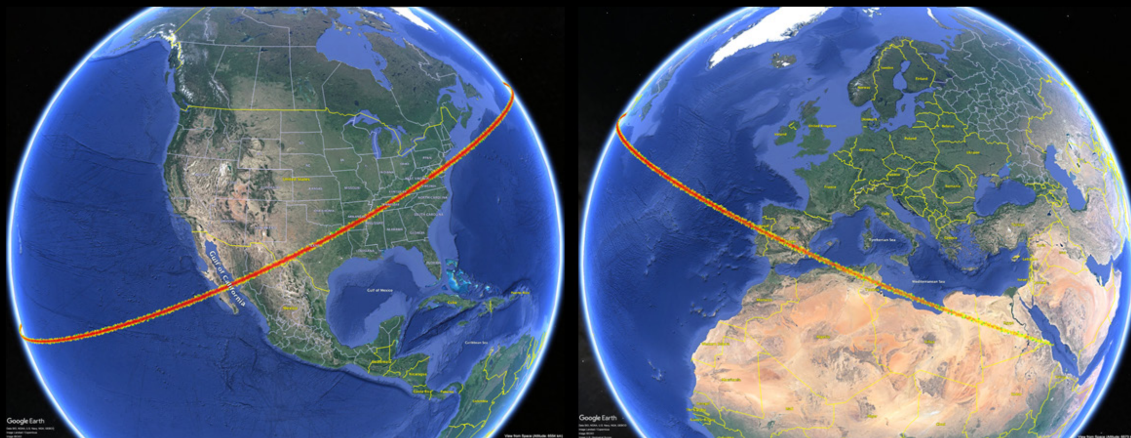

International
Asteroid
Warning
Network
EXERCISE EXERCISE EXERCISE
IAWN Notification
EXERCISE EXERCISE EXERCISE
171


International
Asteroid
Warning
Network
EXERCISE EXERCISE EXERCISE
IAWN Notification
INTERNATIONAL ASTEROID WARNING NETWORK
Potential Asteroid Impact Notification: Hypothetical Scenario
Date: 2 April 2024
From: International Asteroid Warning Network (IAWN)
To: Chair, Space Mission Planning Advisory Group (SMPAG); United Nations Office of Outer Space Affairs (UNOOSA)
Title: Potential for the Impact of Near-Earth Asteroid 2023 TTX
Impact Probability
72% as calculated by NASA JPL CNEOS & ESA NEOCC
Impact Date:
12 July 2038
Impact Risk Corridor:
Potential impact locations span a corridor from the South Pacific, across North America, the Atlantic, Iberian Peninsula, Mediterranean coast of Africa, Egypt, to the coast of Saudi Arabia.
Approximate Size:
Highly uncertain based on brightness and unknown surface reflectivity: most likely ~100–320 m (350–1000 ft), but potentially ~60–800 m in diameter.
Expected Damage Level if Impact Occurs:
Uncertain, but regional- to country-scale. Energy release most likely to be in the range of 6 to 750 megatons TNT, but potentially up to 15 gigatons TNT.
EXERCISE EXERCISE EXERCISE
172

EXERCISE EXERCISE EXERCISE

Impact Risk Corridor

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5



EXERCISE EXERCISE EXERCISE

173

EXERCISE EXERCISE EXERCISE

Impact Risk Dashboard

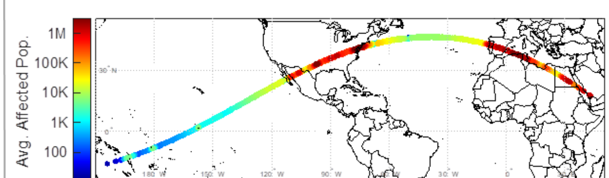
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5

Asteroid and Impact Properties

- Assessment date: 2 April 2024 (T-14 years and 3 months)
- Potential impact date: 12 July 2038
- Earth impact probability: 72%
- Large uncertainties regarding asteroid size, energy, and other properties
- Diameter: ~60–800 m (200–2600 ft), most likely ~100–320 m (330–1050 ft), median 220 m (730 ft)
- Energy: ~6–15,000 megatons TNT (Mt), most likely ~6–750 Mt, median 350 Mt

Impact Risk Swath

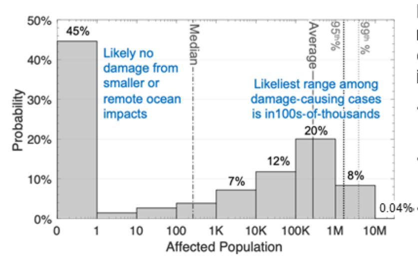
- Potential impact locations colored by the average number of people affected by local ground damage or tsunami



Impact Hazards

- Potential damage sizes and locations are very uncertain
- Potential for no damage and potential for large damage affecting tens of thousands to millions of people are both moderately likely, depending on asteroid size and impact location
- Primary hazard: large blast damage, ranging from blown-out windows to unsurvivable levels
- Ground damage radii: ~20–300 km (12–180 miles), most likely 80–180 km (50–110 miles), median 130 km (80 miles)
- Larger ocean impacts could cause tsunami damage (although less likely and less severe than local blast damage)

Population Risks (given Earth impact)



Probabilities of how many people damage could affect if Earth impact occurs

- Range: 0–20 million people
- ~270,000 avg. if Earth impact occurs
- ~200,000 total avg. risk (with ~72% Earth-impact probability)

EXERCISE EXERCISE EXERCISE

174

EXERCISE EXERCISE EXERCISE

SMPAG

Space Mission Options

Detlef Koschny
Chair, Space Mission Planning Advisory Group (SMPAG)

5th Interagency Planetary Defense Tabletop Exercise
April 2024

EXERCISE EXERCISE EXERCISE 175

EXERCISE EXERCISE EXERCISE

Relevant Tasks of SMPAG

SMPAG

From the terms of reference (available at smpag.net):

1. Purpose. The purpose of the SMPAG is to **prepare for an international response to a NEO impact threat** through the exchange of information, development of options for collaborative research and mission opportunities, and NEO threat mitigation planning activities.

.
.
.

3. Scope. The SMPAG may address the following main areas:

.
.
.

4. Mitigation planning activities

a. **Recommend operational responsibilities for a space-based NEO mitigation campaign.**
b. Work in coordination with the relevant actors potentially involved in the implementation of the threat response.
c. In the case of a credible threat, **recommend viable concepts** for a possible mitigation campaign and directly inform those governments that would coordinate and fund space mission activities and request that they in turn inform UN COPUOS, via the UN Office for Outer Space Affairs if necessary.

EXERCISE EXERCISE EXERCISE 176

EXERCISE EXERCISE EXERCISE

Criteria for SMPAG

SMPAG

Action	Warning Time	Impact Probability	Object Size	Threshold Crossed?
Warn	Any	>1%	>10 m or <absolute magnitude 28	✓
Terrestrial preparedness planning	≤20 years	>10%	>20 m or <absolute magnitude 27	✓
Mission options planning	≤50 years	>1%	>50 m or <absolute magnitude 26	✓

Reference: SMPAG Recommended Criteria & Thresholds for Action for Potential NEO Impact Threat (2017)

U.S. benchmarks for considering execution of space missions have also been crossed.	✓

Reference: Report on Near-Earth Object Impact Threat Emergency Protocols (2021)

EXERCISE EXERCISE EXERCISE

177

EXERCISE EXERCISE EXERCISE

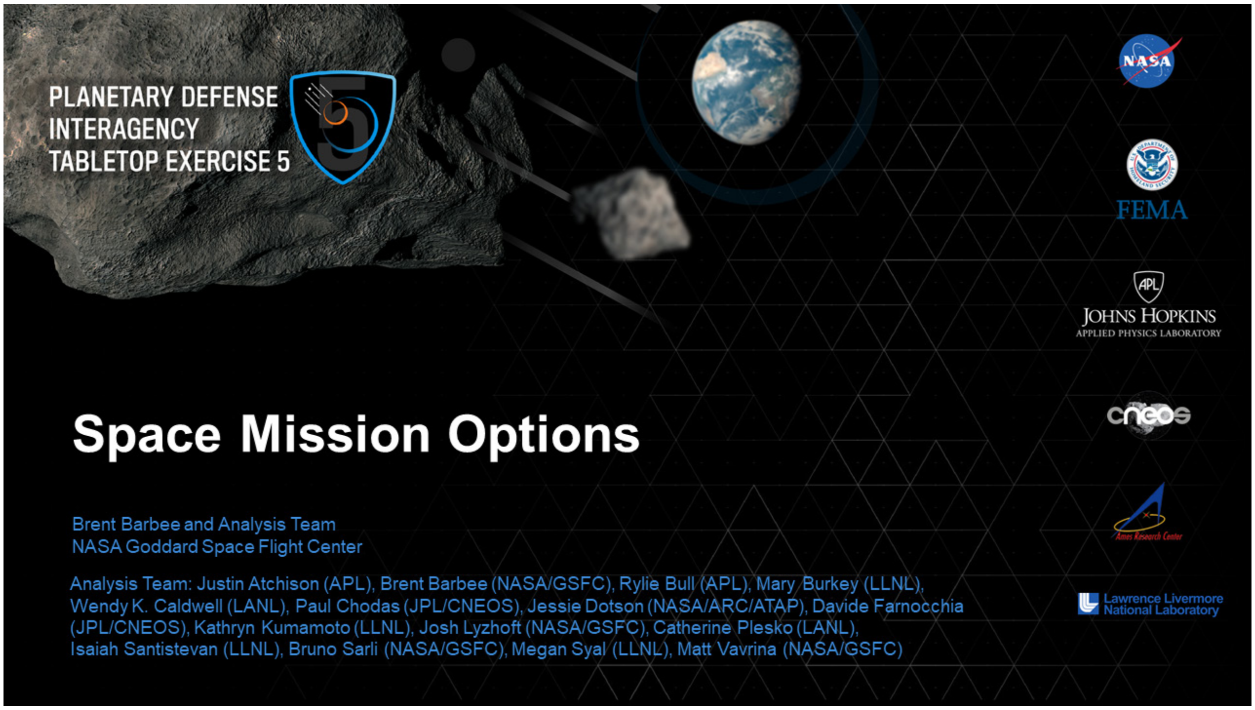
Process on Day 1

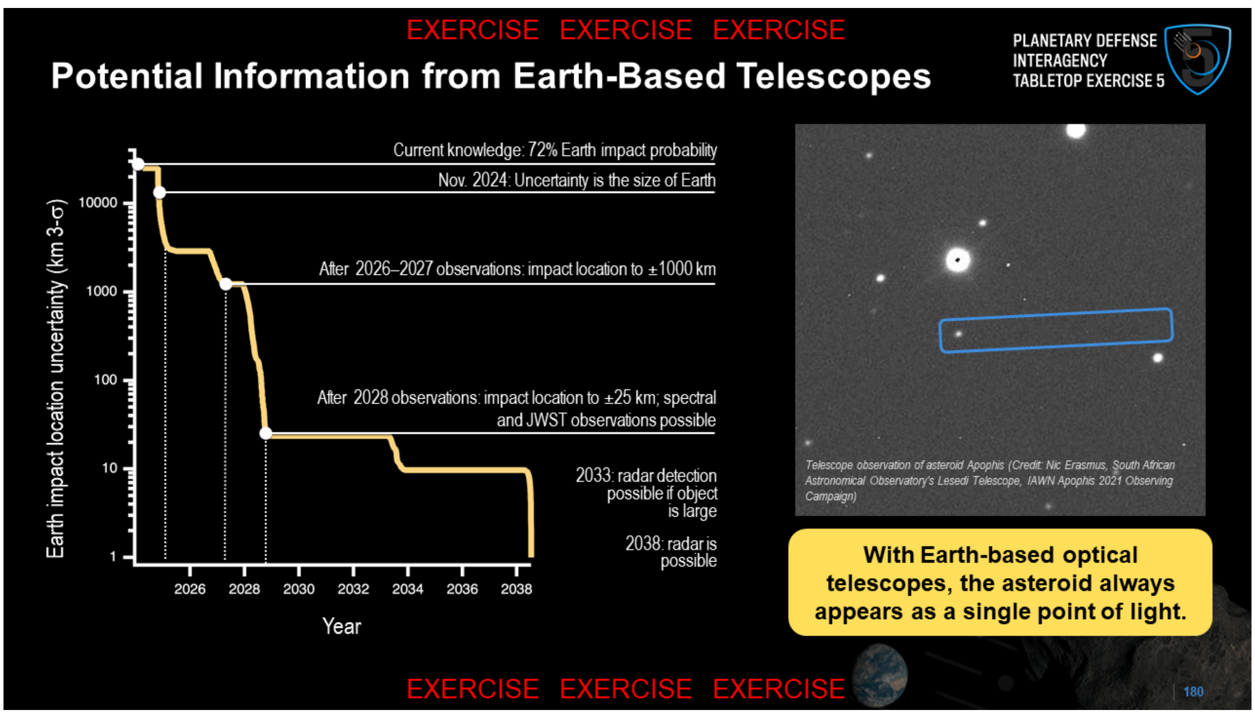
SMPAG

- **Notified about the threat via IAWN**
- **Discussed space mission options and collaborative approaches to implementation**
- **Agreed upon courses of action to recommend for space missions in this scenario**

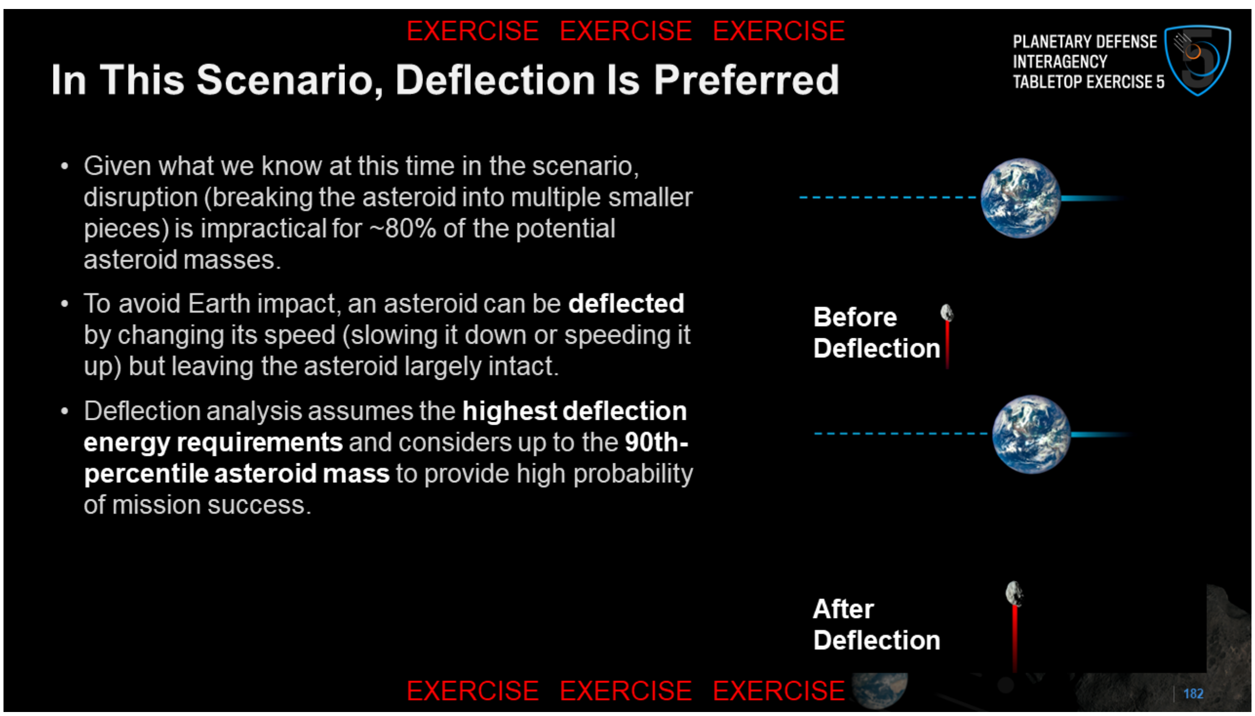
EXERCISE EXERCISE EXERCISE

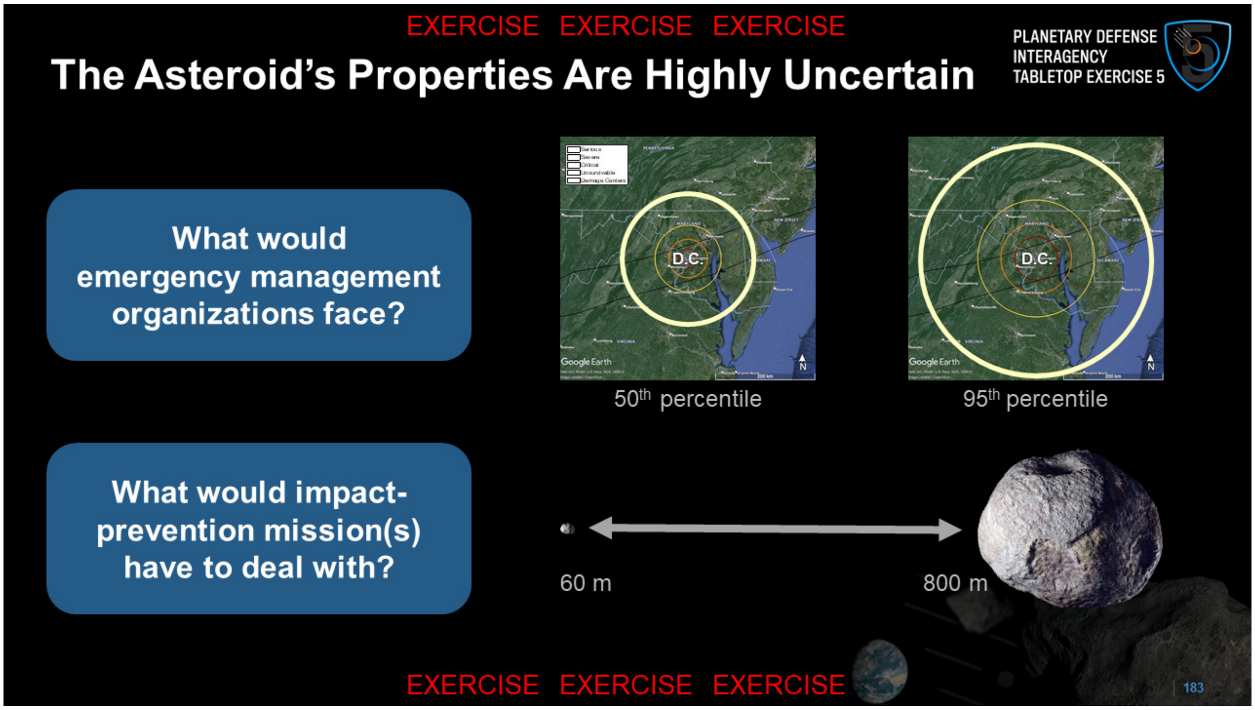
178

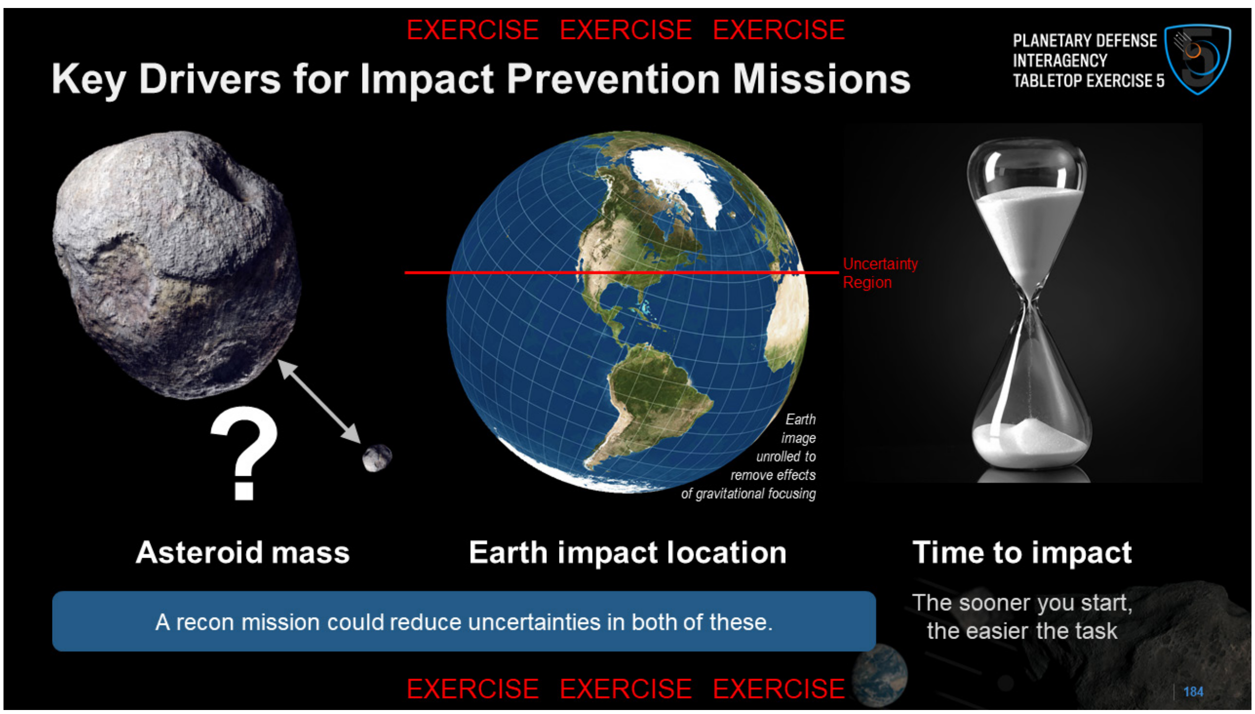

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
FEMA
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
Space Mission Options
Brent Barbee and Analysis Team
NASA Goddard Space Flight Center
Analysis Team: Justin Atchison (APL), Brent Barbee (NASA/GSFC), Rylie Bull (APL), Mary Burkey (LLNL), Wendy K. Caldwell (LANL), Paul Chodas (JPL/CNEOS), Jessie Dotson (NASA/ARC/ATAP), Davide Farnocchia (JPL/CNEOS), Kathryn Kumamoto (LLNL), Josh Lyzhoft (NASA/GSFC), Catherine Plesko (LANL), Isaiah Santistevan (LLNL), Bruno Sarli (NASA/GSFC), Megan Syal (LLNL), Matt Vavrina (NASA/GSFC)
Lawrence Livermore National Laboratory

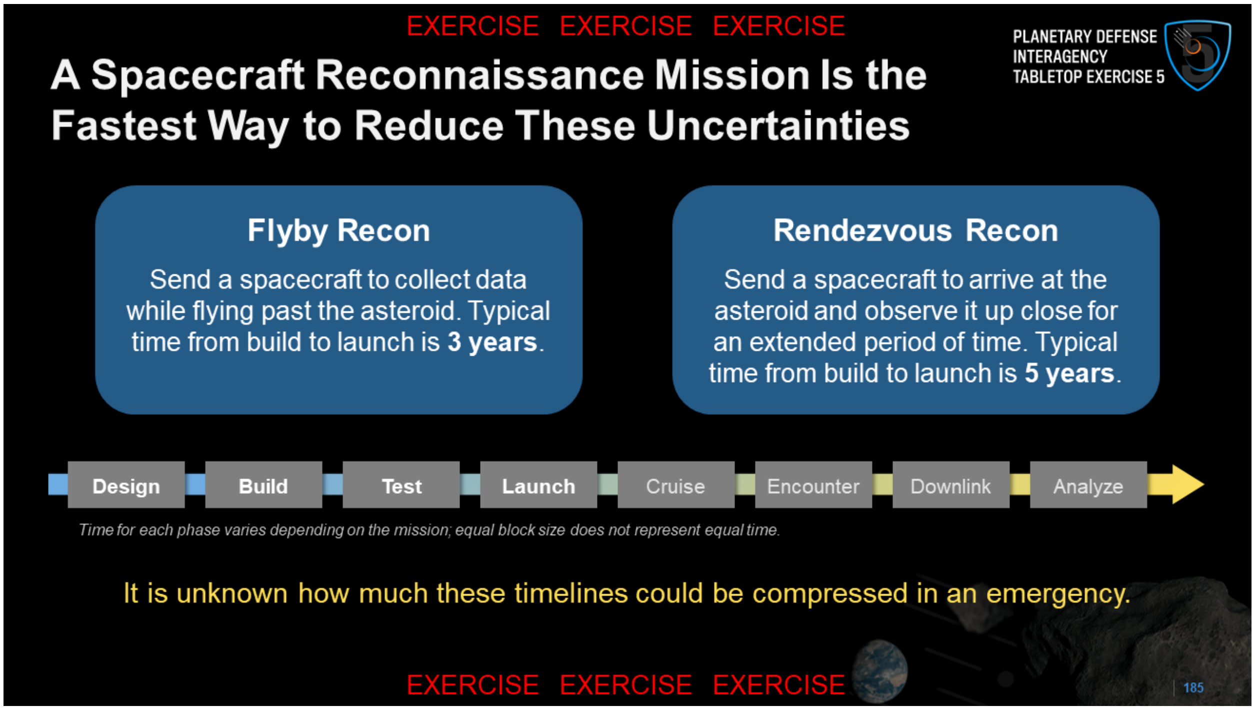

EXERCISE EXERCISE EXERCISE
Potential Information from Earth-Based Telescopes
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Current knowledge: 72% Earth impact probability
Nov. 2024: Uncertainty is the size of Earth
After 2026–2027 observations: impact location to ±1000 km
After 2028 observations: impact location to ±25 km; spectral and JWST observations possible
2033: radar detection possible if object is large
2038: radar is possible
Earth impact location uncertainty (km 3-σ)
10000
1000
100
10
1
2026
2028
2030
2032
2034
2036
2038
Year
Telescope observation of asteroid Apophis (Credit: Nic Erasmus, South African Astronomical Observatory's Lesedi Telescope, IAWN Apophis 2021 Observing Campaign)
With Earth-based optical telescopes, the asteroid always appears as a single point of light.
EXERCISE EXERCISE EXERCISE
180


EXERCISE EXERCISE EXERCISE
Asteroid Impacts May Be Preventable
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Kinetic Impact
Ion Beam
Nuclear Explosive Devices
Successful impact prevention requires adequate warning time and information about key asteroid properties.
EXERCISE EXERCISE EXERCISE
181

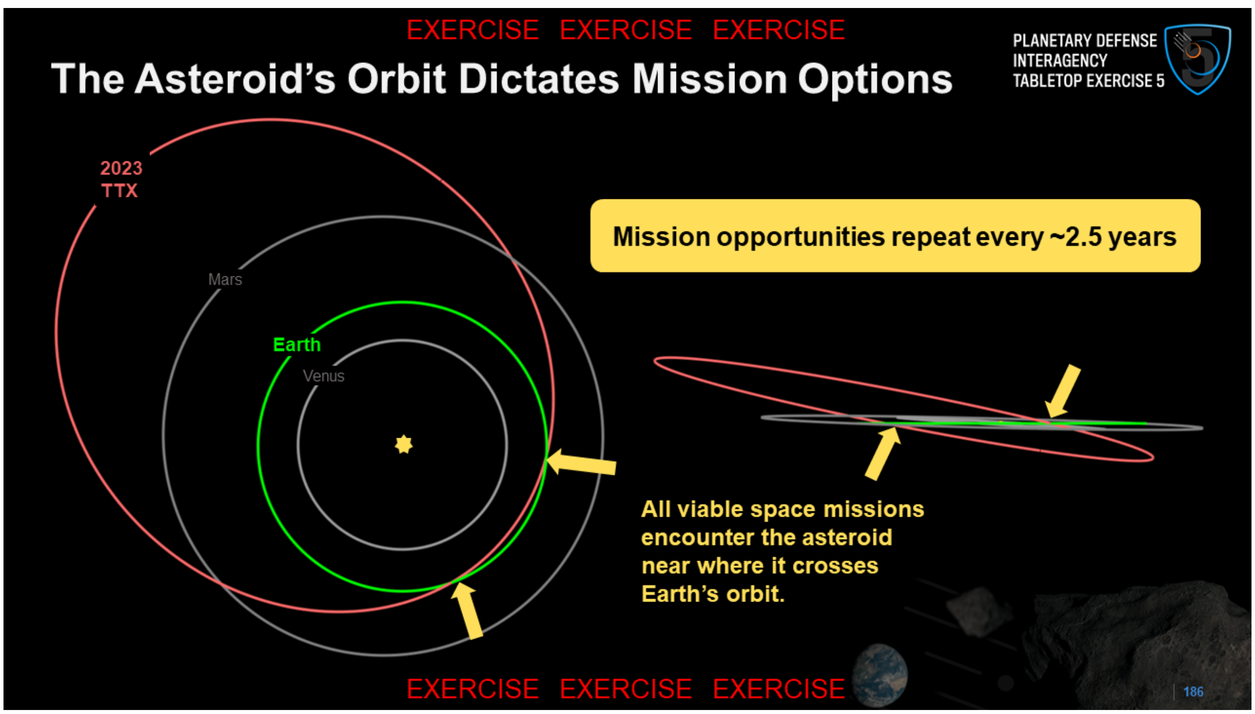

EXERCISE EXERCISE EXERCISE
In This Scenario, Deflection Is Preferred
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Given what we know at this time in the scenario, disruption (breaking the asteroid into multiple smaller pieces) is impractical for ~80% of the potential asteroid masses.
• To avoid Earth impact, an asteroid can be deflected by changing its speed (slowing it down or speeding it up) but leaving the asteroid largely intact.
• Deflection analysis assumes the highest deflection energy requirements and considers up to the 90th-percentile asteroid mass to provide high probability of mission success.
Before Deflection
After Deflection
EXERCISE EXERCISE EXERCISE
182


EXERCISE EXERCISE EXERCISE
The Asteroid's Properties Are Highly Uncertain
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
What would emergency management organizations face?
D.C.
50th percentile
D.C.
95th percentile
What would impact-prevention mission(s) have to deal with?
60 m
800 m
EXERCISE EXERCISE EXERCISE
183

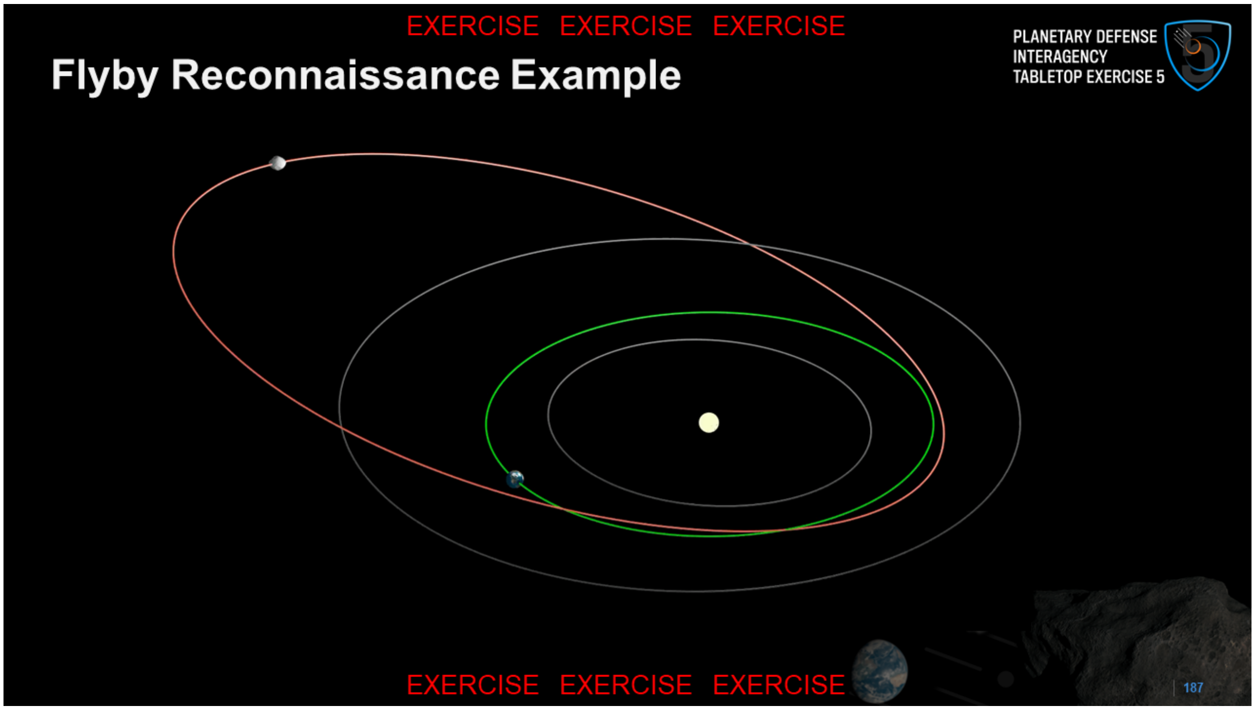

EXERCISE EXERCISE EXERCISE
Key Drivers for Impact Prevention Missions
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Uncertainty Region
Earth image unrolled to remove effects of gravitational focusing
?
Asteroid mass
Earth impact location
Time to impact
A recon mission could reduce uncertainties in both of these.
The sooner you start, the easier the task
EXERCISE EXERCISE EXERCISE
184



EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
A Spacecraft Reconnaissance Mission Is the Fastest Way to Reduce These Uncertainties
Flyby Recon
Send a spacecraft to collect data while flying past the asteroid. Typical time from build to launch is 3 years.
Rendezvous Recon
Send a spacecraft to arrive at the asteroid and observe it up close for an extended period of time. Typical time from build to launch is 5 years.
Design
Build
Test
Launch
Cruise
Encounter
Downlink
Analyze
Time for each phase varies depending on the mission; equal block size does not represent equal time.
It is unknown how much these timelines could be compressed in an emergency.
EXERCISE EXERCISE EXERCISE
185

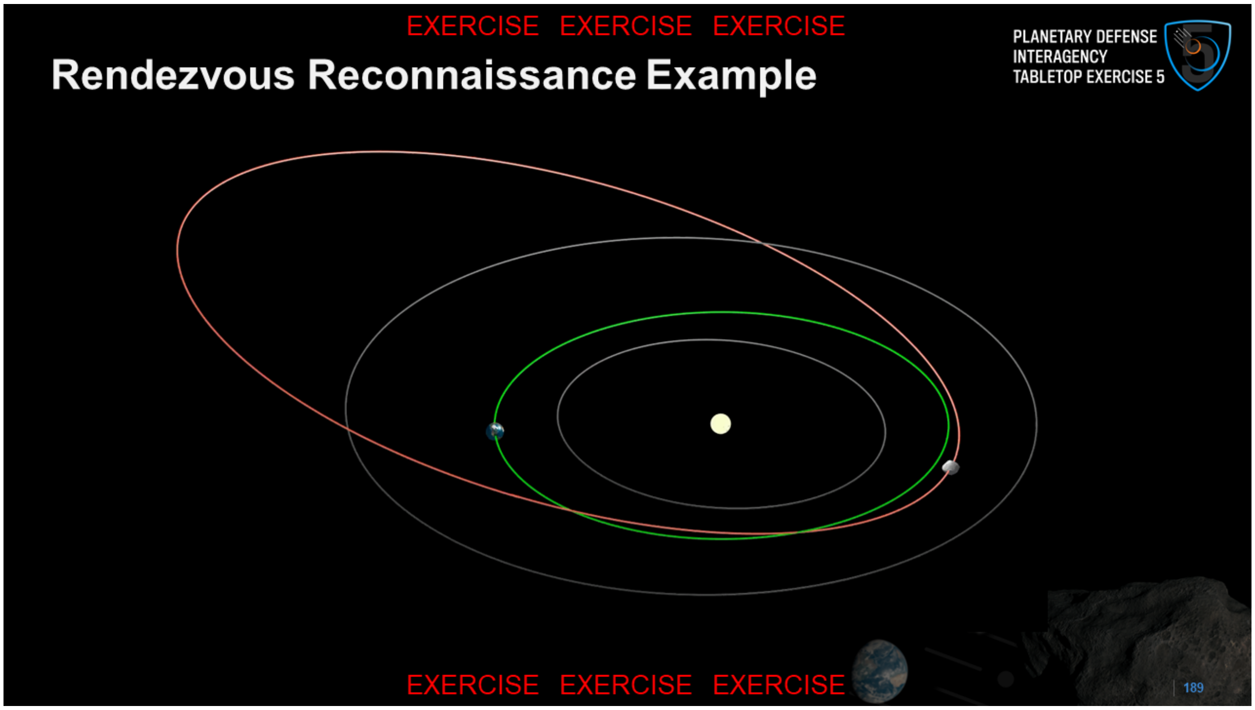


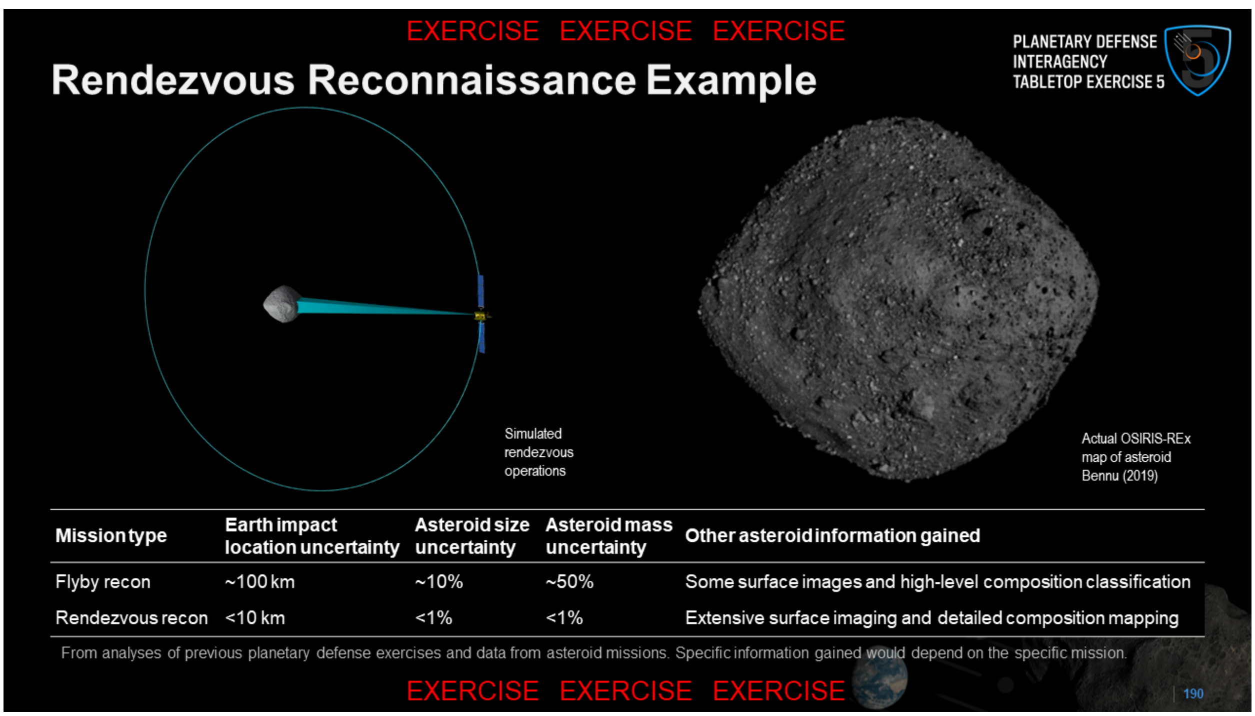
EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
The Asteroid's Orbit Dictates Mission Options
2023 TTX
Mars
Earth
Venus
Mission opportunities repeat every ~2.5 years
All viable space missions encounter the asteroid near where it crosses Earth's orbit.
EXERCISE EXERCISE EXERCISE
186

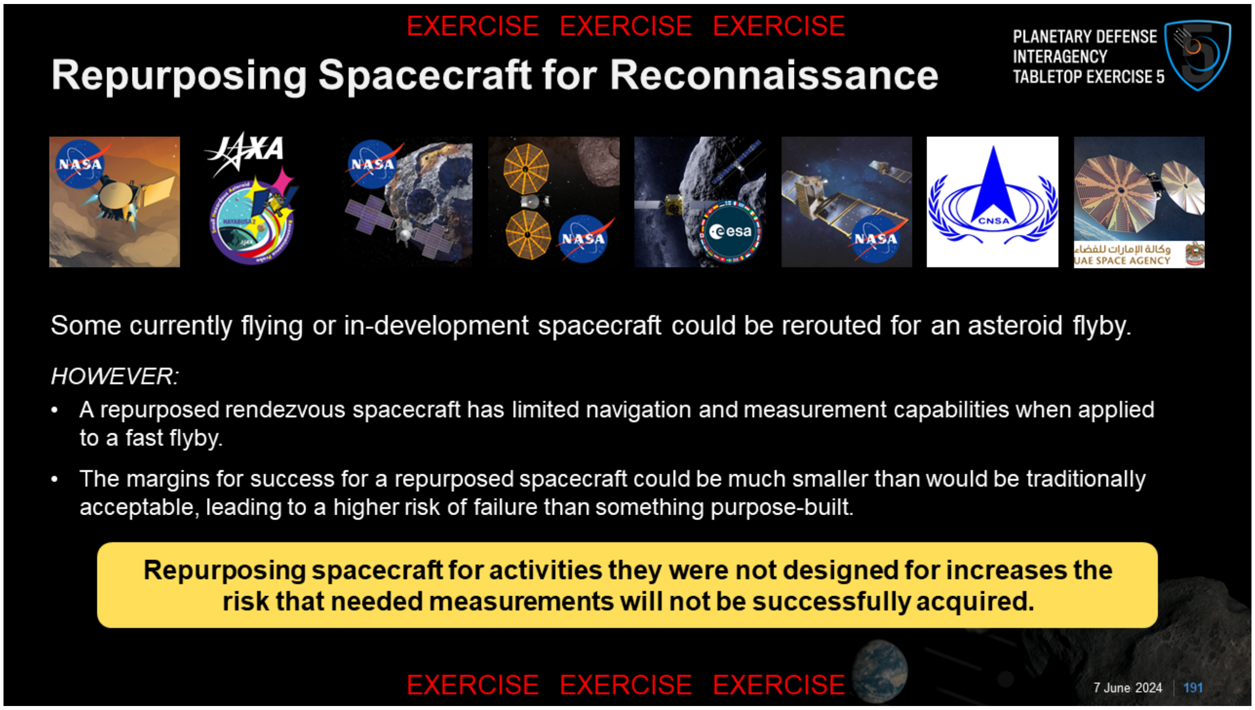


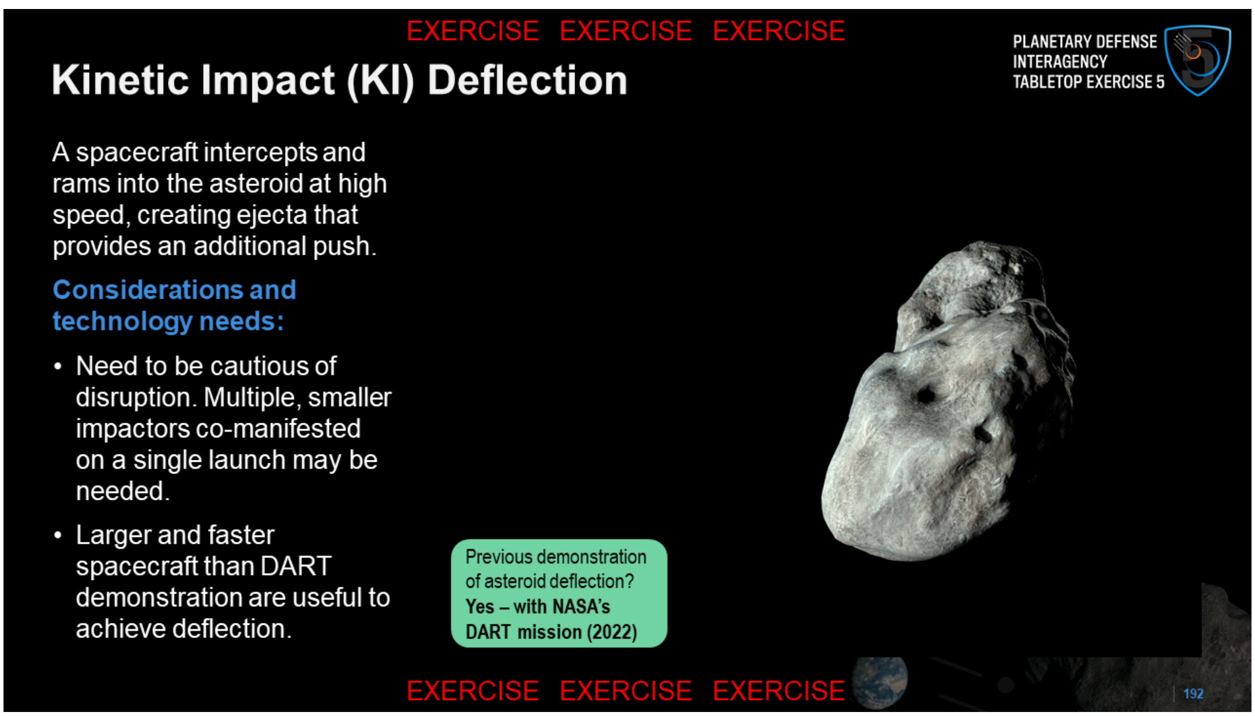
Mission type	Earth impact location uncertainty	Asteroid size uncertainty	Asteroid mass uncertainty	Other asteroid information gained
Flyby recon	~100 km	~10%	~50%	Some surface images and high-level composition classification
Rendezvous recon	<10 km	<1%	<1%	Extensive surface imaging and detailed composition mapping

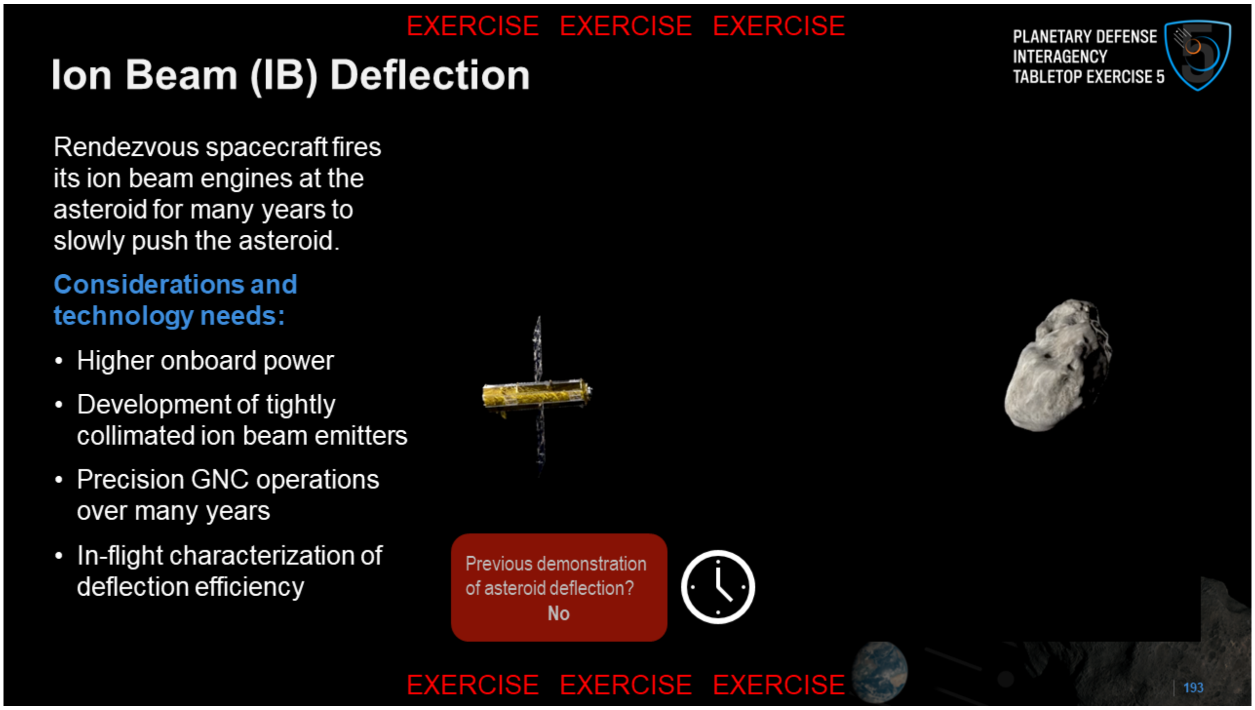
From analyses of previous planetary defense exercises and data from asteroid missions. Specific information gained would depend on the specific mission.

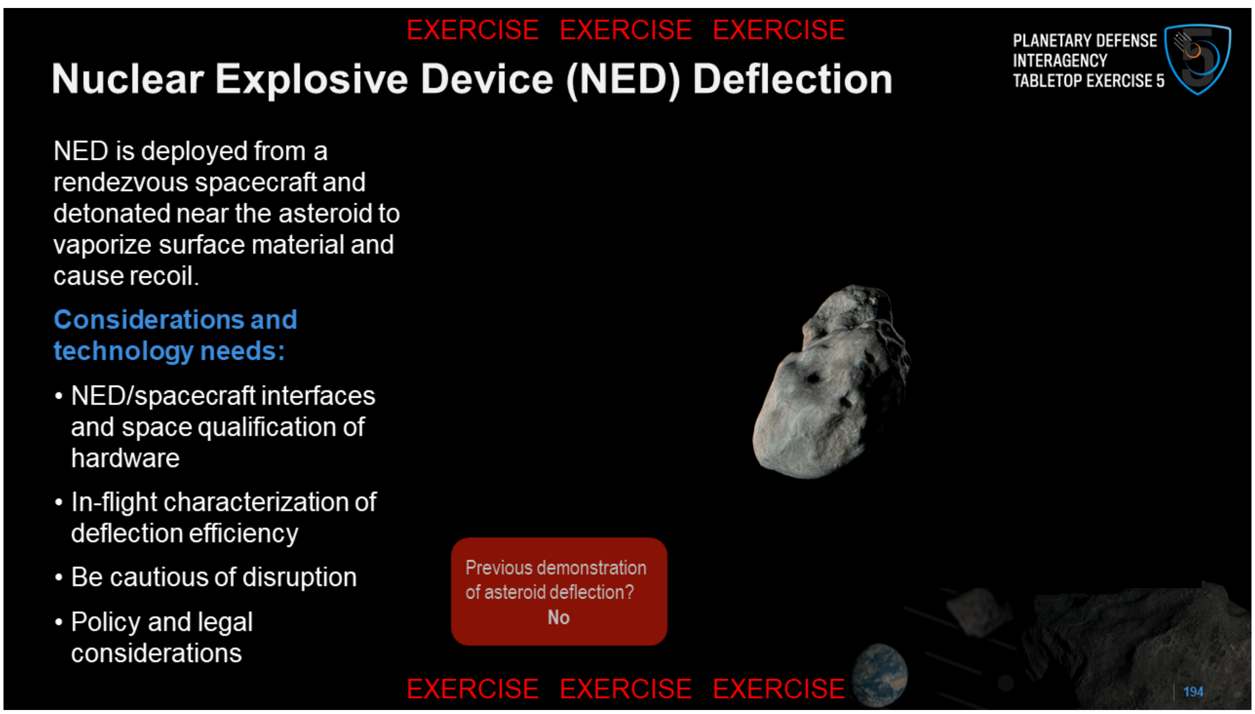

EXERCISE EXERCISE EXERCISE
Rendezvous Reconnaissance Example
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
EXERCISE EXERCISE EXERCISE
189

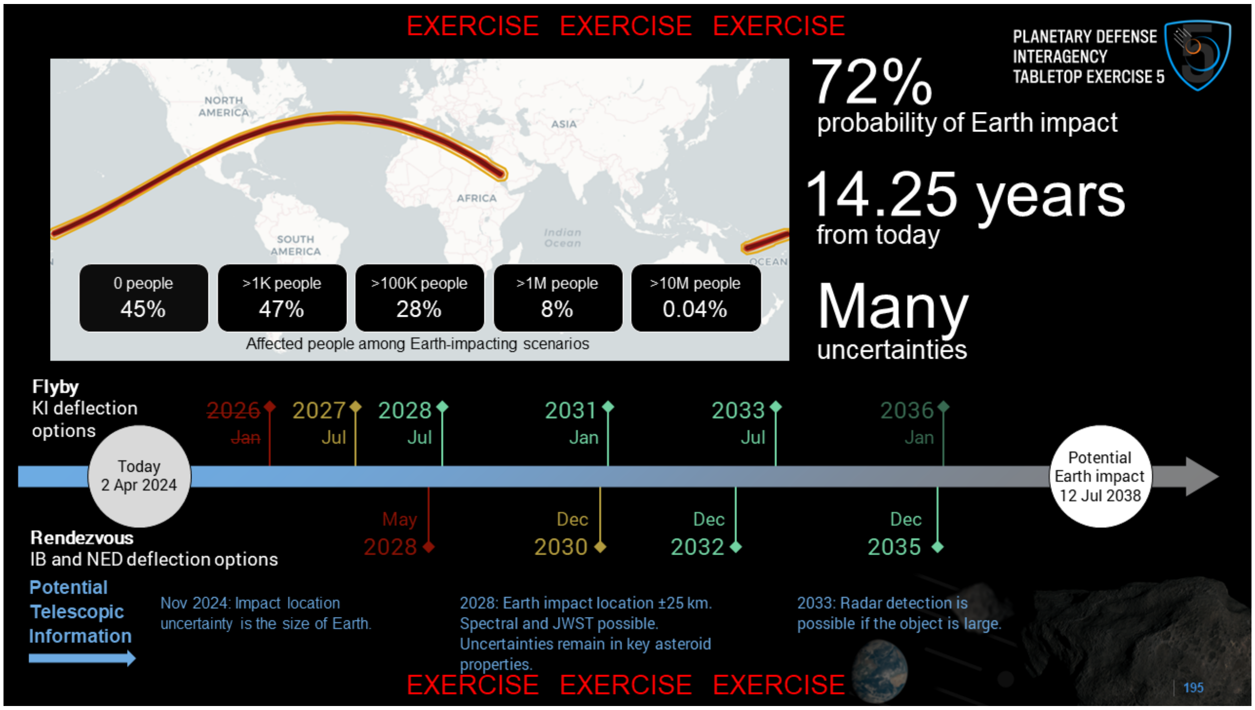

EXERCISE EXERCISE EXERCISE
Rendezvous Reconnaissance Example
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Simulated
rendezvous
operations
Actual OSIRIS-REx
map of asteroid
Bennu (2019)
Mission type | Earth impact location uncertainty | Asteroid size uncertainty | Asteroid mass uncertainty | Other asteroid information gained
Flyby recon | ~100 km | ~10% | ~50% | Some surface images and high-level composition classification
Rendezvous recon | <10 km | <1% | <1% | Extensive surface imaging and detailed composition mapping
From analyses of previous planetary defense exercises and data from asteroid missions. Specific information gained would depend on the specific mission.
EXERCISE EXERCISE EXERCISE
190


EXERCISE EXERCISE EXERCISE
Repurposing Spacecraft for Reconnaissance
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
NASA
JAXA
NASA
NASA
esa
NASA
CNSA
وكالة الإمارات للفضاء
UAE SPACE AGENCY
Some currently flying or in-development spacecraft could be rerouted for an asteroid flyby.
HOWEVER:
• A repurposed rendezvous spacecraft has limited navigation and measurement capabilities when applied to a fast flyby.
• The margins for success for a repurposed spacecraft could be much smaller than would be traditionally acceptable, leading to a higher risk of failure than something purpose-built.
Repurposing spacecraft for activities they were not designed for increases the risk that needed measurements will not be successfully acquired.
EXERCISE EXERCISE EXERCISE
7 June 2024 | 191


EXERCISE EXERCISE EXERCISE
Kinetic Impact (KI) Deflection
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
A spacecraft intercepts and rams into the asteroid at high speed, creating ejecta that provides an additional push.
Considerations and technology needs:
• Need to be cautious of disruption. Multiple, smaller impactors co-manifested on a single launch may be needed.
• Larger and faster spacecraft than DART demonstration are useful to achieve deflection.
Previous demonstration of asteroid deflection? Yes – with NASA's DART mission (2022)
EXERCISE EXERCISE EXERCISE
192


EXERCISE EXERCISE EXERCISE
Ion Beam (IB) Deflection
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Rendezvous spacecraft fires its ion beam engines at the asteroid for many years to slowly push the asteroid.
Considerations and technology needs:
• Higher onboard power
• Development of tightly collimated ion beam emitters
• Precision GNC operations over many years
• In-flight characterization of deflection efficiency
Previous demonstration of asteroid deflection? No
EXERCISE EXERCISE EXERCISE
193


EXERCISE EXERCISE EXERCISE
Nuclear Explosive Device (NED) Deflection
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
NED is deployed from a rendezvous spacecraft and detonated near the asteroid to vaporize surface material and cause recoil.
Considerations and technology needs:
• NED/spacecraft interfaces and space qualification of hardware
• In-flight characterization of deflection efficiency
• Be cautious of disruption
• Policy and legal considerations
Previous demonstration of asteroid deflection? No
EXERCISE EXERCISE EXERCISE
194


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
NORTH AMERICA
ASIA
AFRICA
SOUTH AMERICA
Indian Ocean
OCEAN
0 people 45%
>1K people 47%
>100K people 28%
>1M people 8%
>10M people 0.04%
Affected people among Earth-impacting scenarios
72%
probability of Earth impact
14.25 years
from today
Many
uncertainties
Flyby
KI deflection options
2026 Jan
2027 Jul
2028 Jul
2031 Jan
2033 Jul
2036 Jan
Today 2 Apr 2024
Potential Earth impact 12 Jul 2038
May 2028
Dec 2030
Dec 2032
Dec 2035
Rendezvous
IB and NED deflection options
Potential Telescopic Information
Nov 2024: Impact location uncertainty is the size of Earth.
2028: Earth impact location ±25 km. Spectral and JWST possible. Uncertainties remain in key asteroid properties.
2033: Radar detection is possible if the object is large.
EXERCISE EXERCISE EXERCISE
195


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
EXERCISE EXERCISE EXERCISE
196

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- What, if any, additional information might be helpful for your decision-making needs at this stage?
- How would you approach deciding whether to pursue one or more of these courses of action?

EXERCISE EXERCISE EXERCISE

197

EXERCISE EXERCISE EXERCISE

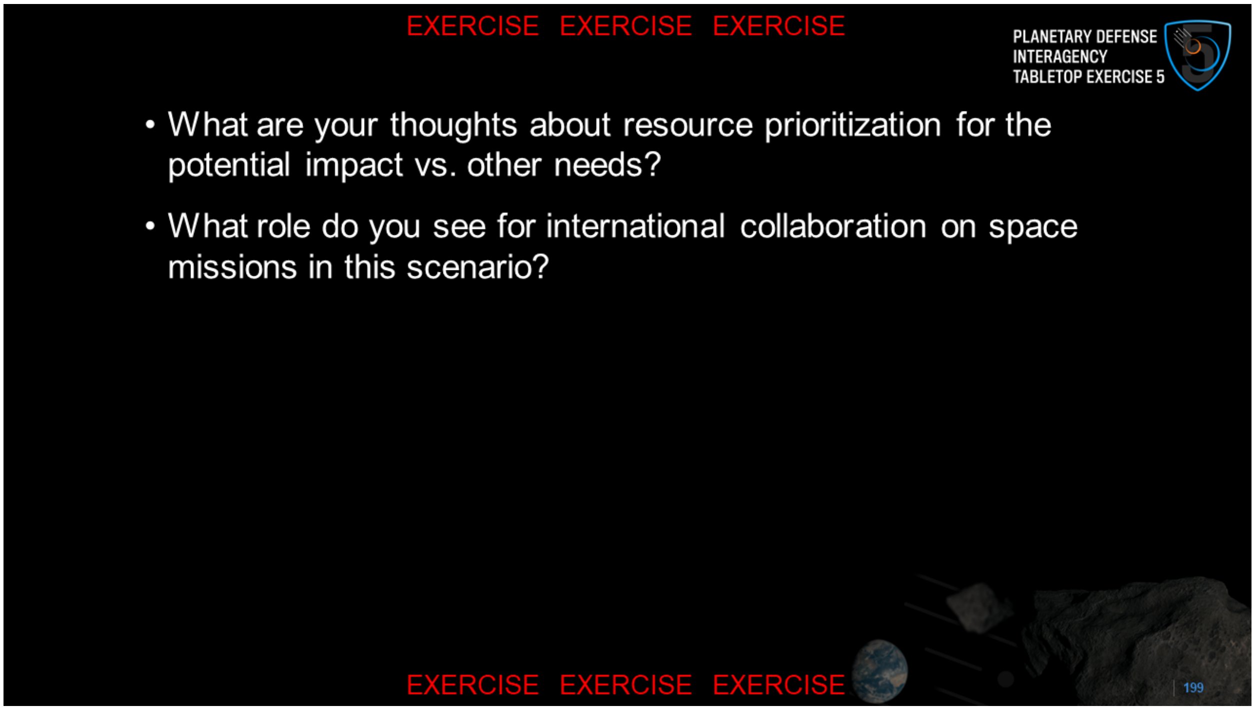
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- Which course(s) of action would you support at this time?
  1. Wait until additional telescopic observations of the asteroid become available in November 2024.
  2. Immediately begin development of a U.S.-sponsored flyby mission.
  3. Start development today of a purpose-built rendezvous reconnaissance spacecraft to provide more detailed and precise information about the asteroid threat.

Option 1 would delay options 2 and 3. Options 2 and 3 are not mutually exclusive.

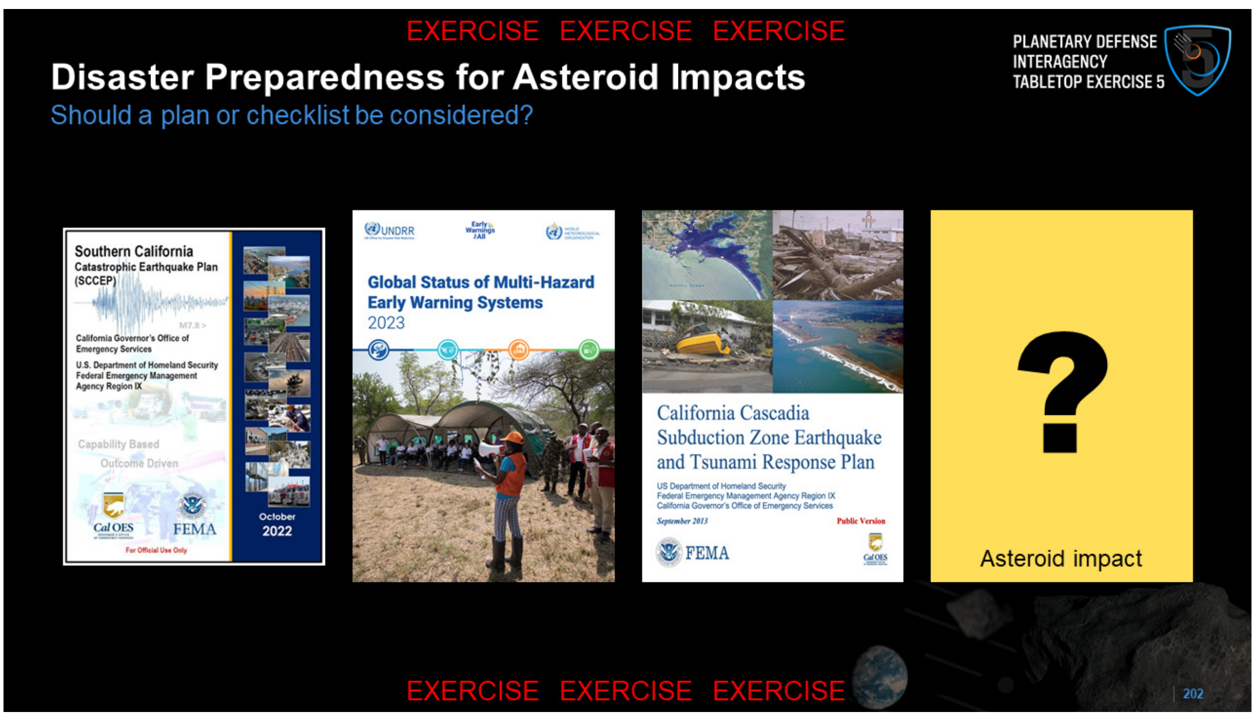
EXERCISE EXERCISE EXERCISE

198


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What are your thoughts about resource prioritization for the potential impact vs. other needs?
• What role do you see for international collaboration on space missions in this scenario?
EXERCISE EXERCISE EXERCISE
199


PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Initial Emergency Preparedness Actions
Respond Today?
Leviticus A. "L.A." Lewis
FEMA Detailee/TTX Coordinator
Planetary Defense Coordination Office
Leviticus.lewis@fema.dhs.gov; Leviticus.a.lewis@nasa.gov
NASA
FEMA
APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
cneos
Lawrence Livermore National Laboratory


EXERCISE EXERCISE EXERCISE
Disaster Preparedness for Asteroid Impacts
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Earthquake
Volcanic eruption
Flood
Hurricane
Wildfire
?
Asteroid impact
EXERCISE EXERCISE EXERCISE
201


EXERCISE EXERCISE EXERCISE
Disaster Preparedness for Asteroid Impacts
Should a plan or checklist be considered?
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Southern California Catastrophic Earthquake Plan (SCCEP)
California Governor's Office of Emergency Services
U.S. Department of Homeland Security Federal Emergency Management Agency Region IX
Capability Based
Outcome Driven
Cal OES
FEMA
October 2022
For Official Use Only
UNDRR
Global Status of Multi-Hazard Early Warning Systems 2023
California Cascadia Subduction Zone Earthquake and Tsunami Response Plan
US Department of Homeland Security
Federal Emergency Management Agency Region IX
California Governor's Office of Emergency Services
September 2013
Public Version
FEMA
?
Asteroid impact
EXERCISE EXERCISE EXERCISE
202

EXERCISE EXERCISE EXERCISE

Possible International Organizations for Asteroid Impact Response Coordination and Planning

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- The International Charter Space and Major Disasters
  - satellite data to support disaster response worldwide
- United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER)
- United Nations Office for Disaster Risk Reduction (UNDRR)
  - Sendai Framework for Disaster Risk Reduction (2015–2030)
  - United Nations Early Warnings for All initiative
- United Nations Disaster Assessment and Coordination System – 2022 – Office for the Coordination of Humanitarian Affairs (UNOCHA)

EXERCISE EXERCISE EXERCISE

203

EXERCISE EXERCISE EXERCISE

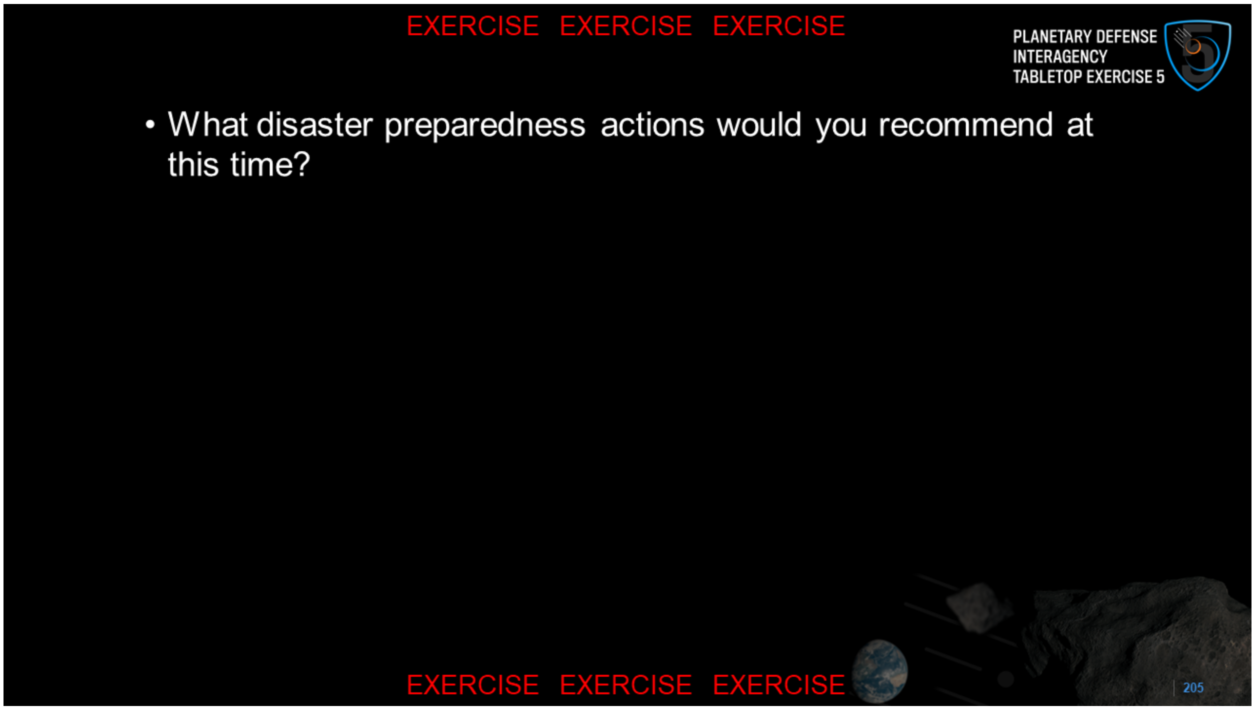
Multi-Hazard Early Warning System (MHEWS): A Possible Way Ahead for a Planetary Defense Scenario

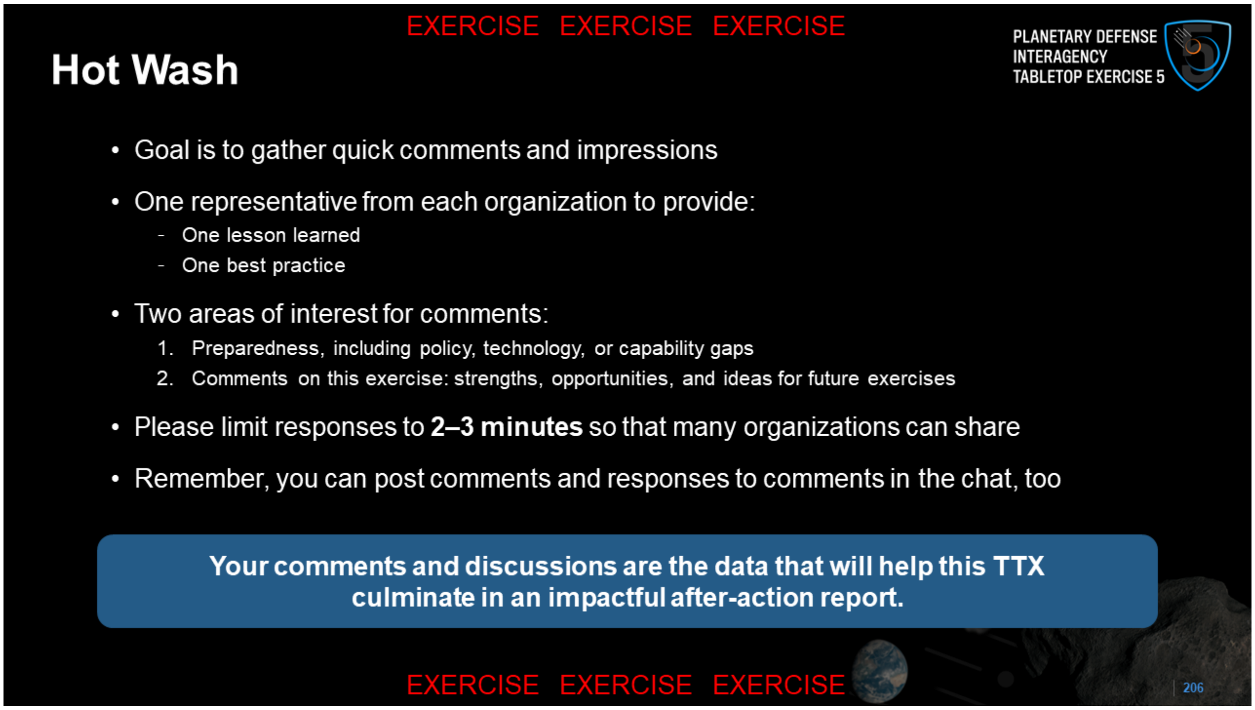
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

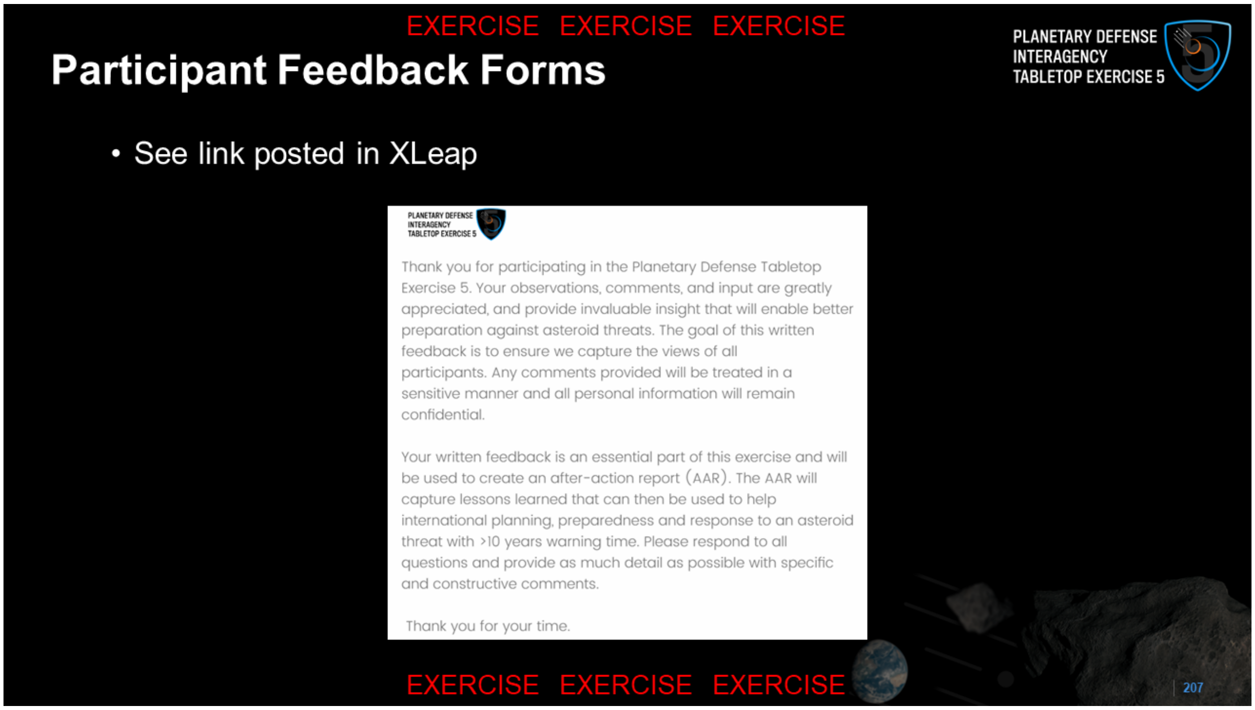
- To address the glaring disparity in the coverage of early warning systems (EWSs), in March 2022, the UN Secretary-General set an ambitious new goal: By 2027, everyone on Earth should be protected by EWSs against increasingly extreme weather and climate change.
- The World Meteorological Organization (WMO) and the UN Office for Disaster Risk Reduction (UNDRR) are leading the UN "Early Warnings for All" initiative.
- A similar program could be developed for a planetary defense scenario.
- Future investments over the five years would be used to advance the four key pillars of a MHEWS.
- Progress across four pillars.
- The comprehensiveness of a MHEWS is determined by countries' self-assessment across four interconnected pillars:
  1. risk knowledge
  2. observations and forecasting
  3. warning dissemination and communication
  4. preparedness to respond

EXERCISE EXERCISE EXERCISE

204

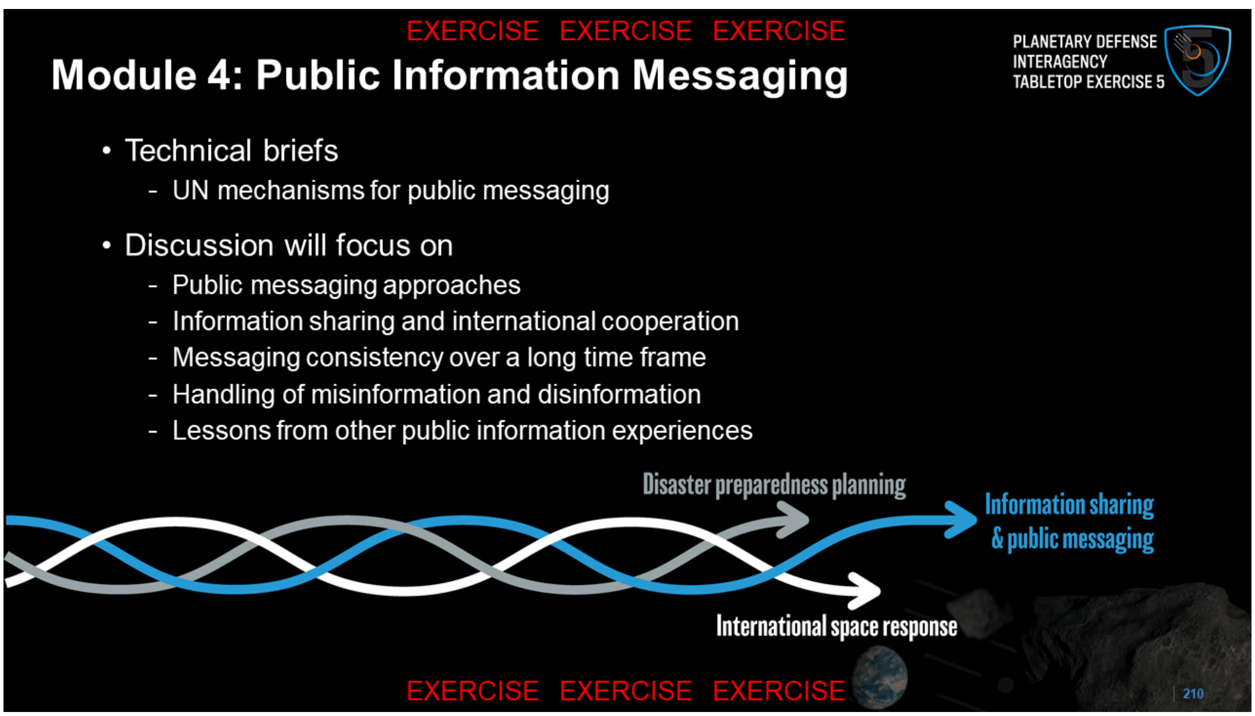

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What disaster preparedness actions would you recommend at this time?
EXERCISE EXERCISE EXERCISE
205


EXERCISE EXERCISE EXERCISE
Hot Wash
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Goal is to gather quick comments and impressions
• One representative from each organization to provide:
- One lesson learned
- One best practice
• Two areas of interest for comments:
1. Preparedness, including policy, technology, or capability gaps
2. Comments on this exercise: strengths, opportunities, and ideas for future exercises
• Please limit responses to **2–3 minutes** so that many organizations can share
• Remember, you can post comments and responses to comments in the chat, too
Your comments and discussions are the data that will help this TTX culminate in an impactful after-action report.
EXERCISE EXERCISE EXERCISE
206

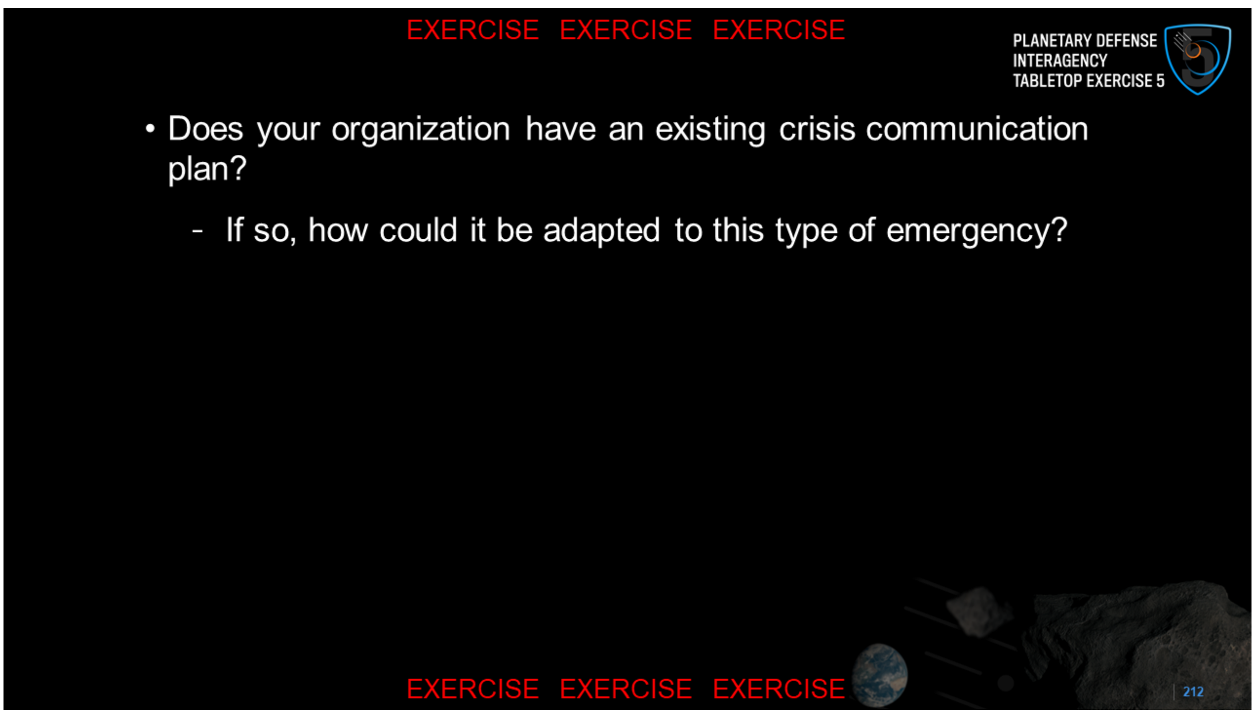

EXERCISE EXERCISE EXERCISE
Participant Feedback Forms
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• See link posted in XLeap
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Thank you for participating in the Planetary Defense Tabletop Exercise 5. Your observations, comments, and input are greatly appreciated, and provide invaluable insight that will enable better preparation against asteroid threats. The goal of this written feedback is to ensure we capture the views of all participants. Any comments provided will be treated in a sensitive manner and all personal information will remain confidential.
Your written feedback is an essential part of this exercise and will be used to create an after-action report (AAR). The AAR will capture lessons learned that can then be used to help international planning, preparedness and response to an asteroid threat with >10 years warning time. Please respond to all questions and provide as much detail as possible with specific and constructive comments.
Thank you for your time.
EXERCISE EXERCISE EXERCISE
207

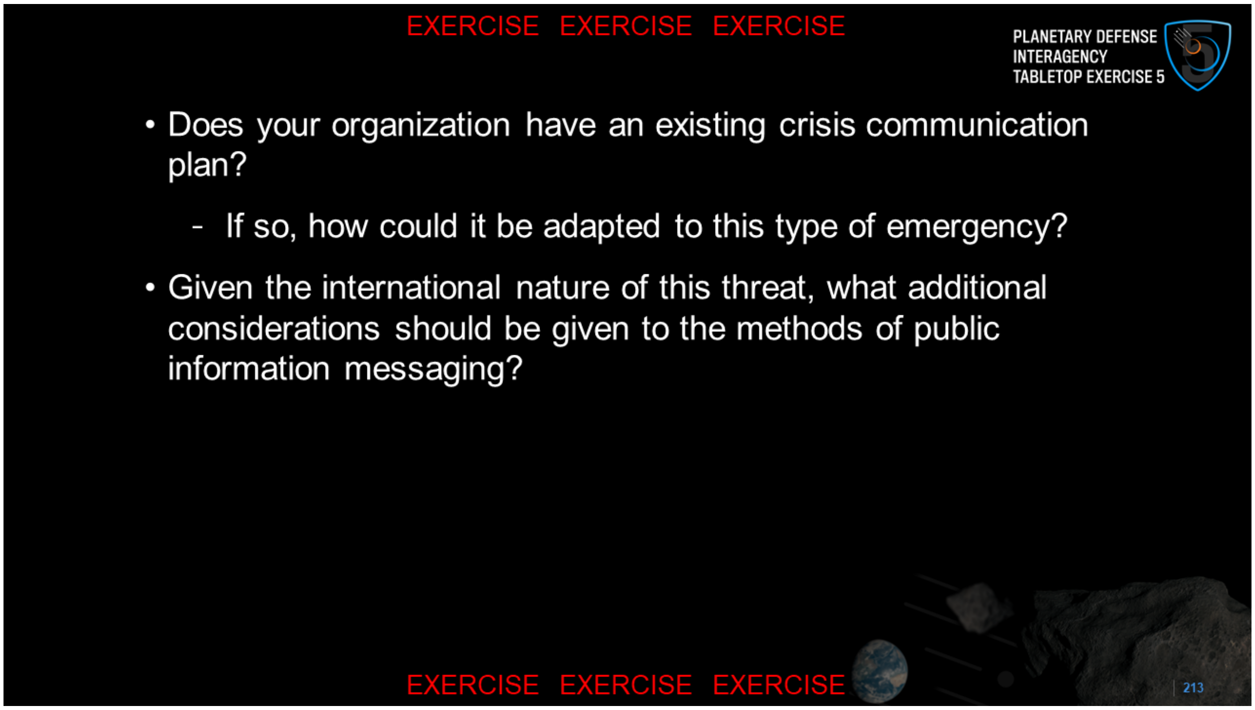

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
NASA
FEMA
APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
cneos
Ames Research Center
Lawrence Livermore National Laboratory
208

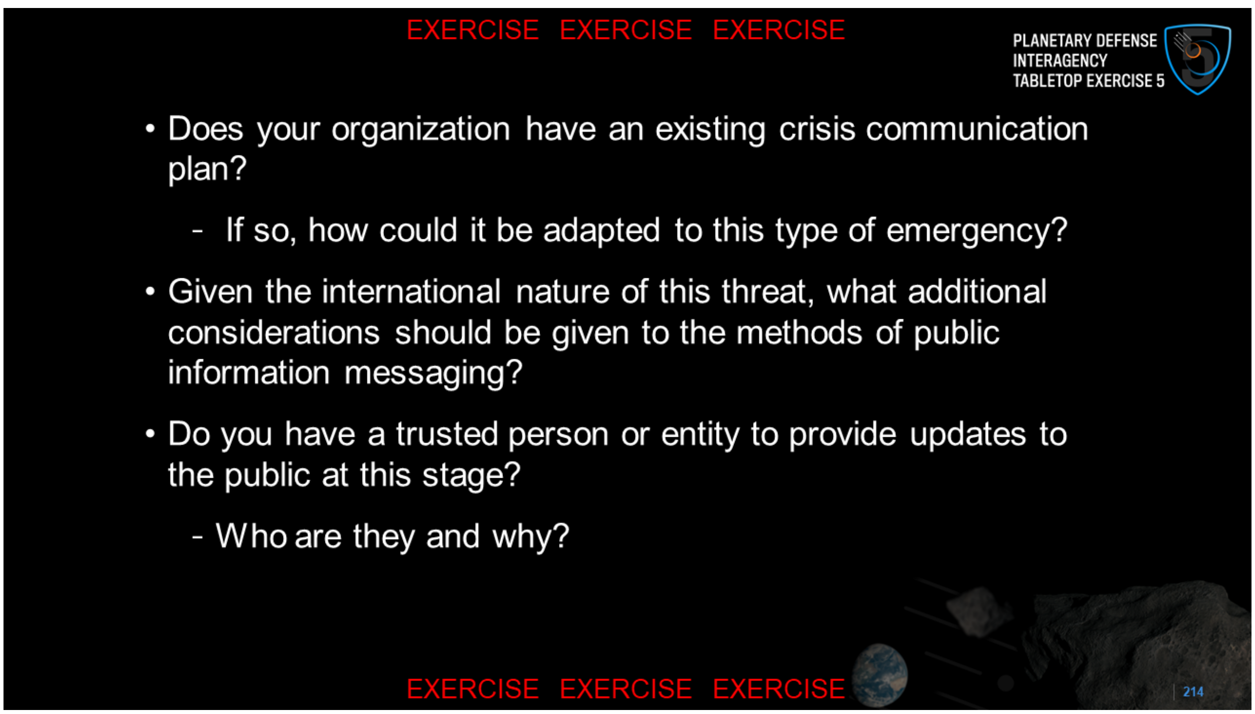
H.2.3. Module 4: Public Information Messaging

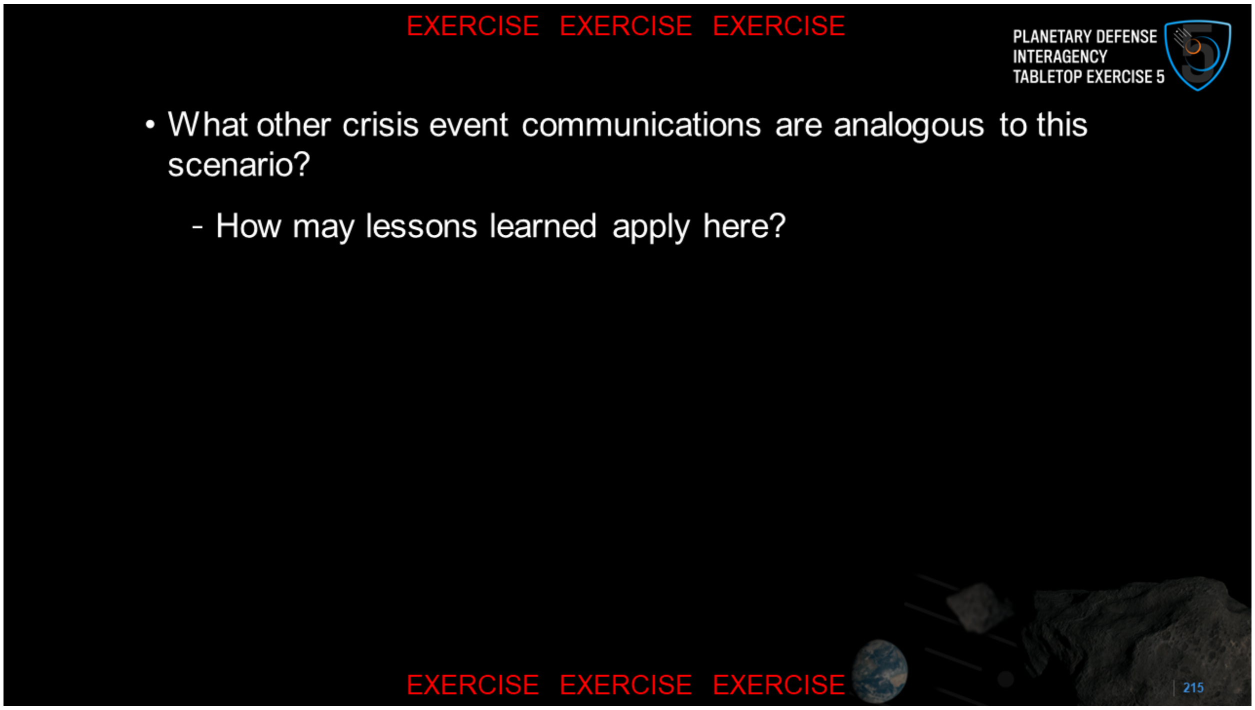


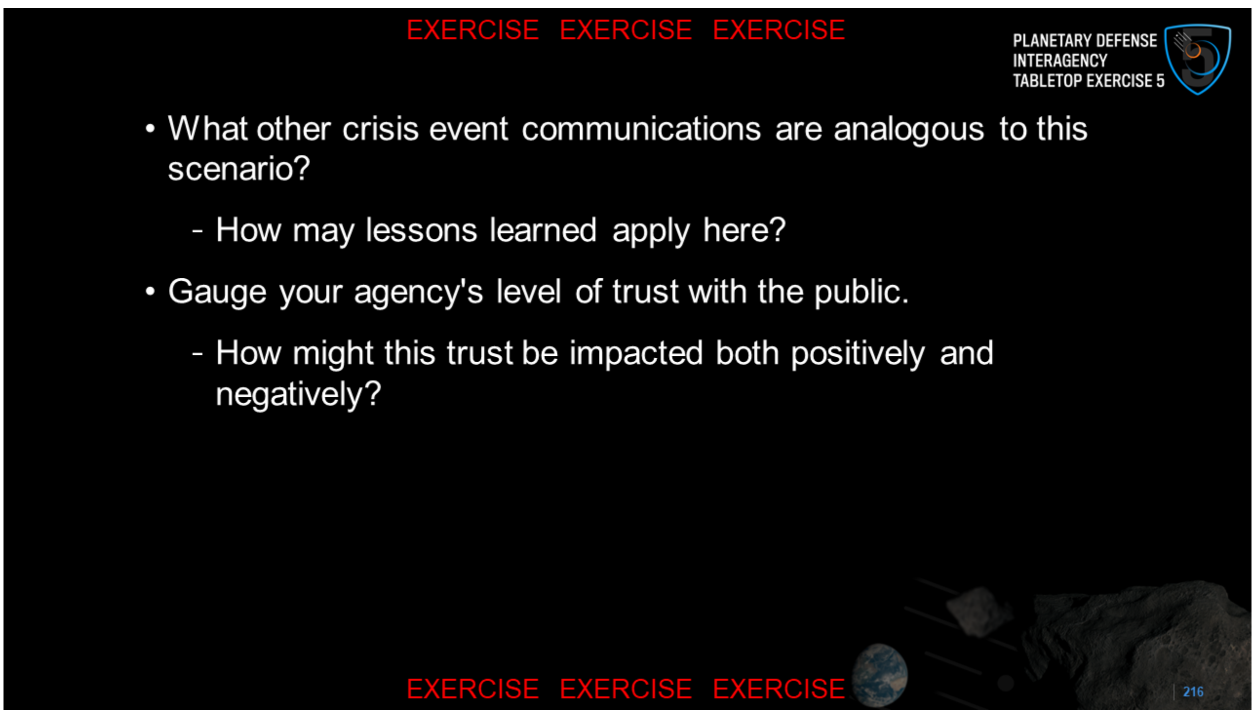

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
News outlets around the world are clamoring for information and the public wants to know what to do
LIVE
BREAKING
NEWS
EXERCISE EXERCISE EXERCISE
211


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• Does your organization have an existing crisis communication plan?
- If so, how could it be adapted to this type of emergency?
EXERCISE EXERCISE EXERCISE
212


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• Does your organization have an existing crisis communication plan?
- If so, how could it be adapted to this type of emergency?
• Given the international nature of this threat, what additional considerations should be given to the methods of public information messaging?
EXERCISE EXERCISE EXERCISE
213


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• Does your organization have an existing crisis communication plan?
- If so, how could it be adapted to this type of emergency?
• Given the international nature of this threat, what additional considerations should be given to the methods of public information messaging?
• Do you have a trusted person or entity to provide updates to the public at this stage?
- Who are they and why?
EXERCISE EXERCISE EXERCISE
214


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What other crisis event communications are analogous to this scenario?
- How may lessons learned apply here?
EXERCISE EXERCISE EXERCISE
215


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What other crisis event communications are analogous to this scenario?
- How may lessons learned apply here?
• Gauge your agency's level of trust with the public.
- How might this trust be impacted both positively and negatively?
EXERCISE EXERCISE EXERCISE
216

EXERCISE EXERCISE EXERCISE

UNITED NATIONS
Office for Outer Space Affairs

Mechanisms for Crisis Communication/Public Messaging: Perspectives from the United Nations Office for Outer Space Affairs

Romana Kofler

Programme Management Officer,
Committee, Policy and Legal Affairs Section

United Nations Office for Outer Space Affairs

EXERCISE EXERCISE EXERCISE

218

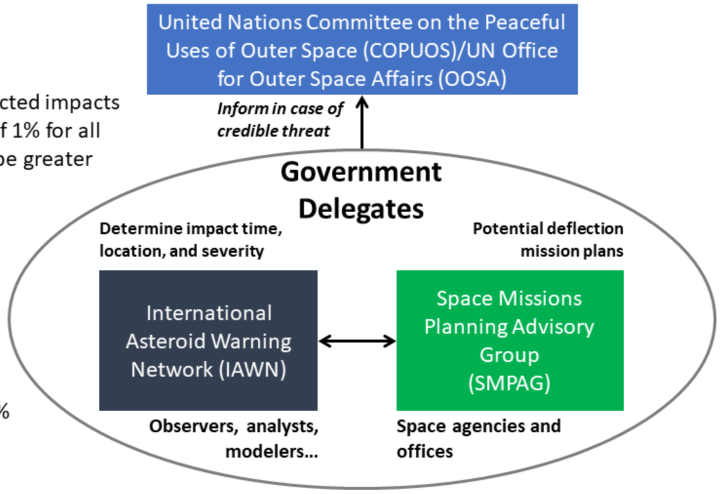
EXERCISE EXERCISE EXERCISE

Information Flow in Case of a Credible Impact Hazard

UNITED NATIONS
Office for Outer Space Affairs

Criteria for IAWN:
IAWN shall warn of predicted impacts exceeding a probability of 1% for all objects characterized to be greater than 10 meters in size.*

Criteria for SMPAG:
- Within 50 years
- Impact probability > 1%
- Size > 50 m



COPUOS report:
Should a credible threat of impact be discovered by IAWN, **the best information available** would be provided by IAWN and **disseminated to all Member States through UNOOSA**.

*Roughly equivalent to absolute magnitude of 28 if only brightness data can be collected.

EXERCISE EXERCISE EXERCISE

219

EXERCISE EXERCISE EXERCISE

UNOOSA's Mandates and Work Related to PD

UNITED NATIONS
Office for Outer Space Affairs

- ❑ Secretariat to COPUOS
- ❑ Works with MS, IGOs, NGOs (space-related)
- ❑ Programme on Space Applications
- ❑ UN-wide coordination – UN-Space
- ❑ UN Register of Space Objects
- ❑ **UN-SPIDER and its network – disaster preparedness and risk reduction**
- ❑ International Committee on Global Navigation Satellite Systems (ICG)
- ❑ **PD-related: Secretariat to SMPAG; cooperation with IAWN**

UNOOSA

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@UN_SPIDER
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UNOOSA and Links to the UN Secretary-General

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Office for Outer Space Affairs

UNOOSA Director:

(a) Serves as the senior adviser to the Secretary-General on outer space affairs;

(b) Represents the Secretary-General at meetings and conferences on matters relating to the peaceful exploration and use of outer space;

. . .

(d) The Director also discharges any other duties that may be assigned to her or him by the Secretary-General;

. . .

(g) Performs representation and liaison functions with permanent missions and permanent observer missions to the United Nations, the host Government, other Governments, and intergovernmental and non-governmental organizations in Vienna, as well as with the Committee on the Peaceful Uses of Outer Space.

UN Secretary-General Bulletin SGB 2020/1

The UN office entirely dedicated to space | Custodian of Space4SDGs
➡ UNOOSA has a responsibility to ensure space makes a difference

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UN Communication – Space Activities (e.g., DART Mission)

UNITED NATIONS
Office for Outer Space Affairs

**Outer Space
James, following your questions on our colleagues in the Office for Outer Space Affairs, whether or not it was informed about NASA's DART mission that deflected an asteroid, and the answer is:

Yes, they did. The DART mission was registered with the United Nations on 3 January of this year. In June, the UN Committee on the Peaceful Uses of Outer Space was briefed by the US on the DART mission, and the Member States noted the launch of this first-ever planetary defence technology demonstration mission, as well as the international collaboration for this effort. The UN Office for Outer Space Affairs commends the efforts behind the DART mission as an important step in protecting the Earth and humanity from potentially harmful asteroid impacts. More in a press release. If we could do the same with climate change, that would be easier.

UNHQ Noon's briefing by the UN Secretary-General's Spokesperson in New York, September 2022

➡ UNOOSA as substantive office for space affairs provides UN Secretary-General inputs on all related topics upon request

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Crisis Communication/Action: UNSG-UN Security Council

UNITED NATIONS
Office for Outer Space Affairs

Mechanisms:

→ **UN Charter**

→ **UN Communications Group (UNCG) SoP**

→ **Emergency Platform**

**** UN Charter**
Article 99

The Secretary-General may bring to the attention of the Security Council any matter which in his opinion may threaten the maintenance of international peace and security.

UNCG

Communicating together in times of crisis:

Standard operating procedures for the UN system

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UN Crisis Communications SoP - UNCG Network

UNITED NATIONS
Office for Outer Space Affairs

- **SoP** applies to all **UN Communications Group (UNCG)** member entities involved in a response to a crisis, **and to internal and external communications**.

It applies to communications procedures at:

- UN Headquarters, where the Department of Global Communications convenes the global UNCG
- Agency, Fund, or Programme at headquarters or regional offices where they coordinate with the Department of Global Communications
- UN Country Teams where many have established a local UNCG.

In exceptional circumstances, the Secretary-General may directly oversee or delegate the authority to the Deputy Secretary-General, or an appointed EOSG representative to oversee the coordination of the UN response....

UNCG is the UN system's common communications platform, a practical measure for bringing the UN system's communications resources and skills under a common umbrella.

Aim: to standardize UN communications guidelines and provide an organizational structure for operating in times of crisis

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UN Department of Global Communications (DGC)

UNITED NATIONS
Office for Outer Space Affairs

- **Worldwide Coverage:** DGC is represented worldwide through a global network of **United Nations Information Centres (UNICs),** located in 60 countries and engaging audiences in more than 80 languages.
- **Multilingualism:** UNICs translate/produce information materials in 134 languages.
- **Work with national and regional media in the country/countries** in which they operate, to provide background briefings and press materials, arrange interviews, and organise media conferences, as well as to place op-eds and feature articles.
- **Social Media:** UNIC social media accounts reach a total of 32 million people across the globe/fake news alert campaigns (e.g., COVID-19 crisis).

- **Five Cs:**
  - **Clarity**
  - **Conciseness**
  - **Consistency**
  - **Coherence**
  - **Courtesy**
- **Getting the News Out**
- **Working with Media**
- **Engaging the Public**
- **Campaigns and Country Operations**

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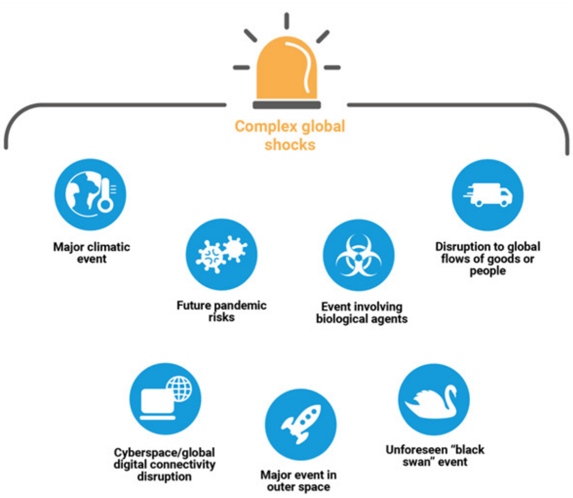
Our Common Agenda Policy Brief 2:

Strengthening the International Response to Complex Global Shocks – An Emergency Platform (March 2023)

UNITED NATIONS
Office for Outer Space Affairs



- A rapid, predictable and structured international response;
- Maximizing the unique convening role of the United Nations;
- Catalysing political leadership through networks of willing Member States;
- Multisectoral, interdisciplinary coordination across the multilateral system;
- Multi-stakeholder engagement and accountability in the global response;
- Strengthened accountability for delivering against commitments and bringing coherence to the international approach.

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Strengthening the International Response to Complex Global Shocks – An Emergency Platform

UNITED NATIONS
Office for Outer Space Affairs

FACTORS THAT CONTRIBUTE TO THE DECISION TO CONVENE AN EMERGENCY PLATFORM

The Secretary-General would decide when to convene an Emergency Platform in response to a complex global shock.

In advance of the decision, the Secretary-General would consult with:

- The President of the General Assembly;
- The President of the Security Council (as appropriate);
- Relevant national authorities and/or regional organizations;
- Relevant United Nations entities, specialized agencies, international financial institutions, and other multilateral institutions and agencies that have been mandated by Member States to respond to sector-specific crises.

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High-Level Objectives of an Emergency Platform

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a) **High-level political leadership.** Leverage the unique legitimacy and convening power of the United Nations in a timely and predictable way; identify and **bring together actors expeditiously at the appropriate level to respond to complex global shocks that require multisectoral, multi-stakeholder action**; build on the role **of the Secretary-General's good offices** to facilitate dialogue between key actors; and/or overcome any obstacles or bottlenecks to an effective response;

b) **Ensure equity and solidarity in the international response.** Ensure that the most vulnerable and those with the least capacity to cope with complex global shocks receive the support and assistance they require, in line with the promise of the 2030 Agenda to leave no one behind;

c) **Coherent multilateral response.** Ensure that the multilateral system can agree upon, advocate, and implement a coherent and joined-up response to a complex global shock;

d) **Inclusive and networked multilateralism.** Provide a multi-stakeholder forum—including, but not limited to, networks of willing Member States, the UN system, international financial institutions, regional bodies, and relevant private sector, civil society, academic, and non-governmental actors—while recognizing the primary role of intergovernmental organizations in decision-making;

e) **Advocacy and strategic communications.** Share timely, accurate data, analysis, and policy recommendations to support global advocacy and build an international political consensus on the way forward;

f) **Secure commitments** and hold key actors to account for supporting the global response.

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Other Examples/Questions

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Other examples/Qs:

→ JPLAN

→ Next:

UNOOSA/EOSG asteroid impact emergency

protocol

/ communication

Joint Radiation Emergency Management Plan of the International Organizations (JPLAN):

Inter-Agency Committee on Radiological and Nuclear Emergencies (IACRNE):
CTBTO, EADRCC, EC, EUROPOL, FAO, IAEA, ICAO, ILO, IMO, INTERPOL, OCHA, OECD/NEA, PAHO, UNDP, UNEP, UNOOSA, WHO, WMO

- **Interagency framework of preparedness for and response to an actual, potential, or perceived nuclear or radiological emergency independent** of whether it arises from an accident, a **natural disaster**, negligence, a nuclear security event, or any other cause
- Aims to ensure the development and maintenance **of consistent and harmonized arrangements for preparedness for and response to nuclear or radiological emergencies**

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EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
EXERCISE EXERCISE EXERCISE
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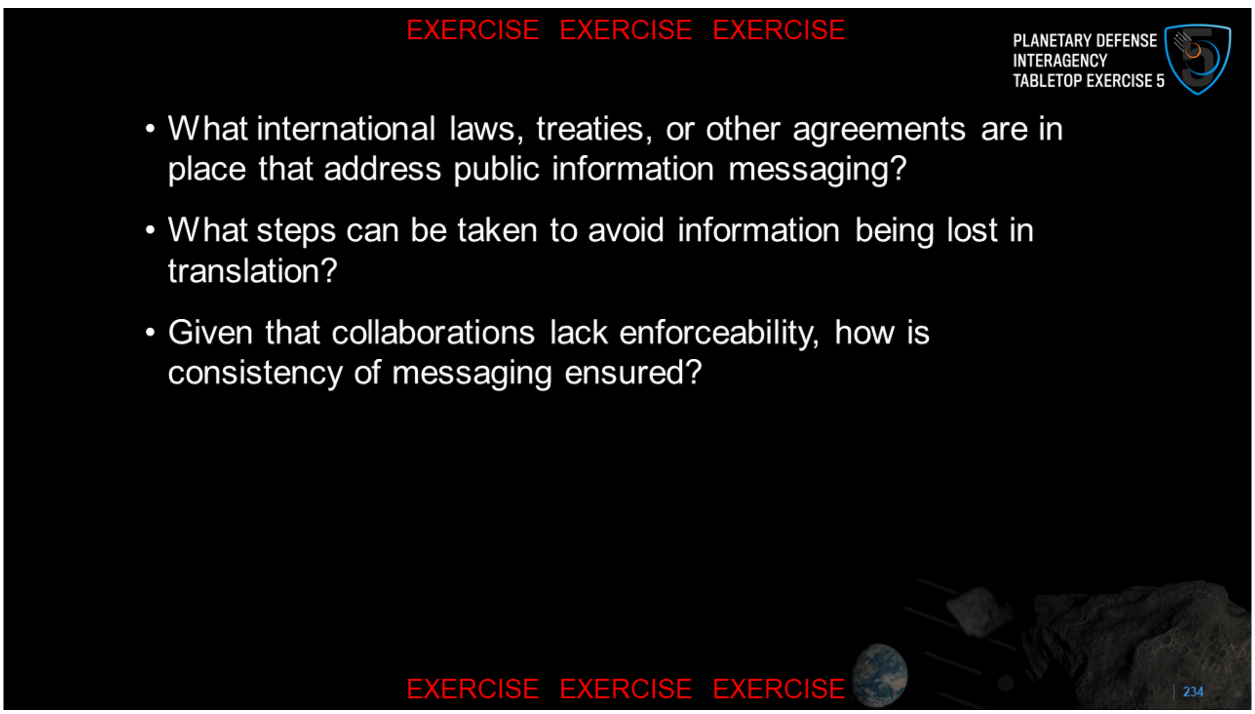
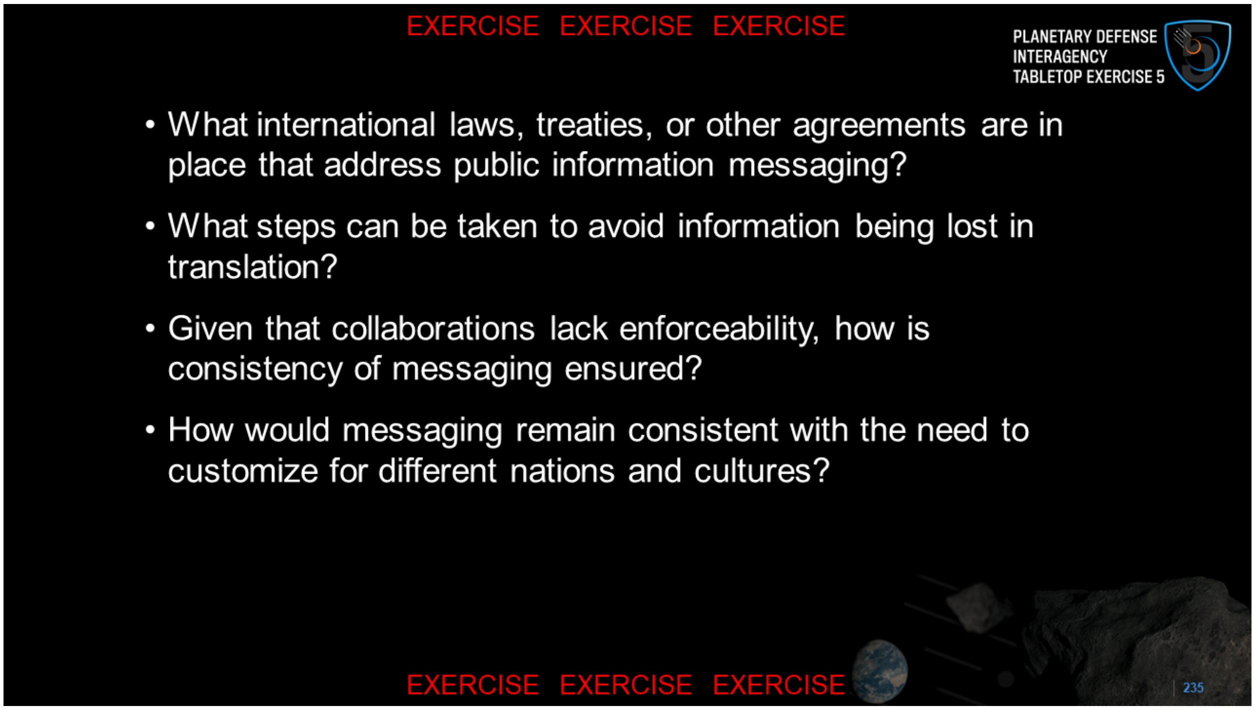
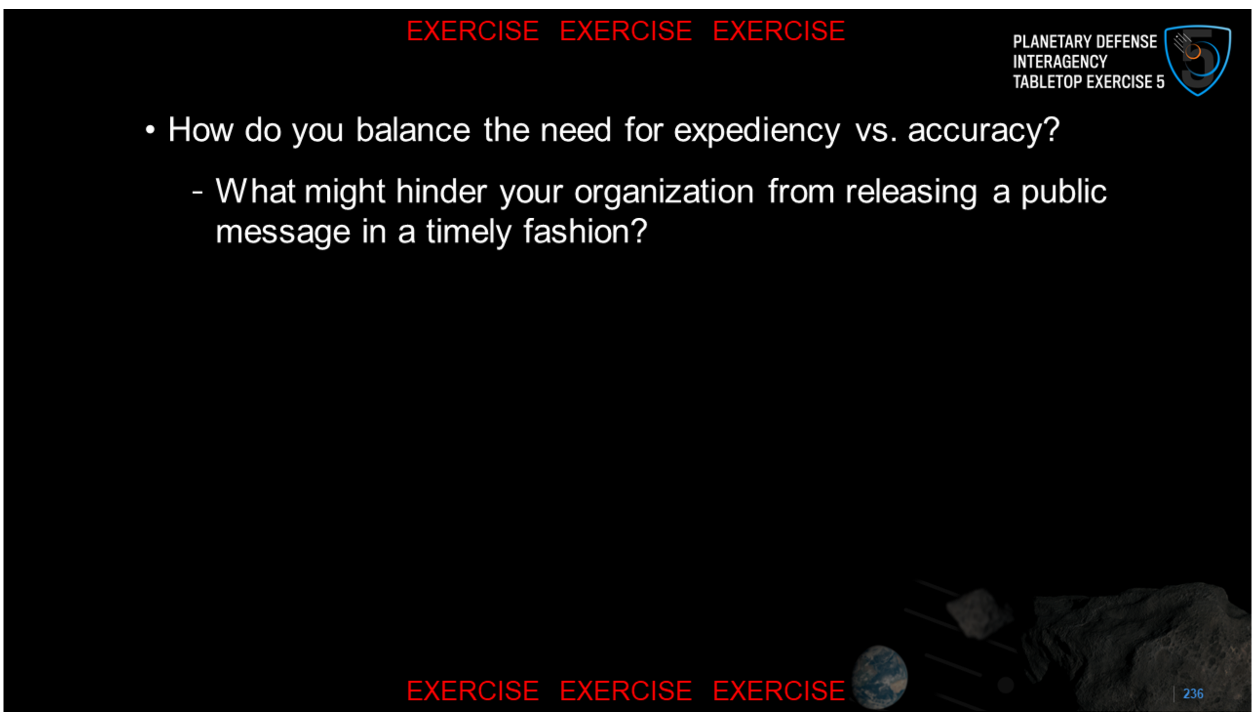
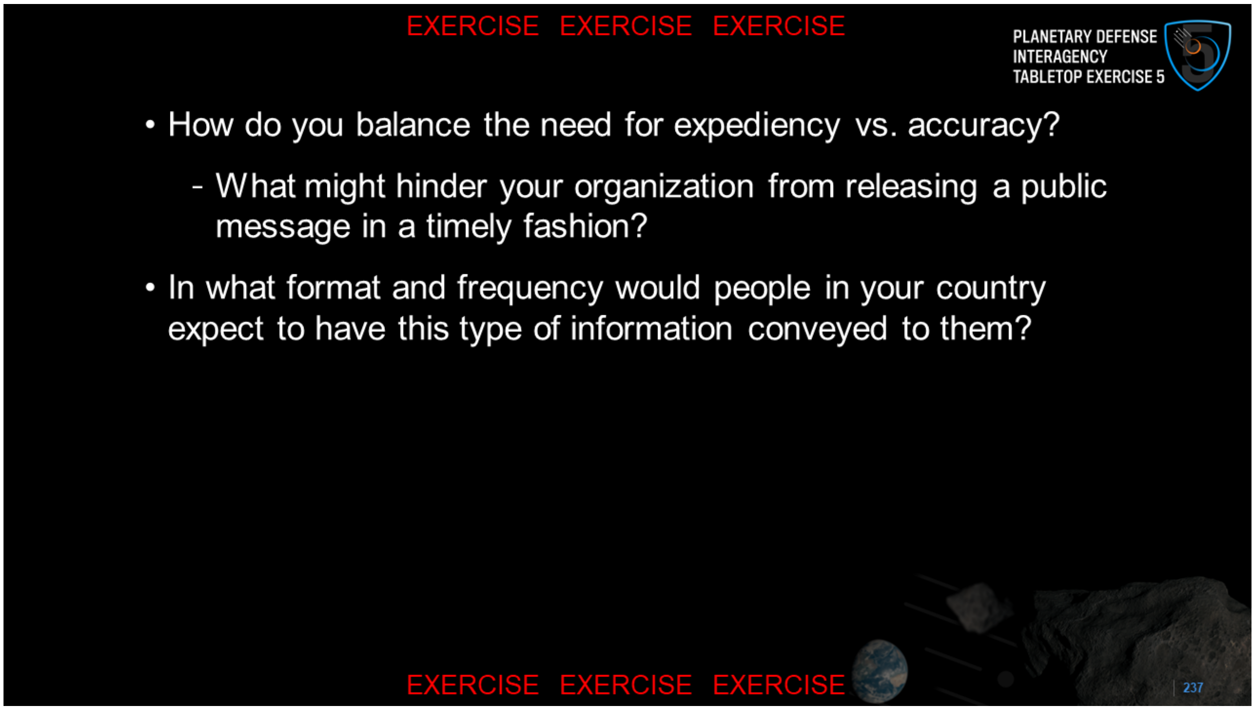
EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What international laws, treaties, or other agreements are in place that address public information messaging?
EXERCISE EXERCISE EXERCISE
232

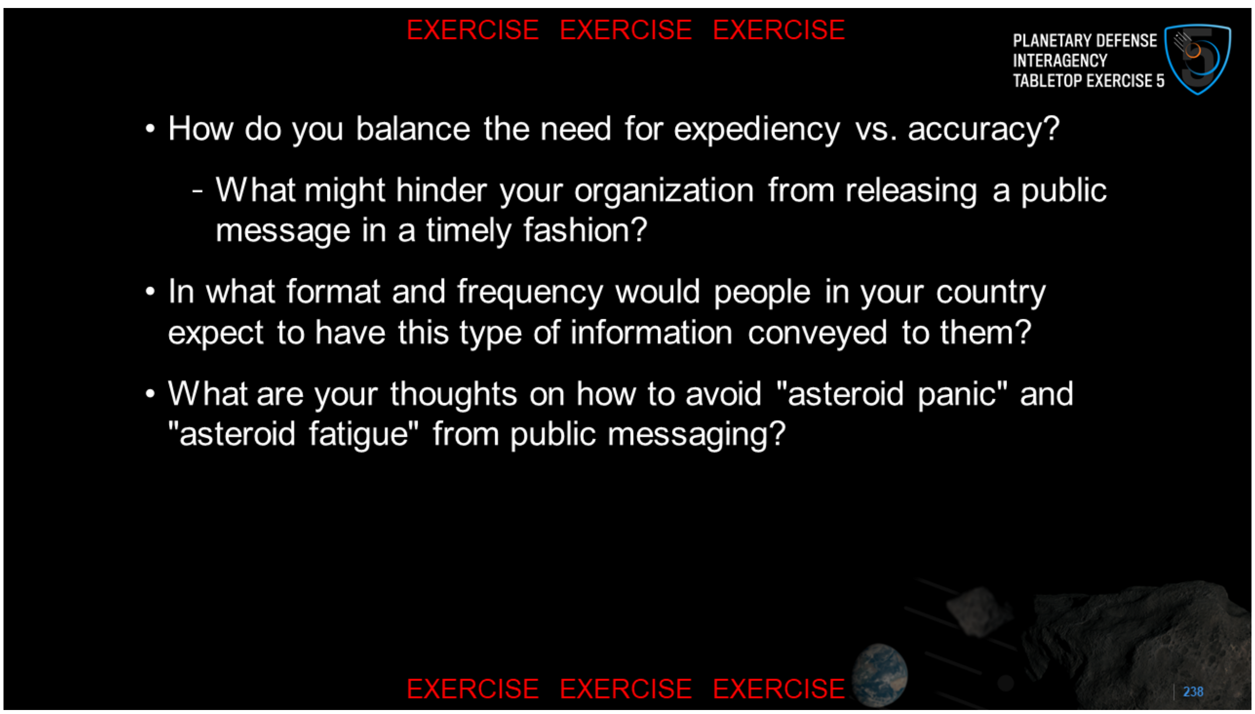

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What international laws, treaties, or other agreements are in place that address public information messaging?
• What steps can be taken to avoid information being lost in translation?
EXERCISE EXERCISE EXERCISE
233

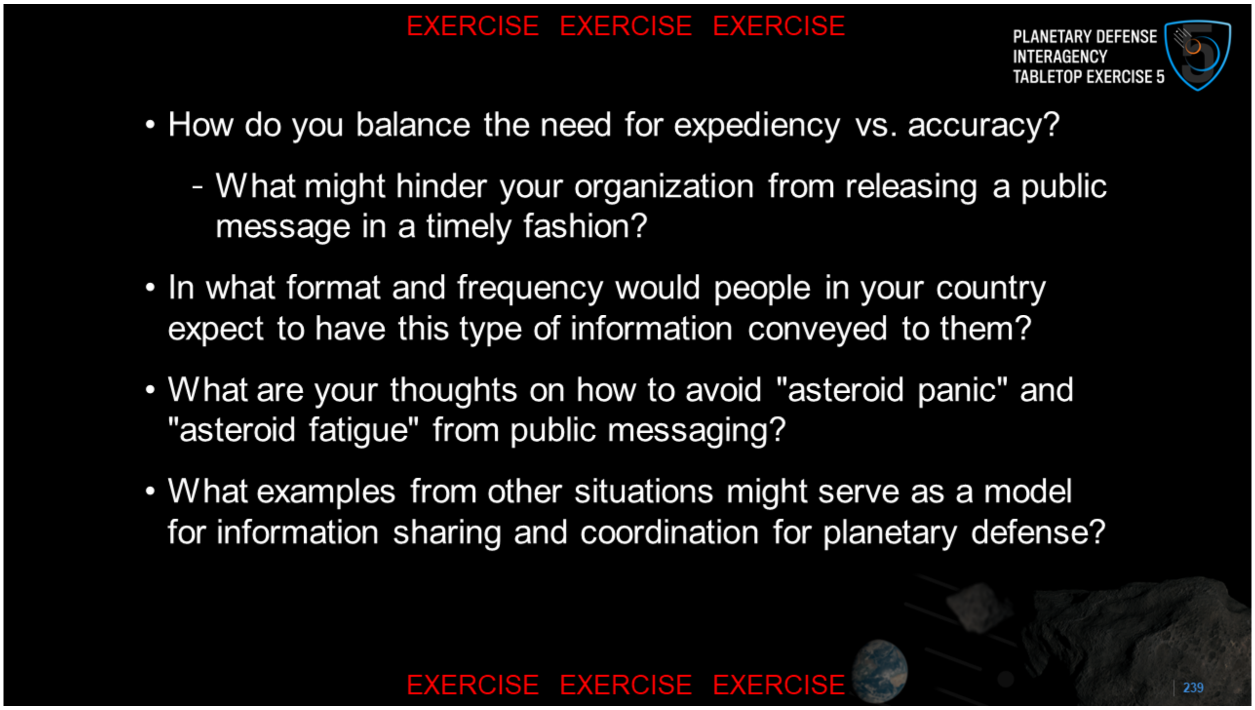

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What international laws, treaties, or other agreements are in place that address public information messaging?
• What steps can be taken to avoid information being lost in translation?
• Given that collaborations lack enforceability, how is consistency of messaging ensured?
EXERCISE EXERCISE EXERCISE
234


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What international laws, treaties, or other agreements are in place that address public information messaging?
• What steps can be taken to avoid information being lost in translation?
• Given that collaborations lack enforceability, how is consistency of messaging ensured?
• How would messaging remain consistent with the need to customize for different nations and cultures?
EXERCISE EXERCISE EXERCISE
235


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• How do you balance the need for expediency vs. accuracy?
- What might hinder your organization from releasing a public message in a timely fashion?
EXERCISE EXERCISE EXERCISE
236


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• How do you balance the need for expediency vs. accuracy?
- What might hinder your organization from releasing a public message in a timely fashion?
• In what format and frequency would people in your country expect to have this type of information conveyed to them?
EXERCISE EXERCISE EXERCISE
237


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• How do you balance the need for expediency vs. accuracy?
- What might hinder your organization from releasing a public message in a timely fashion?
• In what format and frequency would people in your country expect to have this type of information conveyed to them?
• What are your thoughts on how to avoid "asteroid panic" and "asteroid fatigue" from public messaging?
EXERCISE EXERCISE EXERCISE
238


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
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• In what format and frequency would people in your country expect to have this type of information conveyed to them?
• What are your thoughts on how to avoid "asteroid panic" and "asteroid fatigue" from public messaging?
• What examples from other situations might serve as a model for information sharing and coordination for planetary defense?
EXERCISE EXERCISE EXERCISE
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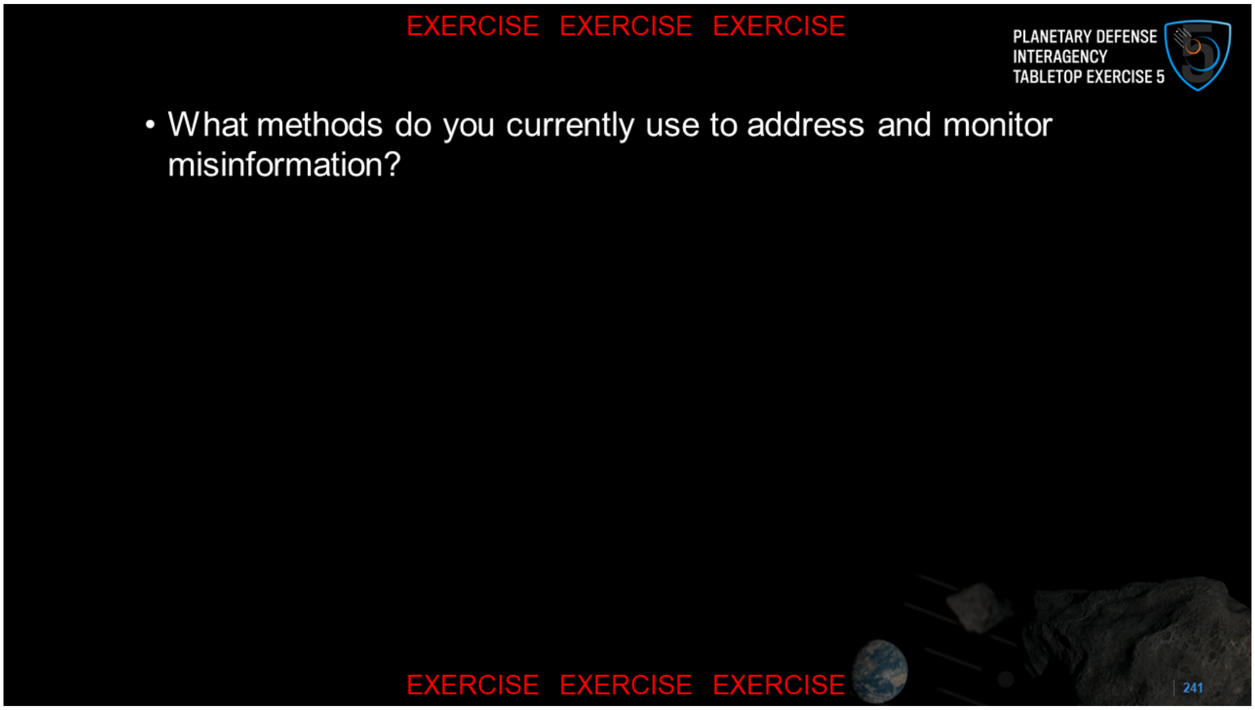
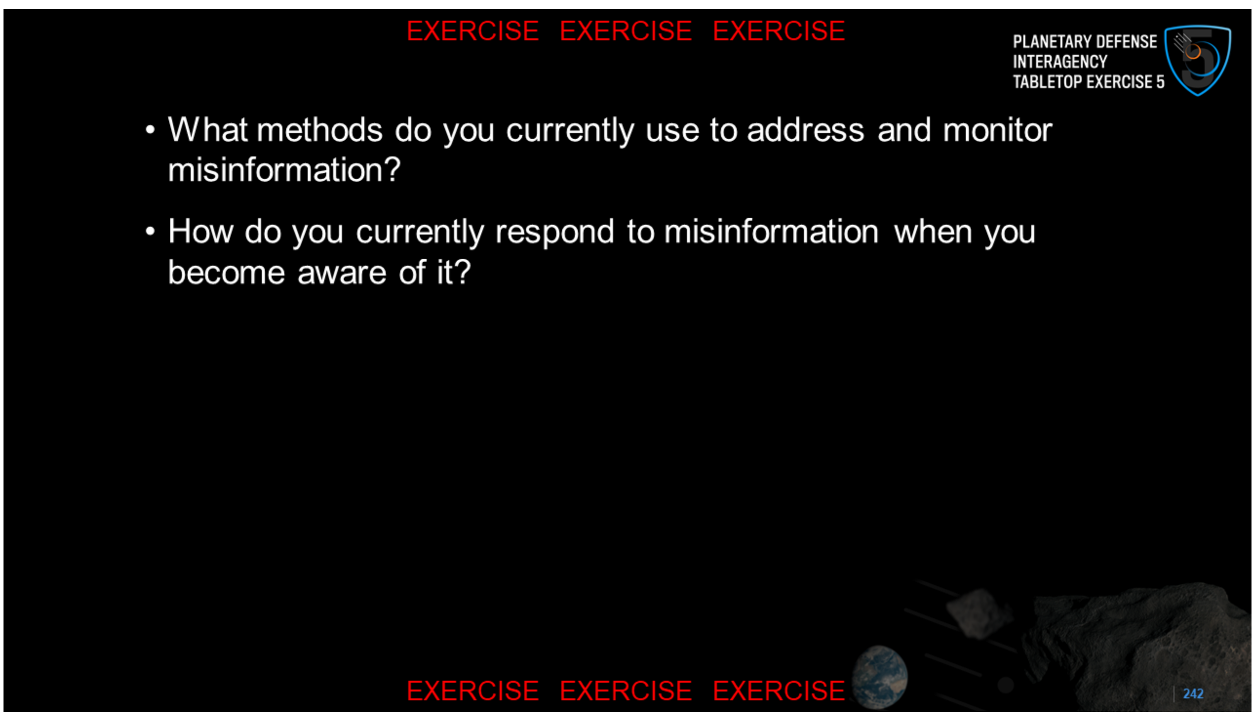
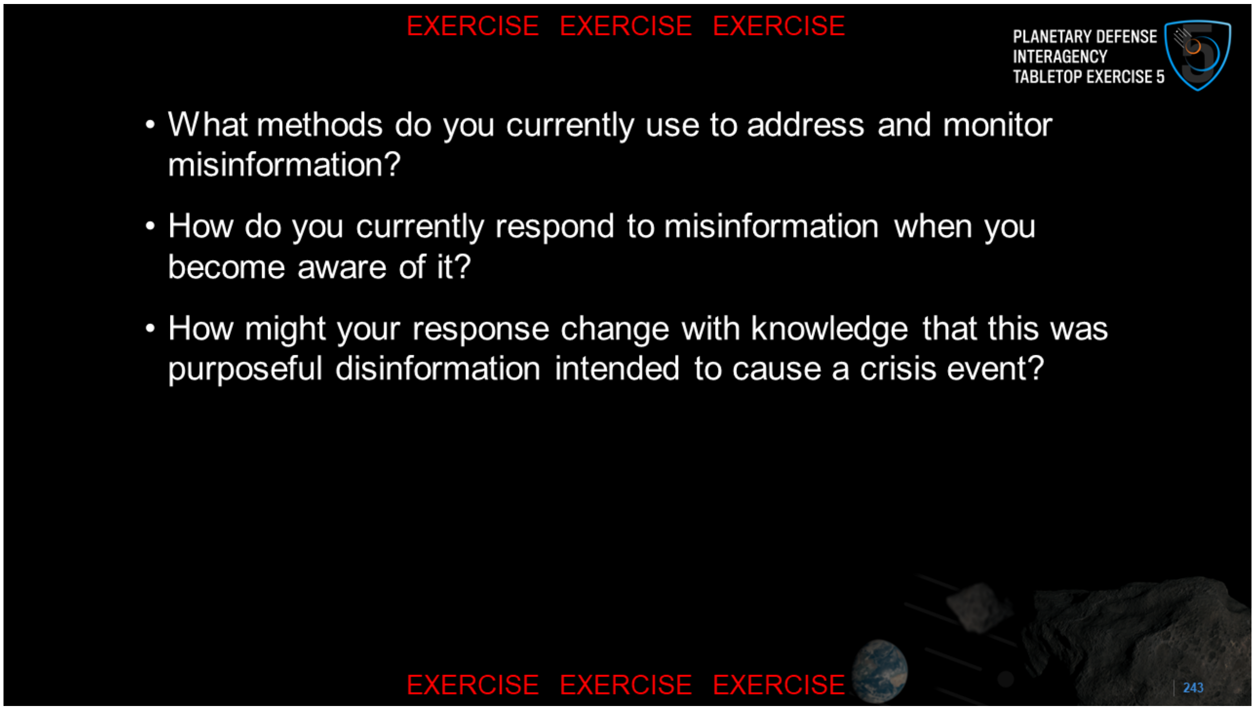
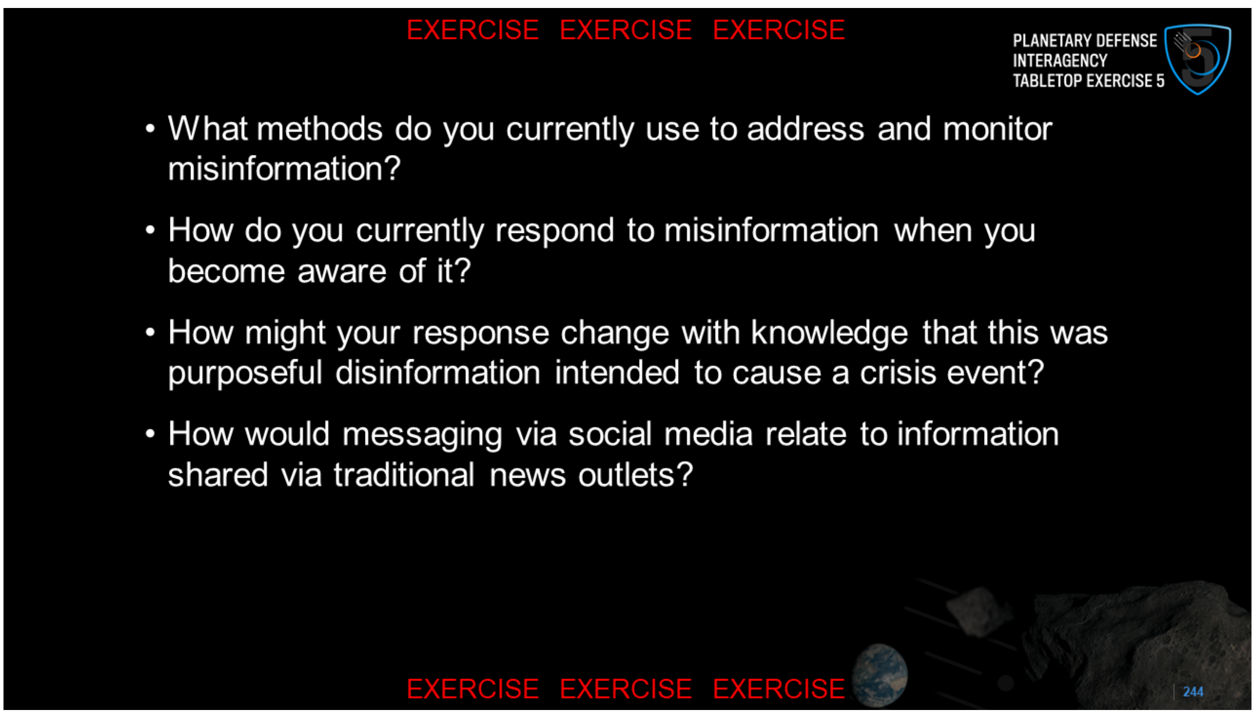
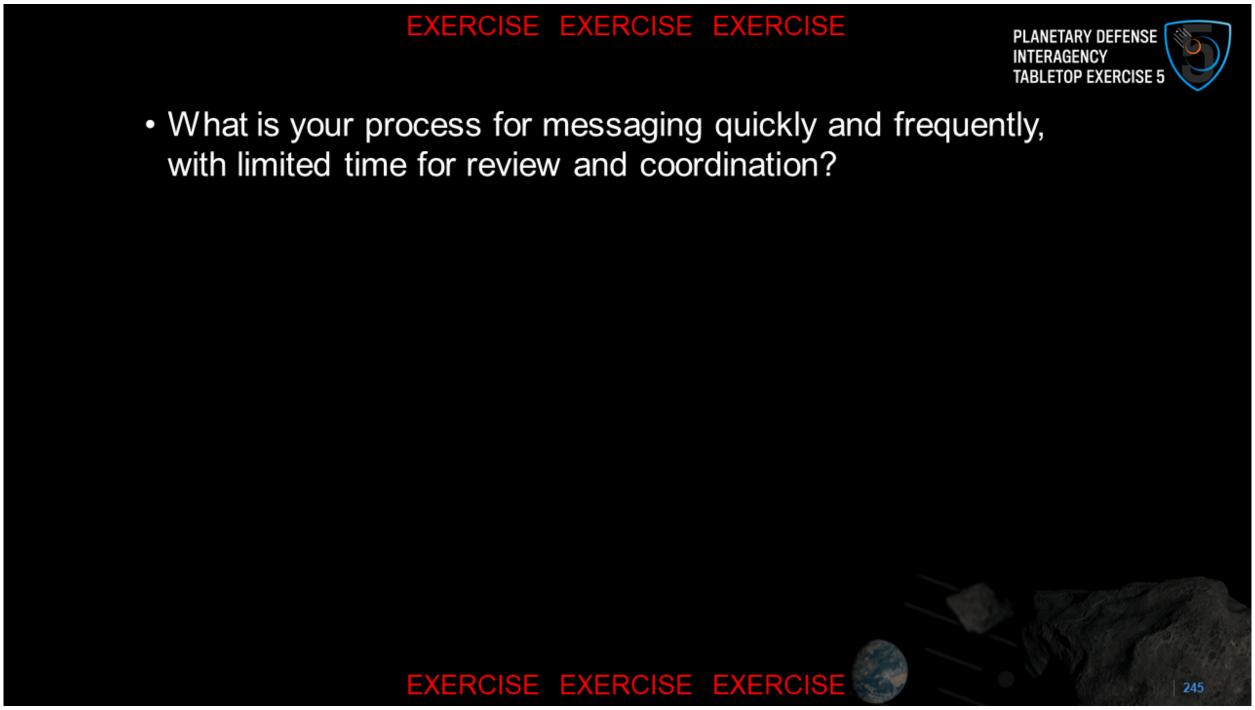
EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Astronomers Scramble to Search for World-Ending Asteroid With No Luck
Is NEO Warning a Ploy for More NASA Funding? Experts Discuss
NASA Calls Hollywood to Learn How to Destroy Asteroid
NASA Administrator Retires to Florida Amid Asteroid Chaos
NASA's Artemis Generation: Is the Moon Our Only Escape From Behemoth Asteroid Killer?
Know Before You Buy: New Map Shows States That May Soon be Obliterated by Giant Asteroid Impact
Tourism for Once Popular Travel Destination in Peril Amid Asteroid Concerns – "It's a Ghost Town"
Social media posts abound and many are inaccurate
EXERCISE EXERCISE EXERCISE
240

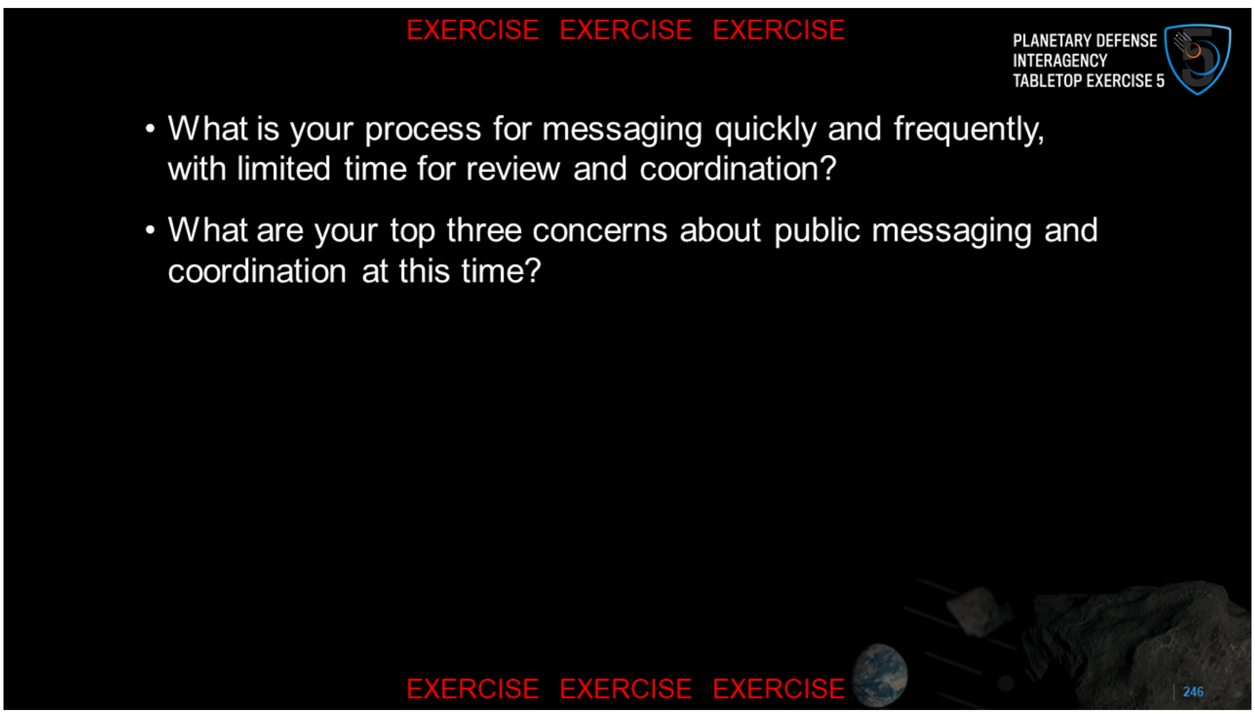

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What methods do you currently use to address and monitor misinformation?
EXERCISE EXERCISE EXERCISE
241

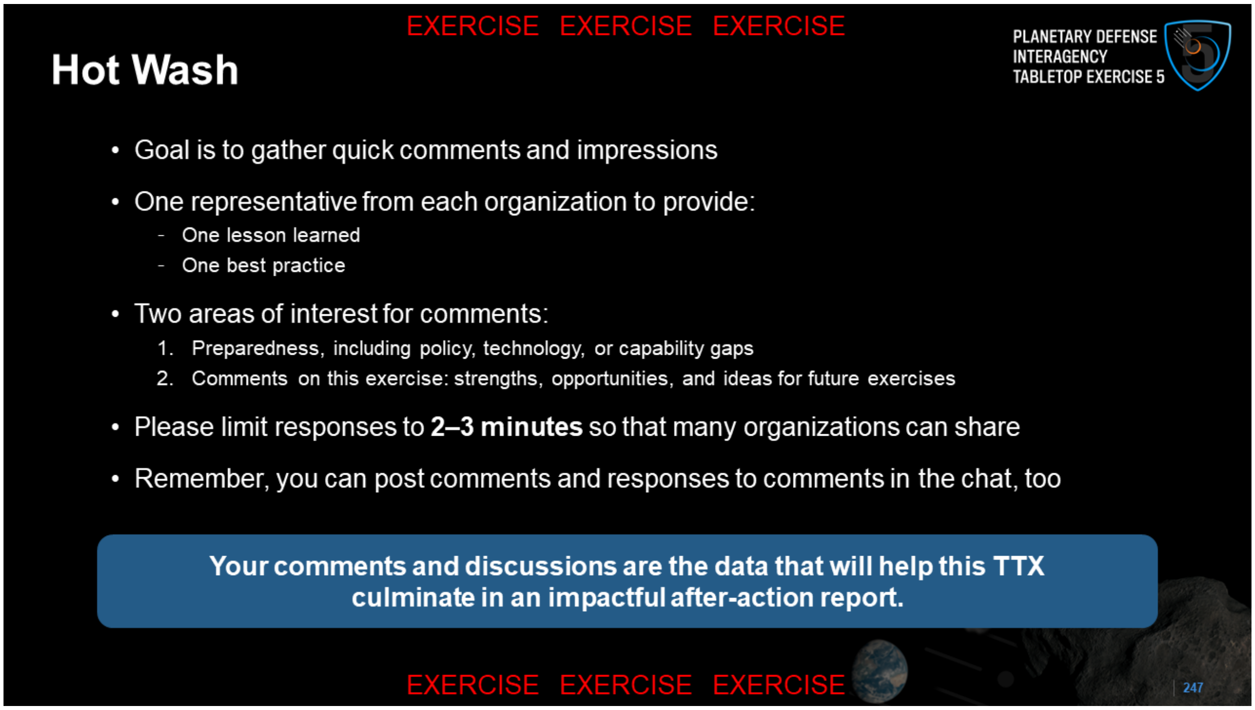

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What methods do you currently use to address and monitor misinformation?
• How do you currently respond to misinformation when you become aware of it?
EXERCISE EXERCISE EXERCISE
242

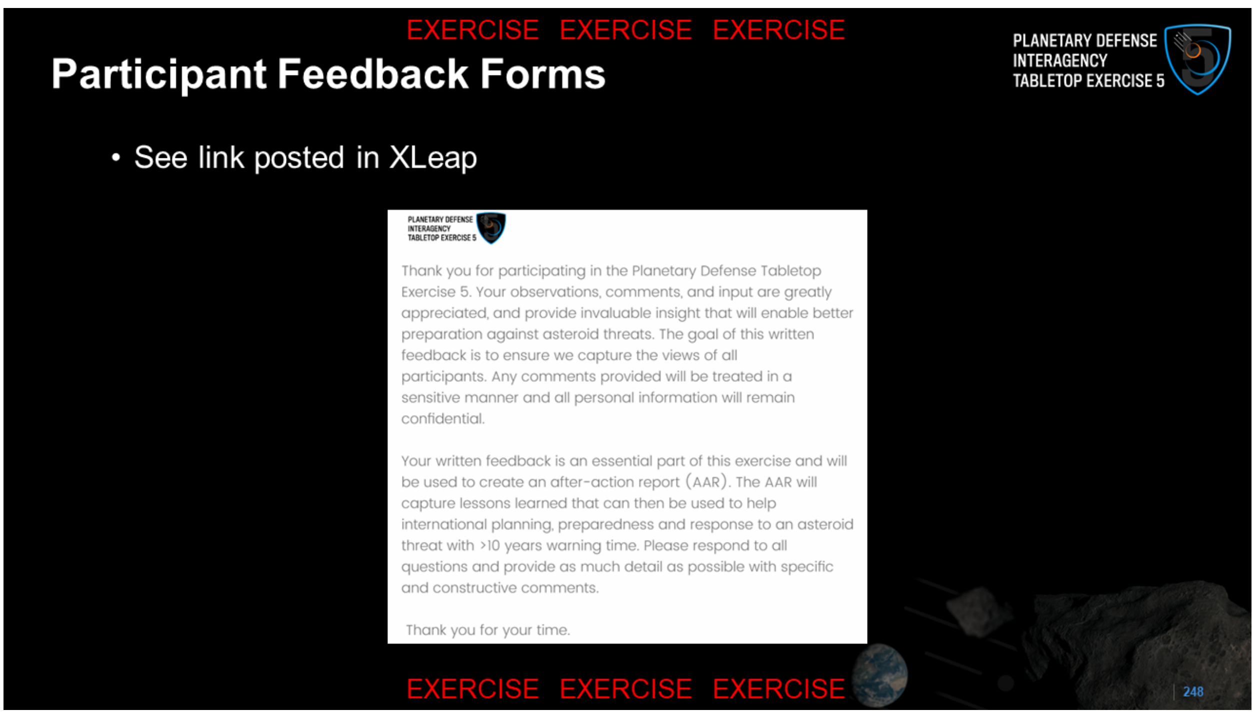

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What methods do you currently use to address and monitor misinformation?
• How do you currently respond to misinformation when you become aware of it?
• How might your response change with knowledge that this was purposeful disinformation intended to cause a crisis event?
EXERCISE EXERCISE EXERCISE
243


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What methods do you currently use to address and monitor misinformation?
• How do you currently respond to misinformation when you become aware of it?
• How might your response change with knowledge that this was purposeful disinformation intended to cause a crisis event?
• How would messaging via social media relate to information shared via traditional news outlets?
EXERCISE EXERCISE EXERCISE
244


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What is your process for messaging quickly and frequently, with limited time for review and coordination?
EXERCISE EXERCISE EXERCISE
245


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What is your process for messaging quickly and frequently, with limited time for review and coordination?
• What are your top three concerns about public messaging and coordination at this time?
EXERCISE EXERCISE EXERCISE
246


EXERCISE EXERCISE EXERCISE
Hot Wash
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Goal is to gather quick comments and impressions
• One representative from each organization to provide:
- One lesson learned
- One best practice
• Two areas of interest for comments:
1. Preparedness, including policy, technology, or capability gaps
2. Comments on this exercise: strengths, opportunities, and ideas for future exercises
• Please limit responses to **2–3 minutes** so that many organizations can share
• Remember, you can post comments and responses to comments in the chat, too
Your comments and discussions are the data that will help this TTX culminate in an impactful after-action report.
EXERCISE EXERCISE EXERCISE
247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Participant Feedback Forms
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• See link posted in XLeap
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Thank you for participating in the Planetary Defense Tabletop Exercise 5. Your observations, comments, and input are greatly appreciated, and provide invaluable insight that will enable better preparation against asteroid threats. The goal of this written feedback is to ensure we capture the views of all participants. Any comments provided will be treated in a sensitive manner and all personal information will remain confidential.
Your written feedback is an essential part of this exercise and will be used to create an after-action report (AAR). The AAR will capture lessons learned that can then be used to help international planning, preparedness and response to an asteroid threat with >10 years warning time. Please respond to all questions and provide as much detail as possible with specific and constructive comments.
Thank you for your time.
EXERCISE EXERCISE EXERCISE
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PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
NASA
FEMA
APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
cneos
Ames Research Center
Lawrence Livermore
National Laboratory
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EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Lunch
EXERCISE EXERCISE EXERCISE
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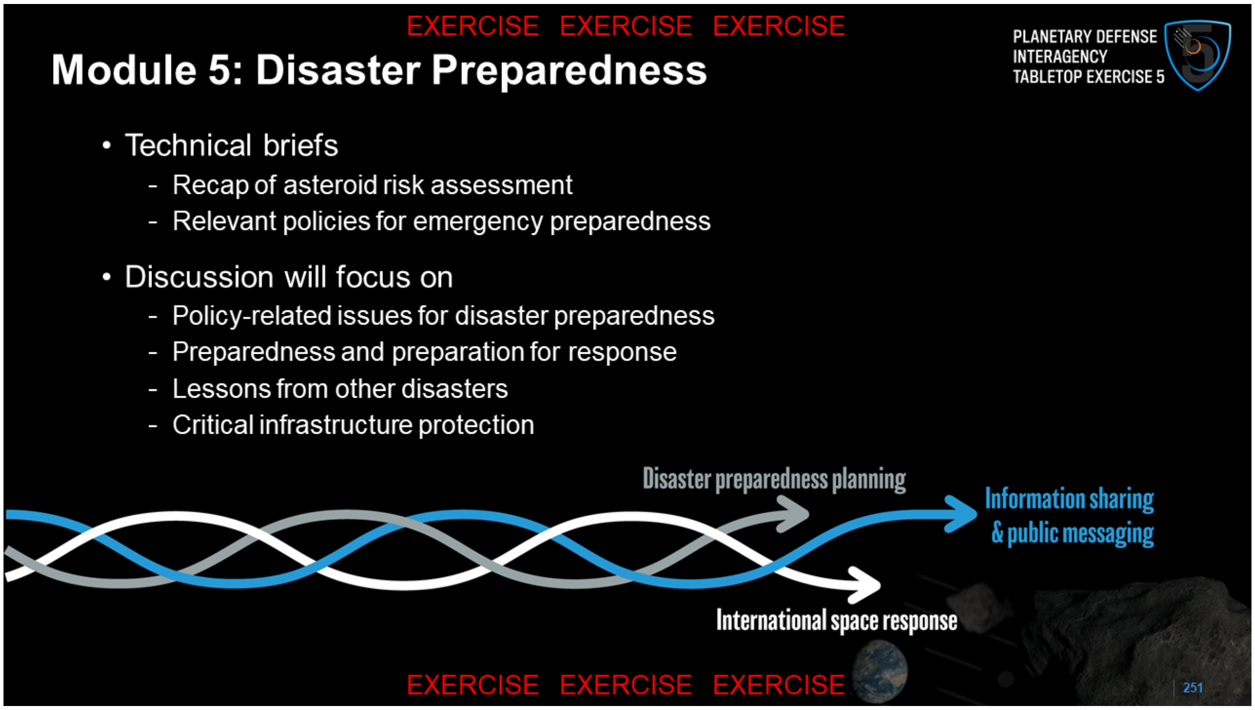
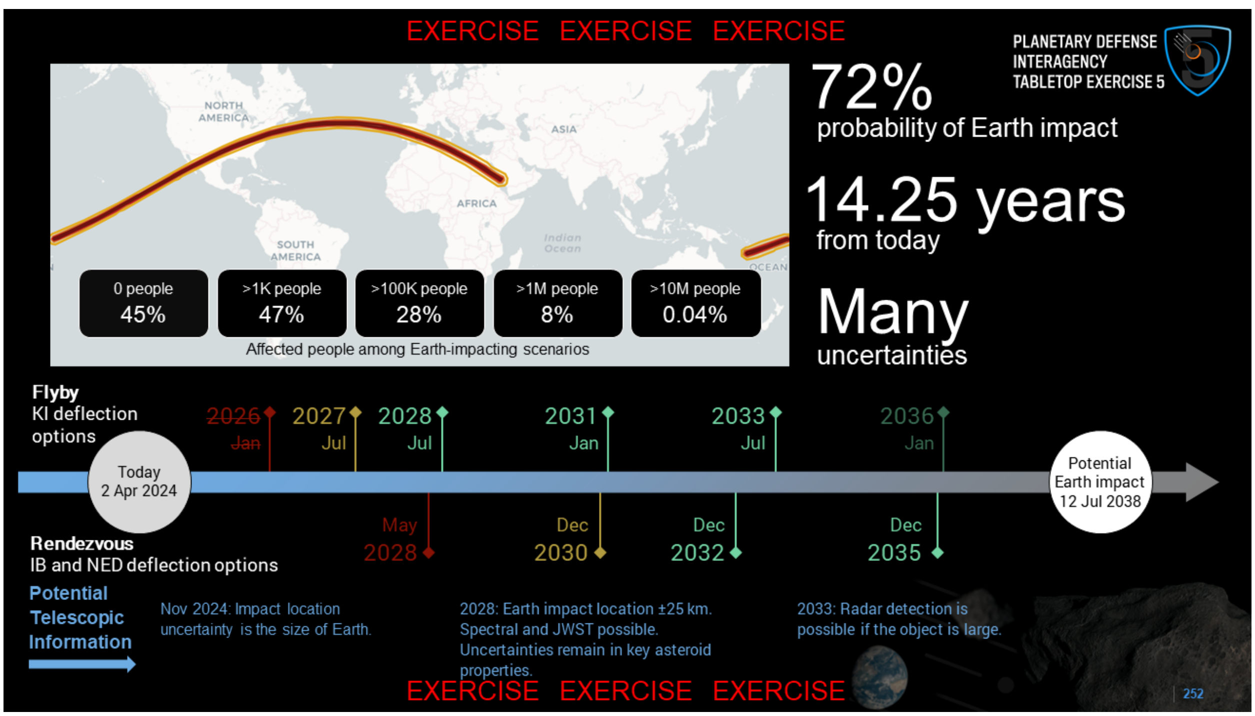
H.2.4. Module 5: Disaster Preparedness





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PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

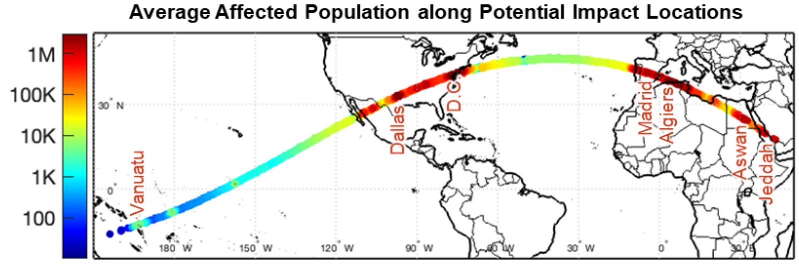
Impact Hazard Summary

72% chance of Earth impact in 14 years by a 60–800 m asteroid with 6–15,000 Mt of impact energy

High risk with large range of potential damage

Little damage or very large damage affecting **tens of thousands to millions** of people are **both likely**.

Average Affected Population along Potential Impact Locations



Range **0–20M people**, average **~270K** among Earth-impact cases

Local Ground Damage:

- Nearly all cases over land or near shore cause large blast damage to populated areas.
- Damage is likely to reach unsurvivable levels, with large areas of serious damage spanning multiple large metro areas, states, or countries.

Tsunamis:

- Large impacts near coasts could cause significant tsunamis.
- Smaller impacts over distant ocean may cause little damage.

Global and Regional Effects:

- Global climate effects are not expected, but largest cases approach estimated thresholds.
- *Potential for other extended environmental or socioeconomic effects is unknown.*

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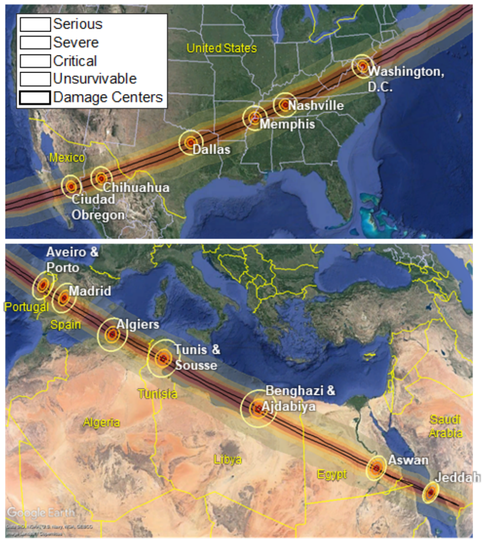
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Ground Damage Risk Swath



Damage risk swath: Extent of regions *potentially* at risk for ground damage, given ranges of potential impact locations and damage sizes (out to 95th percentile).
Rings show median (50th percentile) damage footprints at sample locations.

- Damage severities are likely to reach **unsurvivable levels**, extending to larger areas of structural damage, fires, and shattered windows.
- Damage areas are most likely between **~80 and 180 km (50 and 110 miles) in radius**.
- Largest damage areas could extend out ~**300 km (180 miles) or more in radius**.

	Damage Level Description
Serious	Windows shatter, some structure damage
Severe	Widespread structure damage, or third-degree burns
Critical	Residential structures collapse, or clothing ignites
Unsurvivable	Devastation, structures flattened or burned

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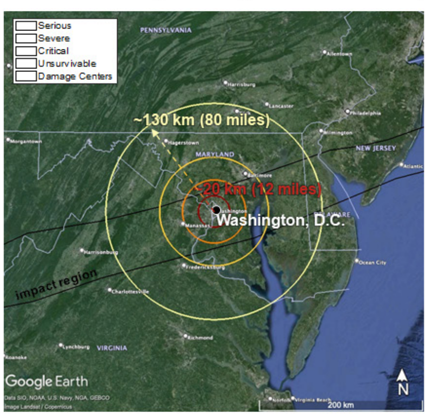
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

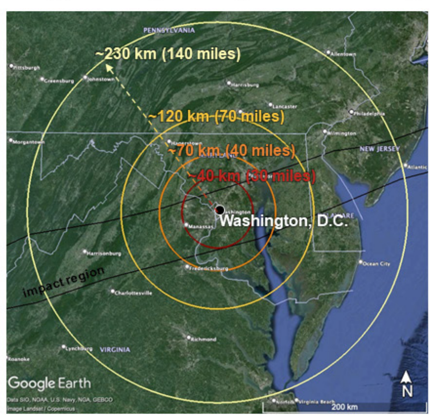
Sample Ground Damage Sizes

Median Damage Size (50th Percentile)



Likely damage sizes could span multiple large metropolitan areas, counties, or states

Large Damage Size (95th Percentile)



Large damage sizes could span multiple states or cover countries

Washington, D.C., USA

highest population damage region along swath

	Damage Level Description
Serious	Windows shatter, some structural damage
Severe	Widespread structural damage, or third-degree burns
Critical	Residential structures collapse, or clothing ignites
Unsurvivable	Devastation, structures flattened or incinerated

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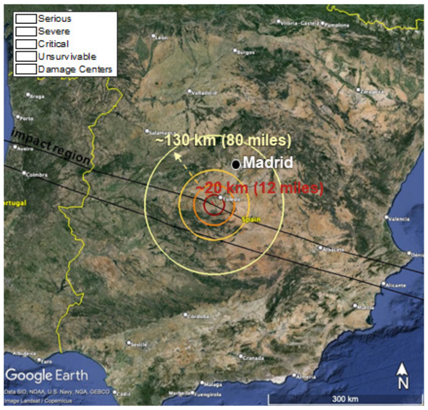
Sample Ground Damage Sizes

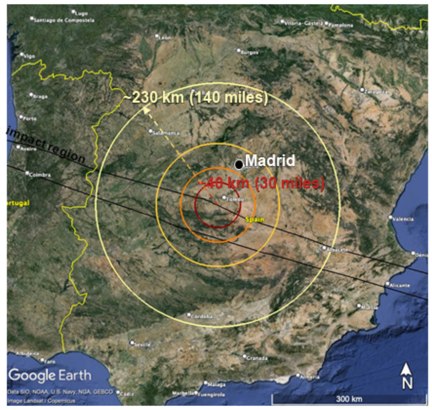
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Median Damage Size (50th Percentile)



Likely damage sizes could span multiple large metropolitan areas, counties, or states

Large Damage Size (95th Percentile)



Large damage sizes could span multiple states or cover countries

Madrid, Spain

highest population damage region in Europe

	Damage Level Description
Serious	Windows shatter, some structural damage
Severe	Widespread structural damage, or third-degree burns
Critical	Residential structures collapse, or clothing ignites
Unsurvivable	Devastation, structures flattened or incinerated

EXERCISE EXERCISE EXERCISE

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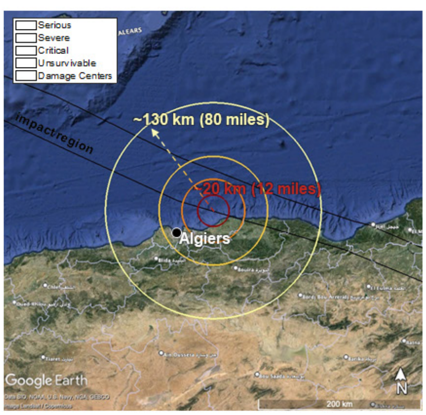
EXERCISE EXERCISE EXERCISE

Sample Ground Damage Sizes

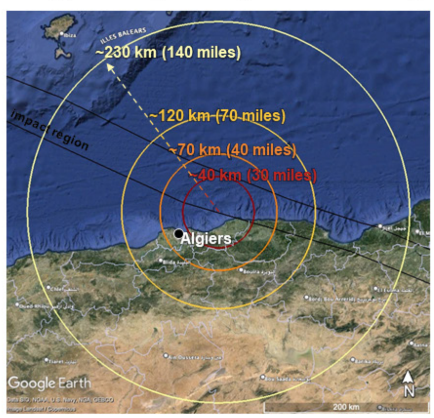
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Median Damage Size (50th Percentile)



Likely damage sizes could span multiple large metropolitan areas, counties, or states

Large Damage Size (95th Percentile)



Large damage sizes could span multiple states or cover countries

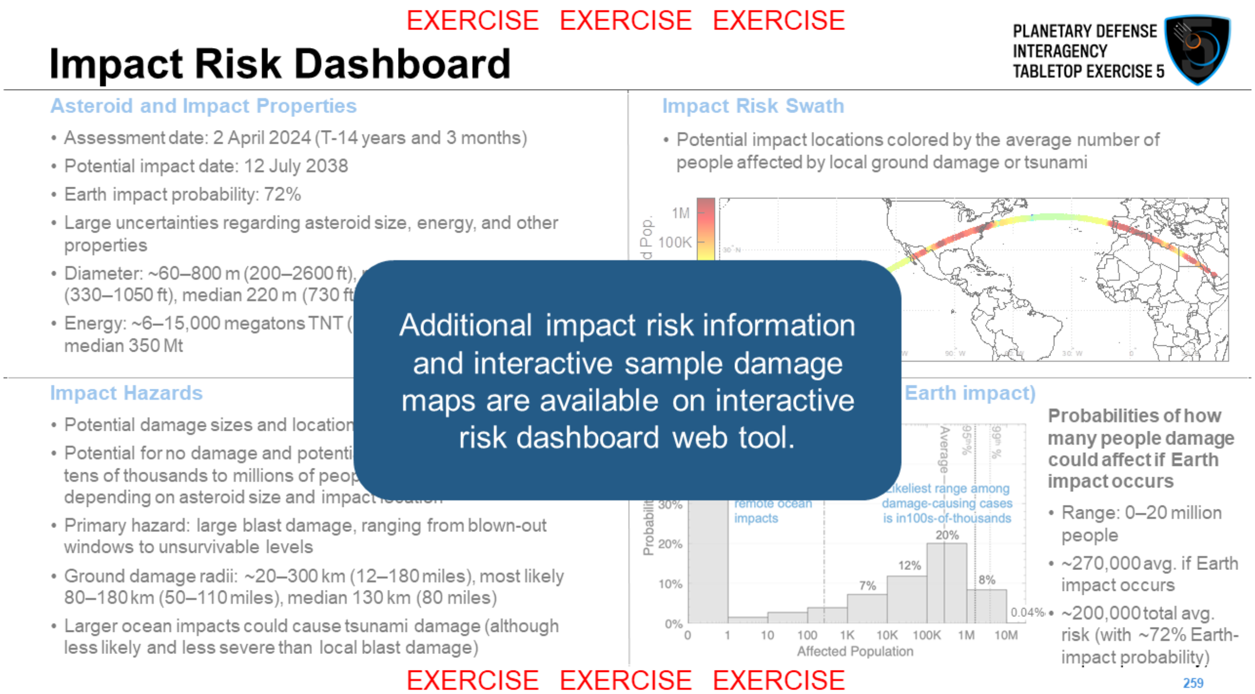
Algiers, Algeria

highest population damage region in Africa

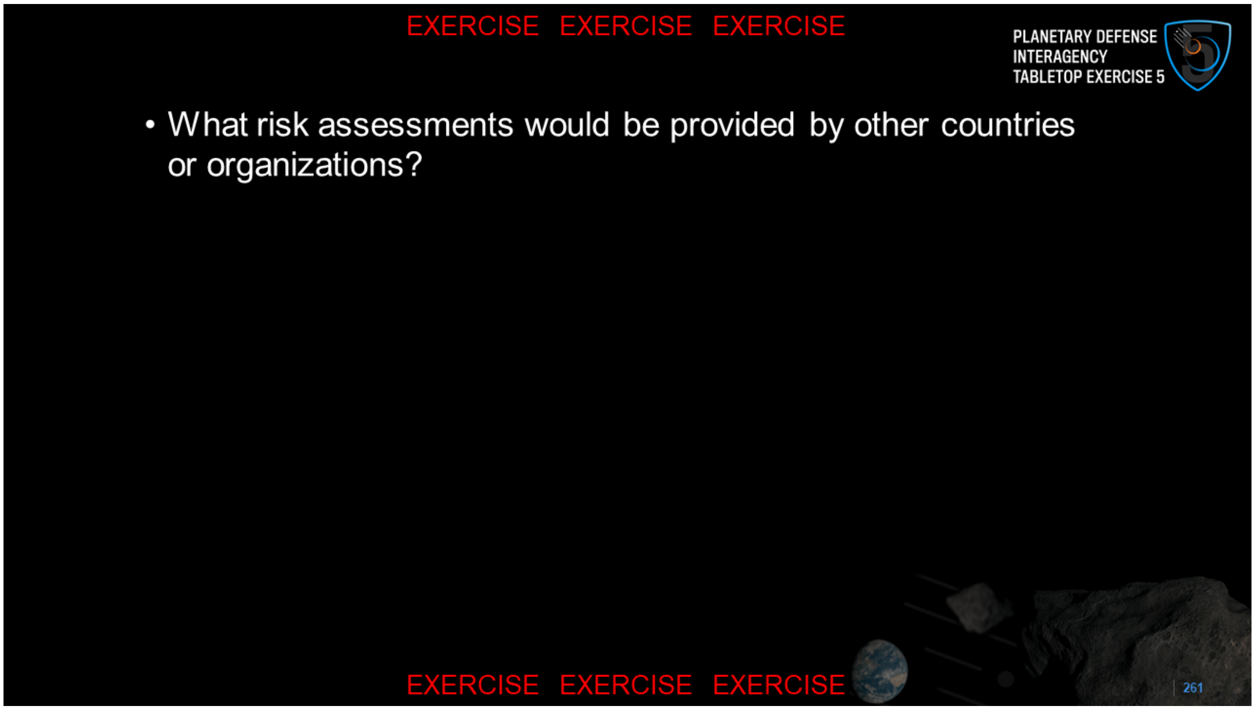
	Damage Level Description
Serious	Windows shatter, some structural damage
Severe	Widespread structural damage, or third-degree burns
Critical	Residential structures collapse, or clothing ignites
Unsurvivable	Devastation, structures flattened or incinerated

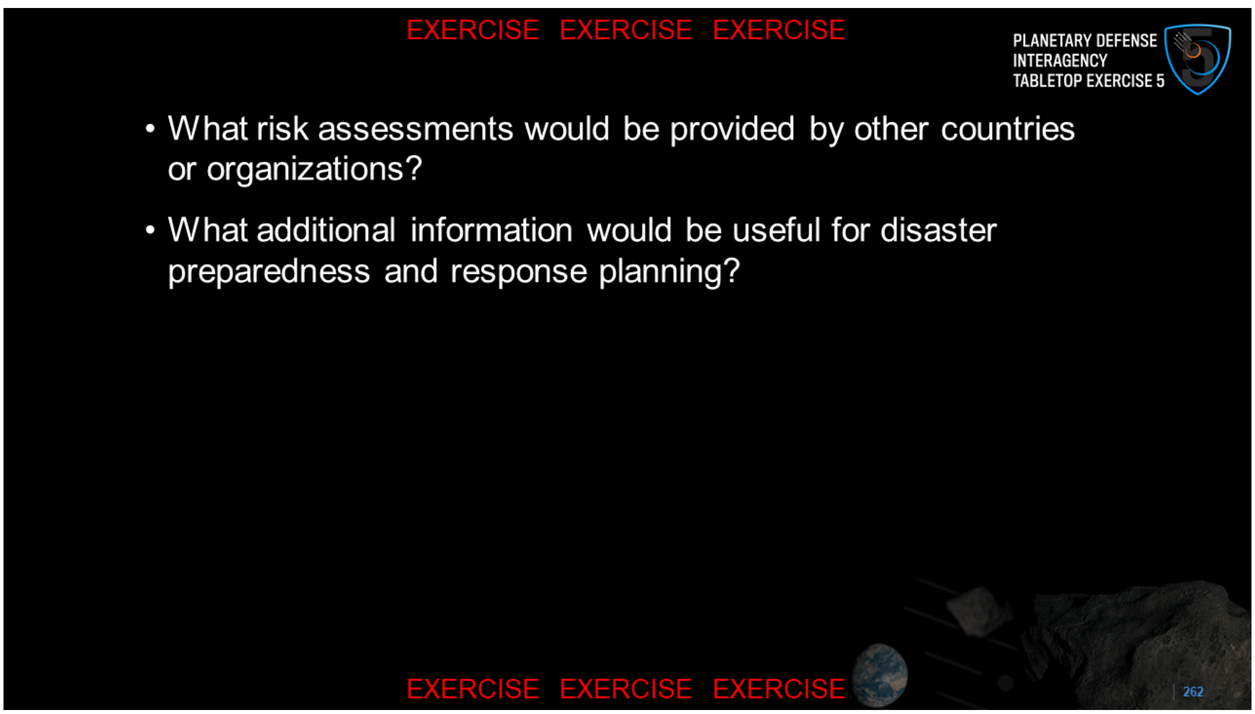
EXERCISE EXERCISE EXERCISE

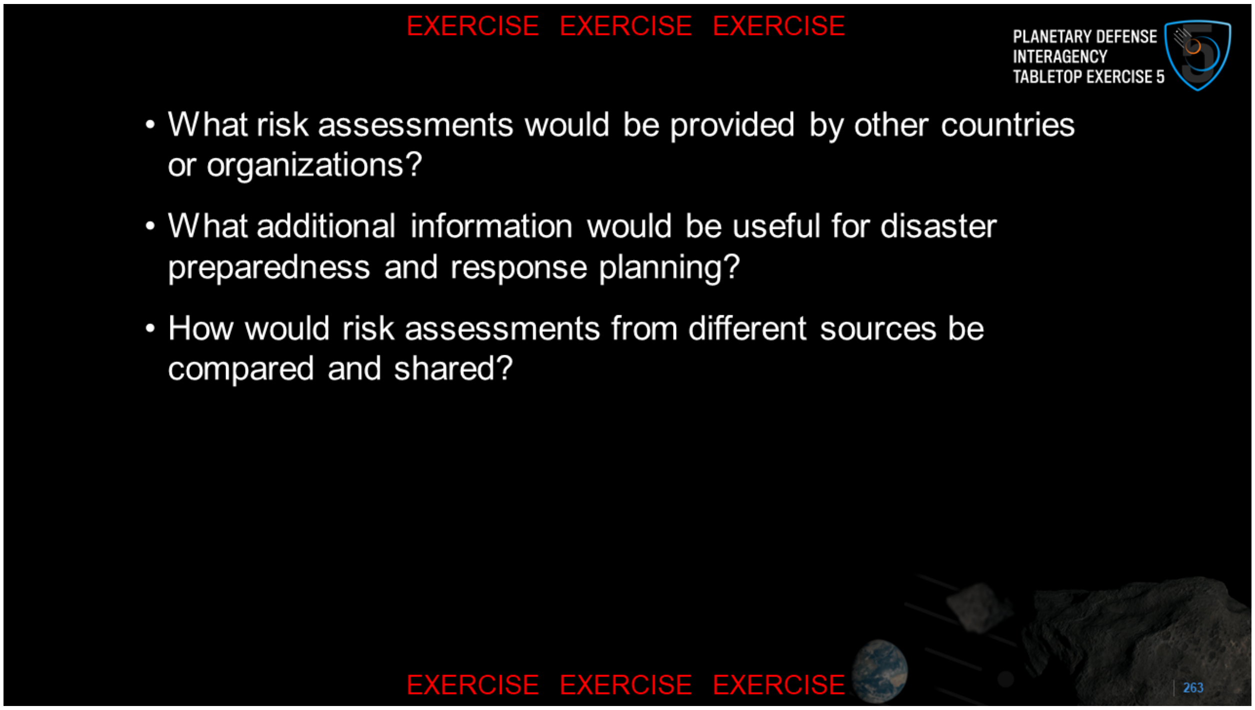
258


EXERCISE EXERCISE EXERCISE
Impact Risk Dashboard
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Asteroid and Impact Properties
• Assessment date: 2 April 2024 (T-14 years and 3 months)
• Potential impact date: 12 July 2038
• Earth impact probability: 72%
• Large uncertainties regarding asteroid size, energy, and other properties
• Diameter: ~60–800 m (200–2600 ft),
(330–1050 ft), median 220 m (730 ft
• Energy: ~6–15,000 megatons TNT (
median 350 Mt
Impact Risk Swath
• Potential impact locations colored by the average number of people affected by local ground damage or tsunami
1M
100K
Additional impact risk information and interactive sample damage maps are available on interactive risk dashboard web tool.
Impact Hazards
• Potential damage sizes and location
• Potential for no damage and potenti
tens of thousands to millions of peop
depending on asteroid size and impact
• Primary hazard: large blast damage, ranging from blown-out windows to unsurvivable levels
• Ground damage radii: ~20–300 km (12–180 miles), most likely 80–180 km (50–110 miles), median 130 km (80 miles)
• Larger ocean impacts could cause tsunami damage (although less likely and less severe than local blast damage)
Earth impact)
Average
95%
99%
remote ocean impacts
Likeliest range among damage-causing cases is in100s-of-thousands
30%
20%
10%
0%
20%
12%
7%
8%
0.04%
0
1
10
100
1K
10K
100K
1M
10M
Affected Population
Probabilities of how many people damage could affect if Earth impact occurs
• Range: 0–20 million people
• ~270,000 avg. if Earth impact occurs
• ~200,000 total avg. risk (with ~72% Earth-impact probability)
EXERCISE EXERCISE EXERCISE
259


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
EXERCISE EXERCISE EXERCISE
260

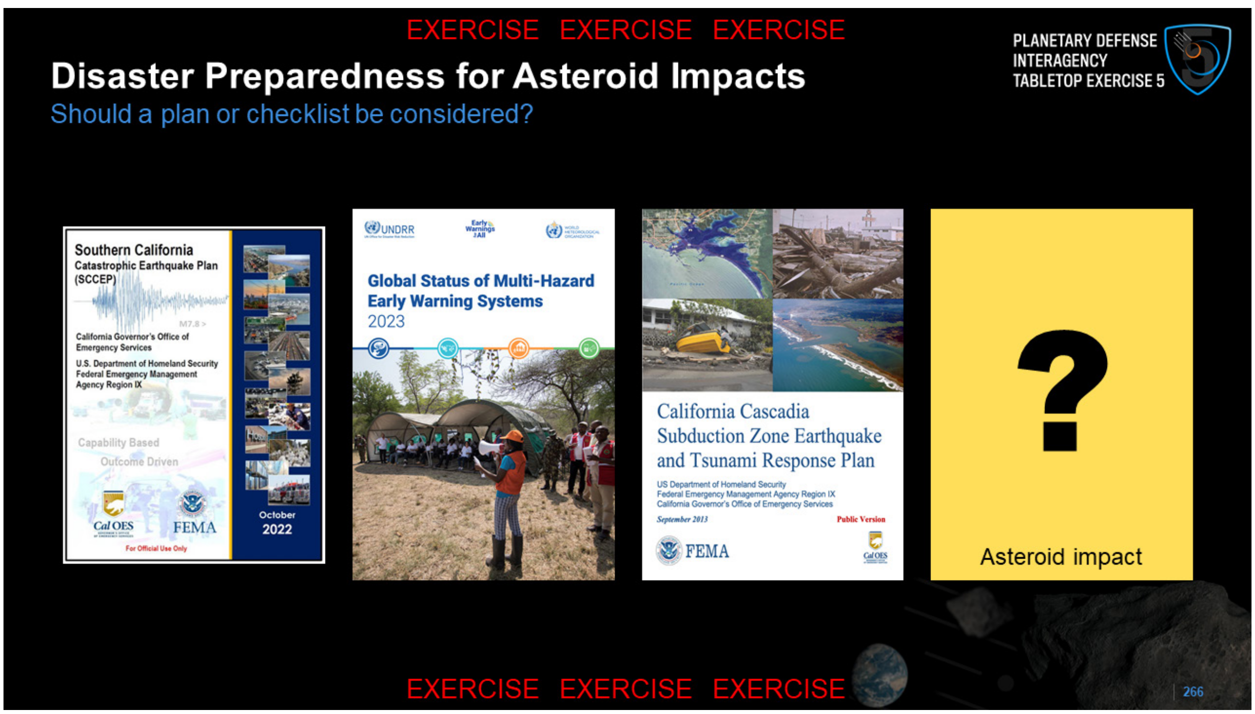

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What risk assessments would be provided by other countries or organizations?
EXERCISE EXERCISE EXERCISE
261


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• What risk assessments would be provided by other countries or organizations?
• What additional information would be useful for disaster preparedness and response planning?
EXERCISE EXERCISE EXERCISE
262

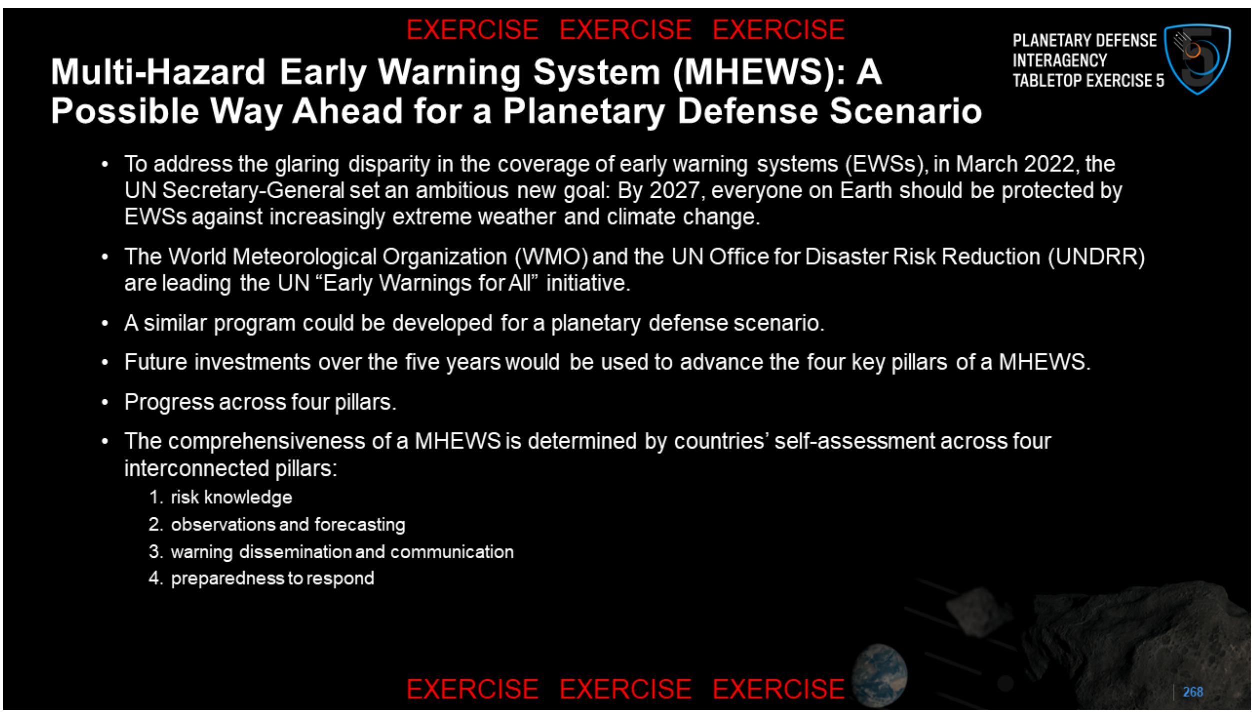

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What risk assessments would be provided by other countries or organizations?
• What additional information would be useful for disaster preparedness and response planning?
• How would risk assessments from different sources be compared and shared?
EXERCISE EXERCISE EXERCISE
263


PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Relevant International Policies for Disaster Preparedness
Leviticus A. "L.A." Lewis
FEMA Detailee/TTX Coordinator
Planetary Defense Coordination Office
Leviticus.lewis@fema.dhs.gov; Leviticus.a.lewis@nasa.gov
NASA
FEMA
APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
cneos
Ames Research Center
Lawrence Livermore National Laboratory

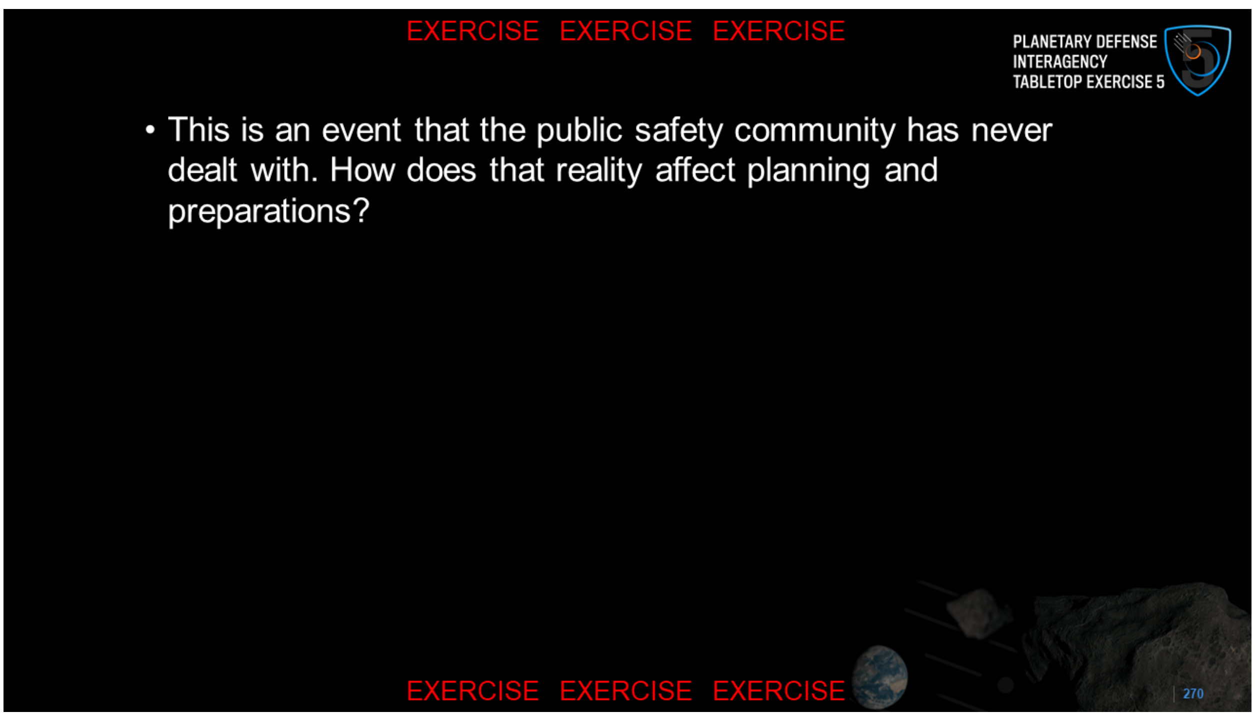

EXERCISE EXERCISE EXERCISE
Disaster Preparedness for Asteroid Impacts
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Earthquake
Volcanic eruption
Flood
Hurricane
Wildfire
?
Asteroid impact
EXERCISE EXERCISE EXERCISE
265

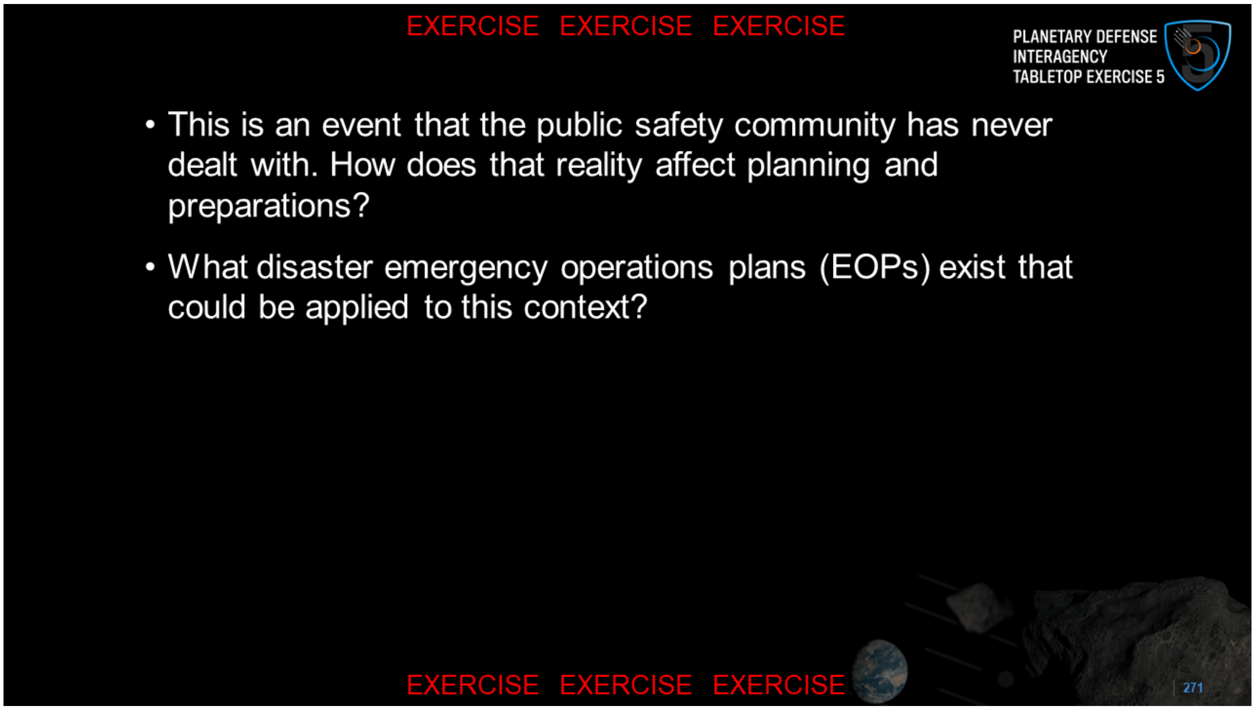

EXERCISE EXERCISE EXERCISE
Disaster Preparedness for Asteroid Impacts
Should a plan or checklist be considered?
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Southern California
Catastrophic Earthquake Plan
(SCCEP)
M7.8 >
California Governor's Office of
Emergency Services
U.S. Department of Homeland Security
Federal Emergency Management
Agency Region IX
Capability Based
Outcome Driven
Cal OES
FEMA
October
2022
For Official Use Only
UNDRR
Early Warnings for All
World Meteorological Organization
Global Status of Multi-Hazard
Early Warning Systems
2023
California Cascadia
Subduction Zone Earthquake
and Tsunami Response Plan
US Department of Homeland Security
Federal Emergency Management Agency Region IX
California Governor's Office of Emergency Services
September 2013
Public Version
FEMA
Cal OES
?
Asteroid impact
EXERCISE EXERCISE EXERCISE
266

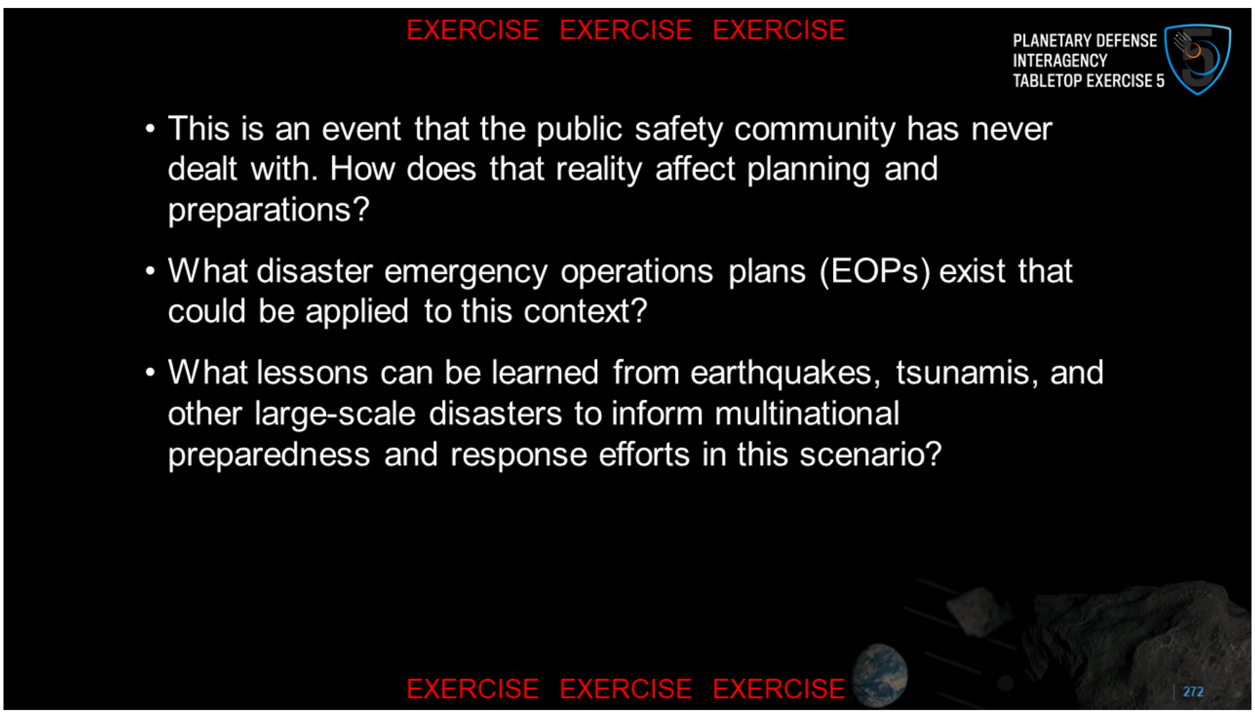

EXERCISE EXERCISE EXERCISE
Possible International Organizations for Asteroid Impact Response Coordination and Planning
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• The International Charter Space and Major Disasters
- satellite data to support disaster response worldwide
• United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER)
• United Nations Office for Disaster Risk Reduction (UNDRR)
- Sendai Framework for Disaster Risk Reduction (2015–2030)
- United Nations Early Warnings for All initiative
• United Nations Disaster Assessment and Coordination System – 2022 – Office for the Coordination of Humanitarian Affairs (UNOCHA)
EXERCISE EXERCISE EXERCISE
267

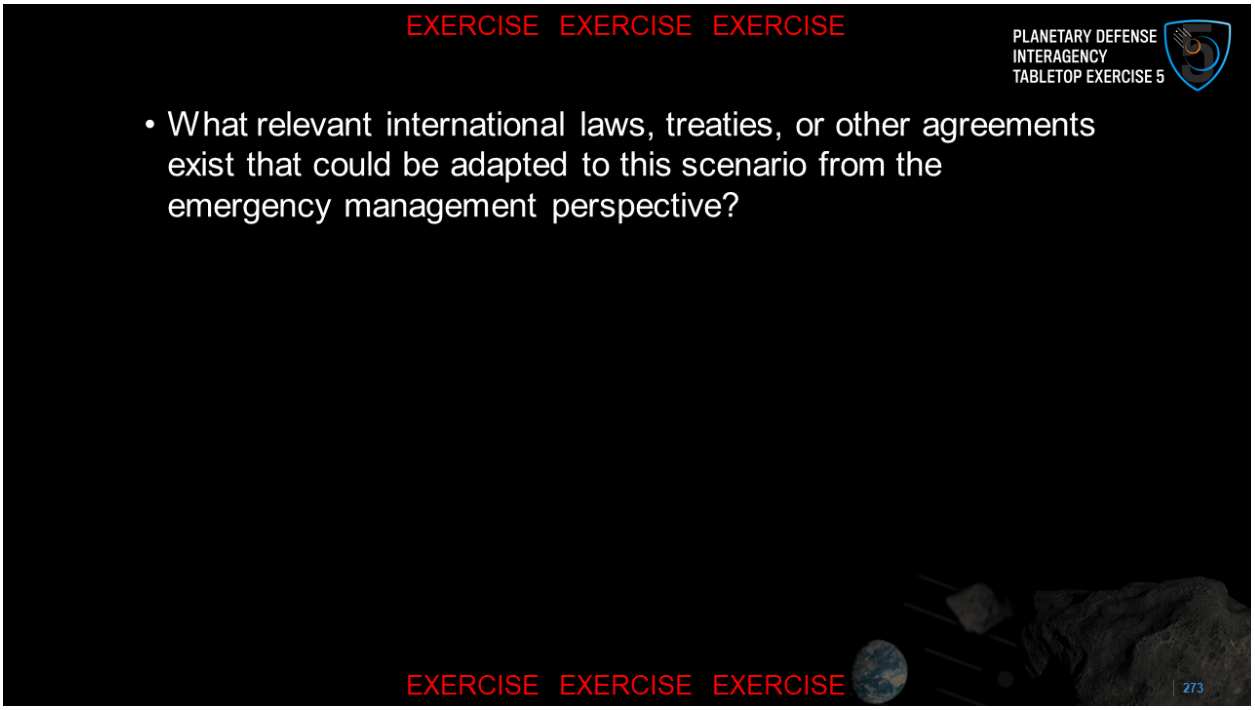

EXERCISE EXERCISE EXERCISE
Multi-Hazard Early Warning System (MHEWS): A Possible Way Ahead for a Planetary Defense Scenario
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• To address the glaring disparity in the coverage of early warning systems (EWSs), in March 2022, the UN Secretary-General set an ambitious new goal: By 2027, everyone on Earth should be protected by EWSs against increasingly extreme weather and climate change.
• The World Meteorological Organization (WMO) and the UN Office for Disaster Risk Reduction (UNDRR) are leading the UN "Early Warnings for All" initiative.
• A similar program could be developed for a planetary defense scenario.
• Future investments over the five years would be used to advance the four key pillars of a MHEWS.
• Progress across four pillars.
• The comprehensiveness of a MHEWS is determined by countries' self-assessment across four interconnected pillars:
1. risk knowledge
2. observations and forecasting
3. warning dissemination and communication
4. preparedness to respond
EXERCISE EXERCISE EXERCISE
268

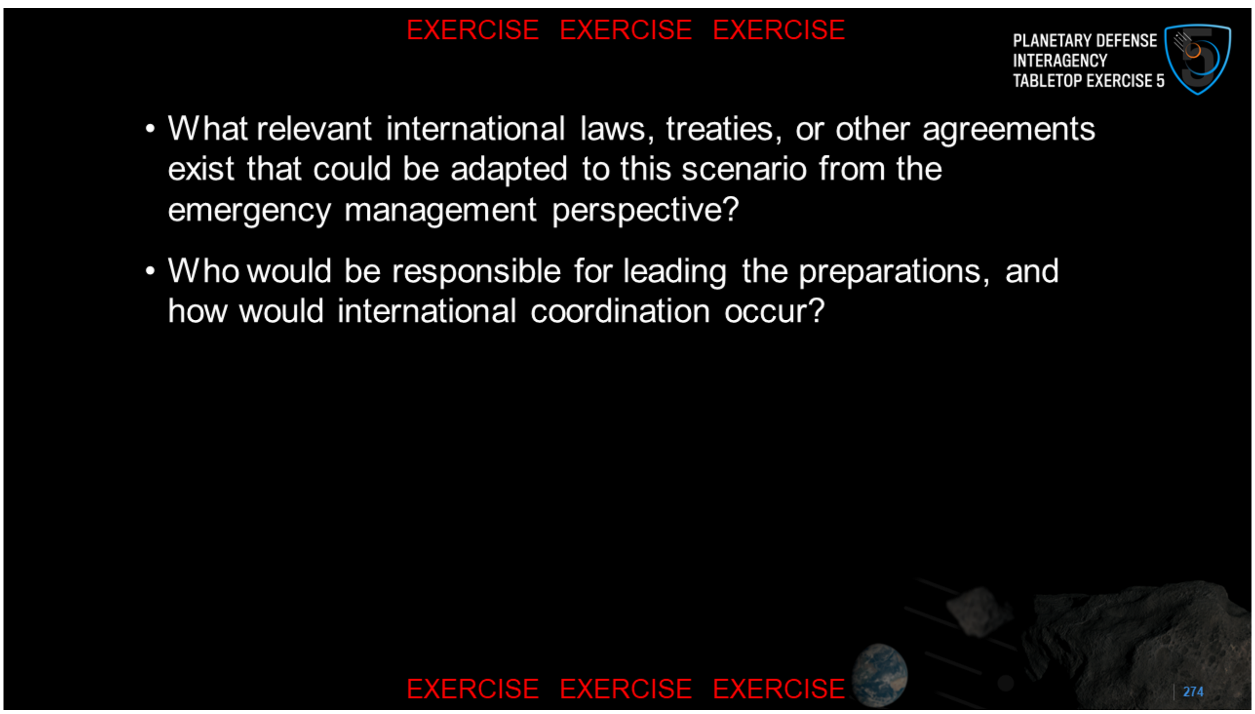

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
EXERCISE EXERCISE EXERCISE
269

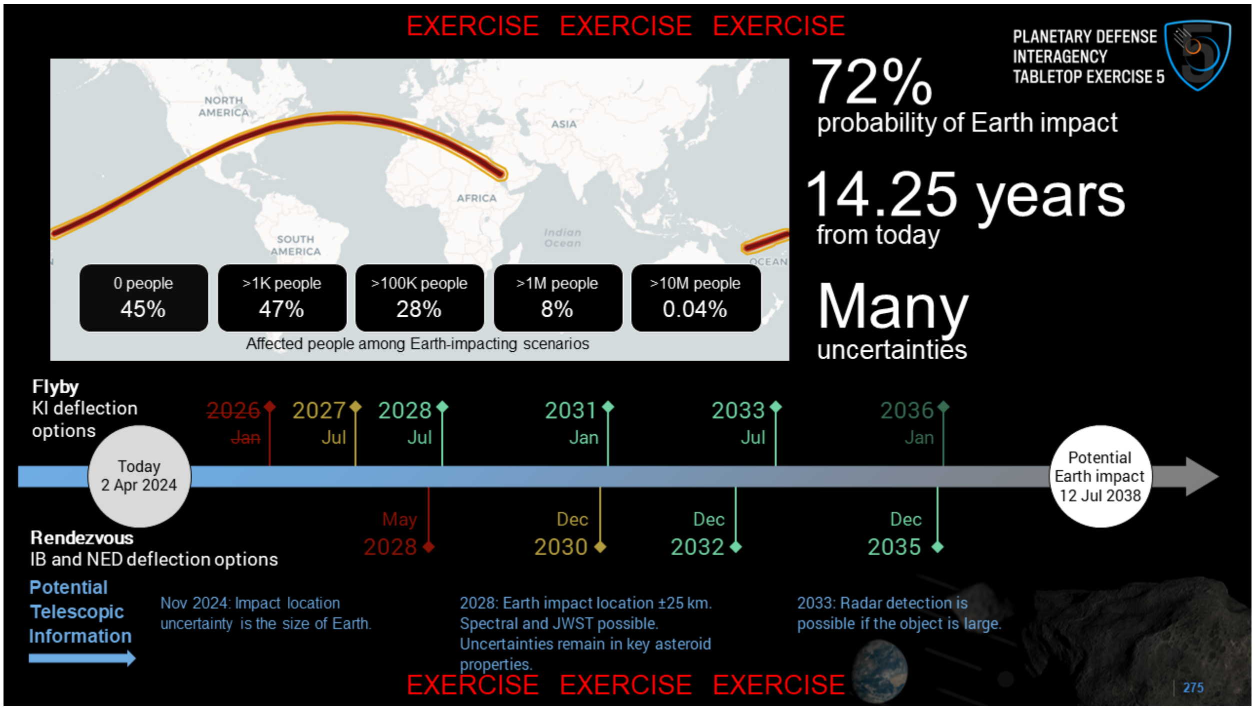

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• This is an event that the public safety community has never dealt with. How does that reality affect planning and preparations?
EXERCISE EXERCISE EXERCISE
270

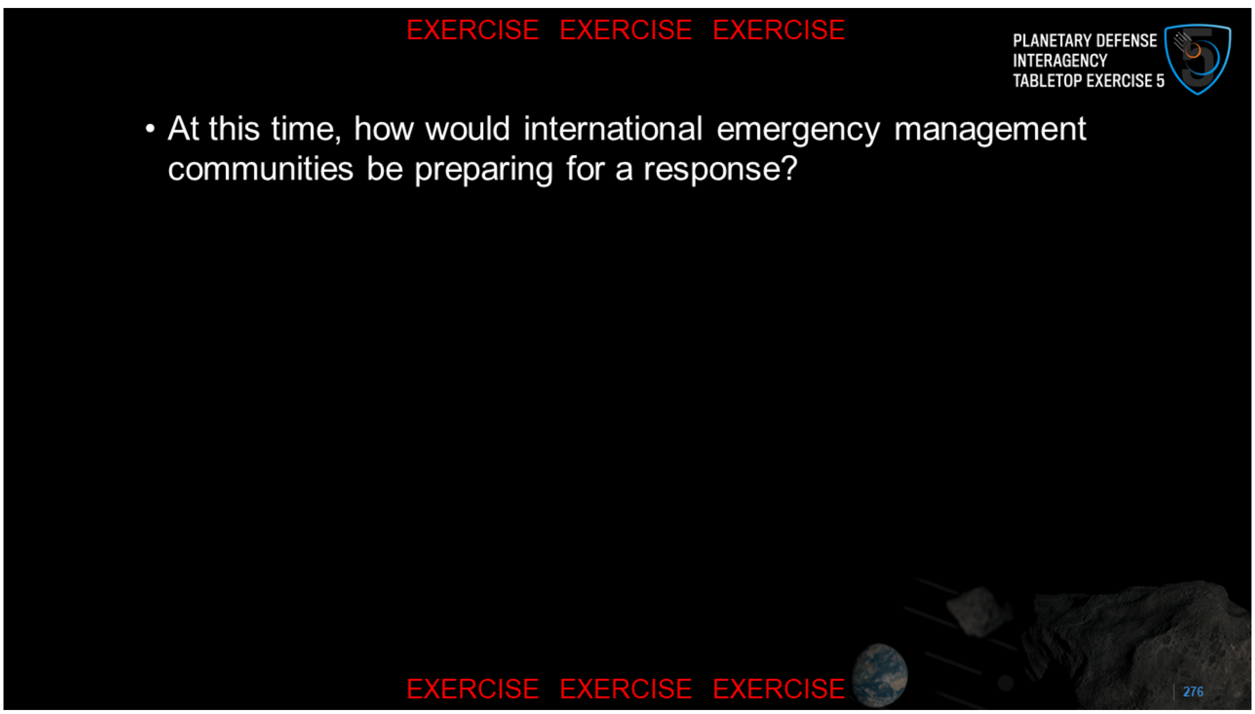

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• This is an event that the public safety community has never dealt with. How does that reality affect planning and preparations?
• What disaster emergency operations plans (EOPs) exist that could be applied to this context?
EXERCISE EXERCISE EXERCISE
271

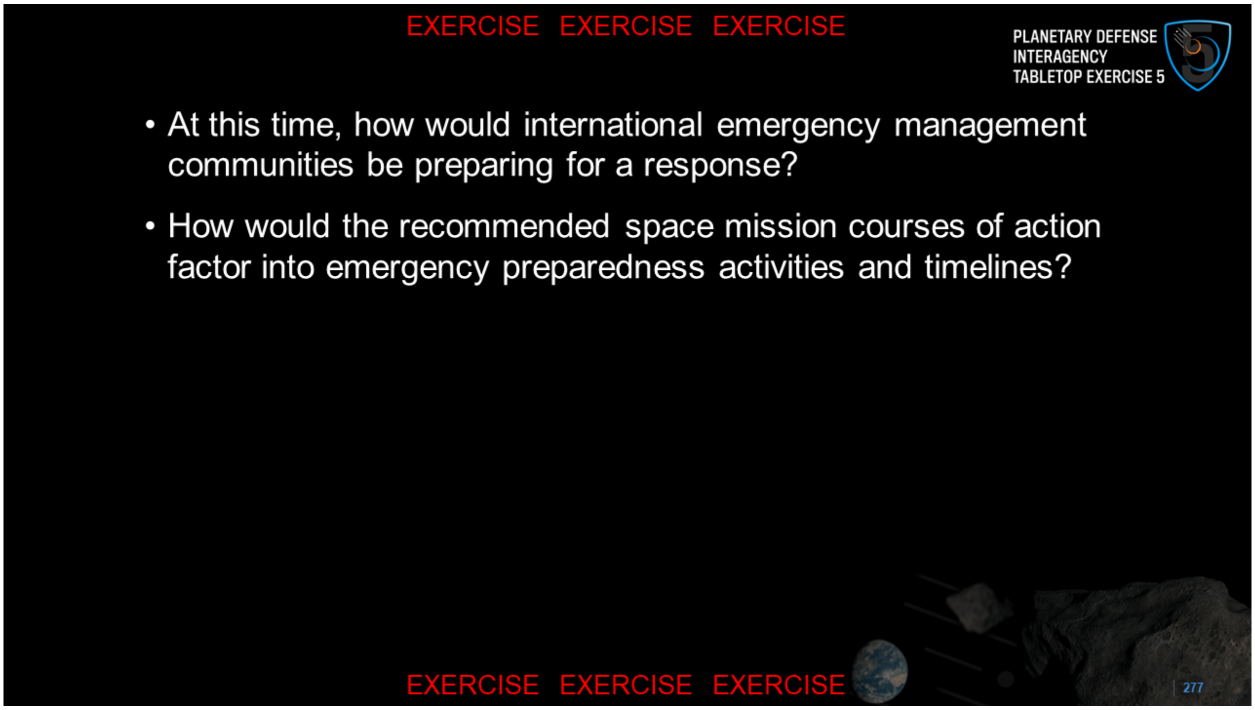

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• This is an event that the public safety community has never dealt with. How does that reality affect planning and preparations?
• What disaster emergency operations plans (EOPs) exist that could be applied to this context?
• What lessons can be learned from earthquakes, tsunamis, and other large-scale disasters to inform multinational preparedness and response efforts in this scenario?
EXERCISE EXERCISE EXERCISE
272

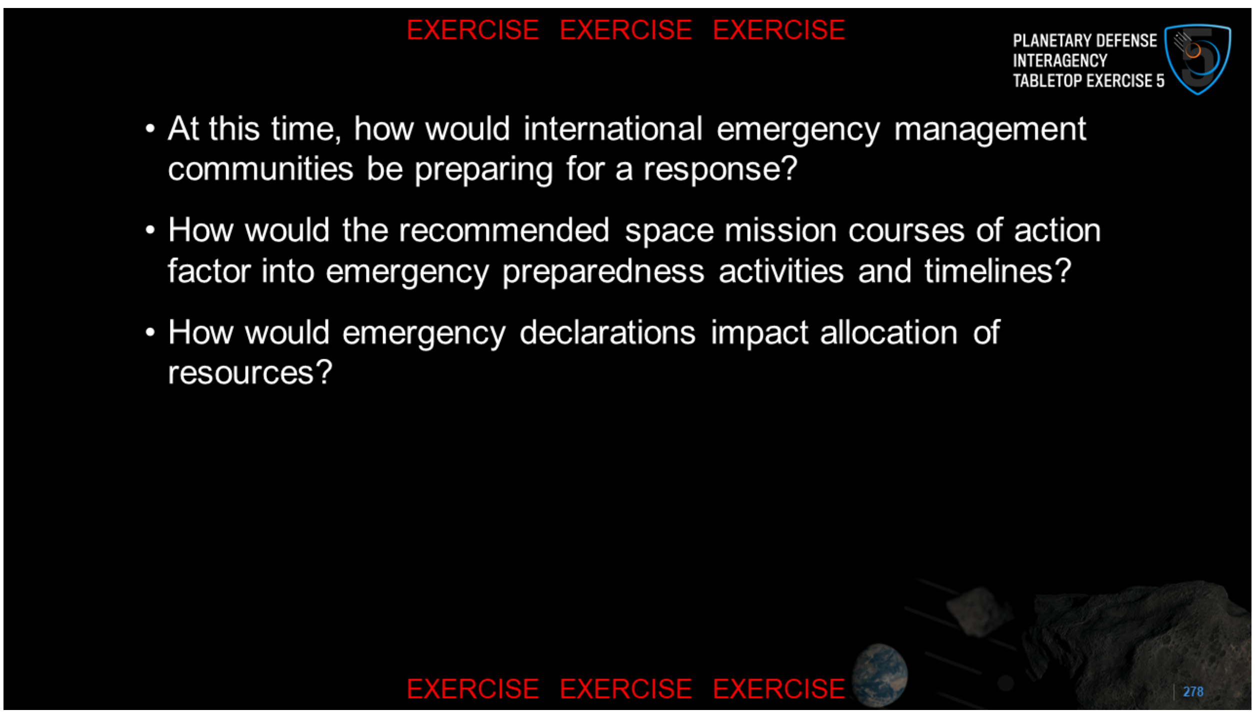

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What relevant international laws, treaties, or other agreements exist that could be adapted to this scenario from the emergency management perspective?
EXERCISE EXERCISE EXERCISE
273

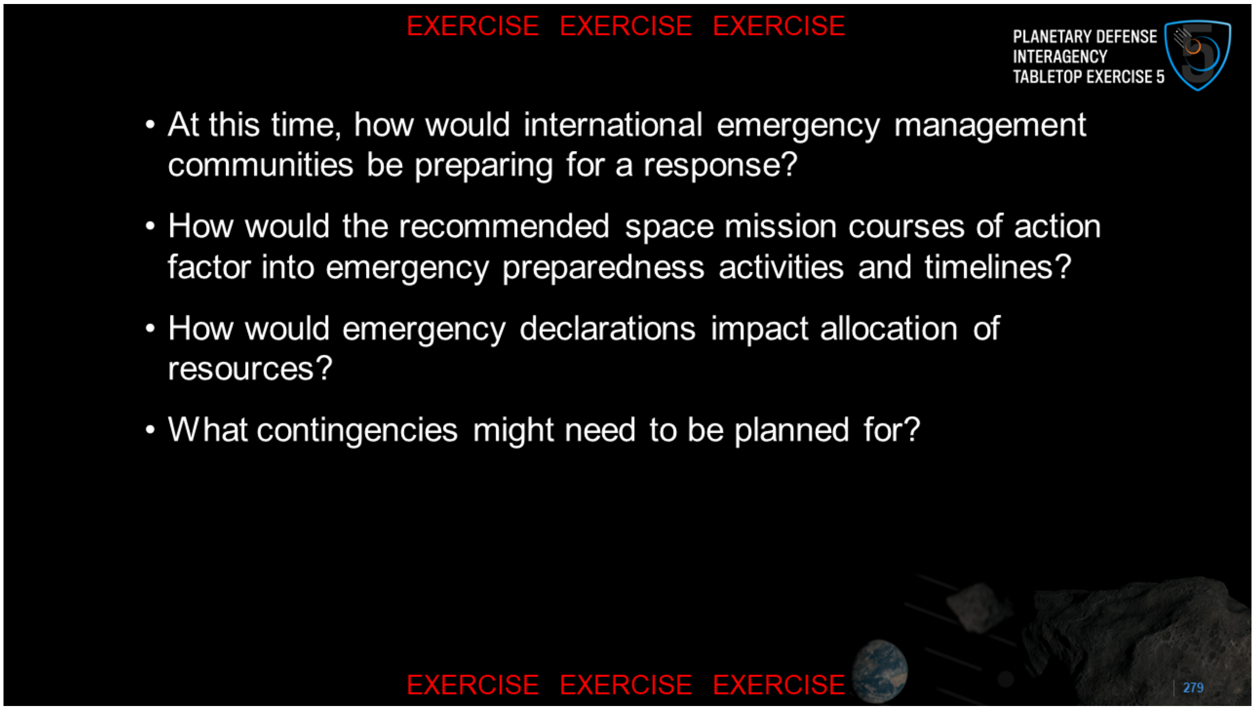

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• What relevant international laws, treaties, or other agreements exist that could be adapted to this scenario from the emergency management perspective?
• Who would be responsible for leading the preparations, and how would international coordination occur?
EXERCISE EXERCISE EXERCISE
274


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
NORTH AMERICA
ASIA
AFRICA
SOUTH AMERICA
Indian Ocean
0 people 45%
>1K people 47%
>100K people 28%
>1M people 8%
>10M people 0.04%
Affected people among Earth-impacting scenarios
72%
probability of Earth impact
14.25 years
from today
Many
uncertainties
Flyby
KI deflection options
2026 Jan
2027 Jul
2028 Jul
2031 Jan
2033 Jul
2036 Jan
Today
2 Apr 2024
Potential Earth impact 12 Jul 2038
May 2028
Dec 2030
Dec 2032
Dec 2035
Rendezvous
IB and NED deflection options
Potential Telescopic Information
Nov 2024: Impact location uncertainty is the size of Earth.
2028: Earth impact location ±25 km. Spectral and JWST possible. Uncertainties remain in key asteroid properties.
2033: Radar detection is possible if the object is large.
EXERCISE EXERCISE EXERCISE
275

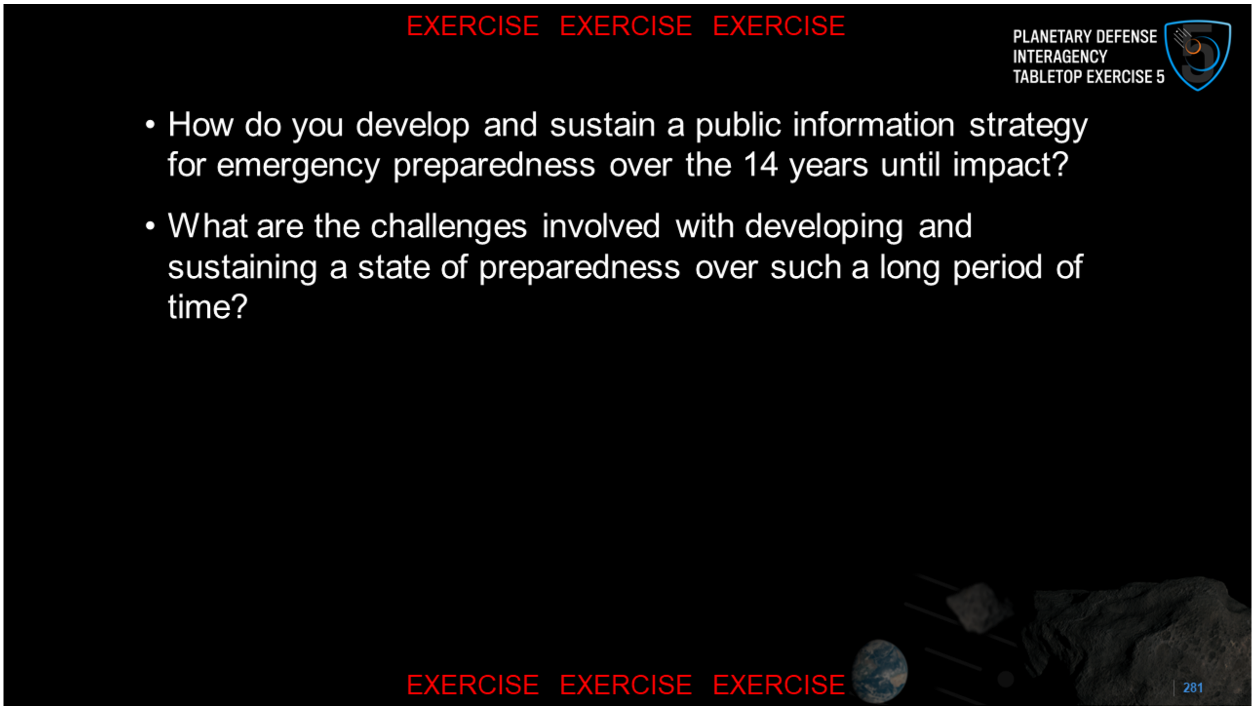

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• At this time, how would international emergency management communities be preparing for a response?
EXERCISE EXERCISE EXERCISE
276

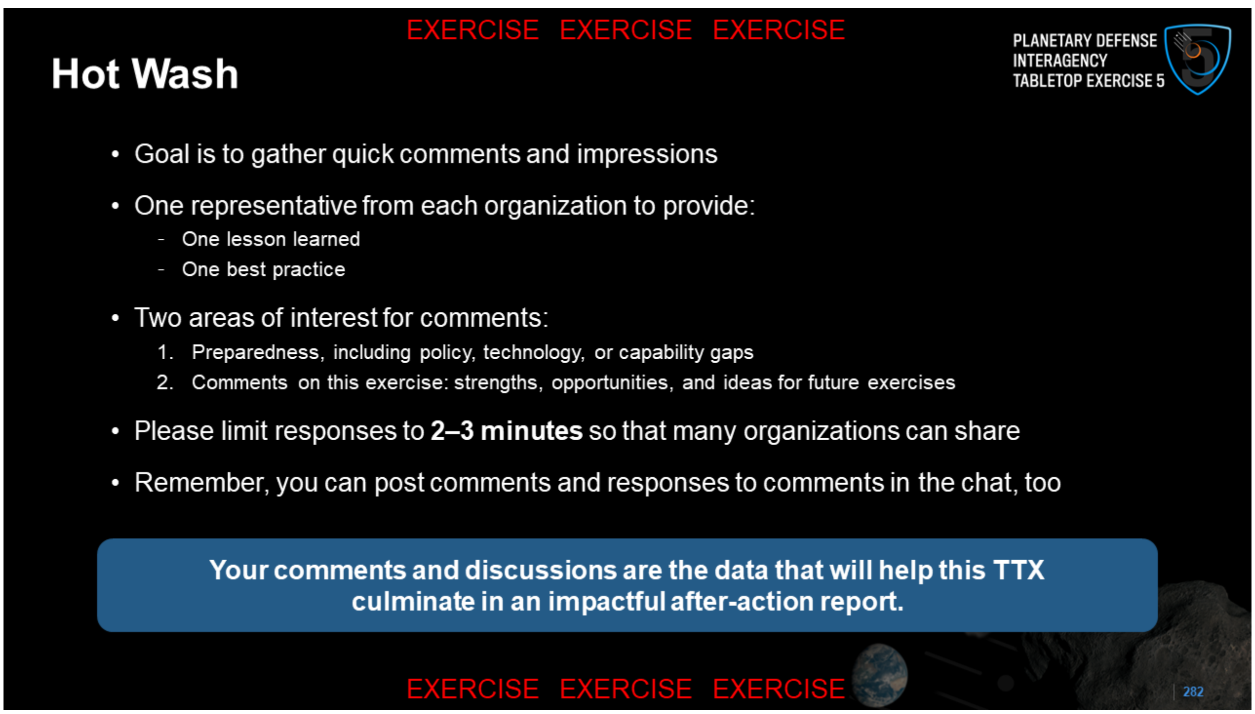

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• At this time, how would international emergency management communities be preparing for a response?
• How would the recommended space mission courses of action factor into emergency preparedness activities and timelines?
EXERCISE EXERCISE EXERCISE
277

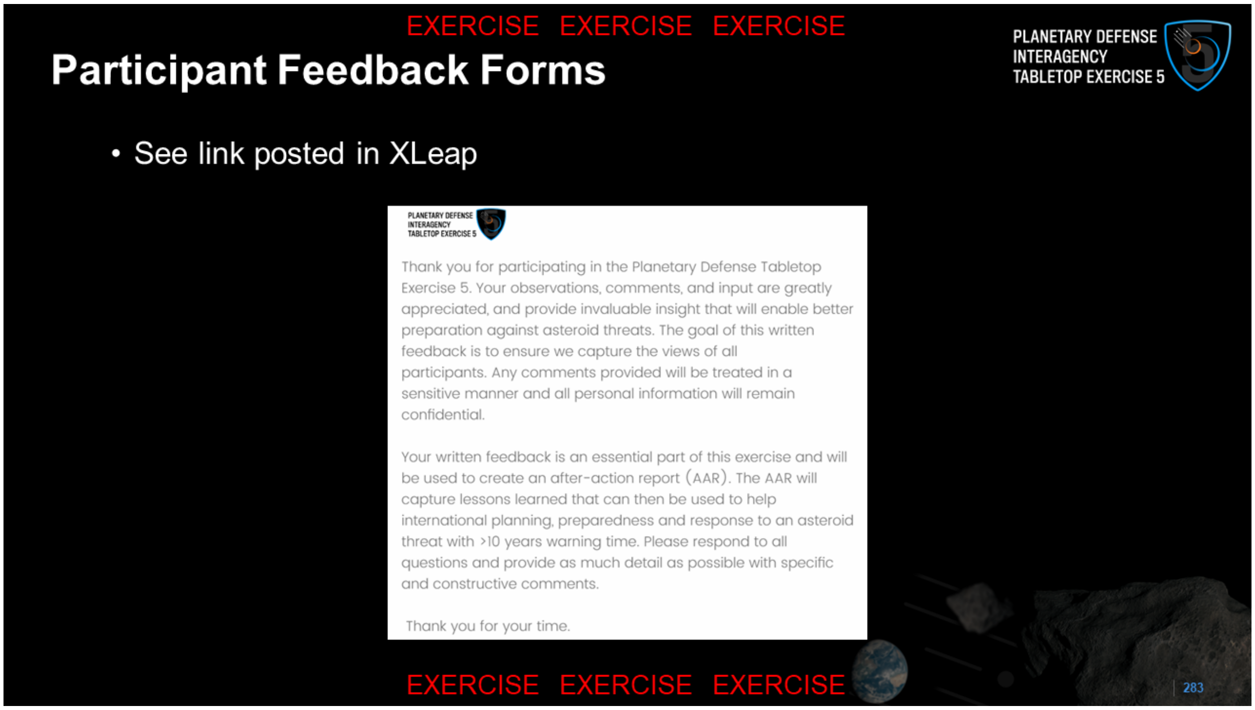

EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• At this time, how would international emergency management communities be preparing for a response?
• How would the recommended space mission courses of action factor into emergency preparedness activities and timelines?
• How would emergency declarations impact allocation of resources?
EXERCISE EXERCISE EXERCISE
278


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• At this time, how would international emergency management communities be preparing for a response?
• How would the recommended space mission courses of action factor into emergency preparedness activities and timelines?
• How would emergency declarations impact allocation of resources?
• What contingencies might need to be planned for?
EXERCISE EXERCISE EXERCISE
279


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• How do you develop and sustain a public information strategy for emergency preparedness over the 14 years until impact?
EXERCISE EXERCISE EXERCISE
280


EXERCISE EXERCISE EXERCISE
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• How do you develop and sustain a public information strategy for emergency preparedness over the 14 years until impact?
• What are the challenges involved with developing and sustaining a state of preparedness over such a long period of time?
EXERCISE EXERCISE EXERCISE
281


EXERCISE EXERCISE EXERCISE
Hot Wash
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• Goal is to gather quick comments and impressions
• One representative from each organization to provide:
- One lesson learned
- One best practice
• Two areas of interest for comments:
1. Preparedness, including policy, technology, or capability gaps
2. Comments on this exercise: strengths, opportunities, and ideas for future exercises
• Please limit responses to 2–3 minutes so that many organizations can share
• Remember, you can post comments and responses to comments in the chat, too
Your comments and discussions are the data that will help this TTX culminate in an impactful after-action report.
EXERCISE EXERCISE EXERCISE
282


EXERCISE EXERCISE EXERCISE
Participant Feedback Forms
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
• See link posted in XLeap
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5
Thank you for participating in the Planetary Defense Tabletop Exercise 5. Your observations, comments, and input are greatly appreciated, and provide invaluable insight that will enable better preparation against asteroid threats. The goal of this written feedback is to ensure we capture the views of all participants. Any comments provided will be treated in a sensitive manner and all personal information will remain confidential.
Your written feedback is an essential part of this exercise and will be used to create an after-action report (AAR). The AAR will capture lessons learned that can then be used to help international planning, preparedness and response to an asteroid threat with >10 years warning time. Please respond to all questions and provide as much detail as possible with specific and constructive comments.
Thank you for your time.
EXERCISE EXERCISE EXERCISE
283


PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
NASA
FEMA
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
cneos
Ames Research Center
Lawrence Livermore National Laboratory
284

H.2.5. TTX Closing

EXERCISE EXERCISE EXERCISE

Revisit the Parking Lot

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- Revisit key discussions from earlier modules that might have been cut short

Module	Description
1	Scene setting and international coordination
2	Space mission options
3	Recommended courses of action
4	Public information messaging
5	Disaster preparedness

EXERCISE EXERCISE EXERCISE

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EXERCISE EXERCISE EXERCISE

Looking to the Future

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

TTX 1

TTX 2

TTX 3

TTX 4

TTX 5

6

Future TTXs

EXERCISE EXERCISE EXERCISE

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EXERCISE EXERCISE EXERCISE

Path Forward

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- Planning team will consolidate observations and participant comments to create a final after-action report (AAR) with:
  - Exercise overview
  - Areas of strength
  - Gap analysis
    - Policy, capability, communication, or technology gaps
    - Recommendations on how to (and if we should) close them
  - Communications analysis
    - Assessments of information sharing and understanding of roles
    - Assessments on effectiveness of briefings
  - Recommendations for future exercises

EXERCISE EXERCISE EXERCISE

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EXERCISE EXERCISE EXERCISE

Final Hot Wash

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

- Comments are welcome that pertain to any module or brief
- Limited time, but we welcome comments and discussion from everyone, so *please be brief to allow opportunity for others to speak.*
- Consider comments related to:
  - Best practice or lesson learned
  - Recommendation for improvement
- You can post comments and responses to comments in the chat, too

All comments from the hot wash sessions will be captured and combined with comments from the chat, the data collectors' notes, and the participant feedback forms to support the development of the After Action Report.

EXERCISE EXERCISE EXERCISE

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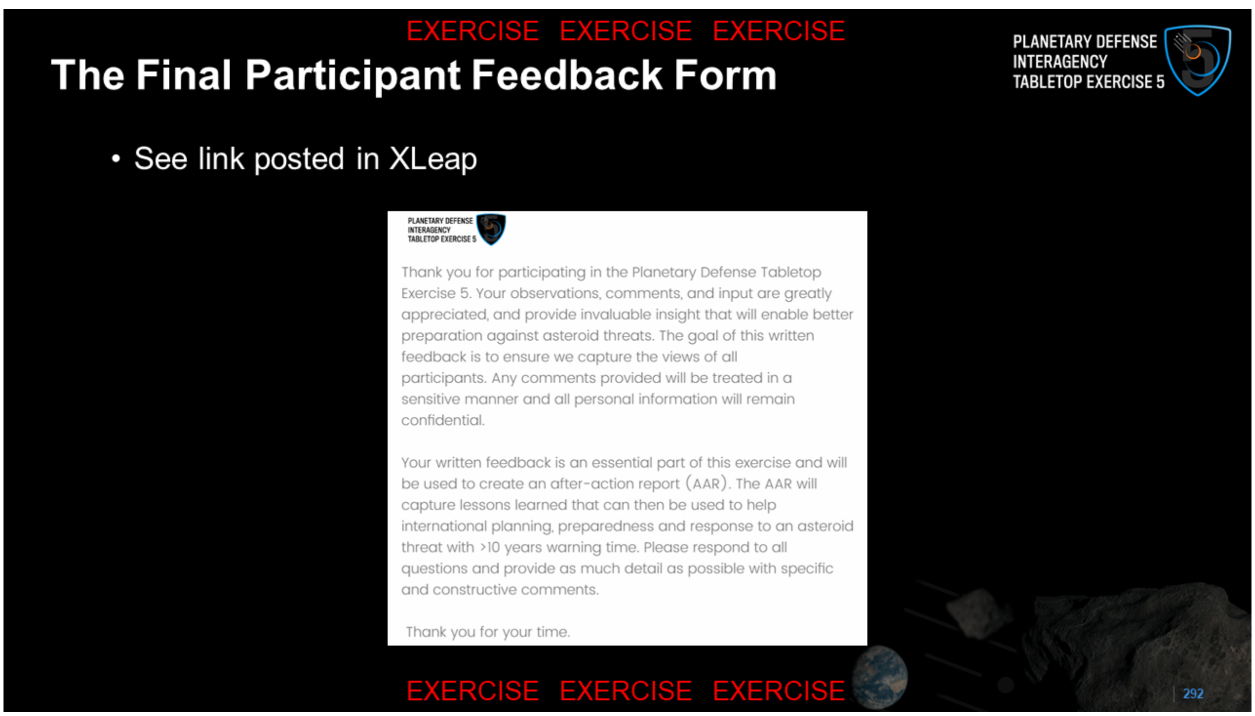
EXERCISE EXERCISE EXERCISE
Closing Remarks from the Sponsor
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
EXERCISE EXERCISE EXERCISE
291


EXERCISE EXERCISE EXERCISE
The Final Participant Feedback Form
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
• See link posted in XLeap
Thank you for participating in the Planetary Defense Tabletop Exercise 5. Your observations, comments, and input are greatly appreciated, and provide invaluable insight that will enable better preparation against asteroid threats. The goal of this written feedback is to ensure we capture the views of all participants. Any comments provided will be treated in a sensitive manner and all personal information will remain confidential.
Your written feedback is an essential part of this exercise and will be used to create an after-action report (AAR). The AAR will capture lessons learned that can then be used to help international planning, preparedness and response to an asteroid threat with >10 years warning time. Please respond to all questions and provide as much detail as possible with specific and constructive comments.
Thank you for your time.
EXERCISE EXERCISE EXERCISE
292


PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5
Thank you for joining us!
NASA
FEMA
APL
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APPLIED PHYSICS LABORATORY
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Ames Research Center
Lawrence Livermore
National Laboratory
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PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5