Population Screening and Protection in Response to Radiological Incidents

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Purpose of Project

Aim 1: Design and advance information – decision support system for population protection and emergency response; Establish a national knowledge databank.

•CDC OPHPR/DSNS/PPA, F. Pietz

•CDC NCEH/EHHE/Radiation Studies Branch, Armin Ansari, Lynn Evans

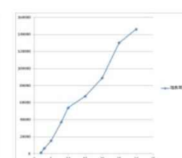
•Various state/local public health directors and coordinators for radiation safety

Aim 2: Collect on-the-ground response and health monitoring data; Provide advice and technology for effective and efficiency screening and decontamination

•Atsuo Suzuki, NanZan University








My work:
Information Technology-Decision Analytics

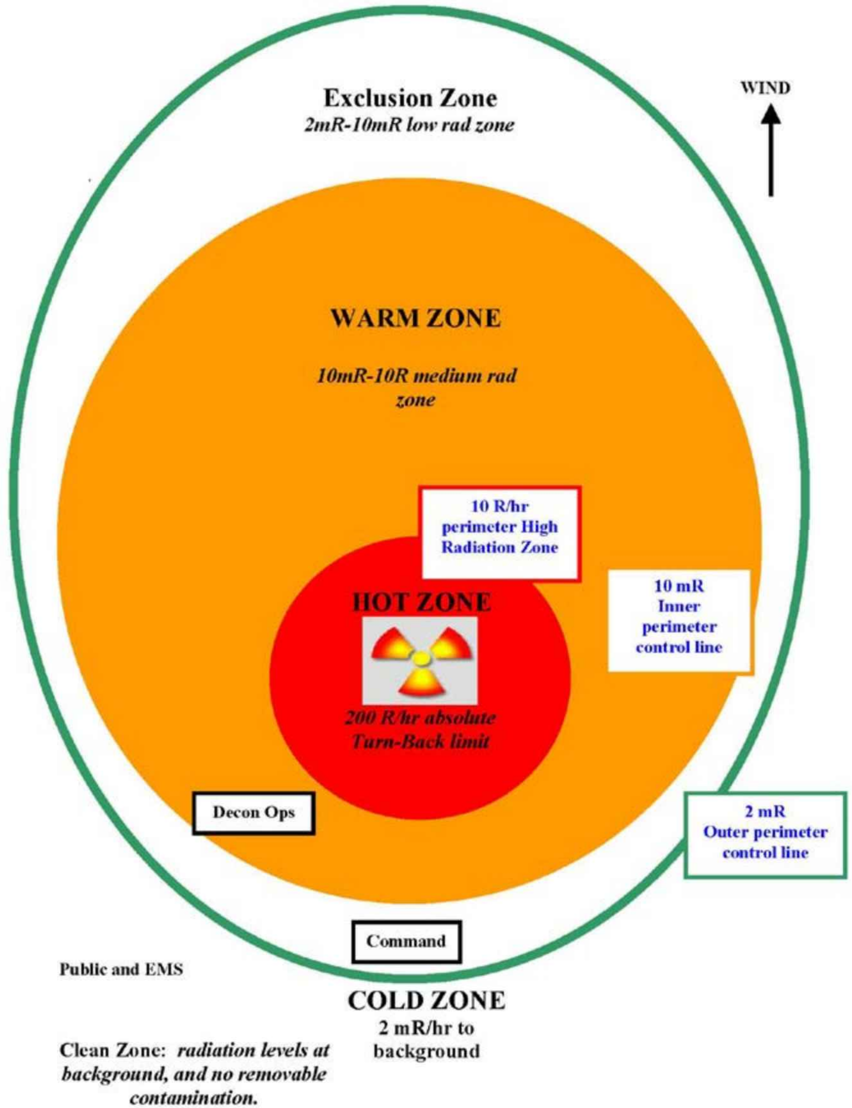
Risk Assessment	Communication
Data / knowledge Management	**Decision-Support:** -Resource Allocation -Rapid Screening -Population Protection

Hazard Zones

The hazard zones were developed by Portland Fire and Radiation Protection Services

Hot Zone	10 R/hr
Warm Zone	10 mR/hr
Exclusion Zone	2 mR/hr
Cold Zone	<2 mR/hr w/ no removable contamination per NCRP 138 values

mR/hr = milli-Roentgens per hour, a standard unit of measurement for radioactivity



Population Monitoring

Evaluate potentially-affected population for:

- Immediate need for medical treatment (both radiation and non-radiation related)
- Presence of contamination on body or clothing
- Intake of radioactive materials
- Removal of external or internal contamination (decontamination)
- Radiation dose received and risk of health effects
- Long-term health effects (needs registry)

Population Monitoring
(Initial Hours)

- Contamination screening criteria
- Radiation survey methodology
- Clothing services
- Transportation services
- Washing facilities
- Registry
- Collection of biological samples
- Worker protection

- Population density and time of day may result in tens, even hundreds of thousands in the vicinity.
- Reconsider plans to cordon off the area and detain those believed to be affected.
- Waiting increases anxiety and the likelihood of inhalation or ingestion of radioactive material.

Population Monitoring

(Day 2 and Beyond)

- Setting up community reception centers
- Practical considerations for reception centers operations
  - Pets
  - Monitoring for external contamination and conducting decontamination
  - Monitoring for internal contamination and conducting decontamination
  - Scaling for size of event

Our Tasks: Develop Computer Systems for

- Evacuating affected area
- Screening and tracking of radiation dosage of workers (ensure safety of workers)
- Determining optimal number of shelters needed
  - Maximize coverage, minimize cross-contamination under resource constraints
  - Minimize disruption
- Setting up community centers for large-scale population health monitoring
- Setting up distribution nodes for food/water/medical supply delivery

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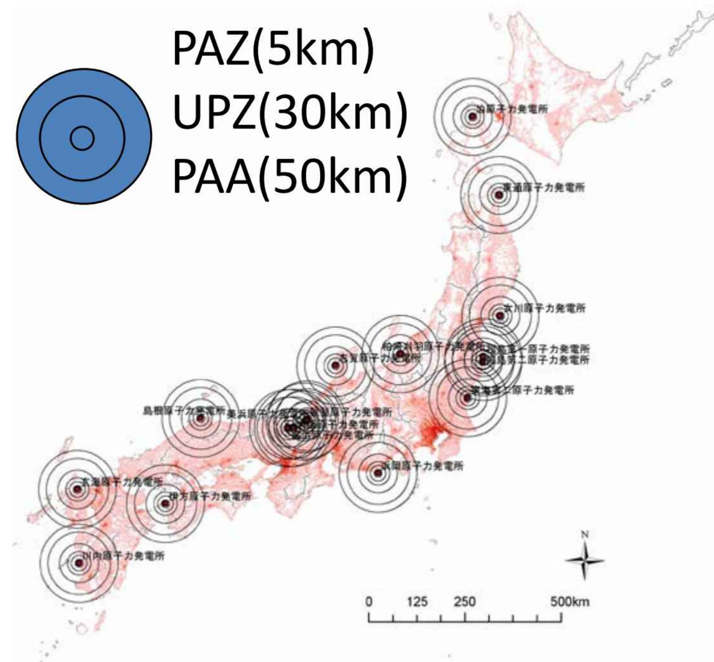
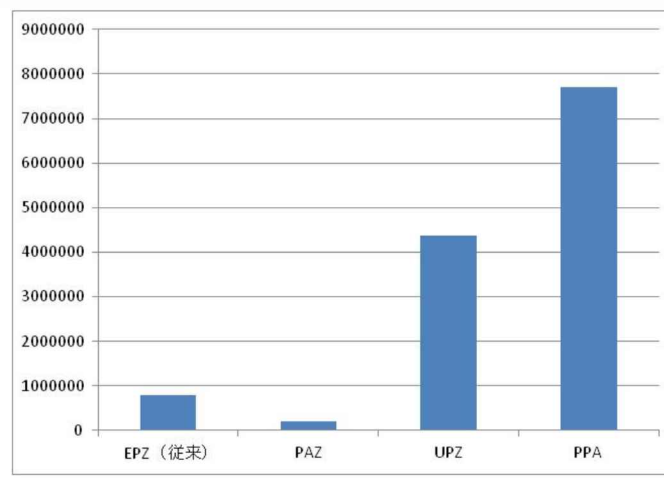
Some Nuclear Plants in Japan

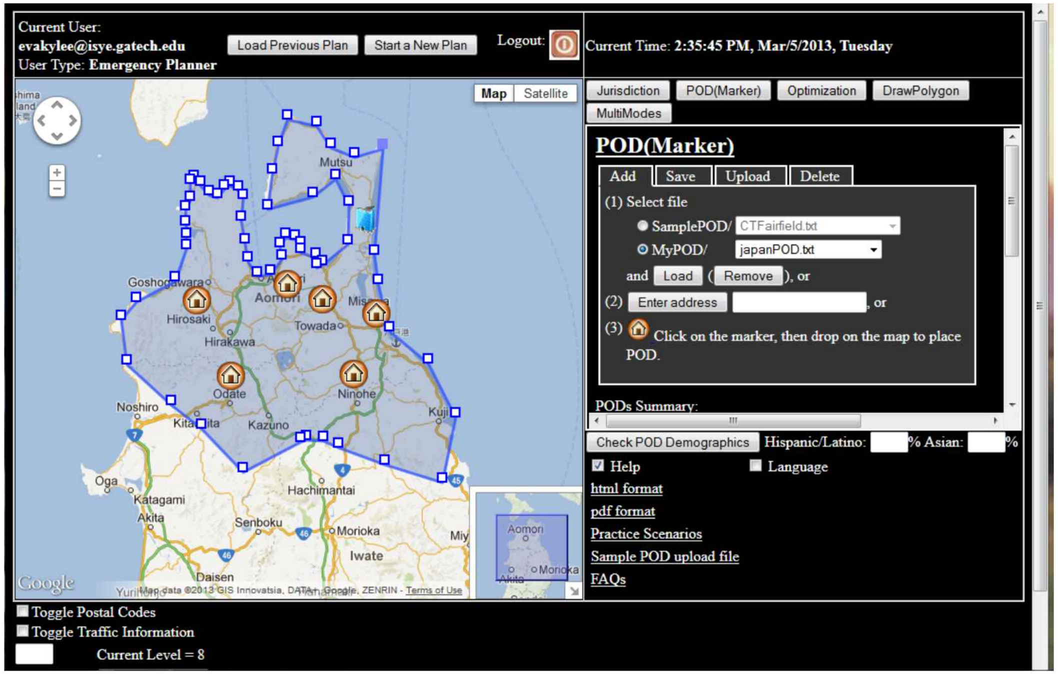
名前	10km	名前	20km	名前	30km
東海第二	25.49	東海第二	73.92	東海第二	94.84
島根	9.00	島根	25.21	浜岡	79.69
柏崎刈羽	8.56	浜岡	24.09	島根	46.60
浜岡	8.26	柏崎刈羽	18.94	柏崎刈羽	45.62
福島第一	5.39	女川	13.20	敦賀	30.35
福島第二	3.61	玄海	13.08	玄海	27.75
玄海	3.31	川内	12.33	川内	24.02
高浜	3.18	敦賀	12.08	女川	22.82
大飯	2.89	高浜	11.62	美浜	22.55
川内	2.85	志賀	10.01	高浜	20.41
伊方	2.67	美浜	9.05	志賀	17.70
美浜	2.33	福島第一	8.88	福島第二	16.35
泊	2.33	伊方	7.44	大飯	15.97
志賀	2.05	福島第二	7.24	福島第一	14.61
女川	1.48	大飯	6.47	伊方	14.23
敦賀	0.43	東通	4.79	泊	8.47
東通	0.40	泊	2.75	東通	7.70

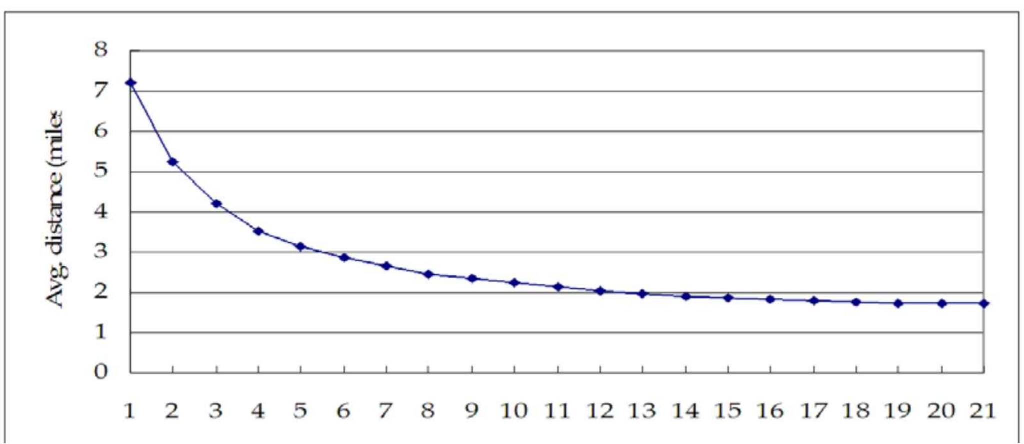


Zone	Radii	Population
EPZ Emergency Planning Zone	8–10km	802,075
PAZ Precautionary Action Zone	3–5km	192,775
UPZ Urgent Protective action Planning Zone	5–30km	4,362,883
PPA Plume Protection Planning Area	30–50km	7,694,758



Determine #s of Screening/Decon Centers





- **Task**: *Determine where and how many*: Study the impact of the number of screening & decontamination centers on the average travel distance/time. Model has many variations.
- **Objective(s):** Minimize distance/time travelled by each household and total facility setup costs
- **Some Potential Constraints:**
  - Each affected household is assigned to exactly one facility
  - Only a limited number of facilities can be opened
  - Every household must be served

Facility Location Model (solve in real-time)

$$Minimize \sum_{i \in K} \sum_{l \in G_i} y_l$$

$$Subject\ to$$

$$\sum_{l \in G_i} y_l \geq 2$$

$$d(r,l)x_{rl} \leq d_{\max} y_l$$

$$\sum_{l \in G_i} x_{rj} = 1$$

$$\sum_{r \in G_i} x_{rj} p_r \leq c_l$$

$$x_{rj}, y_l \in \{0,1\}$$

Minimize # of facilities needed

$$Minimize \sum_{i \in K} \sum_{r \in G_i} \sum_{l \in G_i} x_{rl} d(r,l) p_r$$

$$Subject\ to$$

$$\sum_{l \in G_i} y_l = n_i$$

$$d(r,l)x_{rl} \leq d_{\max} y_l$$

$$\sum_{l \in G_i} x_{rj} = 1$$

$$\sum_{r \in G_i} x_{rj} p_r \leq c_l$$

$$x_{rj}, y_l \in \{0,1\}$$

Minimize total distance/time travelled

Determine the Best Facility Layout

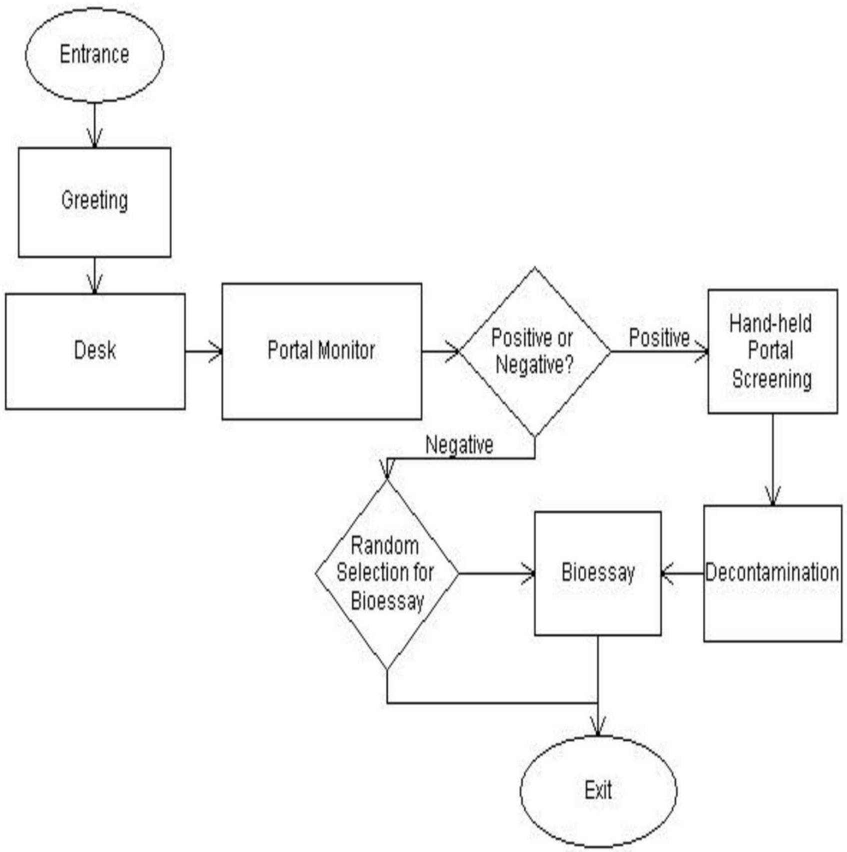
Basic Concepts

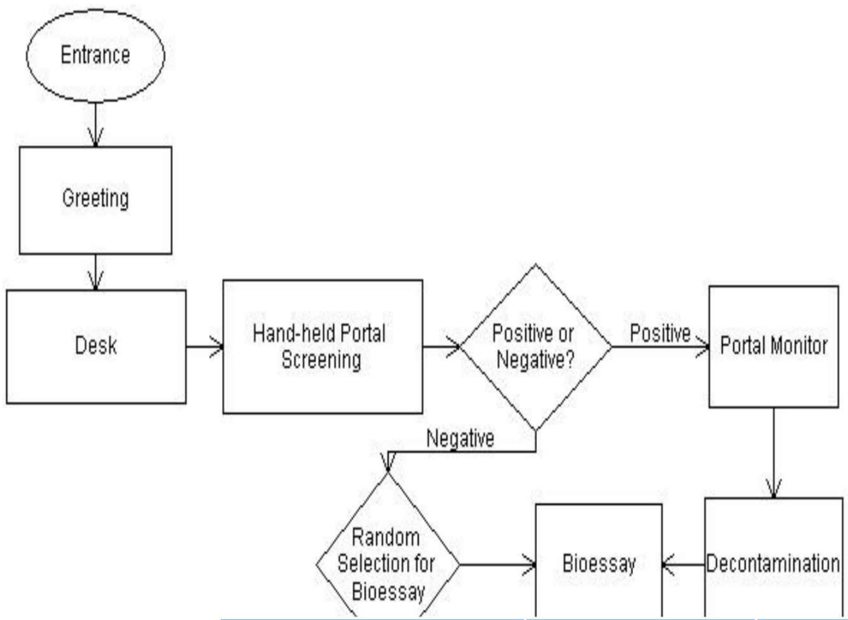
- Head, hands, feet, wounds for screening
  - Focus on Potential for Uptake
  - Focus on most likely contamination sites
- RAM Contamination = Radioactive Dirt
  - Decon = Cleaning
  - Self-decon recommended
  - Technical-decon situationally-dependent

Contamination Screening

- Portal monitors
- Pancake GMs for localization
- Area monitoring and dosimetry for workers
- Radionuclide identification
- Bioassay for checking if there’s internal contamination

Screening / Decon Centers





	Layout 1	Layout 2
Throughput in 12 hours	52,982	40,217
Ave. time spent	8 minutes	15 minutes
Greeting	8 workers	6
Paperwork	8 workers	6
Portal monitor	16	3
Hand-held device	12	43
Decontamination	46	34
Bioassays	10 stations	8

- Maximize throughput with 100 available workers for a 12-hour shift
- Design of layout is important – non-intuitive

NMIP: Mathematical Formulation

min	$z = f\left(\sum_{j \in \mathbf{S}} g_j, c, \theta\right)$		(0)
s.t.	$\underline{m_{ijr}} \leq x_{ijr} \leq \overline{m_{ijr}},$	$\forall\, r \in \mathbf{R}, i \in \mathbf{T}_r,\ j \in \mathbf{S}_{ir}$	(1)
	$\sum_{j \in \mathbf{S}_{ir}} x_{ijr} \leq n_{ir},$	$\forall\, r \in \mathbf{R}, i \in \mathbf{T}_r$	(2)
	$w(x)_j \leq w_{max}$ $q(x)_j \leq q_{max}$ $u_{min} \leq u(x)_j \leq u_{max}$	$\forall\, j \in \mathbf{S}$	(3)
	$\theta(x) \geq \theta_{max}$ $c(x) \leq c_{max}$		(4)
	$x_{ijr} \in \mathbf{Z}_+$	$\forall\, r \in \mathbf{R}, i \in \mathbf{T}_r,\ j \in \mathbf{S}_{ir}$	(5)

Cost at each station = $g_j\,(k_{ijr} x_{ijr}, w_j, q_j, u_j)$

Fukushima Events

- First month after March 11, 2011, over 3000 workers were working on various emergency issues related to the failed nuclear plants. Lack of planning led to miss screening of workers.
- Due to lack of resources and coordination, some citizens living within 20 km from the nuclear plants, received screening 6-9 months after the incidents.
- My tasks:
  - On the ground interviewing citizens, surveying their health and mental conditions, and their knowledge of radiological emergency response
  - Assist in developing guidelines and provide technology for effective large-scale screening and decontamination

On-the-Ground Knowledge

- Most have very little knowledge in radiological incidents
  - General population
    - < 0.1% have radiation safety and emergency response knowledge
  - Citizens living in vicinity of failed nuclear plants (< 20km)
    - 30% have radiation safety knowledge
    - 24% have radiation emergency response knowledge
    - 27% have been screened (9 months after 03/11/11)
      - 23% received medication
    - 4% have health problems and symptoms caused by radiation exposure
- Japan shut down the last of its 54 reactors on May 5, 2012.
- Unit 3 of the Ōi Nuclear Power Plant was restarted on July 1, 2012.
- On-going: assist in employing technology to develop guidelines for preparedness, and real-time rapid emergency response, screening and decontamination

Challenges & Scientific Advances

- Big data (evolving, large-scale, disparate)
- Complex and dynamic mathematical modeling
- Computationally intractable (very difficult to solve using existing software systems)
- ***Our advances:***
  - ***Major breakthroughs in mathematical modeling on realistic complex evolving on-the-ground situations***
  - ***New algorithms developed for rapid solution process***
  - ***Practical decision support system for emergency response managing officials (real-time decision support, must solve the NP-hard problems in CPU seconds)***
  - ***Collected invaluable response data as knowledge databank***
  - ***Since 2005, RealOpt, a system designed for pandemic/biological agent response, has over 7000+ public health site users. It has been used for mass vaccination for flu, H1N1, smallpox, Hepatitis B, anthrax drills, floods, hurricanes, ice storms, fire, etc.***

Thank You

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