EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4

Module 2
Early Preparedness
15 June 2022 (Two Months to Go)

Angela Stickle, Ph.D.
Module 2 Facilitator
Senior Scientist
Johns Hopkins Applied Physics Laboratory
angela.stickle@jhuapl.edu

EXERCISE EXERCISE EXERCISE

Module 2 Roadmap

In this module, we will:

- Provide more information on the asteroid and its potential impact location and damage
  - Discussions will focus on the evolving response preparations and how to respond at a regional/local scale
- Provide information on a potential last-resort mitigation attempt
  - Discussions will focus on potential next steps

EXERCISE EXERCISE EXERCISE

INJECT 2.1: A Fireball Is Reported Over Japan

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4

4 NEWS ...

Cell phone video of an unidentified fireball over Japan taken last night. No word yet on what caused the bright object.

3:19 PM · June 15, 2022

157 Retweets 17 Quote Tweets 327 Likes

Replying to and 3 others

This literally the beginning of the War of the Worlds?

12:59 AM · June 15, 2022

Reply Share

June 15 ...

Fireball over Japan! Are we sure it wasn't a missile??

stripes.com

Austin discusses North Korea's 'direct and serious threat' with counte...

Defense chiefs from the United States, South Korea and Japan met by phone Thursday to discuss a series of North Korean launches last ...

3 4

...

Did the asteroid come early?? Why didn't they tell us??

12:05 AM · June 15, 2022

3,946 Retweets 1,356 Quote Tweets 22.2K Likes

INJECT 2.1: A Fireball Is Reported Over Japan

- How long does it take for our systems to detect and understand a natural fireball?
- How do we message what *we think* happened and calm people down, especially since all they've been hearing about is asteroids for the last four months?

EXERCISE EXERCISE EXERCISE

INJECT 2.1: A Fireball Is Reported Over Japan

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

- How long does it take for our systems to detect and understand a natural fireball?
- How do we message what *we think* happened and calm people down, especially since all they've been hearing about is asteroids for the last four months?
- What are the gaps keeping us from being able to "beat the tweet" or be in a position to authoritatively respond within minutes rather than days?
  - Is it worth investing in closing these gaps?

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4

INJECT 2.2: Scenario Update

15 June 2022: Two Months to Impact
Impact Is Now Certain; Location Is North Carolina

Paul Chodas, Davide Farnocchia & Ryan Park
Center for NEO Studies (CNEOS)
Jet Propulsion Laboratory, California Institute of Technology

EXERCISE EXERCISE EXERCISE

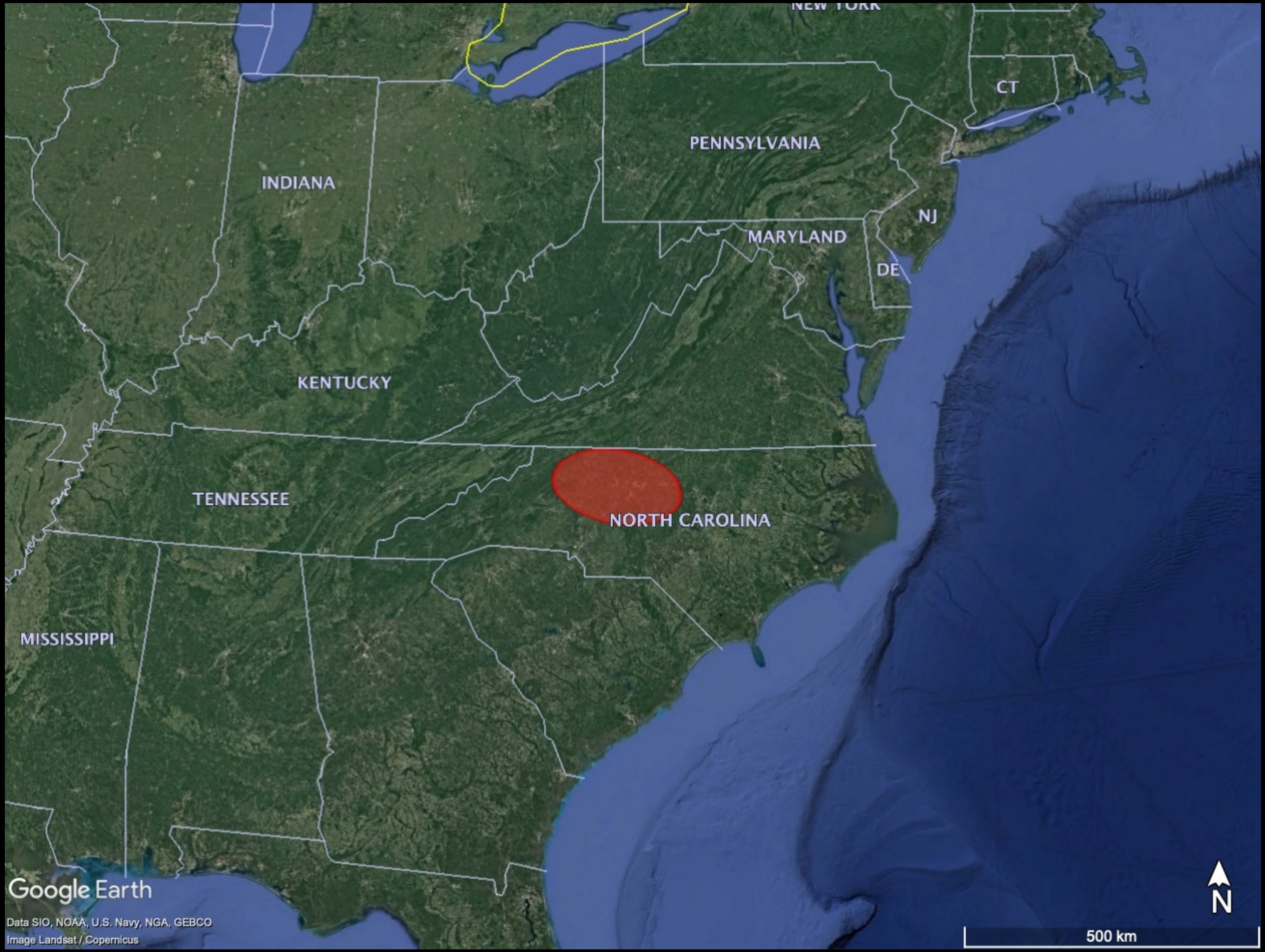
Scenario Update: Module 2

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

- New tracking data for 2022 TTX, now spanning 7 years, have produced a much more accurate orbit for the asteroid, enabling very precise predictions of the impact
- The asteroid is now 100% certain to impact, and the predicted impact location is N. Carolina
- The most important new data were "prediscovery" detections of the asteroid from sky images taken in 2015, when 2022 TTX made a distant flyby of Earth
- Astronomers worldwide have continued tracking the asteroid at every opportunity over the last 4 months, contributing close to a hundred new observations
- 2022 TTX passed through the sky region where the NEOWISE spacecraft points its infrared telescope, but the asteroid was not detected
- If the asteroid is at the large end of its size range, larger than about 340 m (1100 ft), it should have been detected by NEOWISE; since it was not, the large end of the size range can be revised down somewhat to a new size range of 40–340 m (130–1100 ft)

Predicted Impact Region

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4



Shows the region where the 2022 TTX will impact

The impact will occur at: 16 August 2022 at 2:02:10 pm EDT

The asteroid will impact at a velocity of 15.5 km/s or 35,000 mph

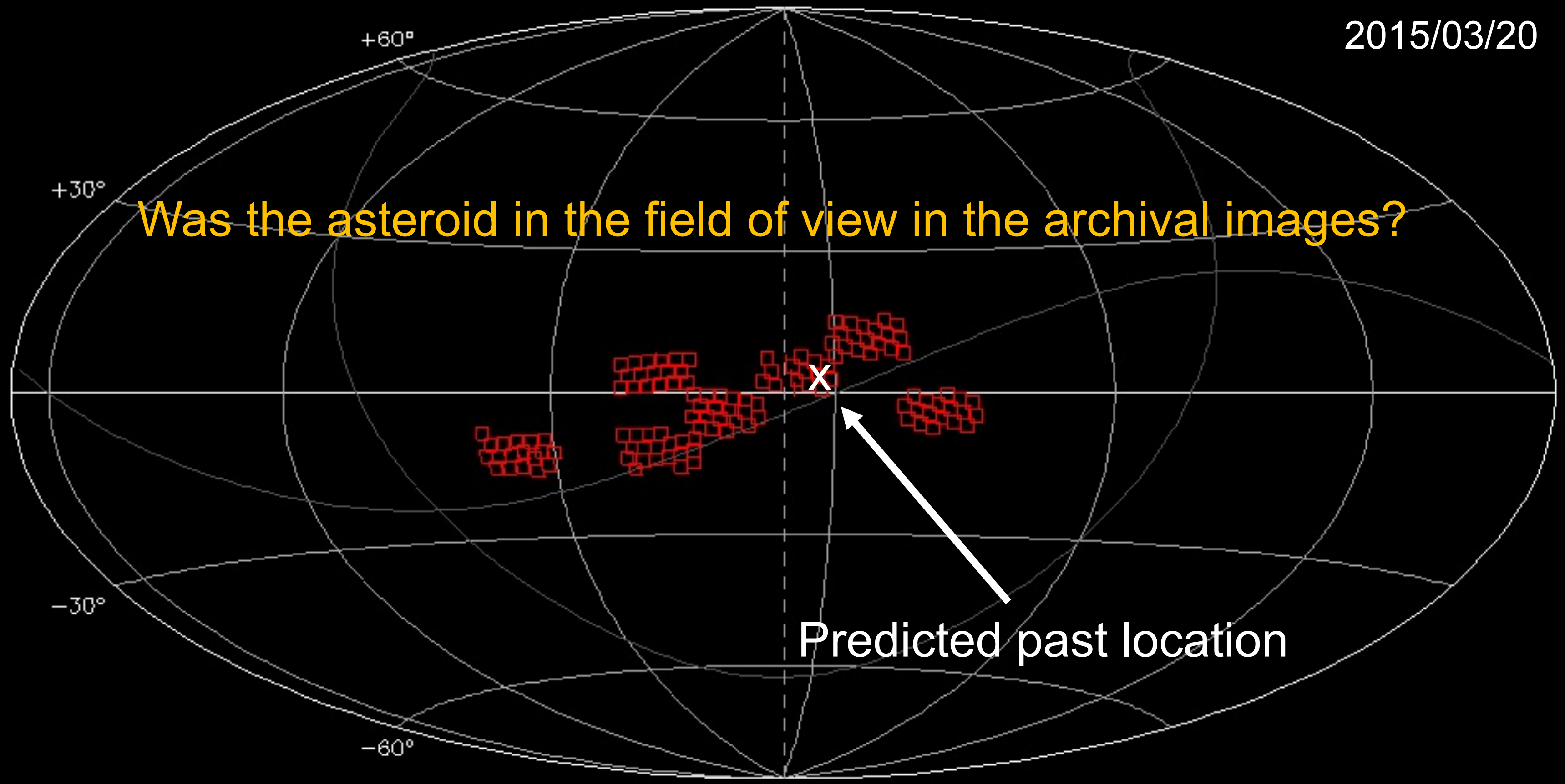
This is not the same as the damage region

EXERCISE EXERCISE EXERCISE

How Precovery Detections Are Made

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4

Sky map showing sky regions imaged by asteroid survey 7 years ago, when 2022 TTX was last near Earth:

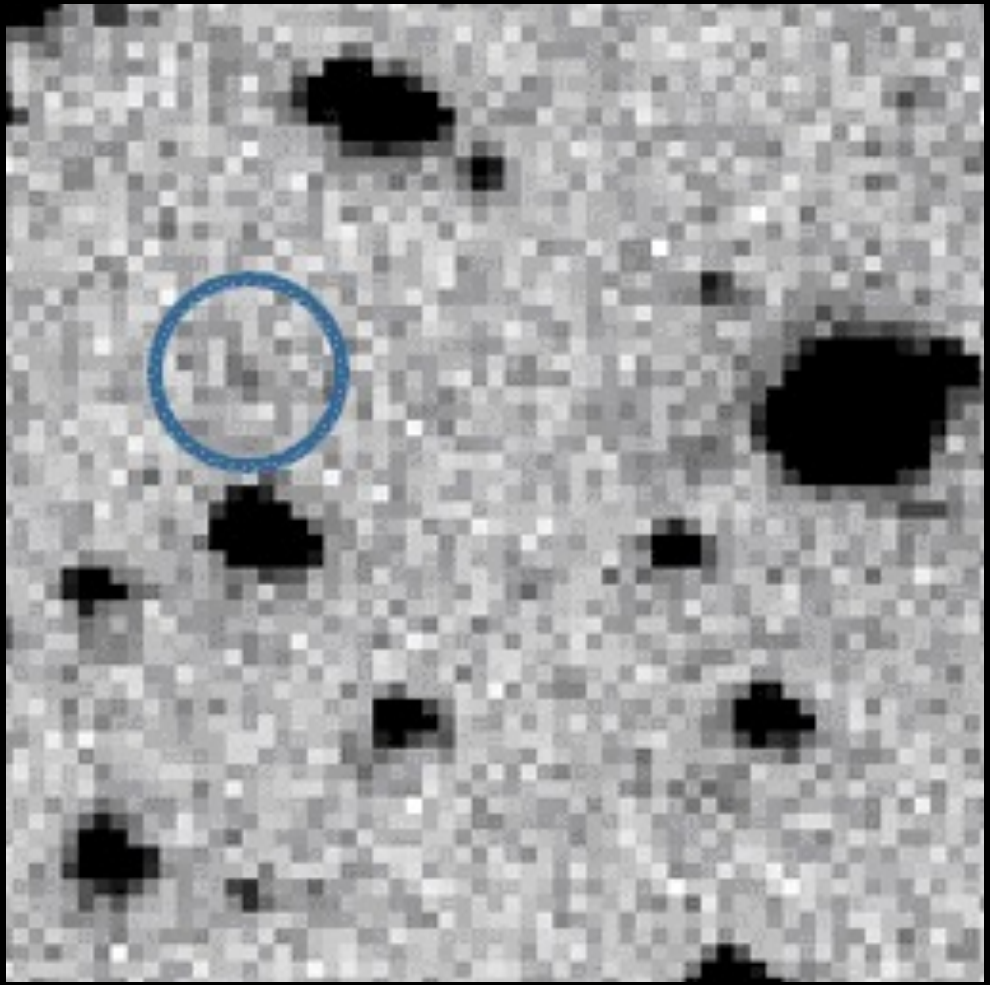


The image locations, and the images themselves, are all archived in a database

If we know an asteroid passed through these image locations, we can go back into the archive and search for it

Precovery Detection of an Asteroid

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4



Credit: Catalina Sky Survey

- Many faint asteroid detections in sky images are spurious (false)
- The processing pipelines must avoid being swamped by too many false detections
- Marginal detections are mostly discarded
- However, if an asteroid is predicted to be in the image, and a marginal detection matches its predicted motion, it's a real detection!

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4

INJECT 2.2: The Probability of Impact Has Risen to 100%

EXERCISE EXERCISE EXERCISE
This is a simulated event.

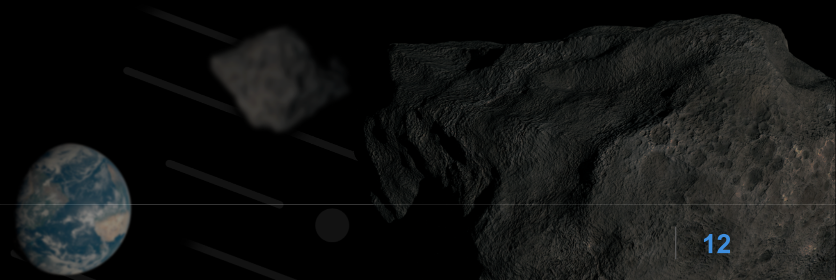
June 15, 2022

From: NASA Planetary Defense Coordination Office
Title: Notification of Asteroid Impact – Update #2

Impact Probability: 100%
Impact Date: 16 August 2022, 18:02 UTC (14:02 EDT)
Impact Risk Corridor: North Carolina
Approximate Size: 130-1100 ft (40-340 m)
Expected Level of Damage if Impact Occurs: Local to Regional
Impact Prevention Feasible: No

- Additional observation has now confirmed there is a 100% probability that asteroid 2022 TTX will impact Earth on 16 August 2022 at approximately 18:02 UTC (14:02 EDT).
- The impact risk corridor, which is the region of Earth where it is possible that 2022 TTX could impact, is in north-west North Carolina.
- The potential impact effects are highly dependent on the size of the asteroid. Based on current data, the size of the asteroid is estimated to be between 130-1100 ft (40-340 m) in size. At the small end of this size range, an asteroid impact over land could result in minor local damage (e.g. air blasts resulting in broken windows and damage to low-integrity structures). At the large end, an asteroid impact could result in a significant surface crater and widespread injuries/casualties and structural damage over a region extending tens to 100+ km.
- The asteroid 2022 TTX has been tracked since initial discovery on 11 February 2022. Detections were also extracted from archival sky images to reduce uncertainty in the asteroid's trajectory. Additional observations will further reduce the uncertainty in the asteroid's trajectory and impact location. The asteroid will be continually observable by telescopes leading up to the potential impact date, except during the full moon.

The PDCO issues an updated notification per NASA Policy Directive 8740.1.



Potential Impact Notification

PLANETARY DEFENSE INTERAGENCY

Summary details →

Impact probability and impact date/time →

Description of impact risk corridor →

Estimated impact effects →

Opportunities for further observations →

Feasibility of impact prevention space missions →

Title: Notification of Asteroid Impact – Update #2

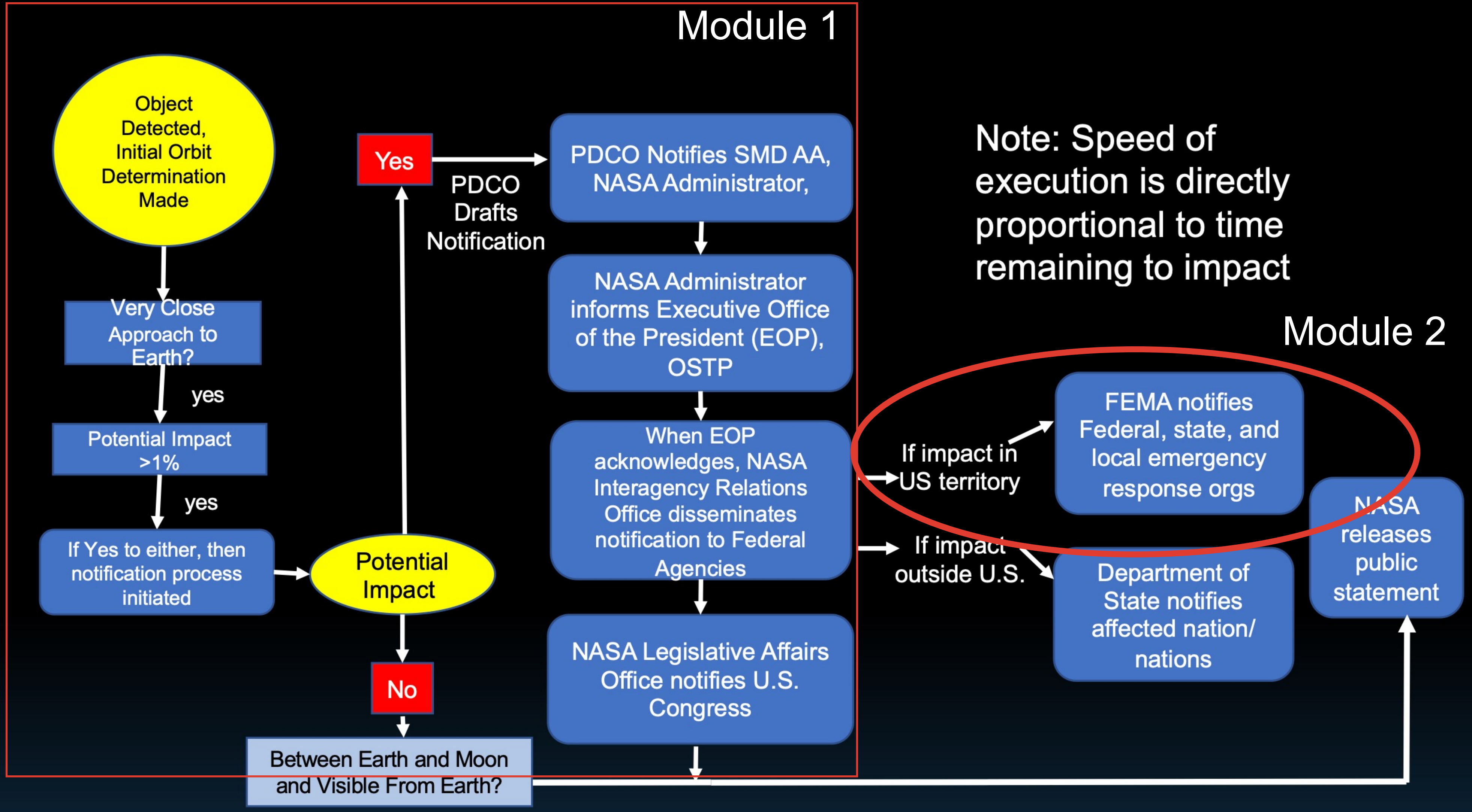
Impact Probability: 100%
Impact Date: 16 August 2022, 18:02 UTC (14:02 EDT)
Impact Risk Corridor: North Carolina
Approximate Size: 130-1100 ft (40-340 m)
Expected Level of Damage if Impact Occurs: Local to Regional
Impact Prevention Feasible: No

- Additional observation has now confirmed there is a 100% probability that asteroid 2022 TTX will impact Earth on 16 August 2022 at approximately 18:02 UTC (14:02 EDT).
- The impact risk corridor, which is the region of Earth where it is possible that 2022 TTX could impact, is in north-west North Carolina.
- The potential impact effects are highly dependent on the size of the asteroid. Based on current data, the size of the asteroid is estimated to be between 130-1100 ft (40-340 m) in size. At the small end of this size range, an asteroid impact over land could result in minor local damage (e.g. air blasts resulting in broken windows and damage to low-integrity structures). At the large end, an asteroid impact could result in a significant surface crater and widespread injuries/casualties and structural damage over a region extending tens to 100+ km.
- The asteroid 2022 TTX has been tracked since initial discovery on 11 February 2022. Detections were also extracted from archival sky images to reduce uncertainty in the asteroid's trajectory. Additional observations will further reduce the uncertainty in the asteroid's trajectory and impact location. The asteroid will be continually observable by telescopes leading up to the potential impact date, except during the full moon.
- The asteroid size cannot be estimated with further precision without radar observations or imagery from a spacecraft that can closely approach the asteroid. Radar observations will be possible no sooner than 12 days prior to the potential impact date, if the asteroid is at the large end of the size range, and possibly not until 5 days prior to the potential impact if the asteroid is at the small end.
- Space missions to prevent the impact are not feasible. Deflection is not possible due to the large velocity change that would be required to deflect the asteroid away from Earth and the limited

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE
COORDINATION OFFICE

Potential Impact Notification Process



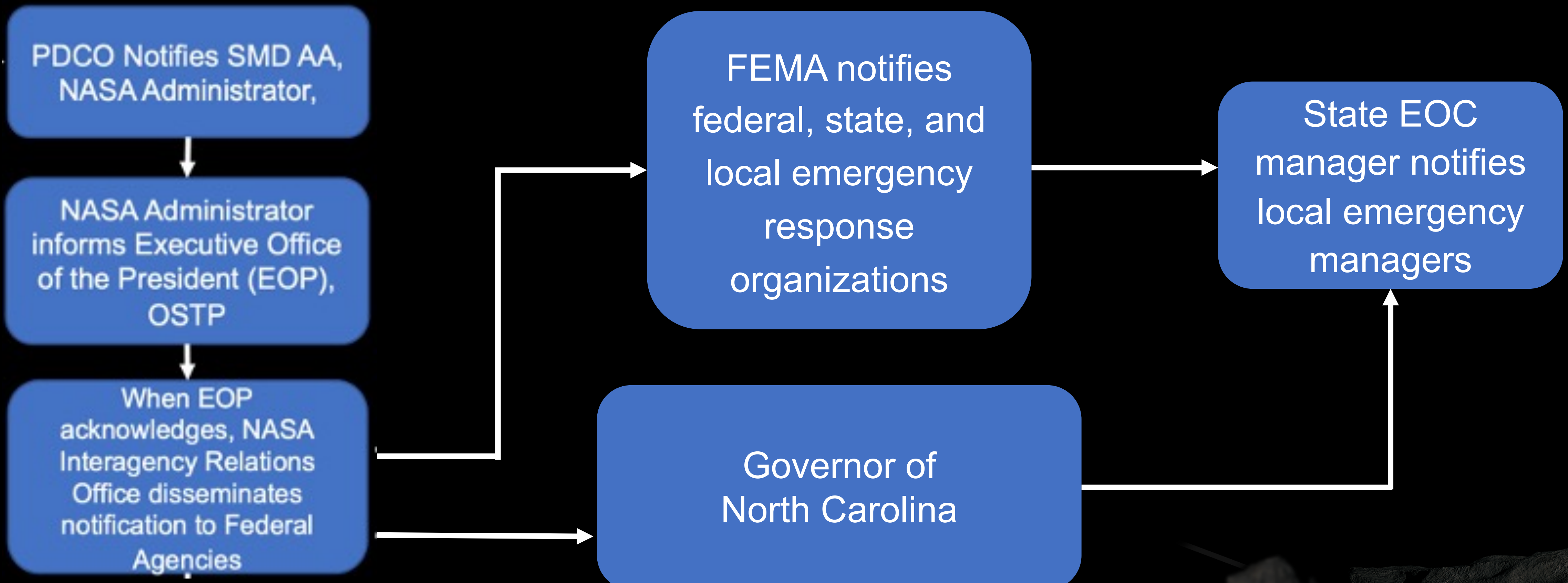
Note: Speed of execution is directly proportional to time remaining to impact

Source: NASA Policy Directive 8740.1 Notification and Communications Regarding Potential Near-Earth Object Threats

EXERCISE EXERCISE EXERCISE

Potential Impact Notification Process Module 2

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4



INJECT 2.2: The Probability of Impact Has Risen to 100%

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

EXERCISE EXERCISE EXERCISE
This is a simulated event.

June 15, 2022

From: NASA Planetary Defense Coordination Office
Title: Notification of Asteroid Impact – Update #2

Impact Probability: 100%
Impact Date: 16 August 2022, 18:02 UTC (14:02 EDT)
Impact Risk Corridor: North Carolina
Approximate Size: 130-1100 ft (40-340 m)
Expected Level of Damage if Impact Occurs: Local to Regional
Impact Prevention Feasible: No

- Additional observation has now confirmed there is a 100% probability that asteroid 2022 TTX will impact Earth on 16 August 2022 at approximately 18:02 UTC (14:02 EDT).
- The impact risk corridor, which is the region of Earth where it is possible that 2022 TTX could impact, is in north-west North Carolina.
- The potential impact effects are highly dependent on the size of the asteroid. Based on current data, the size of the asteroid is estimated to be between 130-1100 ft (40-340 m) in size. At the small end of this size range, an asteroid impact over land could result in minor local damage (e.g. air blasts resulting in broken windows and damage to low-integrity structures). At the large end, an asteroid impact could result in a significant surface crater and widespread injuries/casualties and structural damage over a region extending tens to 100+ km.
- The asteroid 2022 TTX has been tracked since initial discovery on 11 February 2022. Detections were also extracted from archival sky images to reduce uncertainty in the asteroid's trajectory. Additional observations will further reduce the uncertainty in the asteroid's trajectory and impact location. The asteroid will be continually observable by telescopes leading up to the potential impact date, except during the full moon.

The PDCO issues an updated notification per NASA Policy Directive 8740.1.

How should your agency respond to this updated notification?

Is it different from module 1?

Are there additional stakeholders that need to be included in the conversation?

How should the public be notified with the new information?

EXERCISE EXERCISE EXERCISE

INJECT 2.3: There is a 100% Chance of Impact into North Carolina, but the Exact Area at Risk Remains Unknown

Regional, local, and public safety decision-makers have been advised that they now have only two months to prepare.

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4

Asteroid Impact Risk: Module 2

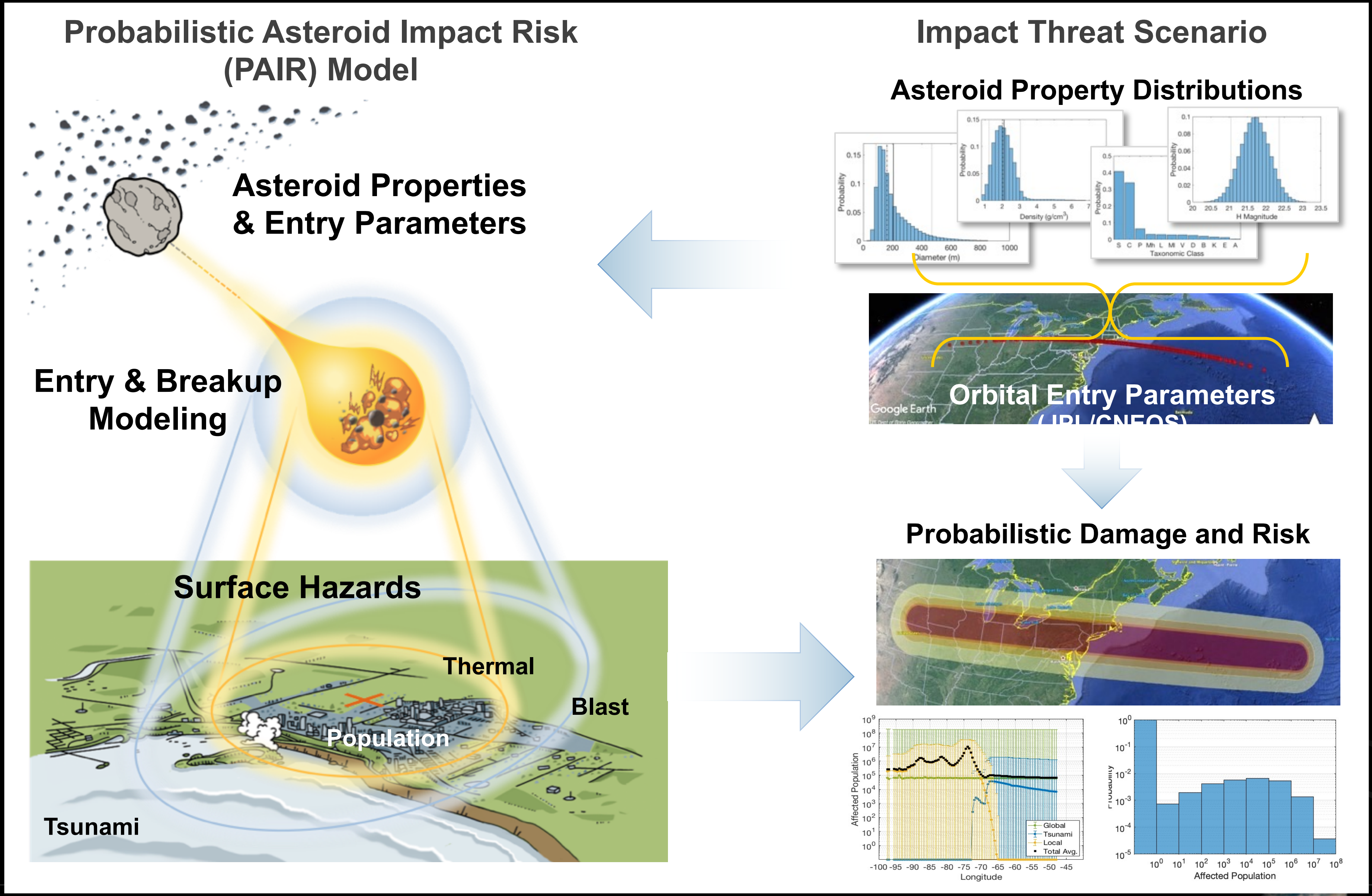
100% Chance of Earth Impact in Two Months

Lorien Wheeler
Jessie Dotson, Michael Aftosmis, Eric Stern, Donovan Mathias
Asteroid Threat Assessment Project (ATAP)
NASA Ames Research Center

EXERCISE EXERCISE EXERCISE

Asteroid Impact Threat Assessment

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4



- Risk model uses fast-running physics-based models to assess millions of impact cases representing the range of possible asteroid properties and impact locations
- Atmospheric entry, breakup, and resulting hazards (blast, thermal, tsunami) are modeled for each case
- Probabilities of the resulting damage sizes, severities, and affected populations are computed
- Regions at-risk are mapped

Asteroid Hazard Summary

- Asteroid sizes and properties remain highly uncertain, resulting in a large range of possible damage
- Primary hazard: Large airburst or ground impact causing destructive blast waves and possibly thermal burns or fires
  - Significant blast damage is almost certain to occur, ranging from shattered windows to potentially unsurvivable levels
  - Thermal damage may also occur in ~45% of (larger) cases, but it tends to be smaller, less severe, and less likely than the blast
  - Blast regions are the larger, more severe areas to guide response planning
- Blast areas could extend out ~100 mi in radius (most likely range 15–70 mi, average ~50 mi radius)

Asteroid Size Ranges

	Diameter	Energy
Range*	40–340 m (130–1100 ft)	1–1200 Mt
Most likely range	55–150 m (180–500 ft)	2–96 Mt
Median	110 m (360 ft)	42 Mt

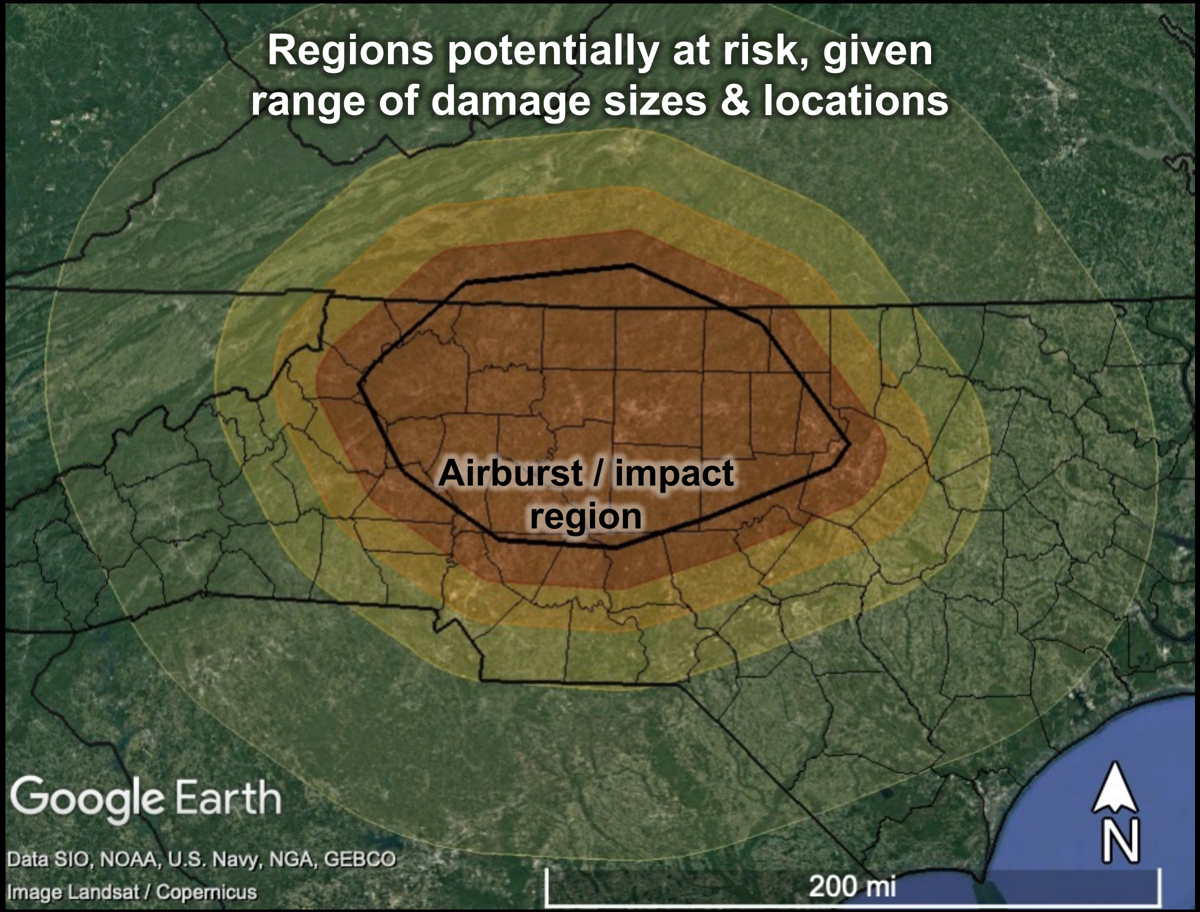
*Upper size range is large but less likely; smaller size ranges are more likely

Potential Blast Damage Severities and Sizes

Damage Level	Potential Blast Effects	Chance of Occurring	Damage Radius Range (miles)
Serious	**Shattered windows, some structure damage**	>99%	0–100 (avg. 50)
Severe	**Widespread structure damage**	~95%	0–50 (avg. 26)
Critical	**Most residential structures collapse**	~85%	0–30 (avg. 14)
Unsurvivable	**Complete devastation**	~60%	0–13 (avg. 5)

Potential Risk Swath

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4



Damage risk swath: Shaded swath areas bound potential at-risk regions given range of damage sizes and airburst/impact locations (black border).

Risk swath shows range of regions ***potentially*** at risk, given ***range*** of possible damage sizes and locations

- Black outline shows current range of potential airburst / impact points (damage-center locations)
- Shaded areas show how far the larger damage estimates ***could*** extend out from around all those points
- Colors show the highest damage severity level that could occur from those larger damage sizes

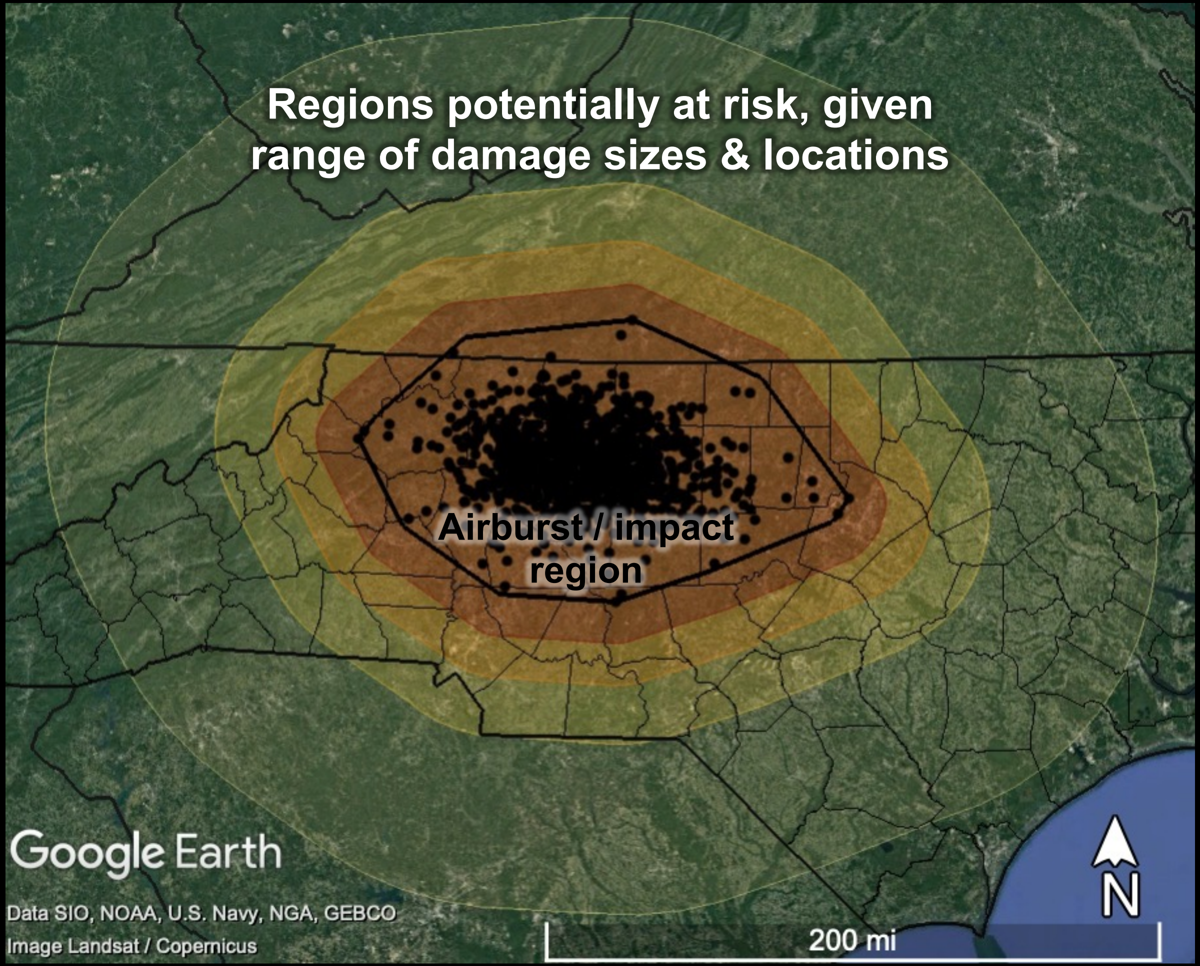
Extent of risk region:

- Centered around NC, with damage potentially extending across many counties and into neighboring states
- 360 x 280 mi (580 x 460 km) across at widest extents

Damage Level	Description
Serious	Shattered windows, some minor structure damage
Severe	Widespread structure damage, doors blown out
Critical	Most residential structures collapse
Unsurvivable	Complete devastation

Potential Risk Swath

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4



Damage risk swath: Shaded swath areas bound potential at-risk regions given range of damage sizes and airburst/impact locations (black border). Dots show a sample of the potential airburst/impact points where the damage could be centered.

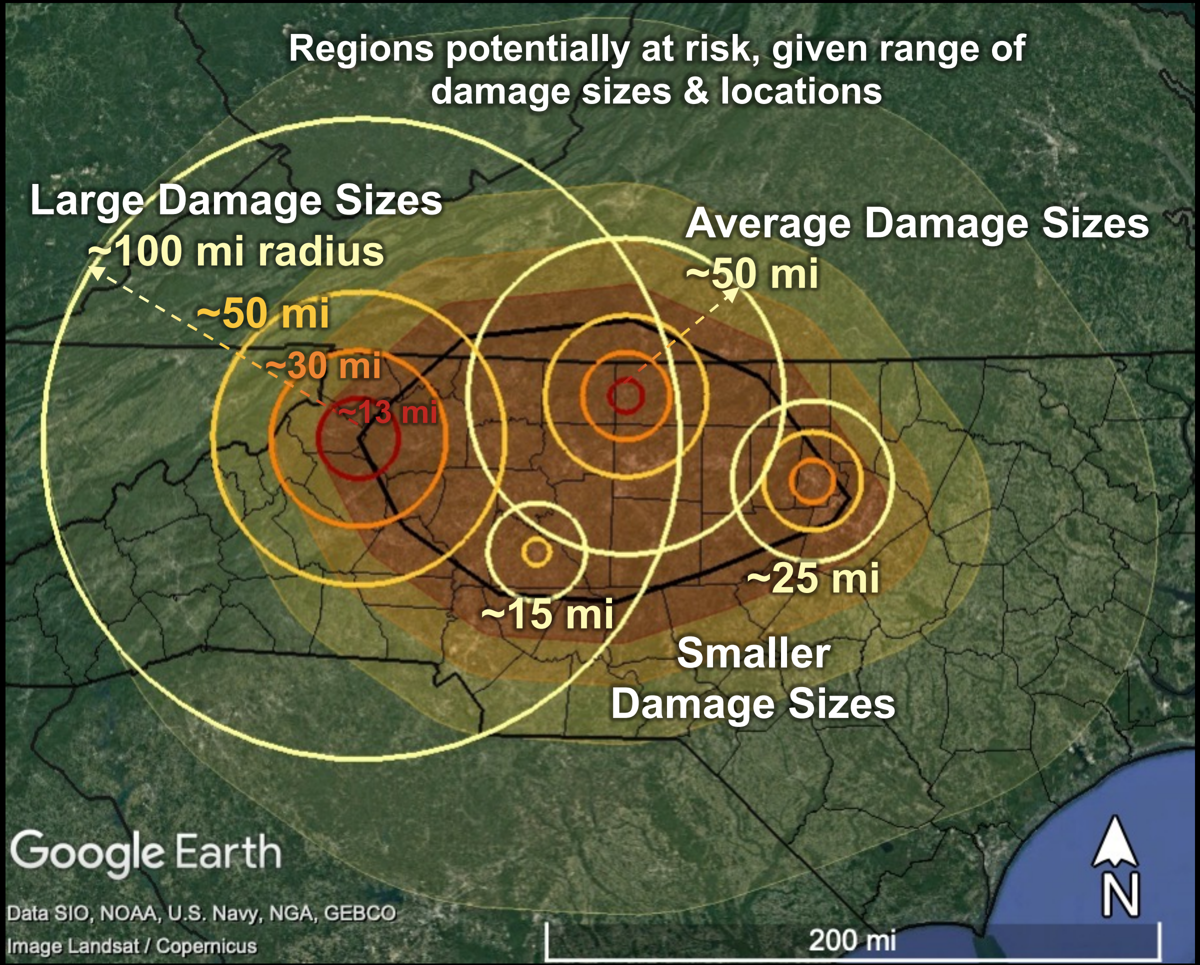
Risk swath shows range of regions ***potentially*** at risk, given ***range*** of possible damage sizes and locations

- **Black outline shows current range of potential airburst / impact points (damage-center locations)**
- Shaded areas show how far the larger damage estimates ***could*** extend out from around all those points
- Colors show the highest damage severity level that could occur from those larger damage sizes

Damage Level	Description
Serious	Shattered windows, some minor structure damage
Severe	Widespread structure damage, doors blown out
Critical	Most residential structures collapse
Unsurvivable	Complete devastation

Potential Risk Swath & Damage Sizes

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4



Damage risk swath: Shaded swath areas bound potential at-risk regions given range of damage sizes and airburst/impact locations (black border). Rings show range of damage footprint sizes at a sample locations.

Wide range of damage sizes and severities could occur, depending on asteroid size and impact factors

- Rings show examples of potential damage footprint sizes and locations
- Each damage size range could occur around any of the potential airburst/impact points within black outline

Damage radius ranges:

- Serious: ~50 mi average (range 0–100 mi)
- Severe: ~26 mi average (range 0–50 mi)
- Critical: ~14 mi average (range 0–30 mi)
- Unsurvivable: ~5 mi average (range 0–13 mi)

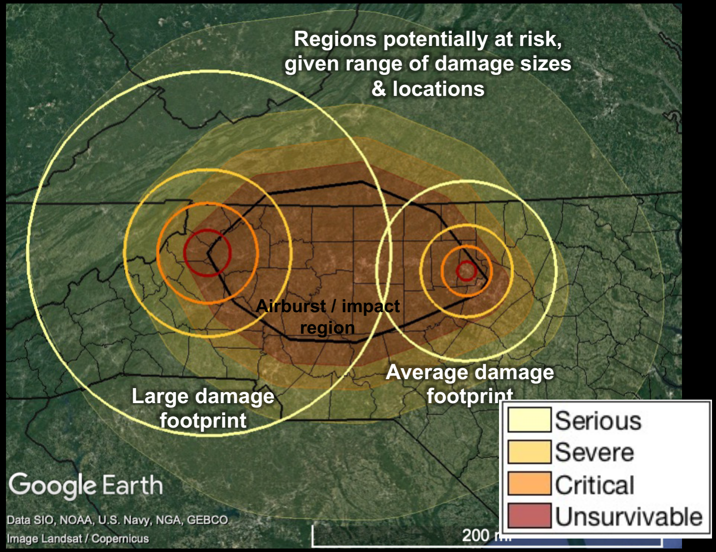
Damage Level	Description
Serious	Shattered windows, some minor structure damage
Severe	Widespread structure damage, doors blown out
Critical	Most residential structures collapse
Unsurvivable	Complete devastation

Impact Risk Summary: Module 2

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

Asteroid Characterization Summary

- Assessment date: 15 June 2022 (T-2 months)
- Impact date: 16 August 2022, impact time ~14:02 EDT
- Earth impact probability: 100%
- Properties: Small reduction in upper size ranges from NEOWISE non-detection. Type and physical properties remain unknown.
- Diameter: 40–340 m (130–1100 ft), most likely range 55–150 m (180–500 ft), median size 110 m (360 ft)
- Energy: 1–1200 megatons (Mt), most likely range 2–96 Mt, median 42 Mt



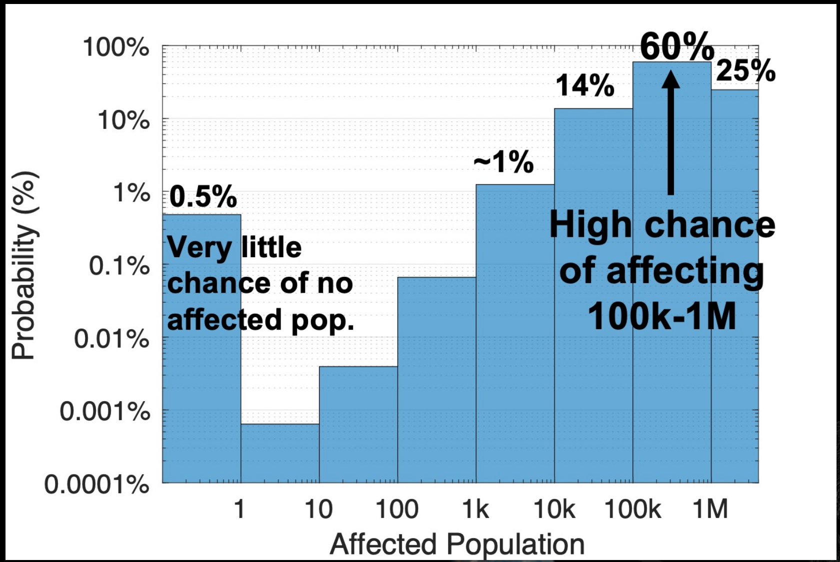
Risk Region Swath

Range of regions potentially at risk to ground damage, given range of potential damage sizes and impact locations

Rings show an average and large damage footprint size at sample locations

Impact Hazard Summary

- Significant damage to populated areas around North Carolina is very likely
- Primary hazard: Airburst causing blast damage, ranging from shattered windows and structural damage to potentially unsurvivable levels
- Damage radii: 0–100 mi, most likely range 15–70 mi, average size ~50 mi
- Affected population: Thousands to millions, 650k average risk. 98% chance of affecting >10k, 85% >100k, 25% >1M, 1% >2M



Population Risk

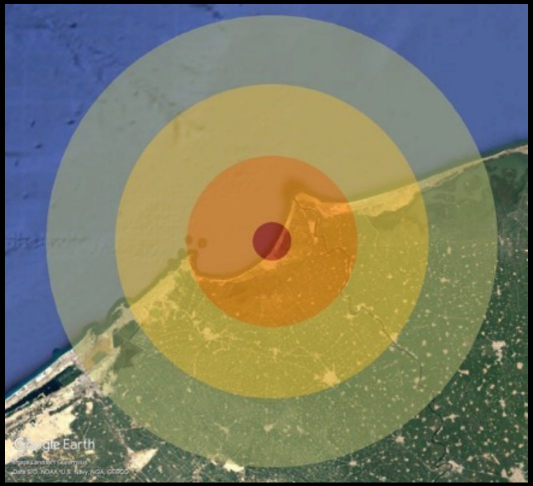
Probabilities of how many people could be affected by the potential damage

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

Module 2 Impact Risk Backup

Local Ground Damage Severity Levels

- Blast and thermal damage are assessed independently at four severity levels
  - For each damage level, the **larger** of the associated blast or thermal damage is used to determine the area and affected population for that level
  - Damage regions indicate ***either*** blast or thermal effects could exceed the given severity, ***not*** the occurrence of both effects within the entire region
- **Blast** is the predominant hazard for this scenario, and tends to be larger and more severe than the potential thermal damage in most cases



Damage Level	Potential Blast Damage Effects	Potential Thermal Damage Effects
Serious	**Shattered windows, some structural damage**	2nd degree burns
Severe	**Widespread structural damage, doors and windows blown out**	3rd degree burns
Critical	**Most residential structures collapse**	Clothing ignition
Unsurvivable	**Complete devastation**	Structure ignition, incineration

Asteroid Size & Properties

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

Asteroid sizes and properties remain highly uncertain

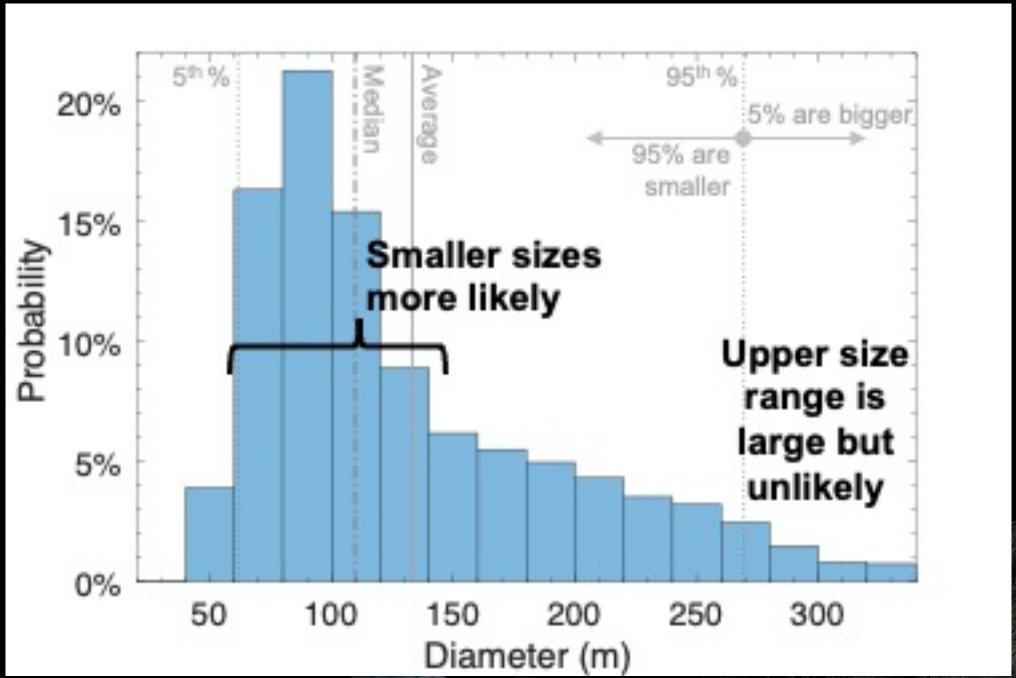
- Small reduction in upper size ranges from NEOWISE non-detection, but primary size probabilities remain similar
- Upper size range is large but relatively unlikely
- Smaller size ranges are more likely
- Type and properties are unknown, ranging from more common stony types and rubble piles to rarer high-density iron types
- Size and density uncertainties result in very large ranges of potential mass and impact energy

Large range of possible asteroid size and energy result in large range of possible damage

Asteroid Size Ranges

	Diameter	Energy
Range	40–340 m (130–1100 ft)	1–1200 Mt
Most likely range	55–150 m (180–500 ft)	2–96 Mt
Median	110 m (360 ft)	42 Mt

Asteroid Diameter Probabilities



Hazard Summary

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

- Asteroid sizes and properties remain highly uncertain, resulting in a large range of possible damage sizes and severities
- Primary hazard: Large airburst or ground impact causing destructive blast waves and possibly thermal heat damage
  - Significant blast damage is almost certain to occur, ranging from shattered windows to potentially unsurvivable levels
  - Thermal damage may also occur, but tends to be less likely, smaller, and less severe than the blast damage
- **Outer blast damage areas could extend out ~100 mi in radius** (most likely 15–70 mi, average ~50 mi radius)

Potential Blast Damage Severities and Sizes

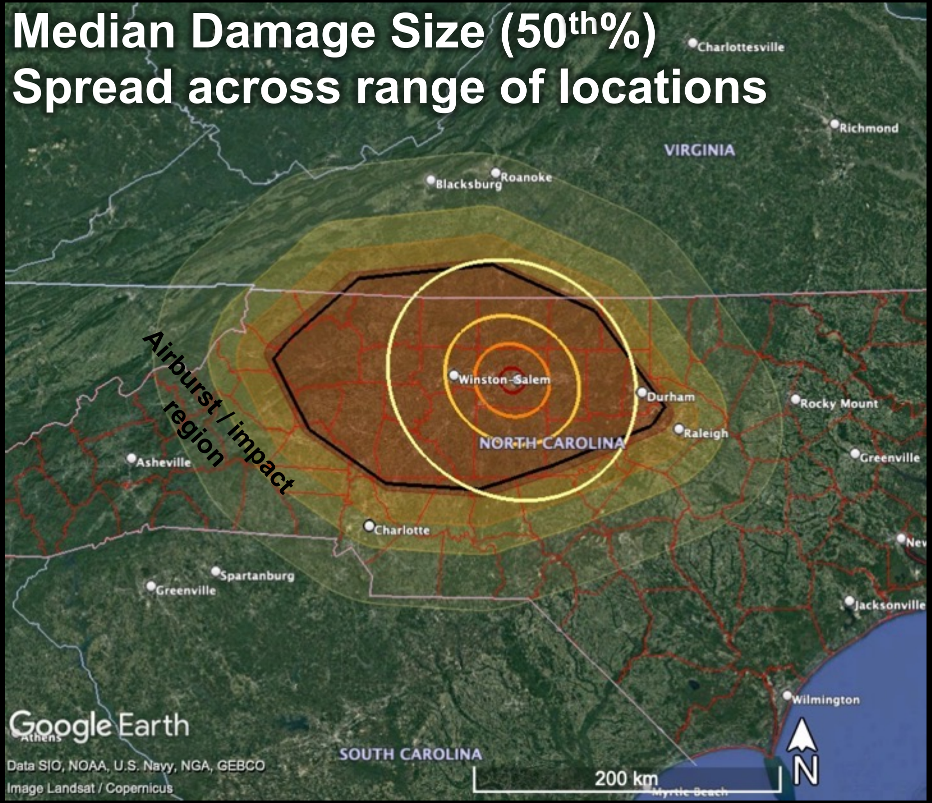
Damage Level	Potential Blast Effects	Chance of Occurring	Damage Radius Range (miles)
Serious	**Shattered windows, some structure damage**	>99%	0–100 (avg. 50)
Severe	**Widespread structure damage**	96%	0–47 (avg. 26)
Critical	**Most residential structures collapse**	86%	0–28 (avg. 14)
Unsurvivable	**Complete devastation**	61%	0–13 (avg. 5)

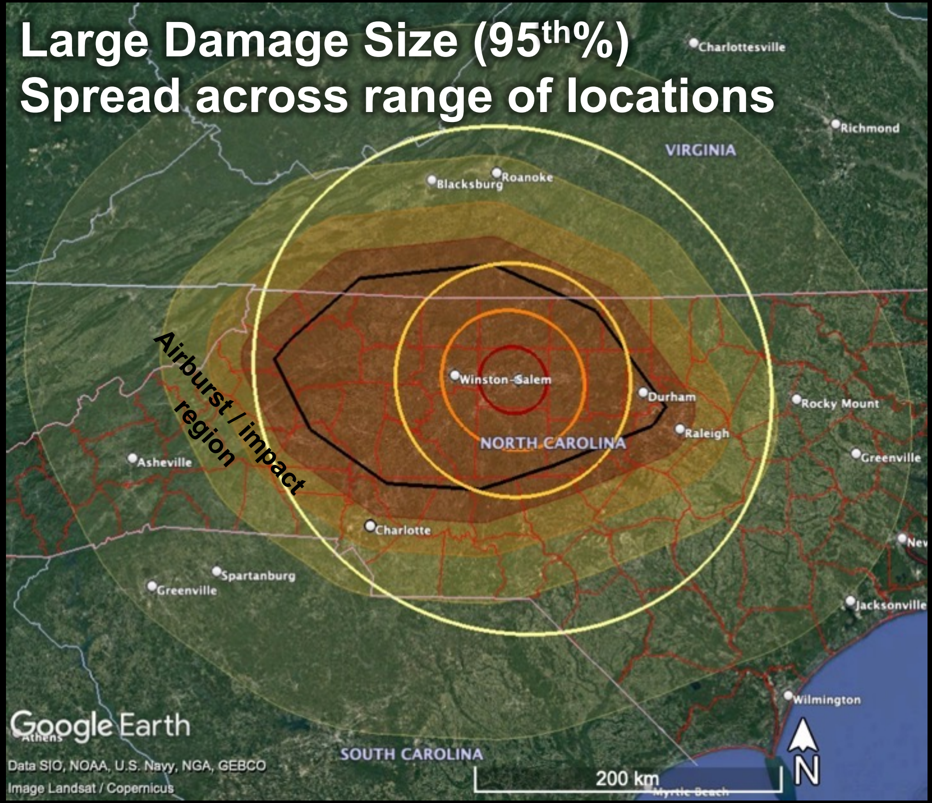
Potential Thermal Damage Severities and Sizes

Damage Level	Potential Thermal Effects	Chance of Occurring	Damage Radius Range (miles)
Serious	2nd degree burns	44%	0–22 (avg. 5)
Severe	3rd degree burns	37%	0–17 (avg. 4)
Critical	Clothing ignition	28%	0–12 (avg. 2)
Unsurvivable	Structure ignition	24%	0–10 (avg. ~1)

Damage Sizes with Location Ranges

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4





- Rings show sample footprint sizes at a single location (Greensboro)
- Black border shows range of potential airburst/impact locations (damage center points)
- Shaded regions show spread of the damage sizes over range of locations

Local Ground Damage Radius Sizes (miles)

Damage Level	Mean	Min	5th %	25th %	**50th %**	75th %	**95th %**
Serious	50	0	16	26	49	70	103
Severe	26	0	4	16	26	35	47
Critical	14	0	0	7	15	21	28
Unsurvivable	5	0	0	0	5	10	13

	Damage Level Description
	Window breakage, some minor structure damage
	Widespread structure damage, doors/windows blown out
	Most residential structures collapse
	Complete devastation

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

INJECT 2.3: There Is a 100% Chance of Impact into North Carolina, but the Exact Area at Risk Remains Unknown

Local and public safety decision-makers have been advised that they now have only two months to prepare.

- When and how does a unified command and/or multi-area coordination center begin to form?
- What are plans for ensuring continuity of government?
- What critical infrastructure in the area requires the most notice for shutdown/evacuation?

EXERCISE EXERCISE EXERCISE

INJECT 2.3: There Is a 100% Chance of Impact into North Carolina, but the Exact Area at Risk Remains Unknown

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

- What operations can be limited to ensure minimal extra population is in North Carolina at the time of impact?
- What is the coordination with the Business Emergency Operations Center (BEOC) to ensure that business and industry maintain feasibility and reliability? How would reducing activities impact the business community as well as nearby businesses that receive resources via I-85 and I-95?

EXERCISE EXERCISE EXERCISE

INJECT 2.3: There Is a 100% Chance of Impact into North Carolina, but the Exact Area at Risk Remains Unknown

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

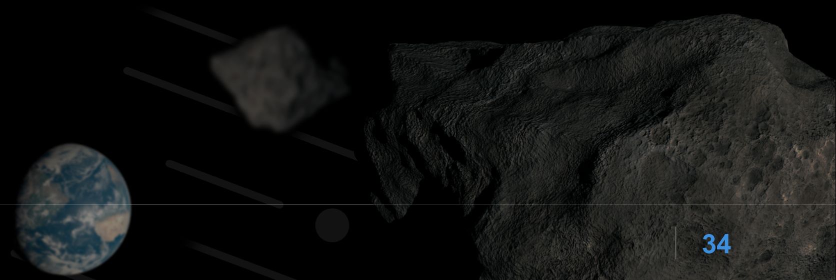
- What are the roles of federal agencies/decision-makers in this scenario?
- What are the roles of state agencies?
- What information is required by each?
- How are actions and decisions by federal agencies coordinated with state-level EM teams?

INJECT 2.4

There might be a possibility to disrupt the asteroid with a suborbital explosion.

An intercontinental ballistic missile (ICBM) equipped with a nuclear explosive device might be able to intercept the asteroid a few minutes before impact.

We would have to prep for a go/no-go decision now.



EXERCISE EXERCISE EXERCISE

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4

Law and Policy

Liability Overview as Relevant to Nuclear Explosive Devices (NEDs)

Aparna Srinivasan, Esq.
TTX Evaluation Lead, Legal Analyst
Johns Hopkins Applied Physics Laboratory
aparna.srinivasan@jhuapl.edu

EXERCISE EXERCISE EXERCISE

FEMA

NORTH CAROLINA

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Accountability for Mitigation Measures

Balancing Act Implemented via Political and Legal Instruments

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

Prime Rule for Liability of Launching States

- **Article VII OST**: *Each State Party...that launches or procures the launching of an object in outer space is internationally liable for damage to another State Party to the Treaty...*
- **Article II, III, The Liability Convention**: Two different liability regimes apply to payment of compensation:
  - Absolute liability: damage caused by a space object on the surface of Earth (or to aircraft in flight)
  - At-fault liability: damage caused by a space object elsewhere than on Earth's surface

Invocation of State Responsibility Exculpatory Clause: Necessity

- Note continued duty of restitution/compensation owed for damage
- May be further mitigated by authority of the UN Security Council

Elements of a Claim

Qualification as a "Launching State"

Damage

Causality or Causal Chain

Fault of the Actor

Liability depends on the unique factual circumstances and legal interpretation governing the planetary defense mission.

Mitigating Liability Risk

Advance Following Potential Measures:

1. Support the establishment of an international decision-making framework
   - Carve out, from existing principles and customary law, standards to govern the specific context of near-Earth object (NEO) threat response actions
   - Develop customary and possibly treaty law to address voids, uncertainty, or absence of relevant international rules
   - Maintain level of global transparency and trust
2. Establish a multilateral agreement (before a NEO impact discovery)
   - Sanctioned by the UN Security Council or via resolution (Chapter VII, UN Charter) identifying thresholds/parameters to authorize a NED response
   - Obtain international acceptance of specific planetary defense measures
   - Incorporate ad hoc or cross waivers of liability
3. National Options to Explore
   - Set thresholds for a 6-month or 12-month mitigation plan
   - Close technology and knowledge gaps

Questions to Consider:

- What if States decide to unilaterally and independently deploy an NED?
- Should we amend treaties to:
  - Deflect an asteroid?
  - Deploy nuclear option in an emergency or test mission?
- How should we ensure that countries will not exploit nuclear option exceptions for NEOs as a pretext for military purposes?
- Should we require that use of NEDs be sanctioned by the UN Security Council?
- What rules should govern storage/acquisition of nuclear material meant for disruption missions?

Determine confidence metrics for decision-makers

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4

Close Proximity Nuclear Disruption with Ballistic Missile Systems

Patrick King, Ph.D.
Staff Physicist
Johns Hopkins University Applied Physics Laboratory
Patrick.King@jhuapl.edu

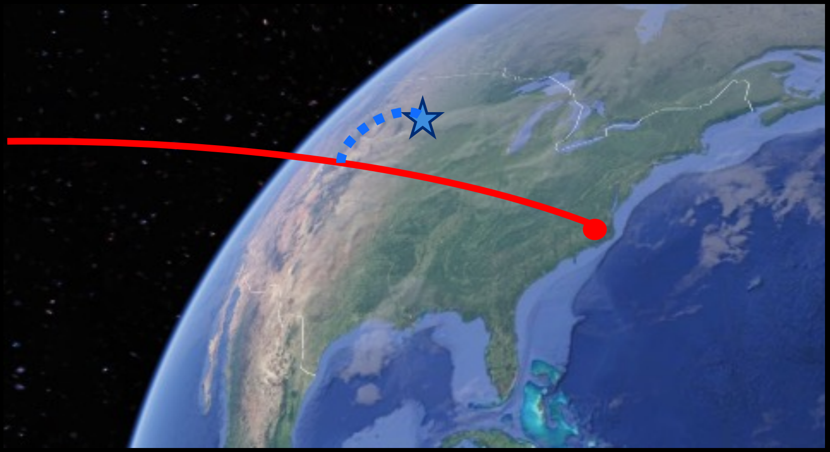
EXERCISE EXERCISE EXERCISE

NASA
PLANETARY DEFENSE COORDINATION OFFICE
U.S. DEPARTMENT OF HOMELAND SECURITY
FEMA
EMERGENCY MANAGEMENT NORTH CAROLINA
WINSTON-SALEM FORSYTH COUNTY NC EMERGENCY MANAGEMENT
CNEOS
Ames Research Center
JOHNS HOPKINS APPLIED PHYSICS LABORATORY

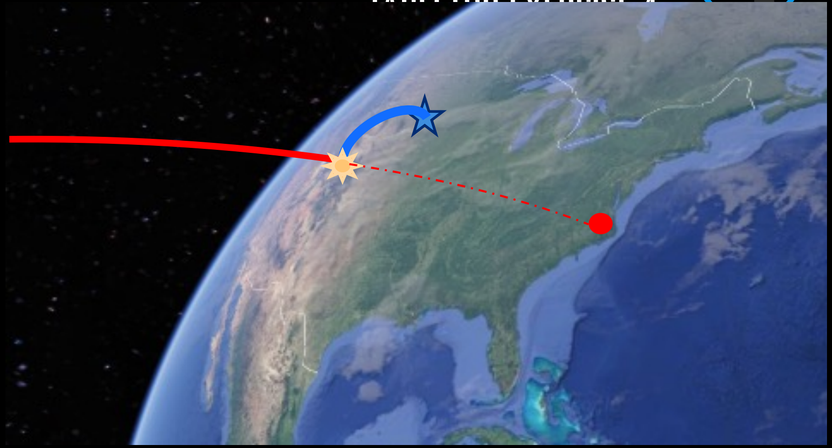
Ballistic Missile Nuclear Intercept Concept

PLANETARY DEFENSE
INTERAGENCY

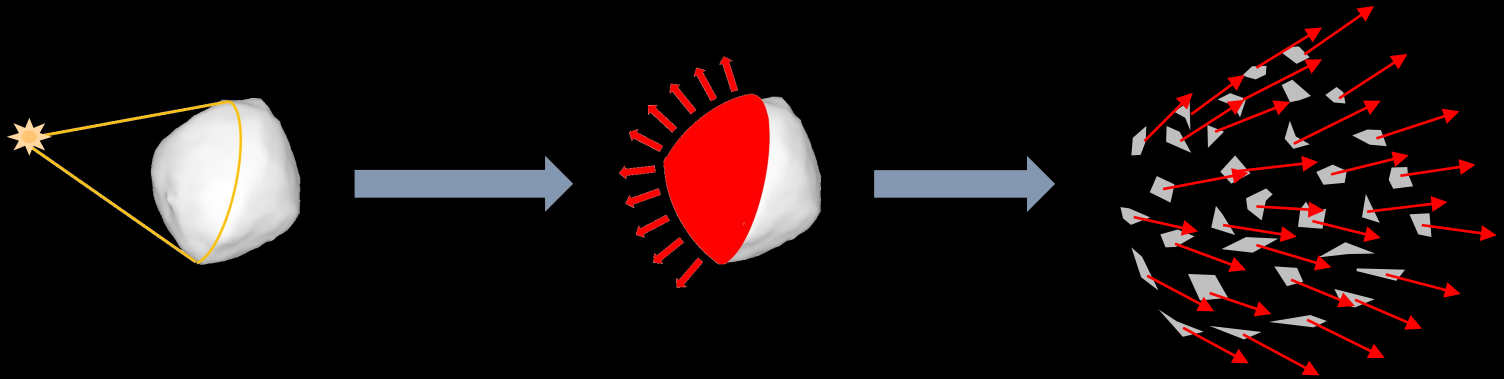
1. Radar/observations refine the orbit of the impactor to high precision.



2. Ballistic missile trajectory and guidance modified to an intercepting trajectory.

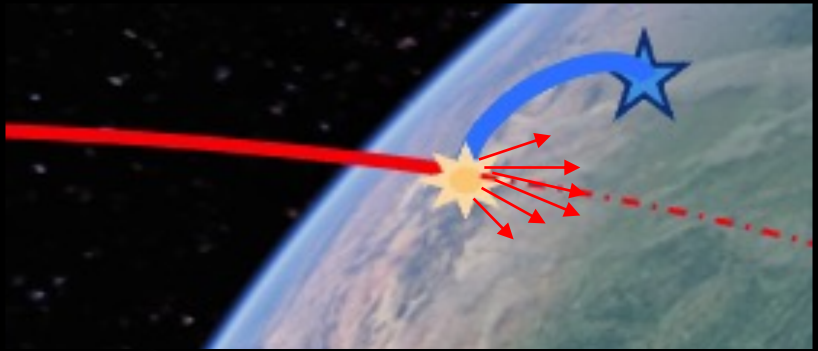


3. Ballistic missile is launched and the payload is detonated near impactor.



4. The nuclear explosive irradiates the surface of the impactor, which explodes and drives a strong shock.

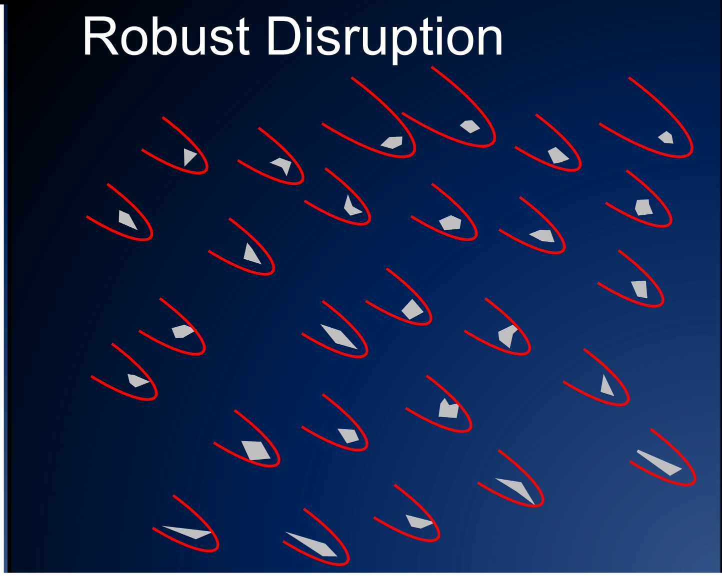
5. The shock shatters the impactor and disperses the fragments, separating them spatially.

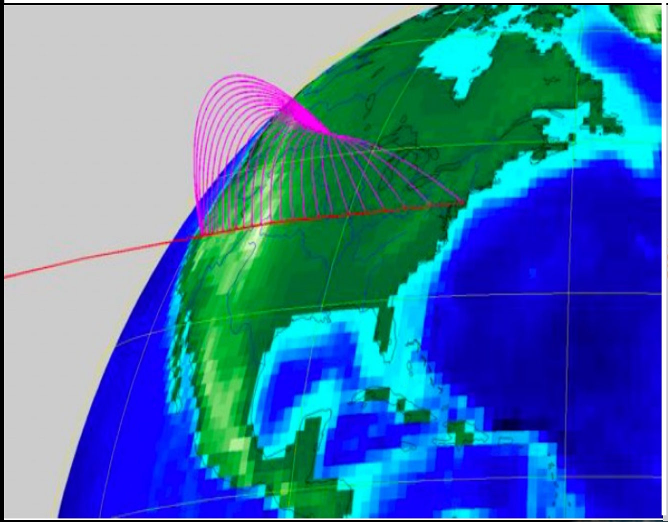


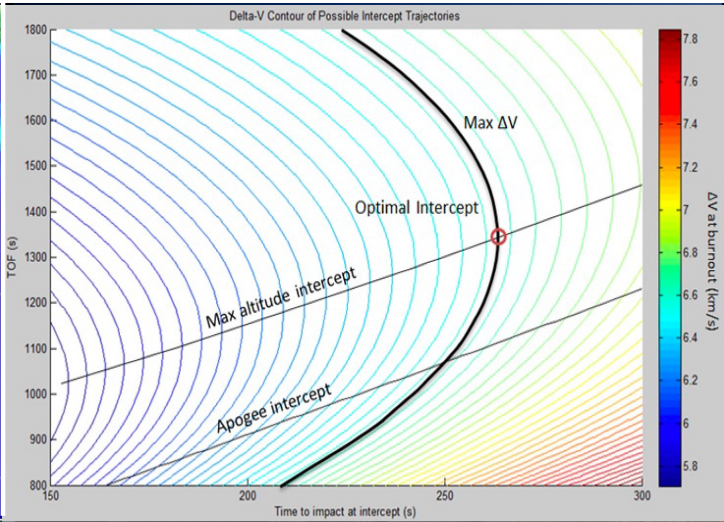
6. The dispersed fragments enter the atmosphere separately, distributing them into many separated bolides, possibly reducing damage.

Effectiveness and Feasibility

- Effectiveness will be closely related to how well-dispersed the fragments are
- Dispersal depends on both the strength of the disruption and how much time before atmospheric entry the fragments are allowed to disperse
- Disruption effectiveness is closely related to delivered yield (device yield, target size, and proximity of burst)
- Preliminary analysis (Hupp et al. 2015) suggests a notional system like a Minuteman III could provide intercept trajectories on the order of minutes before impact
- Further APL analysis suggestive that off-the-shelf guidance accuracy is an important limiting factor for this concept





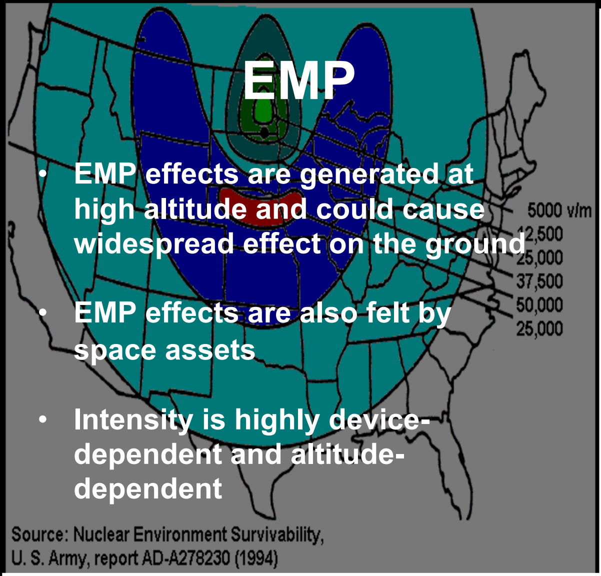


From Hupp et al. 2015

Secondary Consequences and Hazards

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

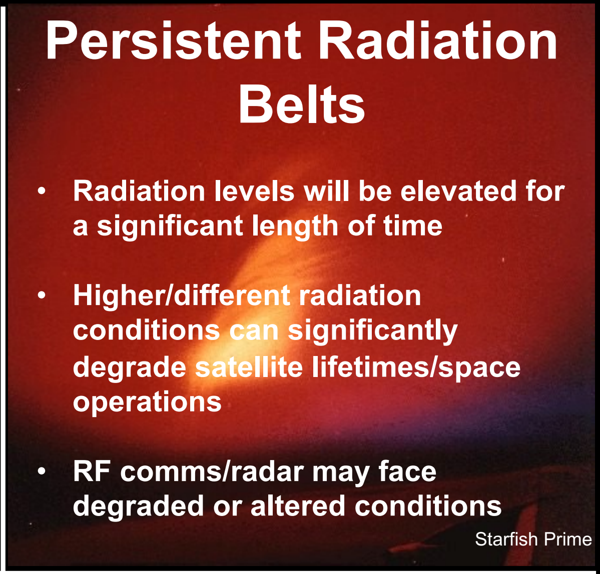
- High-altitude nuclear events (HANEs) are known to produce several hazardous effects
- These effects would be concurrent with any impact consequences and could make a bad situation worse
- These effects may impact both U.S. and foreign assets
- Exact estimates would require detailed analysis but would use established tools (DOD and DOE)
- Persistent effects could potentially affect space operations for an extended period of time (from weeks to even years)
- Some of these effects might be able to be mitigated (e.g. circumvent & recovery procedures)
- These effects are all yield- and altitude-dependent



EMP

- EMP effects are generated at high altitude and could cause widespread effect on the ground
- EMP effects are also felt by space assets
- Intensity is highly device-dependent and altitude-dependent

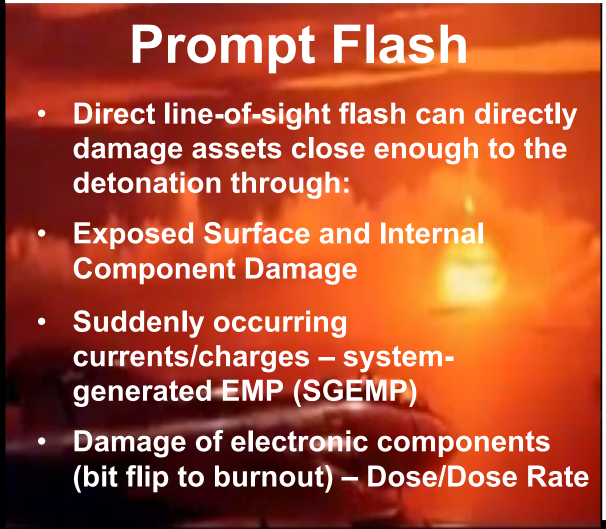
Source: Nuclear Environment Survivability, U. S. Army, report AD-A278230 (1994)



Persistent Radiation Belts

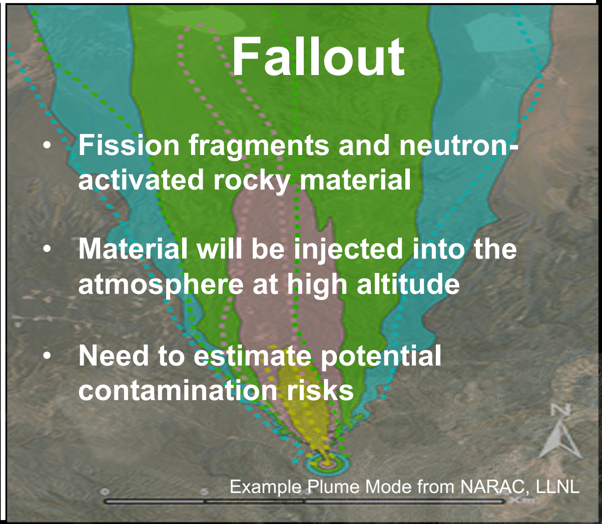
- Radiation levels will be elevated for a significant length of time
- Higher/different radiation conditions can significantly degrade satellite lifetimes/space operations
- RF comms/radar may face degraded or altered conditions

Starfish Prime



Prompt Flash

- Direct line-of-sight flash can directly damage assets close enough to the detonation through:
- Exposed Surface and Internal Component Damage
- Suddenly occurring currents/charges – system-generated EMP (SGEMP)
- Damage of electronic components (bit flip to burnout) – Dose/Dose Rate



Fallout

- Fission fragments and neutron-activated rocky material
- Material will be injected into the atmosphere at high altitude
- Need to estimate potential contamination risks

Example Plume Mode from NARAC, LLNL

Summary

- Disrupting the asteroid before atmospheric entry may significantly reduce the direct consequences of impact. However, this is only possible with a nuclear explosive, and the mitigation effectiveness needs to be studied in more detail.
- “Off-the-shelf” feasibility of using a representative class of suborbital ballistic missiles (similar to Minuteman III) has been explored, and not ruled out, but significant uncertainties do remain.
- The HANE would produce significant effects that could disrupt space operations and potentially cause adverse ground effects.
- All of these results are preliminary and need to be confirmed by more intensive analysis.

INJECT 2.4: There Might Be a Possibility to Disrupt the Asteroid with a Suborbital Explosion

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4

- What U.S. government agencies/departments would have a role in pursuing a course of action or in making a recommendation to the president regarding the decision to proceed?
- What factors, to include liability concerns, would need to be considered in the decision to pursue a close-proximity disruption mission?
- What would you consider to be the most critical gaps impacting the decision to launch a close-proximity disruption mission?

PLANETARY DEFENSE
INTERAGENCY
TABLETOP EXERCISE 4

Comments on slide 10

- Module 2 Early Preparedness Wrap

  https://nsad-jaf-op1.jhuapl.edu:8443/opinio/s?s=7312 | 60 (Aaron Chrietzberg)

Your comment

POST

Contributions identify the contributor

UNCLASSIFIED

Planetary Defense Interagency Tabletop Exercise IV - Module 2 Early Preparedness

APL

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Instructions: We kindly request that you respond to all questions and provide as much detail as possible. Your responses are an essential part of the TTX and will help us capture lessons learned for the after-action report and future exercises. Thank you for your time

Module 2 Early Preparedness Wrap

1. Name and Title (please include rank, if applicable)

2. Organization and Unit/Division.

EXERCISE EXERCISE EXERCISE

PLANETARY DEFENSE INTERAGENCY TABLETOP EXERCISE 4