警察庁 National Police Agency

NRIPS

Radiological Equipments for First Responders

K. Kuroki

National Research Institute of Police Science, Japan

安心・安全社会構築のための研究開発連携国際セミナー
テロ対策技術の最新動向と国際連携（2010.10.8）

NRIPS

Contents

- Radiological terrorism threat
  - What type of R-terrorism may be happen?
    - Radiological Dispersal Device (RDD) ?
    - Radiological Exposure Device (RED) ?
- Radiological equipments for first responders
  - Wire-less devices
  - Operation in high dose rate
    - Must functional in high dose rate over 1Sv/h
  - Prompt criticality and sustained criticality
    - Must functional after prompt criticality
- Remaining problem

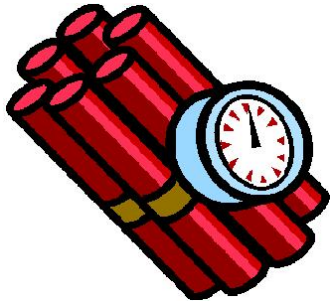
NRIPS

Radiological terrorism threat (1)

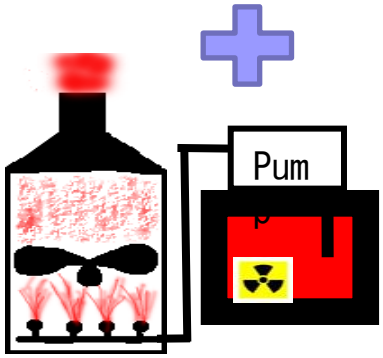
- **Radiological Dispersal Device (RDD) or Dirty Bomb**

(Cs-137, Co-60, Ir-192, Spent Nuclear Fuel, etc.
with conventional explosive or spraying device)

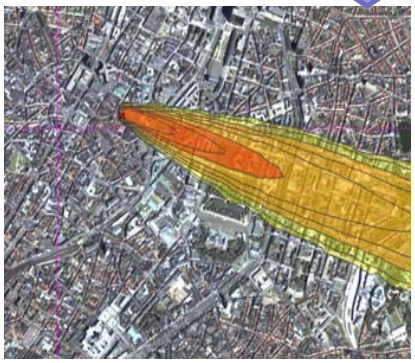
Source for medical therapy and diagnostic machine



Explosive



RI-solution spraying device



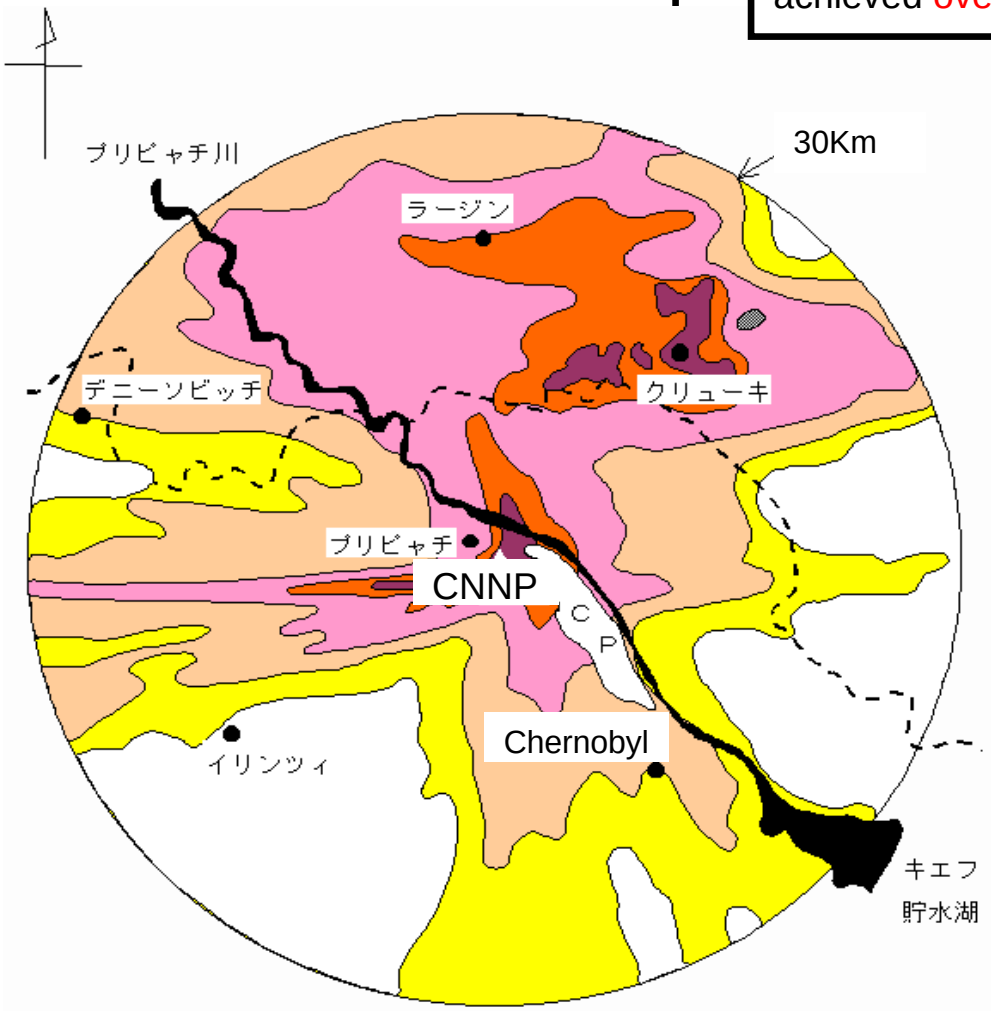
Wide area contamination
- **Major City**
- **Amusement Park**
- **Sports Stadiums**
- **Airport, Seaport, etc**

Particle including radioactivity will be spread

Chernobyl Disaster Contamination Map

If RI of several 1000Ci is efficiently scattered, the same degree of the polluted district as the strongest polluted area in Chernobyl nuclear accident can be achieved over several Km square.

NRIPS



Cs-137 contamination

(Ci／km^2)

	1000 or Higher
	500~1000
	100~500
	20~100
	5 ~20
	5 or Lower

CNPP: **Chernobyl Nuclear Power Plant**

CP : **Cooling Pond**

----- : **Belarus-Ukraine Border**

Radiological terrorism threat (2)

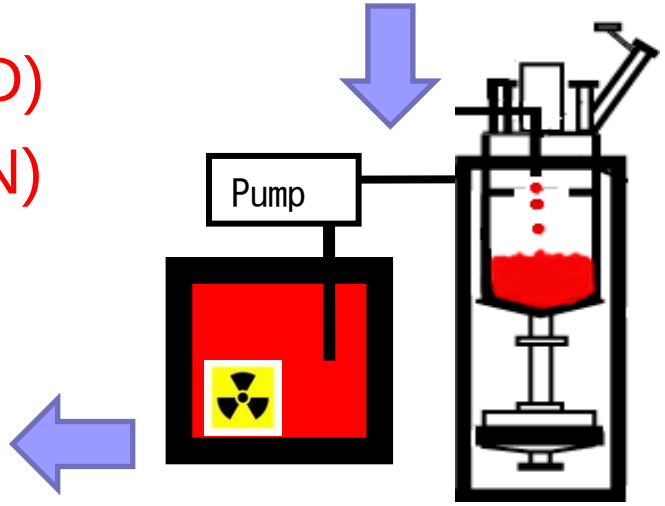
NRIPS

- Nuclear criticality accident at Tokai-mura, Japan on Sep. 30 1999: 370 gU/liter (3.12 kg U-235)

Criticality : 20hours → total $2.5*10^{18}$ fissions
2 Dead 6-10Sv,16-20Sv:1injured 1-4.5Sv
7 workers >50mSv
3 rescue members and
112 public person exposed to neutron radiation

- Radiological Exposure Device(RED) using special nuclear material(SMN)

Sustained nuclear criticality
High dose area → Wide area
(JCO case:350m Evacuation Request)



NRIPS

Dose limit for first responders

Low Dose

Dose limit of public people 1mSv/year
Annual dose(avg@Japan) 2.4mSv/year
X-ray CT 2-10mSv

Stolen Ir-192 370GBq (bare RI : 50mSv/h@1m)

Nuclear criticality accident at Tokai on 1999（>1mSv/h@100m）
3 rescue members 13mSv(calculation)
Criticality-stop-worker 6workers>50mSv, 1worker>100mSv

Dose limit of first responders in emergency work（Lifesaving…）

	Japan	100mSv
	NCRP(USA)	500mSv
	IAEA	1000mSv

Nuclear criticality accident
1 worker(recovered) 1-4.5Sv
LD50（30）(50%Dead in 30 days）4Sv(400rem)
2 workers dead 6-10,16-20Sv

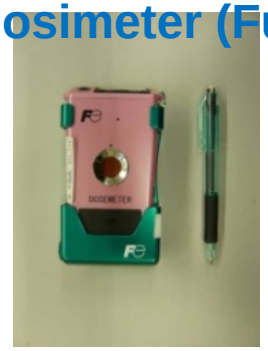
High Dose

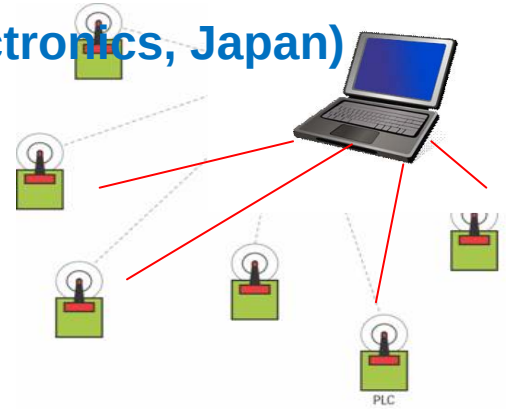
Development of radiation protection system for first responders

NRIPS

- **Why we need wire-less devices?**
  - Dose control of individual members at site
    - **Real time monitor system** for personal dose at site
    - Dose monitoring should be done by back-support team
  - Inform the change of radiation field to each member
    - Gamma → Gamma Neutron

- **Real-time acquisition system of individual dose**
  - Wireless real-time dosimeter (Fuji electronics, Japan)





NRIPS

Evaluation of the durability to radiation

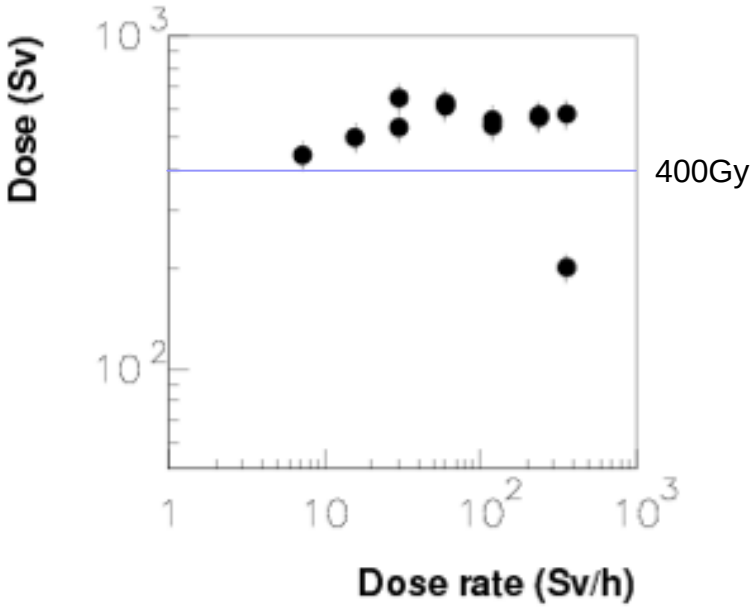
- **Radiation Sources**
  - **X-ray (130keV,300uA)**
  - **Gamma-ray(Co60,1PBq)ATOX**
  - **Neutron(Cf252,400mBq,Standard field)AIST**
  - **Neutron Gamma (TRACY,~20MJ)JAEA**
- **Target Equipments**
  - **AVR microcontrollers**
  - **Wireless network device (1) 2.4GHz**
  - **Wireless network device (2) 303MHz**
  - **Wireless real-time dosimeter**
  - **Real-time dosimeter**

Durability to Radiation

X-ray and Gamma-ray（3Sv/h～100Sv/h）

NRIPS

Total ionizing dose (TID) and dose rate for X-ray irradiation of AVR microcontrollers



TID
for Gamma-ray irradiation (Co-60)

Dose rate of irradiation	AVR microcontrollers	Wireless network device (1) 2.4GHz	Wireless network device (2) 303MHz
100Gy/h	510±22 Gy	484±111 Gy	429±14 Gy
10Gy/h	502±24 Gy	>550Gy	283 Gy
3Gy/h	>165Gy	>165Gy	>165Gy

The TID for electronic modules are significantly higher than median lethal dose(LD50) 4Sv(Gy)

NRIPS

Durability to Radiation

Neutron and gamma-ray (criticality field)

Criticality radiation field

Prompt criticality followed by sustained criticality

***Can the dosimeters work after prompt criticality (neutron-gamma burst)?**

***Can the dosimeters work in high dose rate field (neutron-gamma >6Sv/h at JCO case)?**

TRACY
(Transient Experiment Critical Facility)
Pulsed reactor using 10-wt%-enriched uranium nitrate solution as fuel in the Japan Atomic Energy Agency(JAEA)

NRIPS

Durability to Radiation

Neutron and gamma-ray (criticality field ~6Sv/h)

ADM-353（Aloka,Japan）
gamma：0.01mSv-1mSv
neutron：0.1-1000mSv
Warning : Vibration

NRG13 (Fuji Electronics, Japan)
gamma: 0.1-1000mSv
neutron: 0.3-1000mSv
Wireless network

DMC2000GN (Synodys)
gamma：1μSv-10Sv
neutron：10μSv-10Sv
High dose

Durability to Radiation

Neutron and gamma-ray (prompt criticality ~20MJ)

NRIPS

ADM-353（Aloka,Japan）

Can not measure prompt dose!

Work as dosimeter after prompt Criticality.

NRG13 (Fuji Electronics, Japan)

Can not measure prompt dose.

Wire-less module stop.

Resumed by Power off reset

Work as dosimeter after prompt Criticality

DMC2000GN (Synodys)

Can not measure prompt dose!

Work as dosimeter after prompt Criticality.

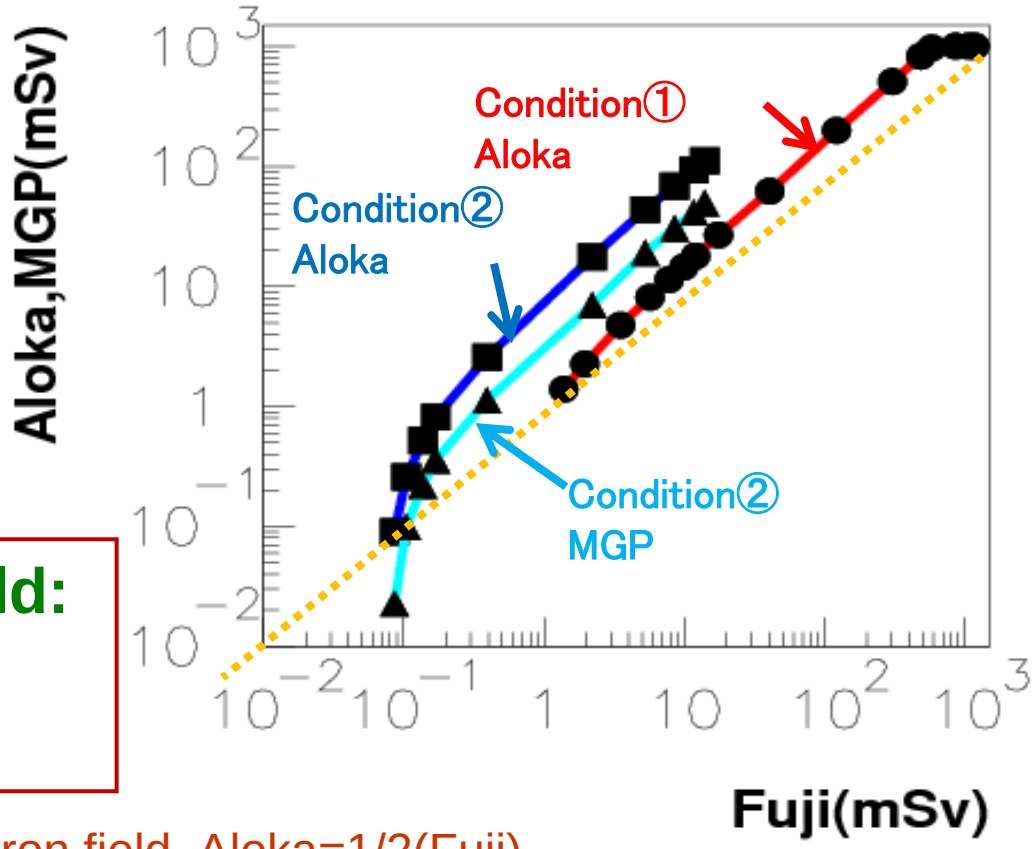
NRIPS

Remaining problem

Accuracy of neutron dosimeter

Exposure condition
TRACY 100W output

①Direct exposure
Distance from the reactor core
1.5m,5m
②Exposure with water shield
(30cm)
Distance from the reactor core
5m



In the same neutron field:
The dose display value changes by ten times.

In Cf252 neutron field Aloka=1/2(Fuji)

Summary

NRIPS

- The electronic module used in dosimeter work at over 100Sv/h gamma field
- The wire-less real time dose monitor system work in high dose rate (Neutron Gamma ~6Sv/h)
- The wire-less real time dose monitor system work after prompt criticality
- **The value of the dose display is ten times different according to the dosimeter in the same radiation condition**

- 共同研究機関
  - 産業技術総合研究所（AIST）
  - 日本原子力研究開発機構（JAEA)