



SAND2013-2928C



**Sandia National Laboratories**

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### Simulation and Modeling of the Effects of an Impact of a Near Earth Object

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# Background

- The Cascadia Subduction Zone extends north and south more than 800 miles on the eastern edge of the Pacific Plate
- The Tohoku event off the coast of Japan resulted from an earthquake on the subduction zone on the western edge of the Pacific Plate
- In 1700 the Pacific Northwest experienced an earthquake and tsunami that rivals the recent incident off of the coast of Japan
- A catastrophic earthquake of this magnitude along the coast of Oregon and Washington is estimated to occur every 500 years and would impact the US from Northern California to Alaska
- In 2011, NISAC performed a study of the potential impacts of such an event on population, infrastructure, and the economy on behalf of DHS





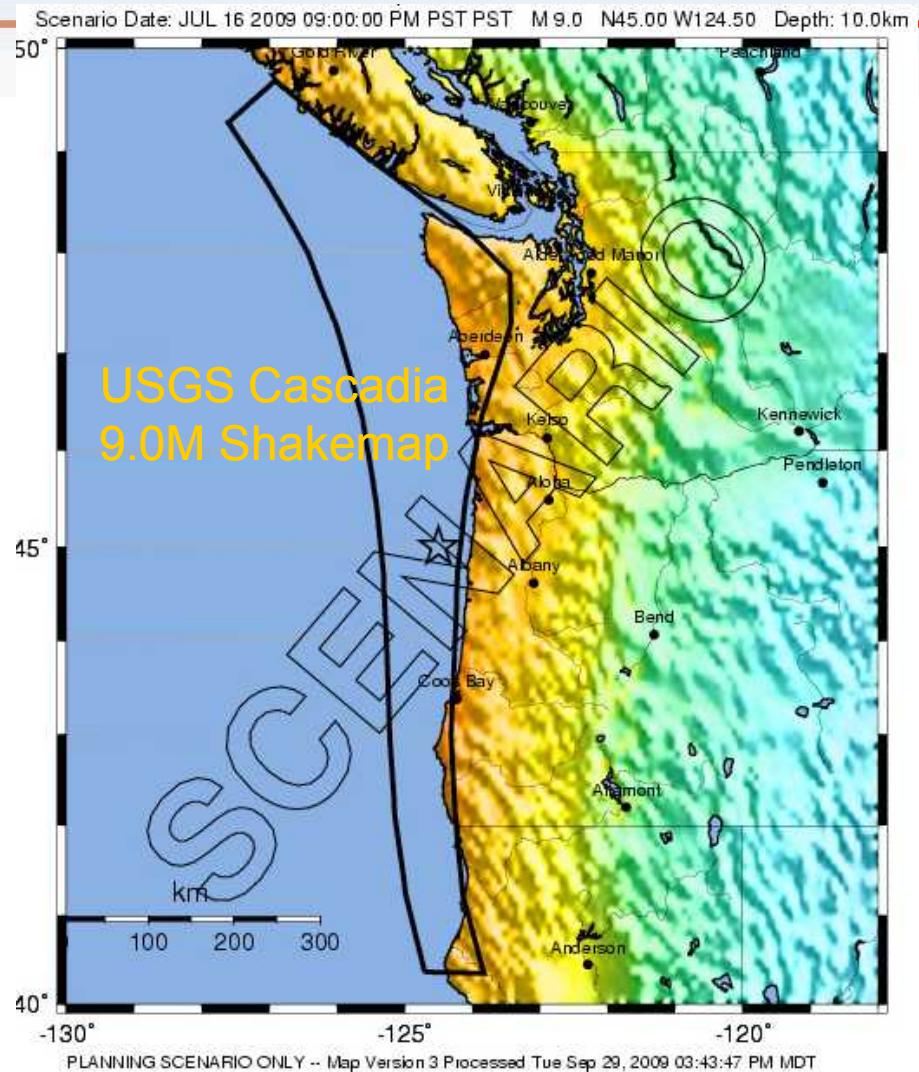
# Overview of the Analytic Approach

- A US Geological Survey 9.0 Magnitude ShakeMap (2009) was used to drive the earthquake impacts
- The NOAA Pacifex 11 Tsunami exercise run were employed to provide a basis for the offshore wave heights
- Both the direct earthquake impacts and the surge zones were used to assess the impacts:
  - Impacts on population
  - Direct impacts on infrastructure
  - Cascading impacts on infrastructure
  - Economic effects



# The Earthquake Scenario

- ShakeMap is a USGS rapid response tool to portray the extent, intensity, and variation of ground shaking in an affected region
- Scenario affects Oregon, Washington, Northern California, and British Columbia
- Resulting tsunami affects the entire Pacific shoreline, including Alaska
- Assume single major tremor 9.0M
  - No significant aftershocks
  - No additional earthquakes triggered along secondary faults





# Results: Impacts on Population

- **Ground Shaking Population Impacts**

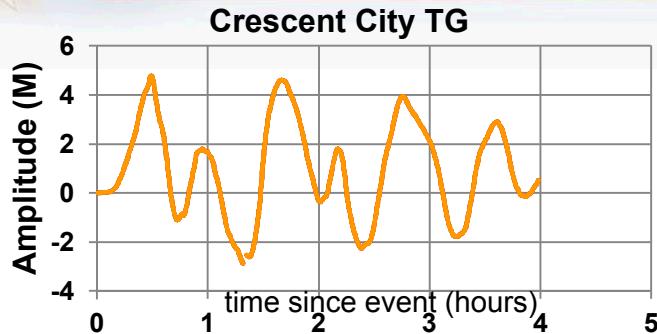
<b>State</b>	<b>Fatalities</b>	<b>Injuries</b>	<b>Comments</b>
• CA	751	774	primarily in Crescent City
• OR	52	190	most in Cannon Beach
• WA	540	1,151	most in Westport

- **Tsunami Population Impacts (for modeled sites only)**

<b>State</b>	<b>Fatalities</b>	<b>Injuries</b>	<b>Comments</b>
• CA	47	1,045	
• OR	674	14,109	Coos County hardest hit in OR
• WA	411	9,508	King County hardest hit overall

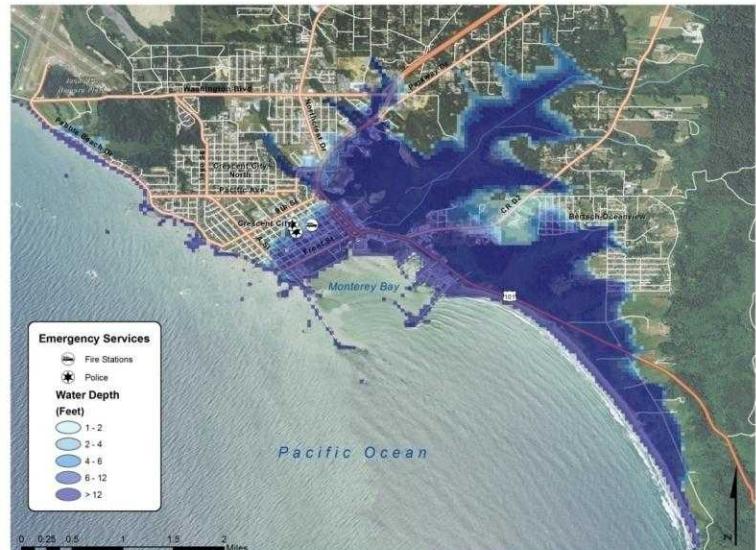
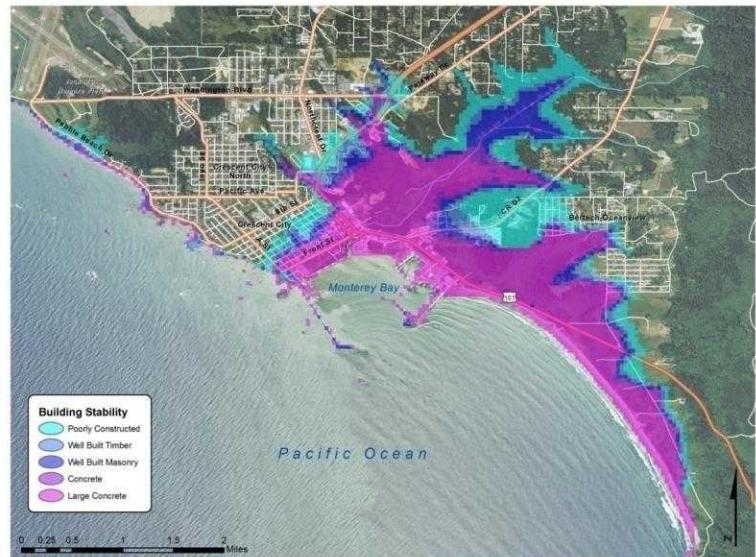


# Results: Tsunami Damage



Marigram

- **Damage state described via**
  - Building Stability map
  - Flood inundation map
- **Building Stability**
  - 5 zones described: Poorly Constructed, Well Built Timber, Well Built Masonry, Concrete, Large Concrete
- **Max inundation depth**
- **Deaths and injuries**

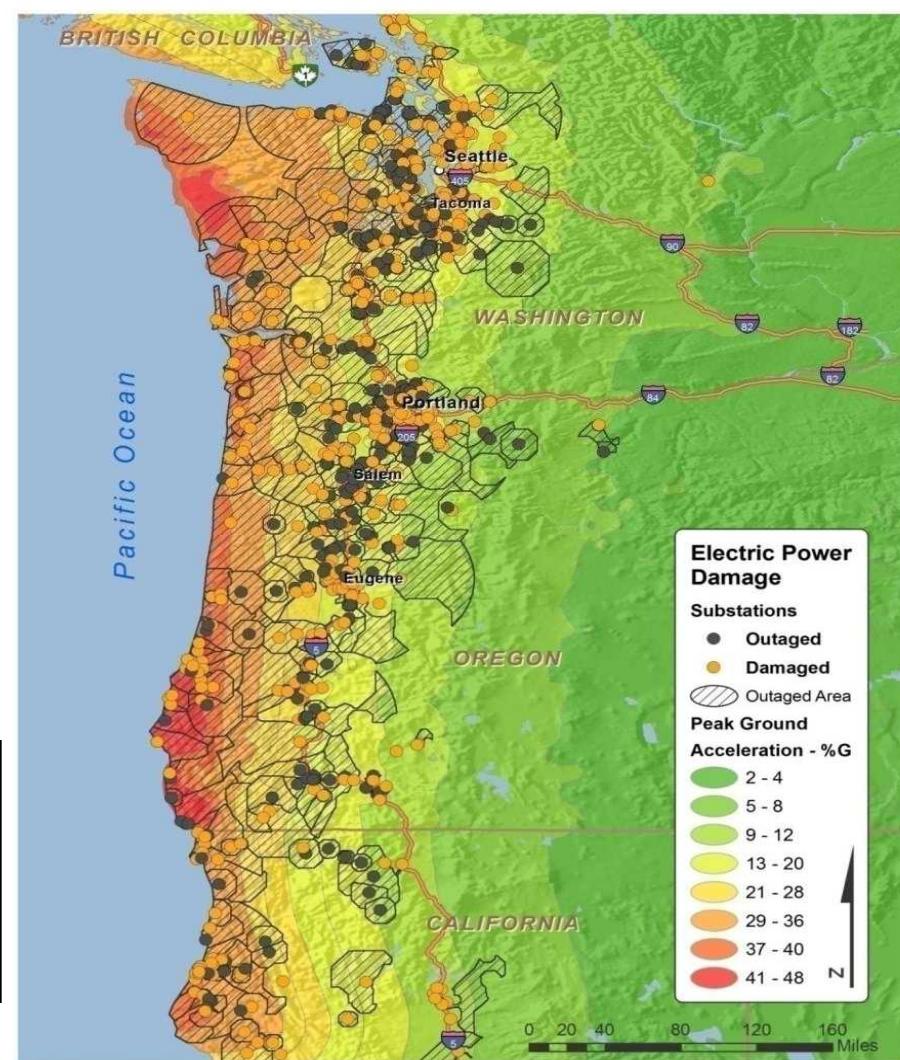


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# Electrical Power

- Electric power asset damage can create outages in the power grid
- On average the electric system loses 6 GW of generating capacity and 11GW of demand (out of 170GW)
- Seattle, Tacoma, Portland, Vancouver Island and all other cities within 100 miles of the Pacific coastline will experience blackout
- Services restored in 1-7+ days

<u>Damage State</u>	<u>Electric Generation</u>		<u>Substations</u>	
	<u>Damage</u>	<u>Lost gigawatts</u>	<u>Damage</u>	<u>Outaged</u>
None/Slight/Outaged	38	2.5	2033	418
Moderate	106	2.7	486	n/a
Extensive	12	0.3	144	n/a
Complete	3	0.1	16	n/a





# Natural Gas

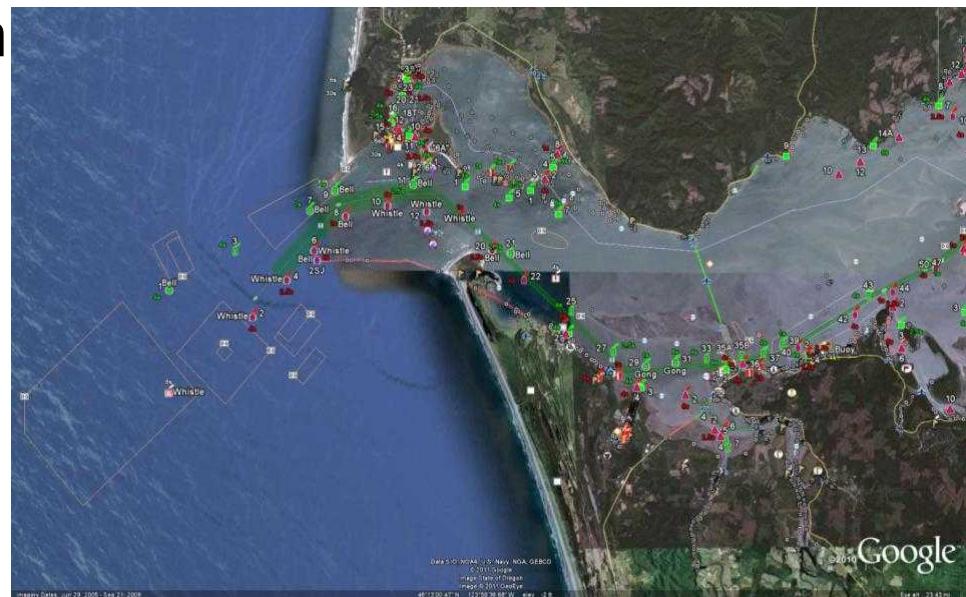
- May impact backbone transmission line serving western WA and OR
- Only about 1/3 of households heat with natural gas (NG) in WA and OR
- Most homes use electricity for heating
- NG is used for power generation in the area, but most power generation in the region is hydroelectric
- NG issues unlikely to cause any power generation shortages for the grid





# Ports & Maritime Infrastructure

- Major port facilities slight damage
- Tsunami closes navigation from Columbia to Pacific
  - Sedimentation
  - Channel Debris
  - Loss of navigation aides
  - Major path for export grains



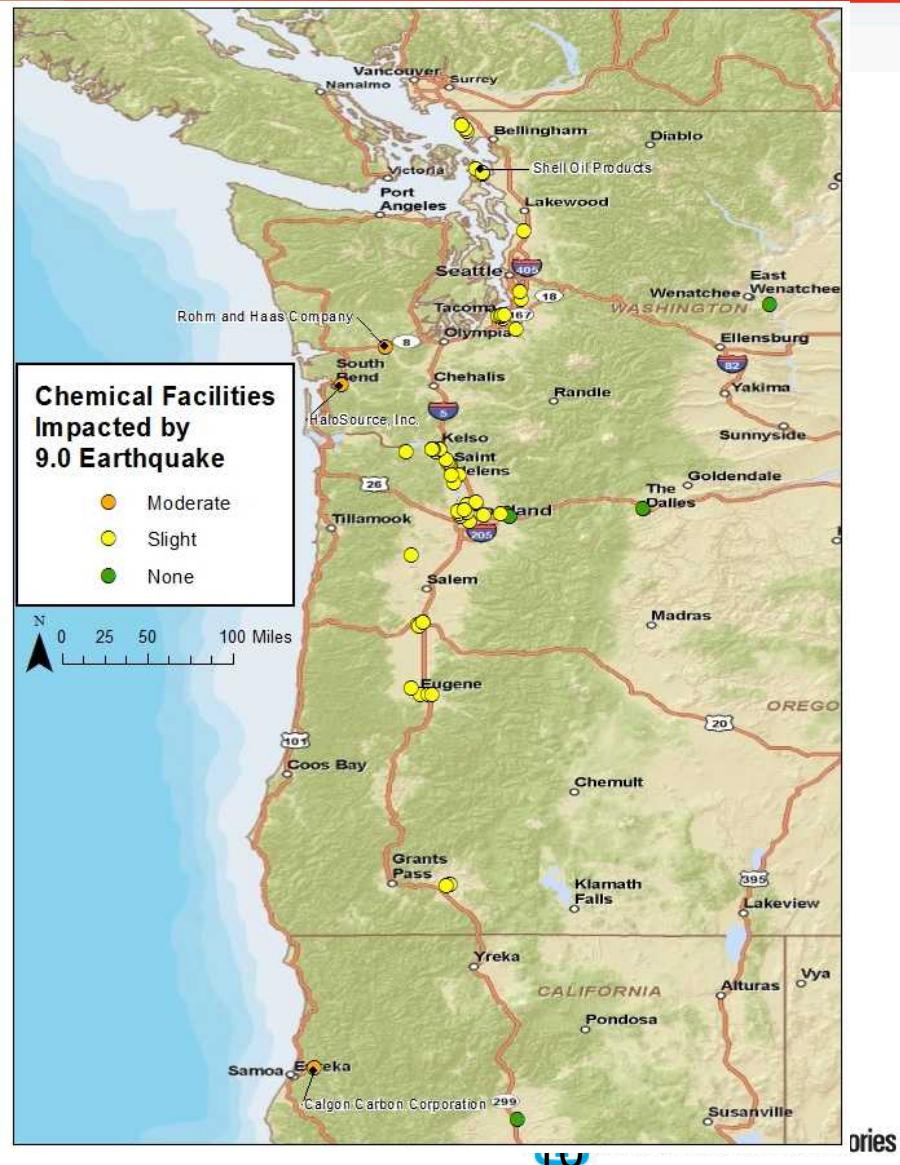
Locations of navigation infrastructure at the mouth of the Columbia River



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# Chemical

- No expected tsunami impacts
- No facilities are expected to receive complete or extensive damage
- 3 facilities expected to receive moderate damage, including Rohm and Haas in Elma, WA , potential national supply chain impacts
  - Only domestic producer of potassium borohydride
  - One of two domestic producers of sodium borohydride
- 50 facilities expected to receive slight damage with no national or regional supply chain impacts



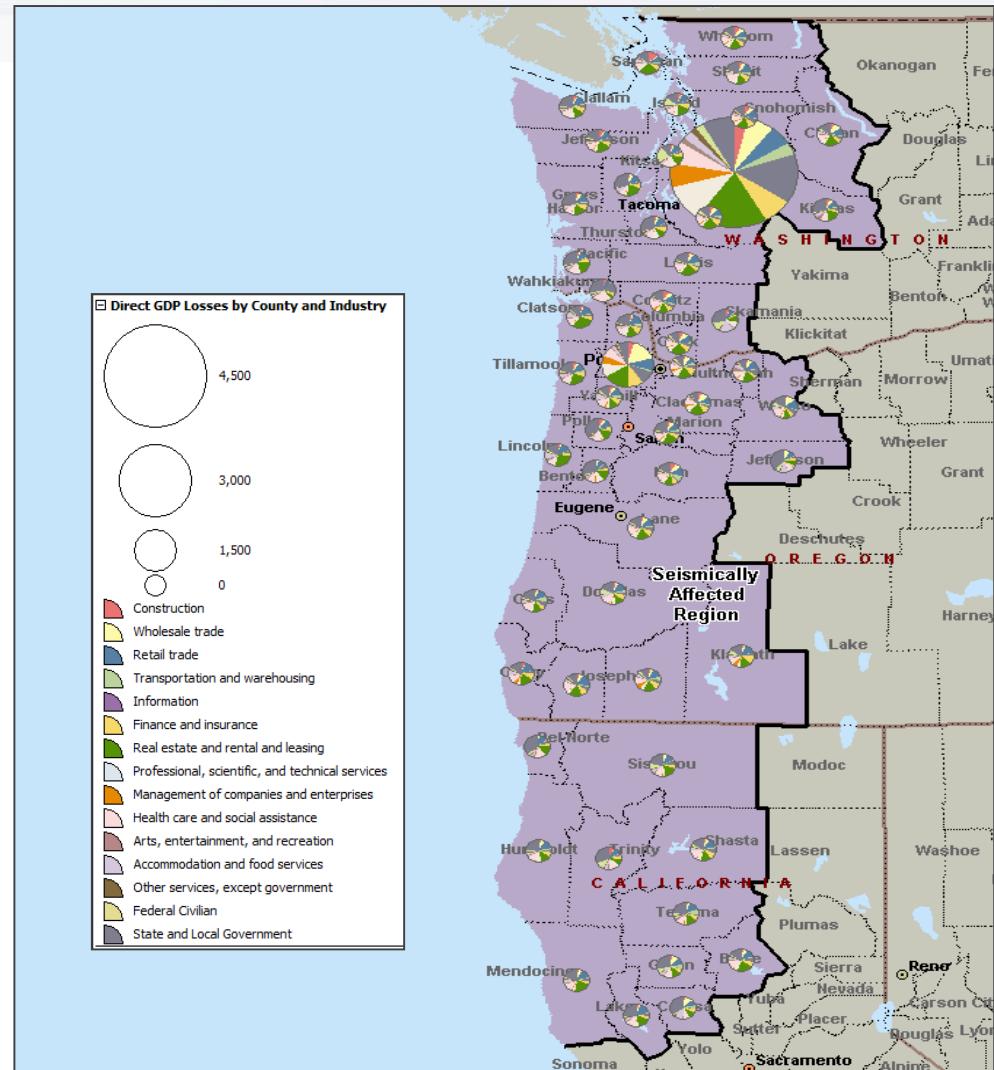


# Restoration of Key Infrastructure Sectors

Time Frame	Activity
<b>Immediate Aftermath</b>	Search and rescue in damage zone, focused on damaged facilities with susceptible populations (e.g., hospitals, nursing homes)
	Transport of emergency response surge capacity through major airports (SeaTac, Portland International) as staging areas for reaching more affected zones (by open roads, helicopter, seaplane), including fire suppression equipment to replace that destroyed by structural failure
	Identification and clearance of paths from areas with functional public health and infrastructure to damage zone
	Evacuation of injured from damage zone to working medical facilities
	Movement (to outpatient facilities) or discharge of ambulatory patients at hospitals in areas with functional public health facilities and infrastructure to clear bed space and shorten transportation times
	Repair of transportation routes (truck, rail) to minimally damaged port facilities near damage zone
	Coordination of truck and rail transport of POL (especially diesel fuel for emergency services vehicles and backup generators) from functional terminals/refineries to damage area and its perimeter
<b>Second Stage</b>	Identification of shelter/housing for key transportation workers and housing/evacuation for their families, to support operational flow of port facilities supporting recovery effort
	Evacuation of those lacking structurally sound housing or infrastructure resources from the damage area, especially those lacking means of home heating
	Repair of POL pipeline and terminal facilities to restore flows beyond the damage area. Rerouting of refined product from other western refineries as capacity allows by rail to undamaged areas
<b>Long-term</b>	Community-centric restoration of infrastructure: <ul style="list-style-type: none"> <li>Basic Infrastructure (water, power, fuels, commodity supplies)</li> <li>Public Services (fire, police, schools)</li> </ul>

# Economic Impacts

- **Total impact of \$49 Billion**
  - CA: \$1 Billion
  - OR: \$19 Billion
  - WA: \$29 Billion
- **Sectors with greatest economic impact:**
  - Telecommunications
  - Waterborne Transportation
  - Transportation Fuels
  - Electric Power is a strong driver of impacts in other sectors





# Probable Impact

- Odds of a significant NEO impact are low but the consequences are grave
- Asteroid hitting in a ocean basin could result in a tsunami catastrophic to coastal areas
- Resulting blast in a city could
- Large Synoptic Survey Telescope (LSST) has identified between 10 and 20 thousand Potentially Hazardous Asteroids (PTA) larger than 100 meters in diameter
- With sufficient warning potential mitigation and response plans can ensue





# Impact Hazard assessment

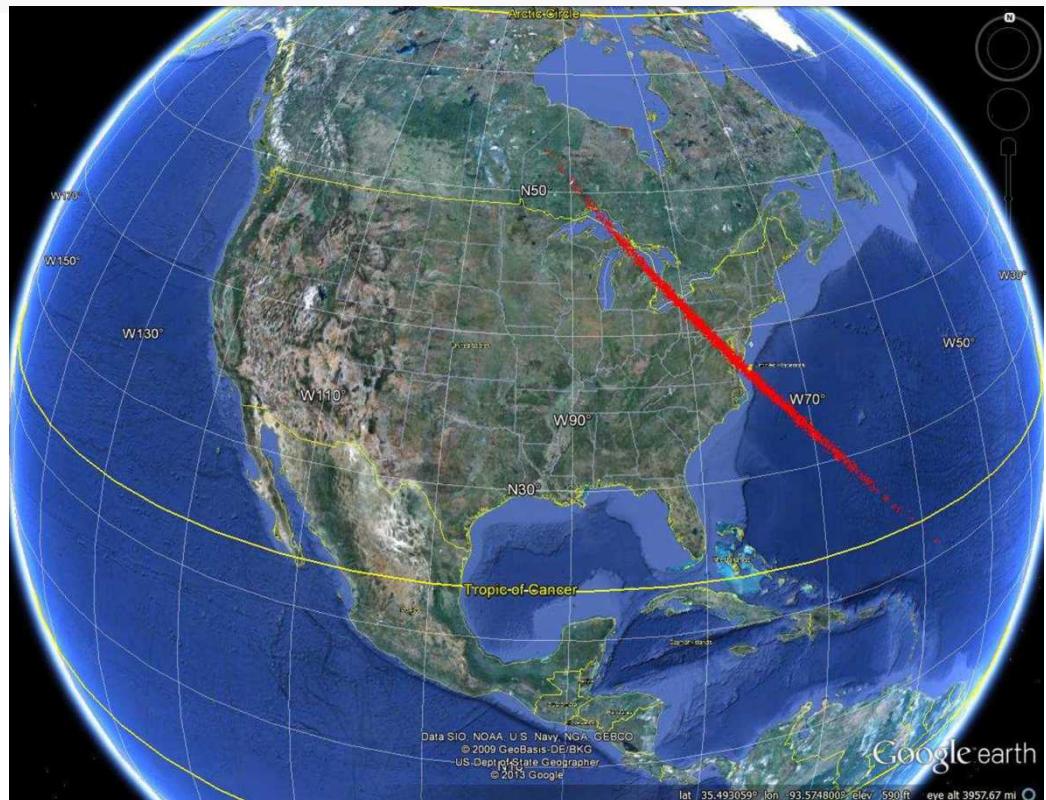
**After the fact, we know that ....**

- The Chelyabinsk Impactor was on a trajectory that caused it to explode between 15 - 25K above the earth surface
- The shock wave from this explosion was on par with about 30 atomic bombs like the ones used in Hiroshima
- Injuries to more than 1000 people were minor with only 2 serious
- Damage to > 4000 buildings within 200,000 sq meters
- Early damage estimated at more than \$33M



# With Advanced Warning

- **Asteroid of 30-100 meters**
- **With two weeks advance notice**
- **Known entry angle of 20°**



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# Damage Could be Immense

For Asteroid 200 meter in diameter

- Impact: Crater diameter 2.1 km (1.31 miles)
- Impact Depth: 595 meters (1470 feet)
- Seismic effects: 5.9 RSM
- The most extreme damage from a airburst occurs at 42000 ft
- If the impact is offshore can expect tsunamis of 40 feet locally and 10 feet over hundreds of miles of coastline



# Worst-case land impact (200-Mt crater-forming)

Richter Scale Magnitude: 5.9

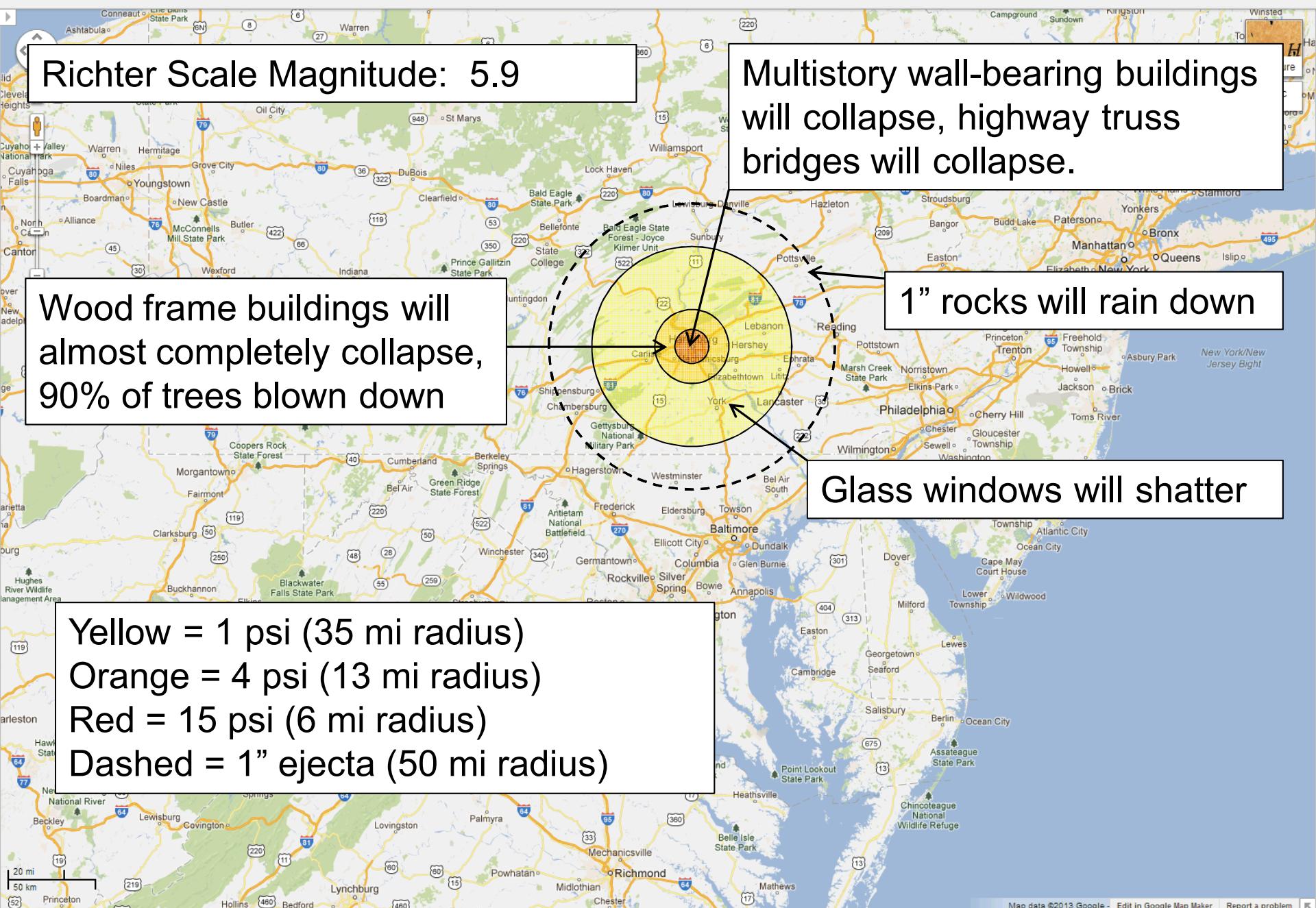
Multistory wall-bearing buildings will collapse, highway truss bridges will collapse.

Wood frame buildings will almost completely collapse, 90% of trees blown down

1" rocks will rain down

Glass windows will shatter

Yellow = 1 psi (35 mi radius)  
Orange = 4 psi (13 mi radius)  
Red = 15 psi (6 mi radius)  
Dashed = 1" ejecta (50 mi radius)



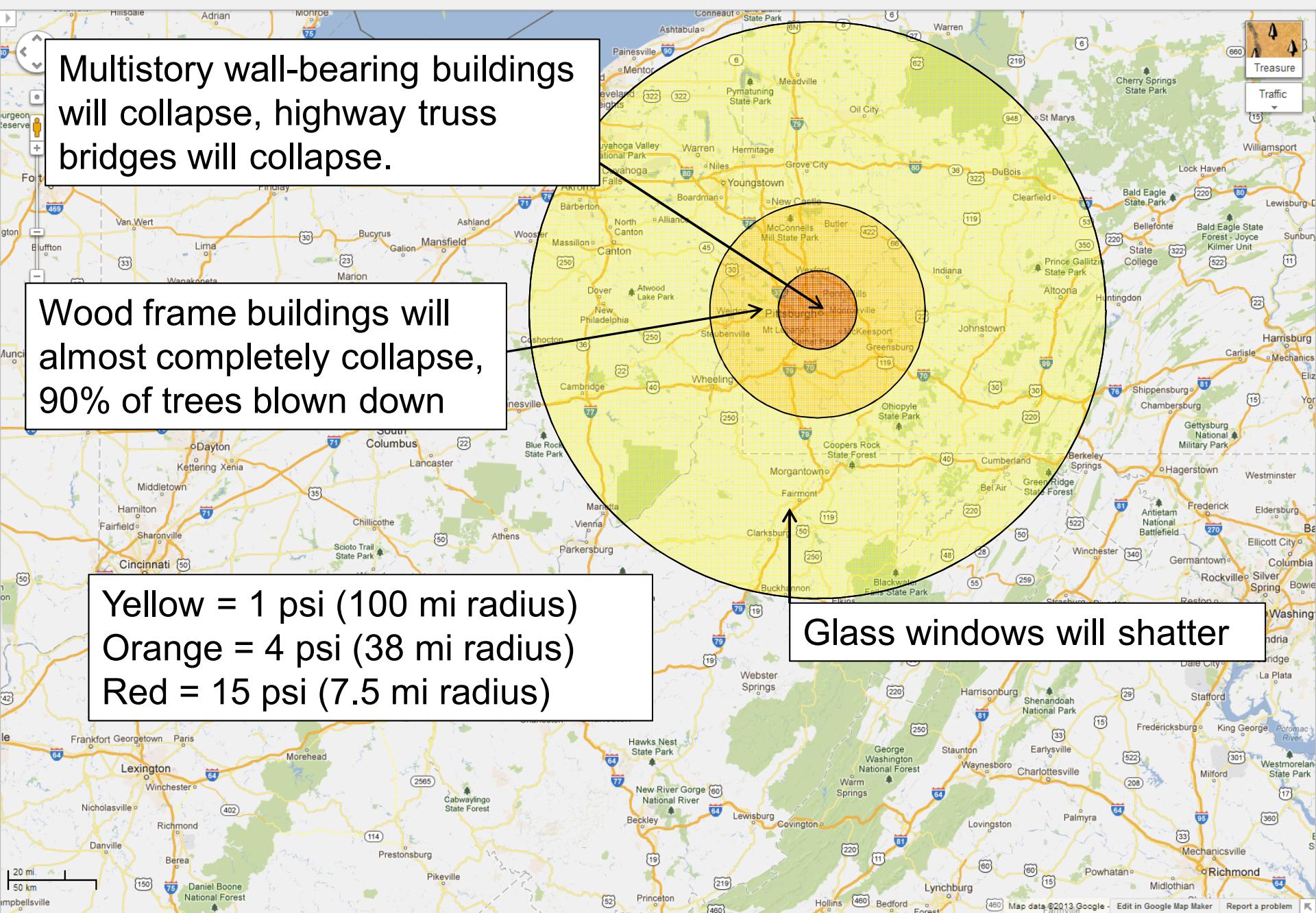
# Worst-case airburst (200-Mt optimal burst height)

Multistory wall-bearing buildings will collapse, highway truss bridges will collapse.

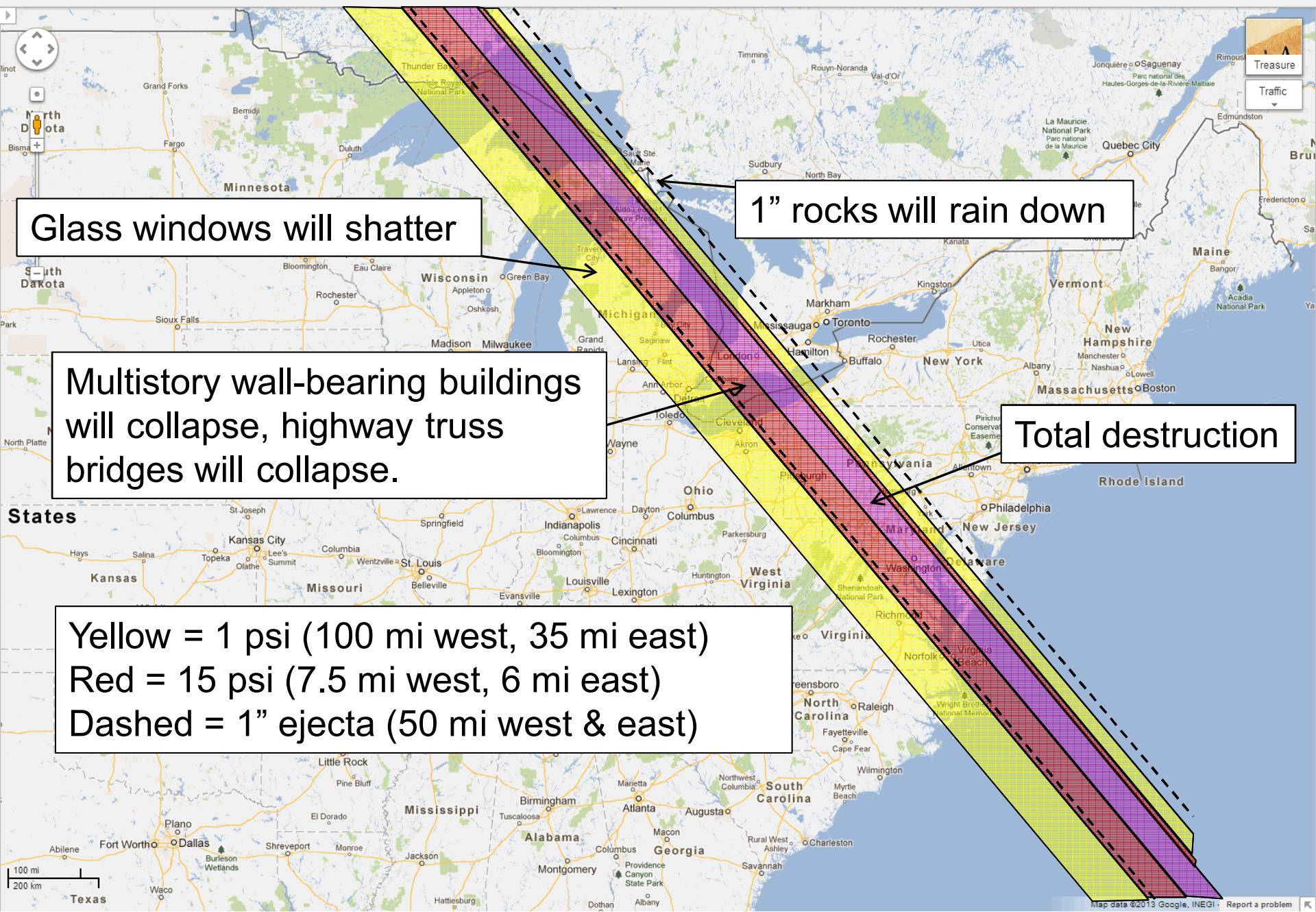
Wood frame buildings will almost completely collapse, 90% of trees blown down

Yellow = 1 psi (100 mi radius)  
Orange = 4 psi (38 mi radius)  
Red = 15 psi (7.5 mi radius)

Glass windows will shatter



# Zone of potential total destruction (crater and/or firestorm)





# Modeling and Simulation Expertise at SNL

**Experience modeling the effect of critical sectors to assist decision makers, planners and first responders with direct and cascading effects including:**

- Human Impacts
- Utilities: Electric Power, Water, Oil/Gas Distribution and Transportation Fuels
- Telecommunications
- Emergency Response Water and Waste Water
- Infrastructure: Bridges, Roads, Locks & Dams, Ports
- Transportation: Roads, navigable water, rail
- Economic Impact: Banking and Finance, Supply Chain



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