HYPOTHETICAL EXERCISE

Probabilistic Asteroid Impact Risk Assessment:
2023 PDC Hypothetical Impact Exercise Epoch 3

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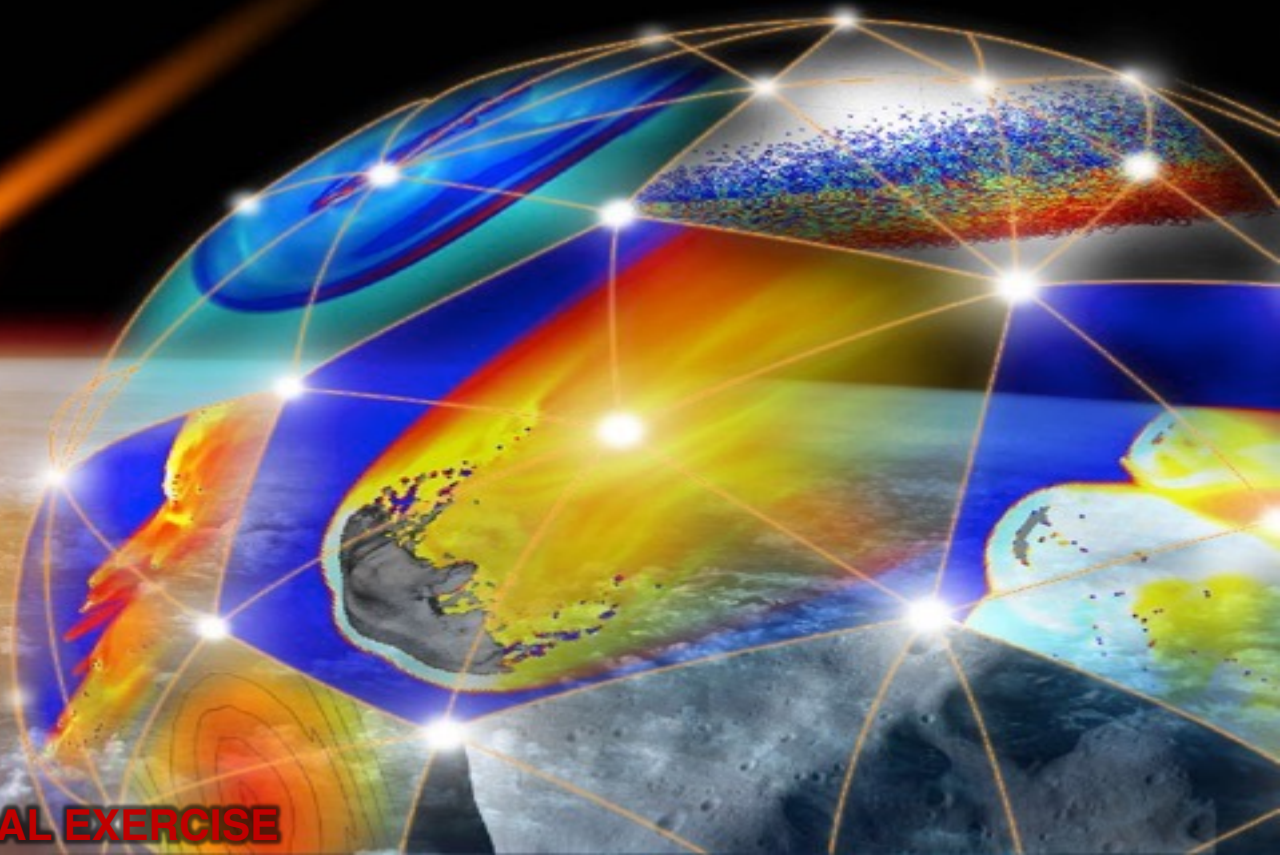


8th IAA Planetary Defense Conference
April 2023

HYPOTHETICAL EXERCISE

Contents

This presentation summarizes impact risk assessment results for Epoch 3 of the 2023 PDC hypothetical asteroid impact scenario. Epoch 3 represents the assessment phase after data is received from a fast fly-by reconnaissance mission, which refines direct size estimates, asteroid type, and impact location range.

Introductory information on the asteroid threat assessment processes and details on the risk modeling, impact hazards, affected population estimates, and damage risk maps used in this assessment can be found in the Introduction to Impact Risk Assessment presentation on the CNEOS impact scenario website.

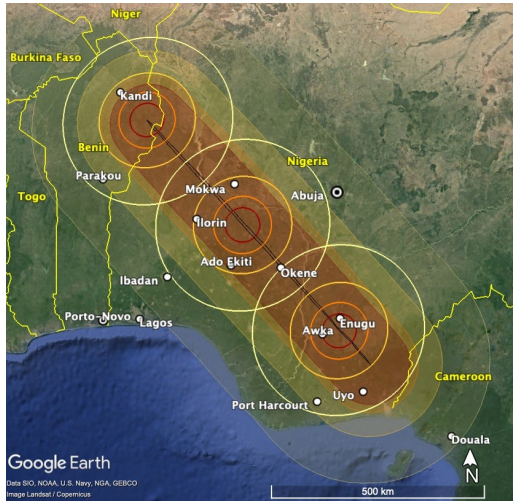
Contents:

Impact Risk Summary

Assessment 3: Fly-by Recon Mission Data, 1 December 2025

Asteroid Characterization Summary

- Potential impact date: 22 Oct. 2036
- Earth impact probability: 100%
- Asteroid size range substantially refined by data from fast fly-by recon mission
- Diameter: 320–1110 m (1050–3640 ft), most likely 550–860 m (1800–2820 ft), median size 700 m (2300 ft)
- Asteroid Impact Energy: 280–28,500 megatons (Mt), most likely 1,150–9,300 Mt, median 6,270 Mt



Risk Region Swath Map

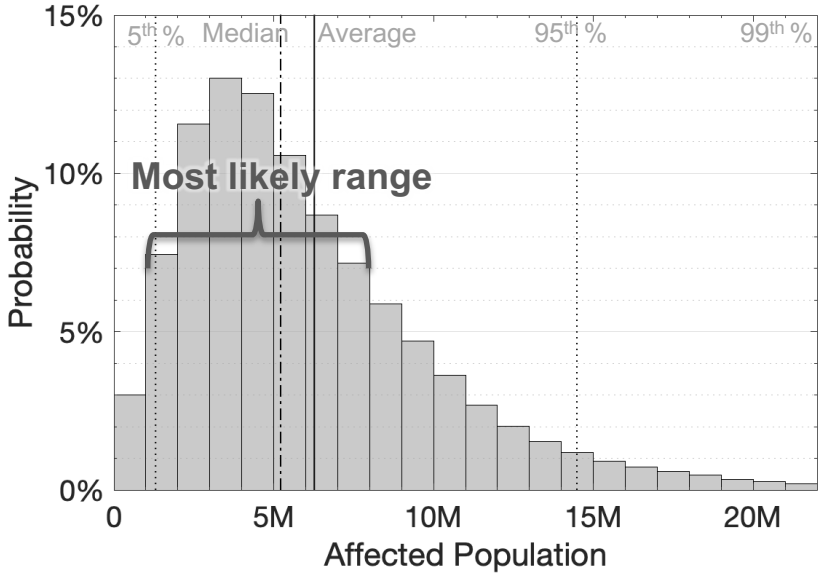
Regions potentially at risk, given range of damage sizes and locations. Median-sized damage areas are shown at sample locations.

- Serious
- Severe
- Critical
- Unsurvivable
- Damage Centers

Hazard Summary

- Primary hazard is a large impact causing devastating blast & thermal damage reaching unsurvivable levels, with very large areas of serious damage
- Unsurvivable regions likely to extend ~15–40 km (~10–25 mi) outward, and possibly out nearly ~200 km (120 mi)
- Serious damage levels (blown in windows, minor structure damage) likely extend ~150–230 km (~90–140 mi) outward, and possibly out 330 km (200 mi) or more
- Minor chance of larger regional or semi-global environmental effects from largest impact sizes

Affected Population Risks



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

Total avg. risk: ~6M

Median: ~5M

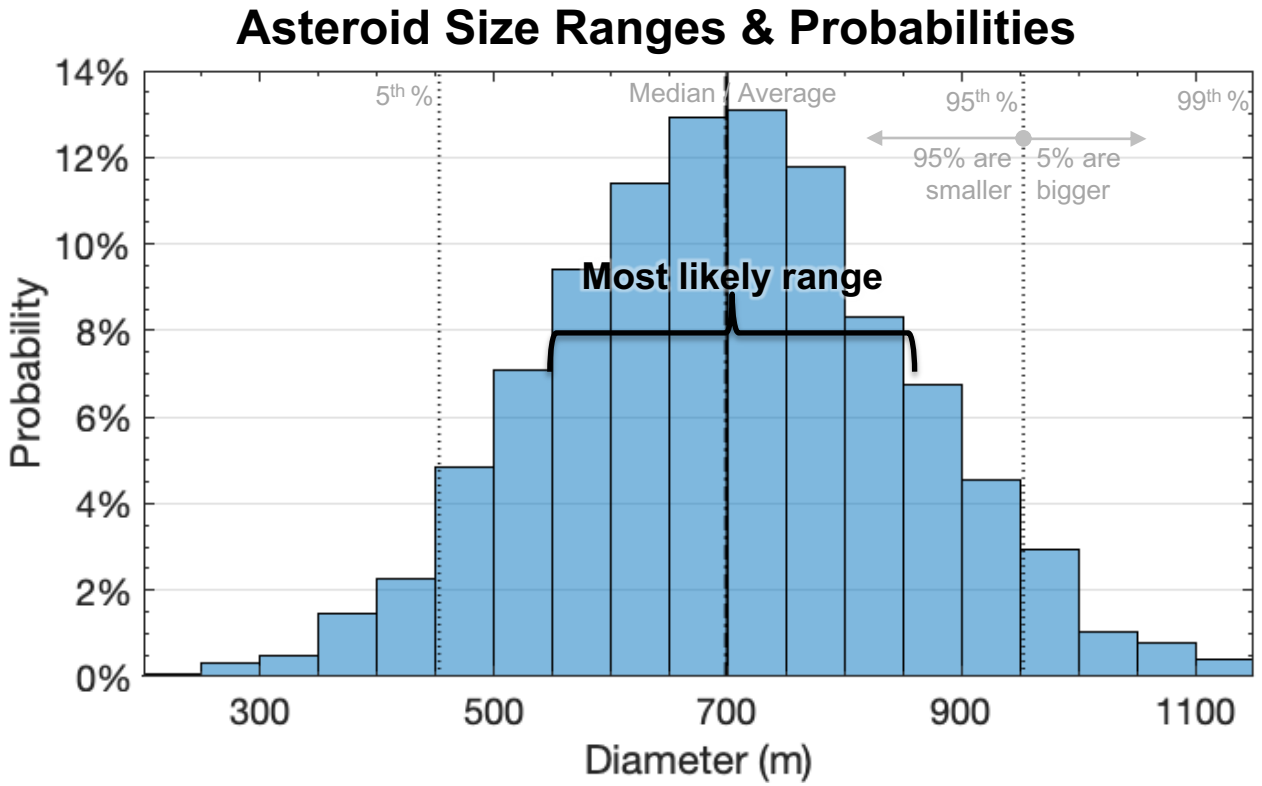
Most likely several millions

Possibly up into tens of millions

HYPOTHETICAL EXERCISE

Asteroid Size & Properties

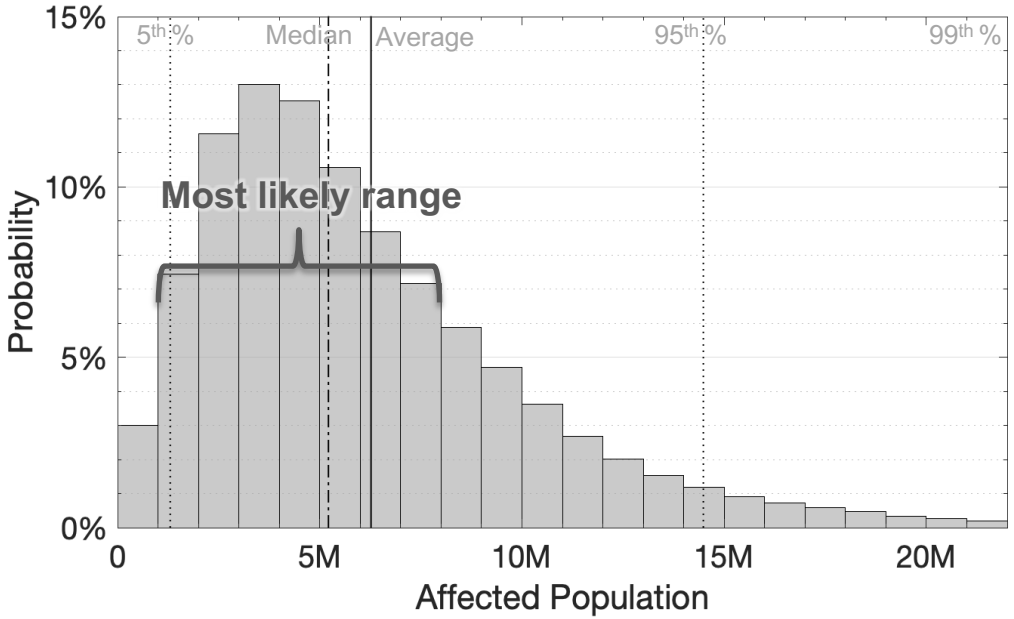
- Asteroid size & property refinements from fast fly-by reconnaissance mission:
  - Imaging from fly-by mission greatly refined direct estimates of asteroid physical size
  - Size uncertainty remains due to limitations of fly-by speed, imaging resolution, and view angle (only one side, potential for shape and dimensions unknown)
  - Asteroid type confirmed to be C type (carbonaceous stony), slightly reducing density estimates and mass ranges
- Size Estimates:
  - Most likely size ranges are ~550–860 m (~1800–2820 ft) in diameter
  - Largest sizes could be over 1 km in diameter
  - Most likely energies ~ 1.2–9.3 Gt, potentially up to ~29 Gt



	Diameter	Mass (kg)	Energy (Mt)
Median	700 m (2300 ft)	3.3e11	6,270
Average	700 m (2300 ft)	4.0e11	7,670
Most likely	550–860 m (1800–2820 ft)	6.0e10–4.9e11	1,150–9,300
Range	320–1110 m (1050–3640 ft)	1.5e10–1.5e12	280–28,500

[Property inference model: J. Dotson PDC 2023]

Affected Population Risks



Population Risk Histogram: Probabilities of affecting the number of people within each range

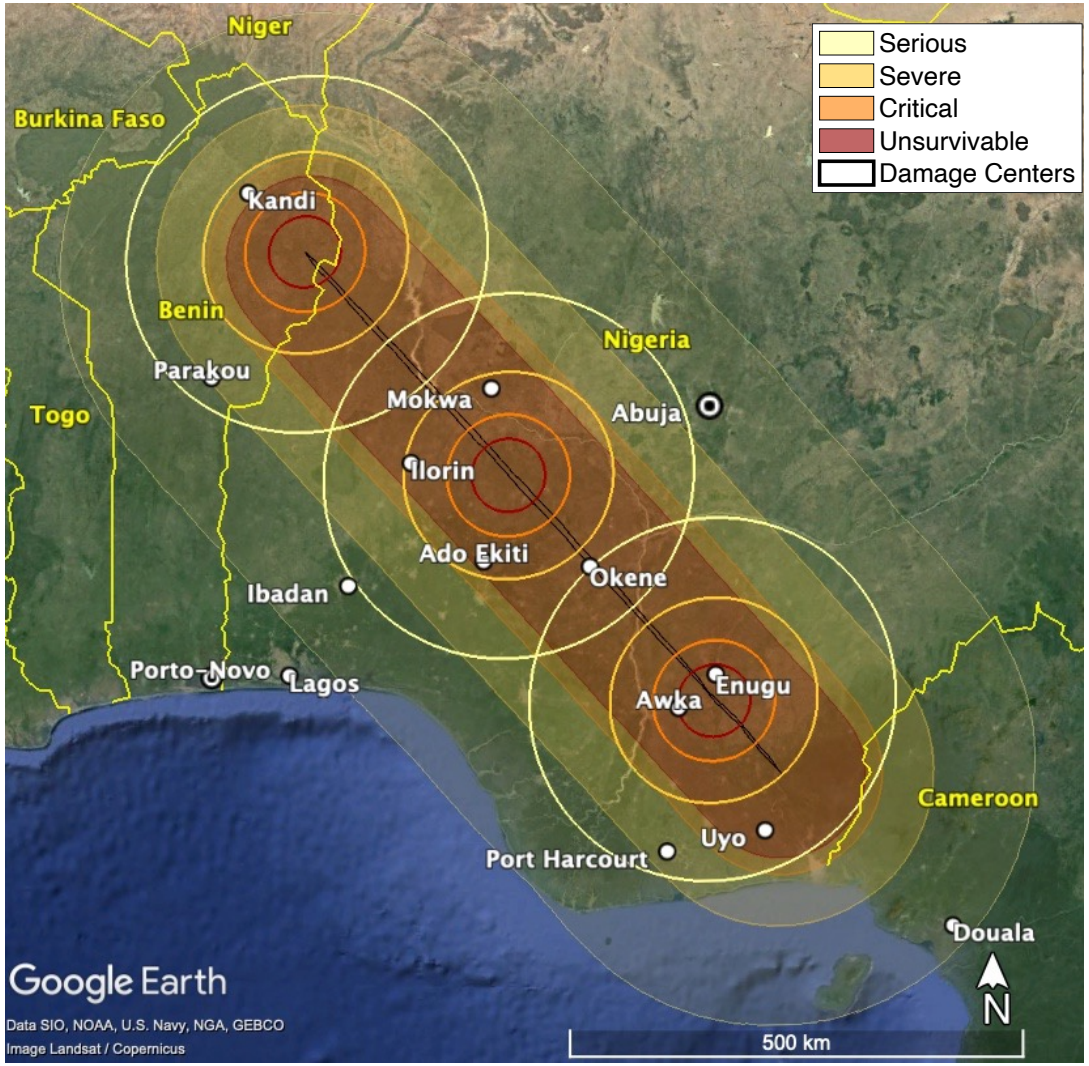
Affected Population Threshold	Probability of Damage Exceeding Threshold
>100K	~100%
>1M	97%
>3M	78%
>5M	52%
>7M	33%
>10M	15%
20M–80M	1.6%

Population Exceedance Risks: Probabilities of damage affecting ***at least*** the given number of people *or more*

- **Affected population range has narrowed to hundreds-of-thousands to tens-of-millions, most likely in the several millions**
  - Damage is most likely to affect several million people
  - Moderate (~15%) chance of larger damage affecting tens of millions
  - Smallest damage almost certain to exceed 300K people (prior chance of smaller damage eliminated)
  - Chance of larger global effects >80M people has been eliminated
- **Affected population risks:**
  - Average population risk: 6.3M people
  - Median: 5.2M people
  - Most likely range (68%): ~1–8M people
  - Potential range (99%): ~300K–22M
  - Full range modeled: 92K–84M

[PAIR affected population details: Stokes et al., 2017]

Damage Risk Swath



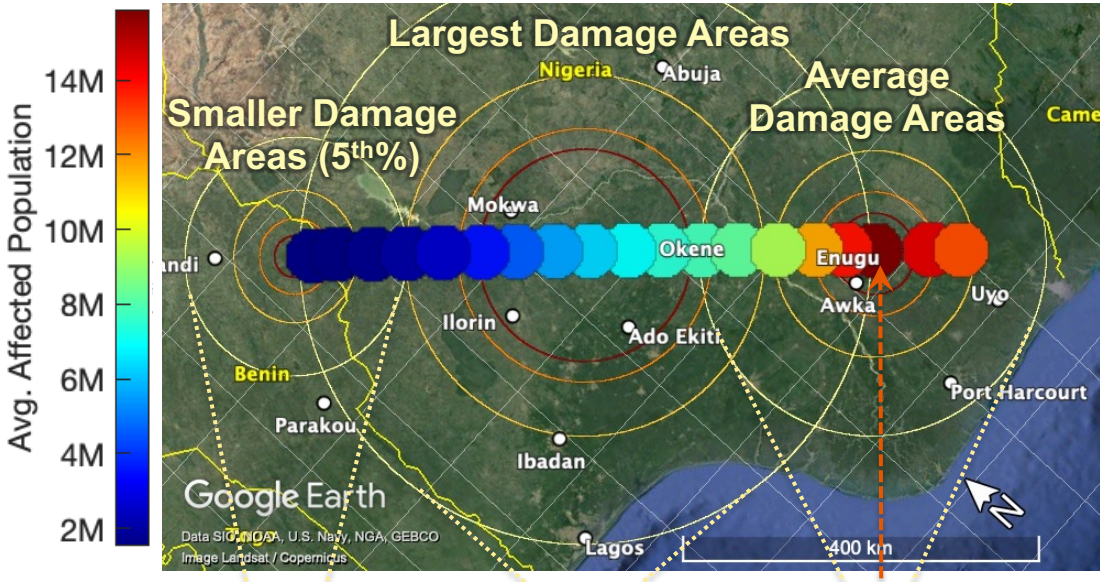
- Damage risk swath:
  - Black outline shows globe-spanning range of potential impact locations modeled (damage-center locations)
  - Shaded areas show potential extent of *local ground damage**, given range of impact sizes and locations, colored by damage severity level
  - Rings show median-sized damage footprints at sample locations
- Extent of current risk region:
  - Spans most of southern and central Nigeria, with potential damage ranges extending into parts of Benin, Cameroon, Niger, Burkina Faso, and Togo.
  - Impact corridor is a narrow track ~740 km (~460 mi) long
  - Damage risk swath region shown is around ~1300 km (~800 mi) long and extends ~560 km (~350 mi) across

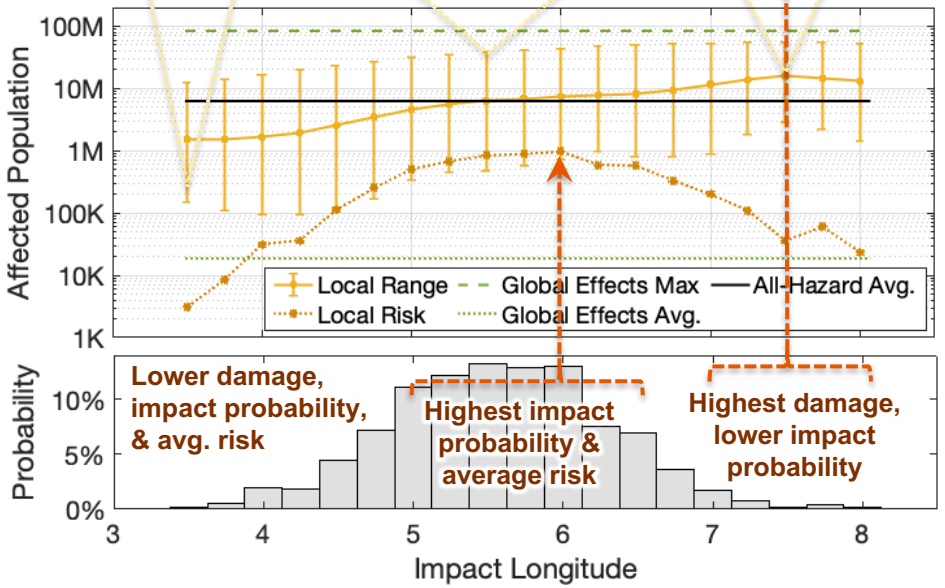
Damage risk swath: Shows extent of regions *potentially* at risk to *local ground damage**, given ranges of potential damage sizes and locations

* Swath extent shown covers local blast or thermal ground damage sizes out to the 95th percentile

Affected Population Ranges Along Swath

- Potential affected population ranges:
  - Average local affected population ranges are ~1M-15/16M across Nigeria and E. Benin
  - Largest cases affect ~10M-55M
  - Smallest cases affect ~100K – 3M
- Highest potential population damage is at SE end of swath, near Enugu, Uyo, Owerri, Port Harcourt
- Greatest population ***risk*** level (average affected population in region scaled by relative likelihood of impact there) is in mid-swath region where impact is likeliest to occur





Average affected population map:
Impact locations along swath colored by average affected population, with sample damage area sizes.

(Note: Averages are within 1/4° longitude increments. All locations could have same range of damage sizes. Map is tilted along swath direction.)

Affected population ranges:
Average and min/max population ranges along swath, with average population risk.

(Note: Values are in 1/4° longitude increments. Average risk is avg. pop scaled by probability of impact there)

Relative impact probability among swath regions

Summary

- **Risk assessment indicates significant potential damage sizes, severities, and risk probability levels across all potential asteroid size ranges and impact locations**
  - Current asteroid size estimates indicate impact would cause very large, devastating local blast and thermal ground damage over populated land regions in Africa.
  - Local damage areas from even the smaller and moderate range of impact sizes would affect hundreds-of-thousands to tens-of-millions of people, and would require large-scale evacuation, civil defense, and infrastructure protection measures over very large areas.
  - Total risk levels have decreased since prior assessment due to fly-by mission refining asteroid size estimates, which has eliminated most of the previous risk of extreme global effects.
- **Recommendations:**
  - Rendezvous reconnaissance missions will help to refine asteroid mass and impact energy range to better prepare mitigation measures and emergency response plans for large potential impact.
  - Additional modeling & simulation studies of large-scale impact effects are recommended to better assess potential damage levels and determine appropriate response measures, given current model uncertainties in these regimes

	Chance of Hazards Causing Damage	**Affected Population Ranges**				
		Average	Median	95th%	99th%	Largest worst-case modeled
Overall Affected Population	100%	6.3M	5.2M	14M	22M	84M
Local Blast/Thermal	100%	6.3M	5.2M	14M	22M	10M
Global Effects	0.02%	20K	0	0	0	84M

HAZARD DAMAGE & RISK DETAILS:

Local Blast & Thermal Damage
Global Effects

Local Blast & Thermal Damage Area Sizes

- Most likely local hazard is a large ground impact causing a highly destructive blast wave and thermal fireball from the entry and impact
  - Significant blast damage is certain to occur, ranging from unsurvivable levels to shattered windows and structure damage over large areas
  - Significant thermal damage is also nearly certain to occur and reach unsurvivable levels (>99% chance)
  - Thermal damage tends to be smaller than the corresponding blast regions, but largest impactors may cause larger critical and unsurvivable thermal damage areas
- Estimated range of possible damage sizes
  - Most likely outer damage radius range is ~150–230 km (90–145 mi)
  - Largest outer damage areas could extend out over 330 km (~200 miles) or more in radius

Potential Blast Damage Severities and Sizes

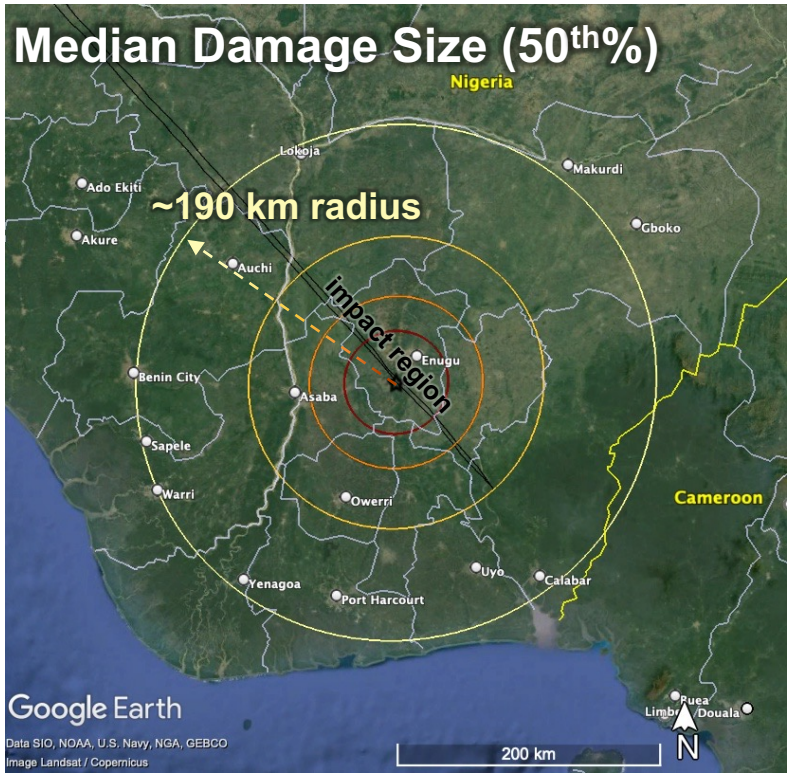
Damage Level	Potential Blast Effects	Chance of Occurring	Damage Radius Ranges (km)		
			Median	Most Likely	Range
Serious	Shattered windows, some structure damage	100%	190	150–230	100–330
Severe	Widespread structure damage	100%	110	80–130	55–180
Critical	Most residential structures collapse	100%	60	45–75	30–100
Unsurvivable	Complete devastation	100%	35	25–40	17–60

Potential Thermal Damage Severities and Sizes

Damage Level	Potential Thermal Effects	Chance of Occurring	Damage Radius Ranges (km)		
			Median	Most Likely	Range
Serious	2nd degree burns	~100%	60	15–95	6–260
Severe	3rd degree burns	~100%	45	10–75	4–200
Critical	Clothing ignition	99.9%	35	7–50	0–140
Unsurvivable	Structure ignition	99.8%	30	6–45	0–120

Sample Ground Damage Sizes over Nigeria

(highest median population damage location along current swath)



- Rings show sample damage footprint sizes at a single sample location
- Black border shows range of potential impact locations (damage center points) along swath
- Percentiles give the chance that the damage region could be up to the given size or smaller

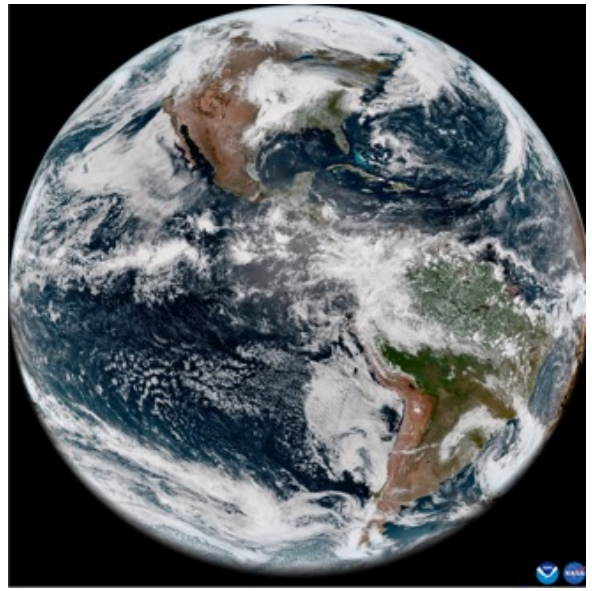
Local Ground Damage Radius Sizes (km / mi)

Damage Level	Mean	25th %	**50th %**	75th %	**95th %**
Serious	200 km (123 mi)	170 km (103 mi)	**190** km (120 mi)	230 km (141 mi)	**280** km (171 mi)
Severe	110 km (70 mi)	90 km (57 mi)	**110** km (68 mi)	130 km (80 mi)	**160** km (102 mi)
Critical	70 km (42 mi)	55 km (33 mi)	**65** km (40 mi)	80 km (48 mi)	**110** km (67 mi)
Unsurvivable	45 km (28 mi)	30 km (19 mi)	**40** km (24 mi)	50 km (32 mi)	**90** km (56 mi)

	Damage Level Description
	Windows shatter, minor structure damage
	Widespread structure damage, or 3rd degree burns
	Residential structures collapse, or clothing ignites
	Devastation, structures flattened or burned

Global Effects (GE)

- Asteroid size refinement from fly-by mission has mostly eliminated risk of global effects, but a minute chance of larger regional or semi-global environmental effects from largest impact sizes remains
  - 0.02% chance of global effects from largest estimated asteroids impact energies
  - Total average GE affected population modeled ~20K people (among all potential impactor sizes, including sub-global sizes)
  - Maximum estimated GE affected population modeled ~80M
- Large uncertainties remain in what asteroid sizes may start to cause onset of these effects, amounts of ejecta, and severity or specifics of resulting climate effects.
- Potential for other large-scale, regional, and secondary cascading environmental effects also remains unknown for these impact size ranges and is not included in current risk modeling results.

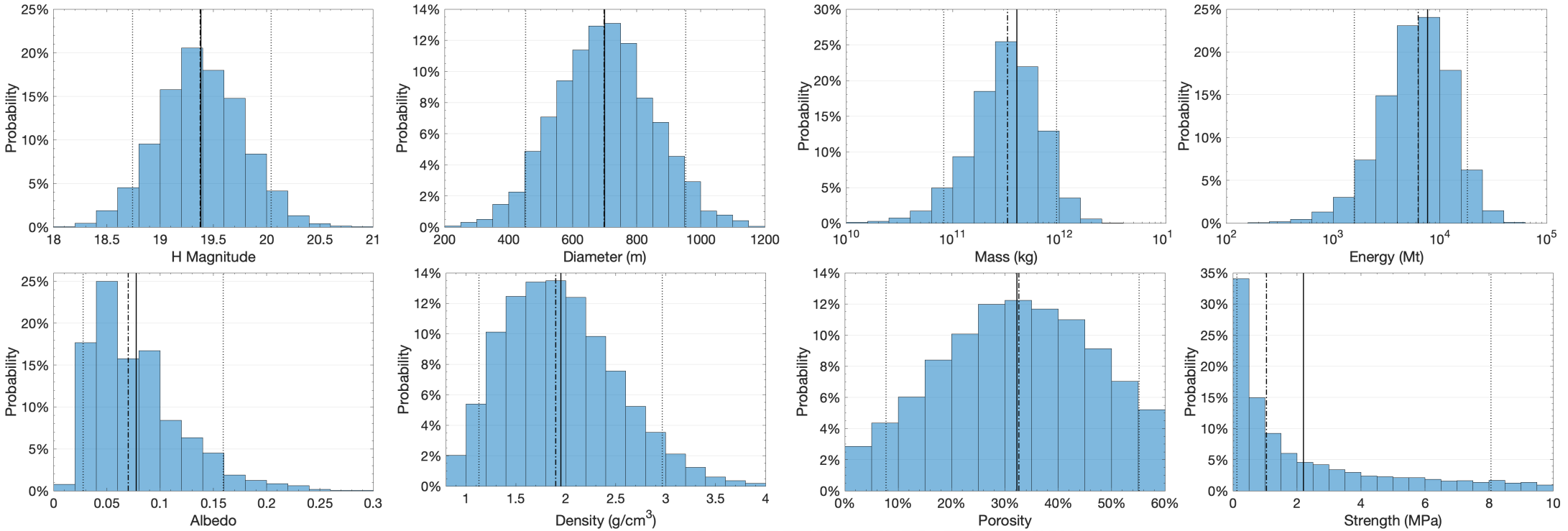


[PAIR global effects model details: Stokes et al., 2017]

Asteroid Property Details

Statistical percentiles and highest-probability interval ranges for asteroid property distribution samples modeled*

	Mean	5th%	25th%	Median (50th%)	75th%	95th%	Most Likely Range (68%)	Potential Range (99%)
Diameter (m)	700	453	596	698	799	953	555 – 859	323 – 1109
Mass (kg)	4.0E+11	8.2E+10	2.0E+11	3.3E+11	5.3E+11	9.4E+11	6.0E+10 – 4.8E+11	1.5E+10 – 1.5E+12
Energy (Mt)	7.7E+03	1.6E+03	3.8E+03	6.3E+03	1.0E+04	1.8E+04	1.2E+03 – 9.3E+3	2.9E+02 – 2.0E+4
H Magnitude	19.38	18.74	19.12	19.38	19.65	20.04	18.98 – 19.76	18.40 – 20.44
Albedo	0.08	0.03	0.04	0.07	0.10	0.16	0.03 – 0.09	0.01 – 0.22
Density (g/cm^3)	2.0	1.1	1.5	1.9	2.3	3.0	1.3 – 2.4	0.82 – 3.5
Porosity (%)	32%	8%	22%	33%	43%	55%	18% – 49%	2% – 60%
Strength (MPa)	2.2	0.13	0.32	1.0	3.3	8.1	0.1 – 2.4	0.1 – 9.6



* Property stats are each computed *independently*. Multiple values from a given percentile cannot necessarily be combined to represent a single physically-plausible asteroid.

[Property model: J. Dotson PDC 2023]

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Related PDC 2023 Presentations

PDC 2023 presentation materials, webcast recordings, and impact exercise details available at:

- https://www.unoosa.org/oosa/en/ourwork/topics/neos/2023/IAAPDC/index.html
- https://atpi.eventsair.com/QuickEventWebsitePortal/23a01---8th-planetary-defense-conference/programme-website/Agenda
- https://cneos.jpl.nasa.gov/pd/cs/pdc23/

PDC 2023 Hypothetical Asteroid Impact Exercise Session (3 April 2023)

- **Wheeler** et al., "Impact Risk Assessment Briefing: 2023 PDC Hypothetical Asteroid Impact Exercise Epoch 1"
- **Chodas** et al., "The 2023 PDC Hypothetical Impact Scenario: Epoch 1 Summary"
- **Barbee** et al., "PDC 2023 Simulated Impact Threat Scenario SMPAG Mission Option Analysis"

Impact Effects (Session 7, 6 April 2023)

- **Wheeler** et al., "Asteroid Impact Risk Across Transitional Hazard Regimes"
- **Dotson** et al., "Consequences of Asteroid Characterization on the State of Knowledge about Inferred Physical Properties and Impact Risk"
- **Coates** et al., "Sensitivity Study of Impact Risk Model Results to Thermal Radiation Damage Model for Large Objects"
- **Chomette** et al., "Machine learning for the prediction of local asteroid damages"
- **Stern** et al., "Advances in Entry Modeling for Impact Risk Assessment"
- **Aftosmis** et al., "High-fidelity Blast Propagation Modeling for Hypothetical Asteroid 2023 PDC"
- **Titus** et al., "Asteroid Impacts and Cascading Hazards"

Disaster Management & Impact Response (Session 8, 6 April 2023)

- **Robertson** et al., "Evacuation and Shelter Plans for Asteroid Impacts"

Space Mission & Campaign Design Session (Session 6, 5 April 2023)

- **Barbee** et al., "Planetary Defense Mission Campaign Design for the 2023 PDC Hypothetical Asteroid Impact Scenario"