Module 1: Scene Setting and Initial International Coordination

- Technical briefs
  - International Asteroid Warning Network (IAWN) notification
  - Current knowledge from telescopic observations
  - Earth impact risk assessment
- Discussion will focus on
  - Comprehension and information sharing about the asteroid threat
  - Notification pathways and processes
  - International coordination
  - Policies to guide decisions

INTERNATIONAL ASTEROID WARNING NETWORK

Potential Asteroid Impact Notification: Hypothetical Scenario

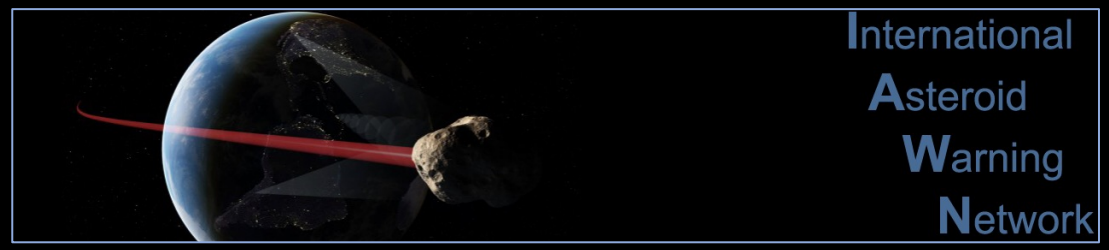
Date: 2 April 2024

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

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

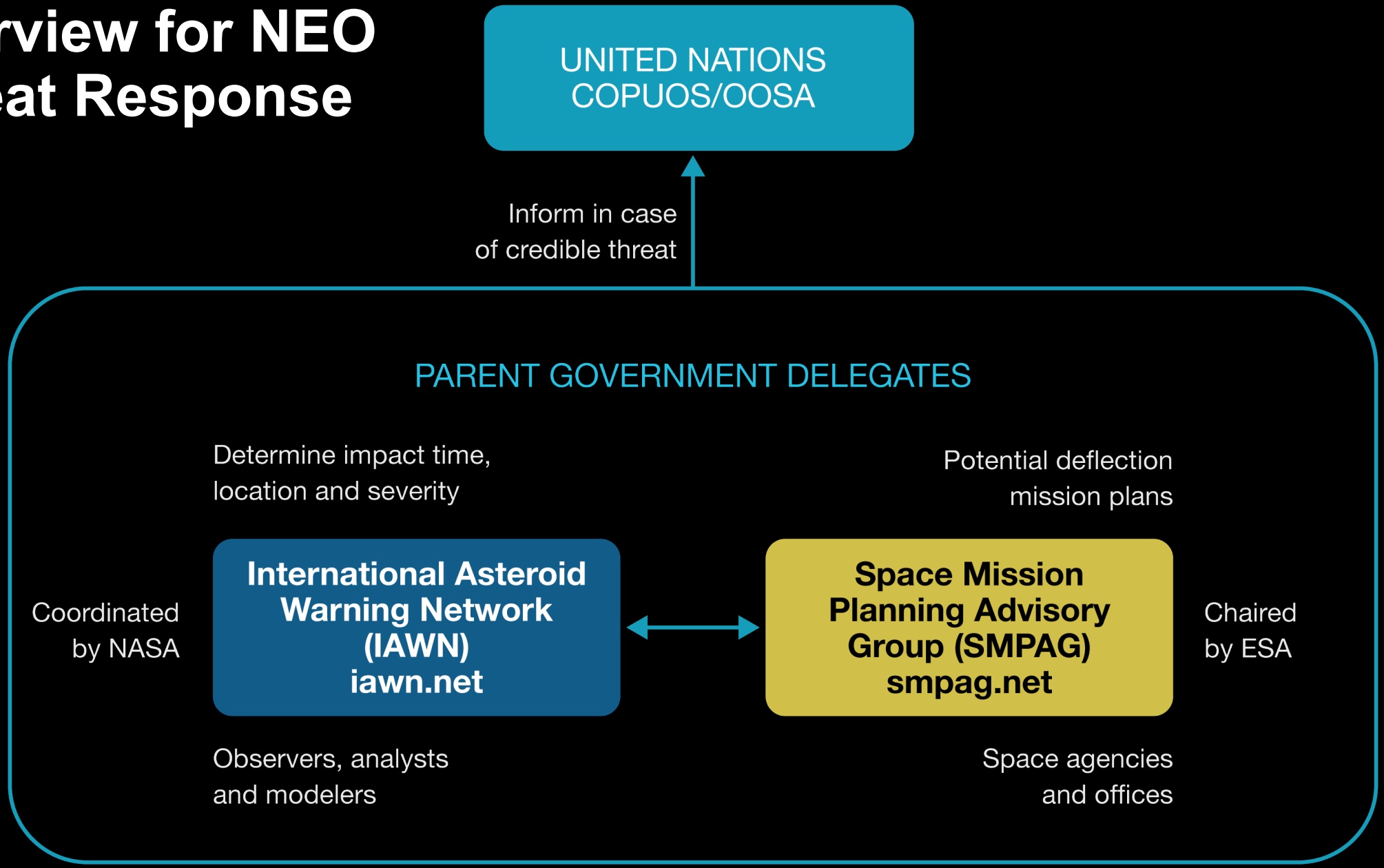
https://iawn.net/

The International Asteroid Warning Network (IAWN)

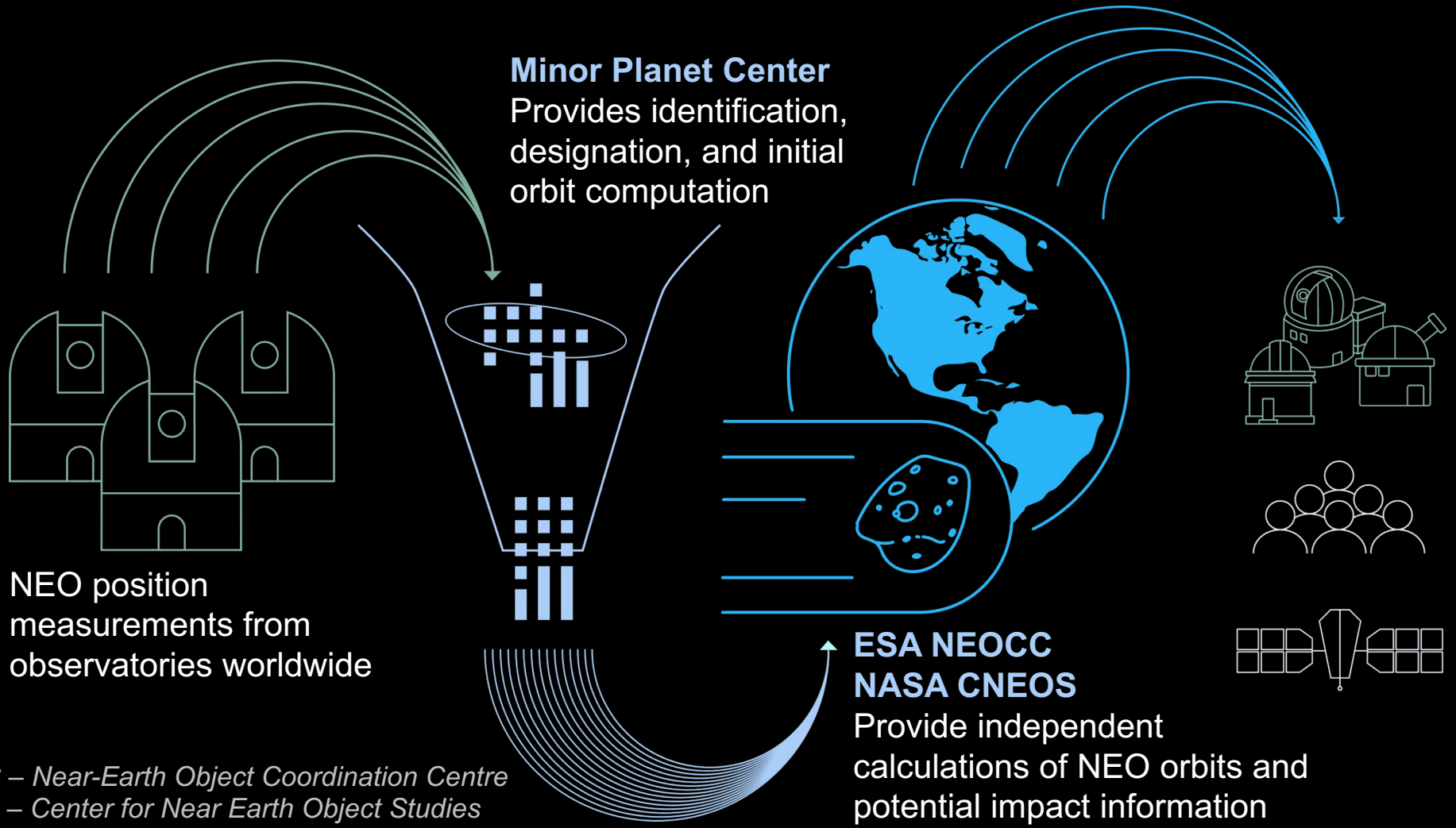
- A worldwide collaboration recommended by the United Nations to detect, track, and physically characterize near-Earth objects
- Signatories include scientific institutions, observatories, and independent astronomers involved in asteroid observations, orbit computation, and modeling
- IAWN's goal is to provide the most accurate and up-to-date information available on the impact potential and effects

Currently 56 signatories from over 25 countries

Overview for NEO Threat Response



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

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

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From: International Asteroid Warning Network (IAWN)

To: Chair, Space Mission Planning Advisory Group (SMPAG);
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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.

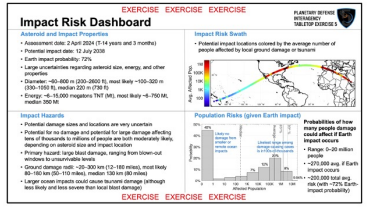

FIGURE 2. Impact risk summary, which provides a high-level overview of the asteroid threat and associated risks of impact.

EXERCISE EXERCISE EXERCISE

IAWN Notification

INTERNATIONAL ASTEROID WARNING NETWORK

Potential Asteroid Impact Notification: Hypothetical Scenario

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Additional information provided next by:

Paul Chodas, *NASA CNEOS*

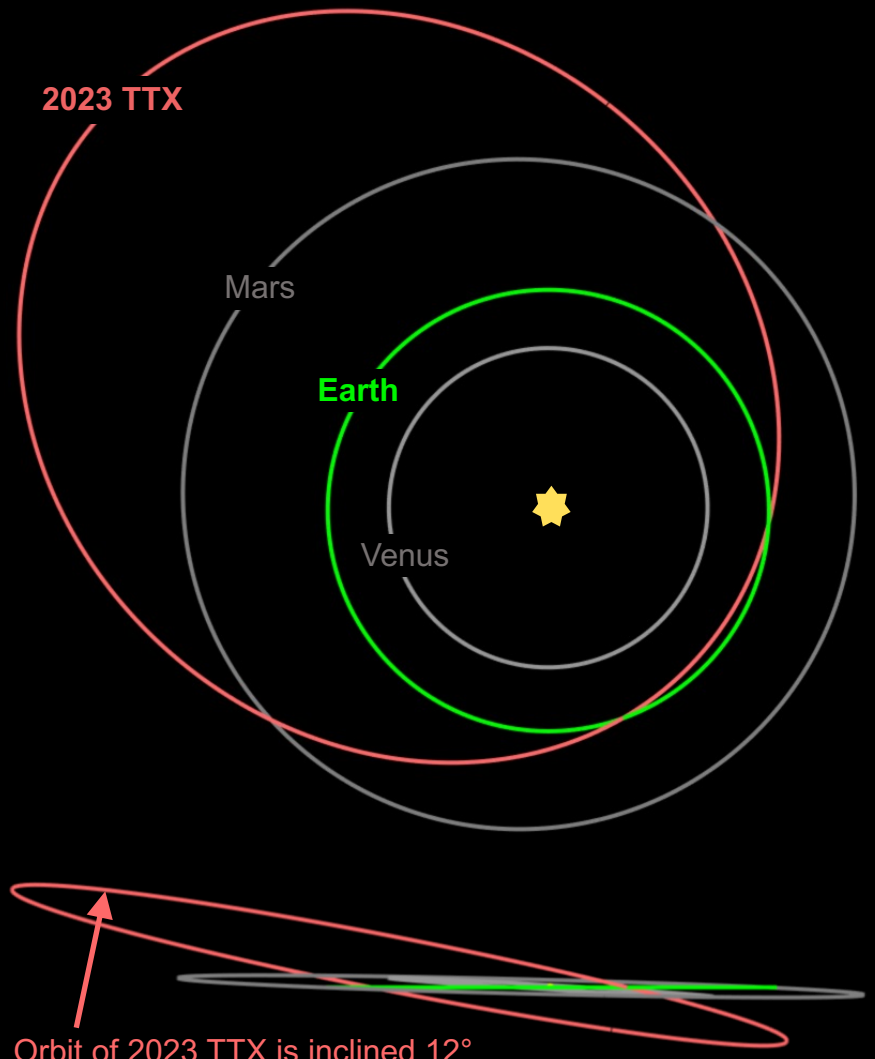
Lorien Wheeler, *NASA ATAP*

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)

Summary of Observations of Asteroid 2023 TTX

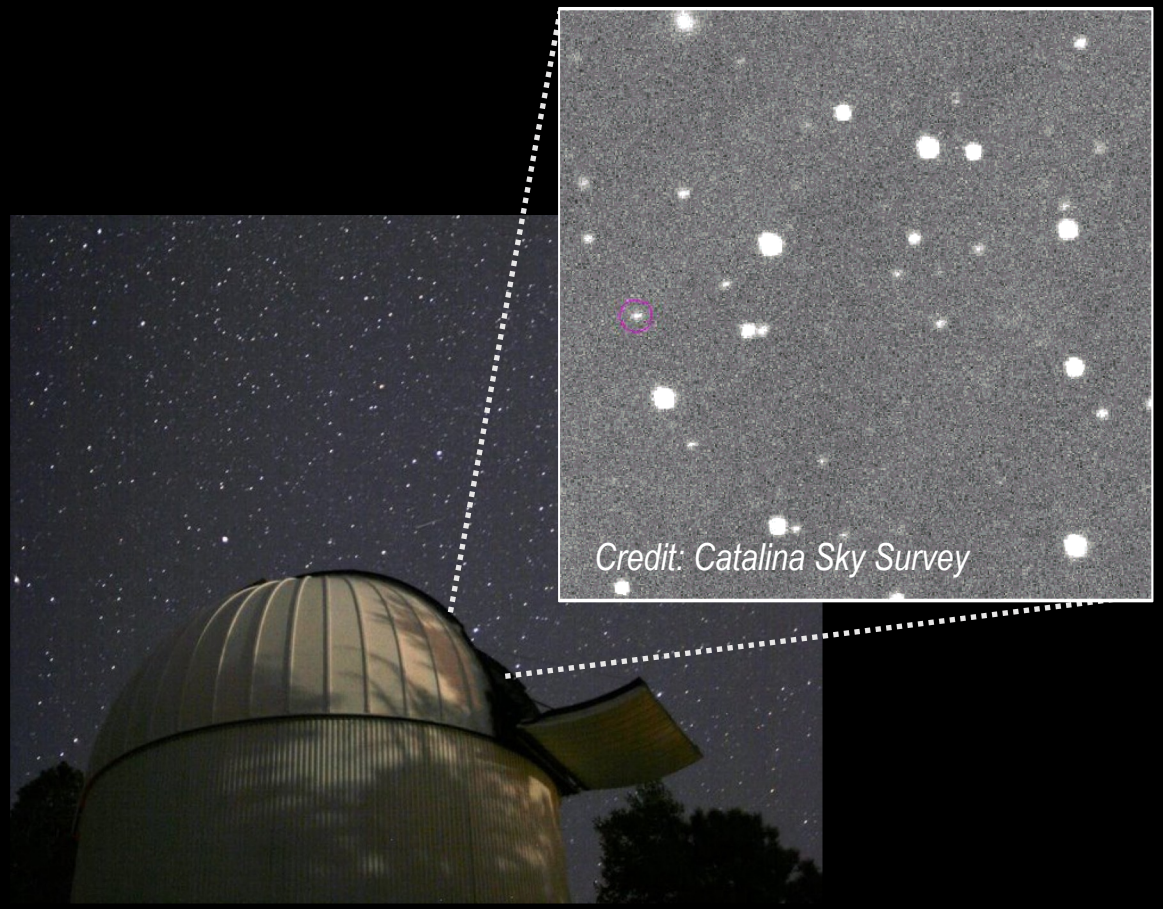


- Discovered on 4 October 2023
  - Asteroid 2023 TTX was also subsequently identified in archived data from previously acquired observations.
- Observations continued for five additional months.
- Observations have ended because the asteroid is now too close to the Sun as seen from Earth and too far 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%

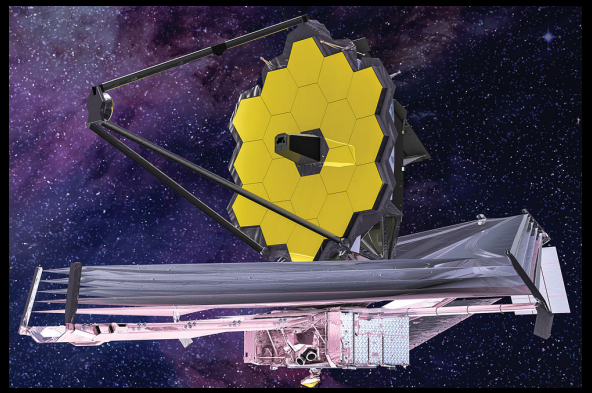
Sources of Telescopic Data



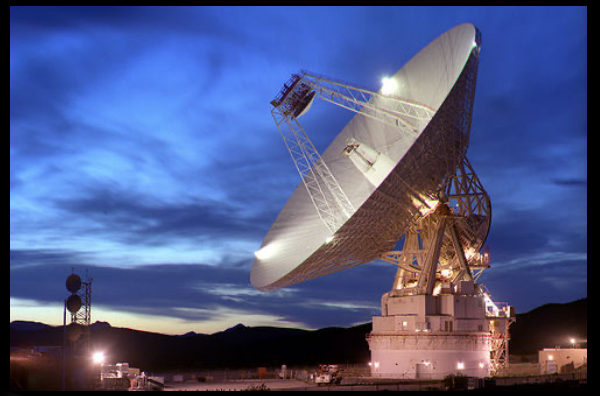
Ground-Based Optical and Infrared
Possible periodically over the next 14 years

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.



Space-Based Infrared
Might be possible in 2028



Ground-Based Radar
Might be possible in 2033

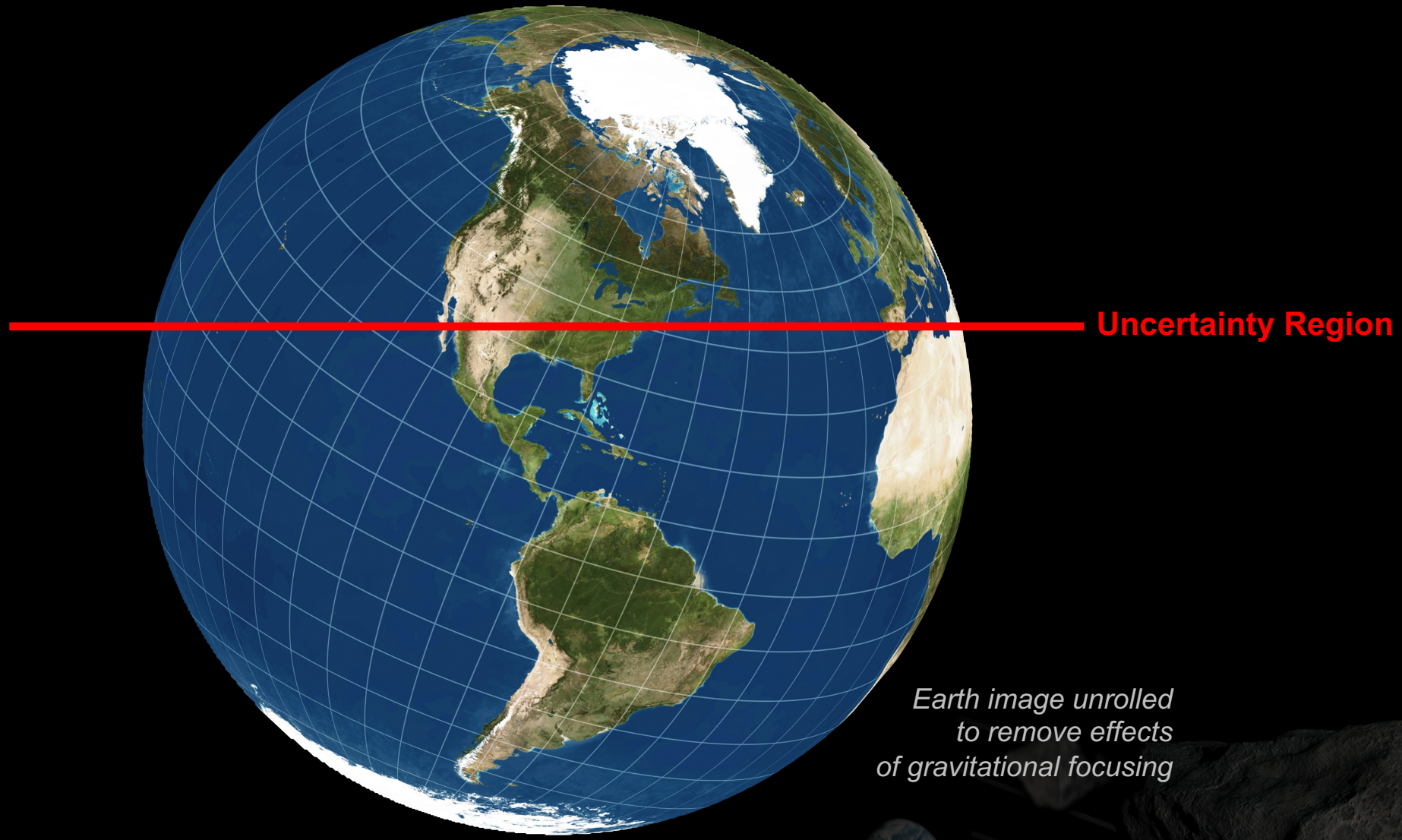
Uncertainty in Earth Impact and Location

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.

Uncertainty in Earth Impact and Location

Current Earth impact probability: 72%

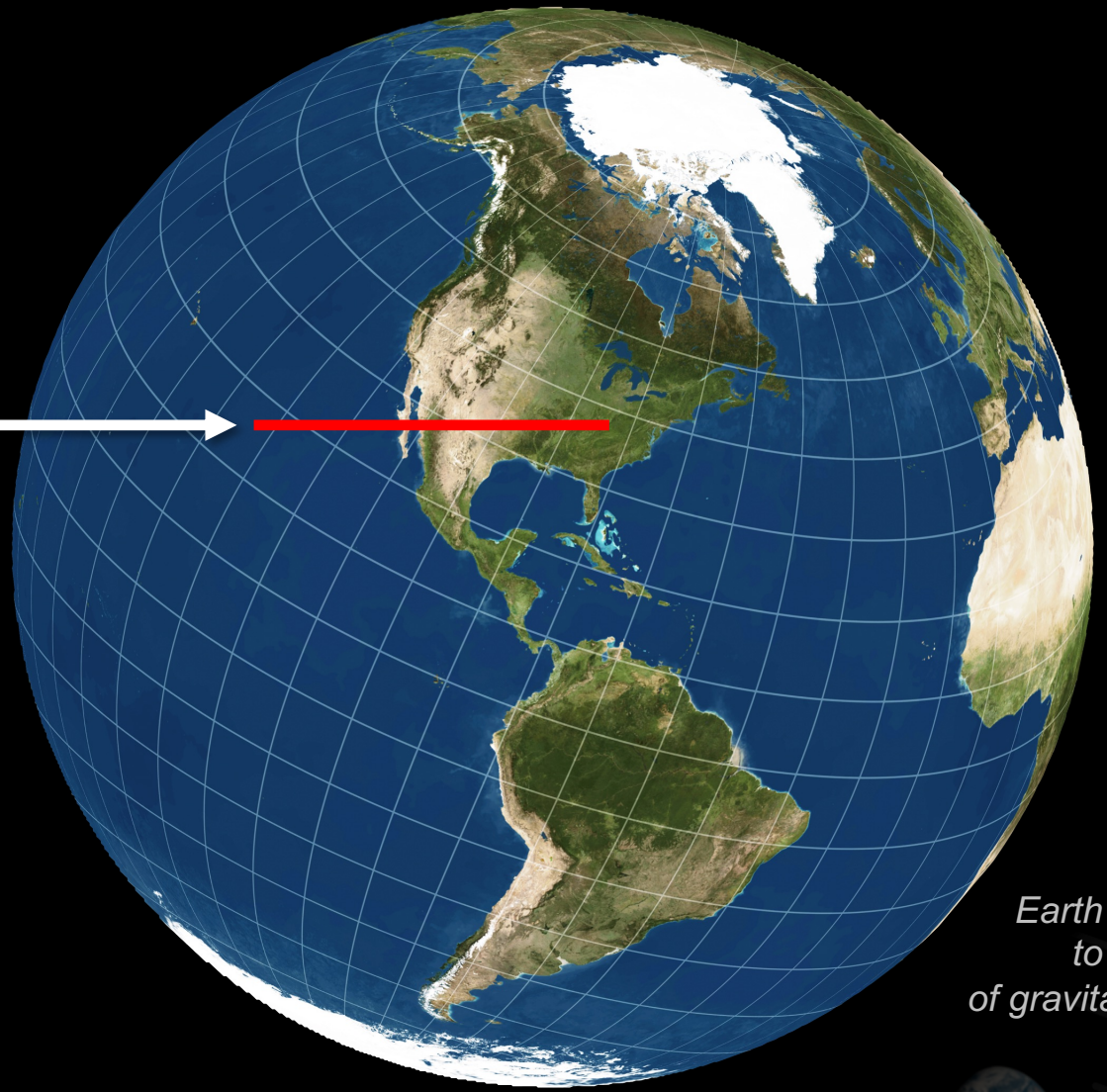


Earth image unrolled to remove effects of gravitational focusing

Uncertainty in Earth Impact and Location

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

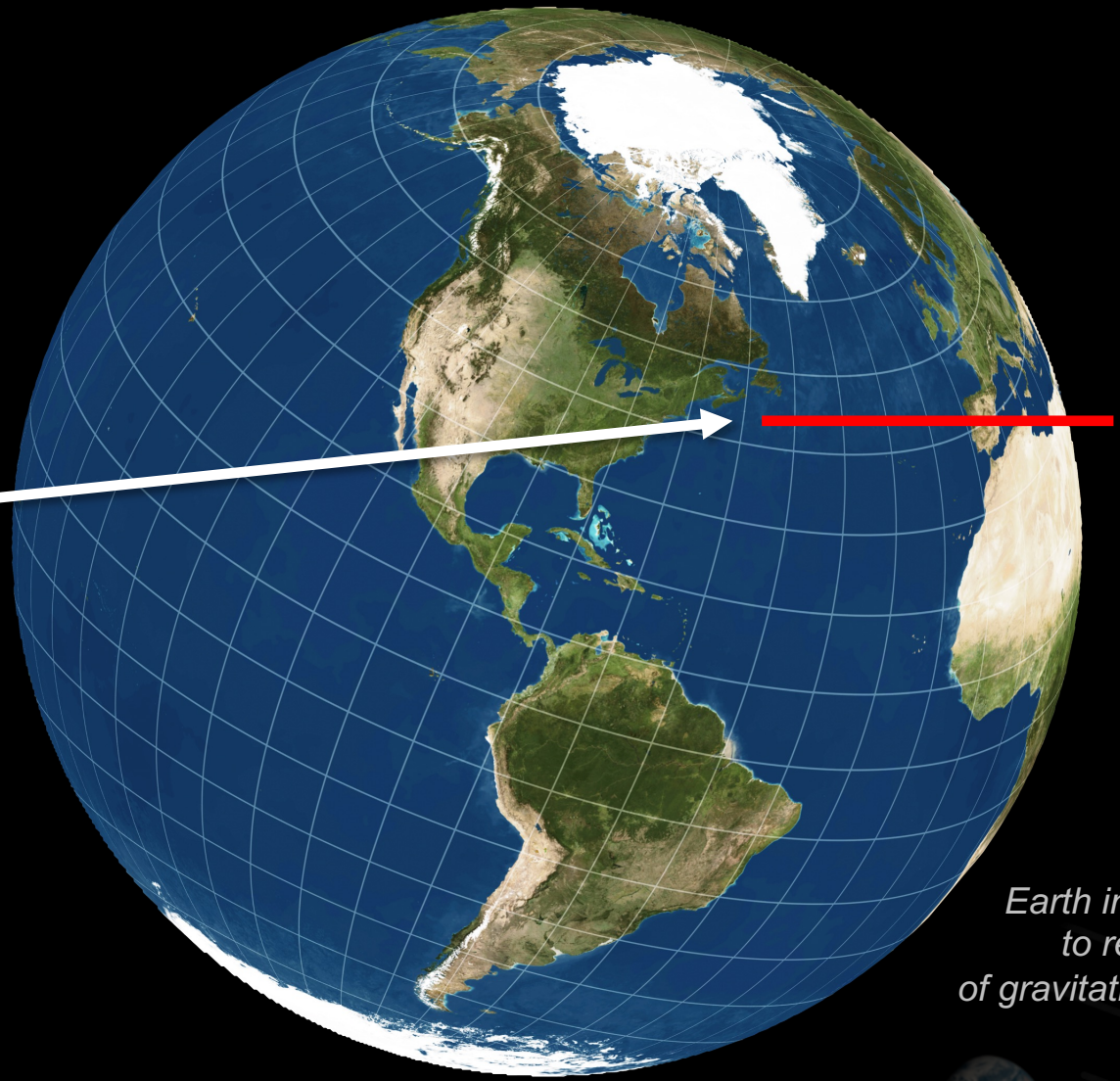
Earth image unrolled to remove effects of gravitational focusing

Uncertainty in Earth Impact and Location

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%)



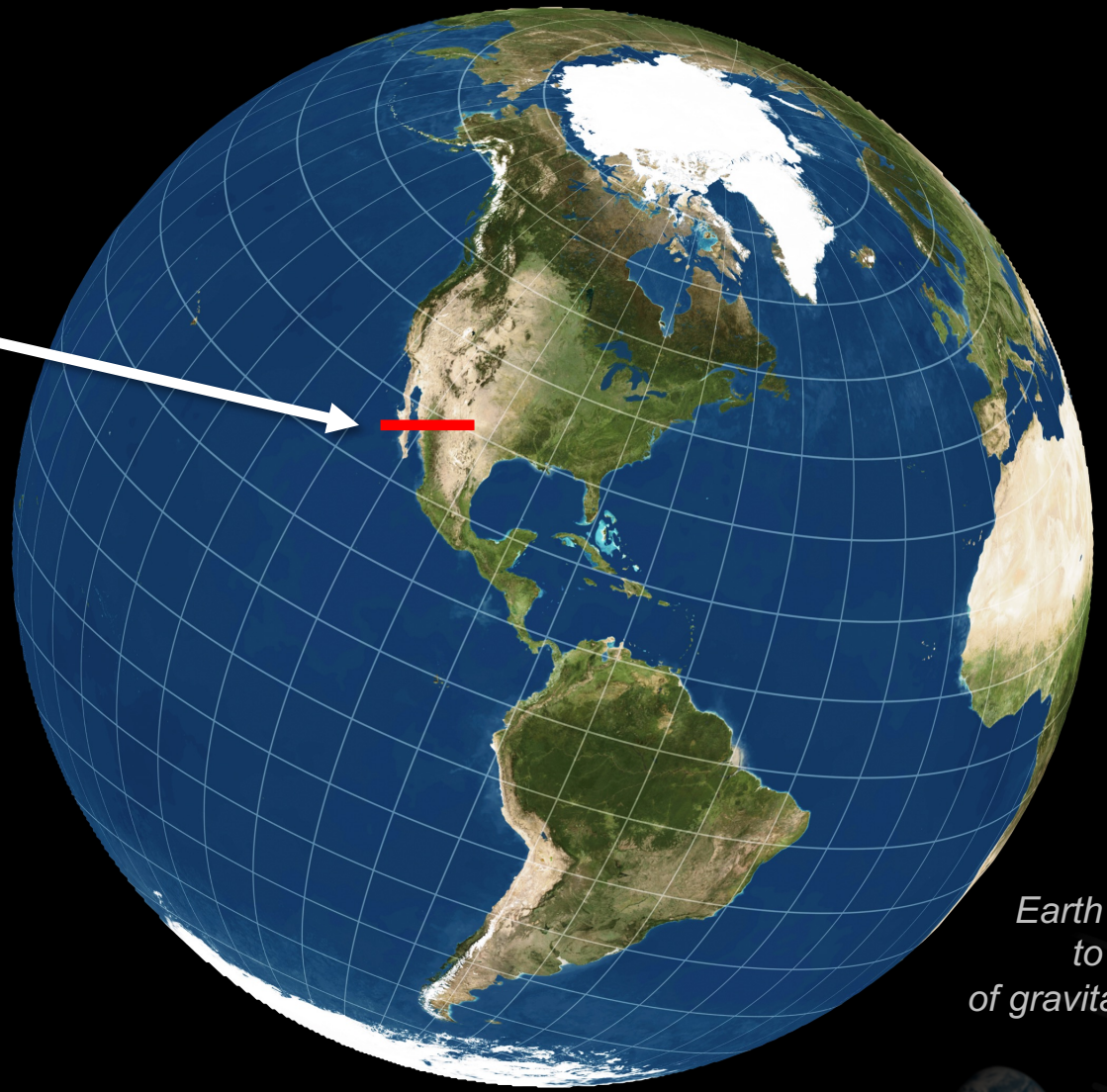
Possible Uncertainty Region in 2026

Earth image unrolled to remove effects of gravitational focusing

Uncertainty in Earth Impact and Location

In 2027, the predicted impact location could narrow down to:

Northern Mexico



Possible Uncertainty Region in 2027

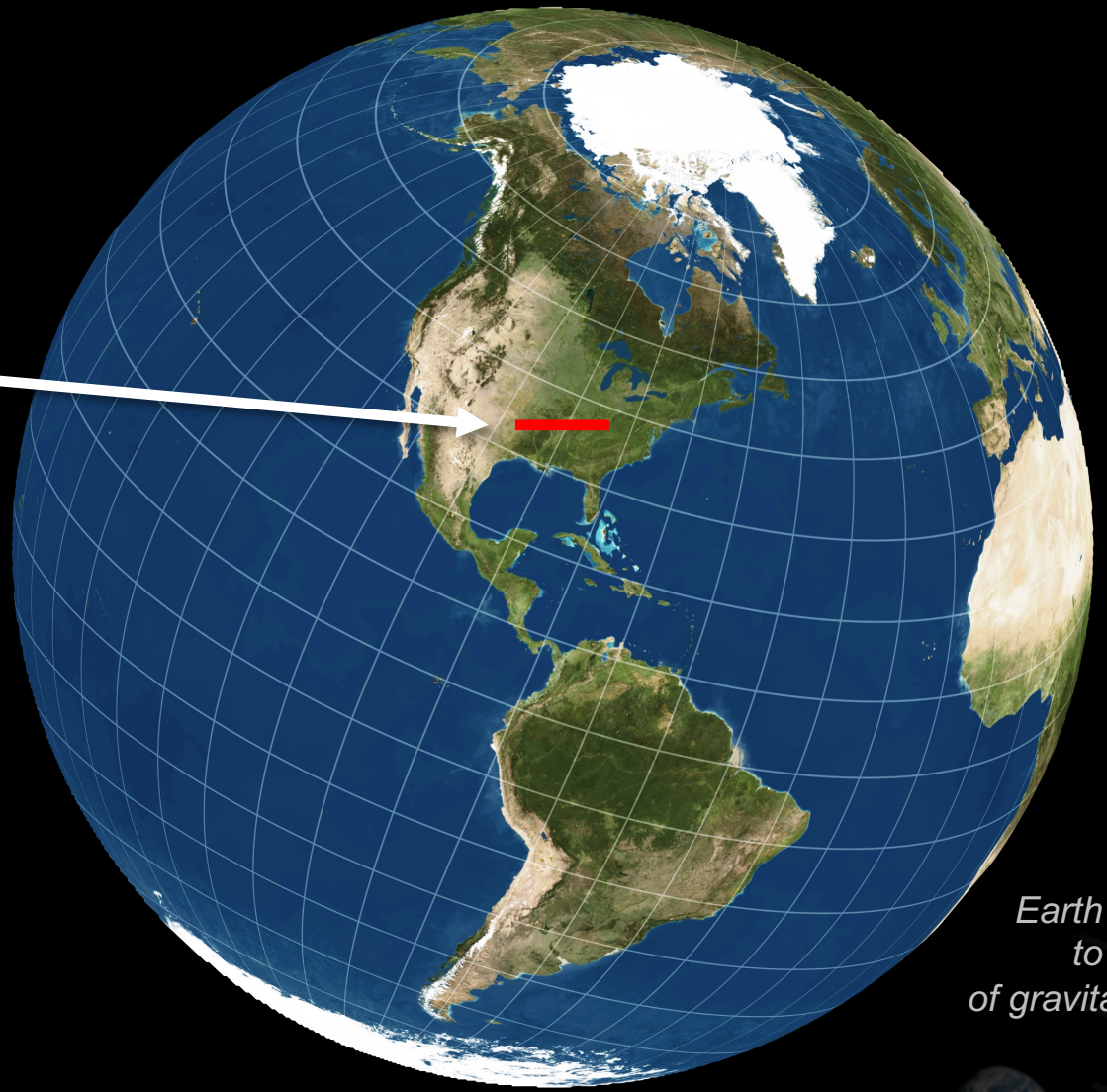
Earth image unrolled to remove effects of gravitational focusing

Uncertainty in Earth Impact and Location

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

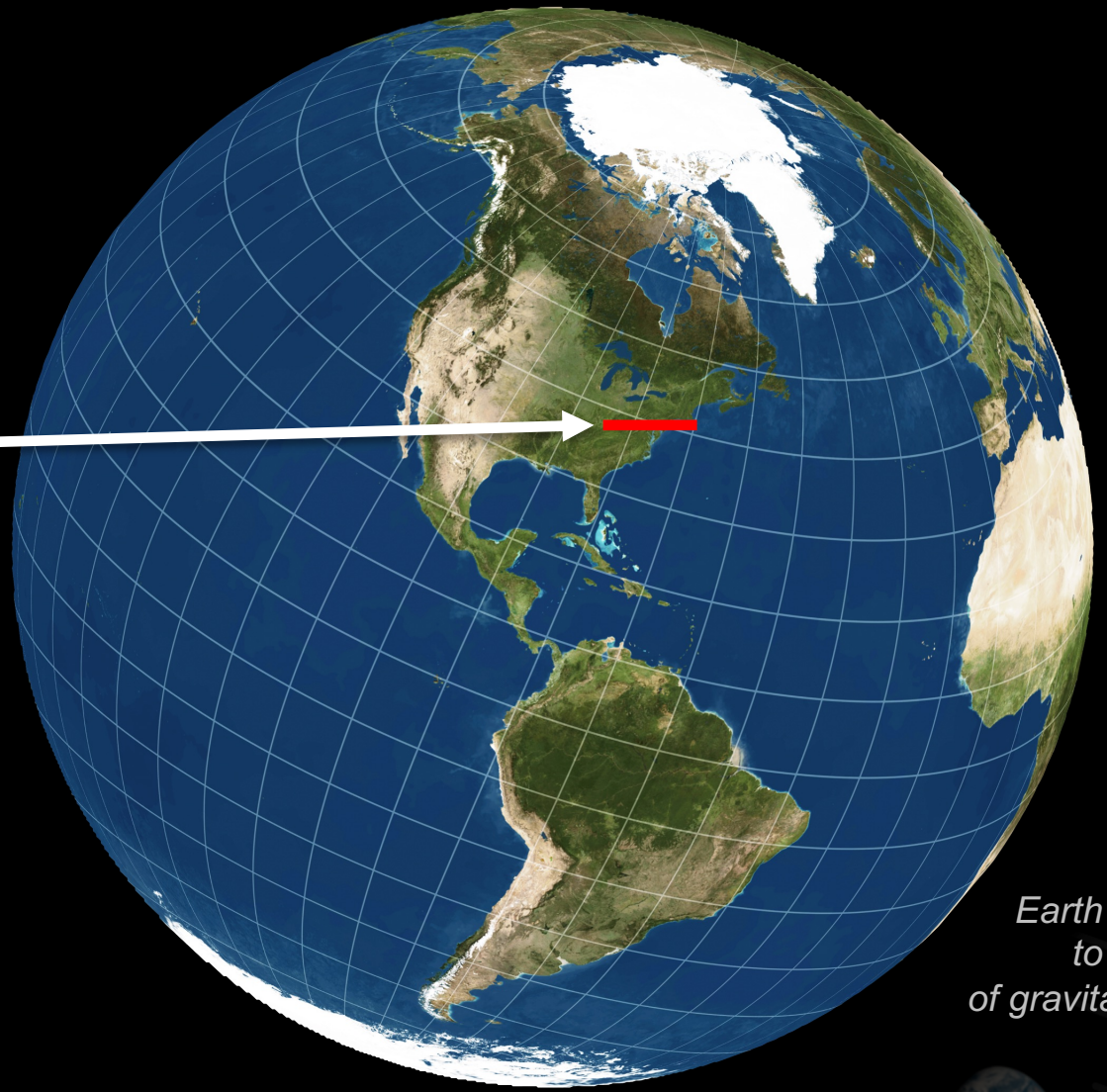
Uncertainty in Earth Impact and Location

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

Uncertainty in Earth Impact and Location

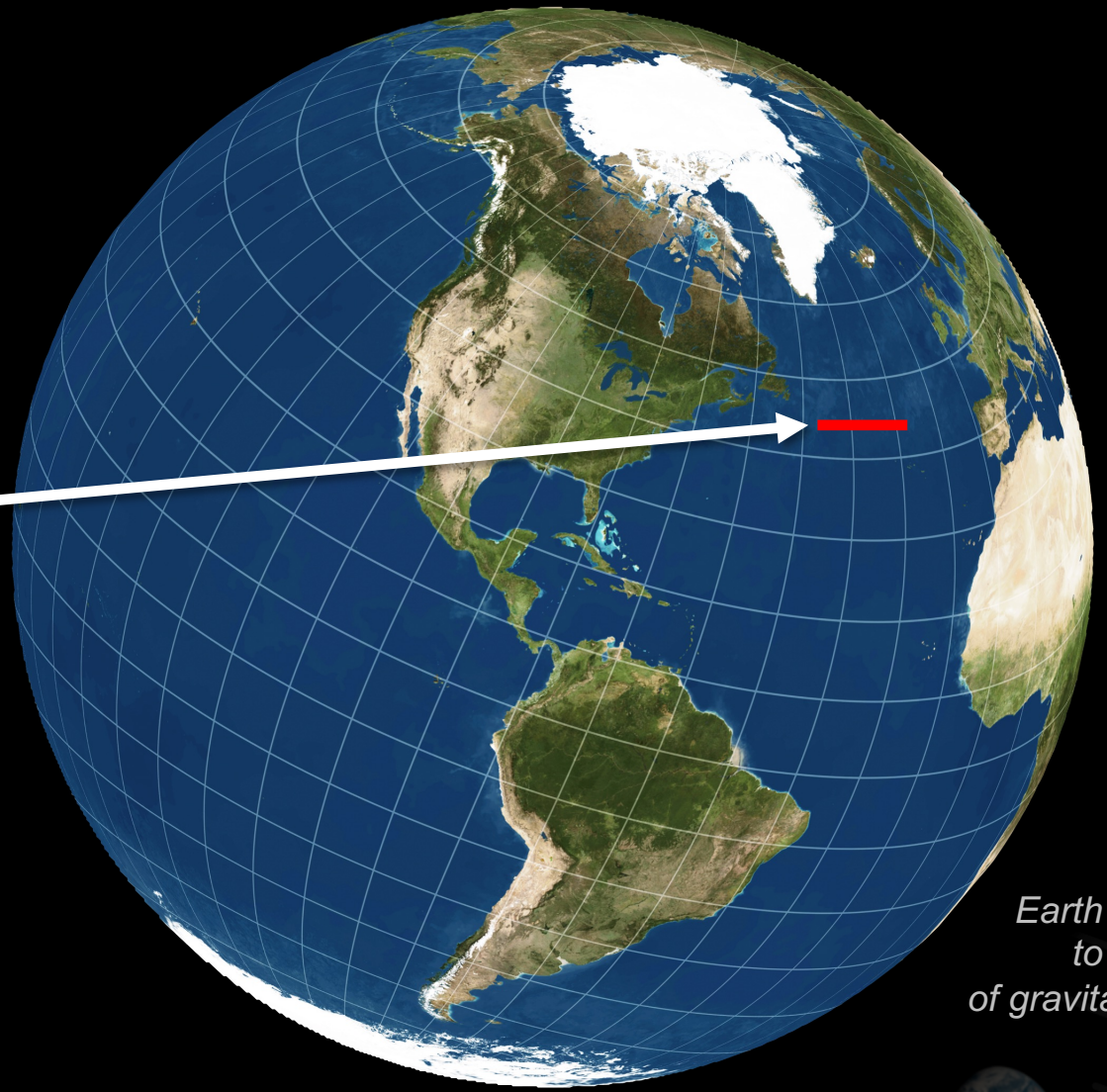
In 2027, the predicted impact location could narrow down to:

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

Uncertainty in Earth Impact and Location

In 2027, the predicted impact location could narrow down to:

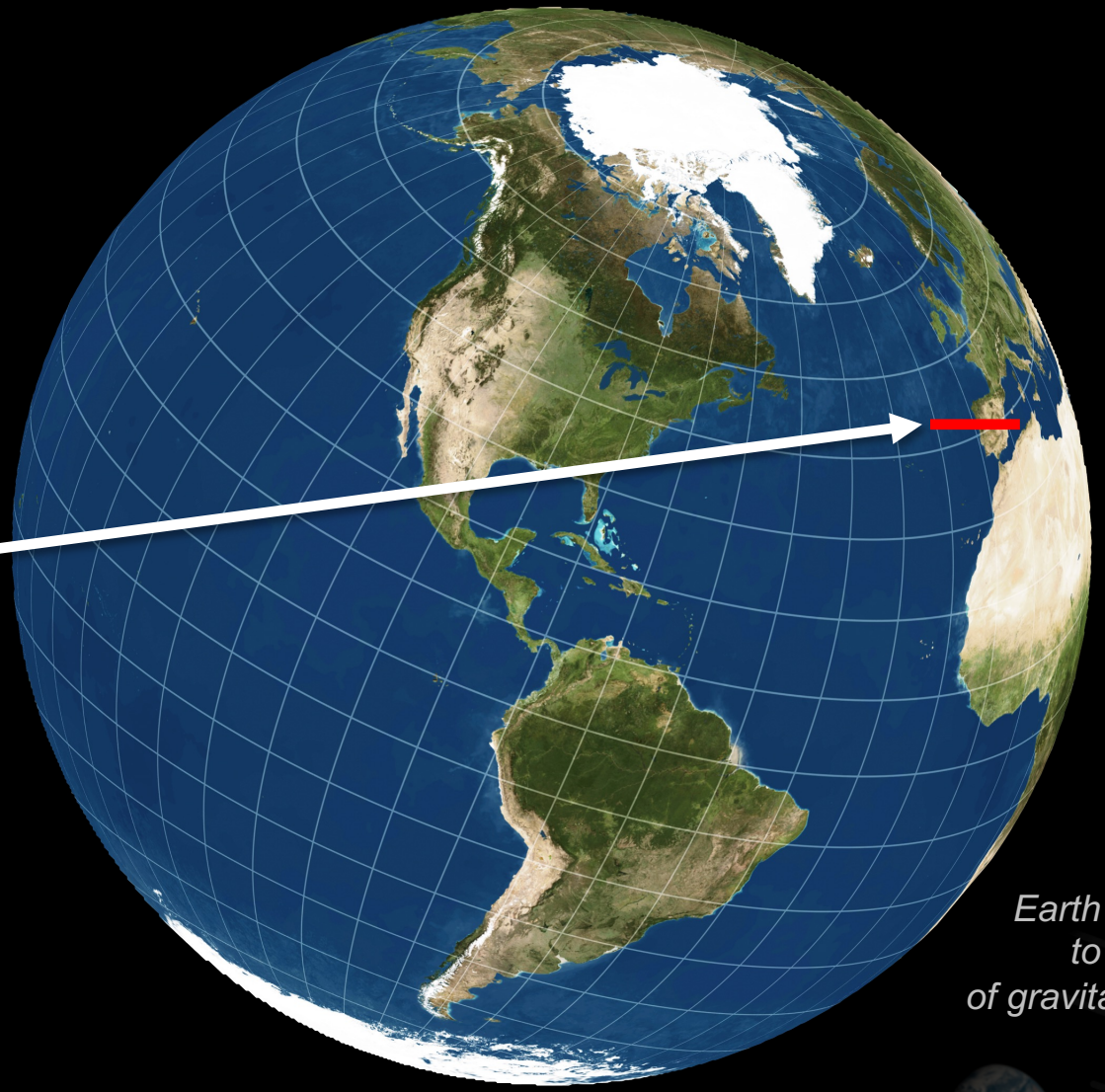
Northern Mexico

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

Uncertainty in Earth Impact and Location

In 2027, the predicted impact location could narrow down to:

Northern Mexico

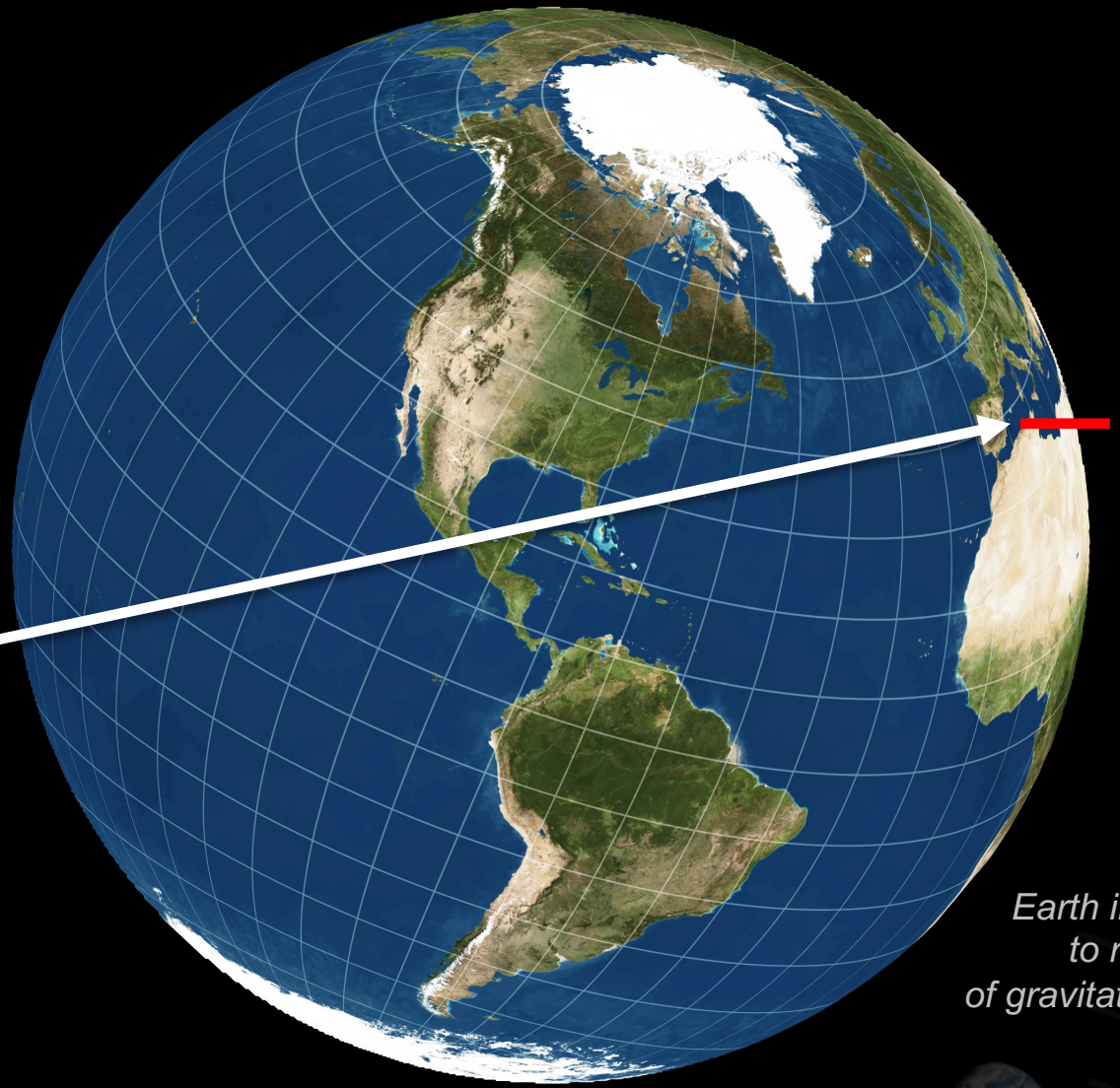
or the central U.S.

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

Uncertainty in Earth Impact and Location

In 2027, the predicted impact location could narrow down to:

Northern Mexico

or the central U.S.

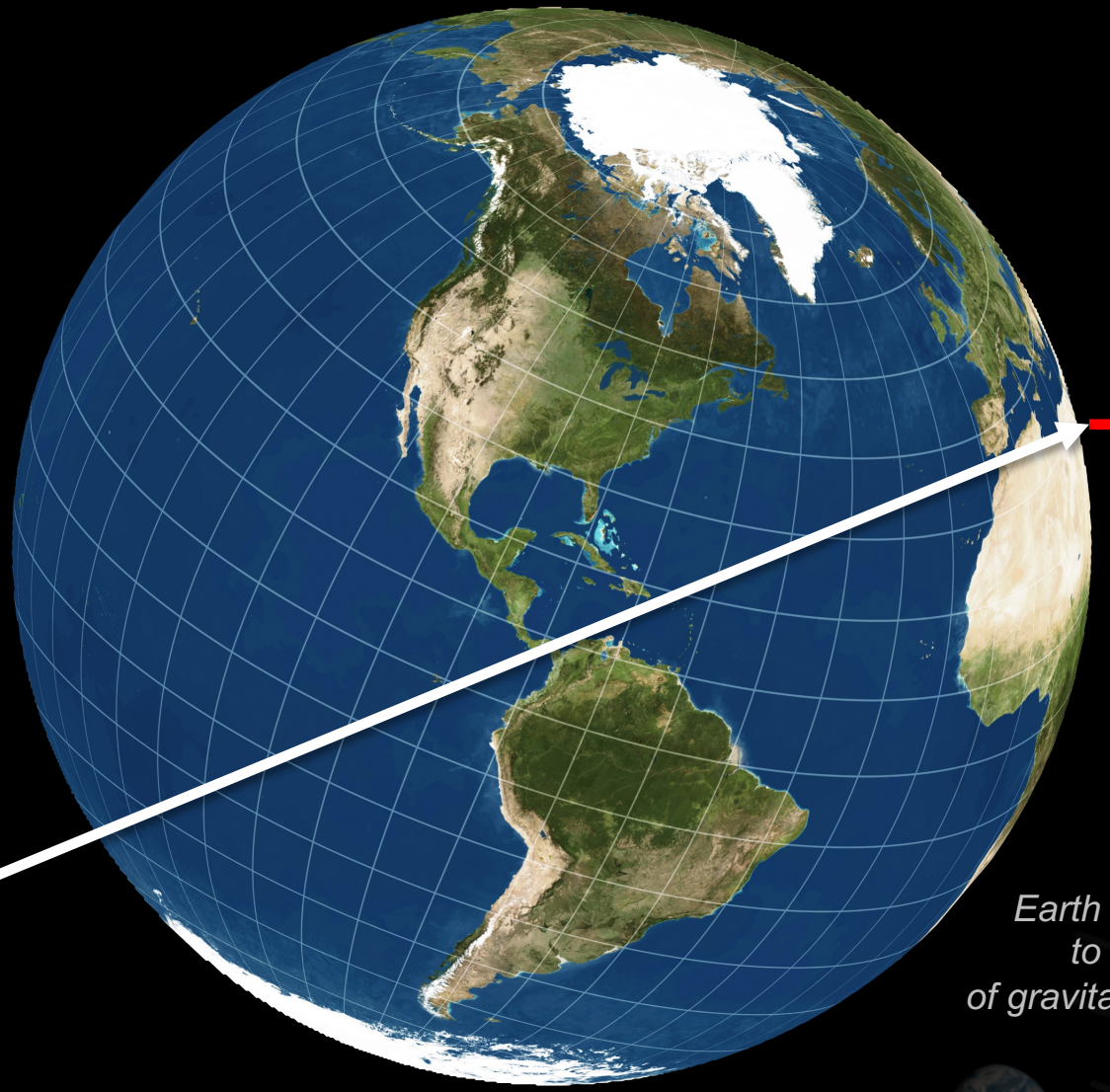
or the eastern U.S.

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

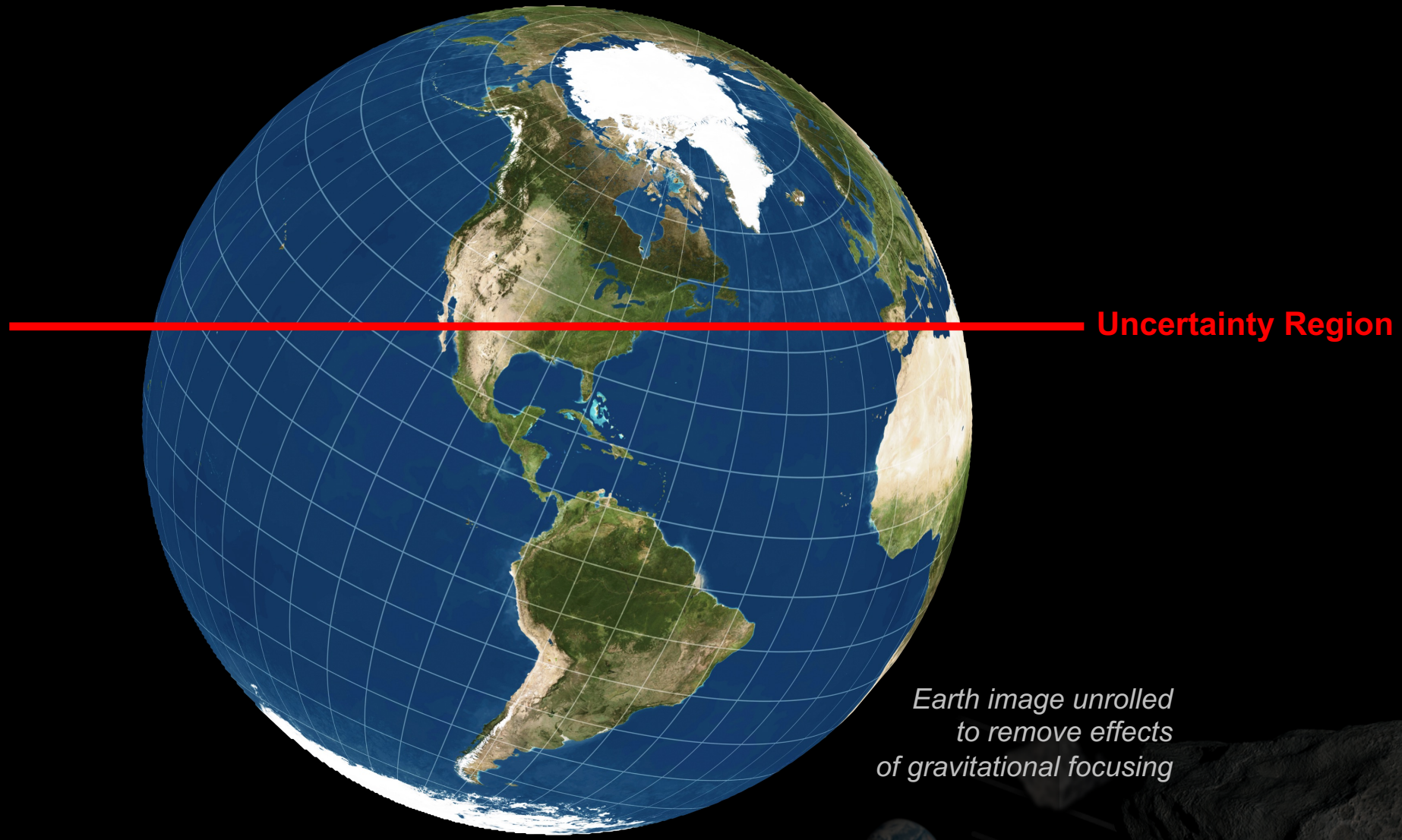


Possible Uncertainty Region in 2027

Earth image unrolled to remove effects of gravitational focusing

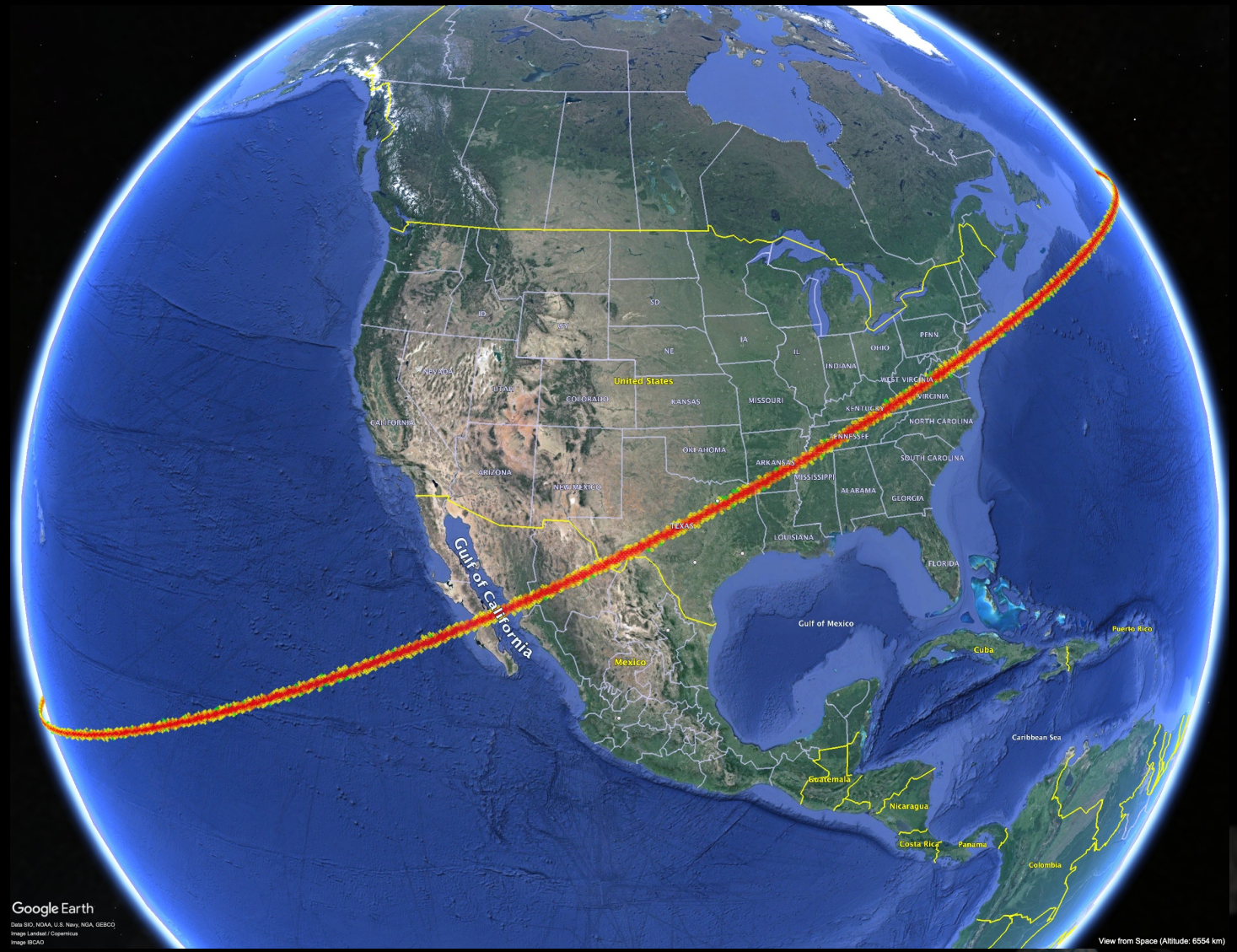
Uncertainty in Earth Impact and Location

But, the <u>current</u> Earth impact probability is 72%



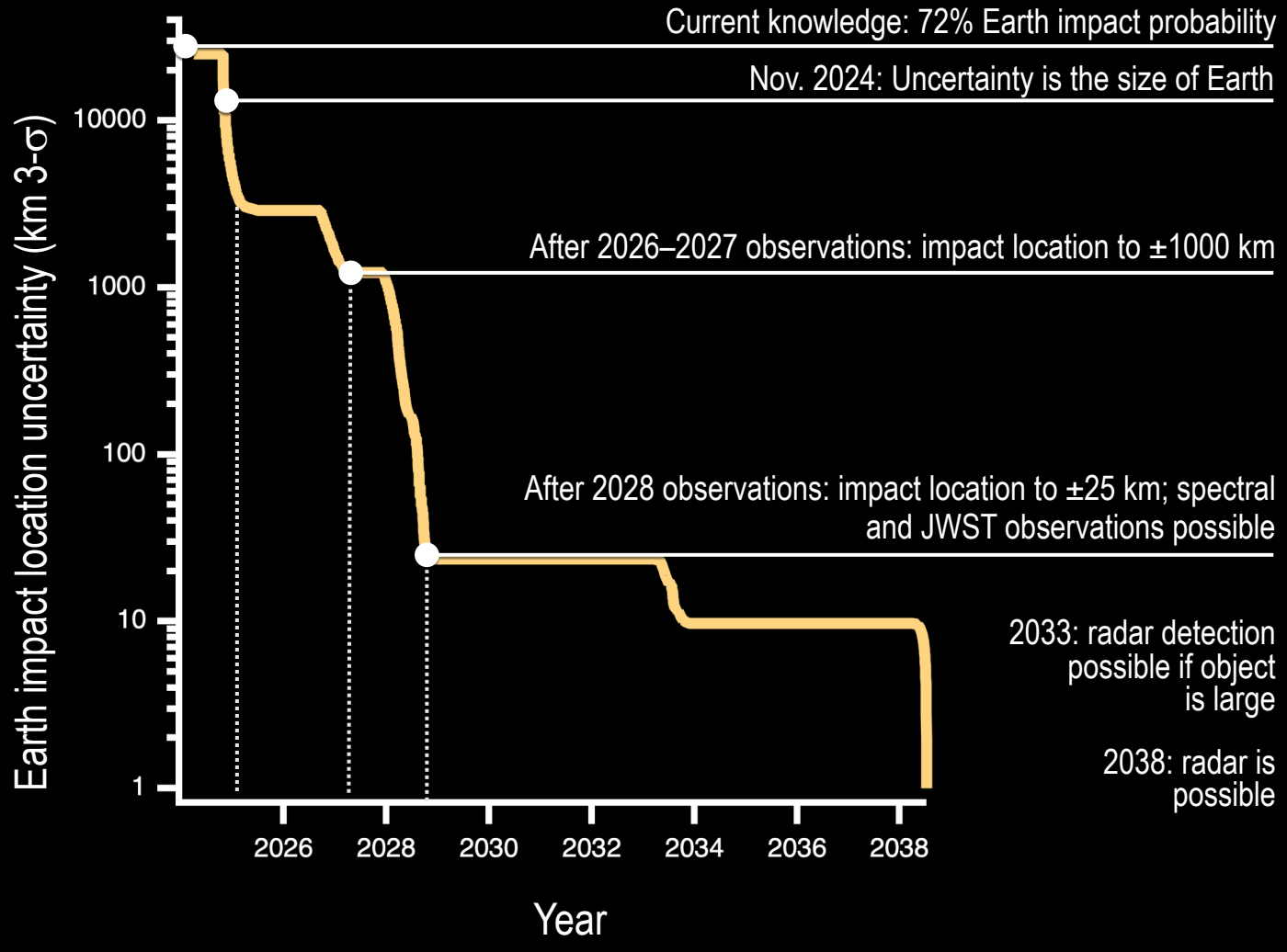
Earth image unrolled to remove effects of gravitational focusing

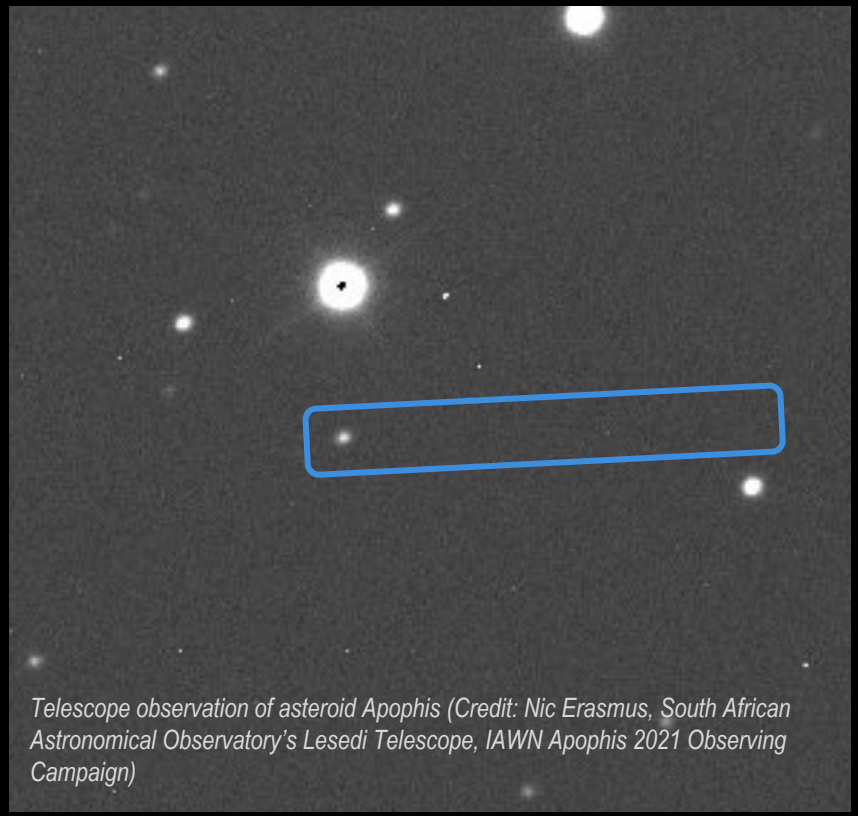
Impact Risk Corridor: Western Part



Impact Risk Corridor: Eastern Part

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
INTERAGENCY
TABLETOP EXERCISE 5

Impact Risk Assessment

Impact Damage Effects, Probabilities, and Regions at Risk

Lorien Wheeler
Jessie Dotson, Grégoire Chomette, Ashley Coates,
Michael Aftosmis, Eric Stern, Donovan Mathias

Asteroid Threat Assessment Project (ATAP)
NASA Ames Research Center

NASA

FEMA

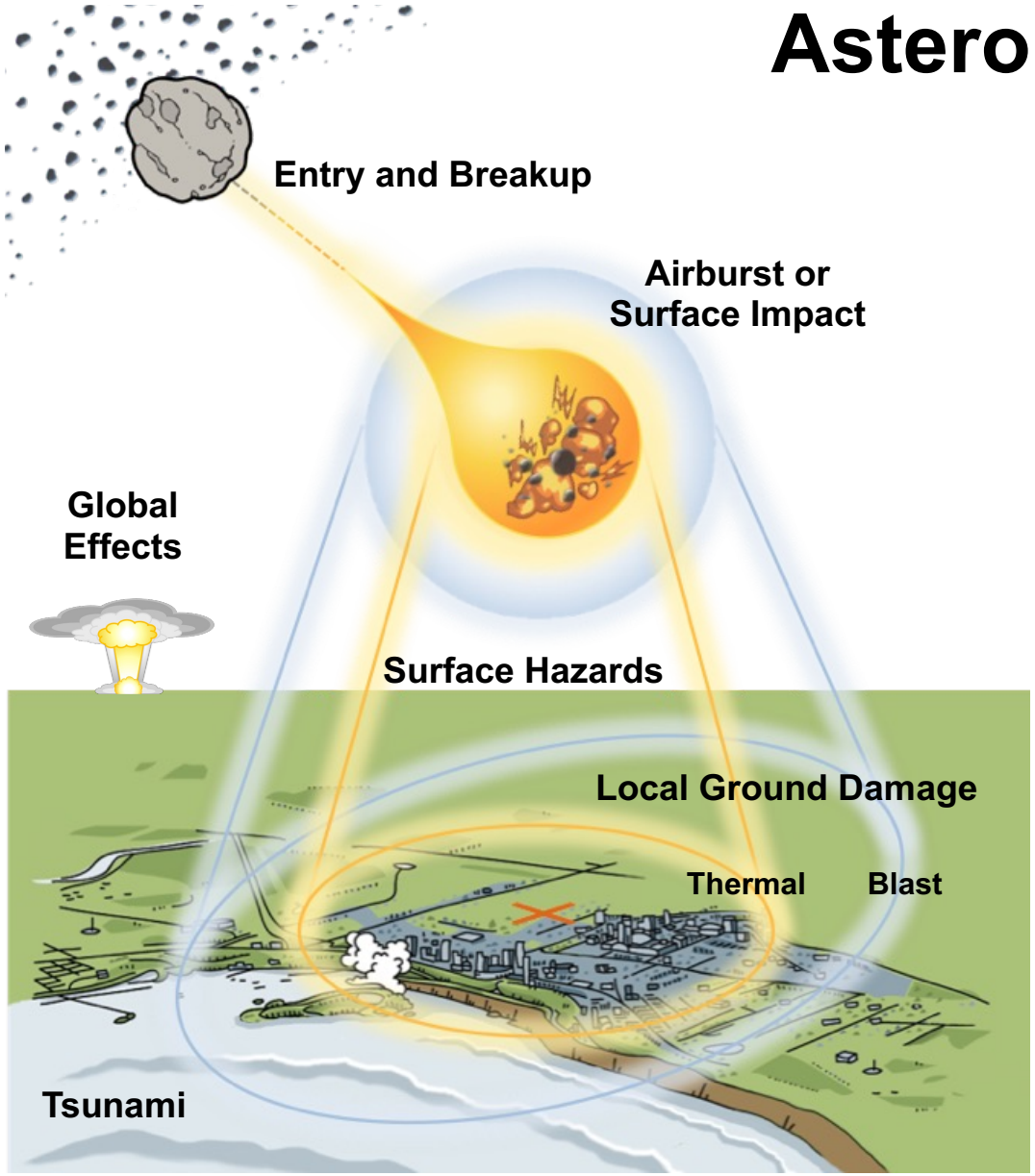
APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

cneos

Ames Research Center

Lawrence Livermore
National Laboratory

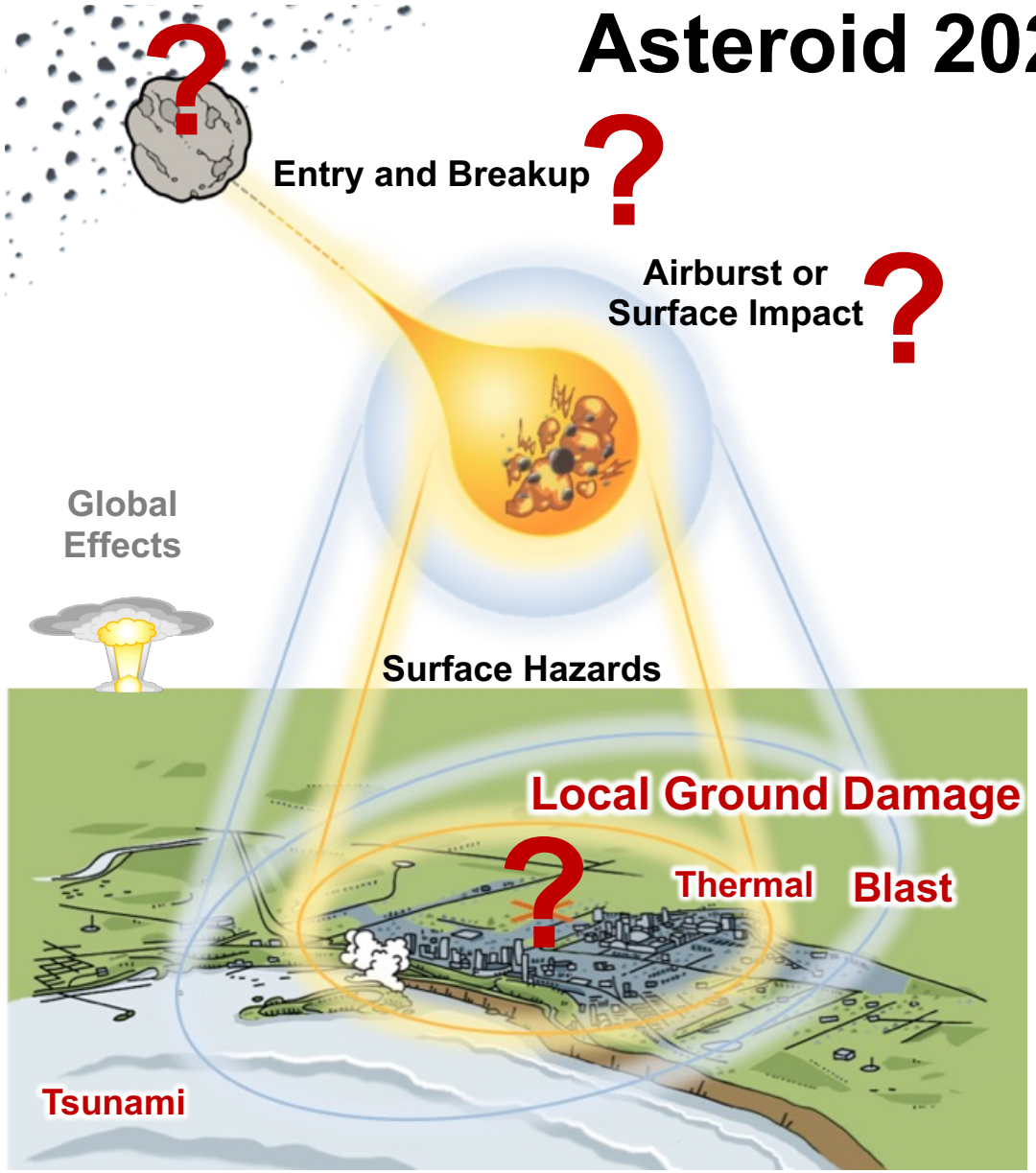
Asteroid Hazards



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.

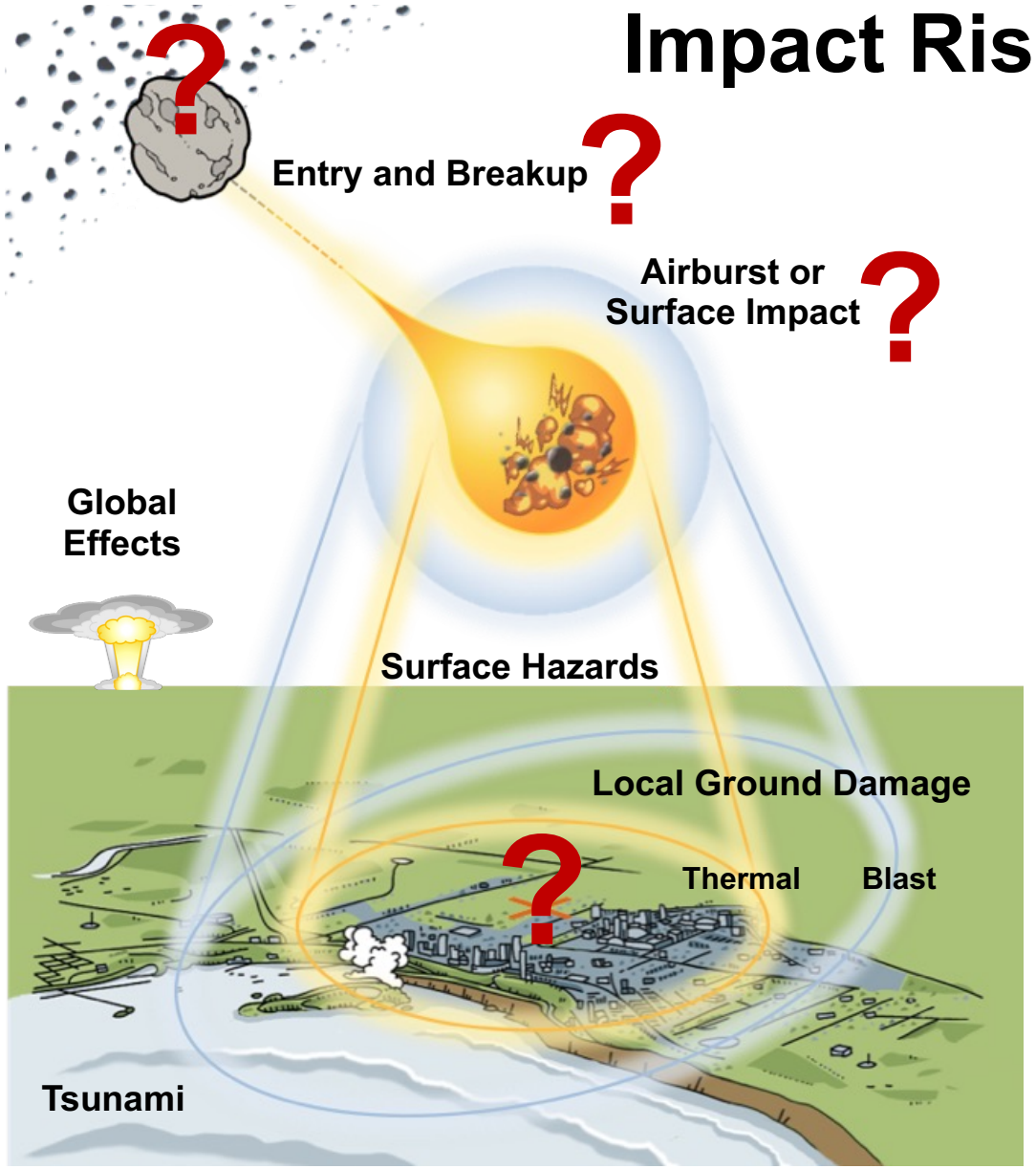
Asteroid 2023 TTX Hazards



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

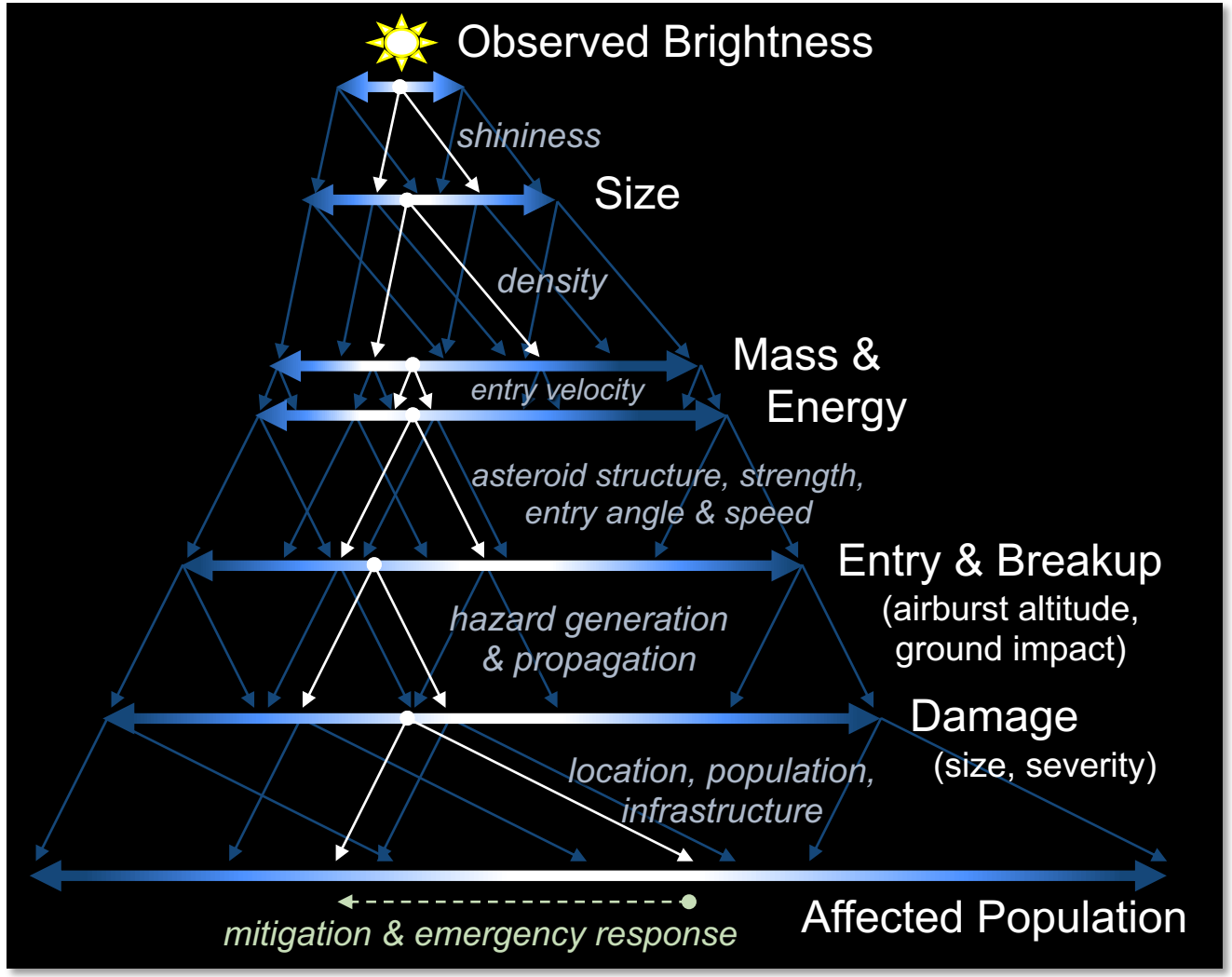
- Primary hazard is a low airburst or ground impact causing a highly destructive blast wave and fireball.
- Larger ocean impacts could cause tsunami damage.
- Largest sizes could cause other extended regional environmental effects.

Impact Risk Assessment



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

Asteroid and Damage Uncertainties

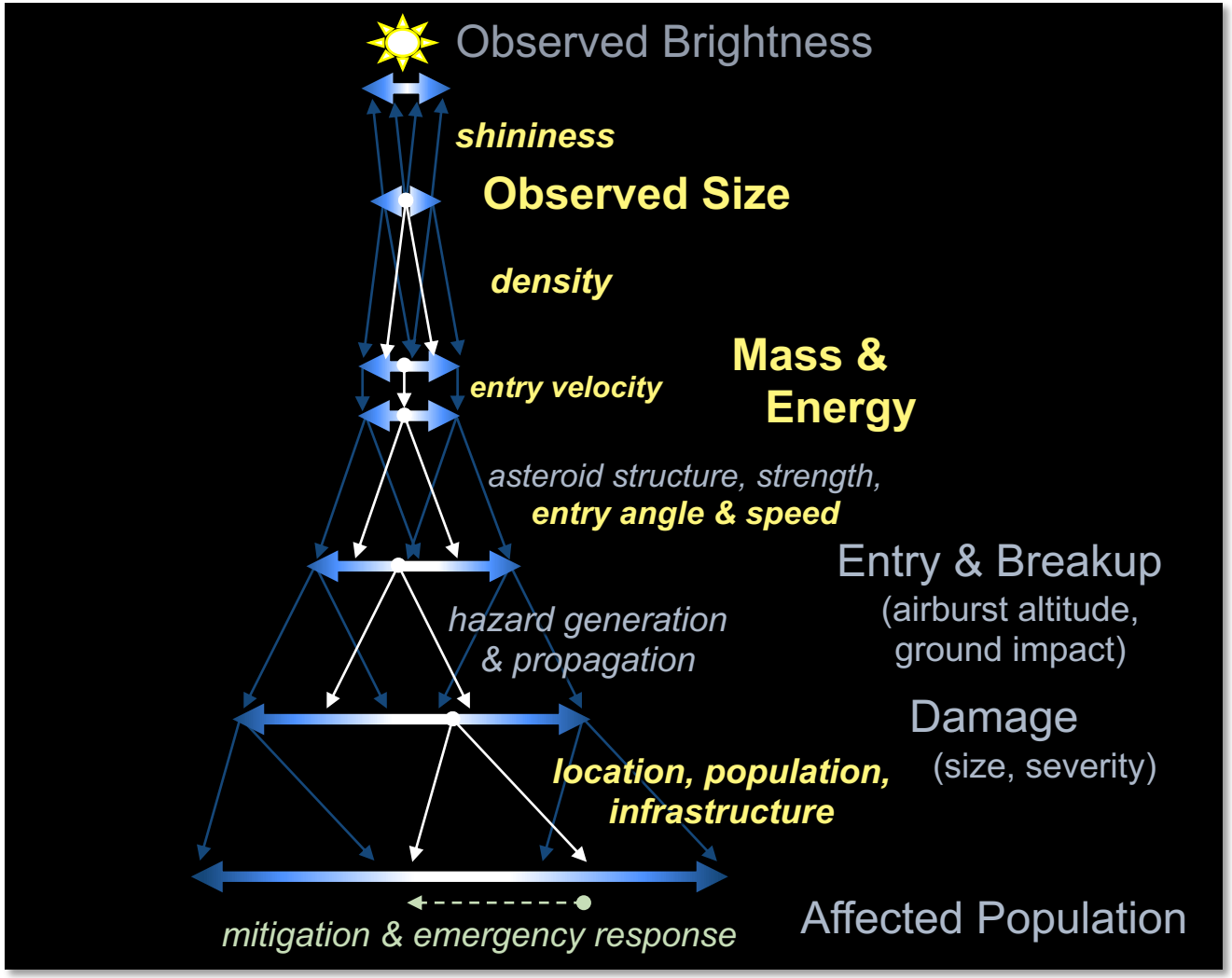


* Conceptual diagram only – Not to scale

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

…cascade into huge uncertainties in potential damage.

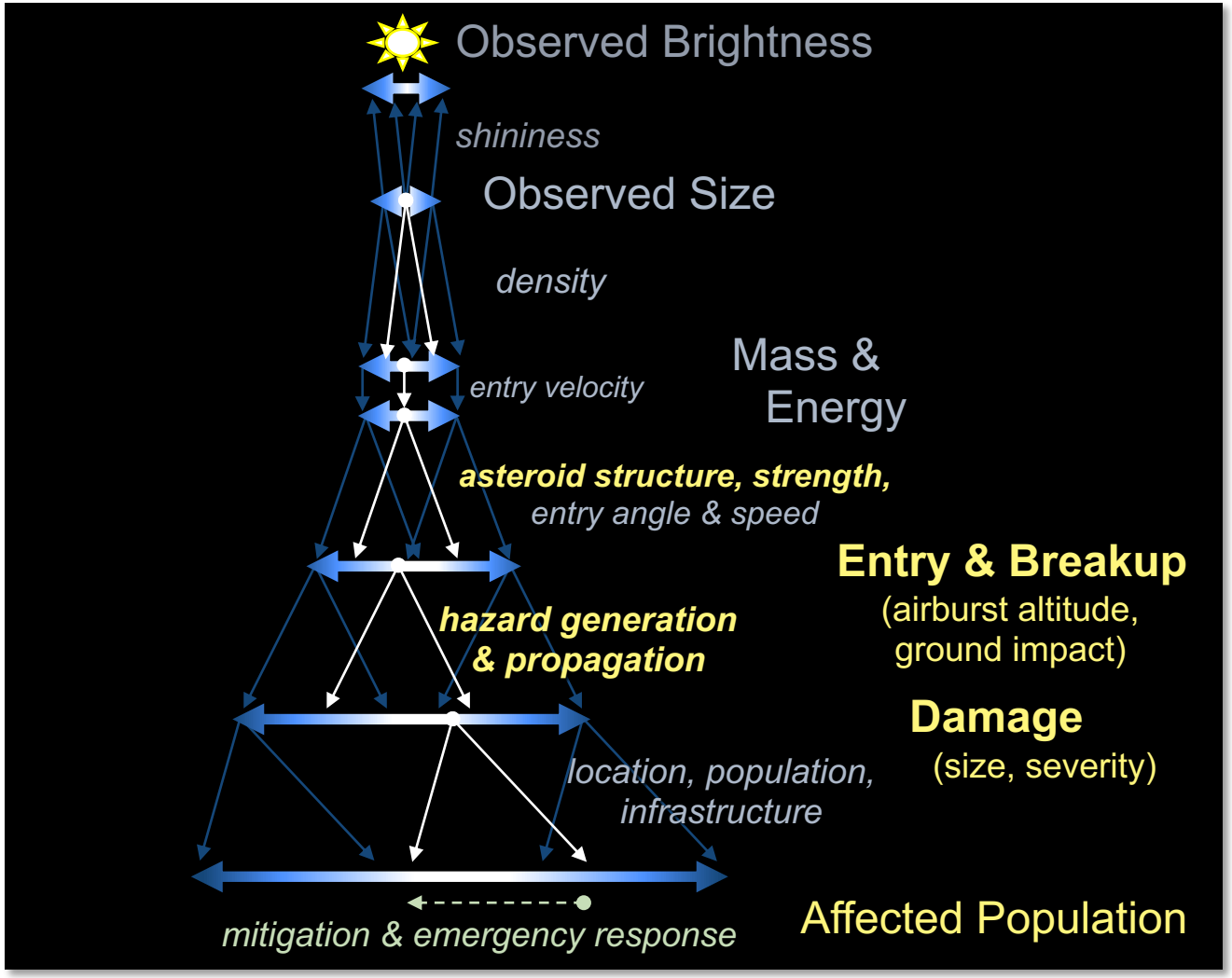
Asteroid and Damage Uncertainties



* Conceptual diagram only – Not to scale

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

Asteroid and Damage Uncertainties



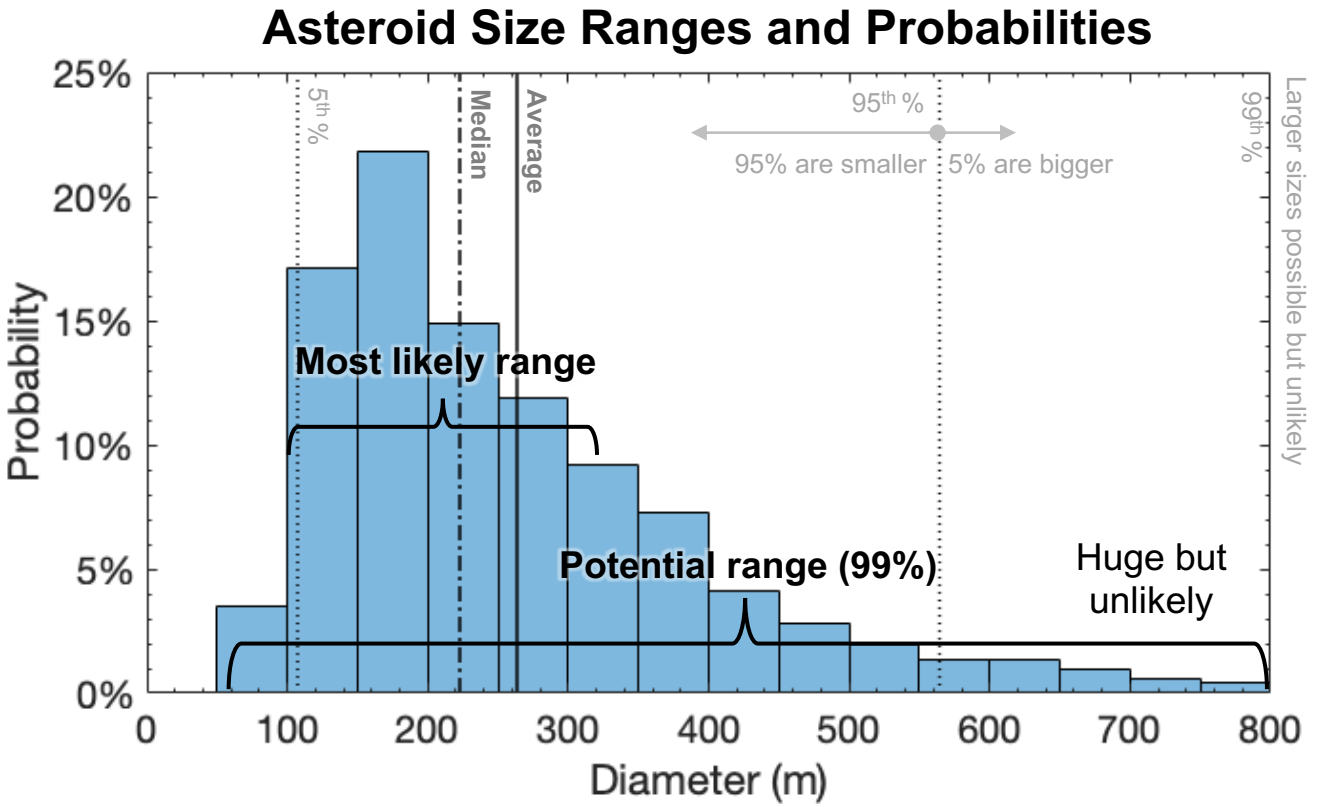
* Conceptual diagram only – Not to scale

?

Some factors will remain uncertain through impact.

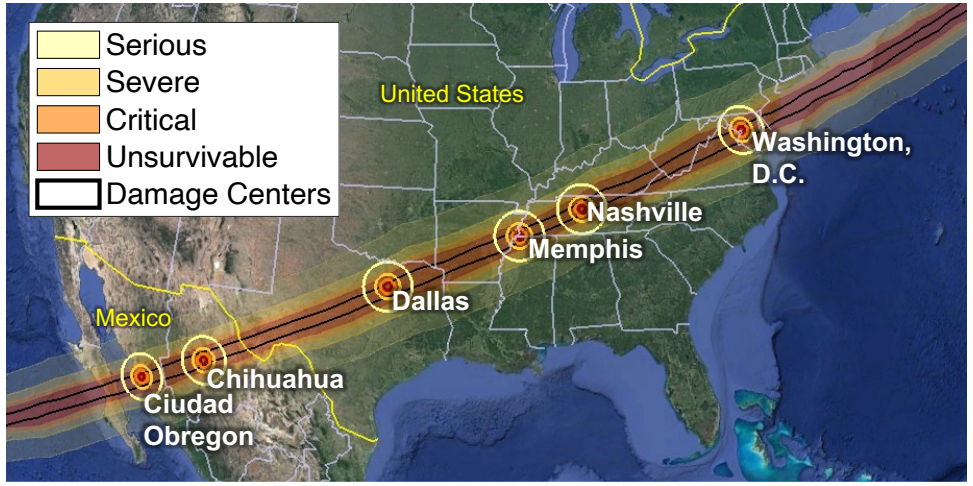
Asteroid and Impact Properties

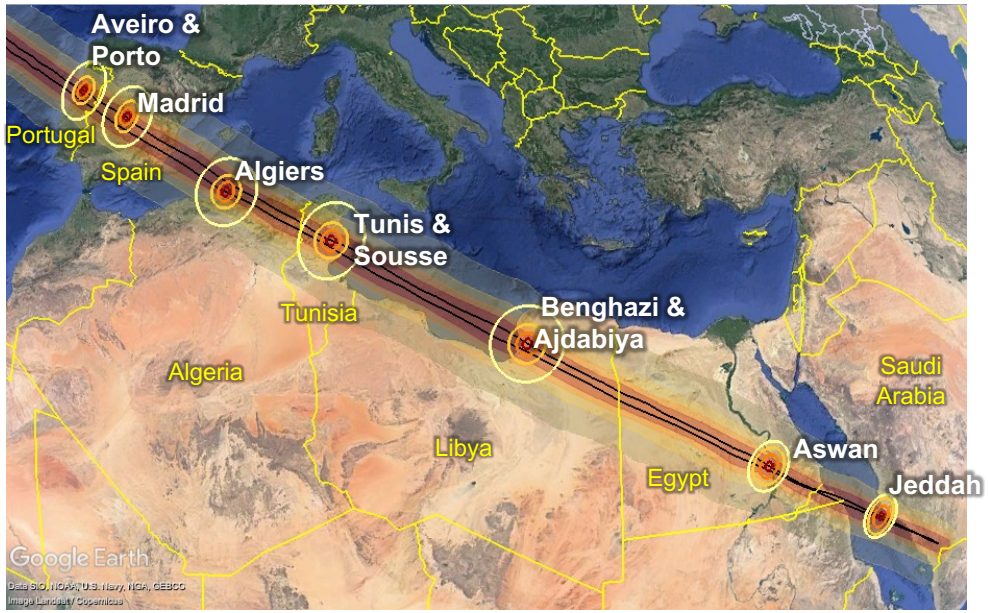
	Asteroid Diameter	Impact Energy (megatons TNT)
Median	220 m (730 ft)	350 Mt
Most Likely	100–320 m (330–1100 ft)	6–750 Mt
Range	60–800 m (200–2600 ft)	6–15,000 Mt



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

Ground Damage Risk Swath



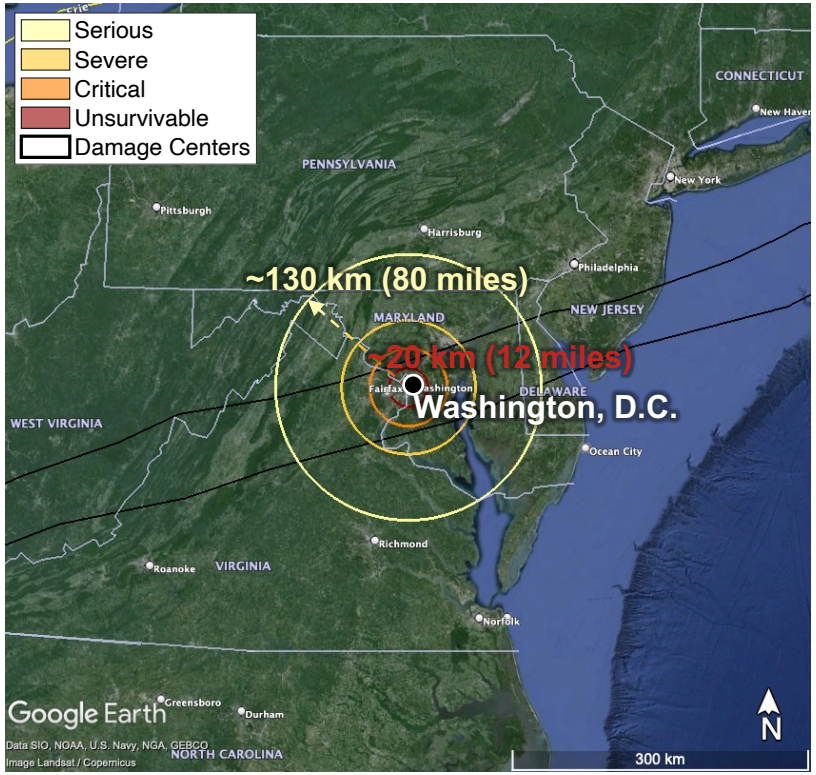


Damage risk swath: Extent of regions *potentially* at risk for ground damage, given ranges of potential impact locations and damage sizes (out to 95th percentile). Rings show median (50th percentile) damage footprints at sample locations.

- 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**.

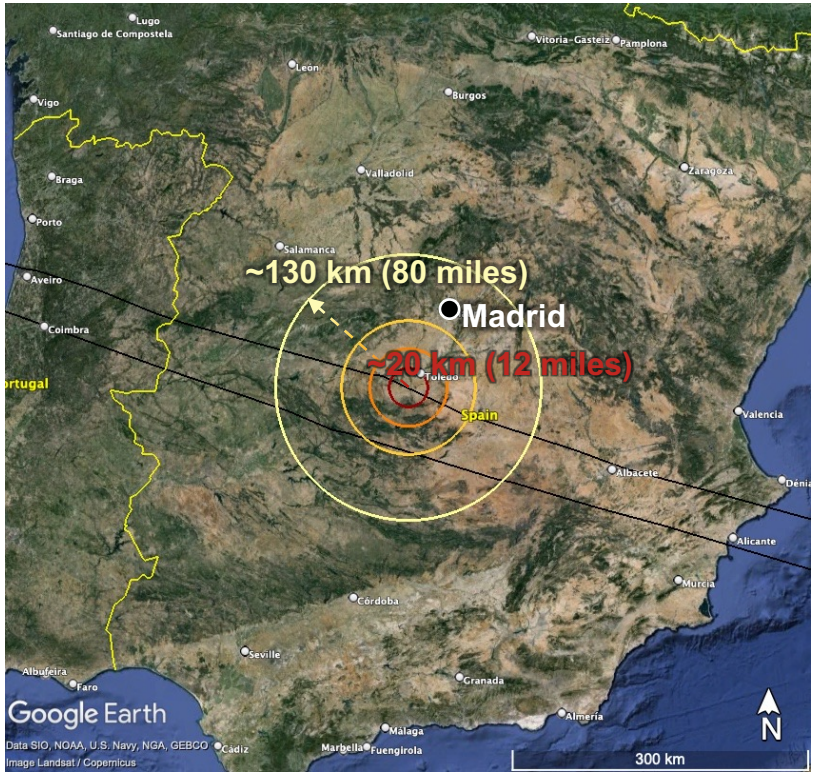
	Damage Level Description
Serious	Windows shatter, some structure damage
Severe	Widespread structure damage, or third-degree burns
Critical	Residential structures collapse, or clothing ignites
Unsurvivable	Devastation, structures flattened or burned

Median Damage Size Examples



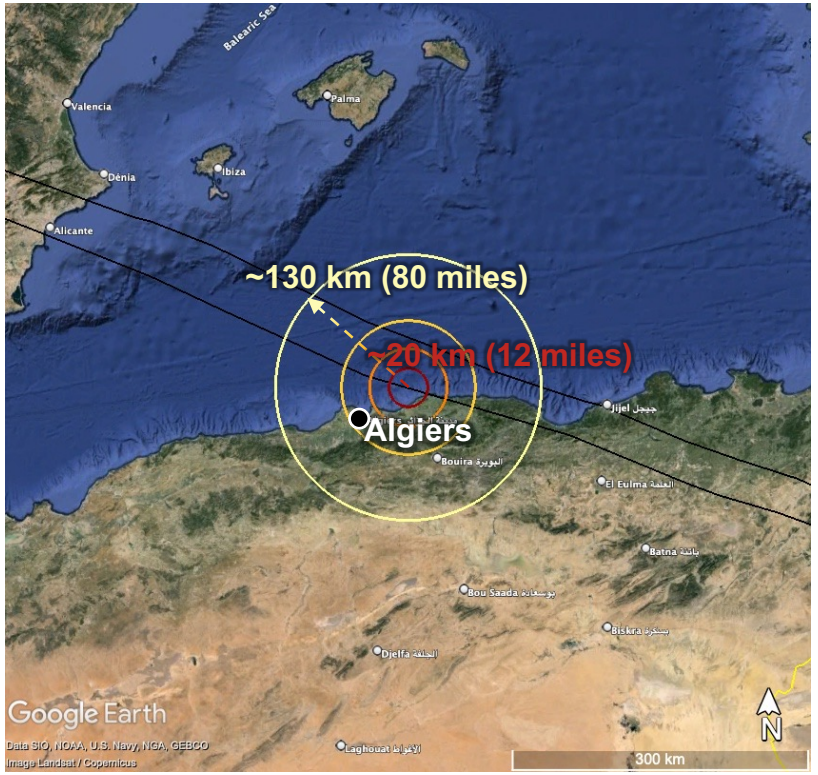
Washington, D.C., USA

highest population damage region along swath



Madrid, Spain

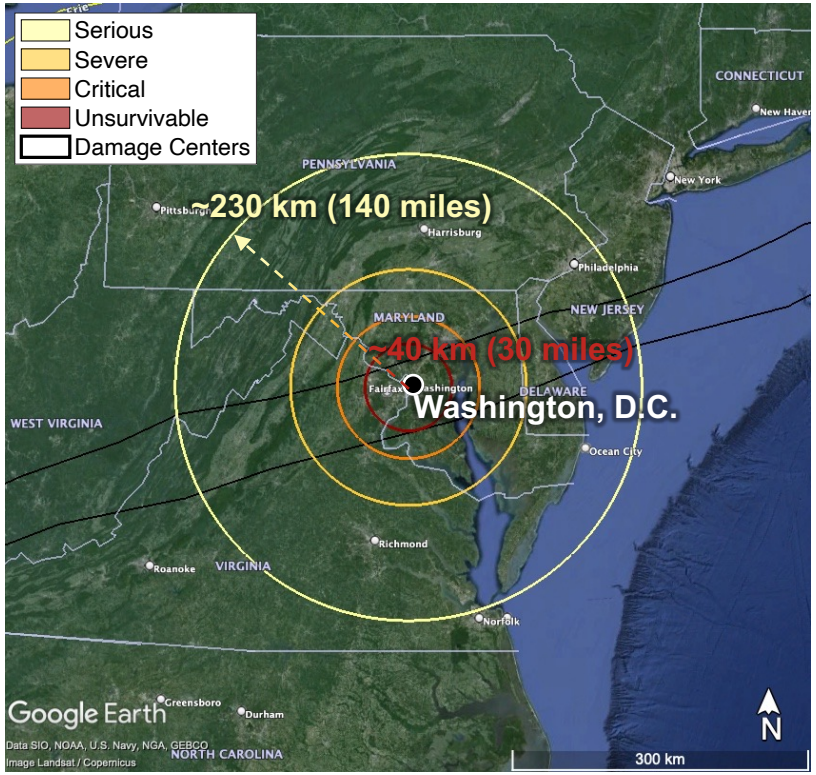
highest population damage region in Europe



Algiers, Algeria

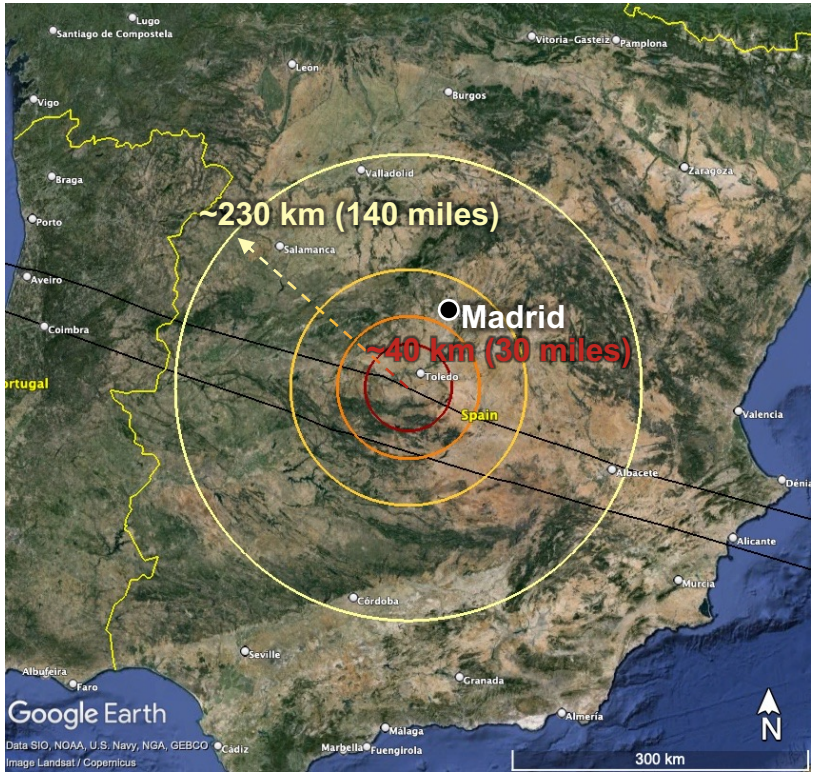
highest population damage region in Africa

Large (95th Percentile) Damage Size Examples



Washington, D.C., USA

highest population damage region along swath



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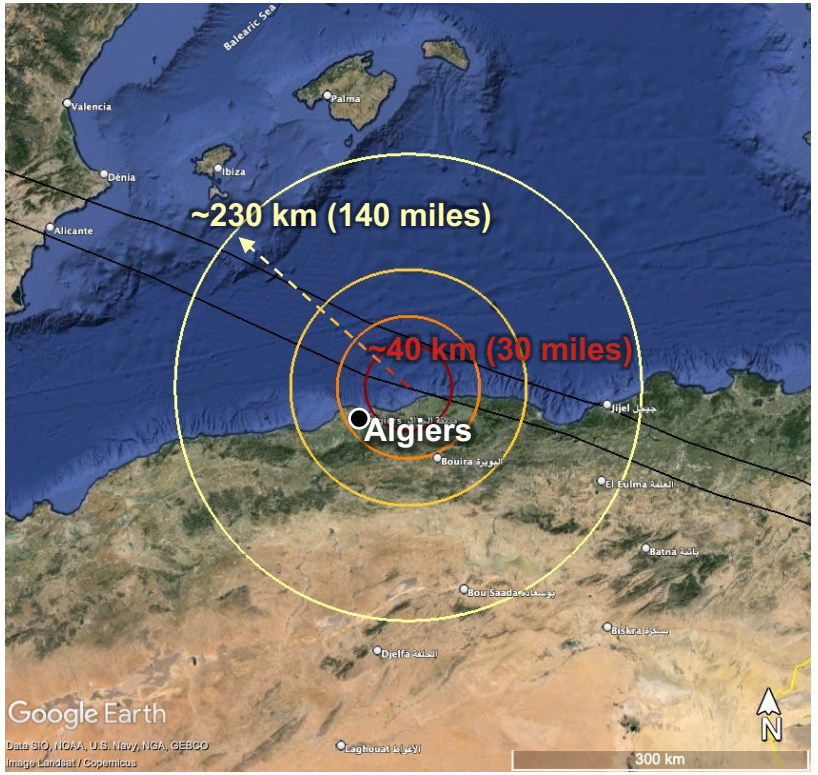


Algiers, Algeria

highest population damage region in Africa

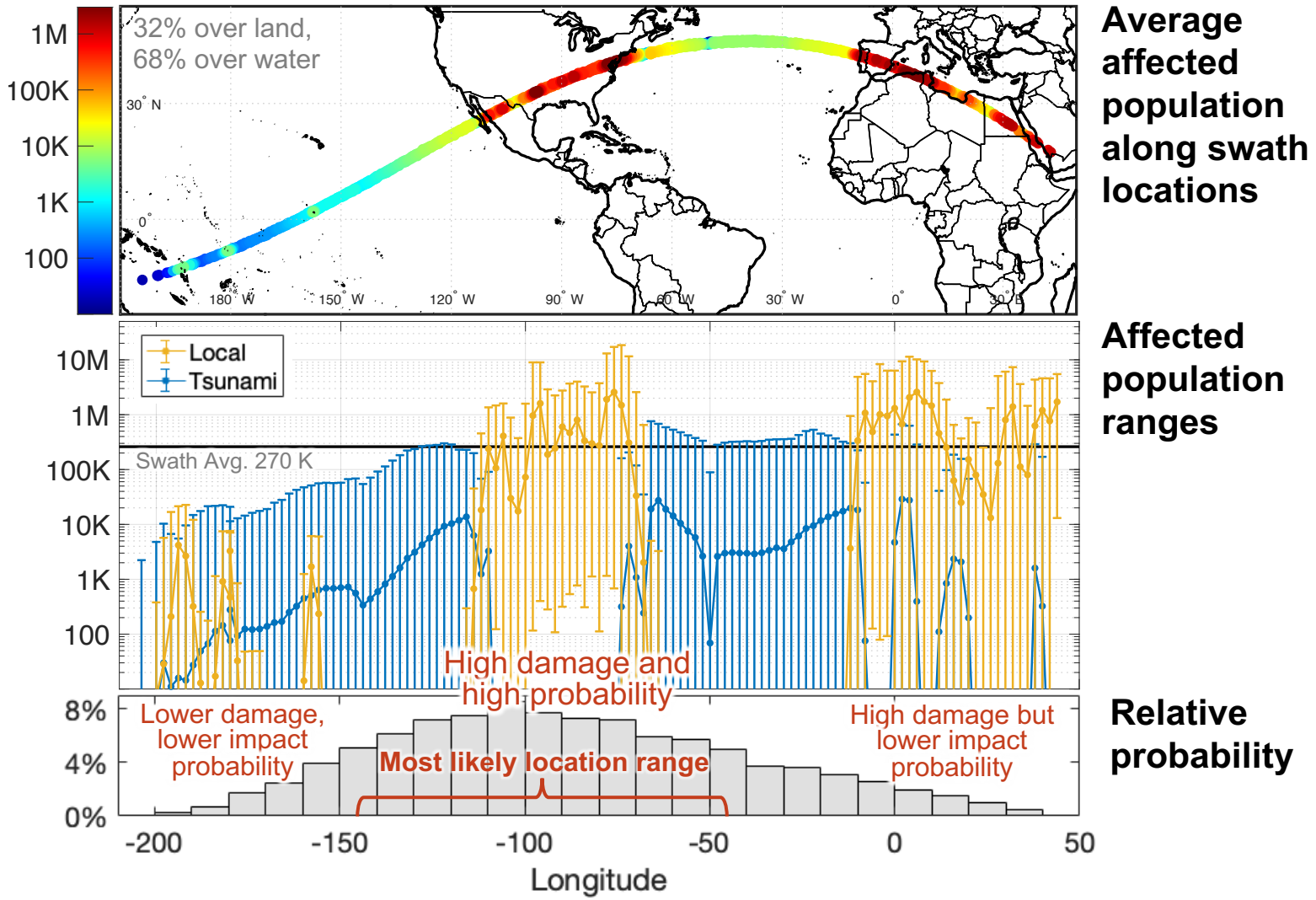
Affected Population Ranges Along Swath

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

Impacts over land cause large population damage

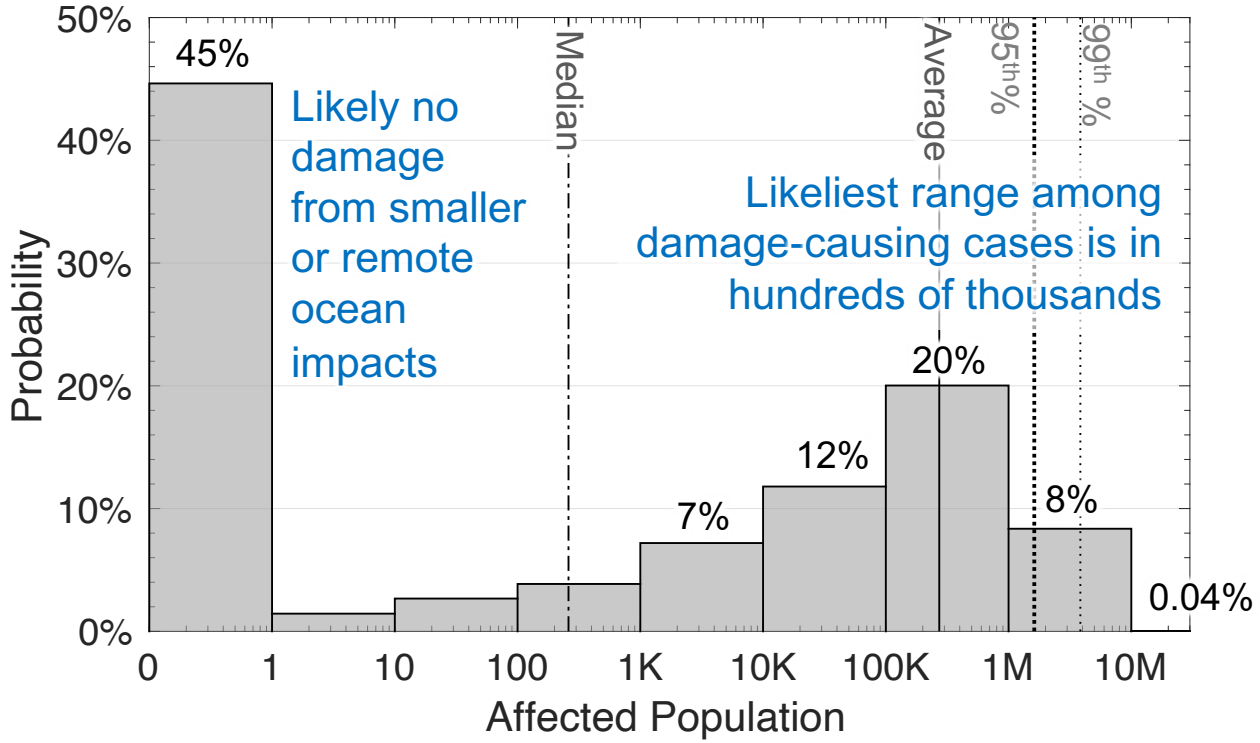
Tsunami damage could be significant if impact is large or near coasts, or minor for smaller mid-ocean impacts

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



Population Risks

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)

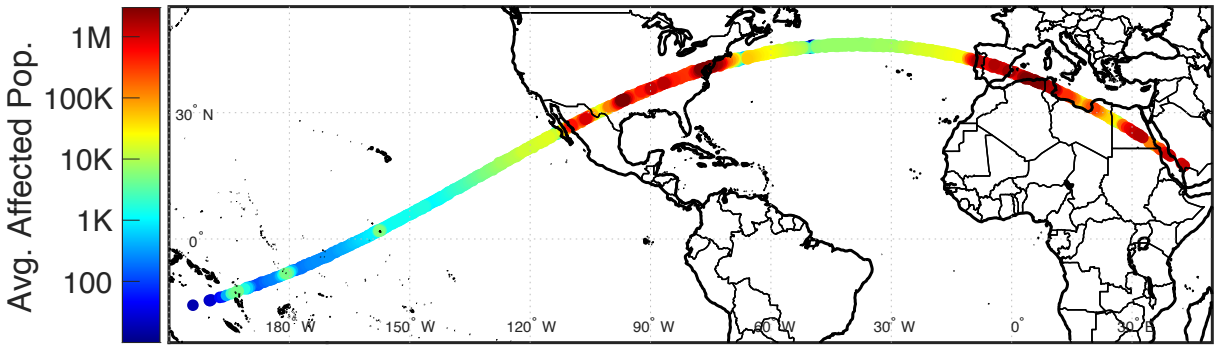
Impact Risk Dashboard

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

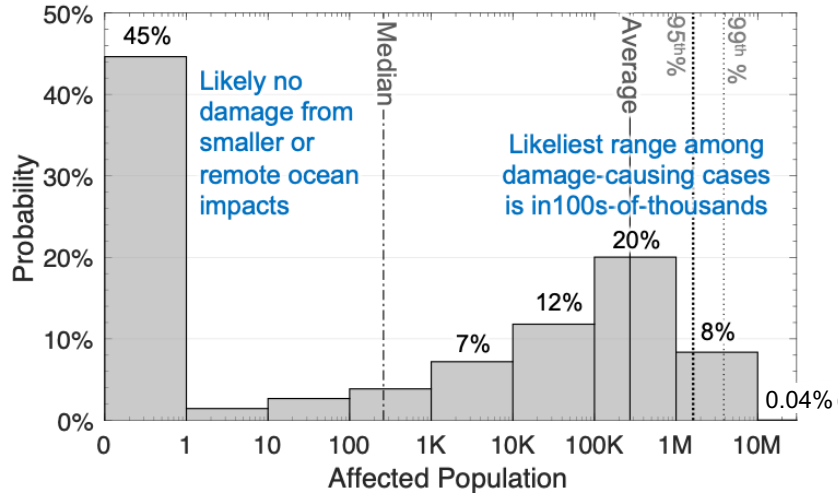
- Potential impact locations colored by the average number of people affected by local ground damage or tsunami



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)

This slide has been intentionally left blank.

- What pieces of information were most relevant to your role, and what questions does this information raise?

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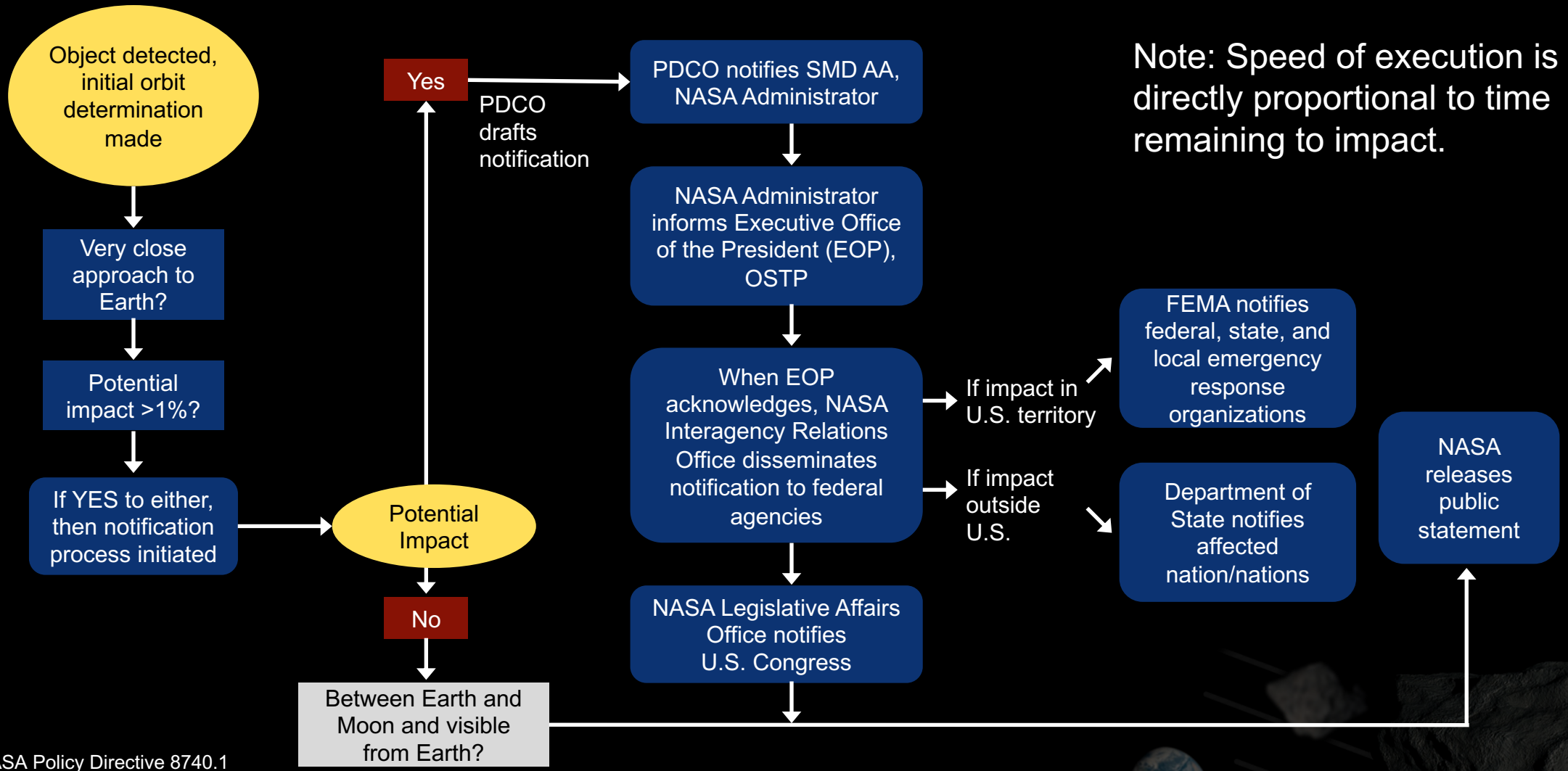
- What, if any, additional information might be helpful given your role and needs at this stage?

Break

U.S. Impact Notification Process



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

- How would notification processes work in countries other than the U.S.?

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- 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?

- What relevant mechanisms exist for international collaboration and coordination?

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- What role might other international organizations or groups, including the UN Security Council, play?

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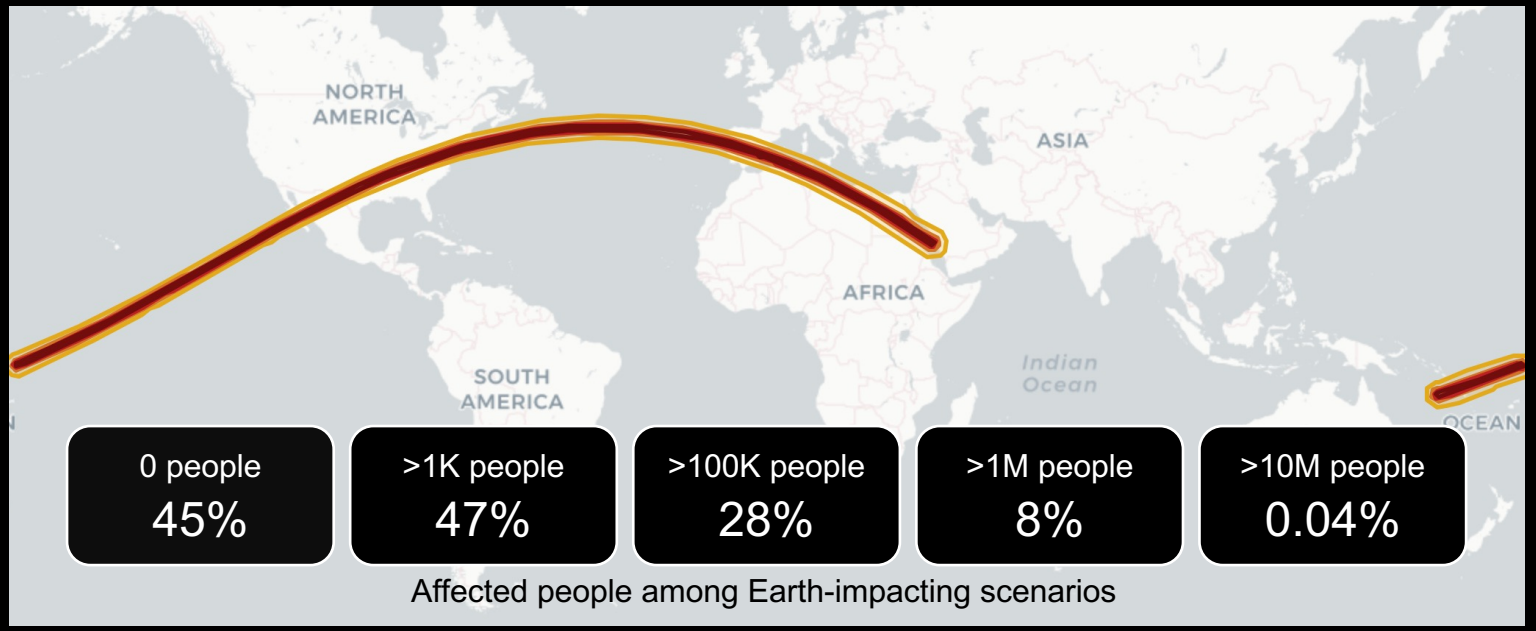
- What role might other international organizations or groups, including the UN Security Council, play?
- How would information be shared and coordinated among agencies and nations?
- Are you aware of any current laws, treaties, or other agreements in place for responding to a multinational emergency?

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 5



Affected people among Earth-impacting scenarios

72%
probability of Earth impact

14.25 years
from today

Many
uncertainties

Potential Telescopic Information

Today
2 Apr 2024

2024
Nov
Impact location uncertainty is the size of Earth.

2028
Earth impact location ±25 km. Spectral and JWST observations possible. Uncertainties remain in key asteroid properties.

2033
Radar detection is possible if the object is large.

Potential Earth impact
12 Jul 2038

- How does the timeframe of 14 years to potential impact factor into your planning?

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- How might you approach coordination of public messaging both among agencies and internationally?

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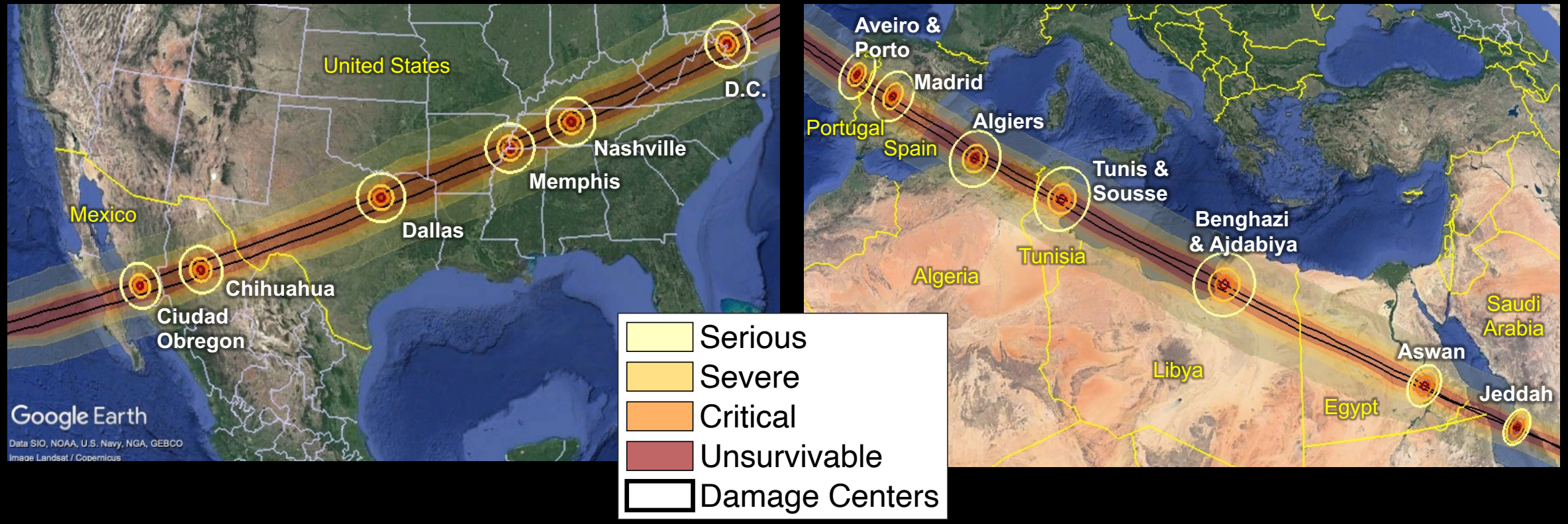
- How might you approach coordination of public messaging both among agencies and internationally?
- How might you approach public safety preparedness planning?

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.

Impact Risk Dashboard

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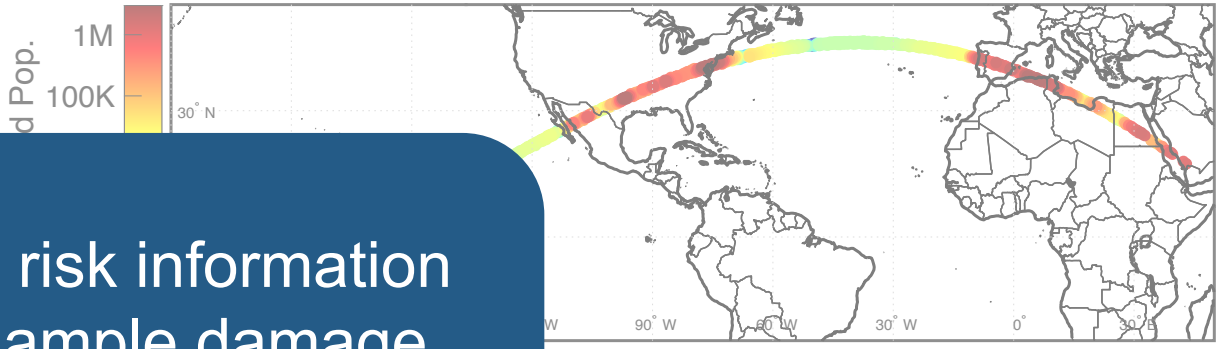

Additional impact risk information and interactive sample damage maps are available on interactive risk dashboard web tool.

Impact Hazards

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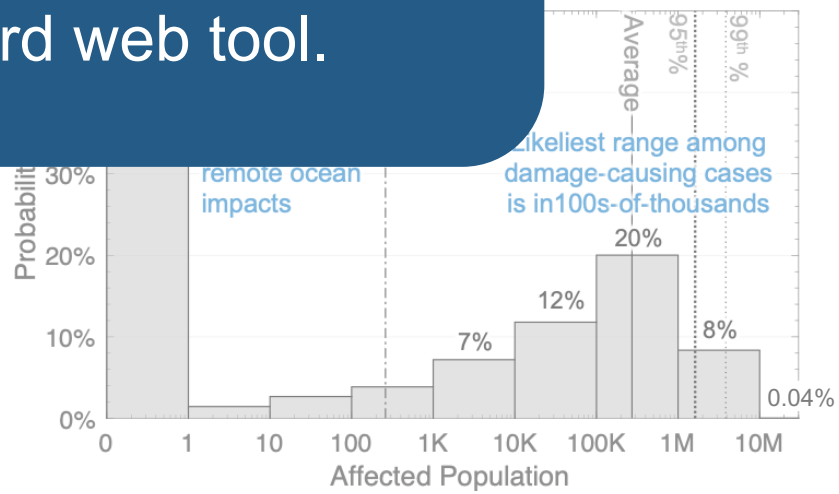
Earth impact)



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- How does the presence or absence of a country in the risk swath affect the role(s) that a country plays at this time?

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- Based on the risk swath and timeline, what discussions would be happening about how to protect critical infrastructure?

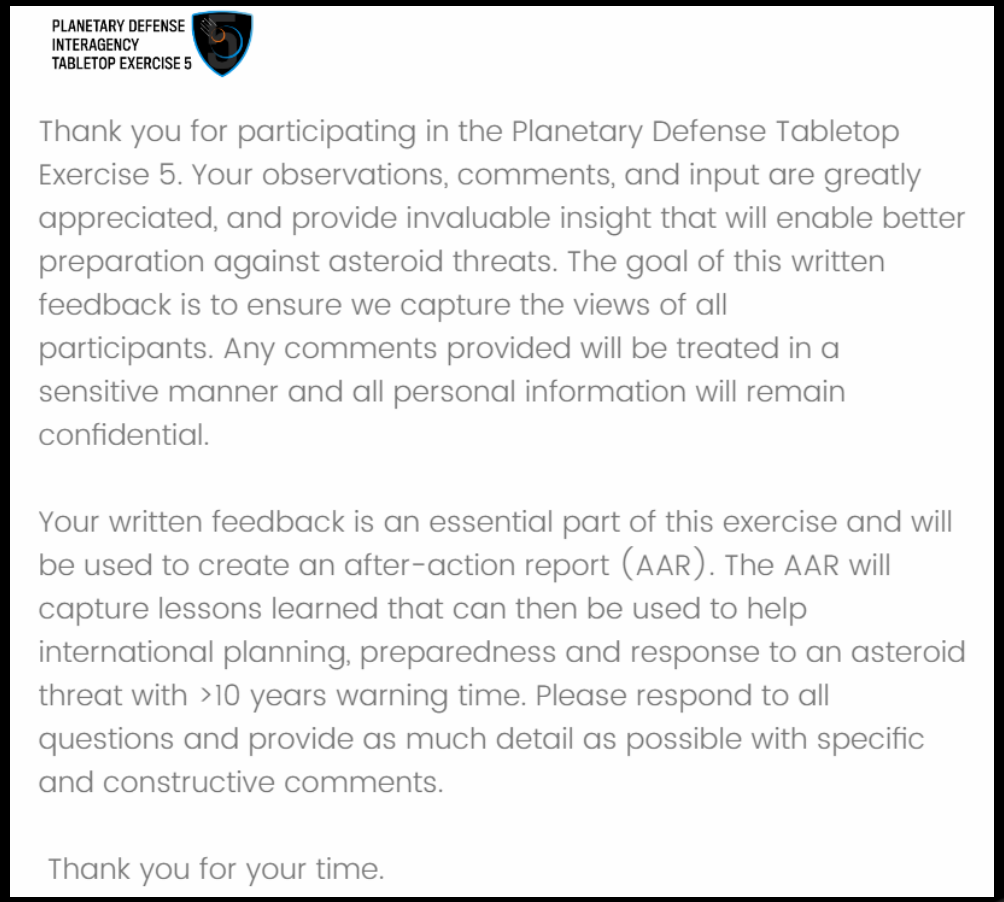
Hot Wash

- 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

FEMA

APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

CNEOS

Ames Research Center

Lawrence Livermore National Laboratory