Module 3: Recommended Courses of Action

- Technical briefs
  - Module 3a/Day 1: None
  - Module 3b/Day 2: Briefing to senior leaders (45 minutes)
- Discussion will focus on
  - International collaboration and coordination
  - Decision-making in the face of uncertainties
  - Processes for identifying recommended courses of action

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

International Asteroid Warning Network

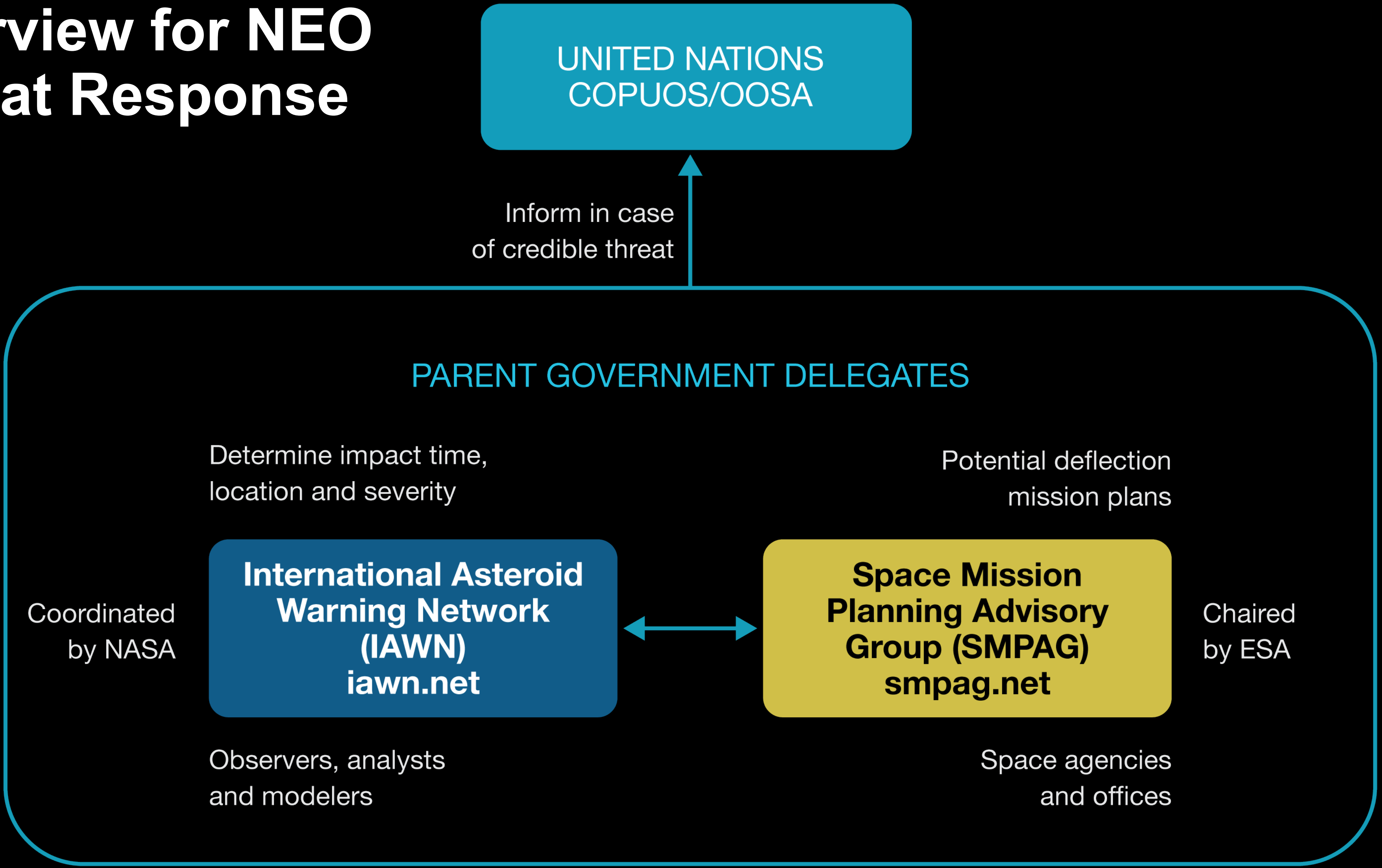
The International Asteroid Warning Network (IAWN)

- 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

Overview for NEO Threat Response



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*

International Asteroid Warning Network

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 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.

- 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.

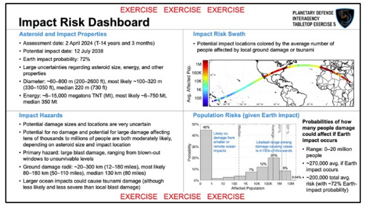


FIGURE 2. Impact risk summary, which provides a high-level overview of the asteroid threat and associated risks of impact.

International Asteroid Warning Network

EXERCISE EXERCISE EXERCISE

IAWN Notification

INTERNATIONAL ASTEROID WARNING NETWORK

Potential Asteroid Impact Notification: Hypothetical Scenario

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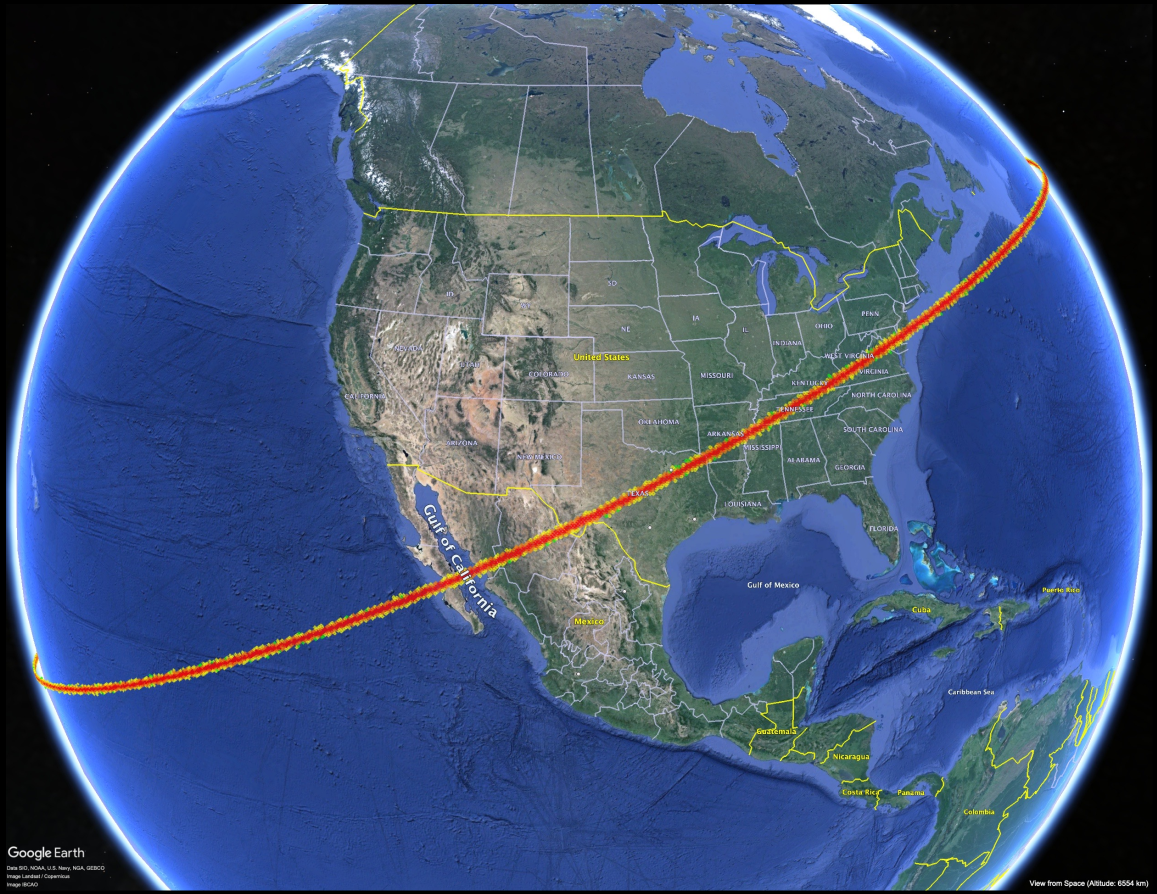
EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Impact Risk Corridor



Impact Risk Dashboard

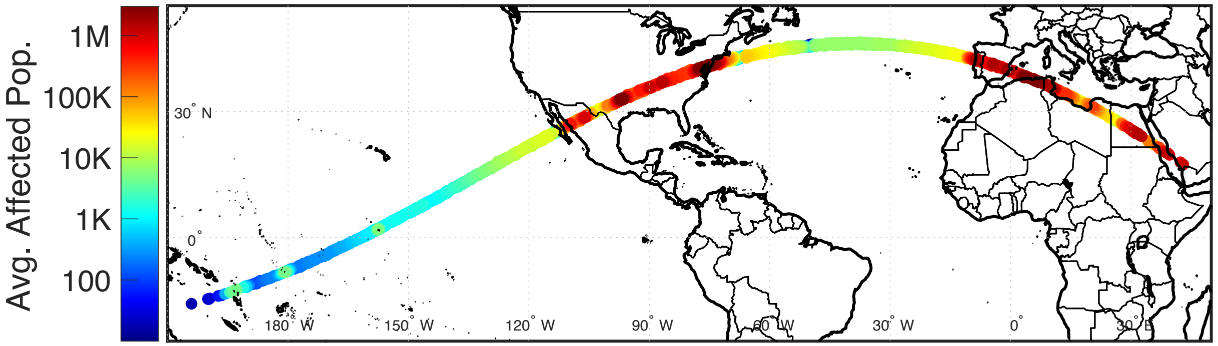
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

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

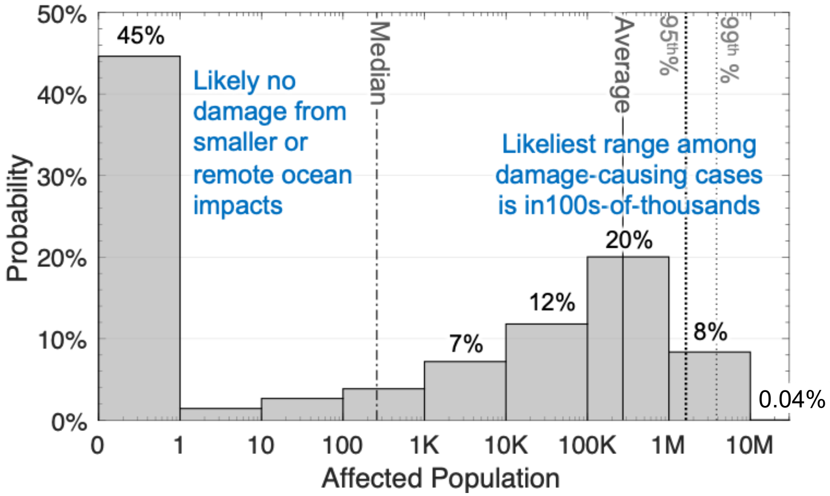
- Potential impact locations colored by the average number of people affected by local ground damage or tsunami



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

SMPAG

Space Mission Options

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

5th Interagency Planetary Defense Tabletop Exercise
April 2024

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.

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.
.

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.

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)

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

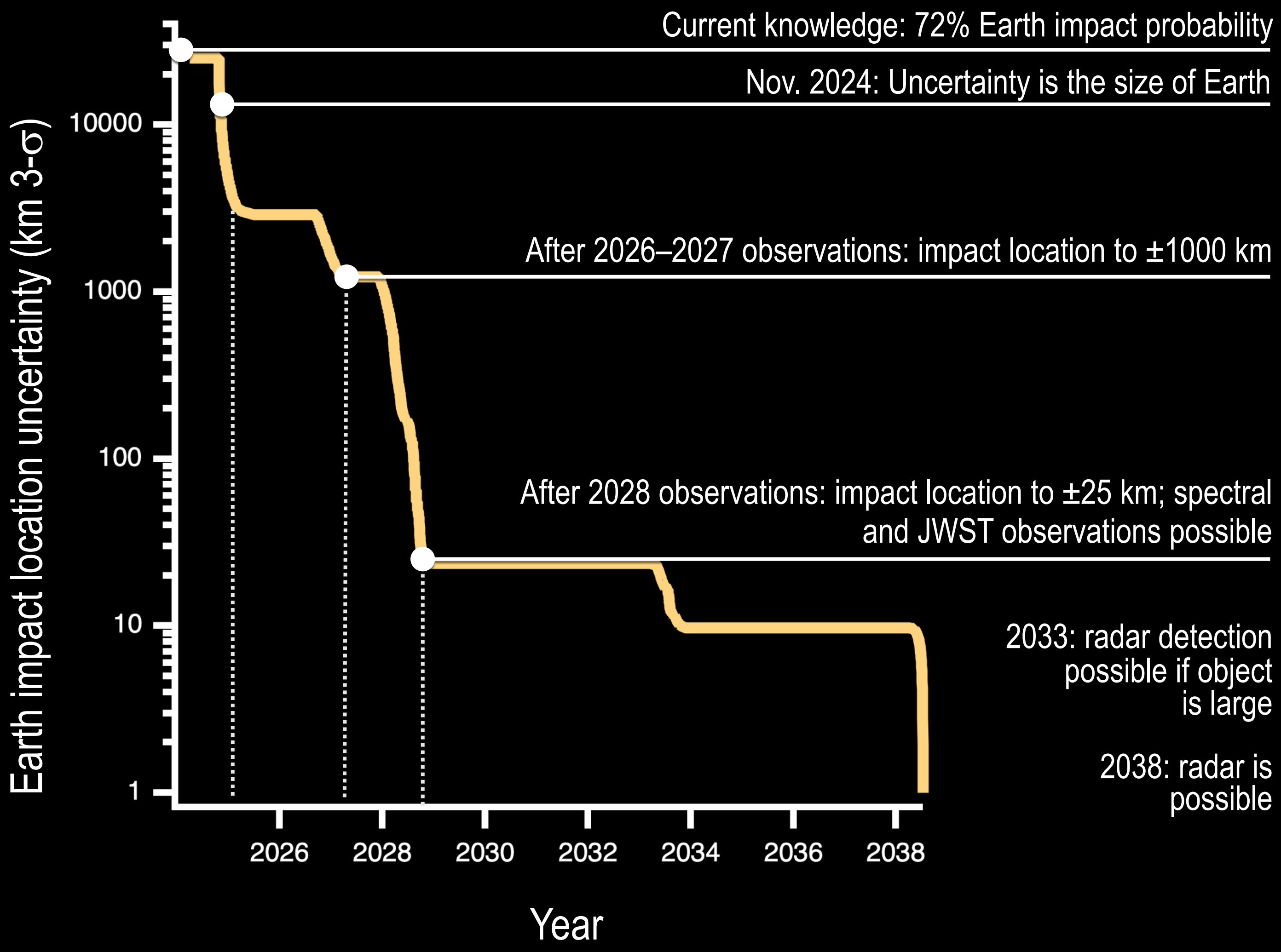
PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 5

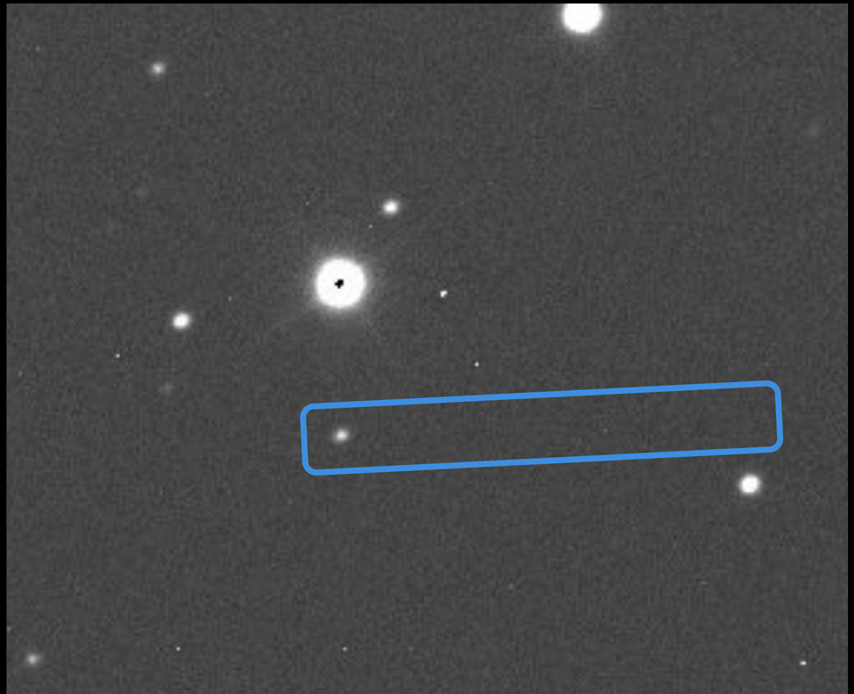
Space Mission Options

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)

Potential Information from Earth-Based Telescopes





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.

PLANETARY DEFENSE
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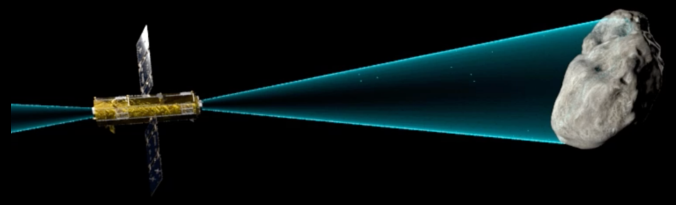
Asteroid Impacts May Be Preventable

Kinetic Impact



Ion Beam

Nuclear Explosive Devices

Successful impact prevention requires **adequate warning time** and **information about key asteroid properties**.

In This Scenario, Deflection Is Preferred

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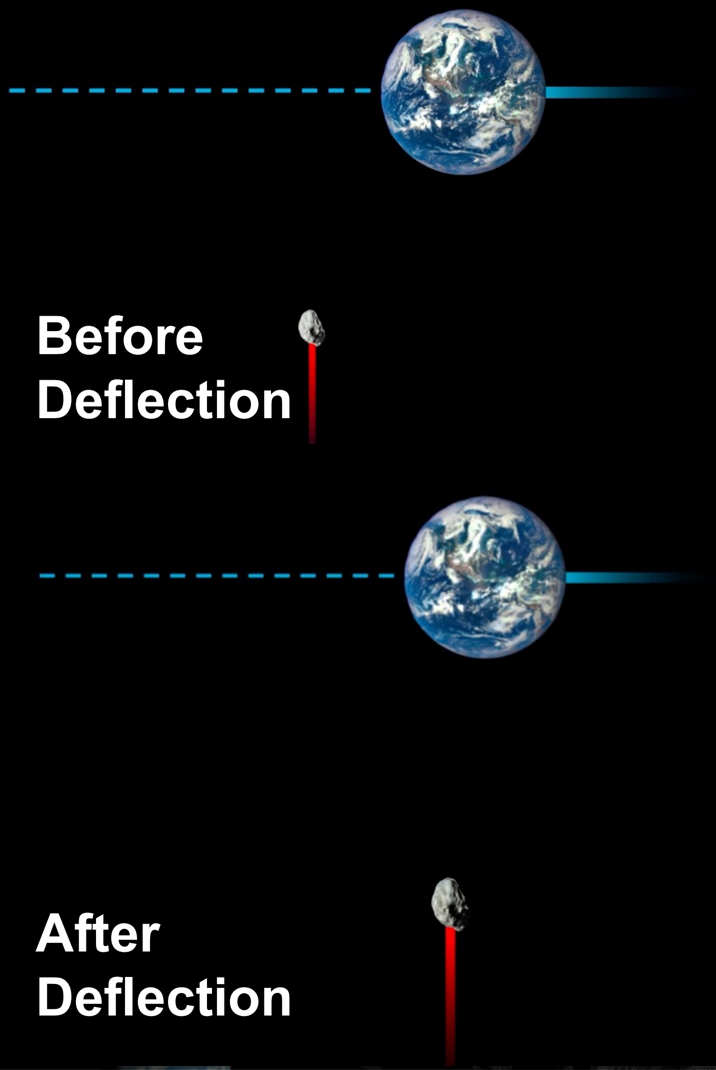
- Given what we know at this time in the scenario, disruption (breaking the asteroid into multiple smaller pieces) is impractical for ~80% of the potential asteroid masses.
- To avoid Earth impact, an asteroid can be **deflected** by changing its speed (slowing it down or speeding it up) but leaving 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.



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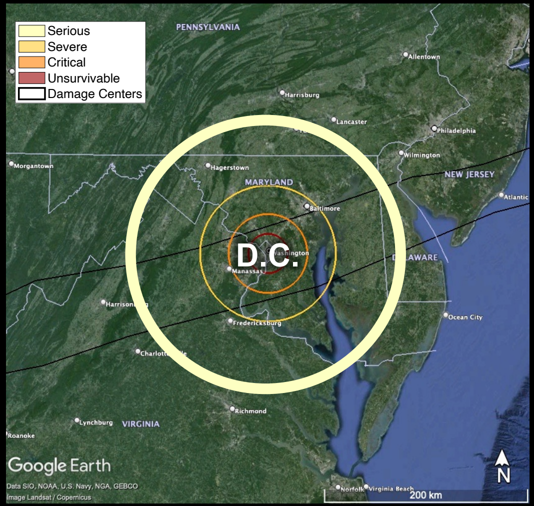
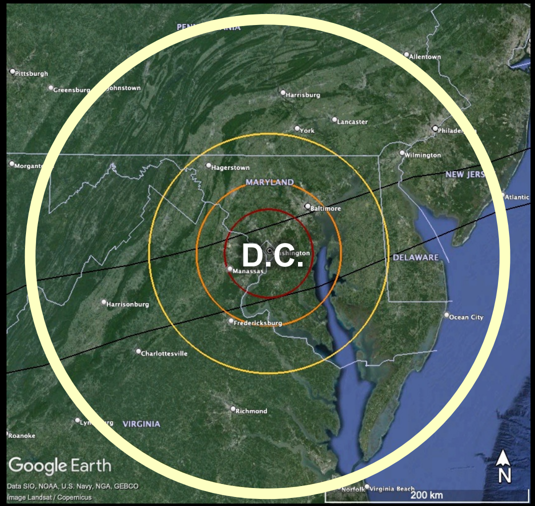
The Asteroid's Properties Are Highly Uncertain

What would emergency management organizations face?

What would impact-prevention mission(s) have to deal with?



50th percentile



95th percentile

Key Drivers for Impact Prevention Missions

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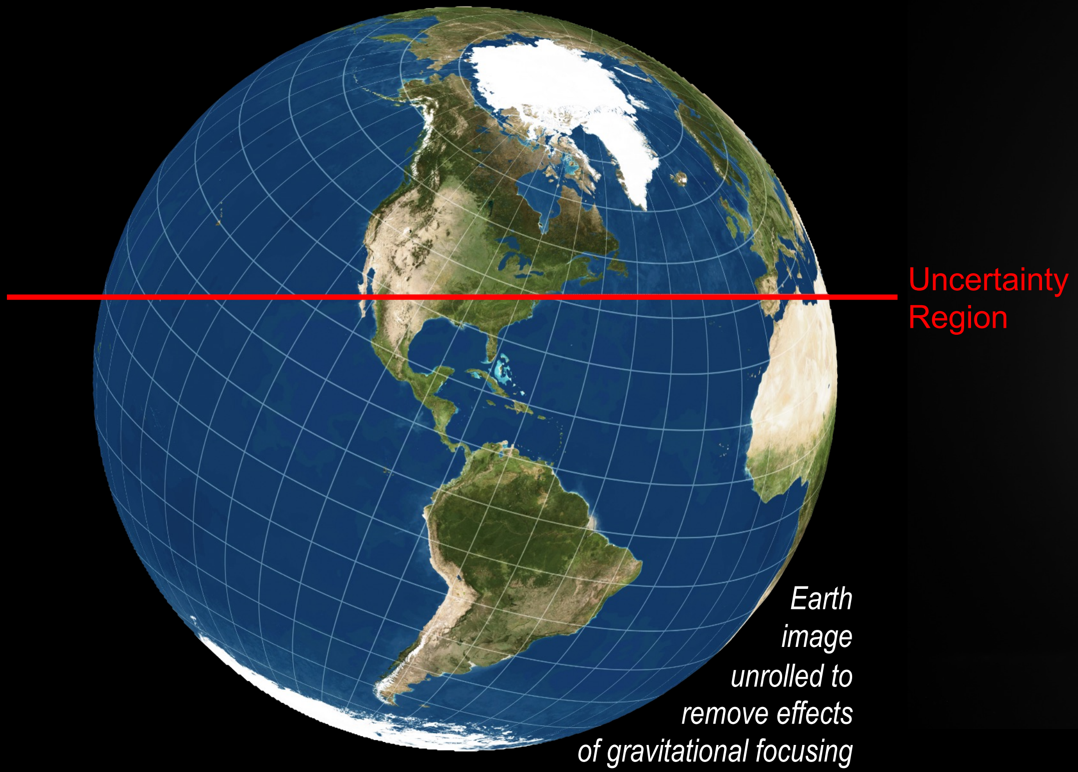


Asteroid mass

Earth impact location

Time to impact

A recon mission could reduce uncertainties in both of these.

The sooner you start, the easier the task

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

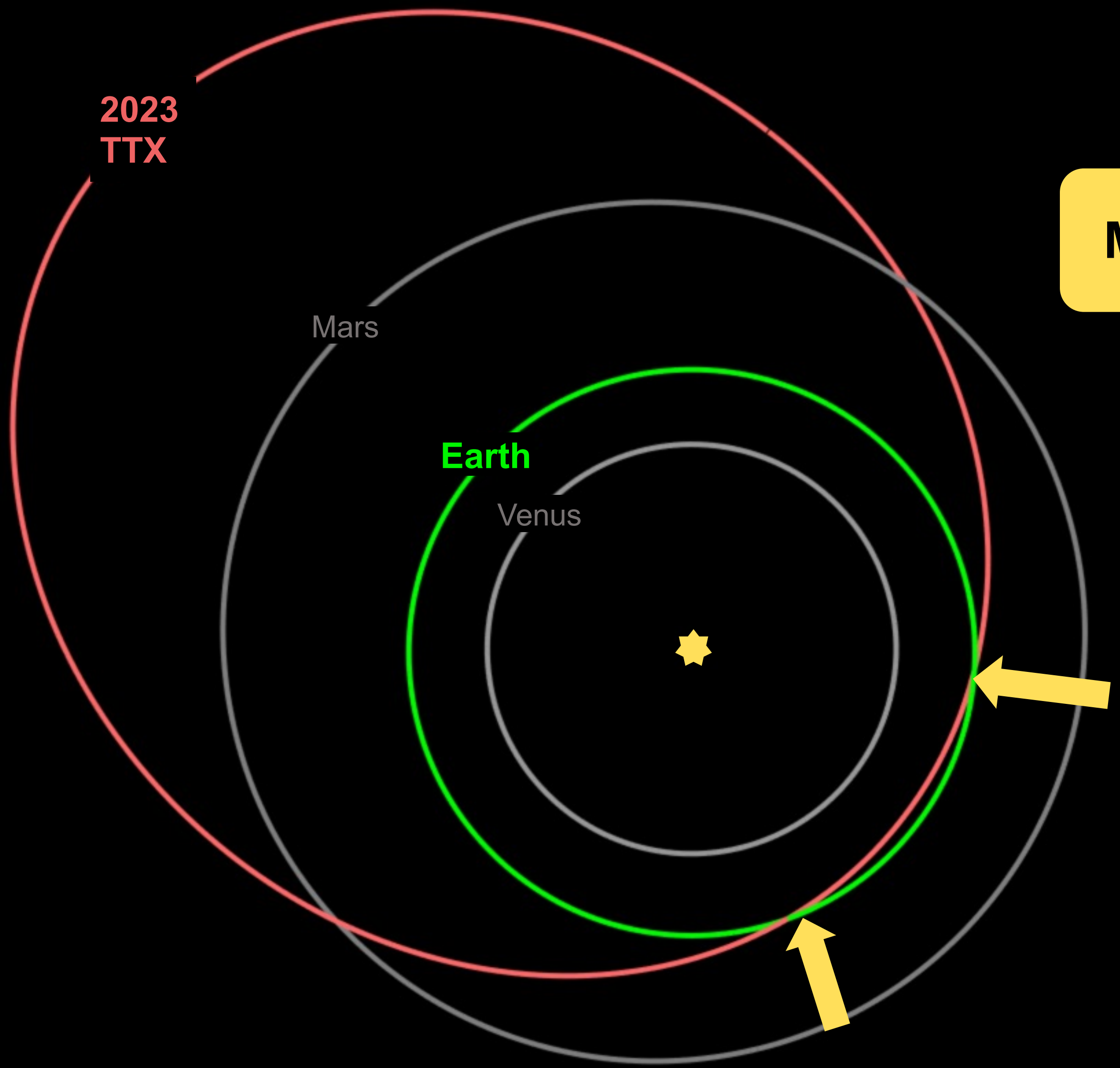
Send a spacecraft to arrive at the asteroid and observe it up close for an extended period of time. Typical time from build to launch is **5 years**.

Design → **Build** → **Test** → **Launch** → Cruise → Encounter → Downlink → Analyze

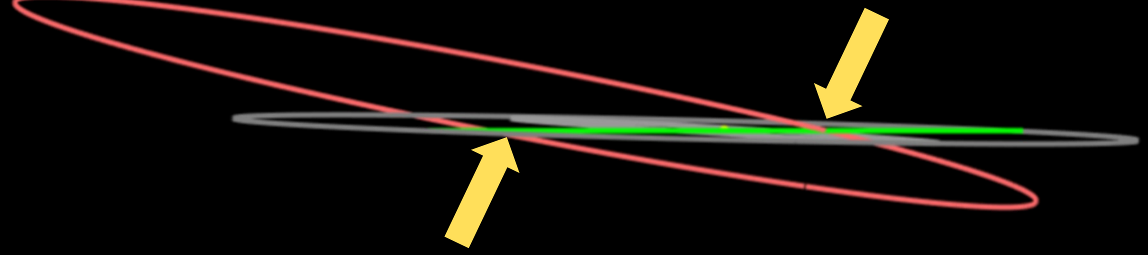
Time for each phase varies depending on the mission; equal block size does not represent equal time.

It is unknown how much these timelines could be compressed in an emergency.

The Asteroid's Orbit Dictates Mission Options

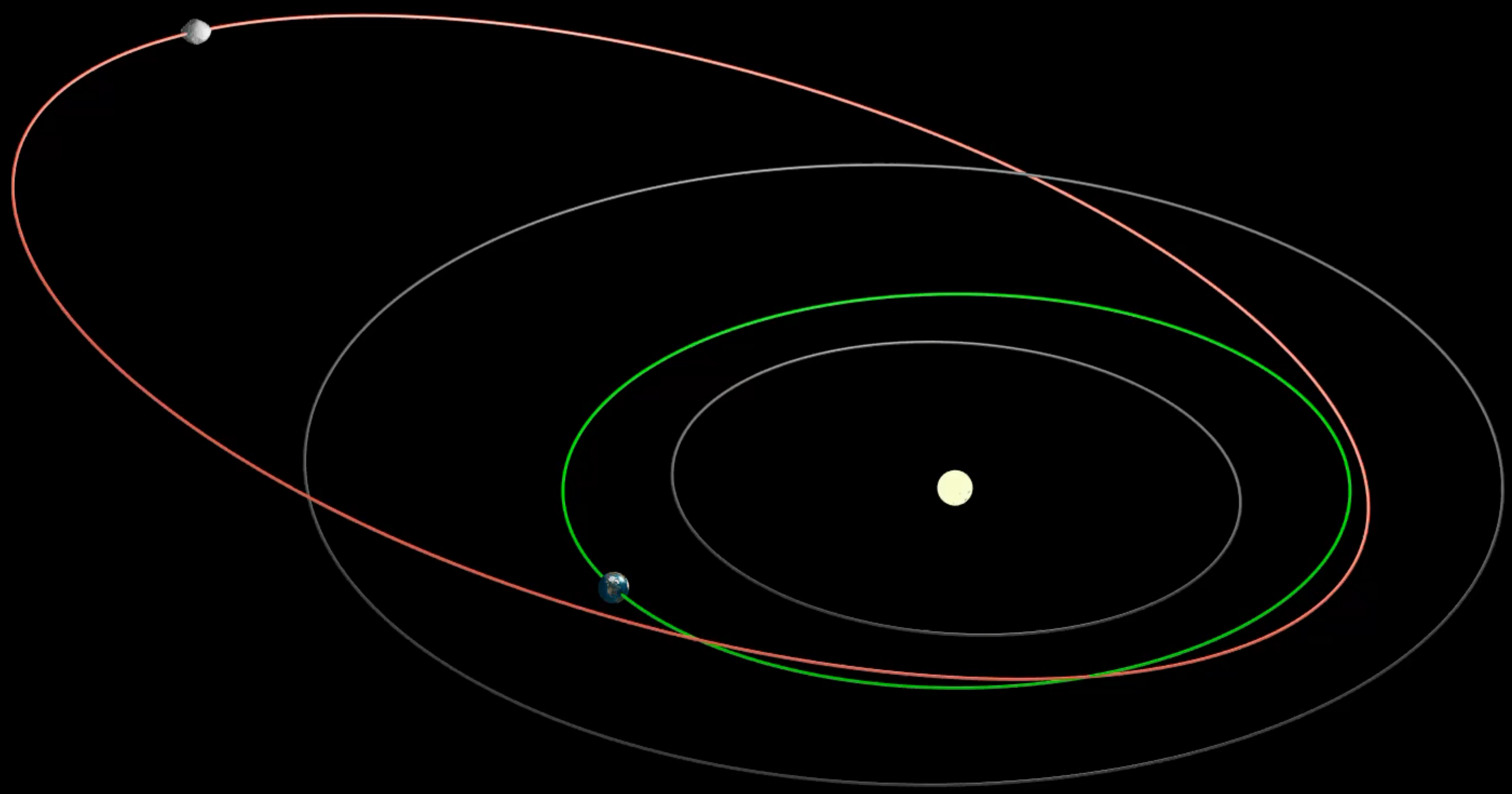


Mission opportunities repeat every ~2.5 years

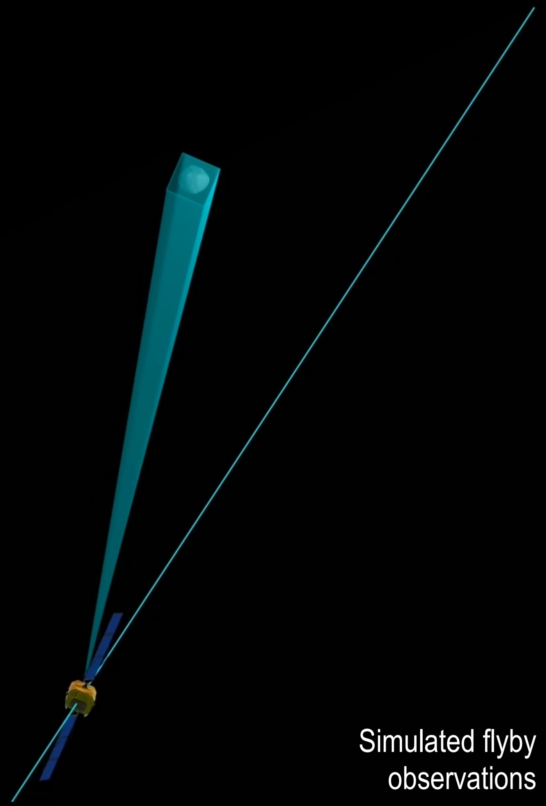


All viable space missions encounter the asteroid near where it crosses Earth's orbit.

Flyby Reconnaissance Example



Flyby Reconnaissance Example



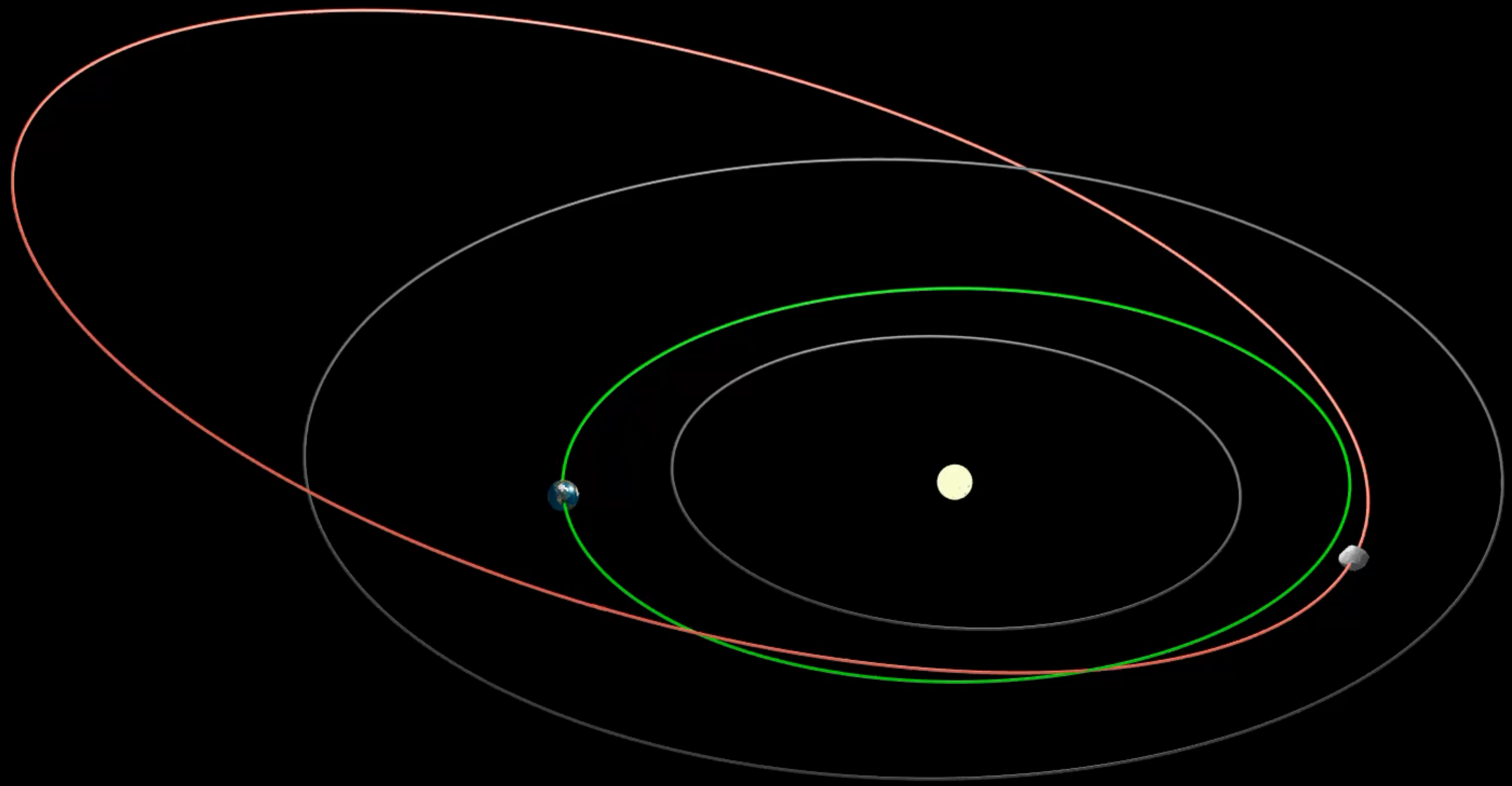
Simulated flyby observations

Actual images of comet Hartley 2 from EPOXI mission (2010)

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.

Rendezvous Reconnaissance Example



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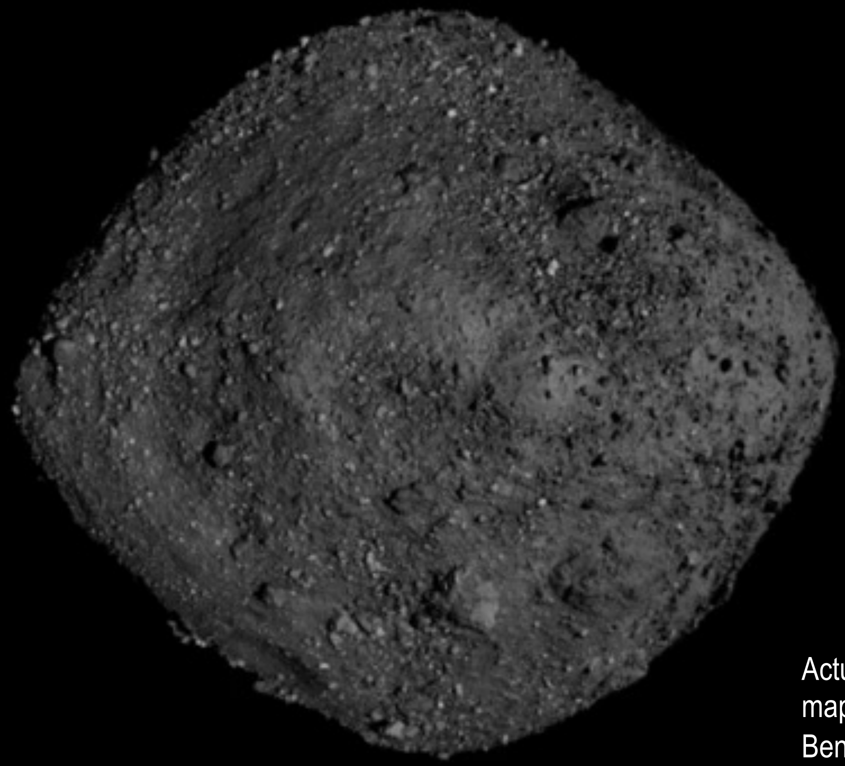
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Rendezvous Reconnaissance Example

Simulated rendezvous operations

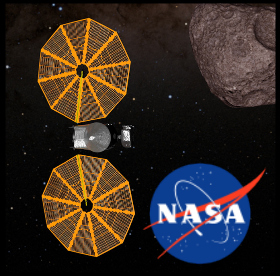


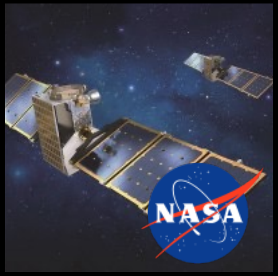
Actual OSIRIS-REx map of asteroid Bennu (2019)

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.

Repurposing Spacecraft for Reconnaissance





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.

PLANETARY DEFENSE
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Kinetic Impact (KI) Deflection

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)

Ion Beam (IB) Deflection

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

Nuclear Explosive Device (NED) Deflection

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

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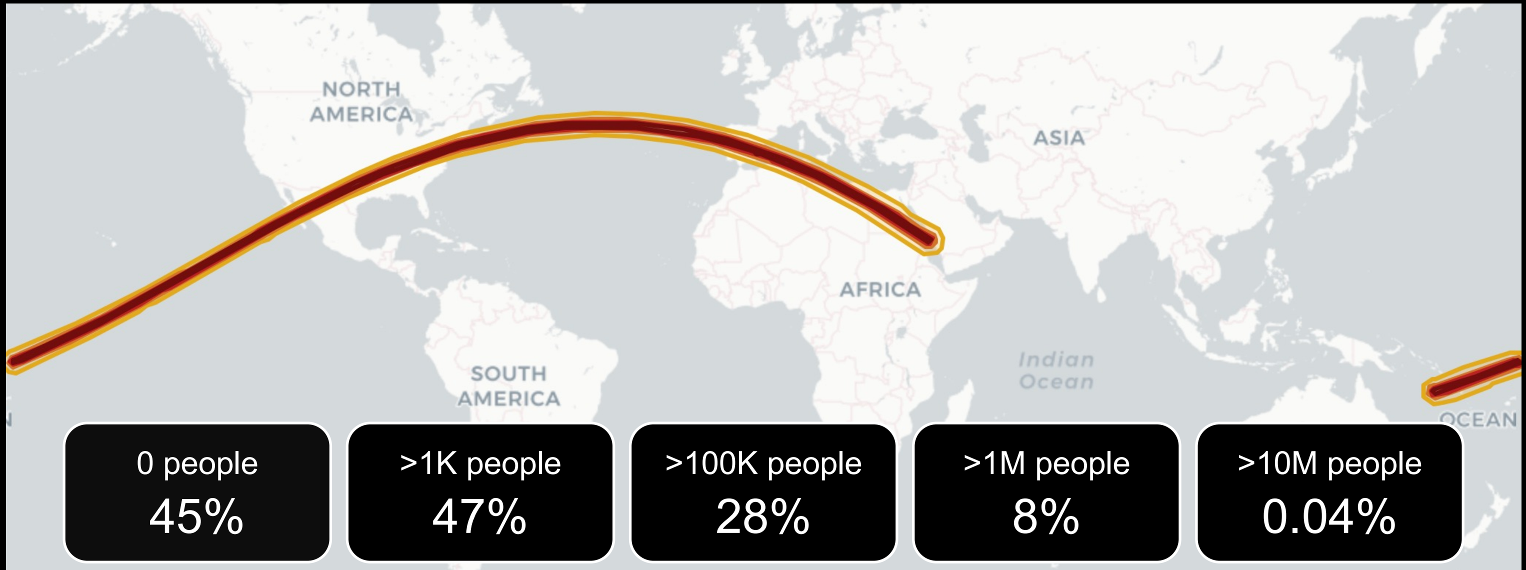

Affected people among Earth-impacting scenarios

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

Rendezvous
IB and NED deflection options

May 2028 · Dec 2030 · Dec 2032 · Dec 2035

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.

Potential Courses of Action

Recommendations based on Day 1 discussions

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.

   ROM LCC ~$200M – $400M

   Work toward a November 2025 launch (accelerated timeline) with a July 2027 asteroid encounter.
   Option to fallback to September 2027 launch (typical timeline) with a July 2028 asteroid encounter.

   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.

   ROM LCC ~$800M – $1B

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

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- 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?

- 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.

- 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?

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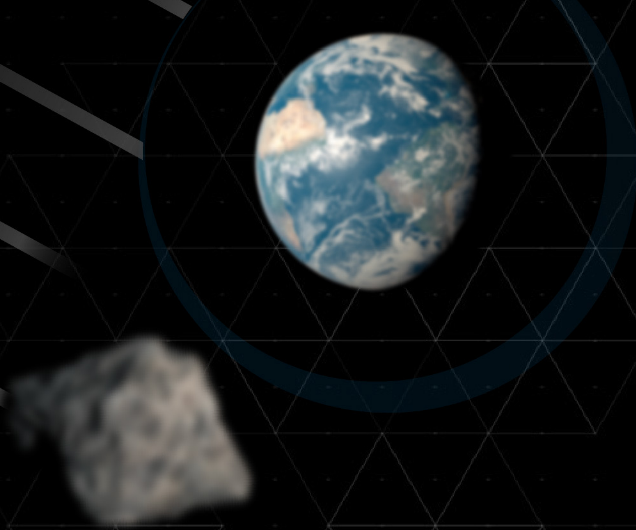


Initial Emergency Preparedness Actions

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

Disaster Preparedness for Asteroid Impacts

Earthquake

Volcanic eruption

Flood

Hurricane

Wildfire

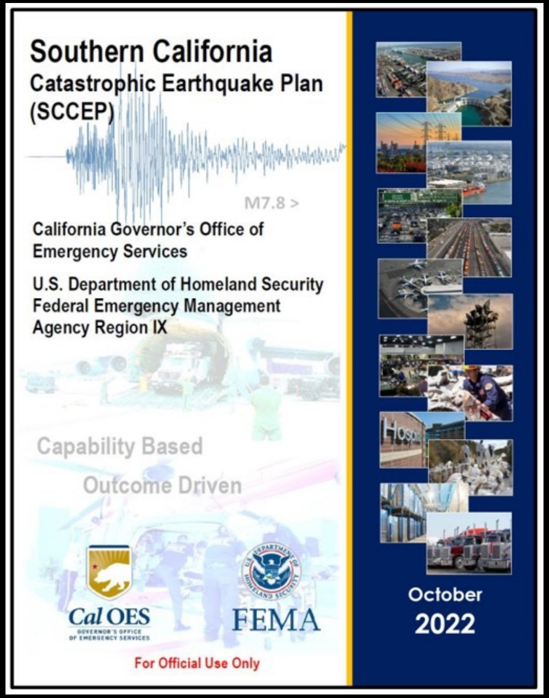
?

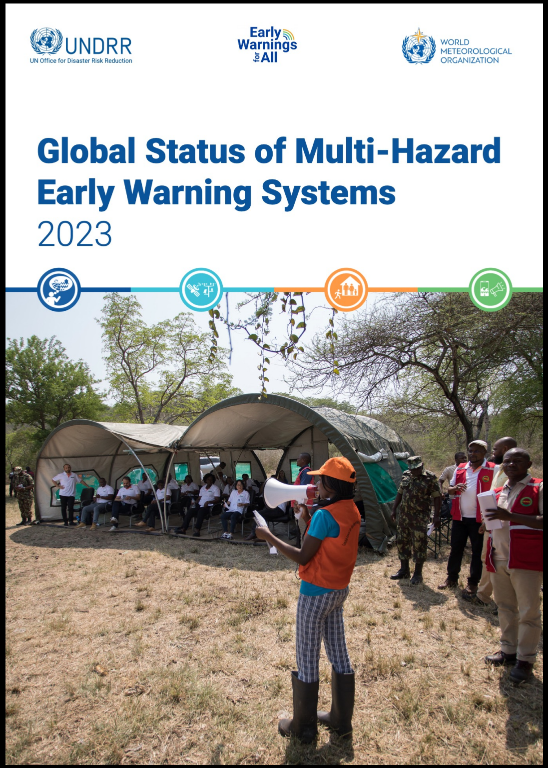
Asteroid impact

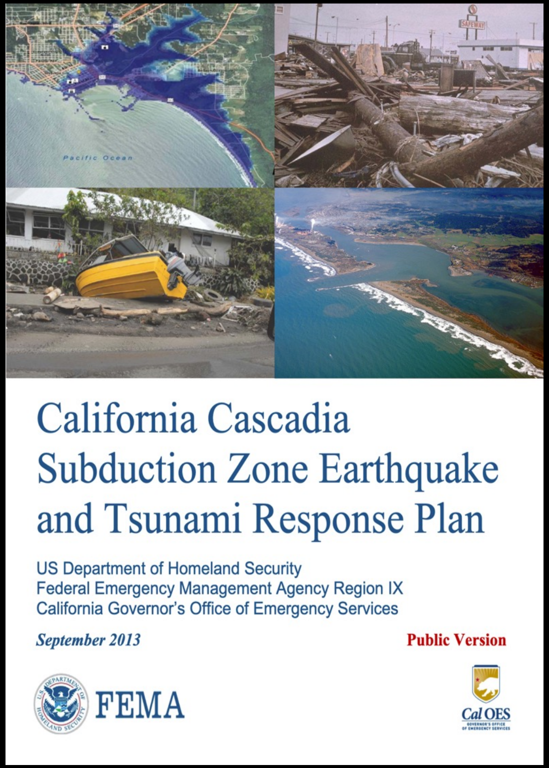
PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

Disaster Preparedness for Asteroid Impacts

Should a plan or checklist be considered?







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Asteroid impact

Possible International Organizations for Asteroid Impact Response Coordination and Planning

- 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)

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

- 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

- What disaster preparedness actions would you recommend at this time?

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.

Participant Feedback Forms

- 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.

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5

NASA

U.S. Department of Homeland Security

FEMA

APL

Johns Hopkins Applied Physics Laboratory

CNEOS

Ames Research Center

Lawrence Livermore National Laboratory

Break