Airburst & Blast Damage Risk Modeling Trends for the PDC25 Impact Scenario

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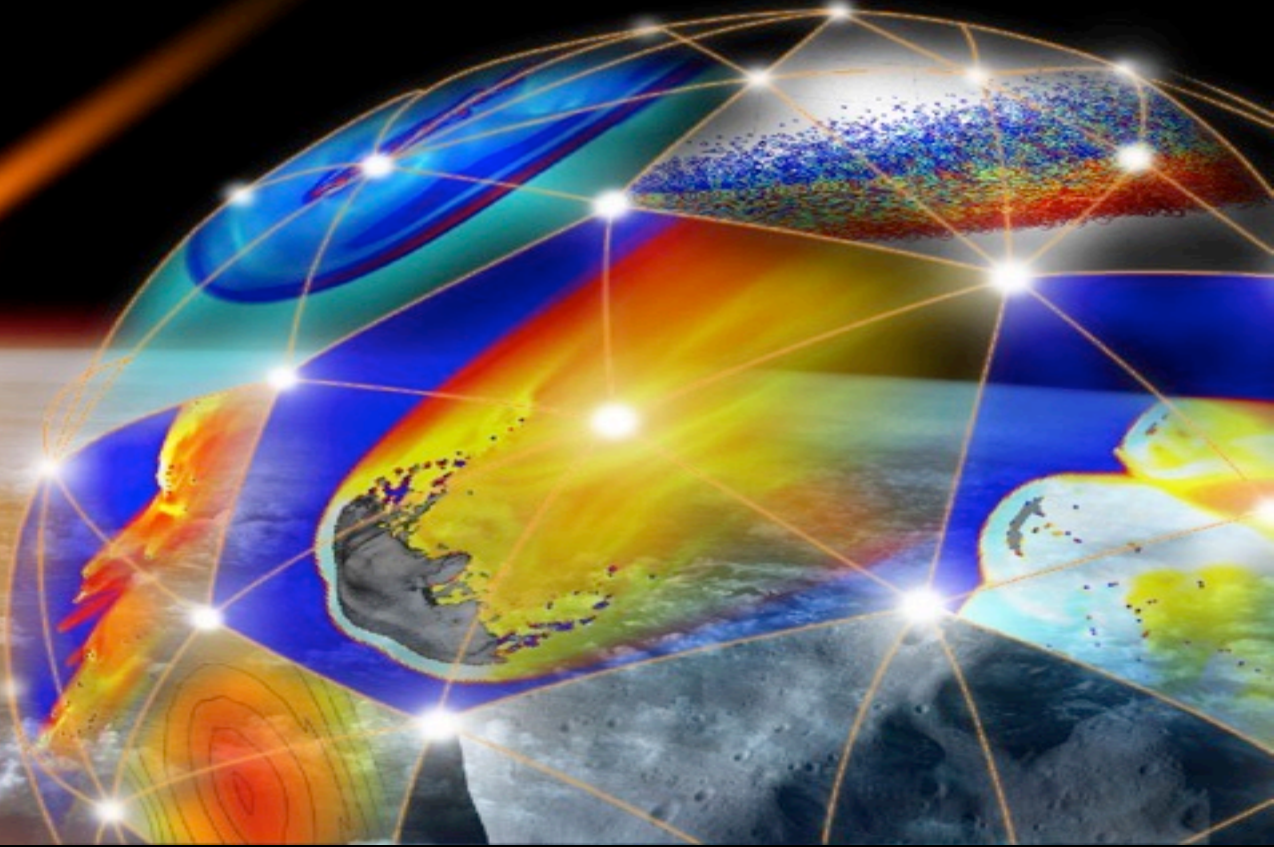

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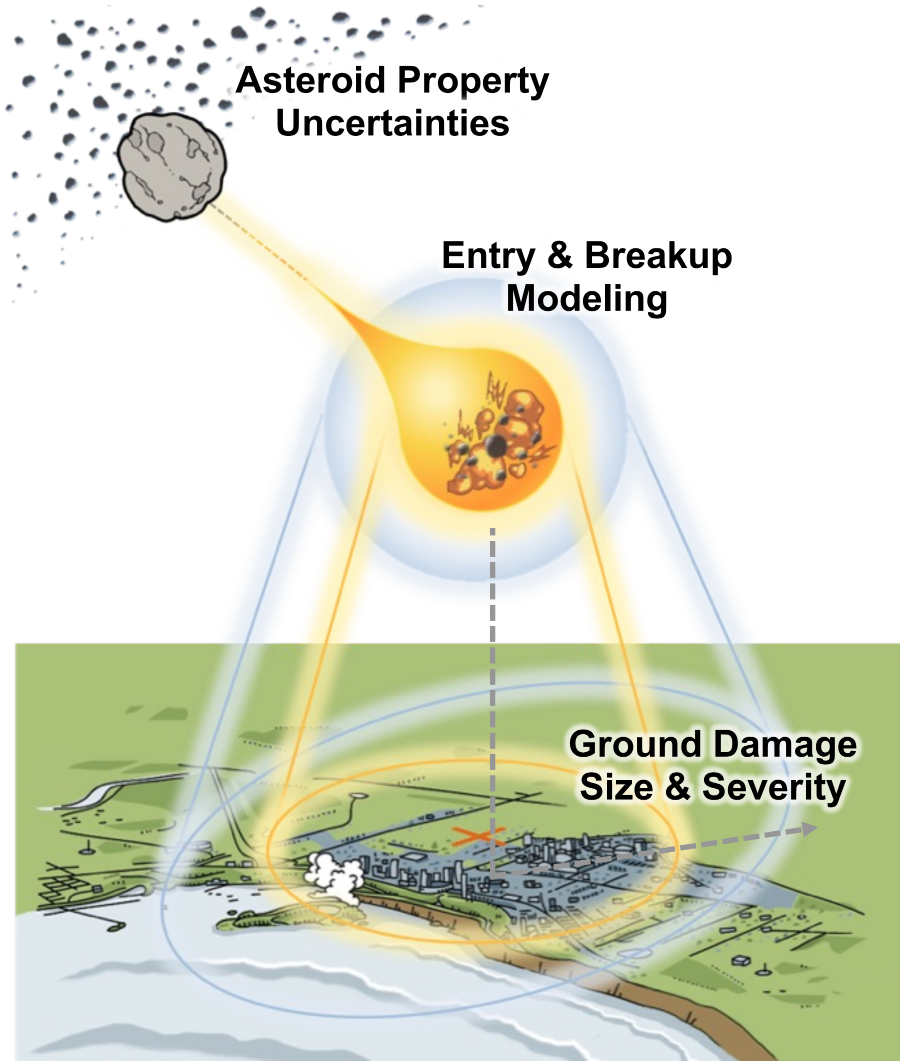
Airburst & Blast Damage Risk Study



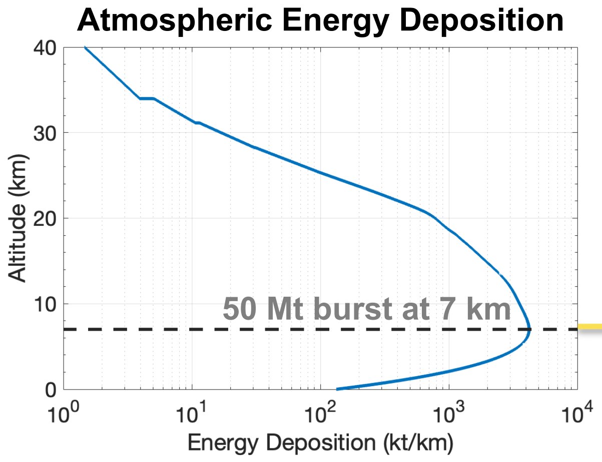
Probabilistic Asteroid Impact Risk (PAIR) Model

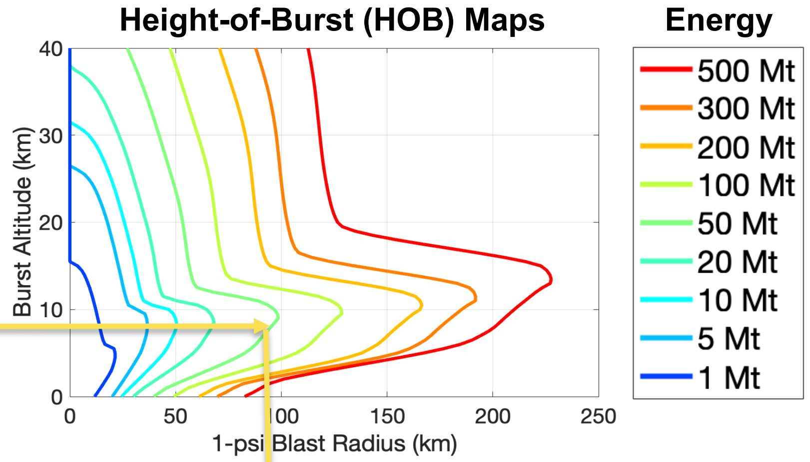
Using the Probabilistic Asteroid Impact Risk (PAIR) model to investigate airburst and blast damage trends for the 2024 PDC25 hypothetical impact scenario

- How current height-of-burst (HOB) blast damage modeling factors affect damage trends
- Sensitivity to entry and airburst altitude variations
- Which sizes or properties drive the greatest damage

PAIR Blast Damage Model

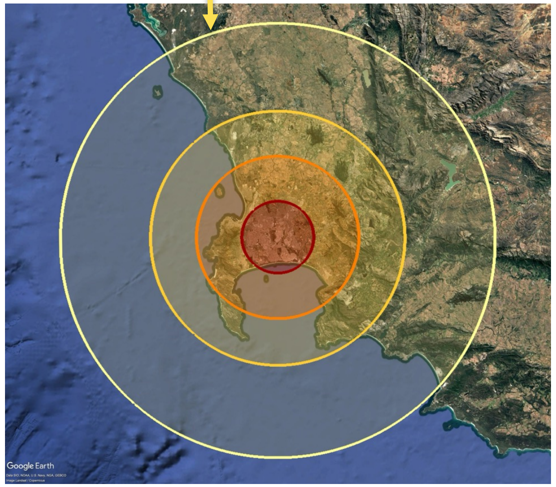
PAIR evaluates blast damage using simulation-enhanced Height-of-Burst (HOB) maps with effective airburst altitudes from entry modeling





- Height-of-burst (HOB) maps give blast footprint sizes based on asteroid energy and effective burst altitude
- Four blast severity levels modeled

- Entry and breakup modeled for each probabilistic impact case
- Effective burst altitude determined from energy deposition peak
- Depends on asteroid properties, entry trajectory, and breakup modeling parameters

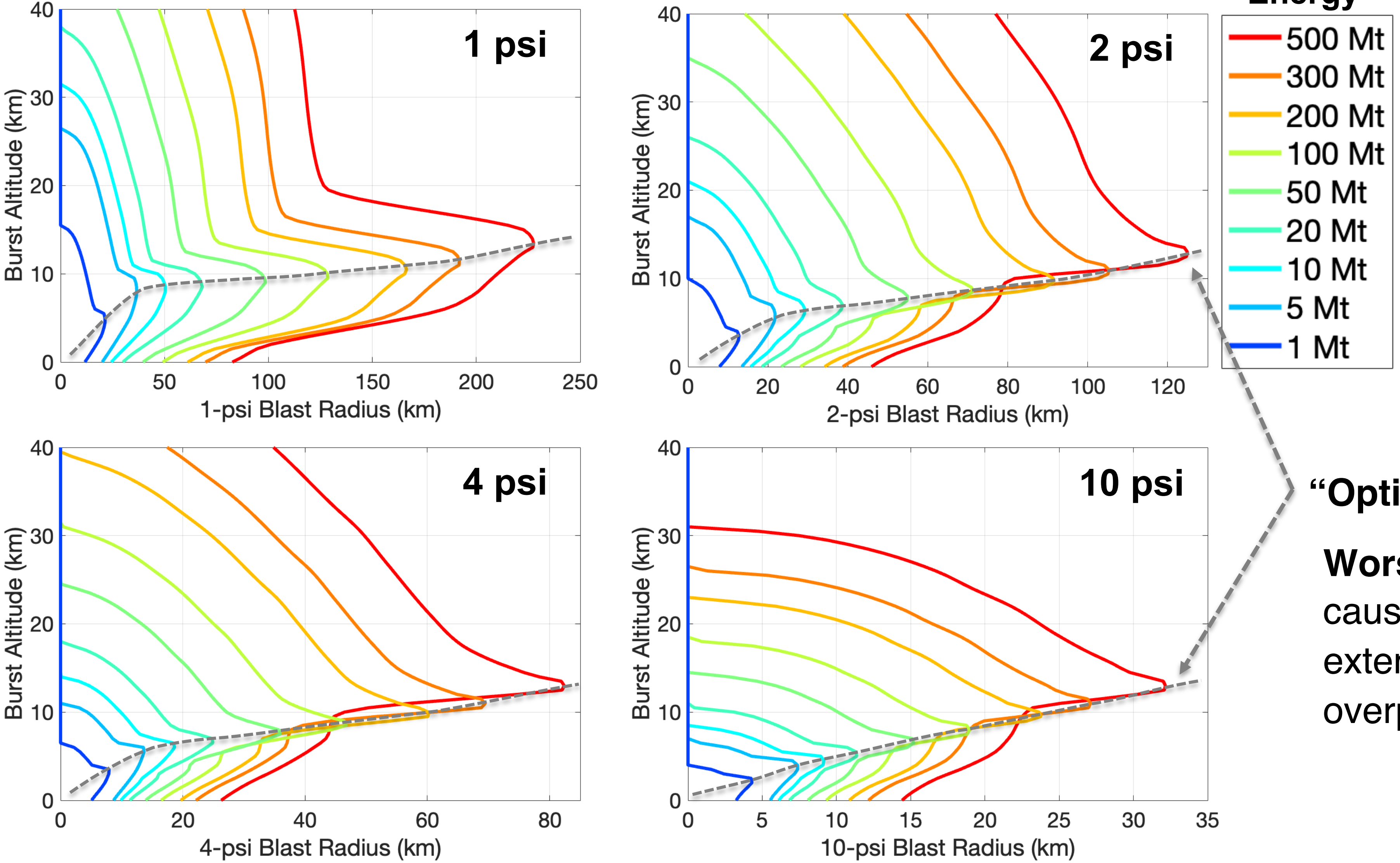


PAIR Blast Damage Severity Levels

Damage Level	Overpressure Threshold	Relative Severity	Damage Effects
Serious	1 psi	10%	Window breakage, some structure damage
Severe	2 psi	30%	Widespread structural damage
Critical	4 psi	60%	Most residential structures collapse
Unsurvivable	10 psi	100%	Complete devastation

PAIR Simulation-Enhanced HOB Maps

PAIR HOB maps for four blast overpressure levels

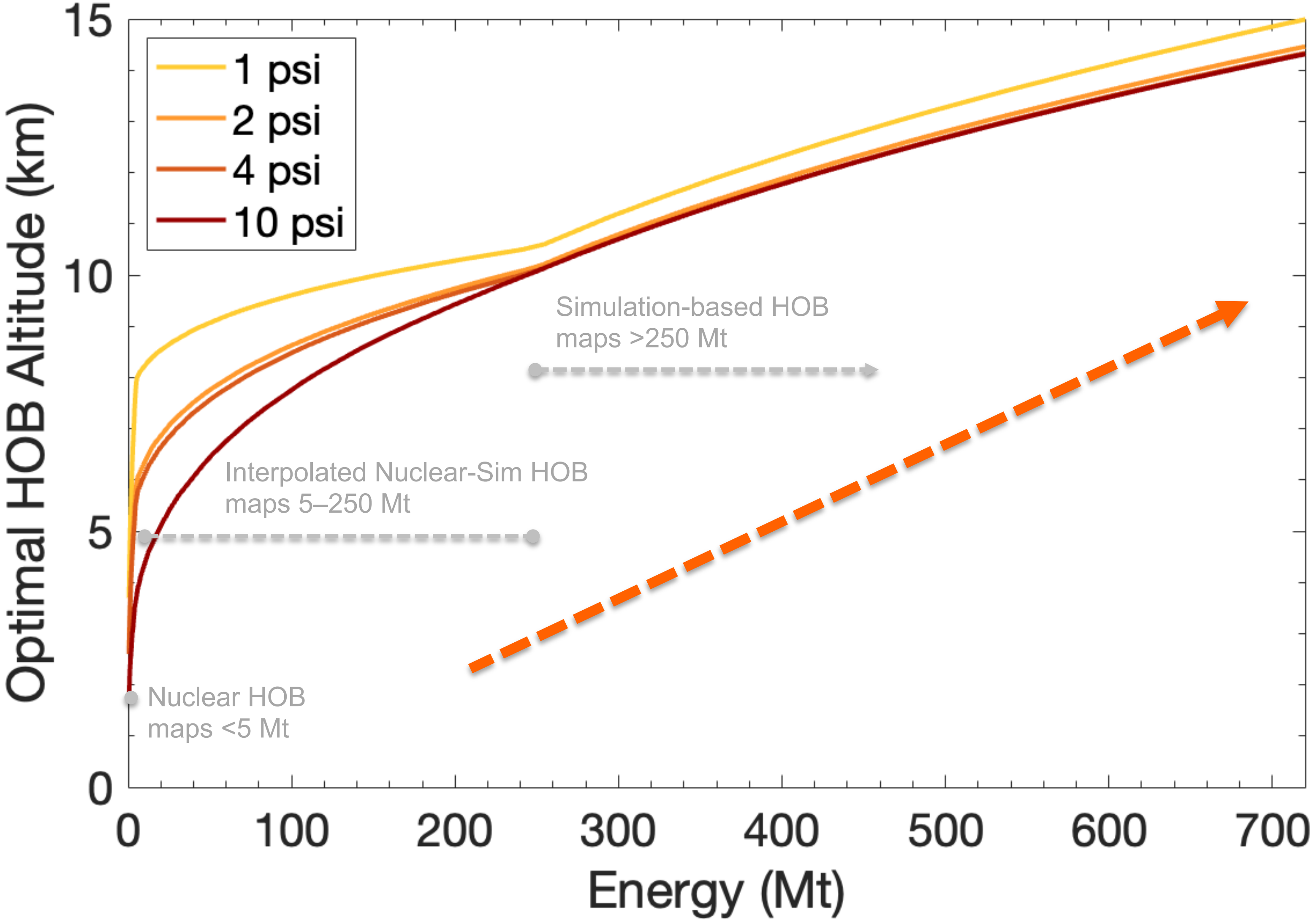


PAIR blast model uses simulation-based maps for energies > 250 Mt, nuclear HOB maps for energies < 5 Mt

"Optimal" HOB:

Worst-case airburst altitude causing **largest ground damage** extent for a given energy and overpressure level

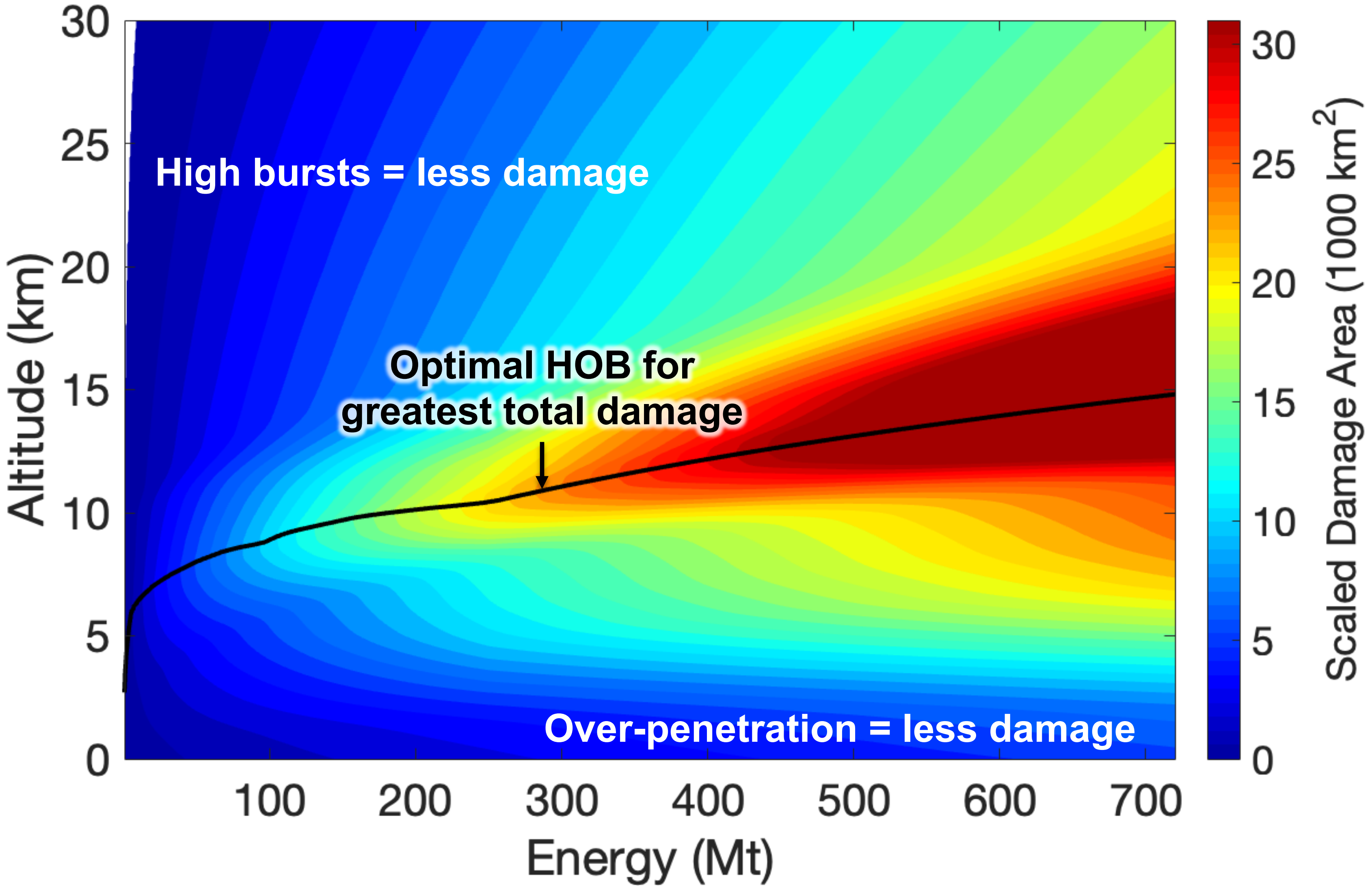
PAIR Optimal Height of Burst (HOB) by Energy



- Optimal (worst-case) HOB increases with energy
- Larger cases must burst higher to do maximal damage

HYPOTHETICAL EXERCISE

Total Severity-Scaled Damage



Total effective damage area from all blast levels, scaled by relative severity

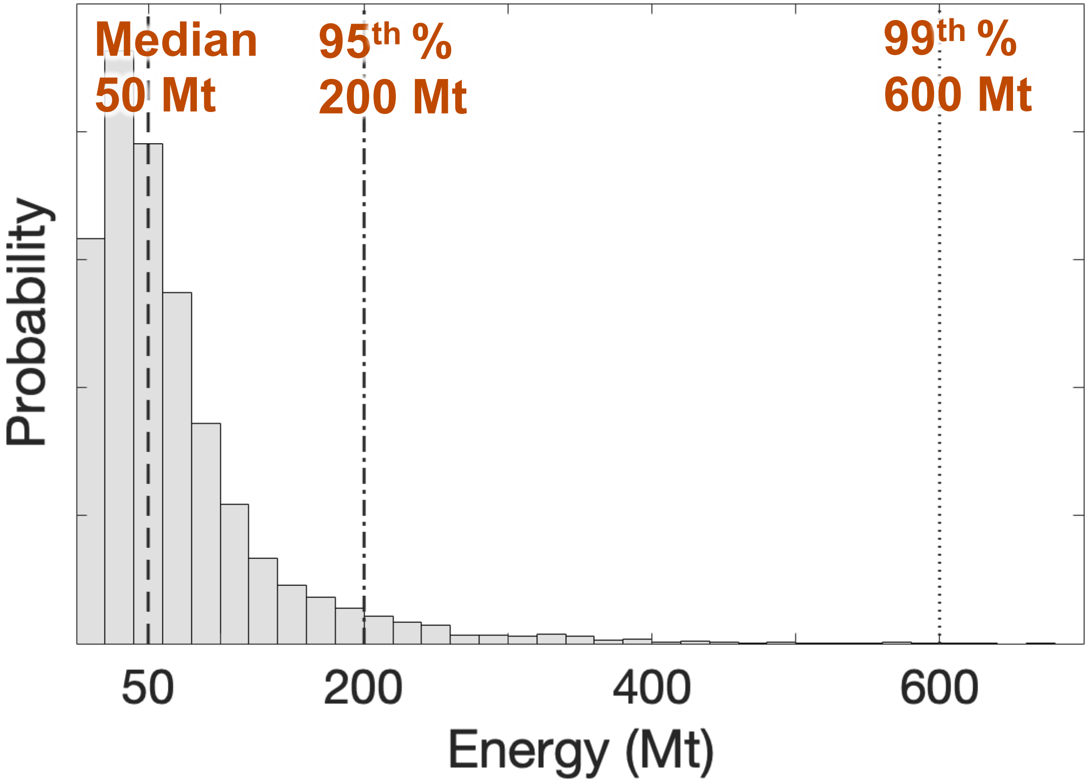
- 10% 1 psi (serious) area
- 30% 2 psi (severe) area
- 60% 4 psi (critical) area
- 100% 10 psi (unsurvivable) area

$$A_s = 0.1(A_{1psi}) + 0.3(A_{2psi}) + 0.6(A_{4psi}) + 1(A_{10psi})$$

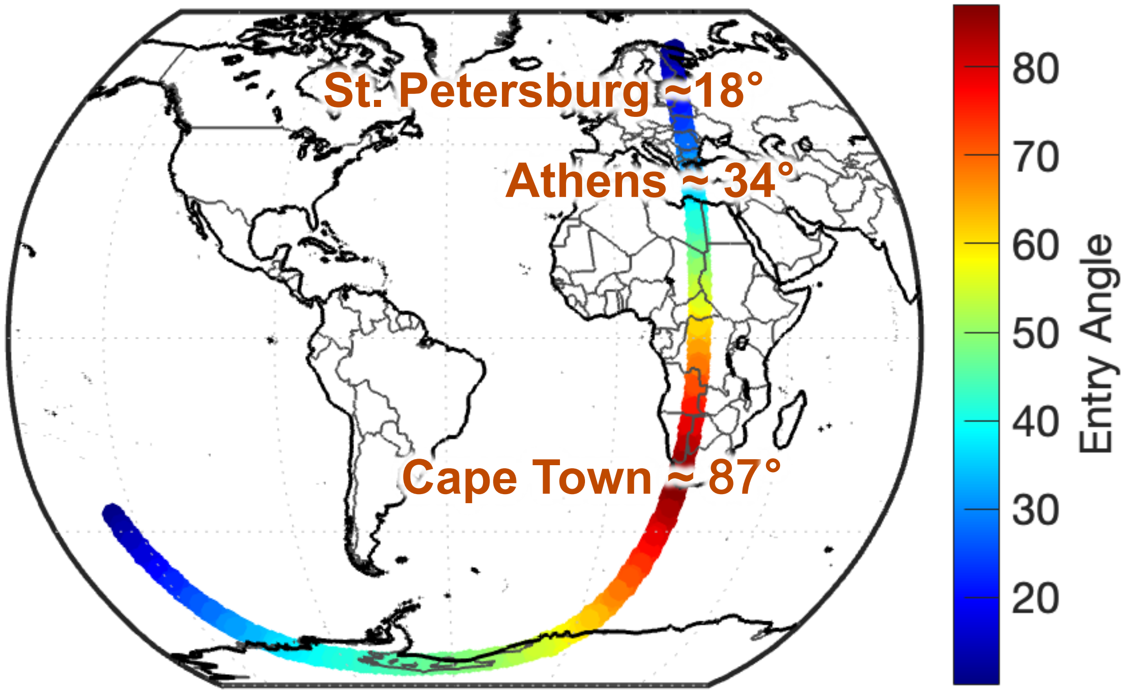
PDC25 Epoch 1 Asteroid Size & Entry Ranges

Early JWST data constrained asteroid size & type, but we still have a large range of possible impact energies and long uncertain impact corridor with full range of entry angles

Asteroid Energy Ranges



Entry Angle (from horizontal)

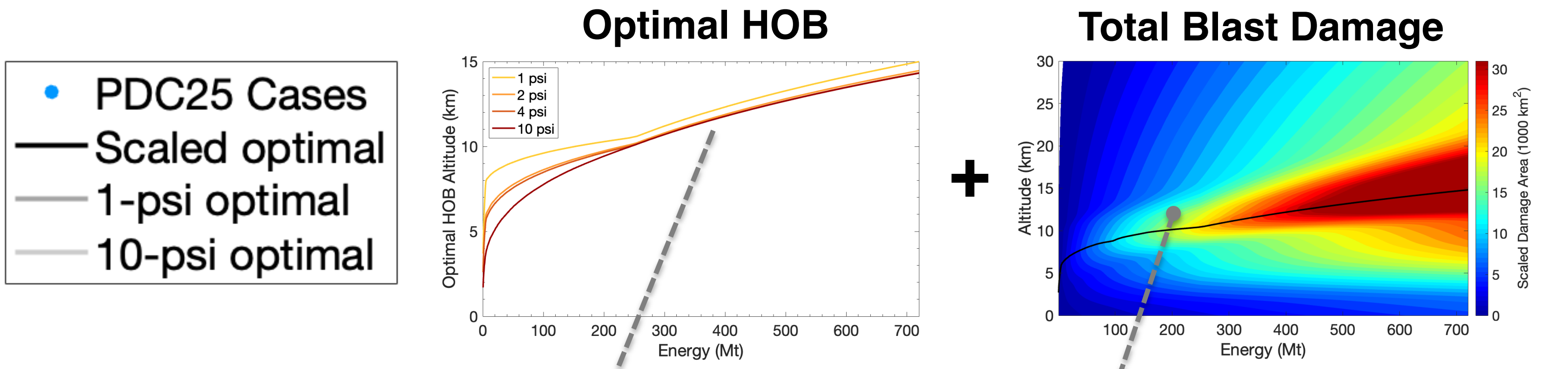


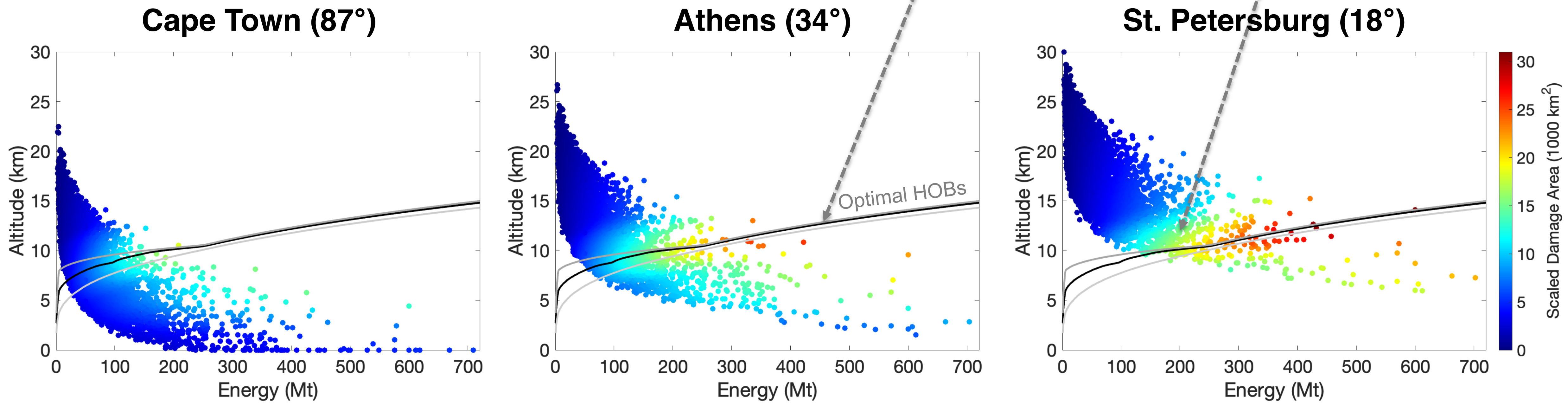
[Property inference model: J. Dotson et al., 2024]

[Impact entry data: D. Farnoccia, CNEOS/JPL, https://cneos.jpl.nasa.gov/pd/cs/pdc25/]

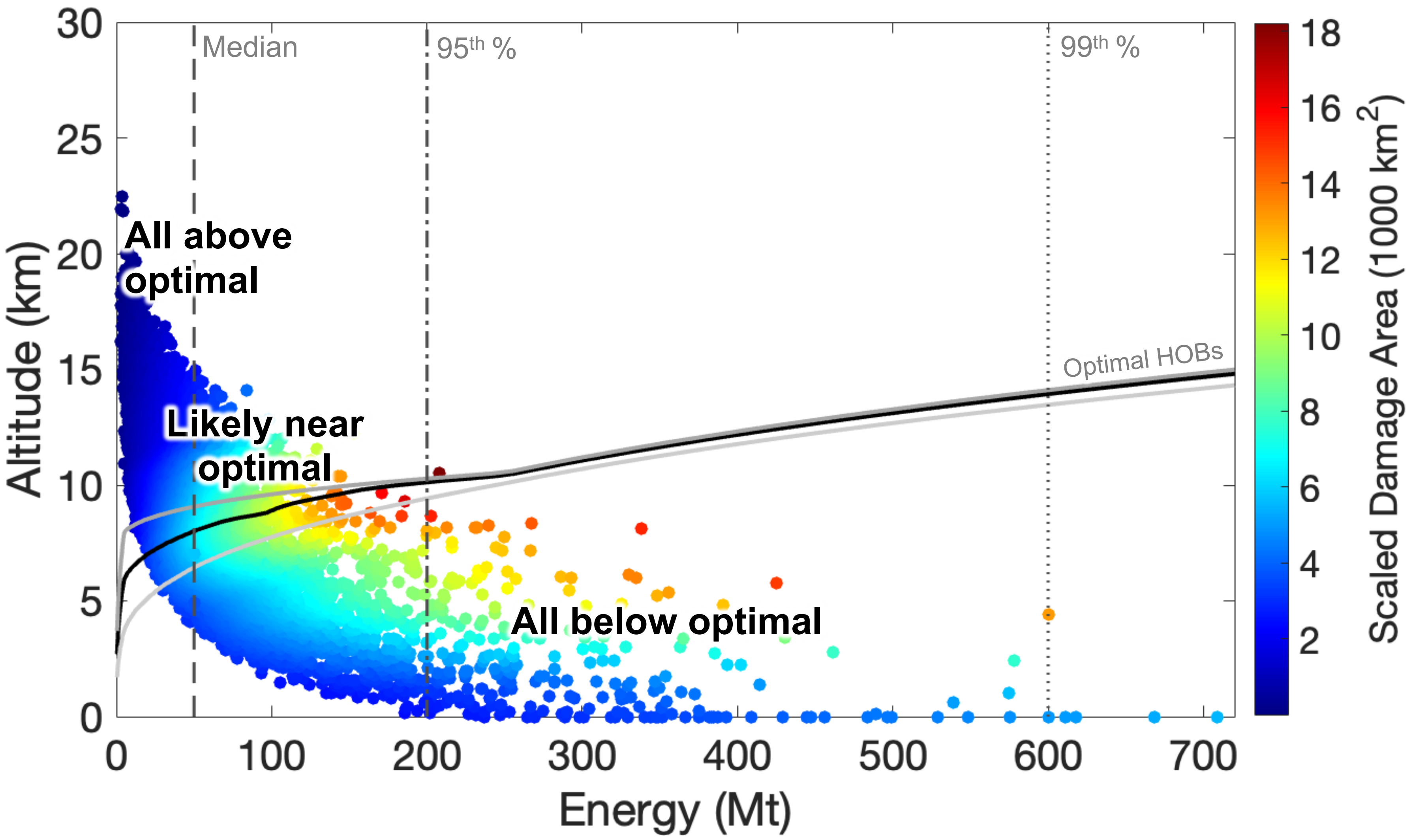
Airburst & Total Blast Damage Trends among PDC25 Cases

Energy and burst altitude of all asteroid cases modeled, colored by total blast damage





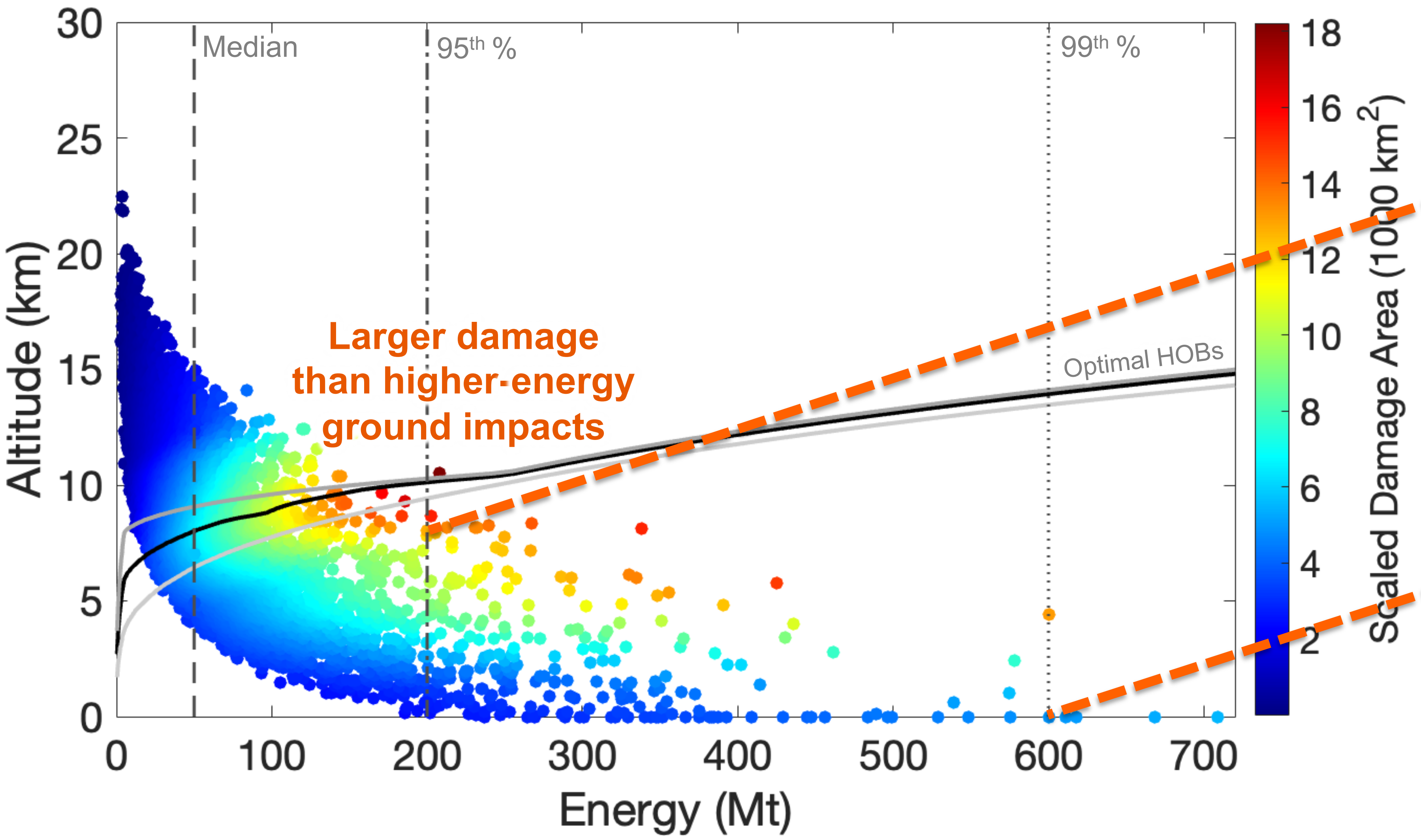
Airburst & Total Blast Damage Trends for Steep Entry (Cape Town)



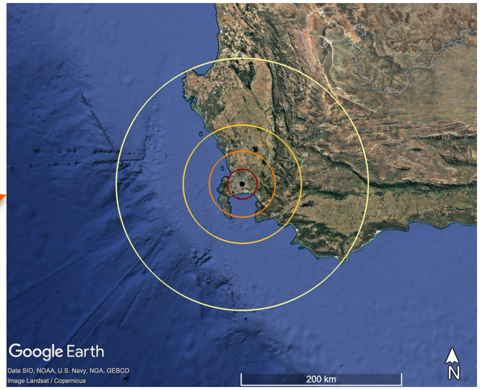
Steep entry trends:

- Cases ~50–100 Mt likely to burst near optimal
- Cases under ~10–20 Mt burst above optimal
- Cases over ~250 Mt all over-penetrate below optimal

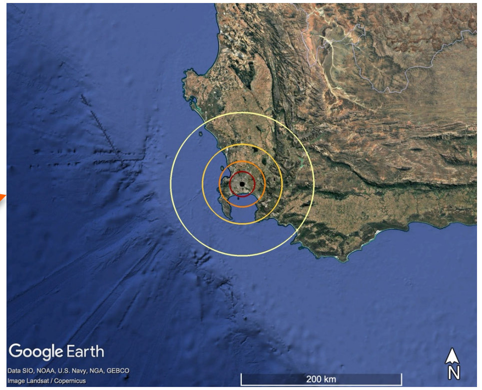
Airburst & Total Blast Damage Trends for Steep Entry (Cape Town)



200 Mt at 8 km altitude

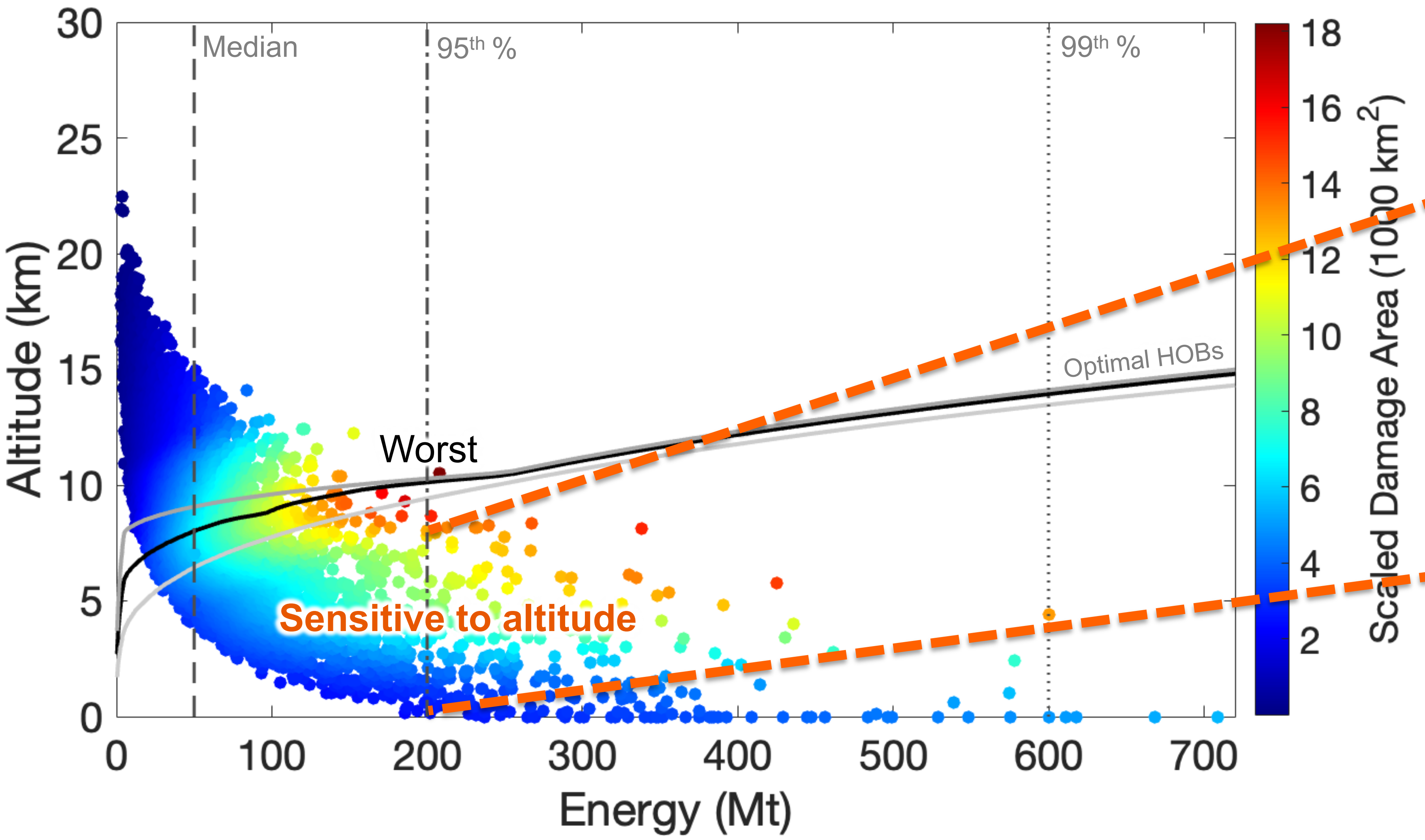


600 Mt ground impact



HYPOTHETICAL EXERCISE

Airburst & Total Blast Damage Trends for Steep Entry (Cape Town)



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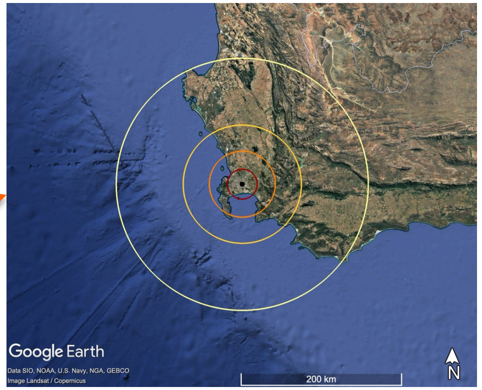

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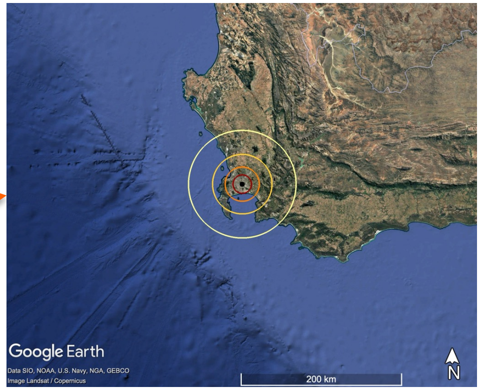

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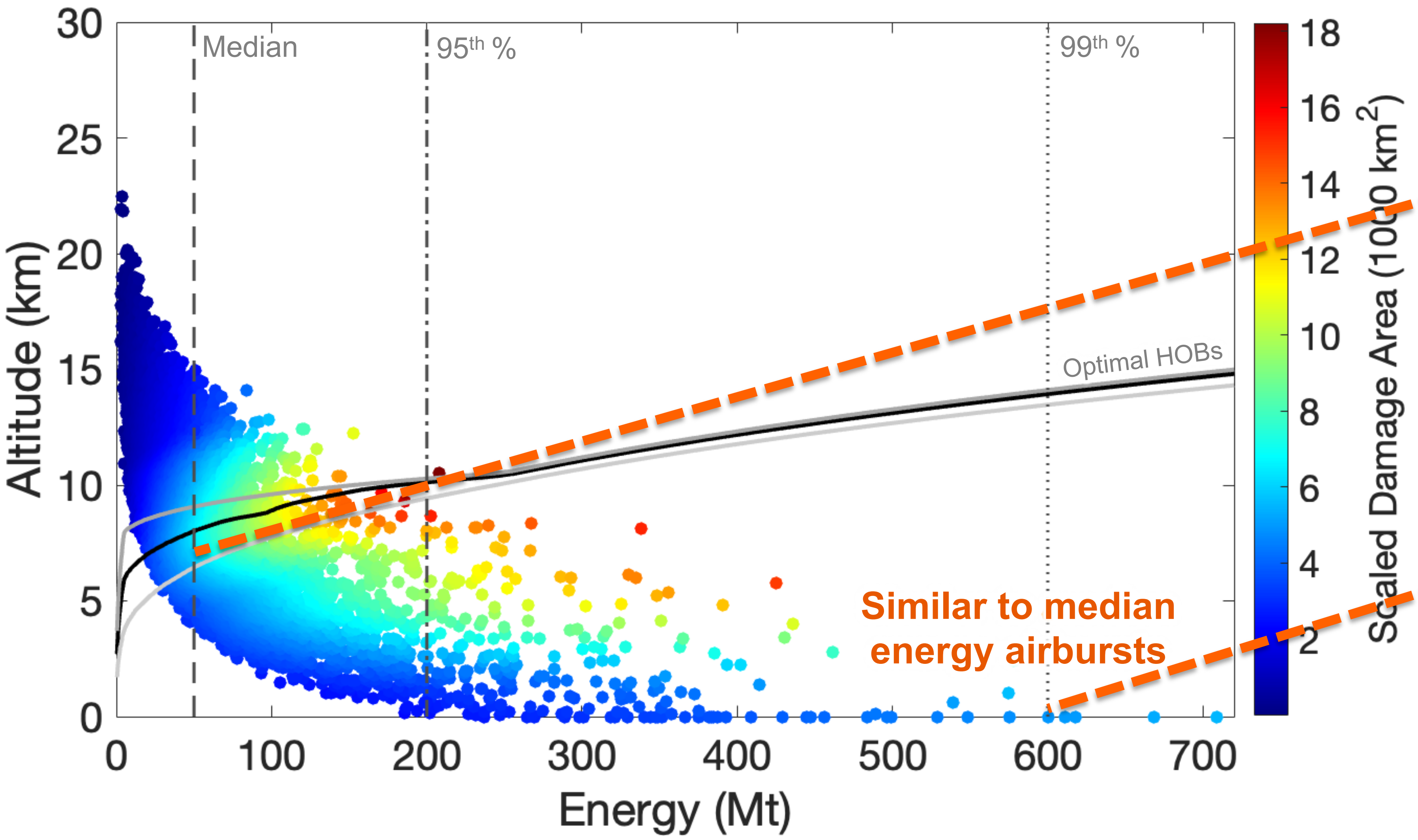
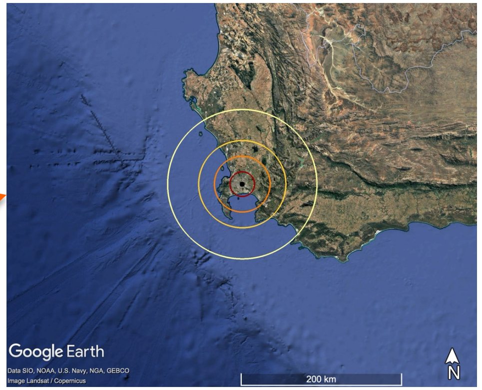
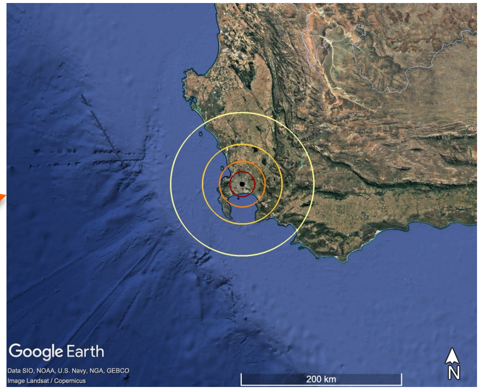


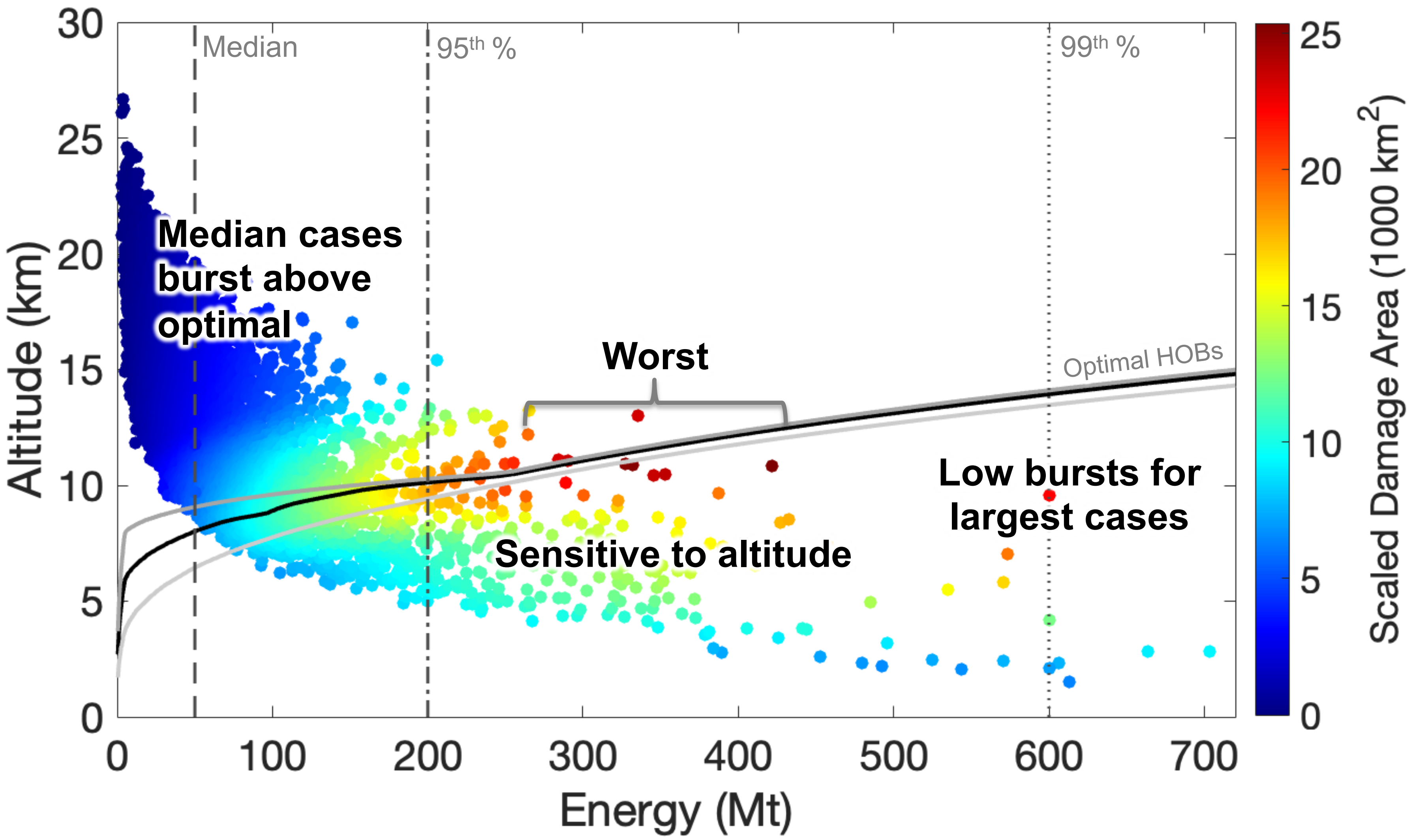
50 Mt at 7 km altitude



600 Mt ground impact



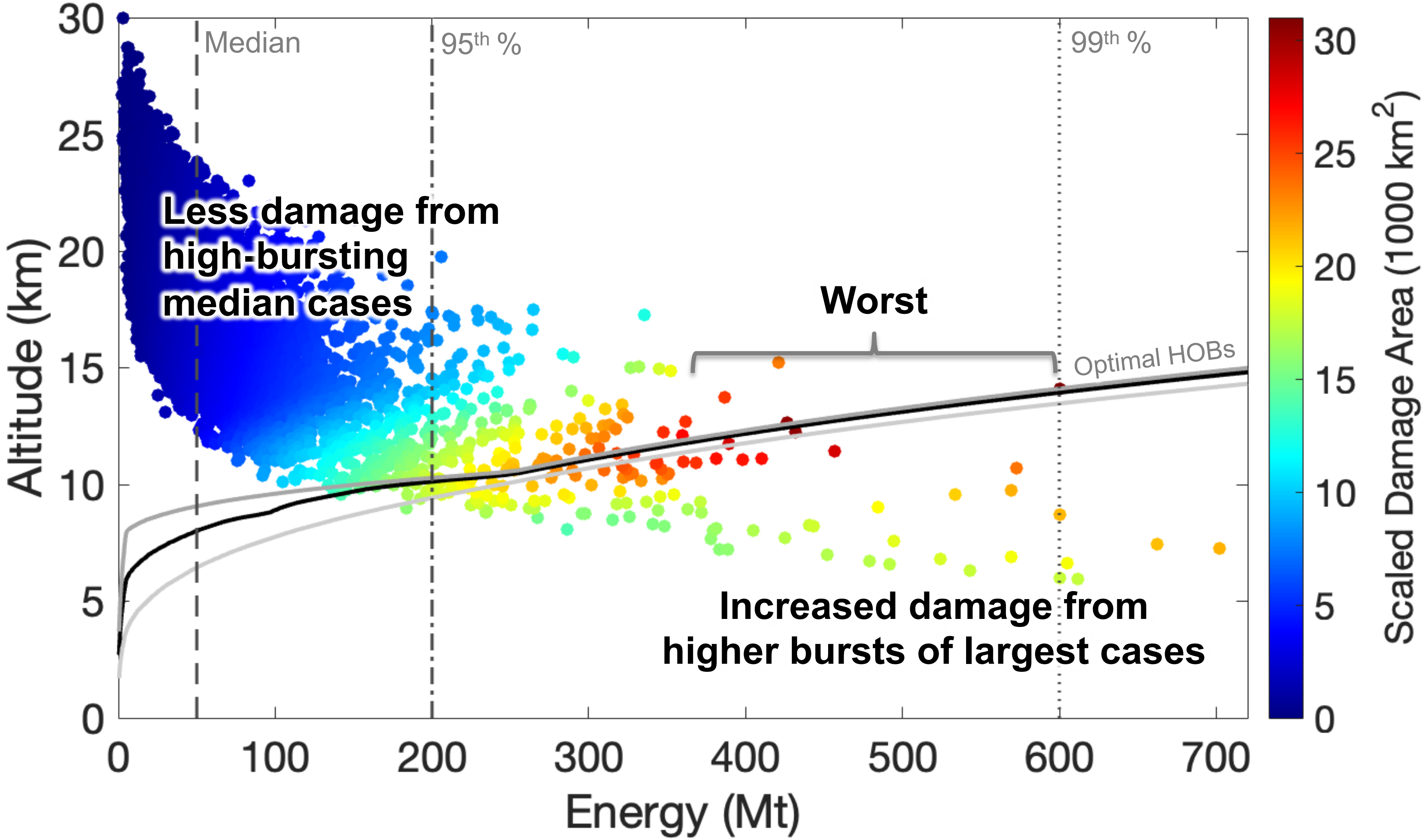
Airburst & Total Blast Damage Trends for Moderate Entry (Athens)



Moderate entry trends:

- Median energies mostly burst above optimal
- Worst damage from ~300–400 Mt cases at high altitudes
- Partial low bursts of largest cases increases their damage

Airburst & Total Blast Damage Trends for Shallow Entry (St. Petersburg)



Shallow entry trends:

- Effective burst altitudes of largest cases rise closer to optimal HOBs
- Worst damage from high-altitude ~400–600 Mt cases

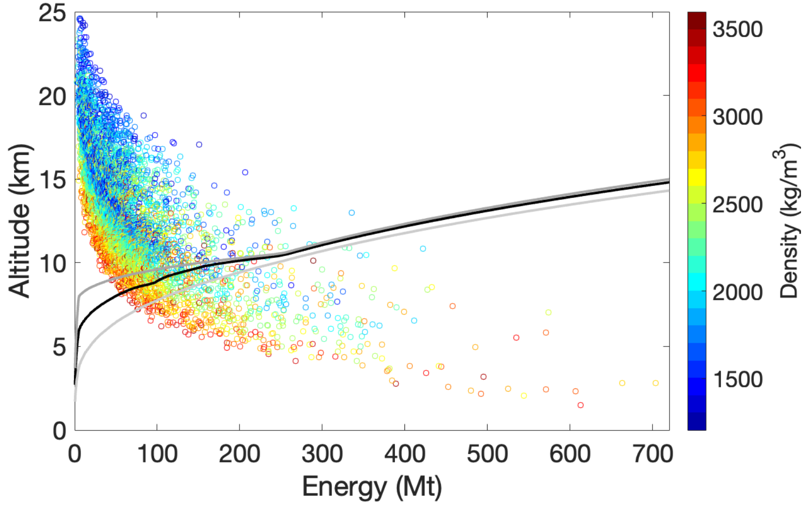
HYPOTHETICAL EXERCISE

Sensitivity to Entry & Airburst Modeling

Airburst altitude sensitivity means uncertain asteroid properties and breakup modeling parameters can notably influence damage trends for specific cases

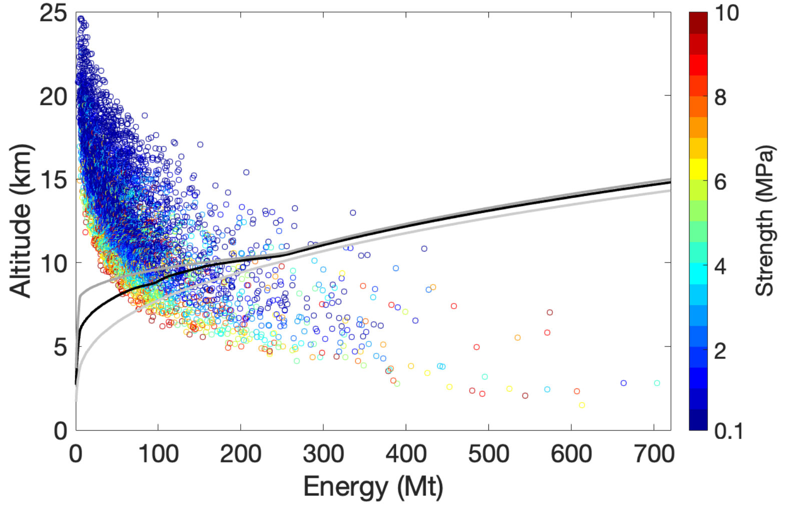
Density

Higher Density
Lower bursts



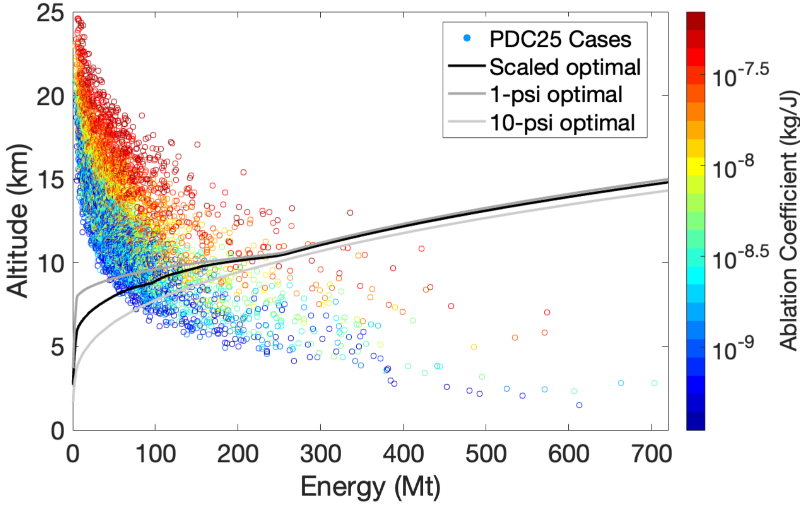
Strength

Highest strengths
Lowest bursts



Ablation

Higher ablation
Higher bursts



Summary

- Blast damage estimates for the initial PDC25 scenario are sensitive to airburst altitude and HOB modeling factors
  - JWST constraints mean airburst variations are not swamped by greater asteroid size uncertainties
  - Airburst altitude ranges span optimal (worst-damage) HOBs for the potential asteroid energies
  - Entry angles along the corridor shift which sizes burst above, below, or near their optimal HOBs, affecting which sizes give the largest damage
- Blast modeling implications and future work
  - HOB models are better suited to evaluating potential damage ranges spanning airburst uncertainties than modeling specific damage cases
  - Point-source HOB approximations don't fully capture effects of high-energy entry columns and large ground-impacting cases
  - High-fidelity CFD simulations are being used to develop improved blast models that will better capture these effects (see talks by M. Aftosmis, W. Spurlock, D. Robertson)

HYPOTHETICAL EXERCISE

References

Probabilistic Asteroid Impact Risk (PAIR) Model

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