



Impact Risk Assessment: 2026 PDC27 Hypothetical Asteroid Impact Exercise *Epoch 2*

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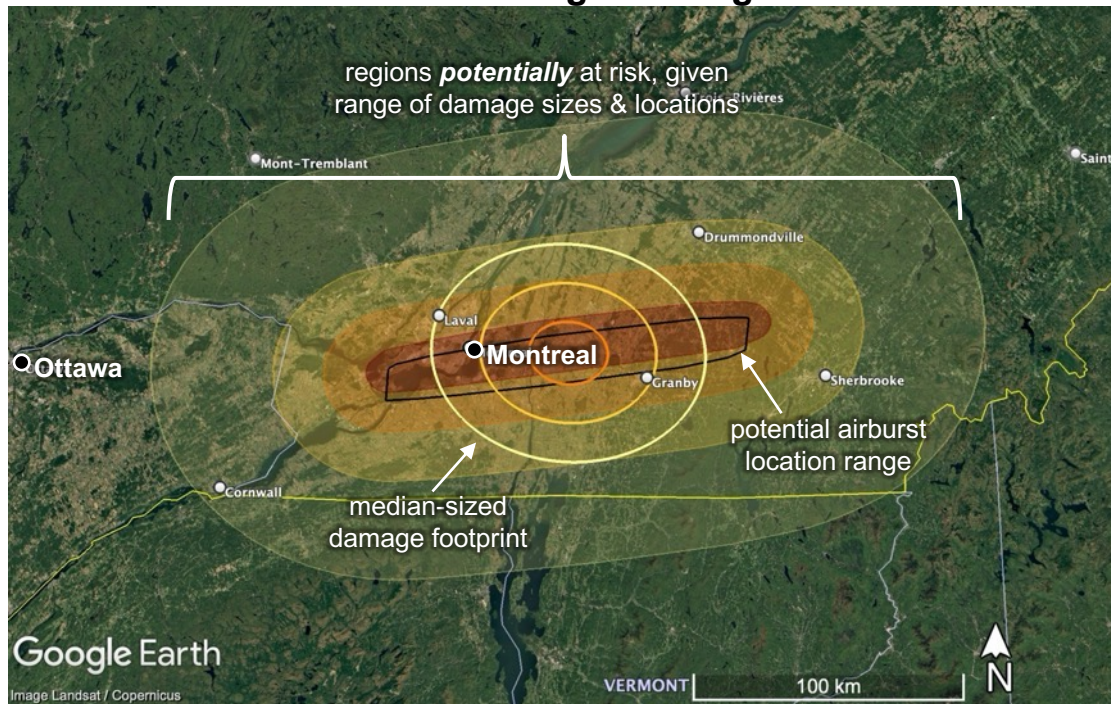


Impact Hazard & Risk Overview

Epoch 2 assessment: 24 July 2034

An asteroid **78–88 m** in diameter with **13–46 Mt** of energy is on an impact course to hit Earth on 30 July 2038, and is expected to cause large blast damage in a region near Montreal, Canada

Potential damage risk regions



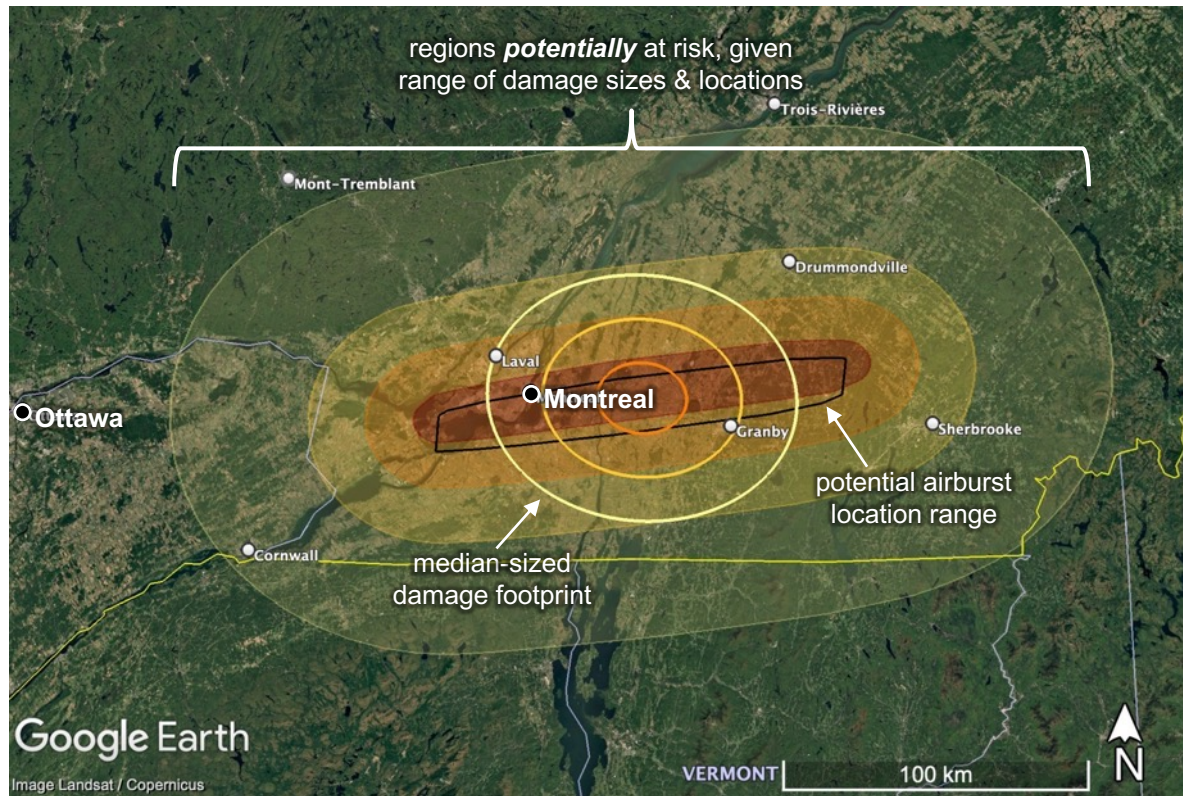
Damage Level Description	
Serious	Windows shatter, some structure damage
Severe	Widespread structure damage or third-degree burns
Critical	Residential structures collapse or clothing ignites
Unsurvivable	Devastation, structures flattened or burned

* Risk swath extents are shown out to the 95th percentile of larger damage sizes around all potential impact locations. Damage would only occur around one location, not across the entire risk region.

- **100% chance of damage** to populated regions
- **Primary hazard:** a high-energy airburst causing a destructive blast wave over large areas
- **Damage severity:** expected to reach at least severe levels and could reach unsurvivable levels near the airburst for the largest cases
- **Damage range:** serious damage would most likely extend ~35–50 km from the blast, and potentially as far as ~100 km in the largest cases
- **Population risk:** damage could affect ~10K–3M people, with an average of ~600K people

What regions could be at risk to damage?

Potential damage risk regions



Asteroid is expected to airburst somewhere over a ~140 km (~90 mi) long ~20 km (10 mi) wide corridor around Montreal, Canada.

Regions within ~100 km (~60 mi) of those locations could be at risk to damage ranging from serious to unsurvivable levels.

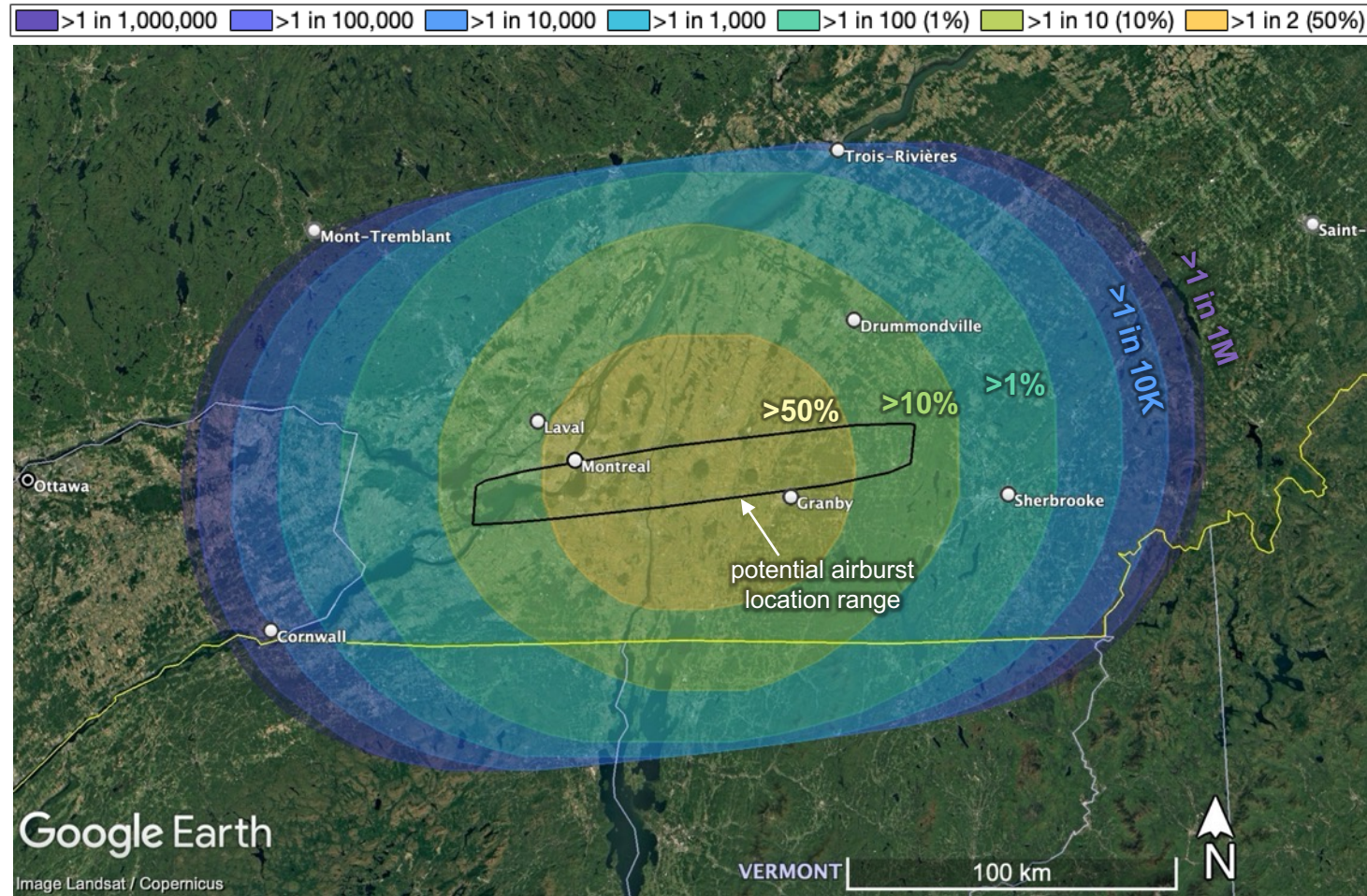
Damage Level Description

Serious	Windows shatter, some structure damage
Severe	Widespread structure damage or 3 rd degree burns
Critical	Residential structures collapse or clothing ignites
Unsurvivable	Devastation, structures flattened or burned

Risk region map showing regions *potentially* at risk to local ground damage, including the range of possible locations and larger damage sizes (out to the 95th percentile). Damage would only occur around one location, not across all risk regions shown.

How likely is damage to occur in each region?

Chance of damage exceeding *at least* serious levels



Damage probability map showing the total chance of damage exceeding *at least* serious levels at each location within the risk region

While damage is *possible* across a large range of regions, it will not occur in *all* regions.

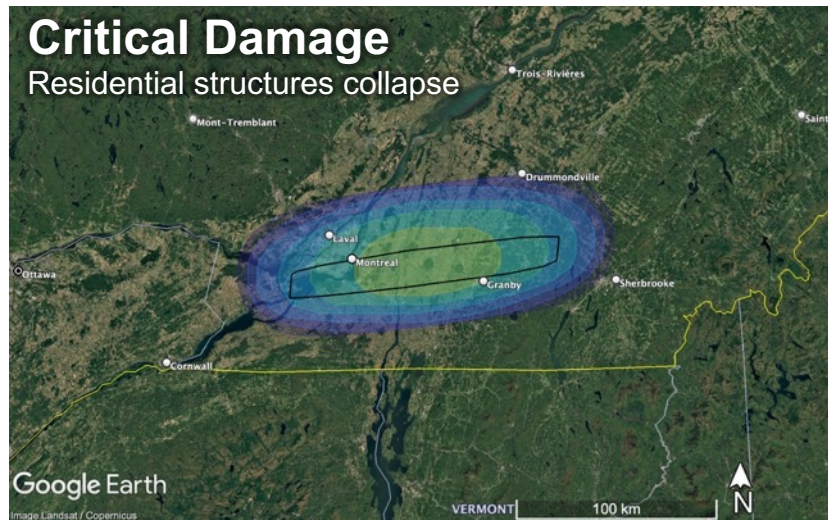
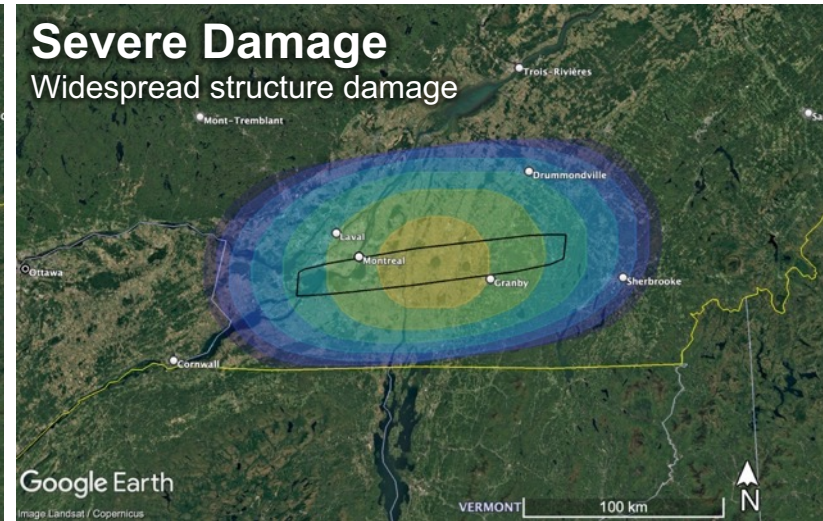
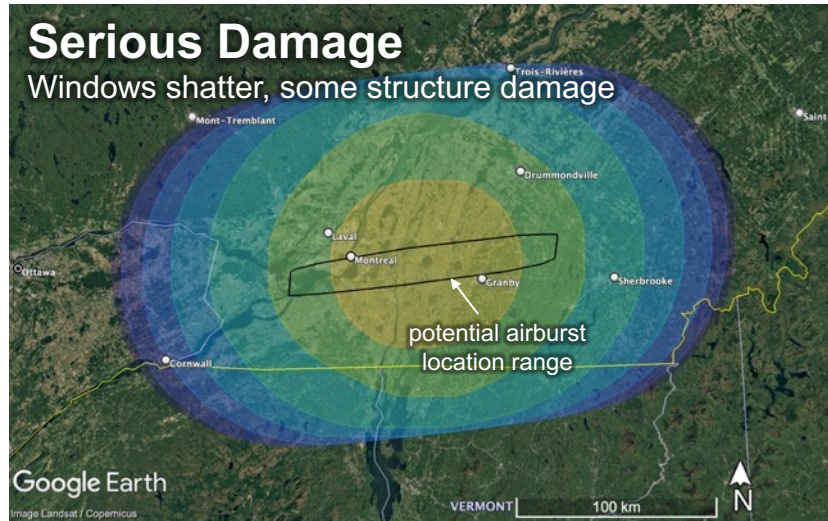
The chance of damage reaching a specific region is much smaller than the total chance of damage.

- Chance of damage reaching a region depends on the likelihood of the asteroid hitting different locations and the likelihood of how far damage could reach
- Chance of damage occurring in different regions ranges from 50-97% near the most likely impact locations and decreases below 1% toward the edges of the risk region

How likely are damage severities in each region?

Chance of damage exceeding each severity level

>1 in 1,000,000
 >1 in 100,000
 >1 in 10,000
 >1 in 1,000
 >1 in 100 (1%)
 >1 in 10 (10%)
 >1 in 2 (50%)



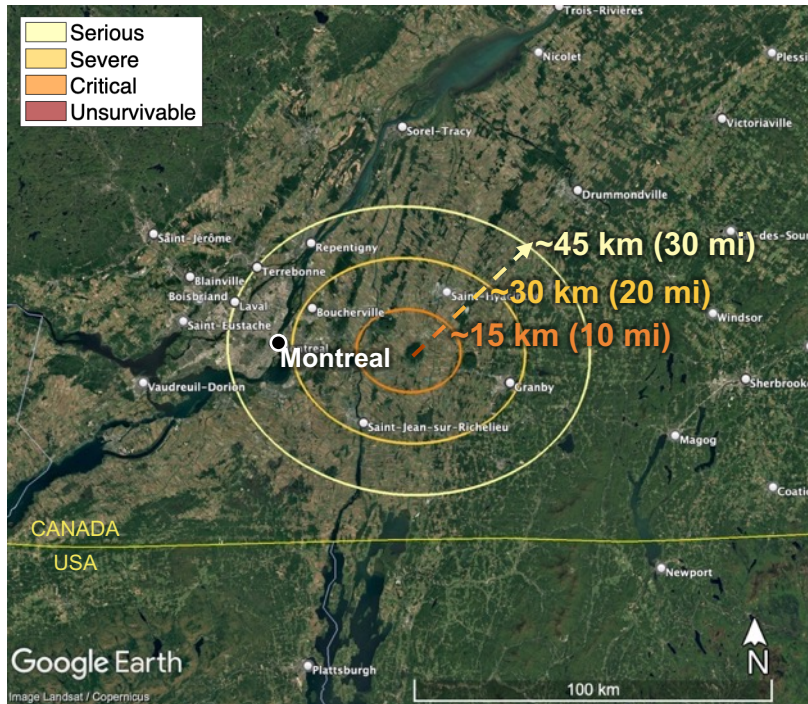
Higher damage severities are less likely and the areas at risk are smaller

- **Chance of serious damage** ranges from **97%** to 1 in a million across a ~310-by-180 km region
- **Chance of severe damage** ranges from **82%** to 1 in a million across a ~230-by-100 km region
- **Chance of critical damage** ranges from **43%** to 1 in a million across a ~190-by-70 km region
- **Chance of unsurvivable damage** ranges from **5%** to 1 in a million across a ~150-by-30 km region

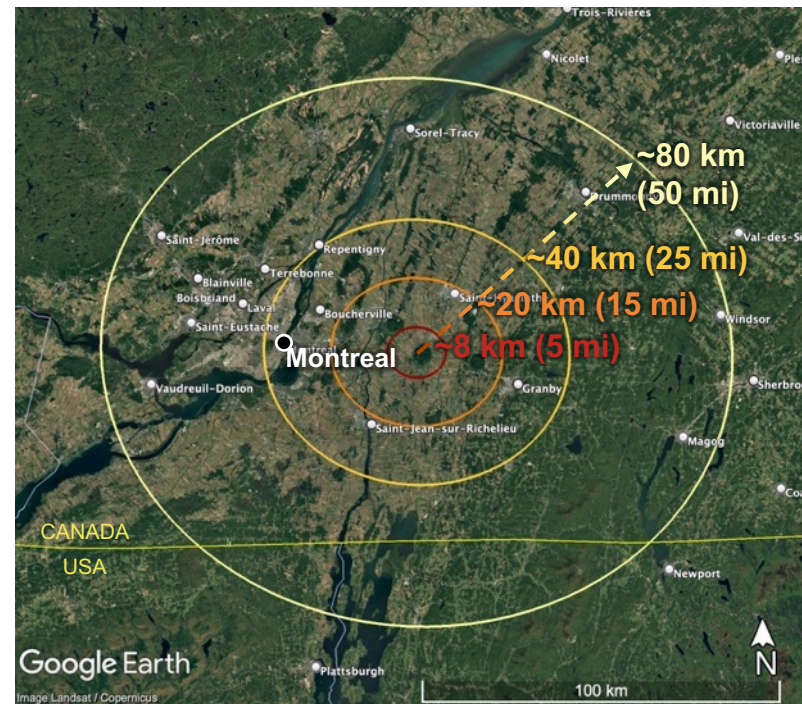
How big could potential damage areas be?

Damage size examples over the most likely central impact location

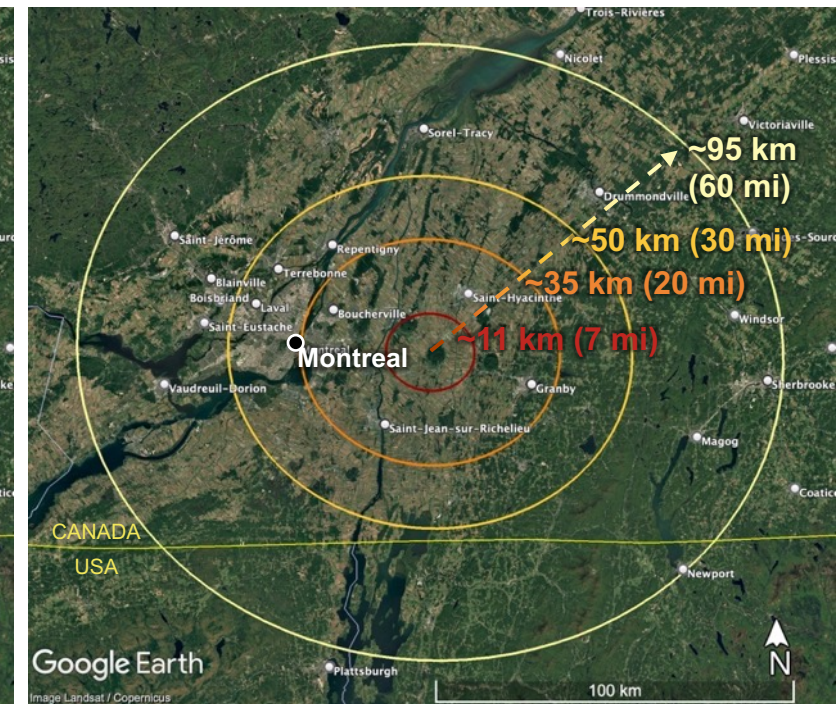
Median (50th%) Damage



Large (95th%) Damage



Largest Modeled



Likely damage could span large metro areas and reach critical damage levels

Large damage sizes could span multiple counties or countries and reach unsurvivable levels

* Damage sizes and shapes vary with different asteroid airburst energies and altitudes. Radii given are circular area equivalents, with larger values rounded to nearest 5 km/mi.

How far is damage likely to reach?

Chance of damage levels occurring

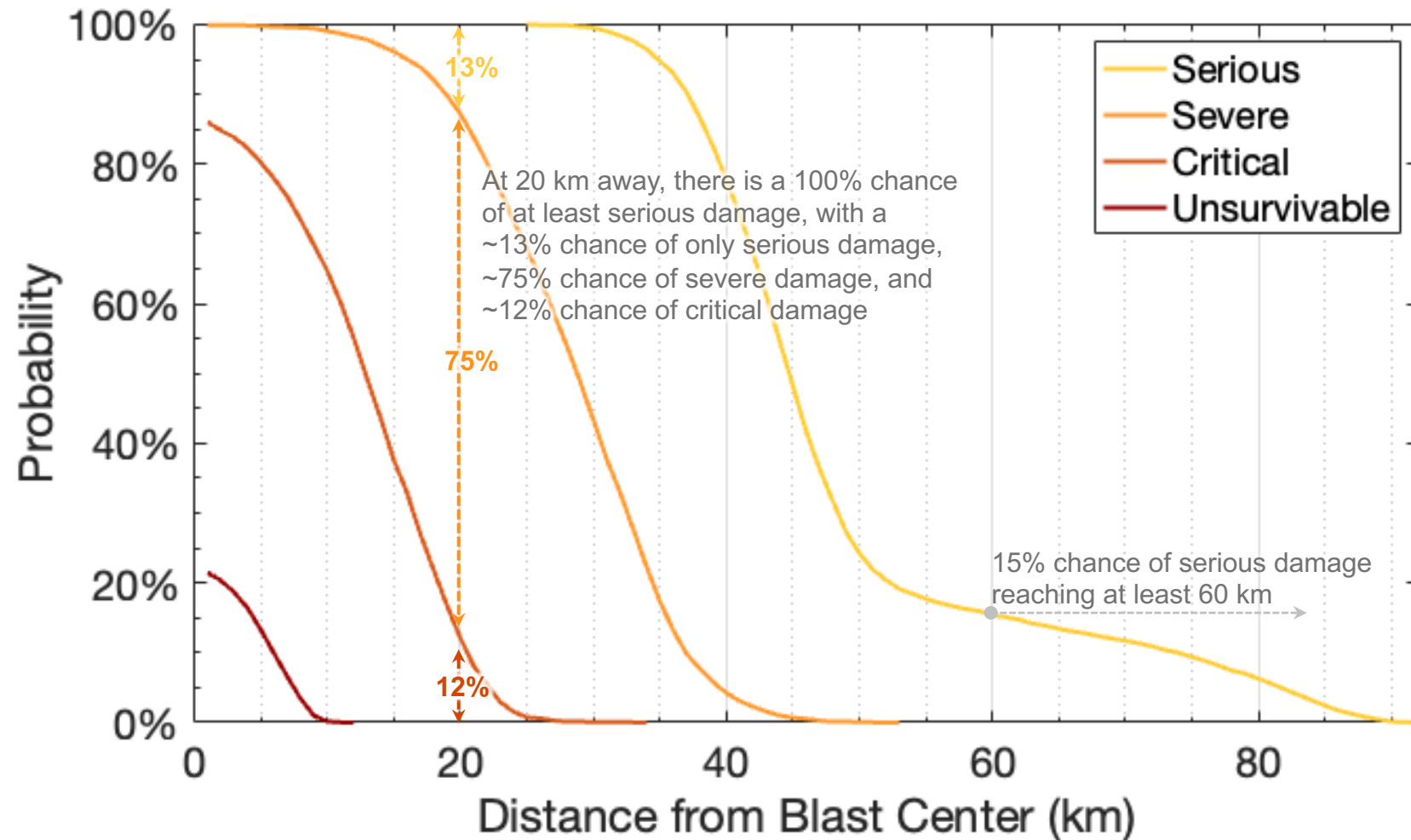
Serious
100%

Severe
100%

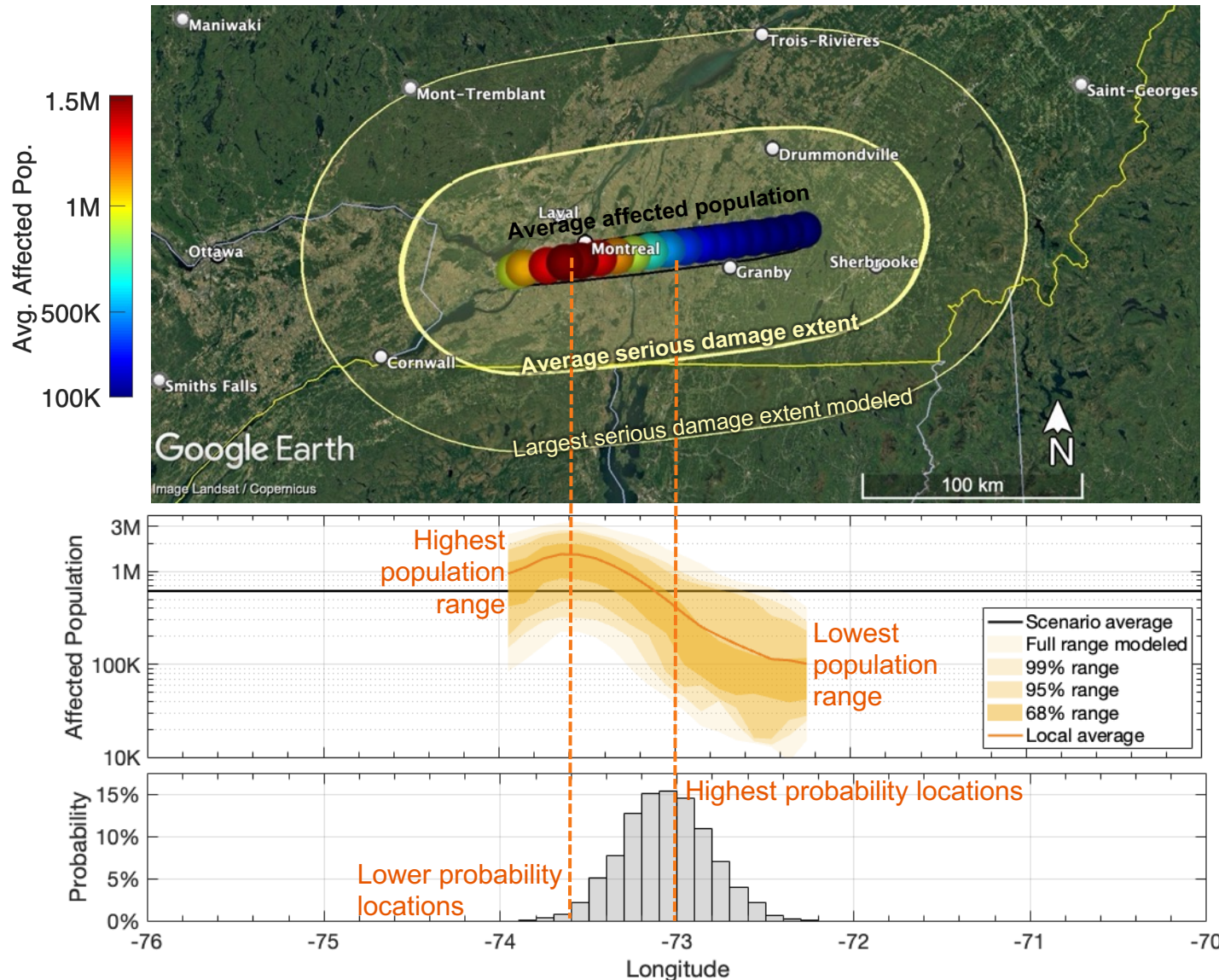
Critical
87%

Unsurvivable
22%

Chance that damage levels will reach different distances from the blast center



How many people could be affected depending on where the asteroid hits?



All impact locations are over populated regions, potentially affecting between **10K and 3M people** depending on damage location and size

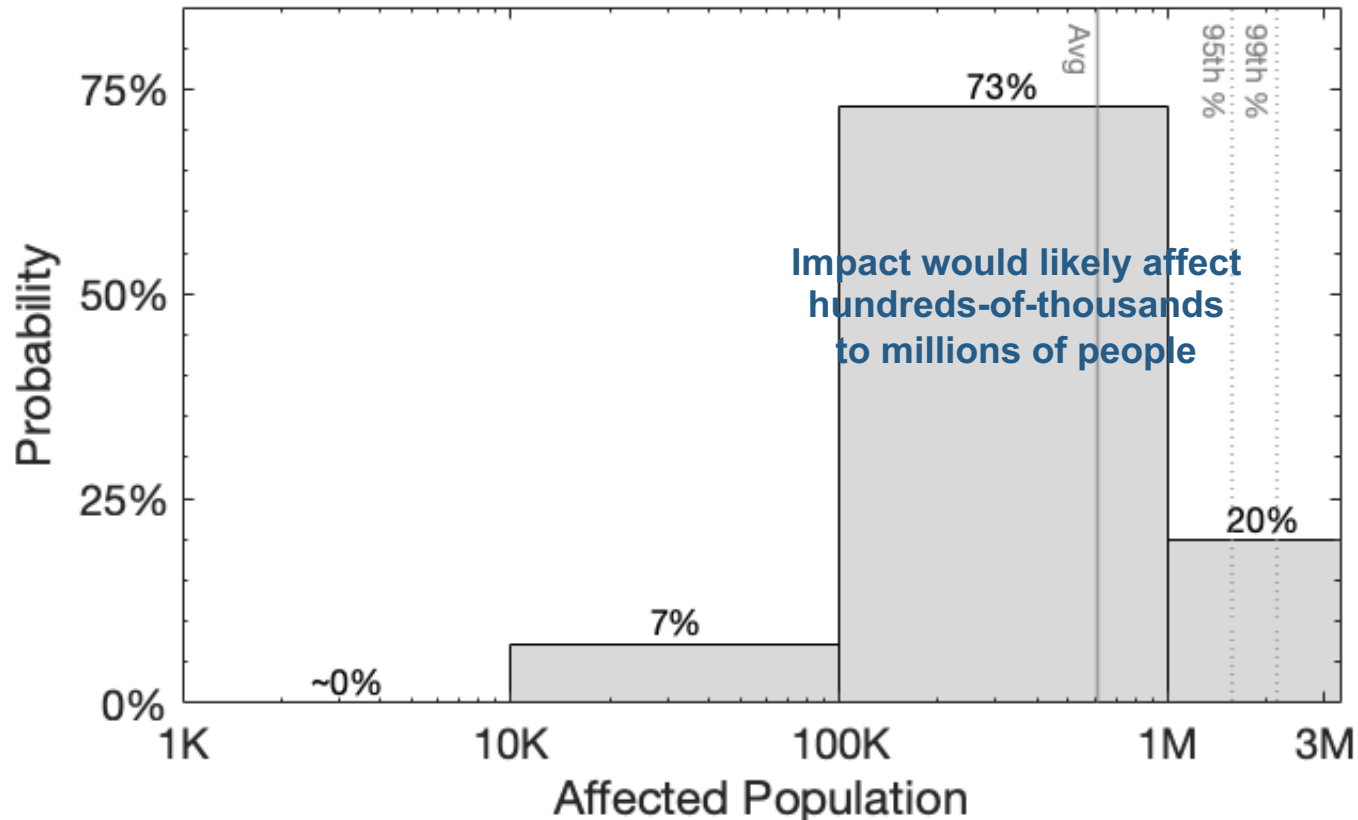
- Average affected population estimates range between 100K and 1.5M depending on location
- Impacts over Montreal area could affect 200K to 3M people (highest population)
- Impacts over Eastward locations could affect 10K to 400K (lowest population)
- Impact is more likely to occur near the middle of the potential impact location range (~40 km east of Montreal)



How many people is damage likely to affect?

100% chance of damage to populated regions, likely affecting hundreds-of-thousands of people, potentially up to ~3 million people

Damage probabilities *among Earth-impacting cases*



Affected population threshold	Chance of damage exceeding threshold
Any	100%
>1K	100%
>10K	100%
>100K	93%
>1M	20%

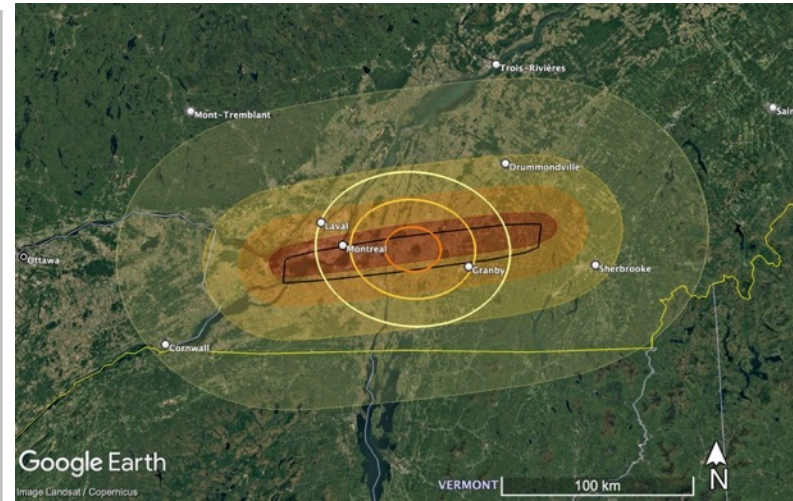
Potential range modeled: 9K– 3.4M
 Average: ~610K people
 Median: ~490K

Impact Risk Summary

Epoch 2 assessment: 24 July 2034

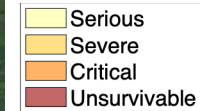
Asteroid Characterization Summary

- 100% chance of Earth impact on 10 July 2038 (in ~4 years)
- Latest observation data: Flyby mission measured diameter (from limited flyby view angles) and confirmed type S spectral class
- Diameter: ~78–88 m (256–290 ft), most likely ~82–84 m (268–277 ft), median size 83 m (272 ft)
- Impact Energy: 13–46 Mt, most likely 20–32 Mt, median 26 Mt
- Properties: S type bulk density ranges, unknown structure



Risk Region Swath Map

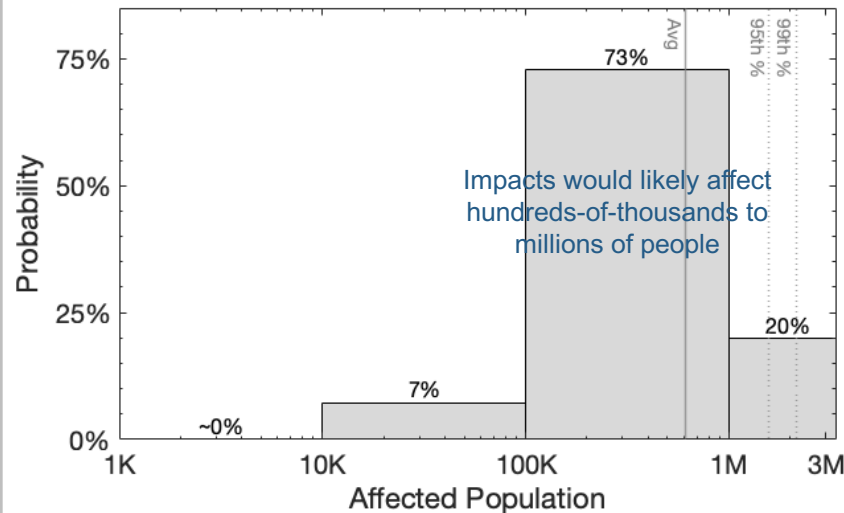
Regions potentially at risk, given range of damage locations and sizes. Median-sized damage areas are shown at sample locations.



Hazard Summary

- Primary hazard is a high-energy airburst and fireball causing a destructive blast wave over large areas
- Blast damage could reach unsurvivable levels near airburst, with serious damage likely extending ~35–50 km (~20–30 mi) in radius, and possibly as far as ~100 km (~60 mi) in largest cases
- Likely damage sizes could span large cities or metro areas, while large damage sizes could span multiple large counties
- There is a 100% chance of serious damage, 100% chance of severe damage, 87% chance of critical damage, and 22% chance of unsurvivable damage occurring
- All current impact locations are over populated regions

Affected Population Risks if the Asteroid Impacts Earth



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

Range: ~9K–3M ppl
Average: ~600K



Additional PDC Scenario Resources

- Additional scenario information, results, and tools available on the CNEOS exercise website:
<https://cneos.jpl.nasa.gov/pd/cs/pdc27/>
 - **Interactive impact risk dashboard:** Additional PAIR impact risk results for this exercise scenario can be explored in an interactive web dashboard tool, which includes additional hazard summaries, detailed plots and data tables on the damage sizes and severities, and zoomable maps of the damage risk swath and sample damage footprint examples.
 - **Google Earth damage risk maps:** A Google Earth KMZ file of the damage risk swath and sample damage footprint sizes for this exercise scenario.
 - **Introduction to Asteroid Impact Risk Assessment presentation:** Introductory background information on the asteroid threat assessment processes, key hazards and factors, and PAIR modeling details.
 - **Asteroid physical properties file:** A csv file containing 5,000 sampled realizations of the object spanning the current distributions of possible asteroid properties for this scenario.
 - **Orbital details:** JPL/CNEOS orbit information, data, and tools.
- ATAP impact risk modeling references:
 - Details on the **Probabilistic Asteroid Impact Risk (PAIR)** model and impact threat assessment process used to produce these results are published in: Wheeler et al., 2024 [[doi:10.1016/j.actaastro.2023.12.049](https://doi.org/10.1016/j.actaastro.2023.12.049)]
 - Details on the **Asteroid Property Inference Network (APIN)** model used to generate the asteroid property cases for this assessment are published in: Dotson et al., 2024 [[doi:10.1016/j.actaastro.2024.04.020](https://doi.org/10.1016/j.actaastro.2024.04.020)]
 - See reference slide for additional ATAP PAIR, hazard modeling, and entry modeling journal papers.



ADDITIONAL SCENARIO DETAILS

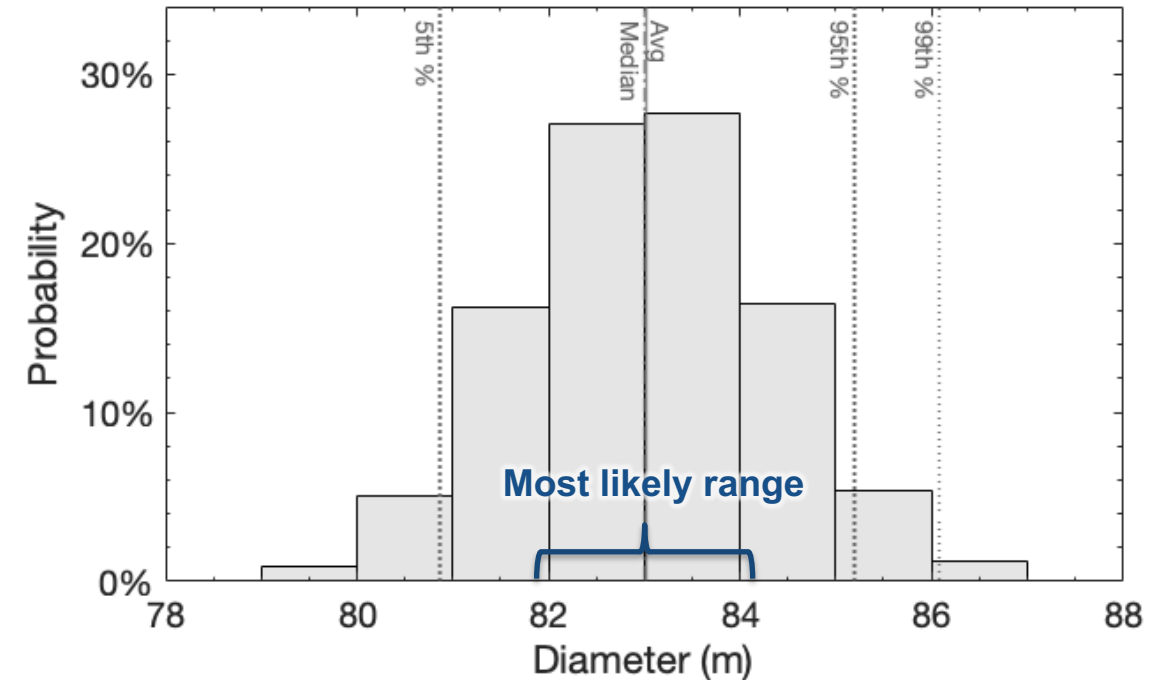


Asteroid Size & Properties

Asteroid size range ~78–88 meters in diameter with a stony type composition and impact energy ~13–46 megatons

- Latest observational data updates:
 - Flyby mission measured diameter of 83.0 ± 1.3 m (1σ) and confirmed type S spectral class
- Estimated asteroid size and property ranges:
 - Asteroid diameter is most likely between ~82–84 m but could be ~78–88 m if the flyby captured the smallest or largest side of a non-spherical asteroid
 - Stony type composition with bulk densities potentially $\sim 1.2\text{--}3.7$ g/cm³ and macroporosity between 0–60%
 - Unknown structural, strength and breakup properties ranging from a weak rubble pile to stronger body
 - Impact energy range is most likely ~20–32 Mt, but could be ~13–46 Mt (entry velocity ~17.97 km/s)

Asteroid Size Ranges & Probabilities



	Diameter (m, ft)	Mass (kg)	Energy (Mt)
Median	83 m (272 ft)	6.64e8	26
Average	83 m (272 ft)	6.72e8	26
Most likely 68%	82–84 m (268–277 ft)	5.12e8–8.32e8	20–32
5th–95th %	81–85 m (265–280 ft)	4.42e8–9.29e8	17–36
Range modeled	78.9–87.4 m (259–287 ft)	3.39e8–1.20e9	13.1–46.4

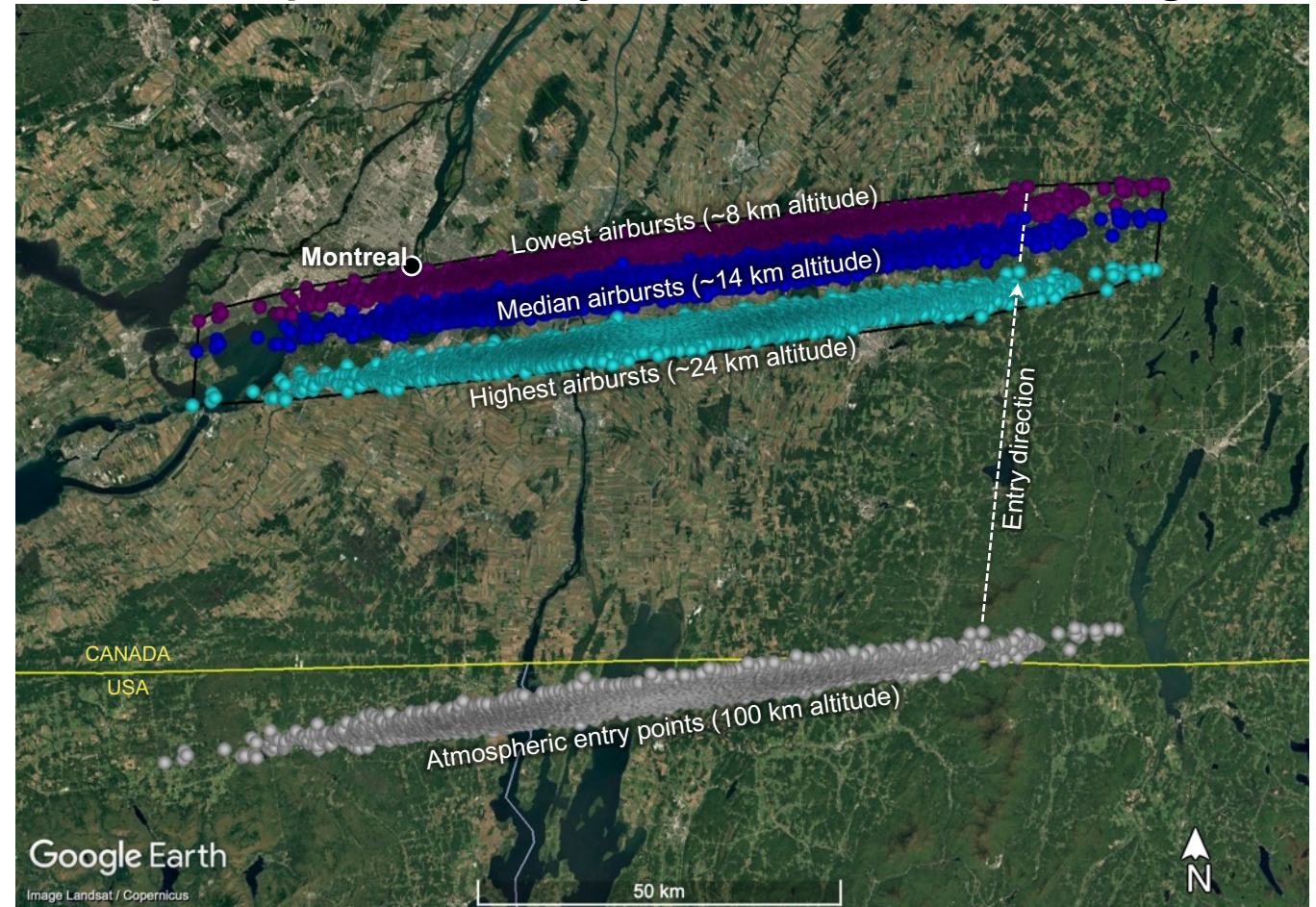
* Property stats are computed *independently* and **cannot be combined** to represent a single asteroid.

Entry Parameters & Airburst Locations

~100% chance of Earth impact
somewhere along a ~140 km (~90 mile)
long ~20 km (~10 mile) wide corridor
around Montreal, Canada

- Entry parameters are now well known from the orbital data:
 - Entry Velocity: ~18.0 km/s (17.97–17.98 km/s)
 - Entry Angle: 56° from horizontal
 - Entry Direction (Heading): ~Northward (5–7° clockwise from N)
- Estimated airburst altitudes range from ~8–24 km depending on uncertain asteroid properties and breakup rates

Sample of potential entry and airburst location ranges



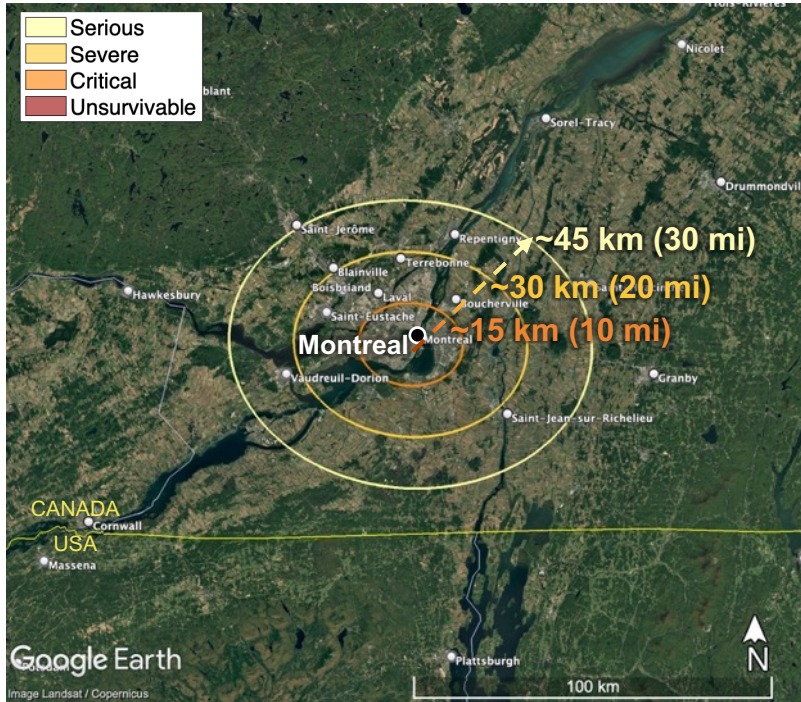
* Points are shown projected to ground-level locations in this view

[Impact entry data: D. Farnocchia, CNEOS/JPL, <https://cneos.jpl.nasa.gov/pd/cs/pdc27/>]

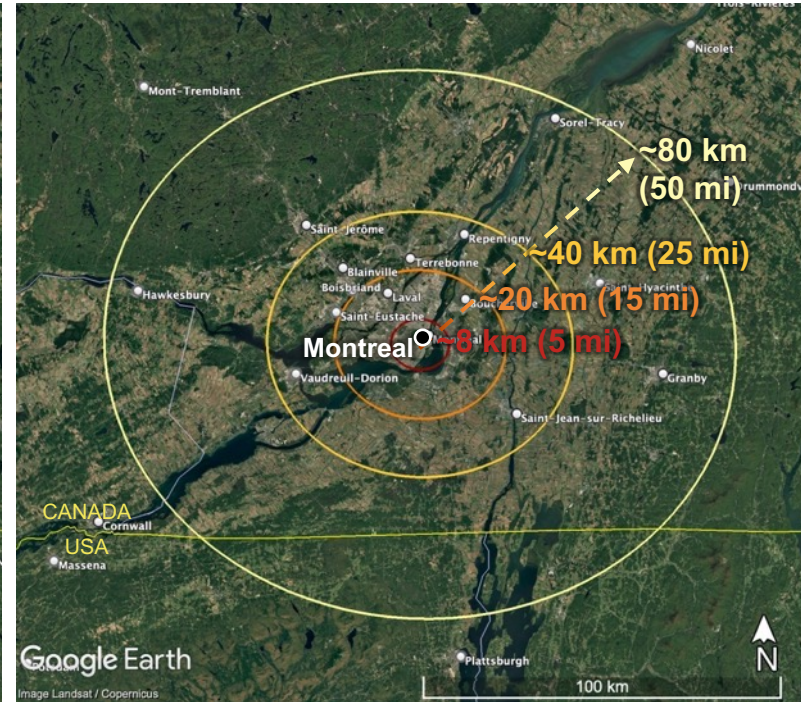
Potential damage areas examples

Example over Montreal, Canada – Highest population damage region along swath

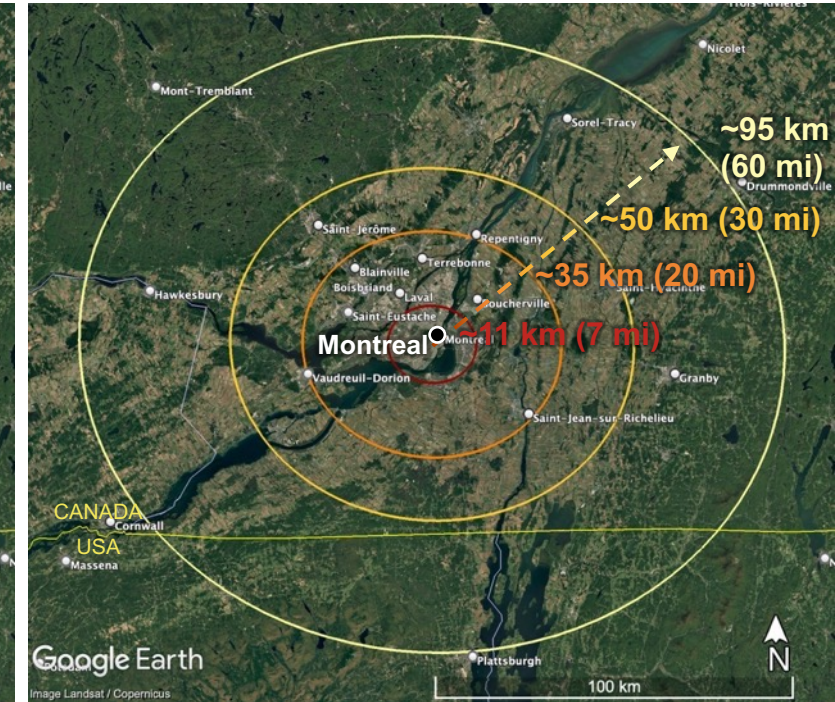
Median (50th%) Damage



Large (95th%) Damage



Largest Modeled



Likely damage could span large metro areas and reach critical damage levels

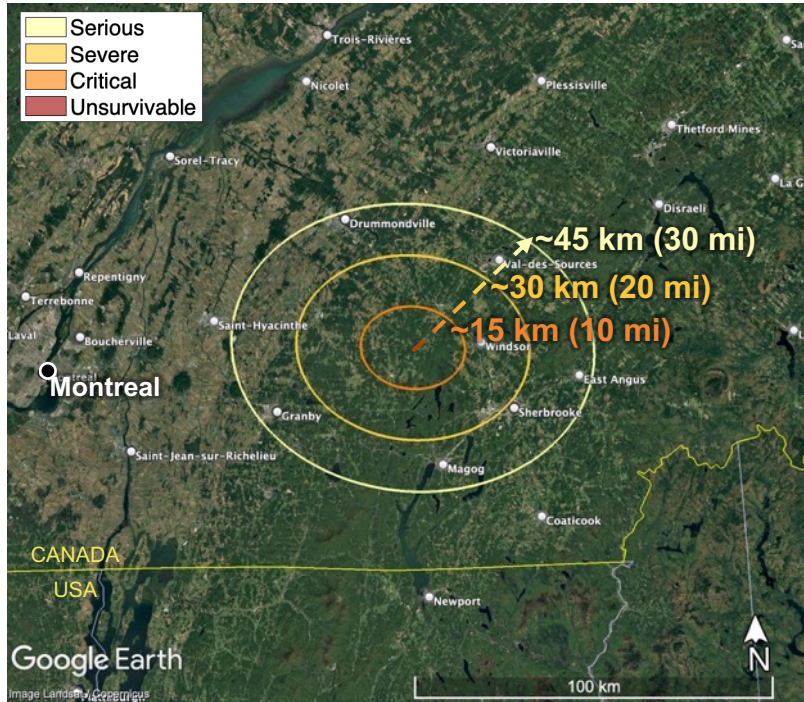
Large damage sizes could span multiple cities or counties and reach unsurvivable levels

* Damage sizes and shapes vary with different asteroid airburst energies and altitudes. Radii given are circular area equivalents, with larger values rounded to nearest 5 km/mi.

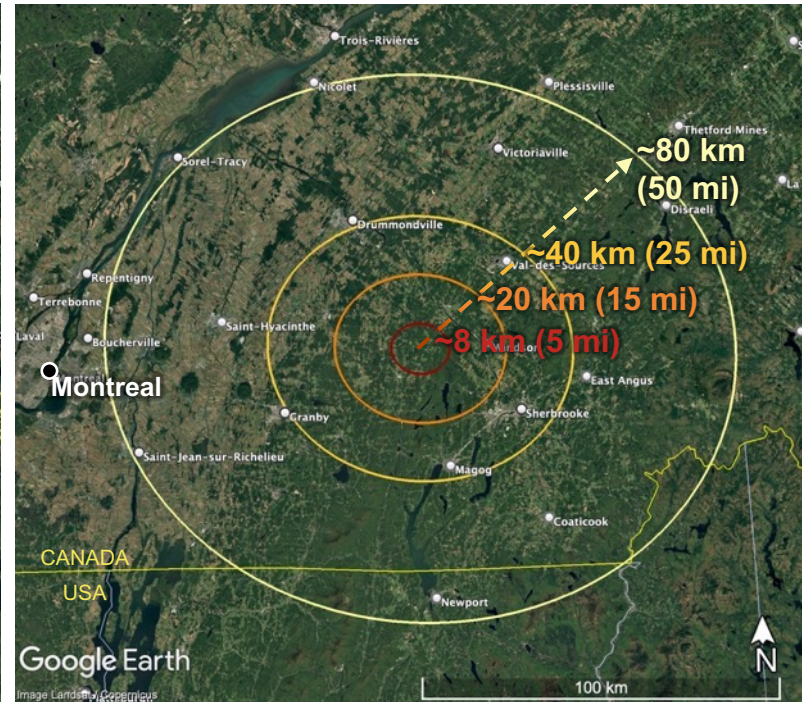
Potential damage area examples

Example over Eastern end of potential impact location range

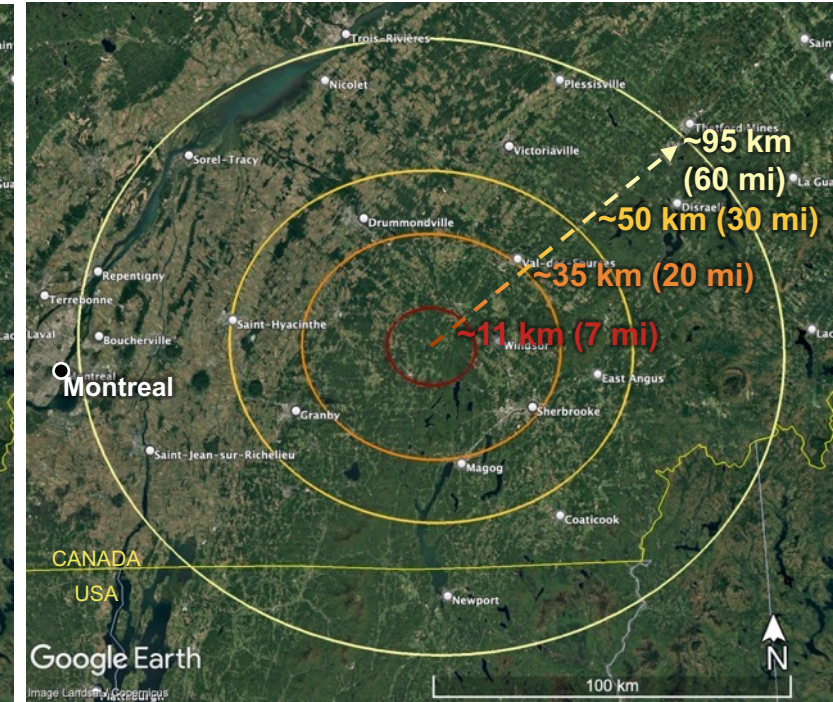
Median (50th%) Damage



Large (95th%) Damage



Largest Modeled



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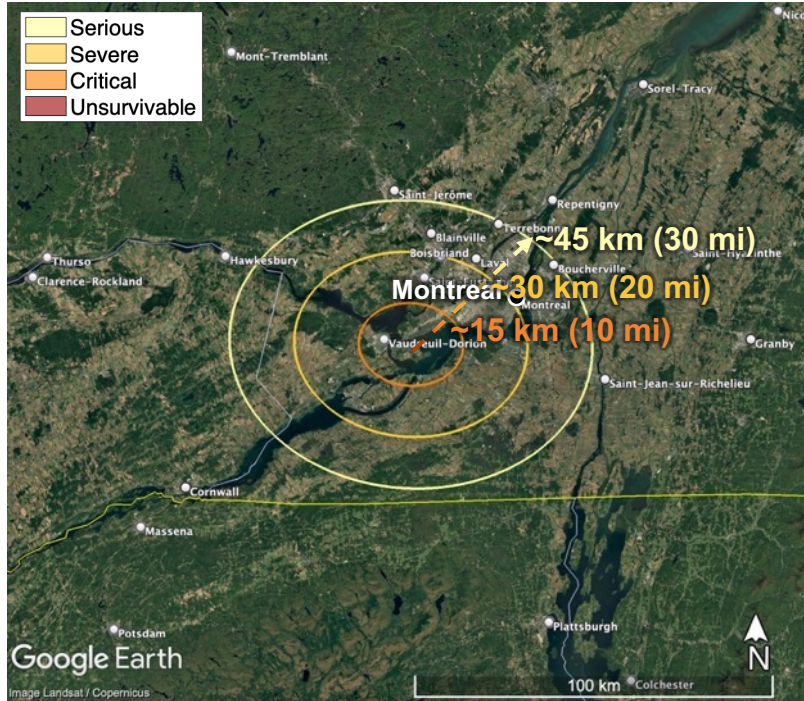
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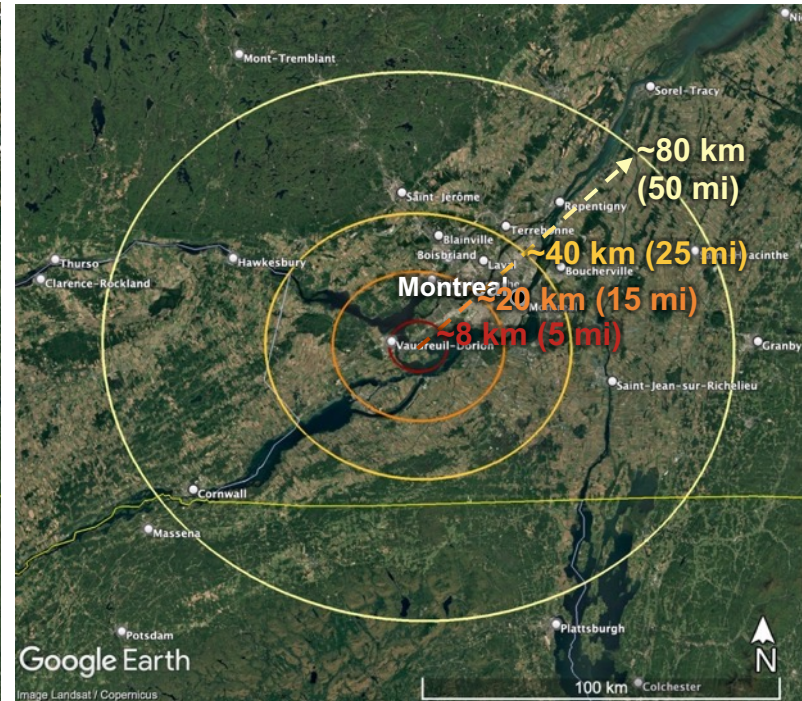
Potential damage area examples

Example over Western end of potential impact location range

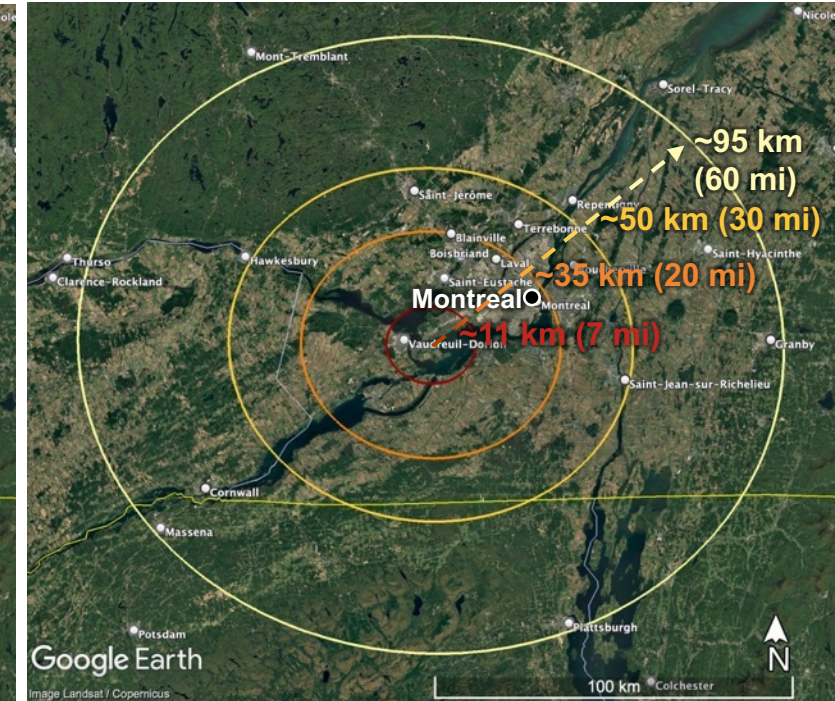
Median (50th%) Damage



Large (95th%) Damage



Largest Modeled



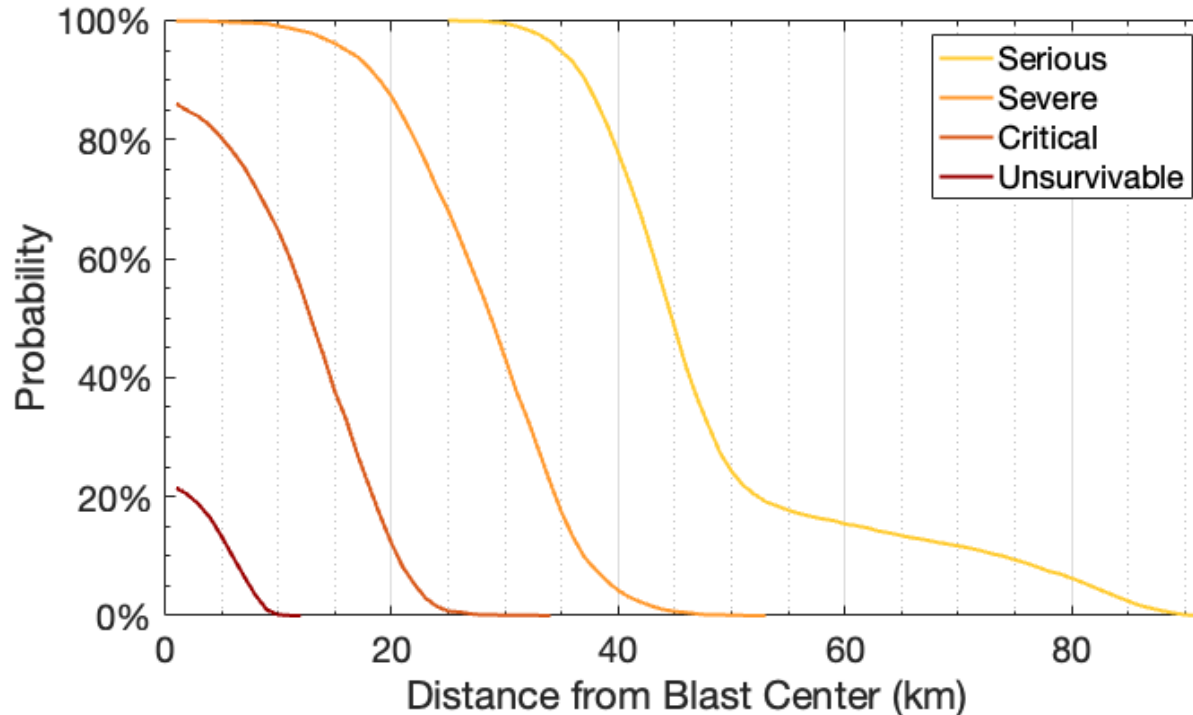
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Large damage sizes could span multiple cities or counties and reach unsurvivable levels

* Damage sizes and shapes vary with different asteroid airburst energies and altitudes. Radii given are circular area equivalents, with larger values rounded to nearest 5 km/mi.

Local Damage Size & Severity Risks

Chance that damage levels will reach at least a given distances from the blast center



Chance of damage levels occurring:

Serious
100%

Severe
100%

Critical
87%

Unsurvivable
22%

- Serious damage would extend at least 25 km, most likely ~35–50 km, and potentially as far as ~95 km
- Severe damage would most likely extend ~20–35 km, potentially as far as ~50 km
- Critical damage would most likely extend ~10–20 km, potentially as far as ~30 km
- Unsurvivable damage is less likely to occur, but could reach as far as ~6-12 km in the largest cases

Relative probabilities of damage levels reaching further than given distances from blast center											
	>2 km	>5 km	>10 km	>20 km	>30 km	>40 km	>50 km	>60 km	>70 km	>80 km	>90 km
Serious	100%	100%	100%	100%	99.6%	78%	24%	15%	12%	6%	0.1%
Severe	100%	100%	99%	87%	43%	4%	0.1%	0%			
Critical	85%	80%	65%	12%	0.1%	0%					
Unsurvivable	20%	13%	0.1%	0%							



Local Blast & Thermal Damage Area Sizes

- Significant blast damage is certain to occur, ranging from large areas of shattered windows and structure damage to potentially unsurvivable devastation near the airburst
- Thermal damage could also occur, but is much less likely and much smaller than the corresponding blast regions
- Outer serious damage extent would most likely be ~35–50 km (~20–30 mi), but the largest blasts could extend as far as ~100 km (~60 miles)

* Damage sizes and shapes vary with different asteroid airburst energies and altitudes. Radii given are circular area equivalents, with larger values rounded to nearest 5 km/mi.

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%	45	35–50	25–95
Severe	Widespread structure damage	100%	30	20–35	0–55
Critical	Most residential structures collapse	87%	15	7–20	0–35
Unsurvivable	Complete devastation	22%	0	0	0–11

Potential Thermal Damage Severities and Sizes

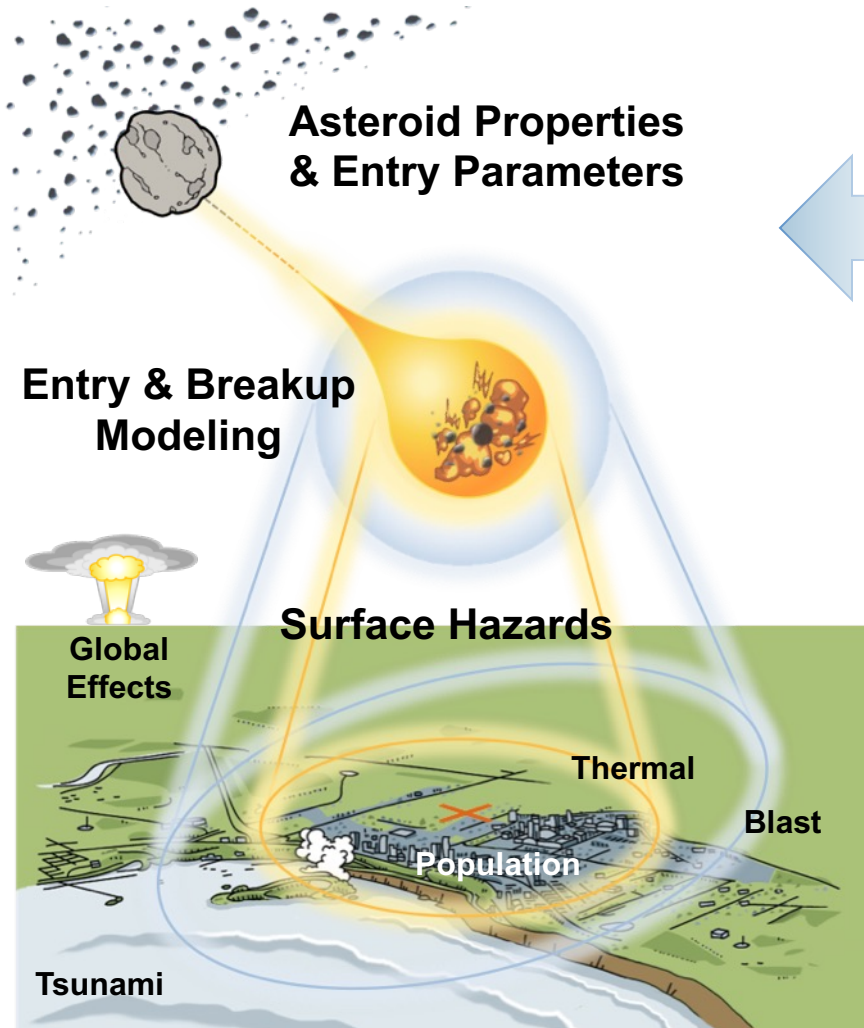
Damage Level	Potential Thermal Effects	Chance of Occurring	Damage Radius Ranges (km)		
			Median	Most Likely	Range
Serious	2 nd degree burns	14%	0	0	0–20
Severe	3 rd degree burns	6%	0	0	0–15
Critical	Clothing ignition	0.7%	0	0	0–7
Unsurvivable	Structure ignition	0.2%	0	0	0–3



PROBABILISTIC ASTEROID IMPACT RISK MODELING DETAILS & REFERENCES

Asteroid Impact Threat Assessment

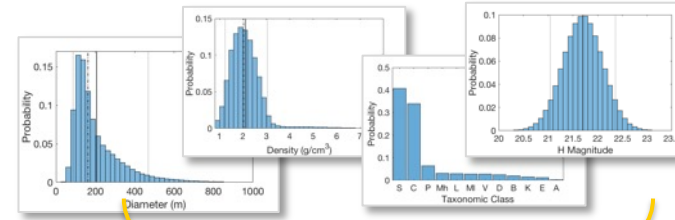
Probabilistic Asteroid Impact Risk (PAIR) Model



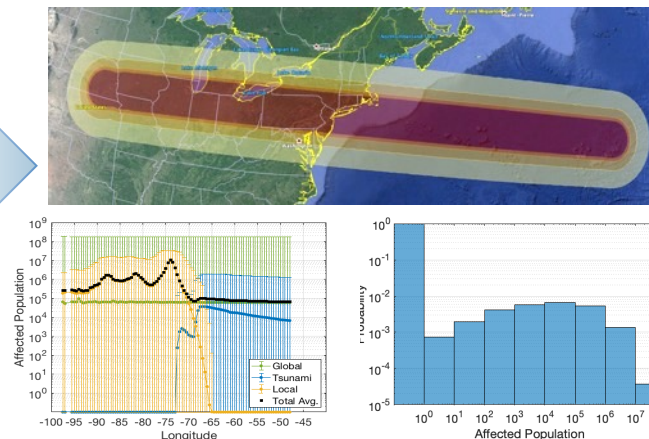
[PAIR model details: Wheeler et al., 2025]

Impact Threat Scenario

Asteroid Property Distributions



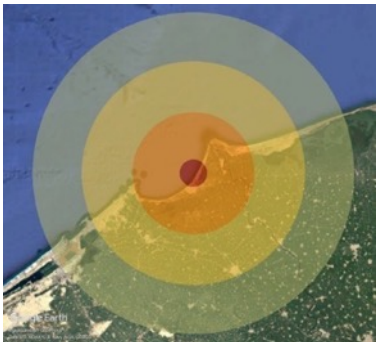
Probabilistic Damage and Risk



- 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, global effects) are modeled for each case.
- Probabilities of the resulting damage sizes, severities, and affected populations are computed.
- Regions at-risk to local damage are mapped.

Local Blast & Thermal Damage Effects

- Large impacts and airburst can generate destructive blast waves and thermal heat radiation that can cause various levels of injury, fatalities, structural damage, and/or fires extending far around the impact location.
- Blast and thermal ground damage are assessed *independently* at four equivalent severity levels
 - The damage region for each severity level is determined from the *larger* of the equivalent blast *or* thermal damage area
 - Local ground damage regions indicate *either* blast or thermal effects could exceed the given severity threshold (*not* necessarily the occurrence of both effects within the entire region)
 - Local affected population estimates within each region are scaled by the relative severity of each damage level
- Blast is the predominant hazard for most airbursting and sub-global-scale asteroid sizes
 - Blast tends to be larger and more severe than the potential thermal damage in most cases, and usually defines the larger outer damage risk regions for emergency response planning
 - Depending on blast energy, airbursts can cause larger blast damage than ground impacts, while thermal damage decreases with airburst altitude

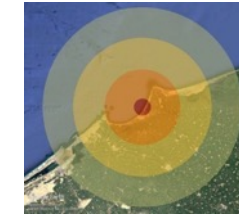


Damage Level	Relative Severity	Blast Damage Effects	Thermal Damage Effects
Serious	10%	Shattered windows, some structural damage	2 nd degree burns
Severe	30%	Widespread structural damage	3 rd degree burns
Critical	60%	Most residential structures collapse	Clothing ignites
Unsurvivable	100%	Devastation, reinforced structures collapse	Structures ignite, incineration

Affected Population Risks

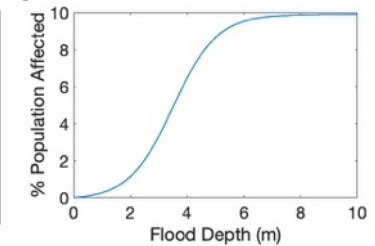
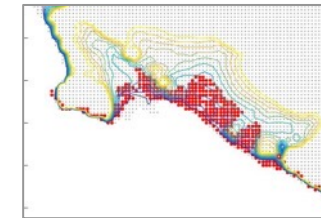
- For each impact case modeled, PAIR computes the estimated number of people affected by each hazard type, based on the modeled damage location, area, severity, and local population
 - Local blast & thermal ground damage:** affects 10–100% of local population depending on severity (additional details in following slides)
 - Tsunami:** affects up to 10% of the local population depending on flood depth in each coastal area (based on tsunami wave height and ground elevation)
 - Global effects:** affects estimated fractions of total world population, based on total impact energy and a randomly sampled severity factor
 - Total affected population** estimates for each impact case are taken as the number of people affected by the largest hazard produced (not sums of multiple hazards)
- Affected population risks:** population results for each impact case are aggregated to compute total population **risks**, reflecting the likelihoods of the possible effects for the overall impact scenario (i.e., probabilities of the impact affecting given ranges or thresholds of people)
- Population data source:** SEDAC Gridded Population of the World (GPW) v4.11 gridded population counts, year 2020 UN-adjusted values

Local Blast & Thermal Affected Population

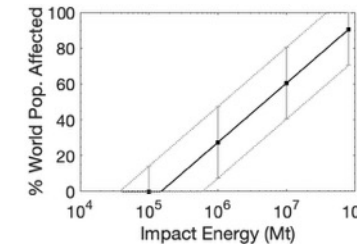


Severity	% Pop. Affected
Serious	10%
Severe	30%
Critical	60%
Unsurvivable	100%

Tsunami Affected Population



Global Effects Affected Populations

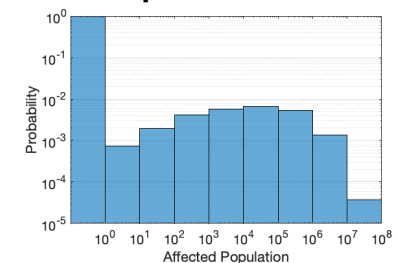


Impact Energy (MT)	% Population Affected		
	Min	Nominal	Max
4.E+04	0	0	0
8.E+04	0	0	10
2.E+05	0	0	20
3.E+05	0	10	30
6.E+05	0	20	40
1.E+06	10	30	50
2.E+06	20	40	60
5.E+06	30	50	70
1.E+07	40	60	80
2.E+07	50	70	90
4.E+07	60	80	100
8.E+07	70	90	100

SEDAC Gridded Population Data



Population Risks





ATAP Impact Risk & Hazard Modeling Papers

Probabilistic Asteroid Impact Risk (PAIR) & Asteroid Characterization:

- **Wheeler et al., 2024.** Risk assessment for asteroid impact threat scenarios. Acta Astronautica. [doi:10.1016/j.actaastro.2023.12.049](https://doi.org/10.1016/j.actaastro.2023.12.049)
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