

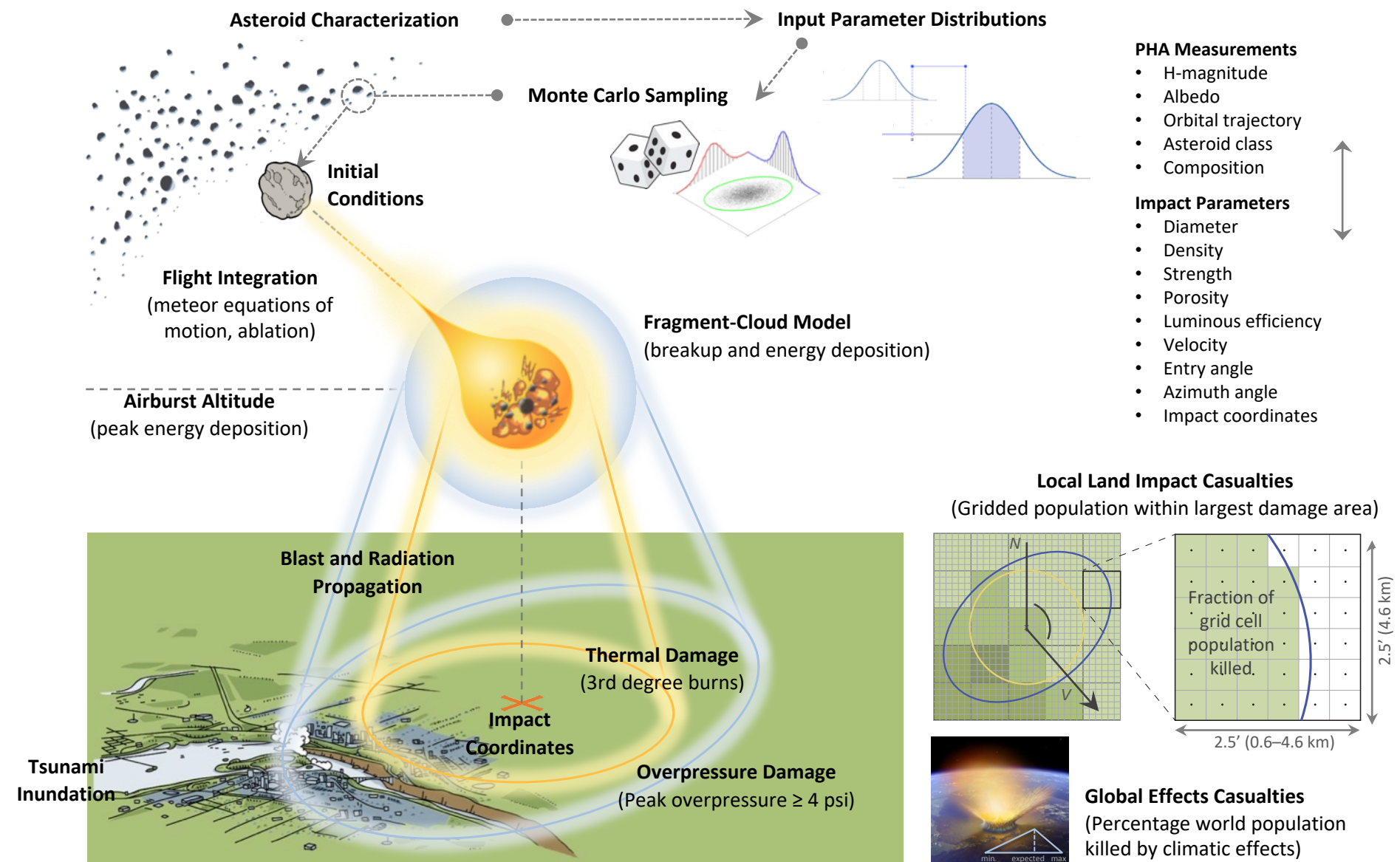
Bayesian Inference of Asteroid Physical Properties: Application to Impact Scenarios

Jessie Dotson, Lorien Wheeler,
Clemens Rumpf, & Donovan Mathias

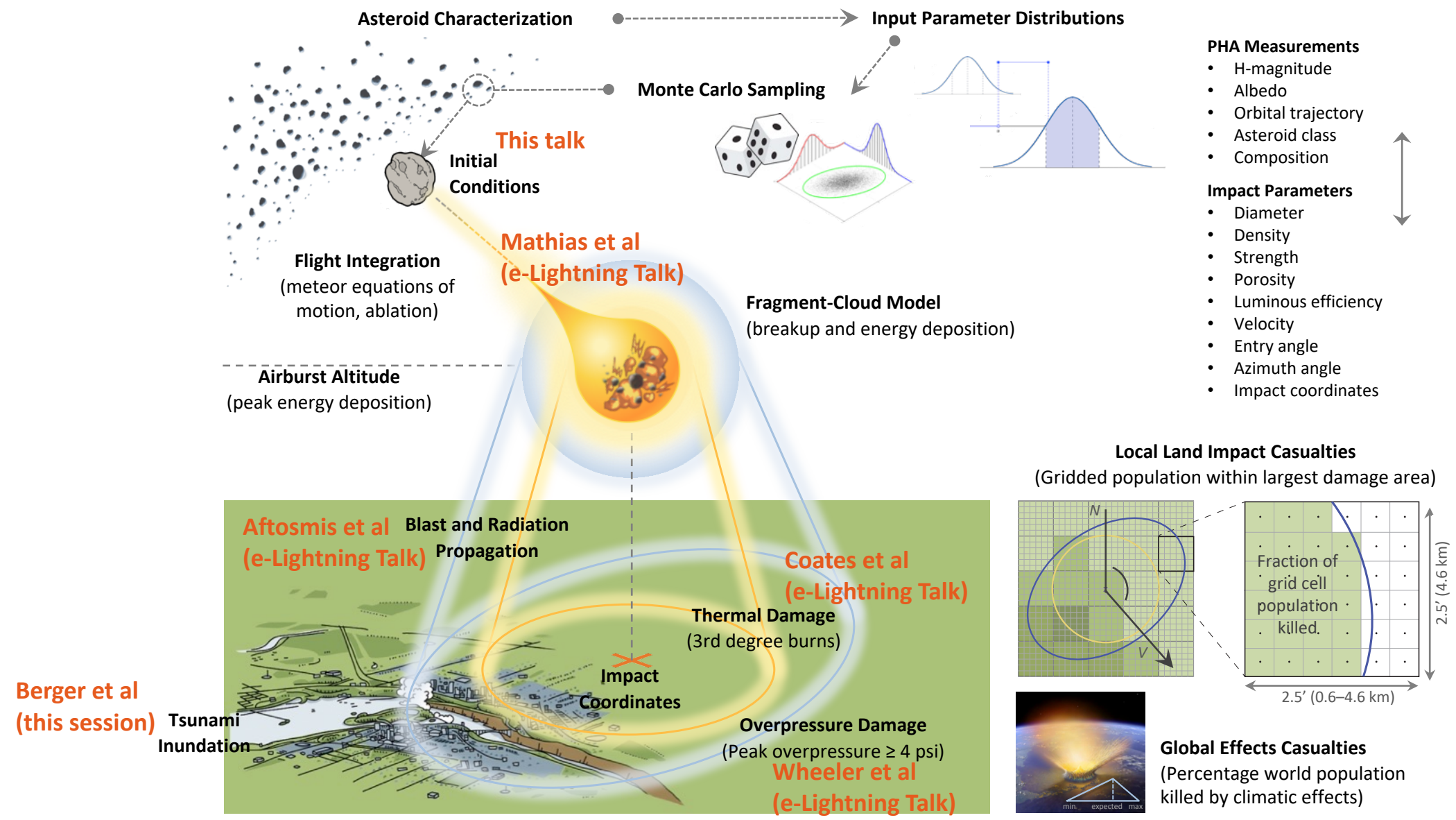
NASA Ames Research Center



Probabilistic Asteroid Impact Risk Model



Probabilistic Asteroid Impact Risk Model



Asteroid Physical Property Risk Model Inputs

diameter

density

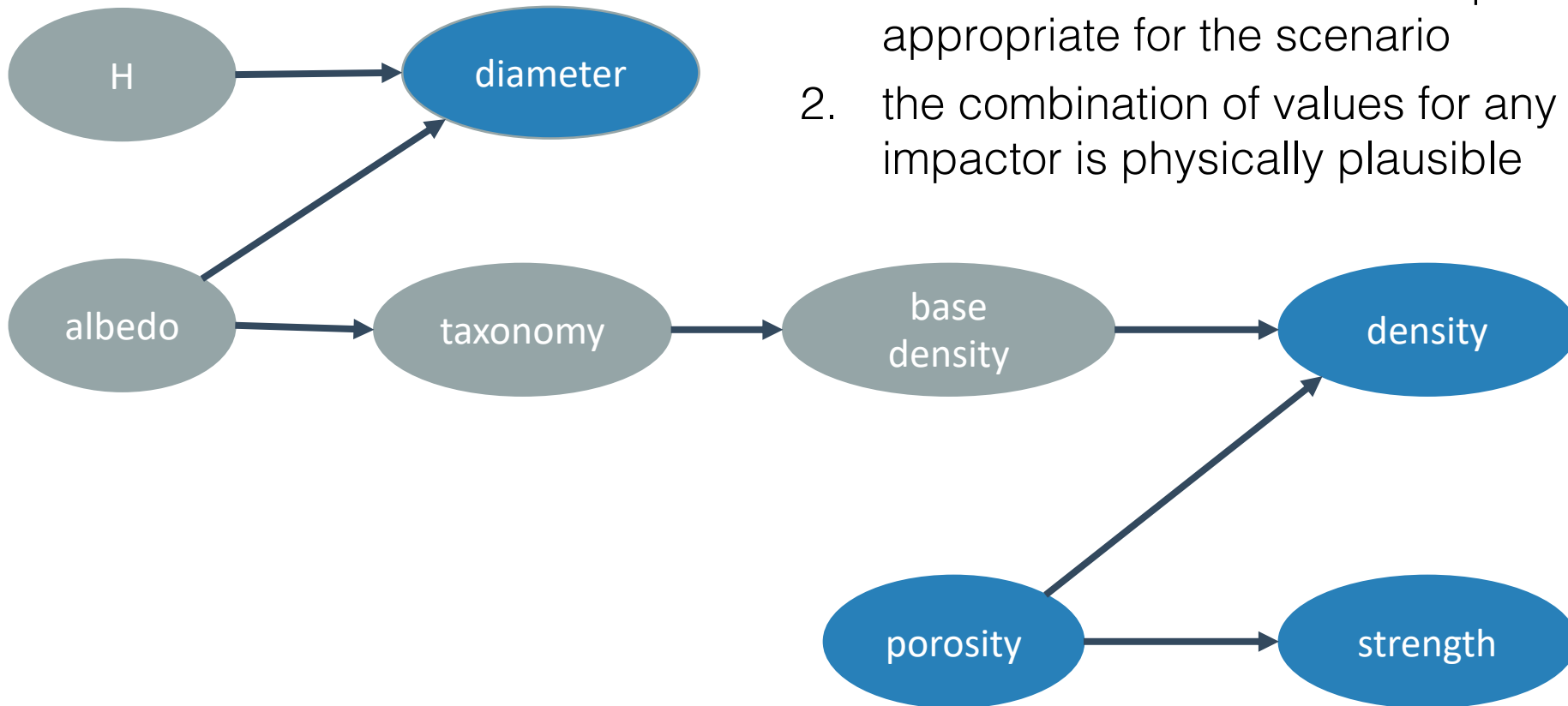
porosity

strength

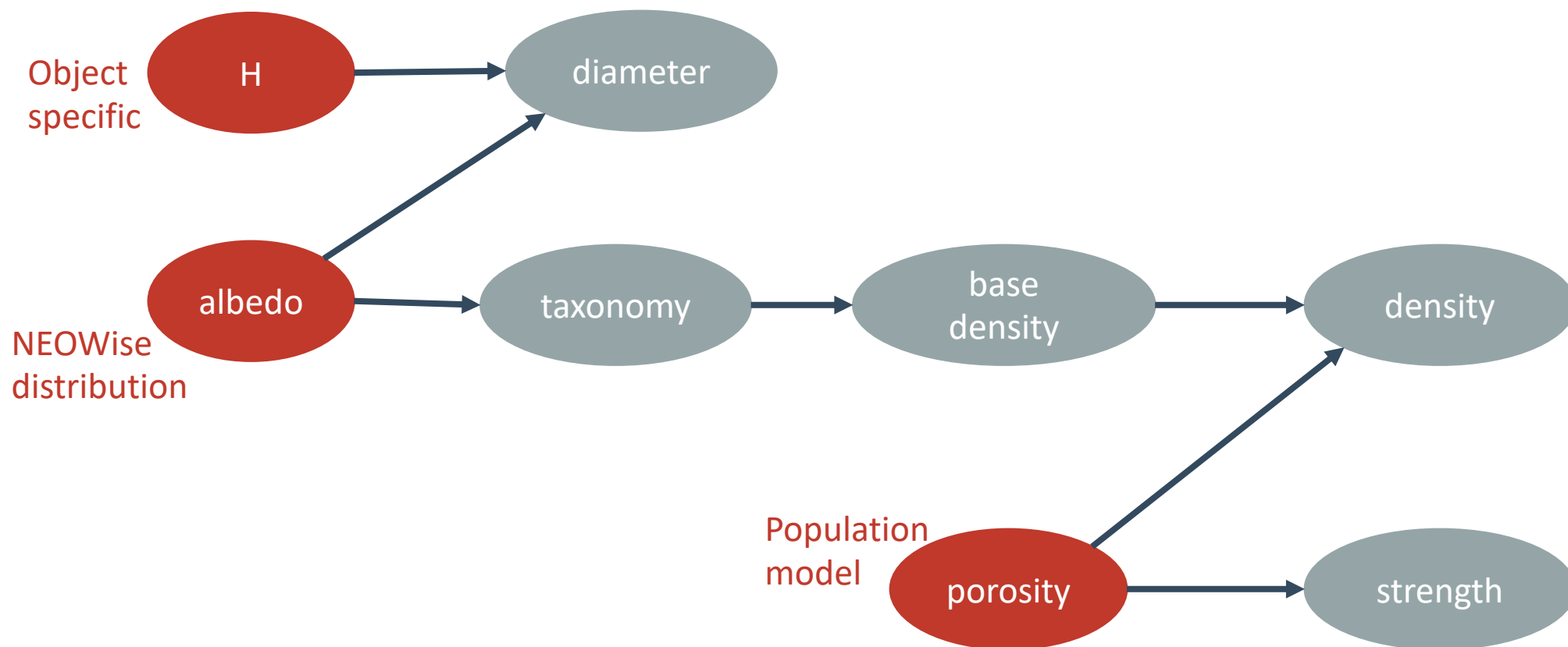
Asteroid Physical Property Inference Network

Goal: generate virtual impactors such that

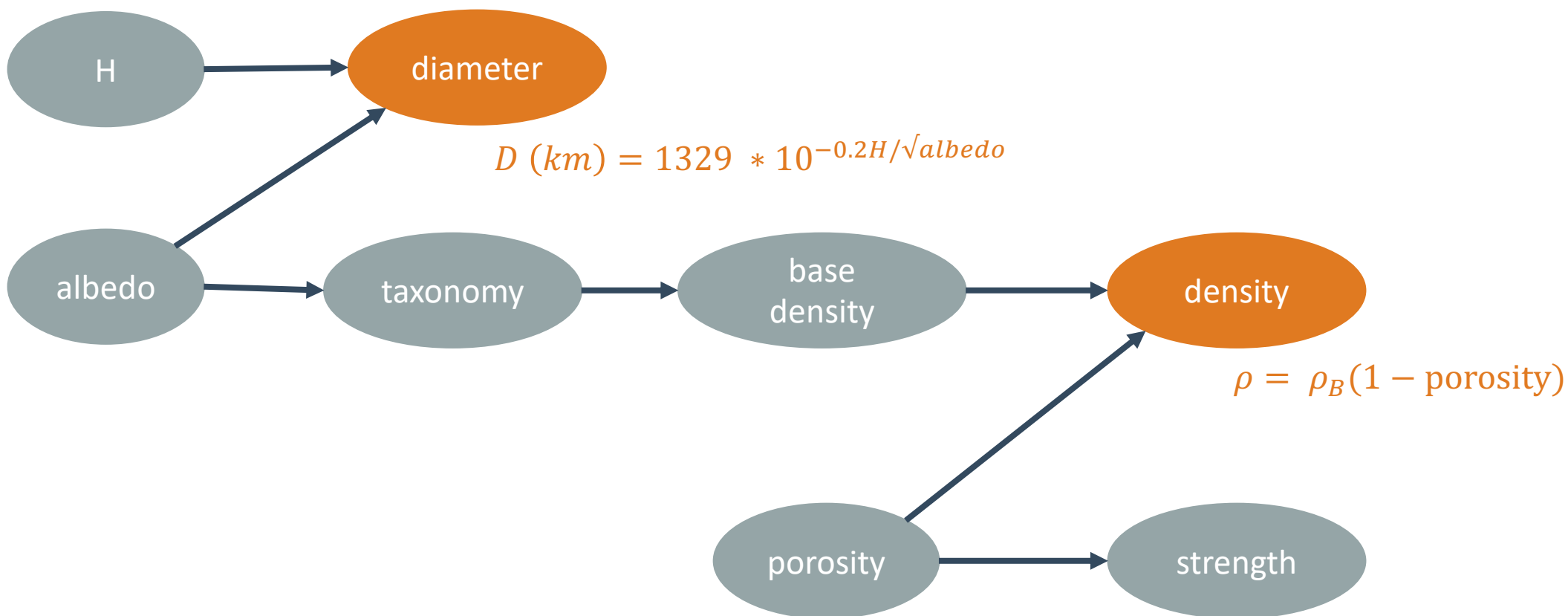
1. the distribution of values are plausible and appropriate for the scenario
2. the combination of values for any virtual impactor is physically plausible



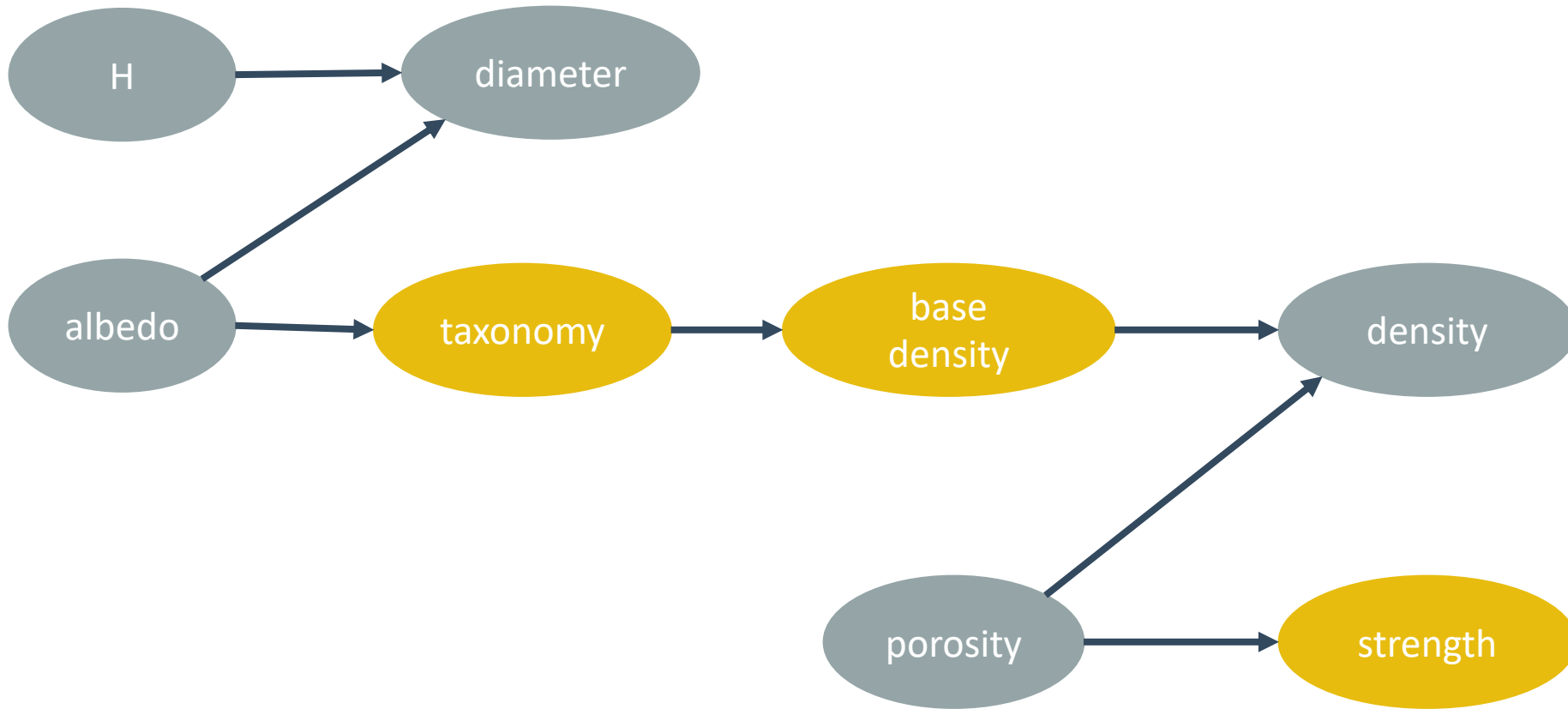
Data Derived Properties



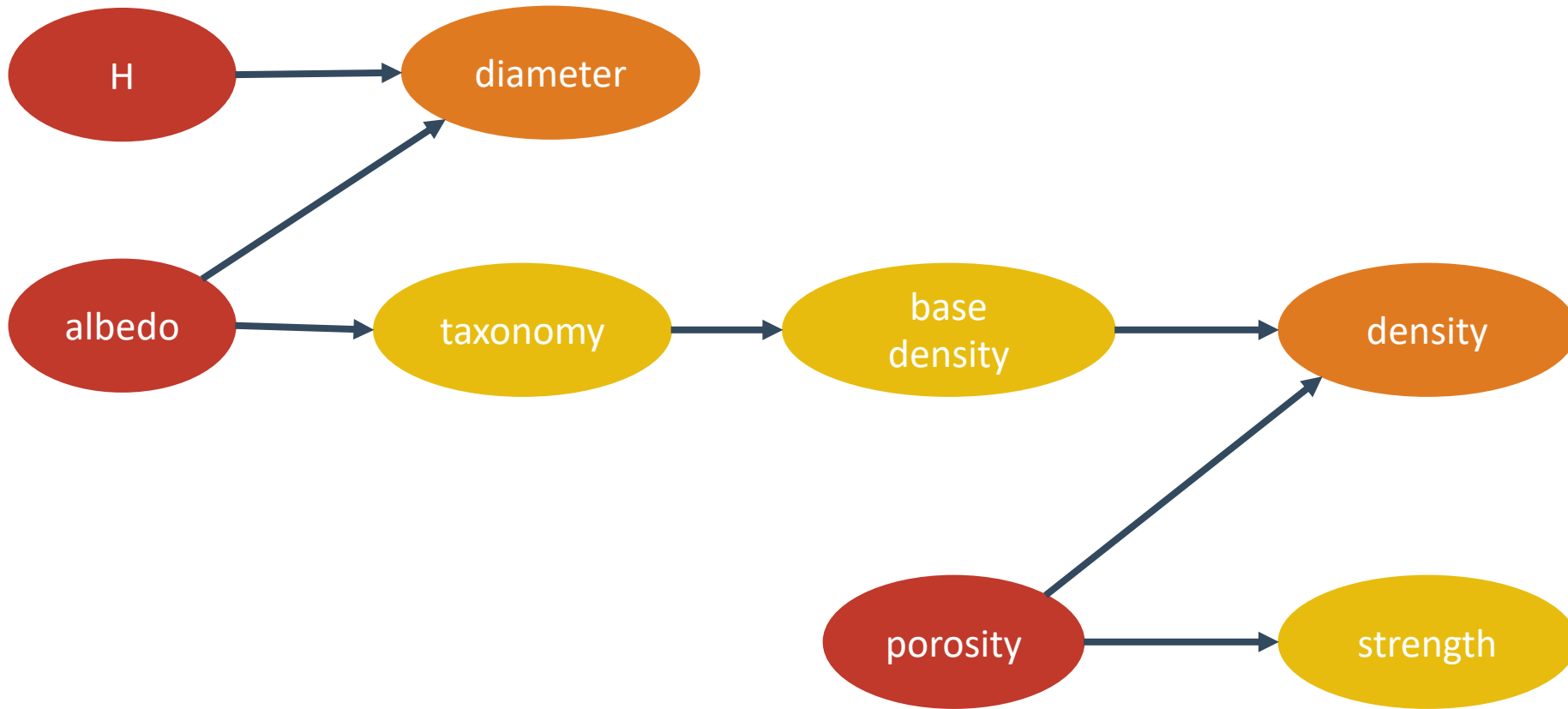
Calculated Properties



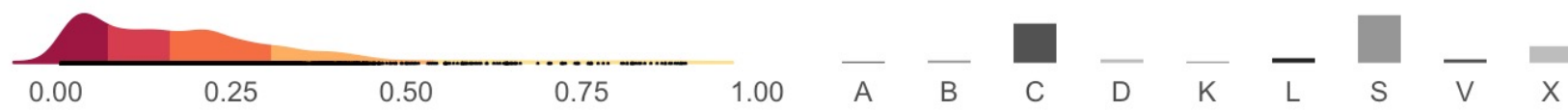
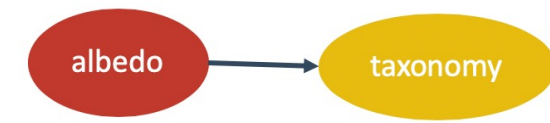
Inferred Properties



Asteroid Physical Property Inference Network



Taxonomy



Taxonomy is inferred from albedo via Bayes Theorem

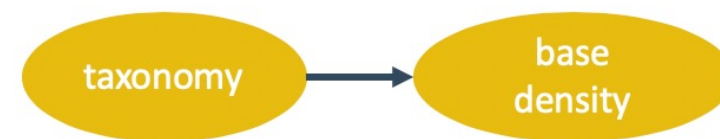
$$P(\text{taxonomy}|p_v) \sim P(p_v|\text{taxonomy}) * P(\text{taxonomy})$$

albedo distribution
for a specific taxonomy

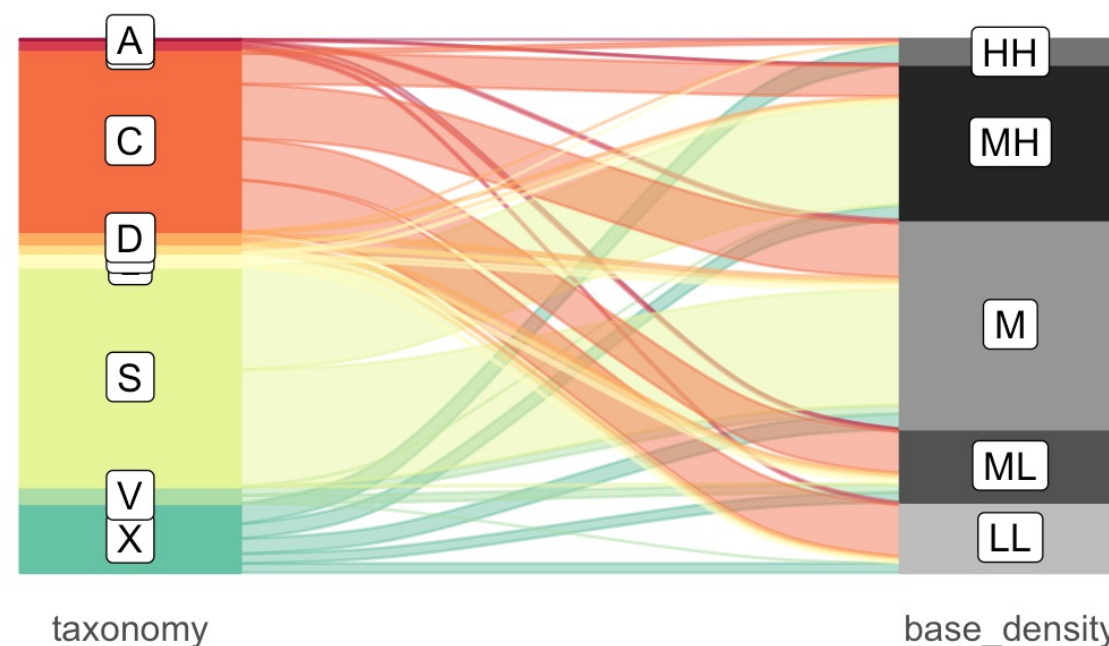
frequency of
taxonomy in the
population



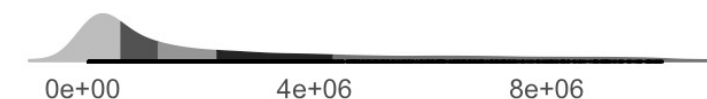
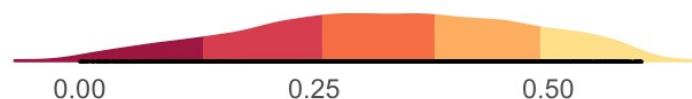
Base Density



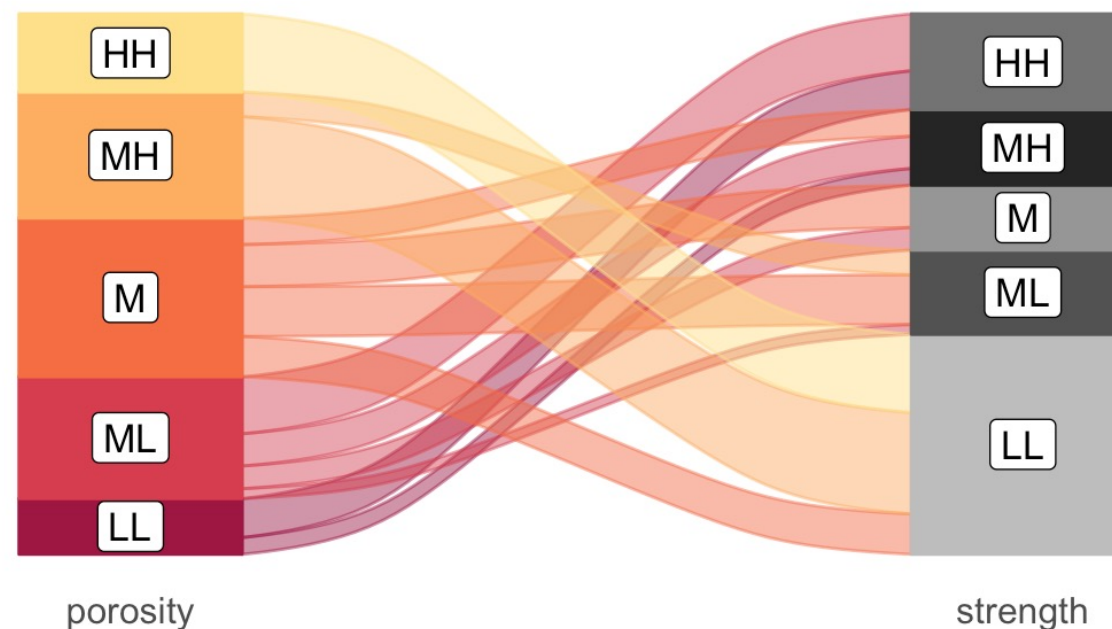
- A literature derived mapping was used to associate each taxonomy with related meteorites.
- Density measurements of meteorites were used to derive base density distributions for the associated taxonomy.
- Base densities were randomly selected from these distributions.



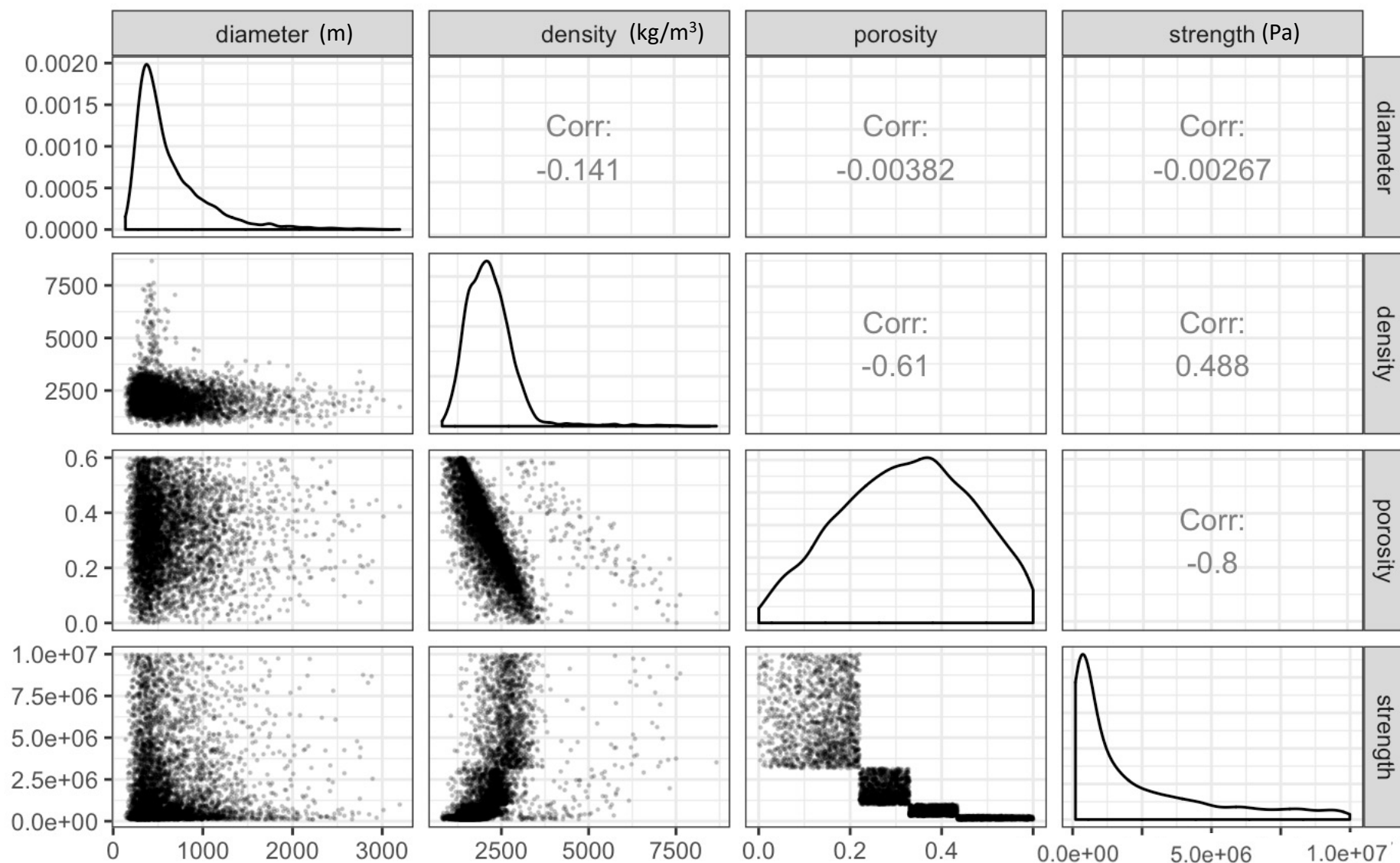
Aerodynamic Strength



- Strength values are selected from a uniform distribution in log space
- Virtual impactors in the lowest porosity quartile are randomly assigned a strength from the strongest quartile
- Other quartiles are mapped similarly



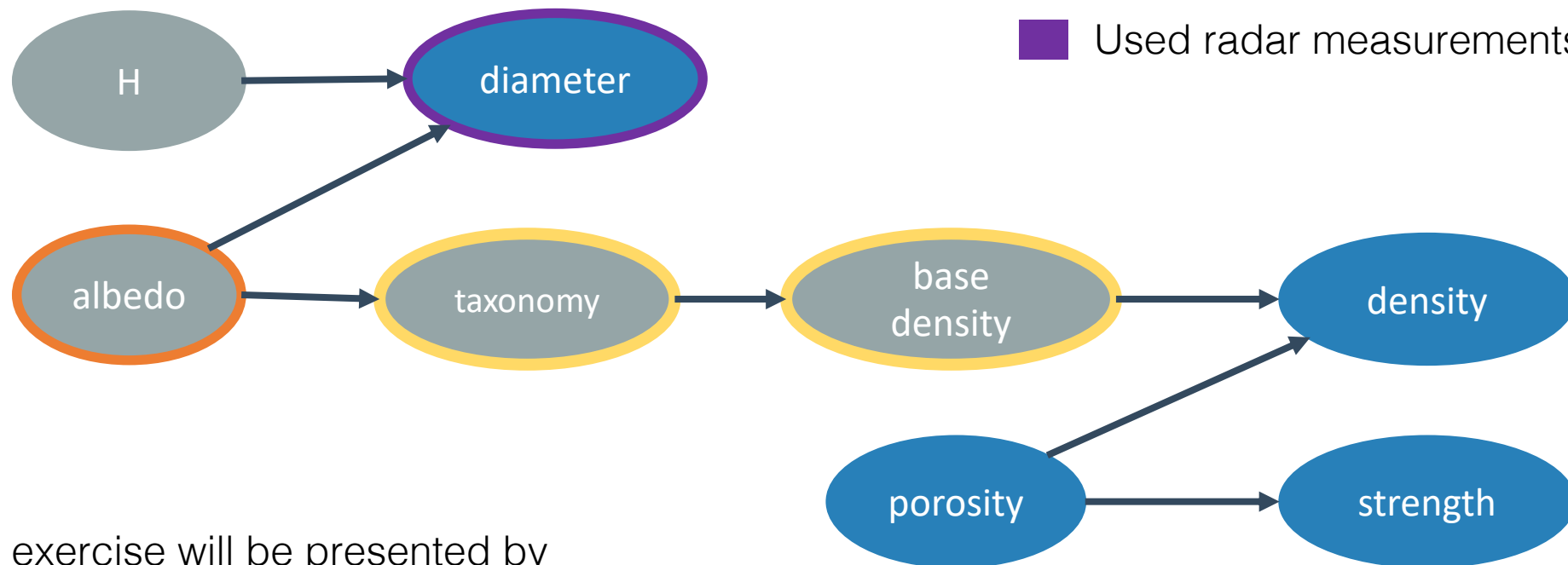
Asteroid Physical Property Risk Model Inputs



Characterization results can be incorporated into the inference network

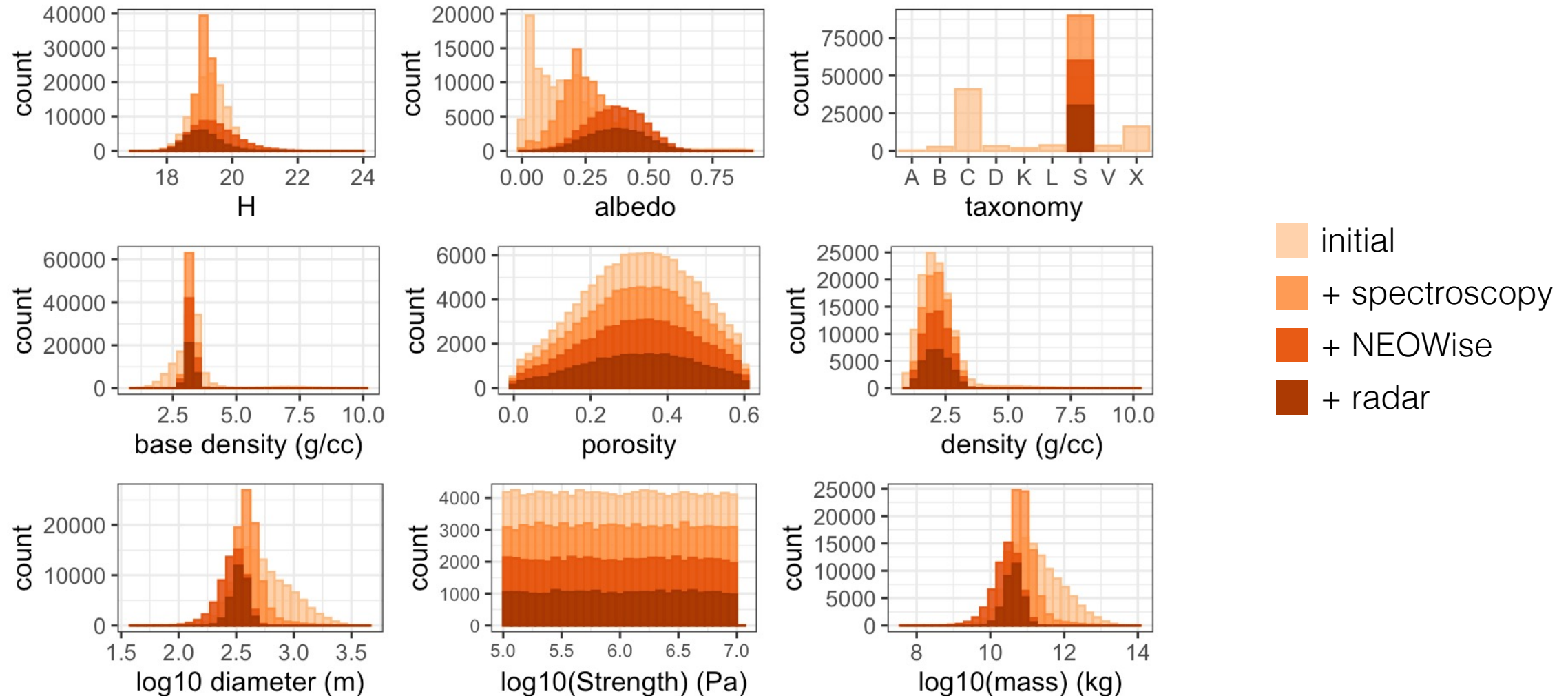
Apophis Exercise Example:

- Used spectroscopy results
- Used NEOWise measurements
- Used radar measurements

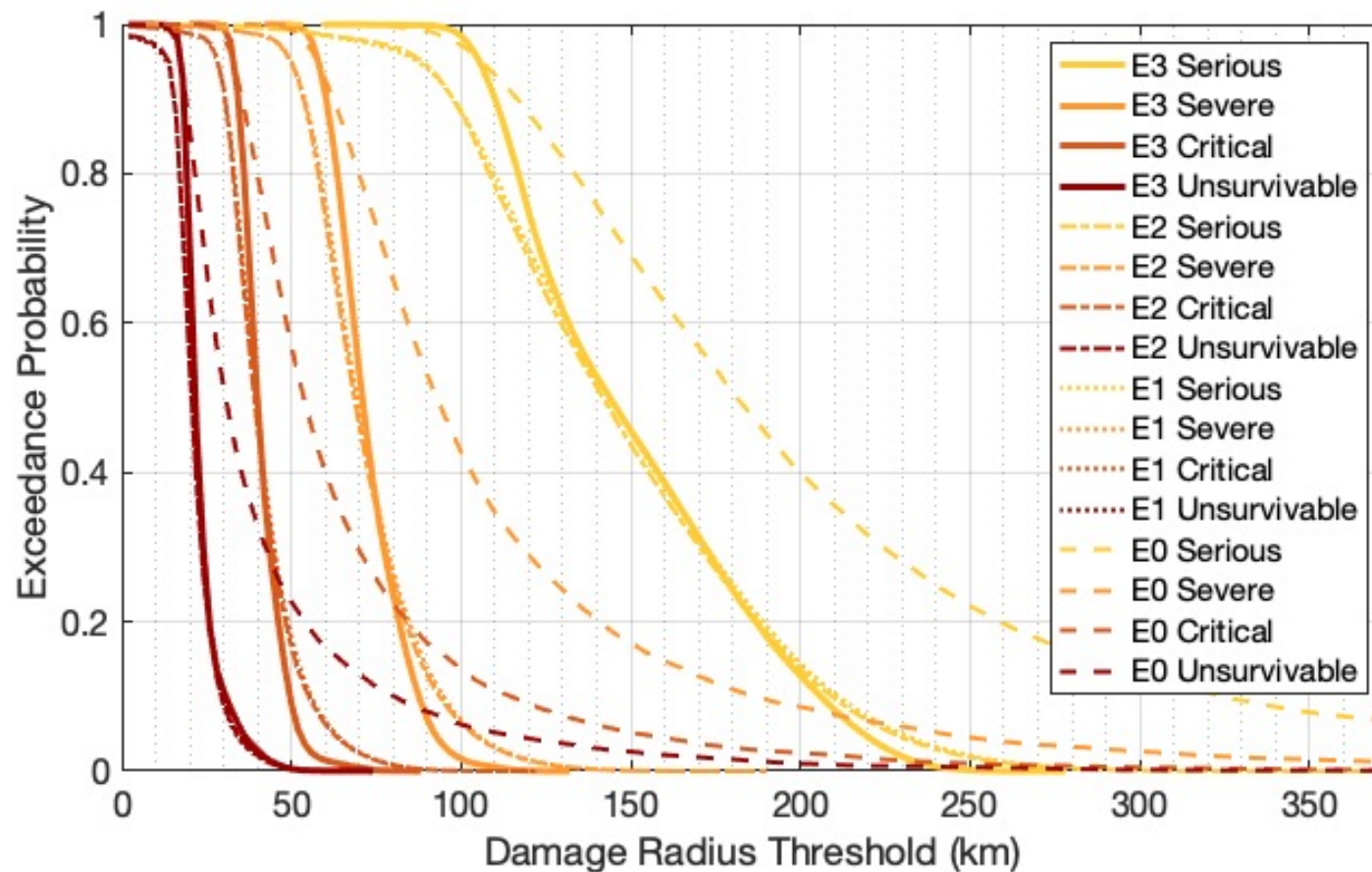


Apophis exercise will be presented by Kelley et al in session 13

Property distributions incorporate characterization observations



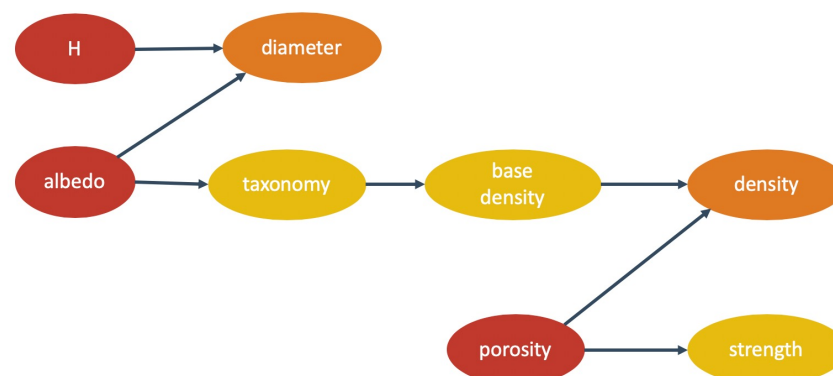
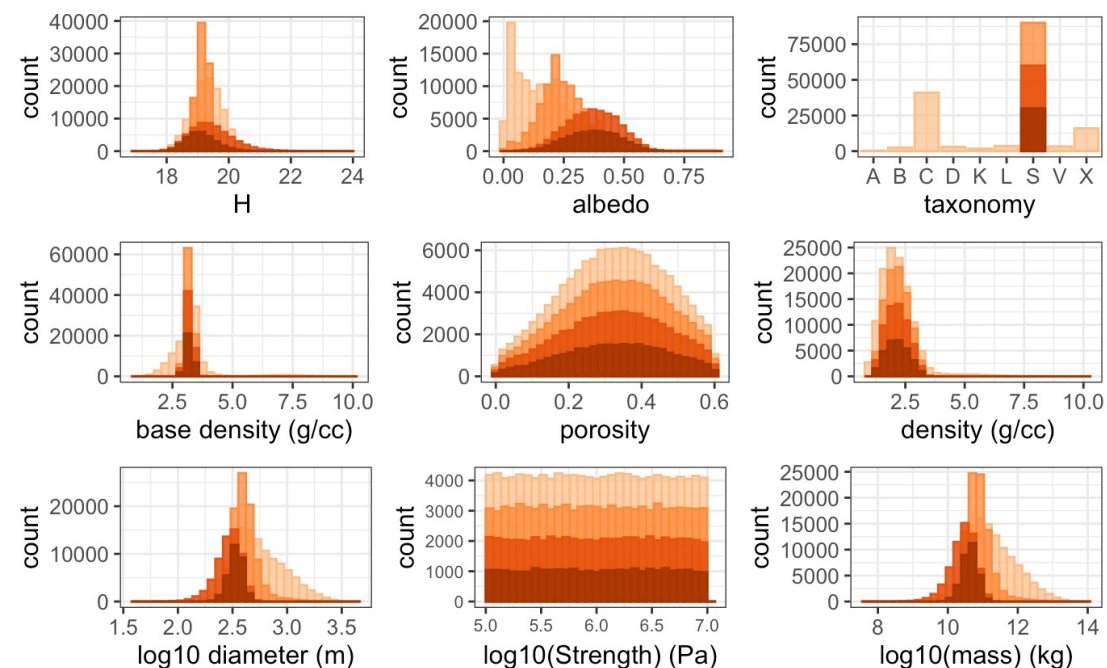
Local Damage Regions for different property sets



E0: initial
 E1: + NEOWise
 E2: + spectroscopy
 E3: + radar

Physical Property Inference in Planetary Defense Scenarios

- Inference network simulates virtual impactors such that the distribution of their physical properties and the combination of these values for any impactor are physically plausible.
- The inference network has been used to support a variety of planetary defense exercises. (e.g. PDC, Apophis campaign)
- Future work includes improving inference nodes and improving ability to incorporate observational results.



Meteorite Property References

Densities

Borovicka and Kalenda 2003; MaPS
Britt and Consolmagno 2003; MaPS
Britt and Consolmagno 2004; LPSC
Consolmagno and Britt 1998; MaPS
Hogan et al 2015; Icarus
Kohout et al 2014; Icarus
Li et al 2012; JGR
Macke 2010; Dissertation
Matsui et al 1980; Memoirs of National Institute of Polar Research
McCausland et al 2010; LPSC
McCausland et al 2007; MaPS
Opeil et al 2010; Icarus
Szurgot et al 2014; MetSoc
Wood 1963; The Solar System Vol. 4

Asteroid Property References

Mainzer et al 2016; NASA Planetary Data System
Carry 2012; PS&S

Asteroid to Meteorite Association References

Burbine et al 2002; Asteroids III
Burbine 2016; LPSC
DeMeo et al 2015; Asteroids IV
de Leon et al 2012; Icarus
Weisberg et al 1996; Geochemica et Cosmochimica Acta