NRA
Nuclear Regulation Authority

Application of MACCS2 in S/NRA/R

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IMUG 2015
Sept. 21-22, North Bethesda, MD

Outline

- Discussion of Safety Goals in Japan
- Objectives of Level 3 PRA research in S/NRA/R
- Previous Research
  - Development of methodology for multi-unit
  - Incorporation of revised evacuation models
- Current Research
- Summary

Discussion of Safety Goals in Japan (1/2)

"Interim Report on the Investigation and Review on Safety Goals",
Special Committee of Nuclear Safety Commission, December 2003.

Quantitative goal (proposal) : Average early fatality risk and cancer fatality risk by radiation exposure resulting from accidents of a nuclear facility should be less than 10^{-6} per year, respectively.

"Performance Goals for Light Water Nuclear Power Reactor Facilities",
Special Committee of Nuclear Safety Commission, March 2006.

Quantitative goal (proposal) : Core Damage Frequency should be less than 10^{-4} per year, and Containment Failure Frequency should be less than 10^{-5} per year.

Discussion of Safety Goals in Japan (2/2)

"Main issues discussed in previous commissions (- Apr. 3, 2013) related to safety goals", Secretariat of Nuclear Regulation Authority, April 2013.

Nuclear Regulation Authority (NRA) stated that the result of studies in former Nuclear Safety Commission will be the basis for the discussion of safety goals in NRA and that NRA will continue to discuss safety goals.

[Risk index stated in the Commercial Reactors Improving Safety Guide*]

- Core Damage Frequency
- Containment Failure Frequency
- Exceedance Frequency of Cs-137 release over 100 TBq

* Nuclear Regulation Authority, "Guideline for Evaluation Report for Improving Commercial Power Reactor Safety", Nov. 27, 2013

Objectives of Level 3 PRA research in S/NRA/R

- Identify dominant accident sequences and its individual risks and
- examine the effect of evacuation for typical plants in Japan.

1. Provide technical background for discussion of safety goals.
2. Provide support for formulation and revision of nuclear emergency response guideline.

Previous Research (1/2)

- Introduction of MACCS (1993) and MACCS2 (1997)
- Preparation of Japanese site data
- Level 3 PRA for BWR and PWR plants using MACCS2
  - Internal events (under operation / shutdown)
  - Seismic events (under operation / shutdown)

Technical Report
Study on Level 3 PSA for internal events (BWR), JNES/SAE05-003, June 2005
Study on Level 3 PSA for internal events (PWR), JNES/SAE05-008, August 2005

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"Performance Goals for Light Water Nuclear Power Reactor Facilities", Special Committee of Nuclear Safety Commission, March 2006.

Previous Research (2/2)

- MACCS2 analyses for emergency preparedness and responses
  - Fukushima Dai-ichi NPP accident analysis (2011)
  - Nuclear Emergency Response Guideline (2012)
- Development of methodology for multi-unit
  - Application of multiple source superposition evaluation model
  - Frequency per combination of release categories
- Incorporation of revised evacuation models

Development of Methodology for Multi-unit

Development of Methodology for Multi-unit

Background

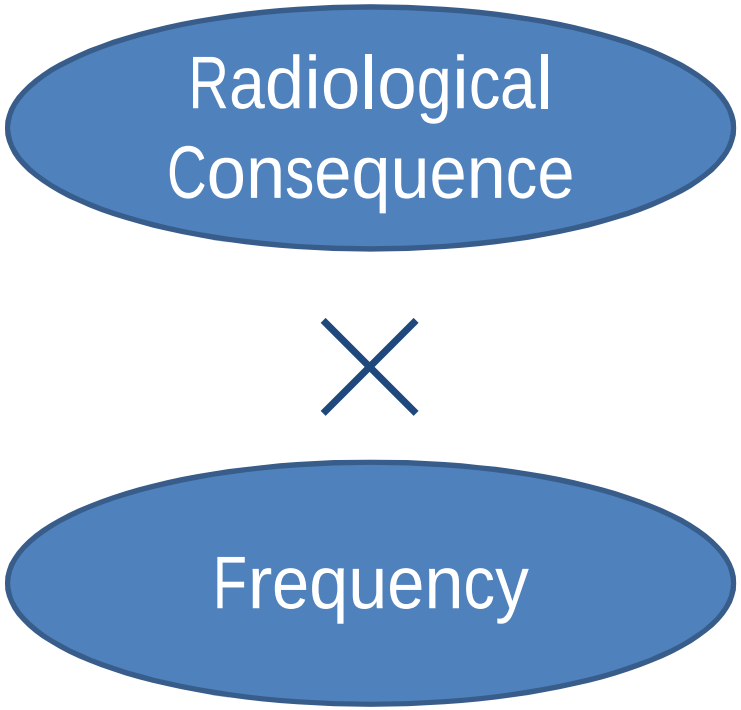
- "Interim Report on the Investigation and Review of Safety Goals" released by Special Committee of Nuclear Safety Commission on December 2003 proposed "per site" evaluation.

Situation in Japan

- Most NPPs have multiple units, distances from each unit to its site boundary are relatively short, and population density around NPP is relatively high.
- Multiple units were actually damaged in the accident at TEPCO's Fukushima Dai-ichi Nuclear Power Plant.

Development of Methodology for Multi-unit

Approach



- Superposition of Concentration
- Superposition of wind direction appearance frequency

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MACCS2 modification

- Containment Failure Frequency required for each combination of release categories

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FreCTooL

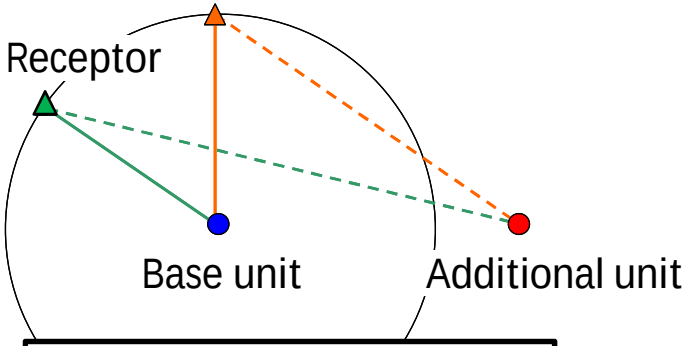
(Frequency Calculation Tool for Level 3 PRA)

Development of Methodology for Multi-unit

☐Application of multiple source superposition evaluation model

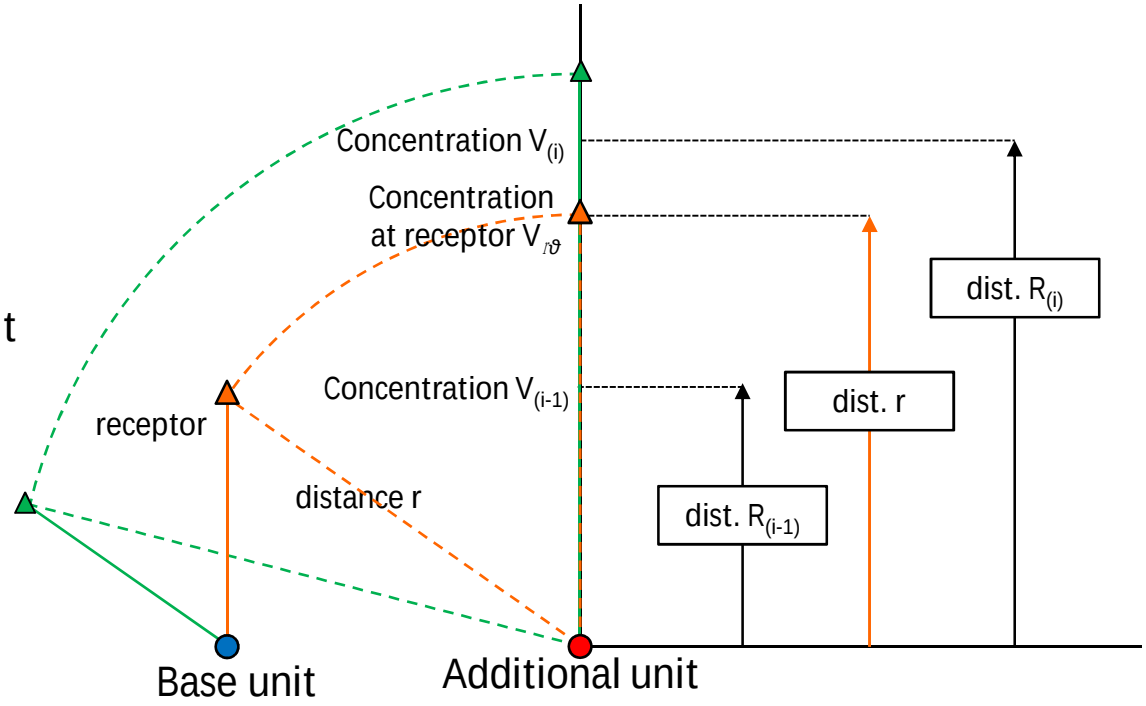
Superposition of concentration

1. Spatial mesh is defined based on distances and directions from the base unit.
2. Concentration due to releases from additional units at the receptor of each spatial mesh are calculated by linear interpolation



Distance and direction from additional unit to the receptor vary

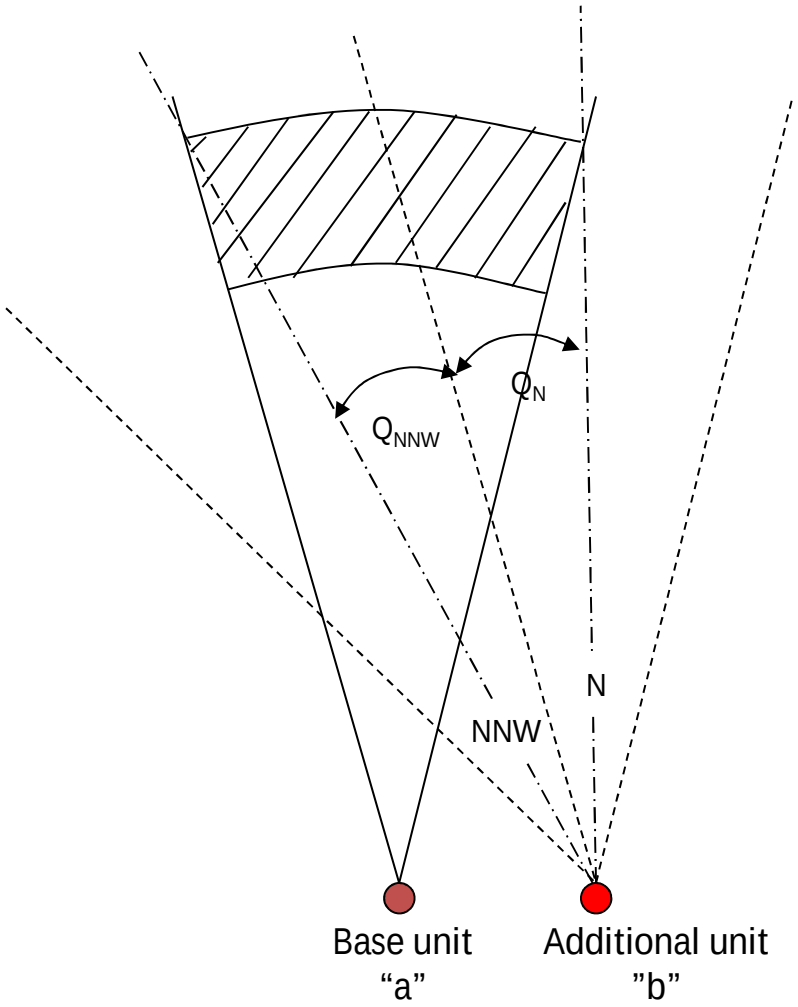
Distance and direction (16 azimuth directions) at each spatial mesh are saved.



Reference) Japan Nuclear Energy Safety Organization, "Development of Level 3 PSA methodology", JNES/SAE06-005 (2006) (in Japanese)

Development of Methodology for Multi-unit

Superposition of wind direction appearance frequency



Ex. In the case where base unit “a” and additional unit “b” is located as shown in the figure,

Wind direction appearance frequency f_b toward shaded area (north direction of a base unit) from an additional unit “b” is calculated as follows:

$$f_b = f_N\left(Q_N/\frac{\pi}{8}\right) + f_{NNW}\left(Q_{NNW}/\frac{\pi}{8}\right)$$

f_N : north wind frequency

f_{NNW} : north-northwest wind frequency

Q_N : angle in radians that north direction of unit “b” and shaded area overlaps

Q_{NNW} : angle in radians that north-northwest direction of unit “b” and shaded area overlaps

Calculate wind direction appearance frequency of additional units by repeating the calculation above for all meshes.

Reference) Japan Nuclear Energy Safety Organization, “Development of Level 3 PSA methodology", JNES/SAE06-005 (2006) (in Japanese)

Development of Methodology for Multi-unit

Frequency Calculation Tool

Multiple unit Level 1 PRA output

Combination of accident sequences
(result of Monte-Carlo sampling from SECOM2-DQFM)

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Single unit Level 2 PRA output

Conditional containment failure probability of release categories

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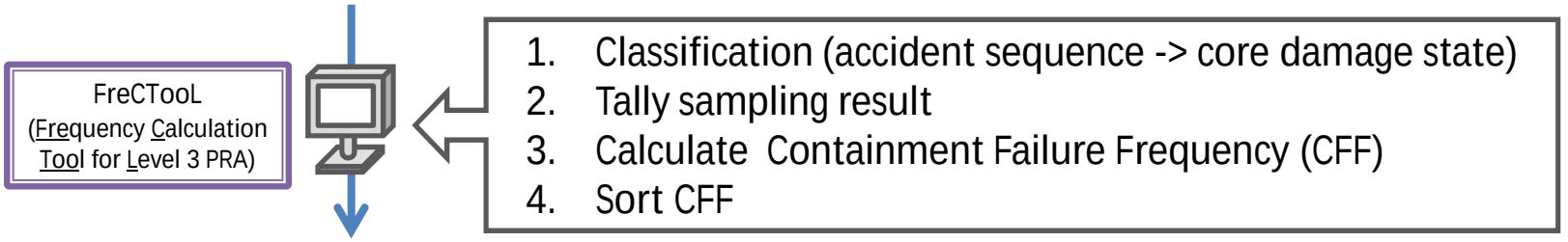
Seismic Hazard



Frequency necessary in Level 3 PRA

Containment Failure Frequency for each combination of release categories.

Incorporation of revised evacuation model

Incorporation of revised evacuation model

Background

Based on its effectiveness and credibility evaluation, … protection measures should be appropriately considered as risk reduction measures to fulfill safety goal

"Interim Report on the Investigation and Review on Safety Goals",
Special Committee of Nuclear Safety Commission, December 2003.

Former Guide

EPZ (Emergency Planning Zone) Approx. 8 ~ 10 km

Revised after TEPCO's Fukushima Dai-ichi NPP Accident

Revised Guide

PAZ (Precautionary Action Zone) Approx. 5 km

UPZ (Urgent Protective action Planning Zone) Approx. 30 km

1. Expansion of protective planning area
2. Phased evacuation

Nuclear Regulation Authority, "Nuclear Emergency Response Guideline", Oct. 31, 2012 (Revised Apr. 22, 2015)

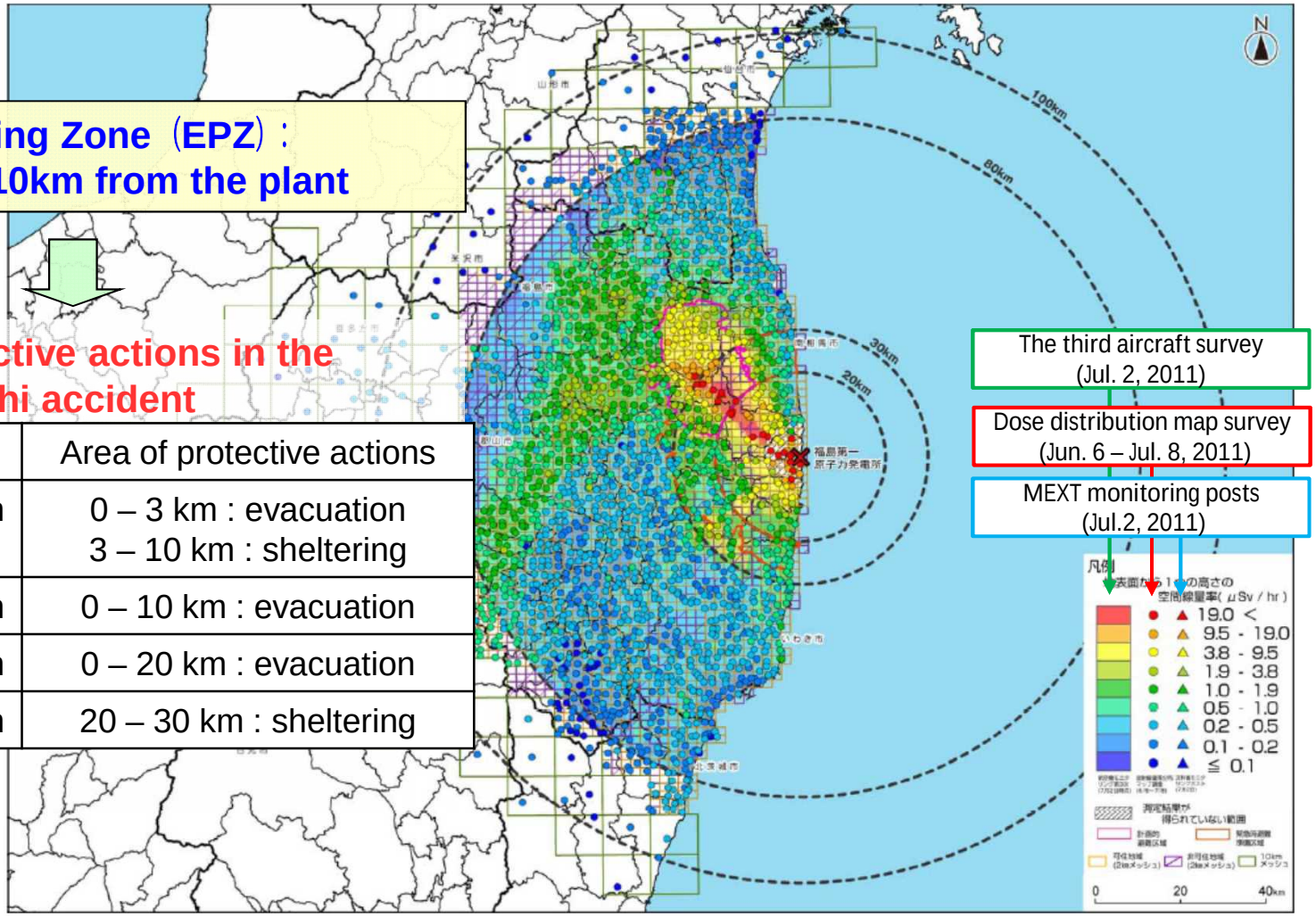
Incorporation of revised evacuation model

The area of protective actions in the Fukushima Dai-ichi accident

Emergency Planning Zone（EPZ）:
Approx. 8～10km from the plant

The area of protective actions in the Fukushima Dai-ichi accident

day	time	Area of protective actions
Mar. 11	9:23 pm	0 – 3 km : evacuation 3 – 10 km : sheltering
Mar. 12	5:44 am	0 – 10 km : evacuation
Mar. 12	6:25 pm	0 – 20 km : evacuation
Mar. 15	11:00 am	20 – 30 km : sheltering



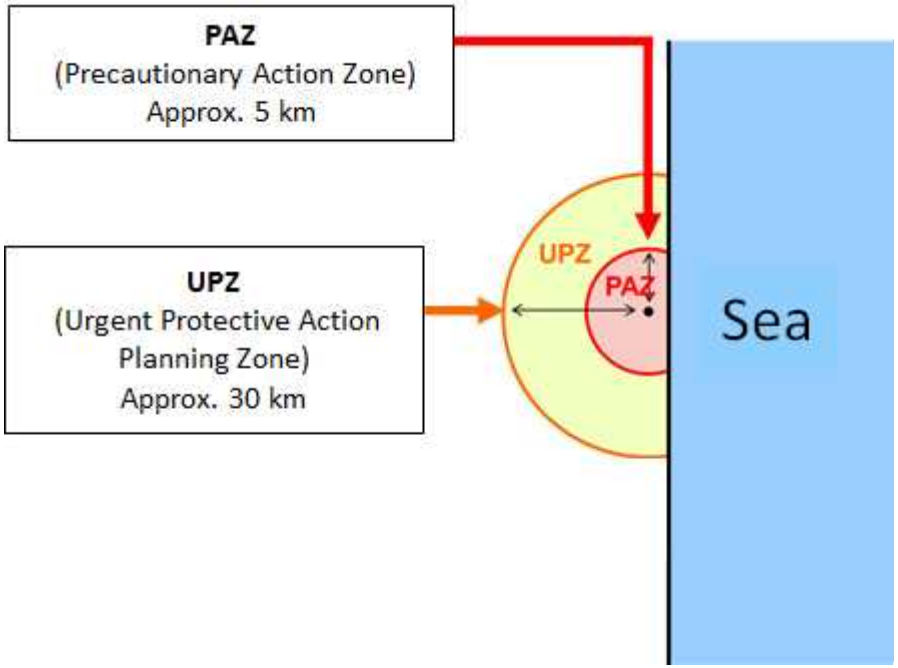
Reference) MEXT, “Amendment of “Preparation of Distribution Map of Radiation Doses, etc. (Air Dose Rate Map) by MEXT” Released on August 2”, att.2, August 12, 2011.

Incorporation of revised evacuation model

Image of PAZ and UPZ

PAZ (Precautionary Action Zone): Around 5 km in radius from a nuclear power station
This is the zone where residents take swift actions (e.g., evacuation) before a release of radioactive material to the environment that is caused by nuclear accident.

UPZ (Urgent Protective action Planning Zone): Approximately between 5 and 30 km in radius
This is the zone where residents take actions (e.g., sheltering, intake of iodine tablets) based on the emergency action level (EAL) and the operational intervention level (OIL) with environmental monitoring data.



Reference) Nuclear Regulation Authority, “Nuclear Emergency Response Guideline”, Oct. 31, 2012 (Revised Apr. 22, 2015)

Incorporation of revised evacuation model

Approach (1/2)

- Use different evacuation scenario
  - PAZ (- 5 km) … Prompt evacuation
    - Evacuate after assumed delay time
  - UPZ (5 - 30 km) … Phased evacuation
    - Shelter after assumed delay time; Evacuate after plume pass through

- Time needed for plumes to pass through vary depending on accident scenarios and distances from a release point

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- In order to set evacuation time after the passage of plume, evacuation parameters are set depending on release timings and distances

Incorporation of revised evacuation model

Approach (2/2)

If plume is released after delay time for sheltering

- Set reference time point (REFPNT) to ARRIVAL
- Sheltering already finished at REFPNT

Evacuation delay time (after ARRIVAL) = Plume duration + α

<Assumption>
Example of α :
5 hr (5 - 13 km)
12 hr (13 - 20 km)
24 hr (20 - 30 km)

If plume is released before delay time for sheltering

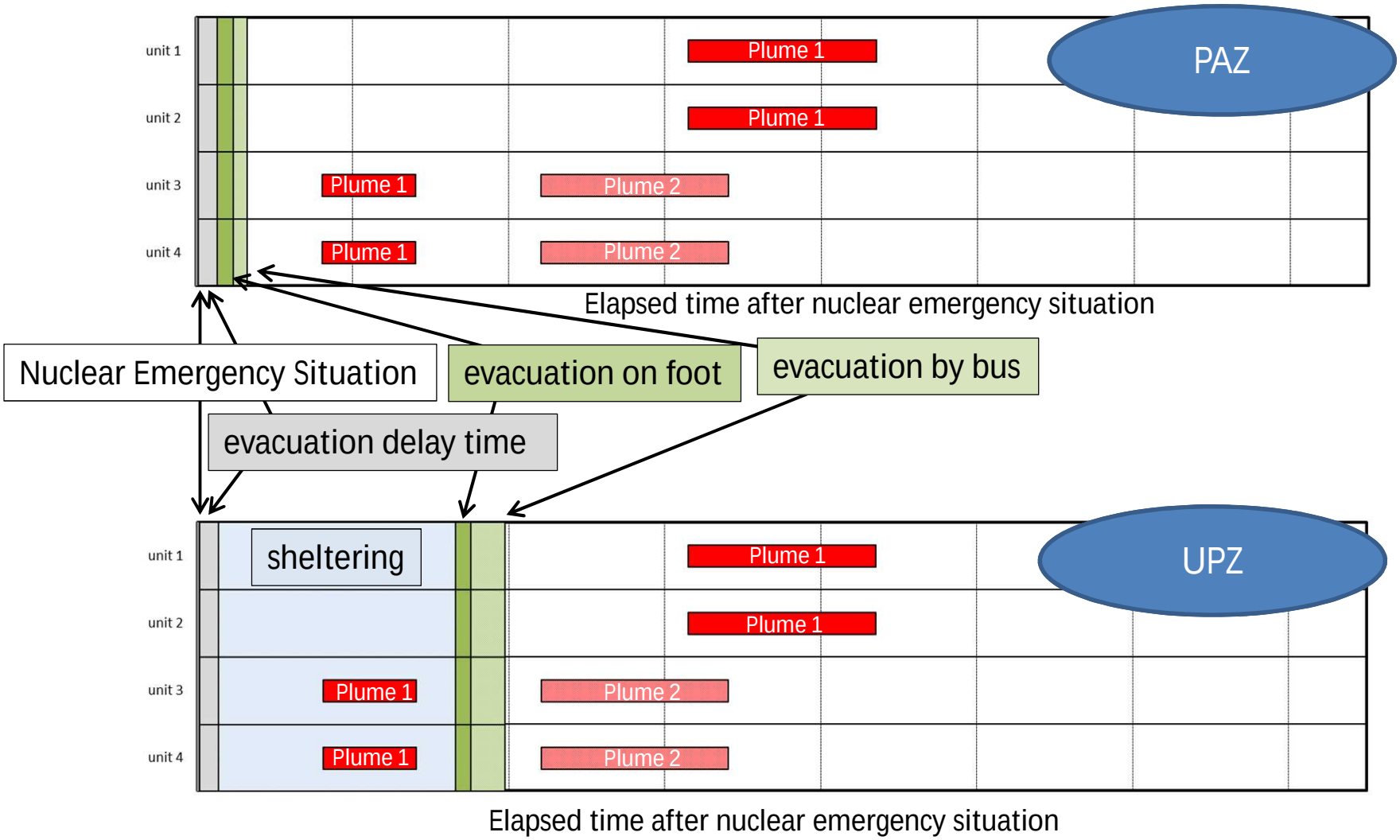
- Set reference time point (REFPNT) to ALARM
- Start sheltering after assumed delay time

Evacuation delay time (after ALARM) = Release time + Plume duration - ALARM time + α

Note:
Depending on atmospheric condition, evacuation could start before the passage of plume.

Incorporation of revised evacuation model

Example of evacuation model



Current Research

- PRA study for external events
  - Multiple unit PRA
  - PRA with Accident Management

- Introduction of OSCAAR
  - Modification of OSCAAR and preparation of latest site data (commissioned to JAEA), mainly intended for use in supporting emergency planning.

*OSCAAR : Level 3 PRA code developed by Japan Atomic Energy Agency.

Summary

- The purposes of Level 3 PRA study in S/NRA/R are to provide technical background for formulation and revision of safety goals and to provide support for emergency planning and responses.
- For these purposes, MACCS2 has been introduced.
- Analysis results has been incorporated in the report on performance goals released by Special Committee of Nuclear Safety Commission.
- Methodology for a multiple unit site was developed and revised evacuation model was incorporated.