NAS Beebe Symposium: The Science and Response to a Nuclear Reactor Accident

Post Emergency Transition to Recovery

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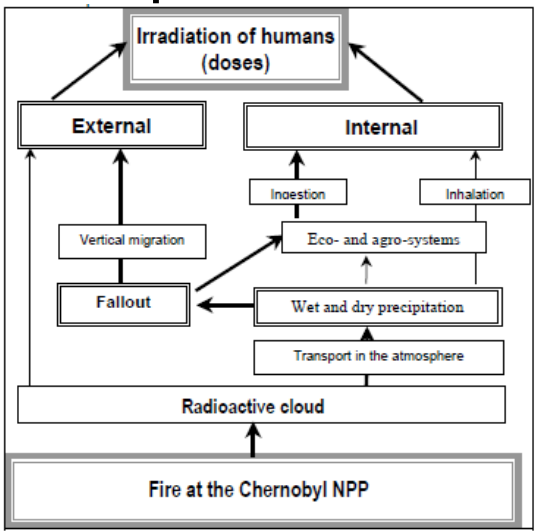
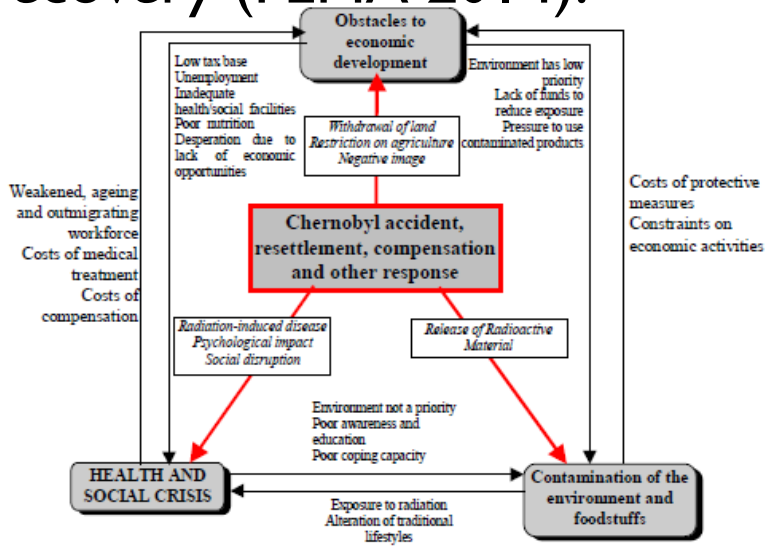
History As Our Guide

- Findings from Chernobyl demonstrate the greatest public doses were derived not from the plume, but from the ingestion of contaminated food (UNSCEAR 2011). Results from Fukushima appear similar (UNSCEAR 2013).
- The socioeconomic and environmental consequences can be catastrophic for long periods of time (United Nations 2002)
- Findings are the highest costs for emergencies are not those of initial response, but for long-term recovery (FEMA 2014).



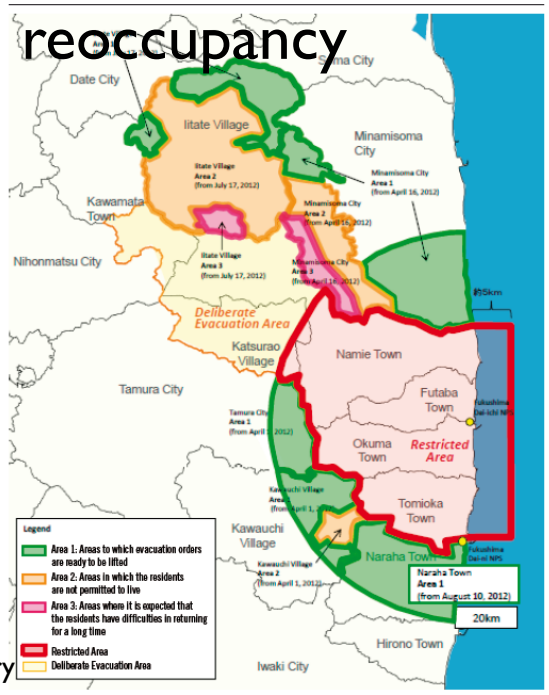
Source: UNSCEAR 2011



History As Our Guide

- Recent experience during the Liberty RadEx exercise in Philadelphia (Aquino 2010) indicates more people than might at first be estimated are willing to tolerate some excess radiation dose if they can return to "normalcy" sooner.
- Fukushima reinforced what was seen in that exercise: evacuated people with trusted facts about the radiological condition facts must be substantial partners in reoccupancy decision-making (Hasegawa 2013).

2011	Target	Orders	Name of the Zone
11 March	2 km radius from the station	Compulsory Evacuation (issued by the Fukushima prefectural government)	Restricted Zone
	3 km radius	Compulsory Evacuation	Restricted Zone
12 March	10 km radius	Compulsory Evacuation	Restricted Zone
	20 km radius	Compulsory Evacuation	Restricted Zone
15 March	Between 20–30 km	Shelter indoors	Evacuation Prepared Area
22 April	Between 20–30 km	Shelter indoors or evacuation by own means	Evacuation Prepared Area
	Areas with air radiation dose more than 20 mSv/year	Evacuation within 1 month	Deliberate Evacuation Area
16 June	Spots with air radiation dose of over 20 mSv/year	Recommended for Evacuation	Specific Spots Recommended for Evacuation
30 Sept.	Between 20–30 km	Lifting of the order to shelter indoors or evacuation by own means	Lifting of Evacuation Prepared Area

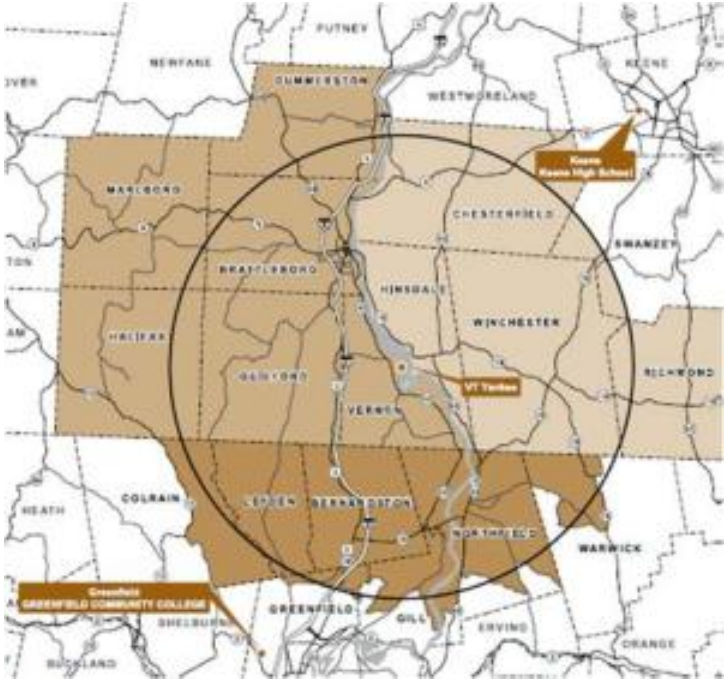


Source: Japan Ministry of Economy, Trade and Industry

The Early Response Decision: Evacuate or Shelter-in Place?

- The state where the nuclear reactor resides makes the decision to evacuate or shelter-in-place for its citizens.
- Frequently, multiple states are affected making collaboration among them critical and confusion of citizens possible.

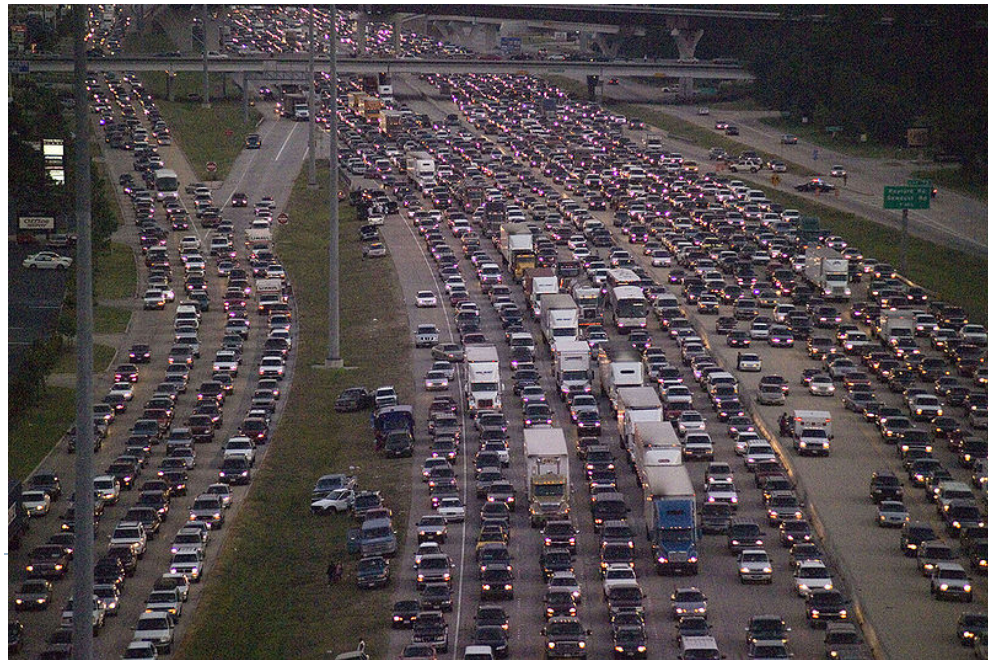
Some jurisdictions evacuate whole towns, while others evacuate just those parts within the 10 mile evacuation emergency planning zone



Source: Vermont Division of Emergency Management and Homeland Security

- Deciding whether to evacuate or shelter-in-place is one of the hardest decisions to make, especially when information is imperfect which is often the case.
  - Evacuations may result in serious consequences including evacuee deaths (Tanigawa et al 2012).
  - Sheltering-in-place may lead to high radiation doses when there are high concentrations of radioactivity in the plume, especially where building structure provides poor shielding of radiation and shelter from contaminants.

Night time evacuation in Japan



Evacuation near Houston, Texas prior to landfall of Hurricane Rita Sept. 2005

When To Evacuate or Shelter-in Place

- Evacuation is preferable when there is time to do so safely before evacuees receive significant radiation dose.
  - Many nuclear reactor accident scenarios are slow developing.
  - However, we must be prepared for fast-breaking scenarios as well.
- Shelter-in-place is preferred when conditions may result in greater dose or harm if people were evacuated:
  - High radiation already exists from deposition or a plume,
  - Extreme weather or another natural disaster restricts travel,
  - Hostile actions in the area threaten evacuees.
- Some people just will not or cannot evacuate.

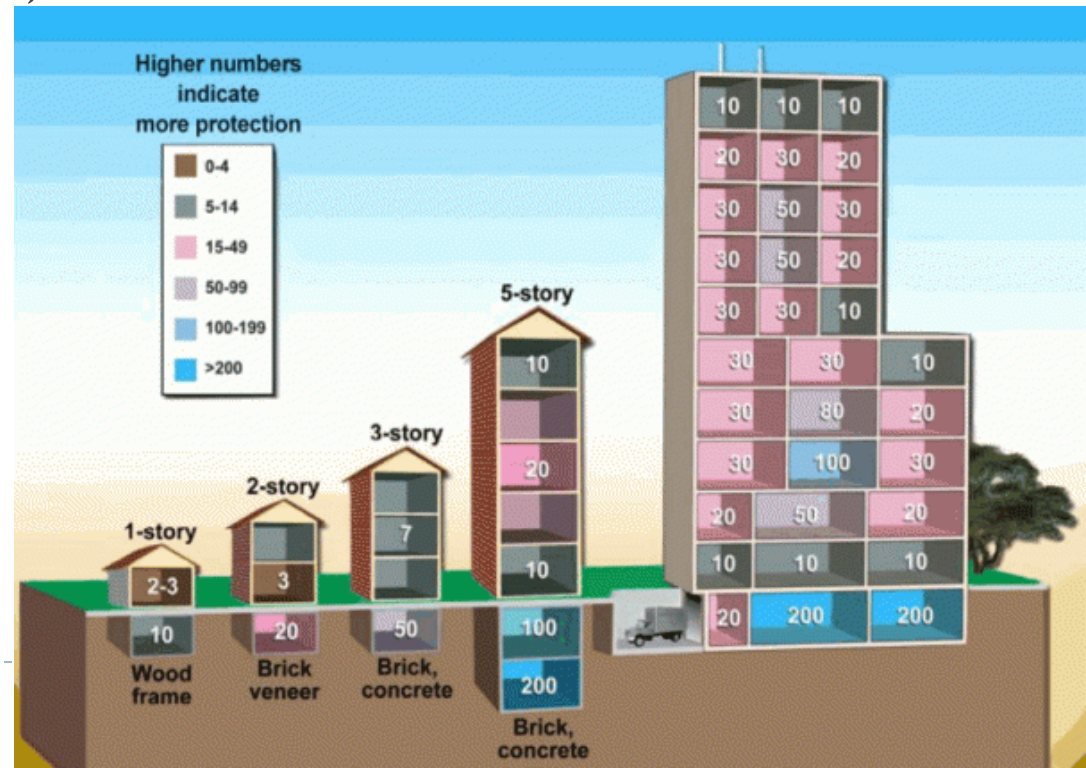
The Alternative Chosen Determines the Nature of All Future Actions.

- Evacuation
  - Are the radiation doses sufficient for the risks?
  - Where do evacuees go?
  - How can thousands of people be monitored adequately for protective care?
  - Many need highly specialized care.
  - What about those who did not leave?
  - How do we register evacuees for dose reconstruction and medical follow-up?

The Alternative Chosen Determines the Nature of All Future Actions.

- Shelter-in-place
  - What guidance should be provided so those sheltering are protected?
  - What do we do for those who self-evacuated?
  - For those too ill to move, what do we do for their caretakers.

We have to know the effectiveness of structures within which people would seek shelter



Source: Disaster Medicine and Public Health Preparedness

Long-Term Efforts: Relocation, Reentry and Reoccupancy

- Relocation occurs after the initial evacuation when new information shows new populations in new areas are at risk of undesirable dose. Where relocation occurs is mostly a function of the weather during the radioactivity release period.
- Reentry occurs when people enter radiologically restricted areas for life safety functions or to protect critical infrastructure.
  - Doses for those reentering must be estimated beforehand and managed during reentry.
  - Multiple reentries may be needed over a long term recovery.
  - Reactor staff are well-practiced at this, offsite response organizations often are not.
- Reoccupancy occurs when people are allowed to go back to previously evacuated areas.

Protective Action Guidelines (PAGs)

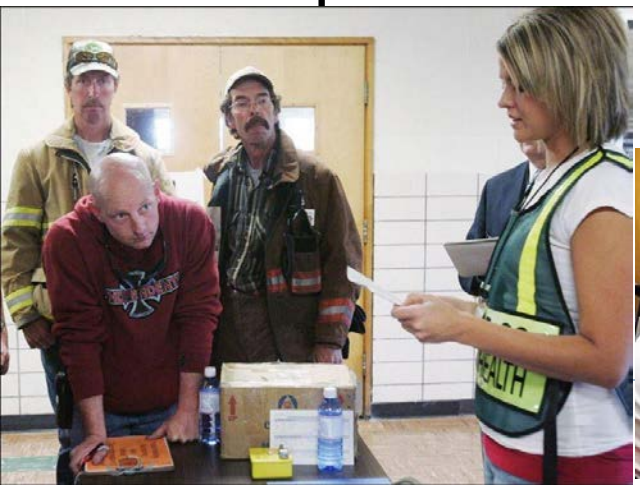
- The Environmental Protection Agency PAGs address evacuation, based on plume dose from a reactor release, and relocation, based on the deposition of radioactive materials on the ground after the release has ended.
- There are no PAGs for Reentry or Reoccupancy.
  - Reentry is managed to prevent dose to those providing lifesaving or protection to critical infrastructure.
  - Dose is only one variable that is considered for reoccupancy. Other considerations include:
    - The economic and other values people assign to the land and structures, and
    - The costs of cleanup and safely managing contaminated waste and debris.
- There are significant costs and benefits to be weighed for reentry and for delays in reoccupancy.

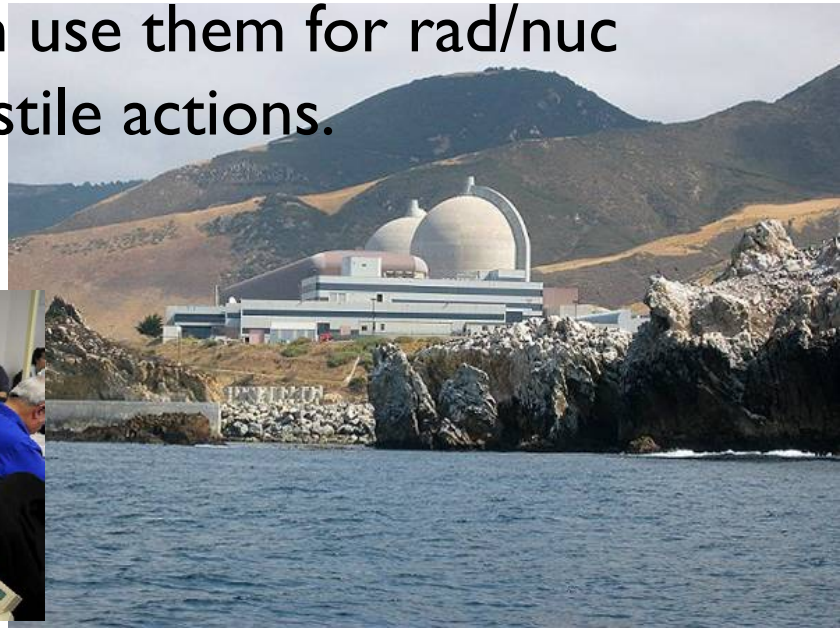
Planning, Practice and Improvement

- The current schedule of reactor emergency exercises is heavily weighted to test evacuation and shelter-in-place decisions.
- Exercises to test preparedness for long-term consequences occur only every eight years.
  - Jurisdictions may ***respond*** reasonably well, but ***recovery*** may be more costly in many ways because of insufficient attention to it.
  - Like the actual activities, planning, practicing and being prepared for reentry, reoccupancy and other elements of recovery involves more people and other resources.
  - These costs may be leveraged by exercising plans designed for both the rarer radiological emergency scenario and the more common non-radiological emergency scenarios.
- Some residents do not think exercises are conducted with adequate resources, participation, frequency or seriousness.

Leveraging our Investments

- The nation and states have invested much in nuclear reactor emergency preparedness.
- Exceptional rad/nuc models for plume and dose projection and reception center and staging area management may be employed for other hazards.
- Those jurisdictions possessing assets and trained for nuclear reactor emergencies can use them for rad/nuc transportation accidents and hostile actions.





Leveraging our Investments

- For those jurisdictions that have no nuclear reactors or high value targets that have prompted rad/nuc preparedness, mutual aid from neighboring jurisdictions with reactor emergency preparedness capabilities can be of benefit.
- As nuclear reactors are decommissioned, support for rad/nuc preparedness capabilities should continue for the broader welfare of the jurisdictions that no longer host a reactor.
- Support of these mature applications for the nation's nuclear reactors must be financial, for example with grants. Regulatory mandate may be needed.
- *It should be less costly to maintain and more broadly use what has already been built than to build anew in the future.*

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