

5 megaton asteroid explodes 12 km above surface: frames are every half second

## FEMA asteroid impact tabletop exercise simulations

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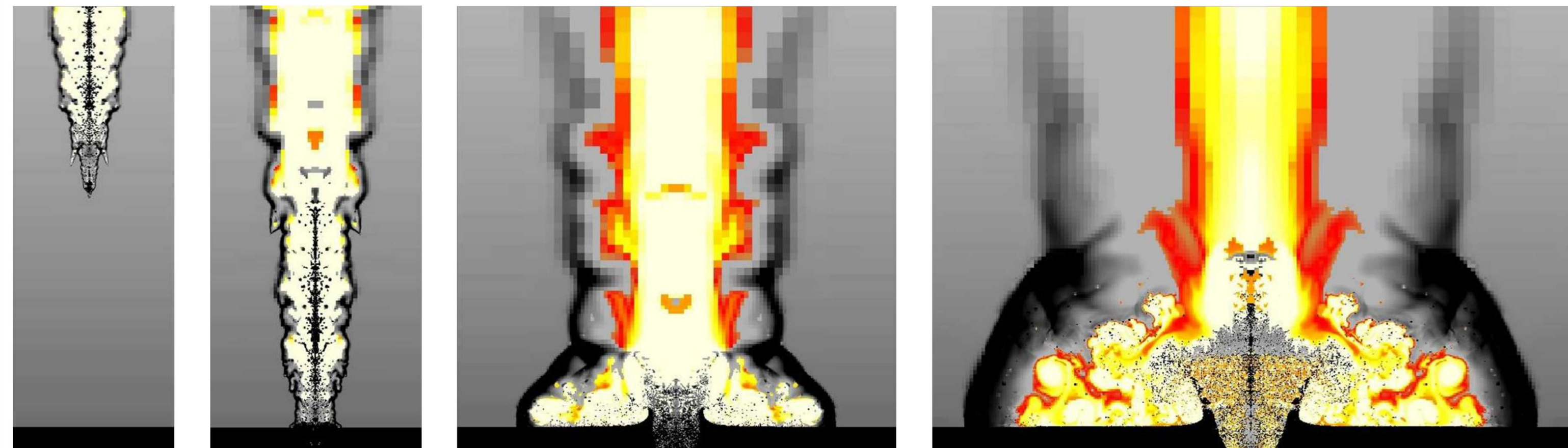
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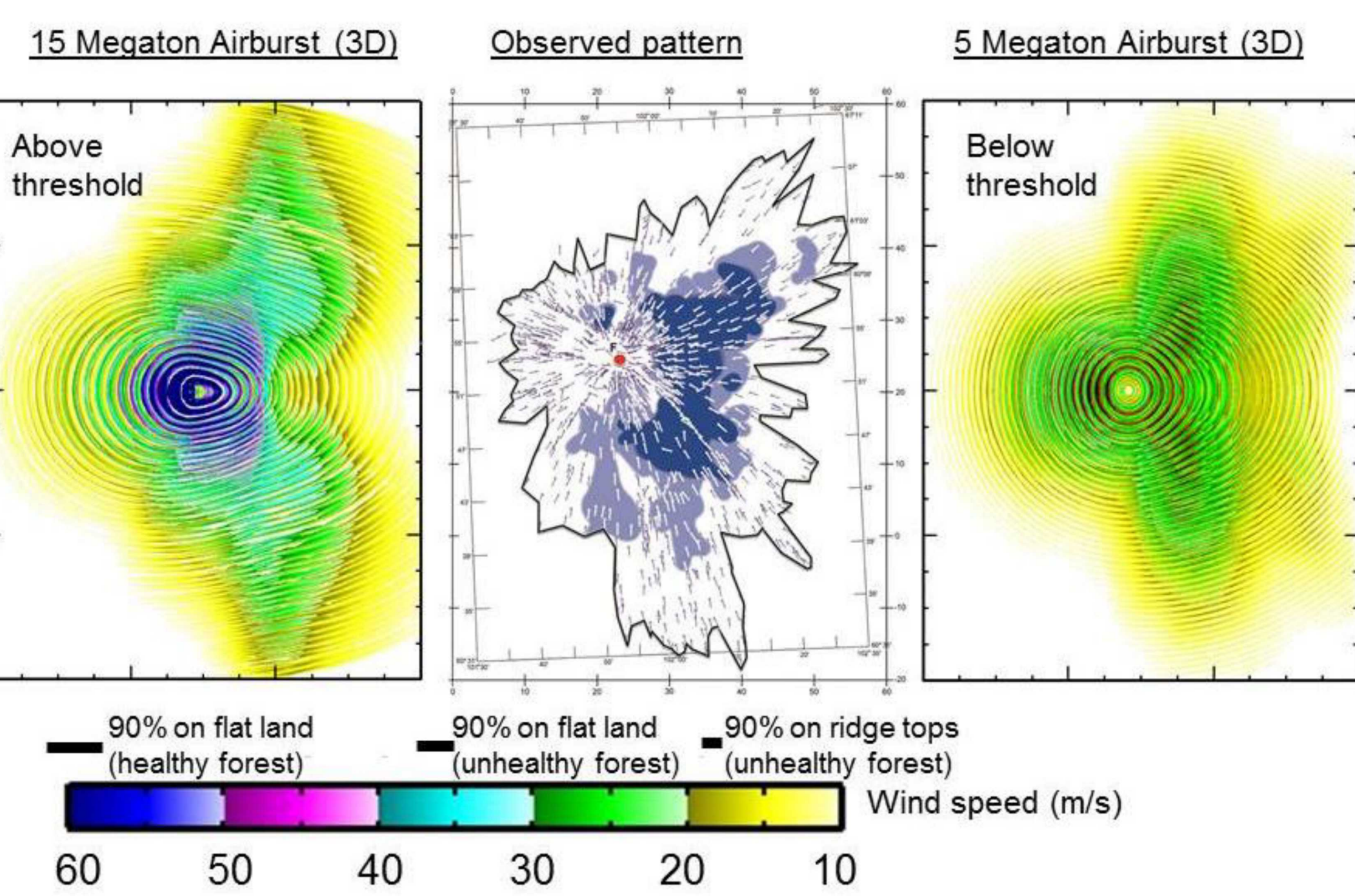
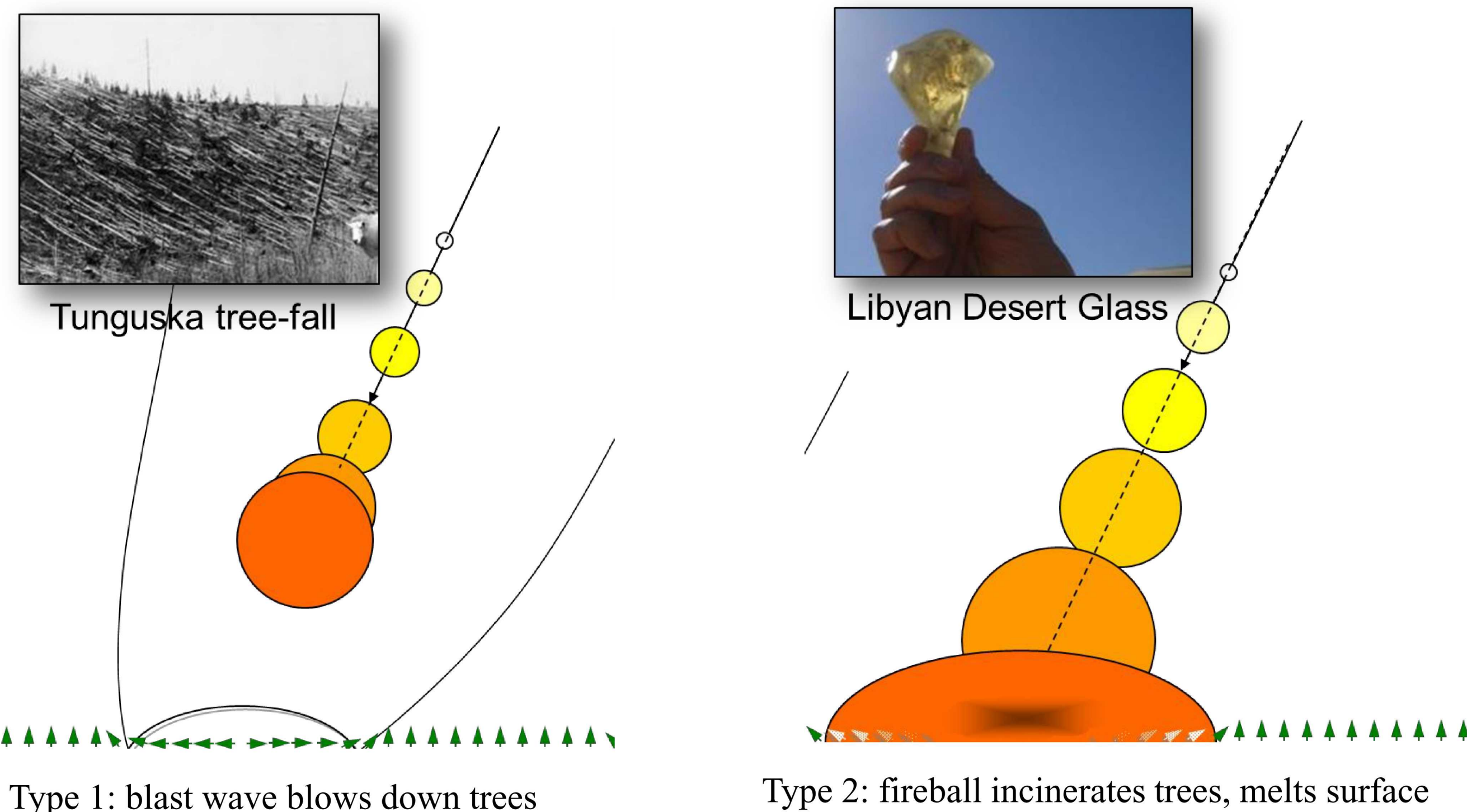
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We describe the computational simulations and damage assessments that we provided in support of a tabletop exercise (TTX) at the request of NASA's Near-Earth Objects Program Office. The overall purpose of the exercise was to assess leadership reactions, information requirements, and emergency management responses to a hypothetical asteroid impact with Earth. The scripted exercise consisted of discovery, tracking, and characterization of a hypothetical asteroid; inclusive of mission planning, mitigation, response, impact to population, infrastructure and GDP, and explicit quantification of uncertainty. Participants at the meeting included representatives of NASA, Department of Defense, Department of State, Department of Homeland Security/Federal Emergency Management Agency (FEMA), and the White House. The exercise took place at FEMA headquarters. Sandia's role was to assist the Jet Propulsion Laboratory (JPL) in developing the impact scenario, to predict the physical effects of the impact, and to forecast the infrastructure and economic losses. We ran simulations using Sandia's CTH hydrocode to estimate physical effects on the ground, and to produce contour maps indicating damage assessments that could be used as input for the infrastructure and economic models. We used the FASTMap tool to provide estimates of infrastructure damage over the affected area, and the REAcct tool to estimate the potential economic severity expressed as changes to GDP (by nation, region, or sector) due to damage and short-term business interruptions.

### Airburst Physics



Simulations suggest that airbursts couple more energy to the ground than nuclear explosions of the same yield



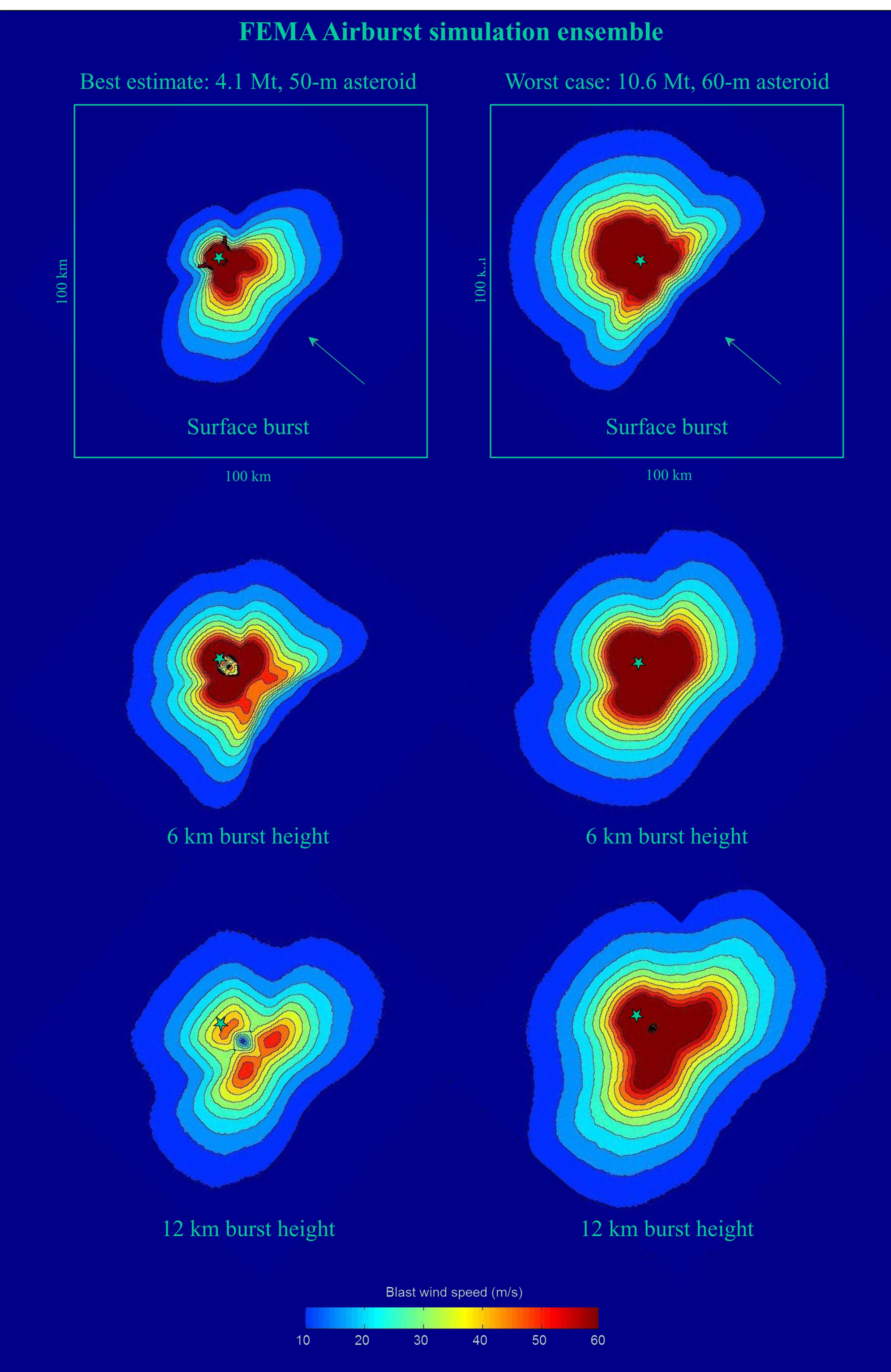
Pattern of tree fall at Tunguska is consistent with 3-5 megaton airburst and provides observational "validation"

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

### The 2014 FEMA Scenario

*"The Federal Emergency Management Agency has activated the National Response Coordination Center to prepare for an imminent and certain large scale catastrophic event which will affect Texas, neighboring states, and possibly nations bordering the Gulf of Mexico. The catastrophic event will occur at approximately noon local time on September 5, 2021 and will be caused by impact of an asteroid estimated to be about 50 meters (~160 ft.) in size. Details of what is currently known about the threat and of our past efforts to deflect the object are included in this package. This disaster will be unprecedented in recorded times and will seriously affect our nation's oil refining and other major industries, as well as the lives and property of many of our citizens. The President has directed FEMA to lead the response effort and be prepared to execute with state and local officials plans to minimize/mitigate these effects."*

Information was revealed to the participants as a series of discrete "injects" in which there was prescribed uncertainty in the size of the object and its point of impact. Information based on realistic orbital dynamics was provided to our group by Paul Chodas of JPL. We treated this information as our input and announced it to the participants as "what we have been told." We used it to estimate the worst-case physical effects, which in turn became the input to infrastructure and economic consequence analysis.



We ran an ensemble of CTH simulations in which asteroid size, kinetic energy, and height of burst were prescribed. The patterns of maximum wind speed at ground level were plotted as contour maps and used to generate damage maps. The stars are located at the point where the impact would take place in the absence of an atmosphere. The asteroid is approaching from the southeast (arrows). In reality, wind speed (and resulting dynamic pressure) are not the only damage mechanism.

### First Inject: 30 days before impact

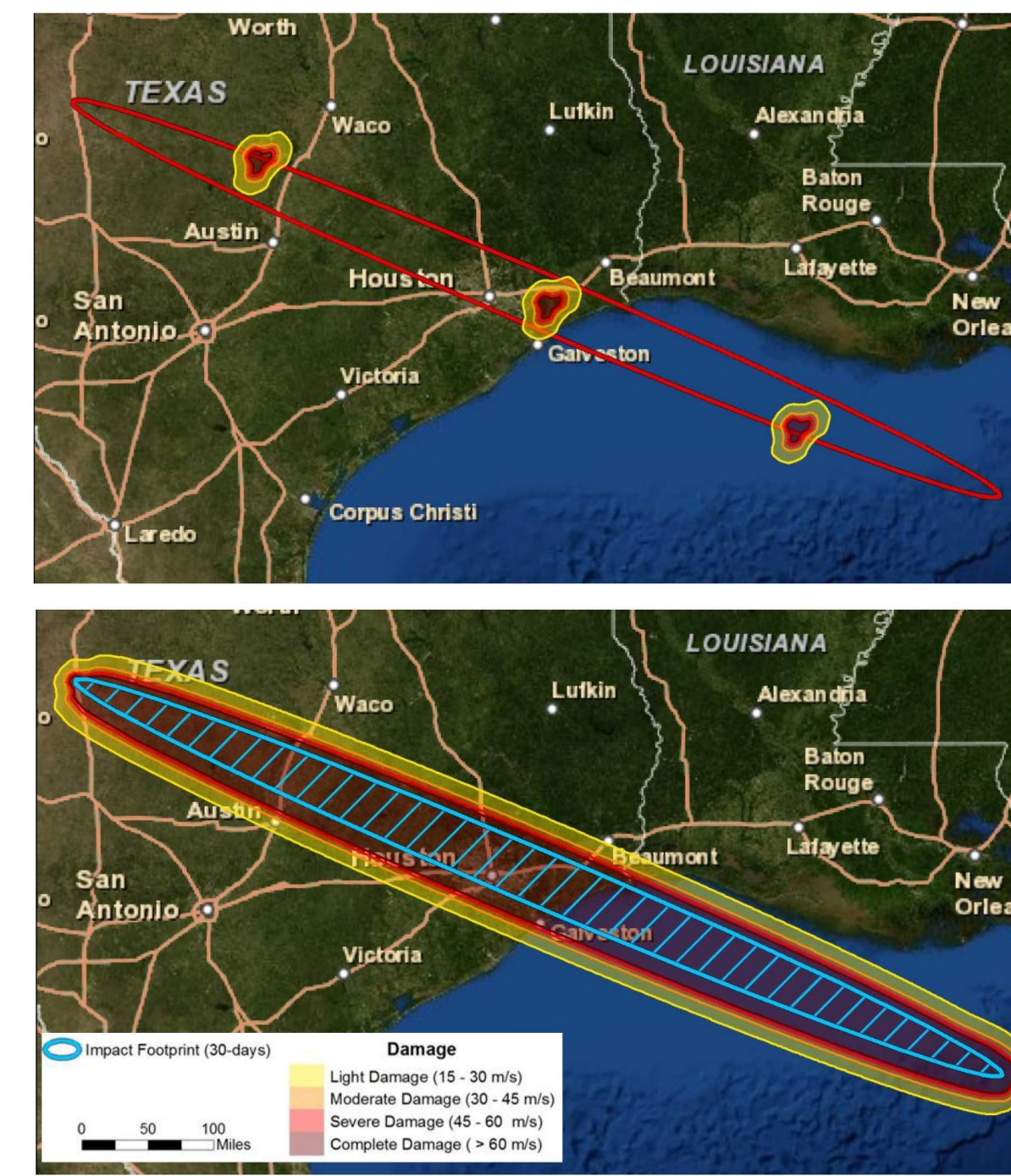
Input: What we have been told

- Entry speed: 15.4 km/s
- Size: 40-60 meters diameter
- Composition: Stone, density 2.2-3.3 g/cm<sup>3</sup>
- Entry angle: 39.5° from horizontal
- 10.6 Mt airburst or impact cannot be ruled out

Input: Uncertainty in impact location

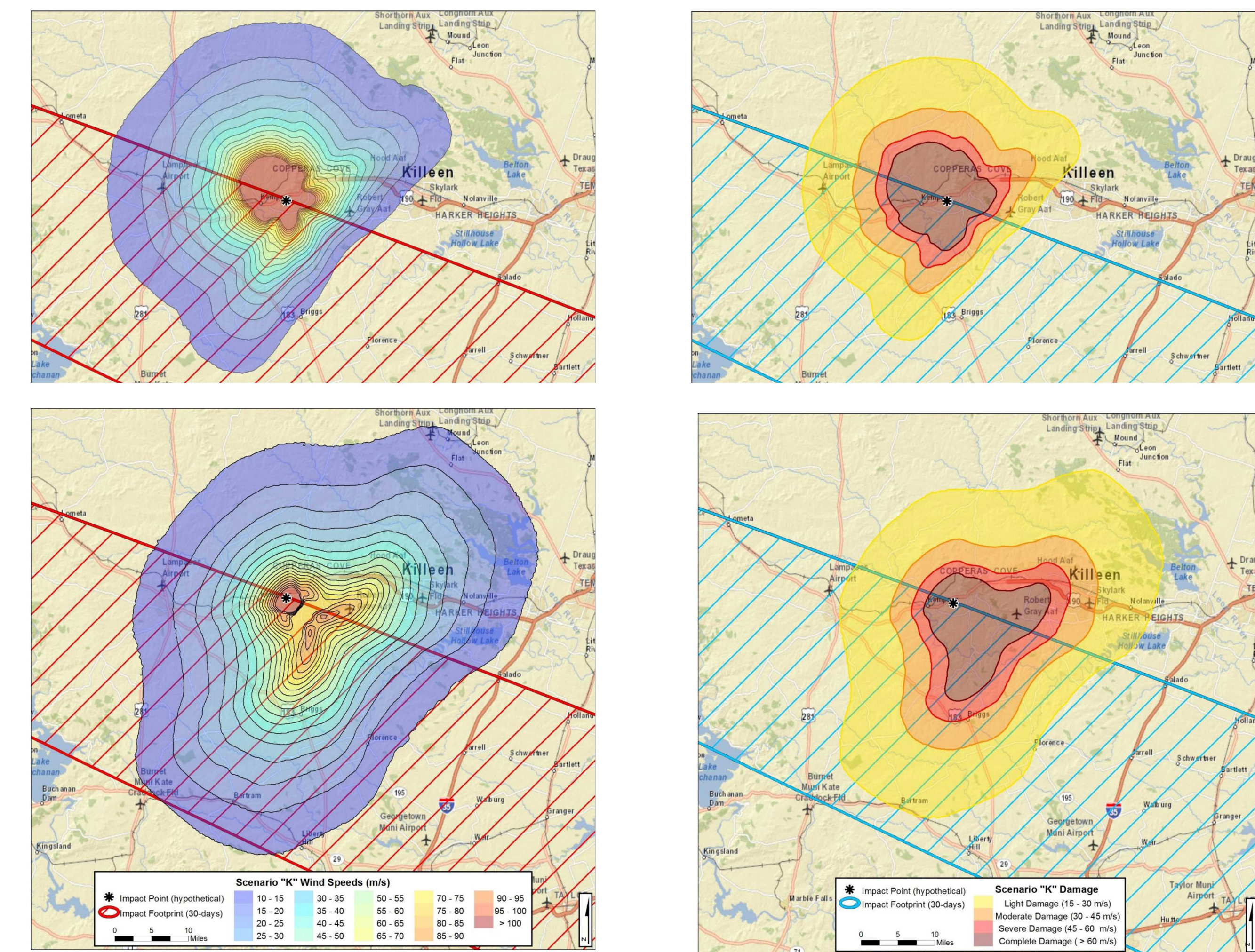


Output: Damage maps

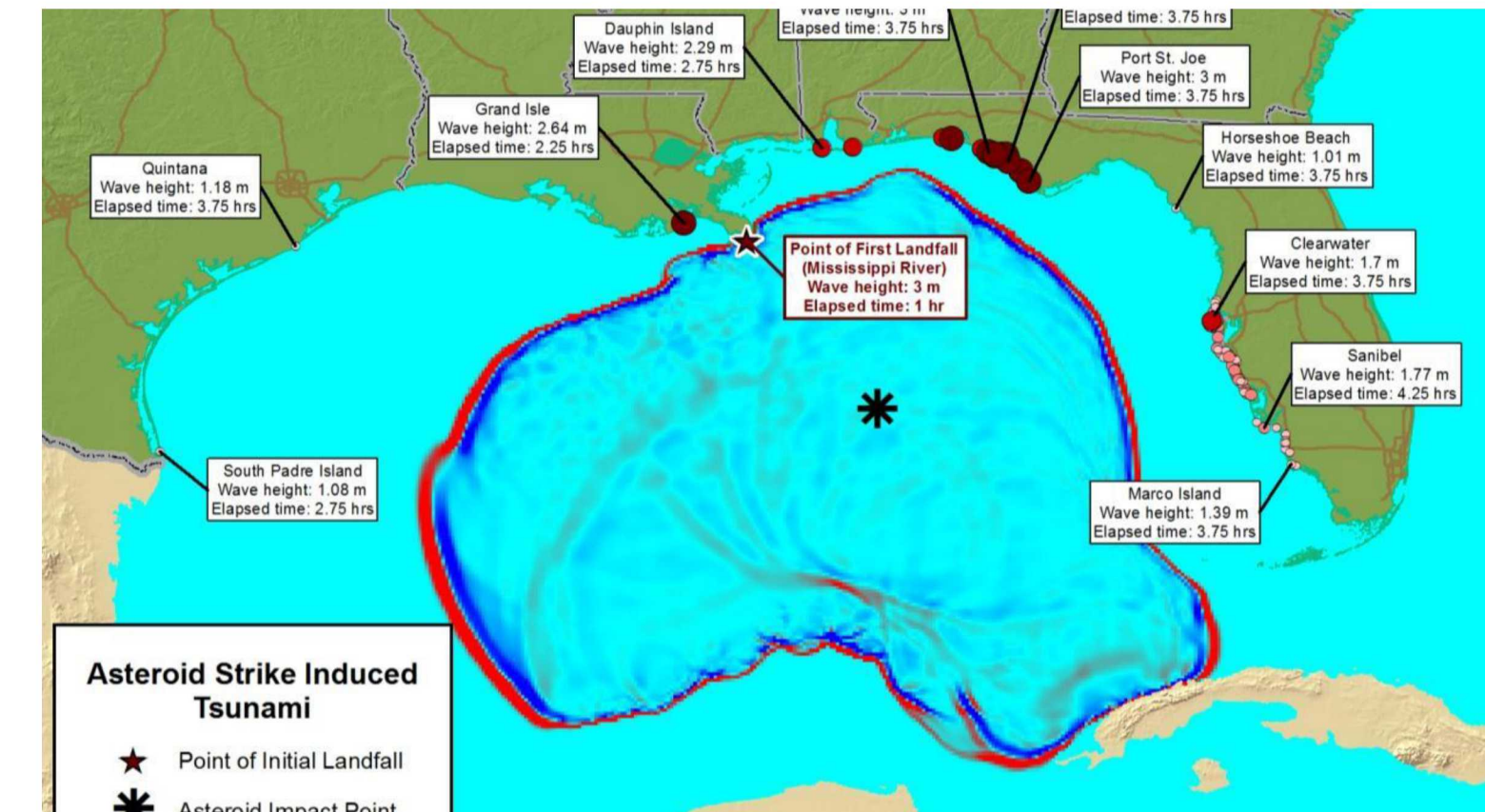


Upper: discrete map showing possible footprints. Lower: Composite map showing worst possible damage at any location.

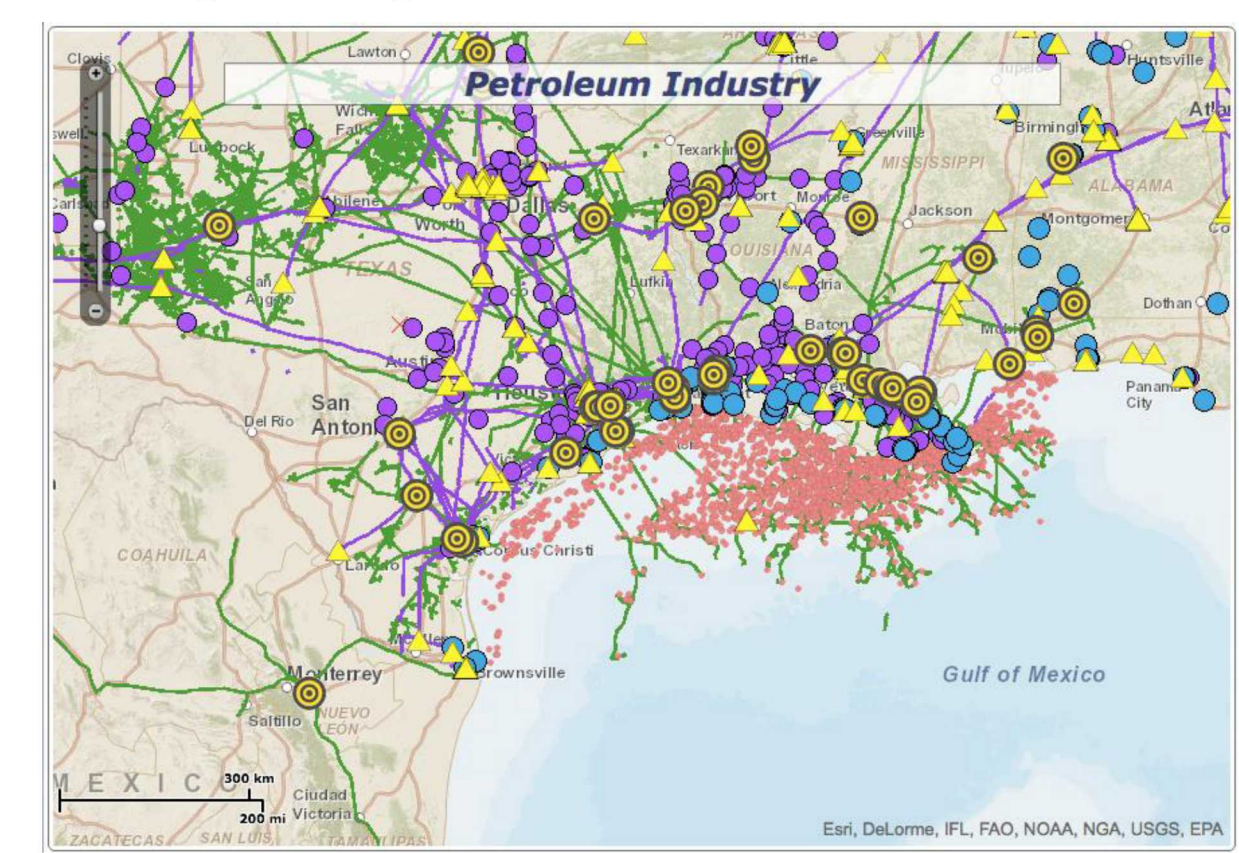
Output: Worst-case airburst wind speed and damage predictions for various possible impact locations



Output: Tsunami prediction (Souheil Ezzedine, LLNL)



Output: maps of infrastructure at risk

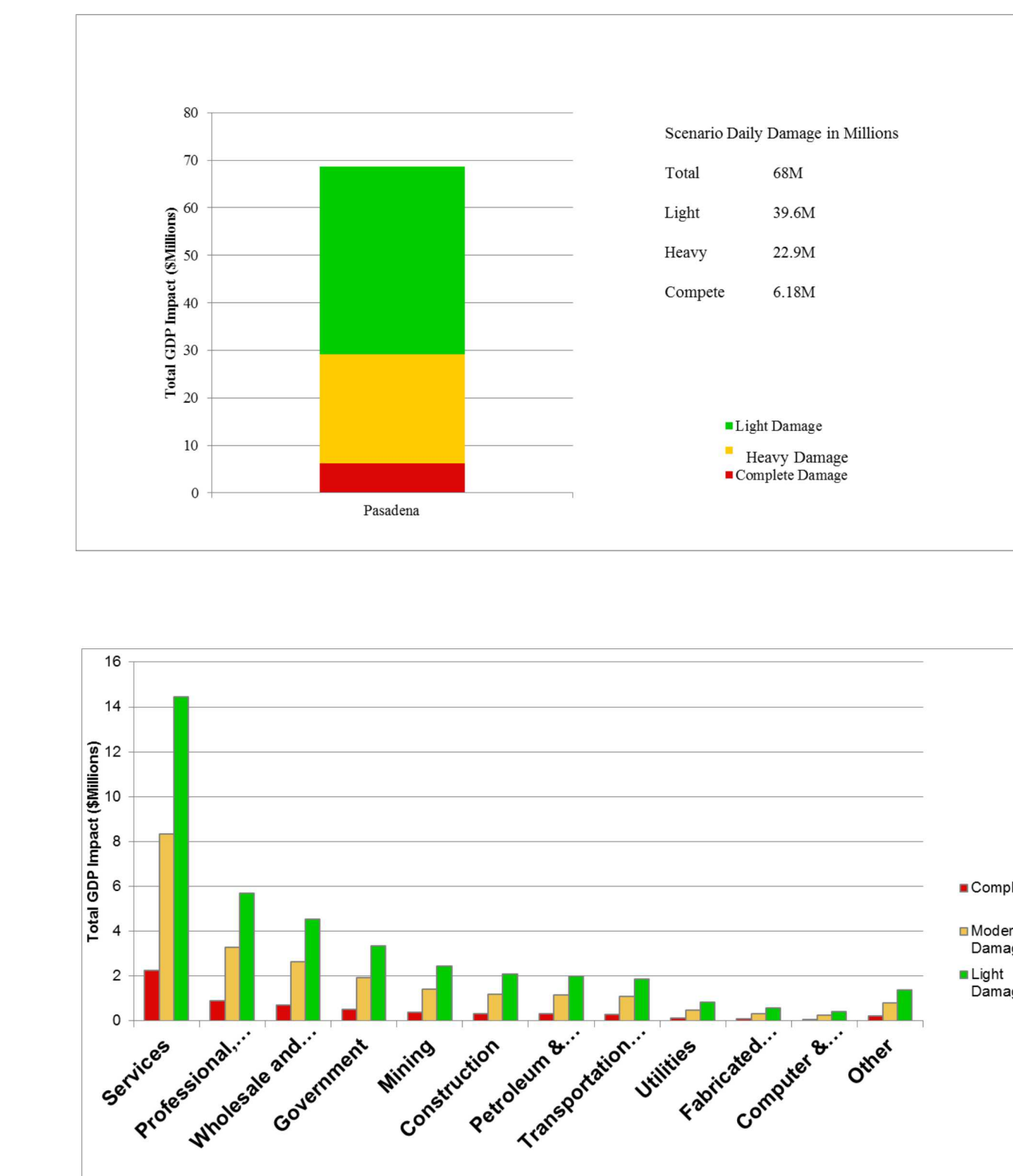


### Second Inject: 6 days before impact

Input: What we have been told:

- Entry speed: 15.4 km/s
- Size: 50 meters diameter
- Composition: Stone, density 2.2 g/cm<sup>3</sup>
- Entry angle: 39.5° from horizontal
- ~4.1 Mt airburst or impact cannot be ruled out

Output: economic consequences



Output: Discrete and composite damage maps for evacuation and disaster management

