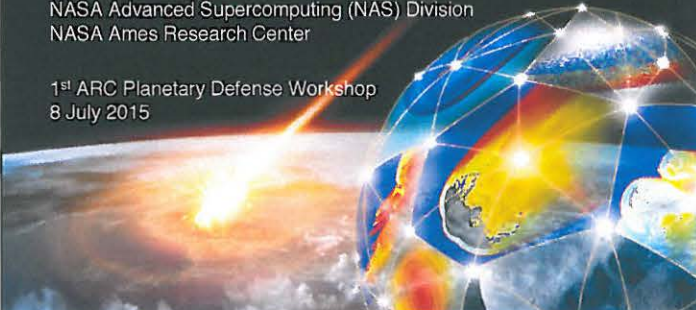



## Sensitivity to Uncertainty in Planetary Defense Risk Assessment

Donovan Mathias  
 NASA Advanced Supercomputing (NAS) Division  
 NASA Ames Research Center


1<sup>st</sup> ARC Planetary Defense Workshop  
 8 July 2015

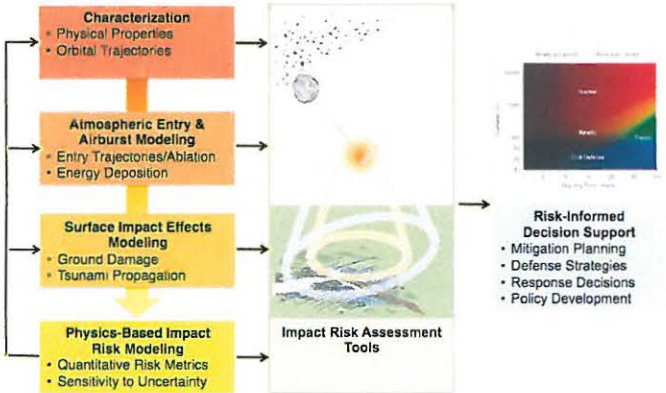
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## Tasks, Products, and Interactions



**Characterization**

- Physical Properties
- Orbital Trajectories

**Atmospheric Entry & Airburst Modeling**

- Entry Trajectories/Ablation
- Energy Deposition

**Surface Impact Effects Modeling**

- Ground Damage
- Tsunami Propagation

**Physics-Based Impact Risk Modeling**

- Quantitative Risk Metrics
- Sensitivity to Uncertainty


**Impact Risk Assessment Tools**

**Risk-Informed Decision Support**

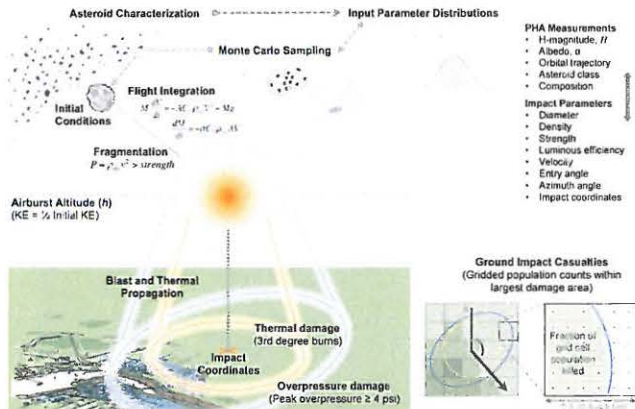
- Mitigation Planning
- Defense Strategies
- Response Decisions
- Policy Development

Credit: Tim Warchocki

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## Physics-Based Impact Risk Model



**Asteroid Characterization** → **Input Parameter Distributions**

**Initial Conditions** → **Flight Integration** → **Fragmentation**

$\dot{M} = -\dot{M} \rho_a v^3 - M \rho_a v^3$   
 $\dot{M} = -\dot{M} \rho_a v^3$

**Fragmentation**  
 $P = \rho_a v^3 > \text{strength}$

**Airburst Altitude (h)**  
 $(KE = \frac{1}{2} \text{Initial KE})$

**Ground Impact Casualties**  
 (Gridded population counts within largest damage area)

**Impact Parameters**

- Diameter
- Density
- Strength
- Luminous efficiency
- Velocity
- Entry angle
- Azimuth angle
- Impact coordinates

**PHA Measurements**

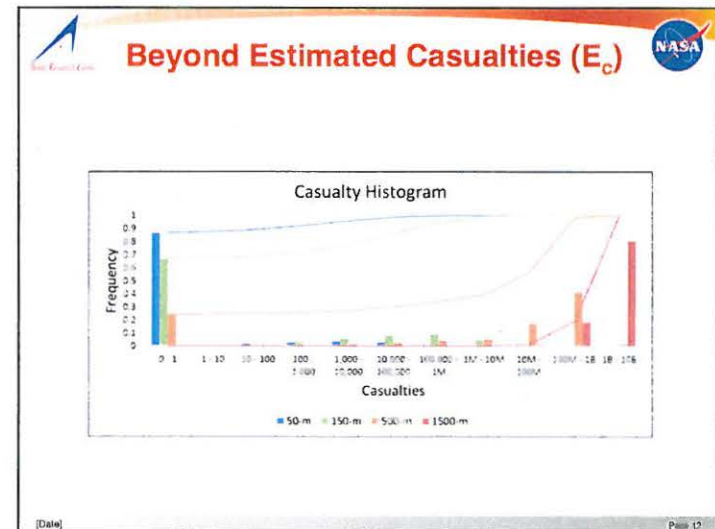
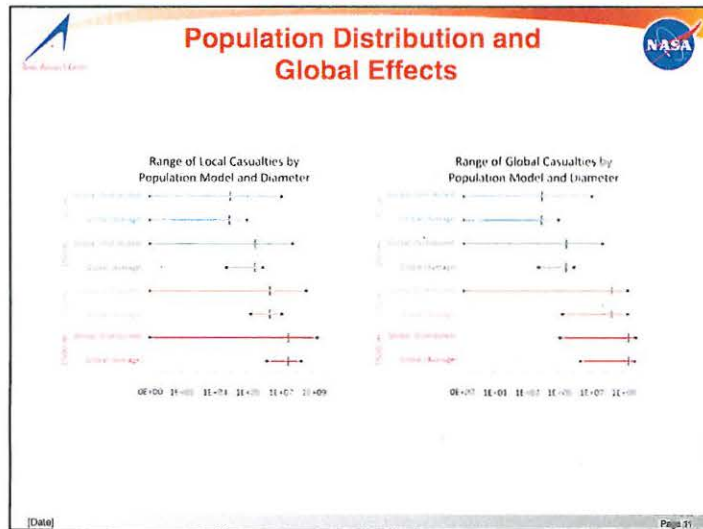
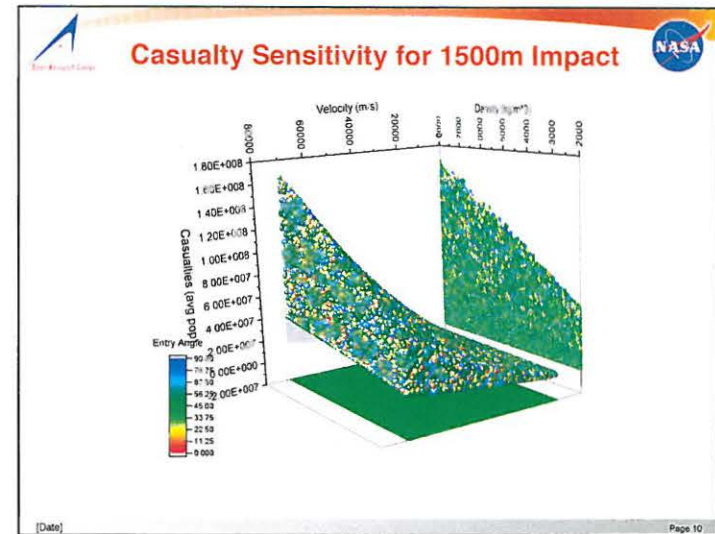
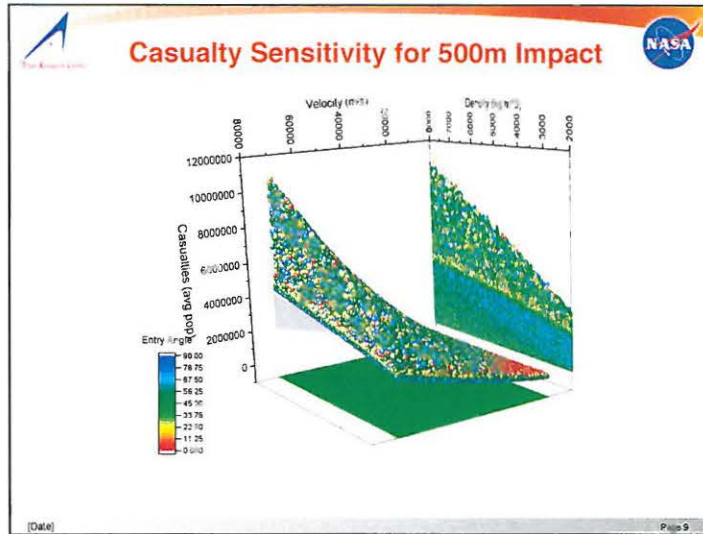
- H-magnitude,  $H$
- Albedo,  $a$
- Orbital trajectory
- Asteroid class
- Composition

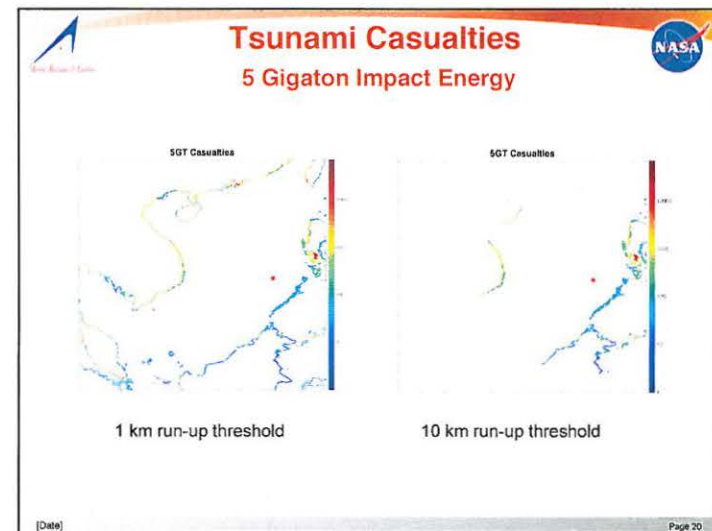
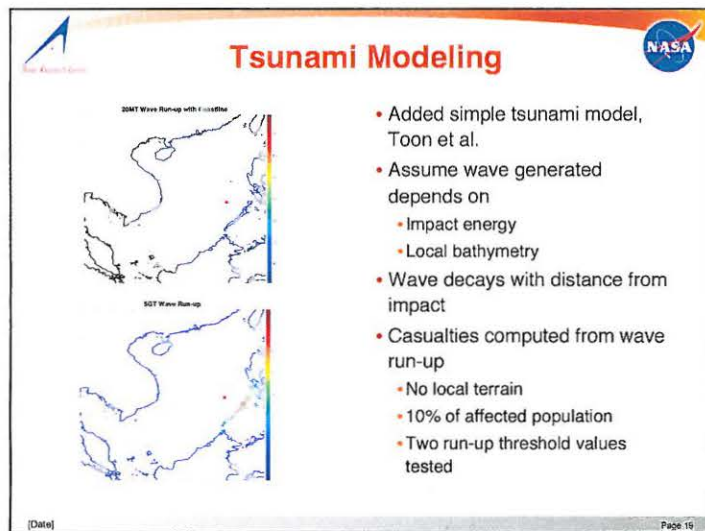
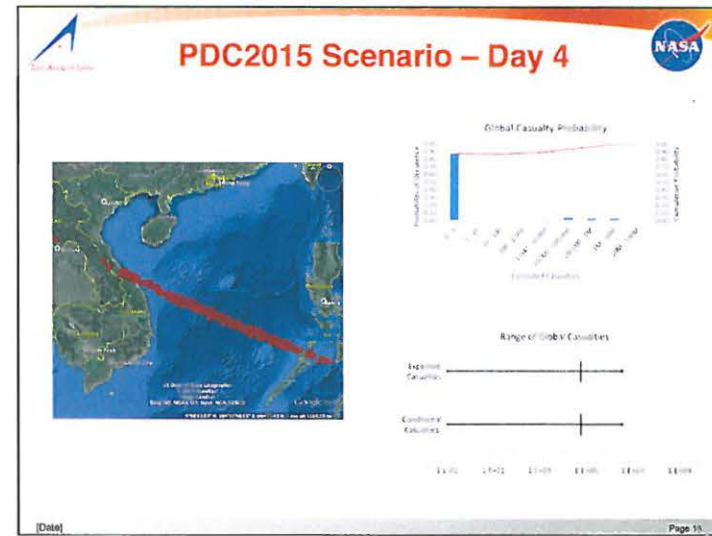
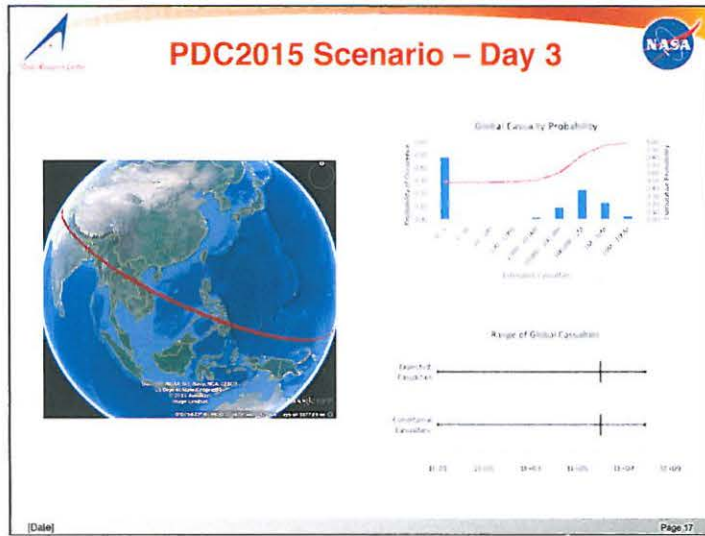
**Blast and Thermal Propagation**

- Thermal damage (3rd degree burns)
- Overpressure damage (Peak overpressure  $\geq 4$  psi)

Fraction of ground population killed

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### Example 3: Problem Overview

- Goal
  - Assess inherent assumptions with literature airburst models
- Task scope
  - Define single, fixed-parameter impact scenario
  - Compare literature model results with those anchored in high-fidelity simulations?
- Questions
  - Are traditional meteoroid physics models sufficient for energy deposition prediction?
    - Ablation
    - Pancaking
    - Point-source airburst
  - How sensitive are ground damage estimates to these assumptions?

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### Demonstration Case

- Test case parameters
  - Size = 20 m diameter
  - Density = 3 g/cc
- Flight path integration based on assumed initial state
  - 20 km/s
  - 20° entry angle
- Mass loss computed using high-fidelity simulation-generated relations
- Progressive fragmentation model used for breakup and energy deposition curve
- Blast footprint from spherical point source + CFD corrections
- Results compared with Chelyabinsk damage

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### Simulation Elements

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### Results

100 meters, 90 degrees

Ground Footprint

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