



Lessons Learned from Criticality Accident in Tokai-mura (I) Outline of the Accident

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*** Japan Atomic Energy Research Institute (JAERI) and Japan Nuclear Cycle Development Institute (JNC) have been unified and become Japan Atomic Energy Agency (JAEA) on 1 October 2005.**

Victims

Nuclear criticality continued for 20 hours!

**30
September
1999**

C

**2 - 3 GyEq;
alive**

**6 - 9
GyEq;
died
210
days
later**

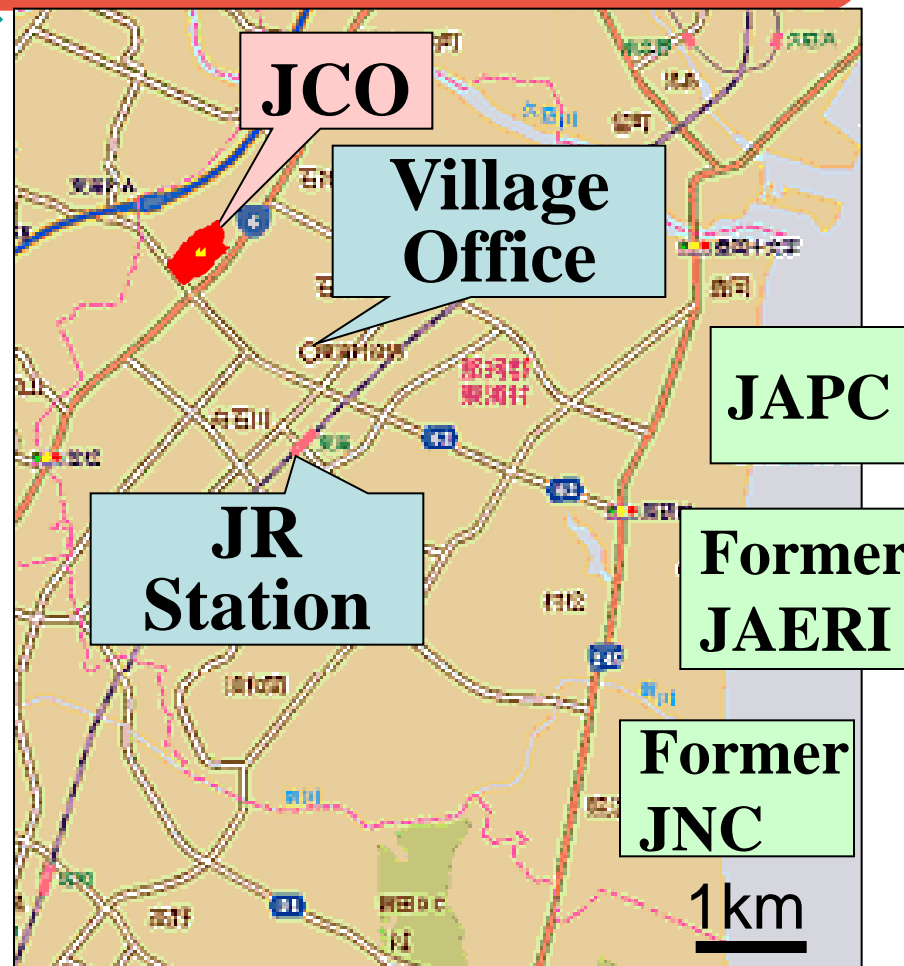
B

A

**16 - 25 GyEq;
died 82 days later**

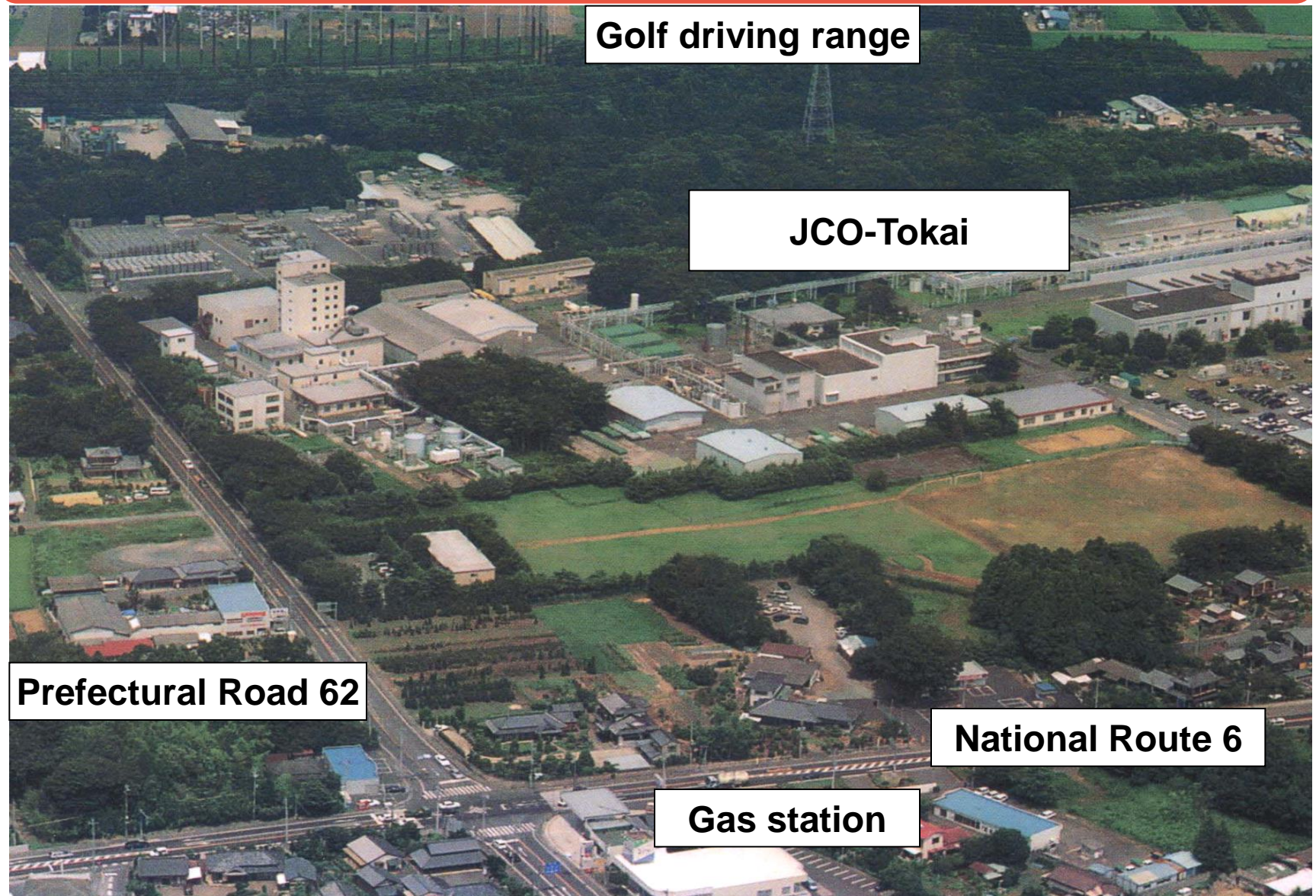
**18.8 wt%-
enriched U
in
 $\text{UO}_2(\text{NO}_3)_2$
solution,
370gU/L**

Where is Tokai-mura?



Tokai-mura

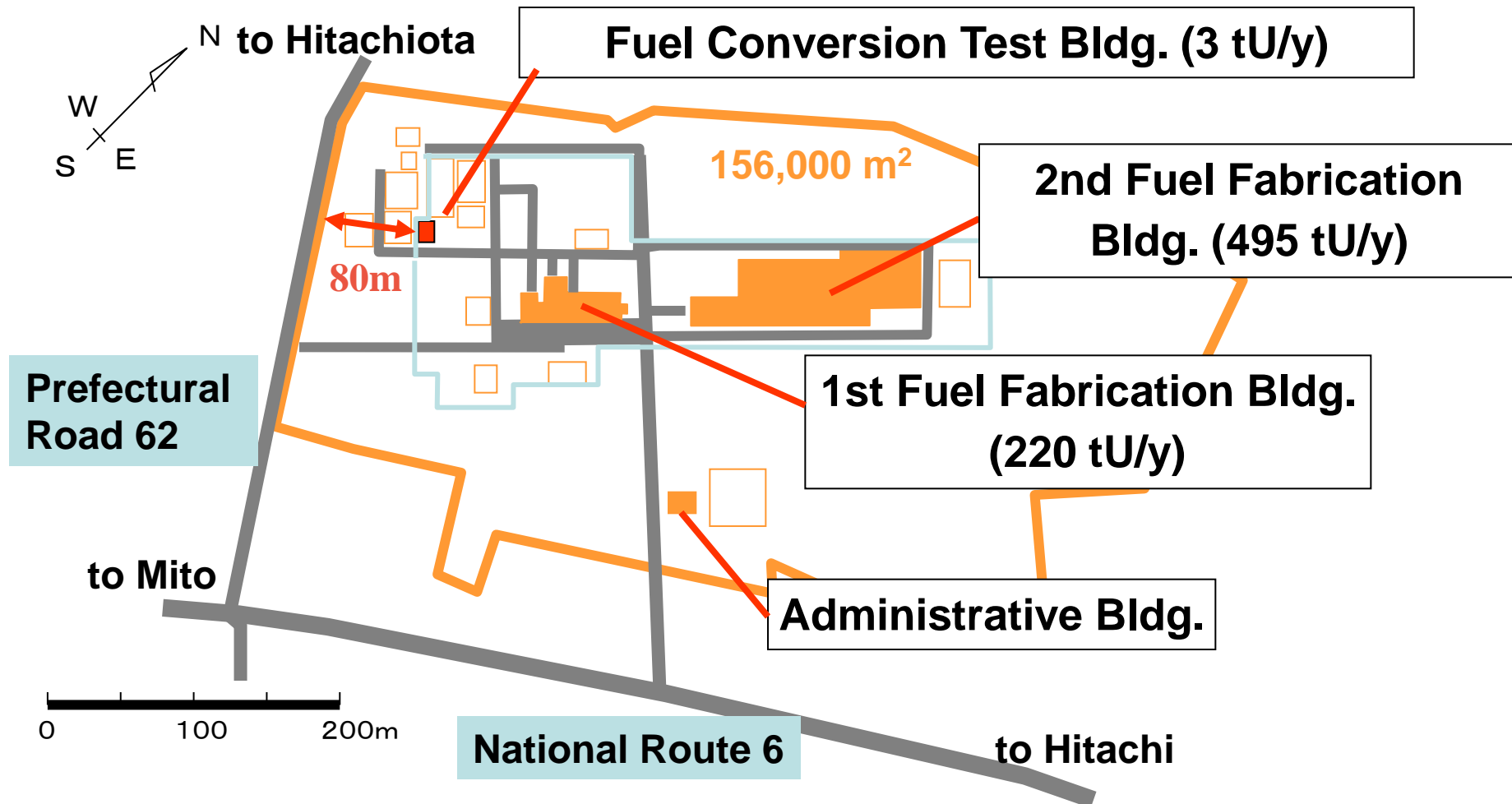
Vicinity of JCO



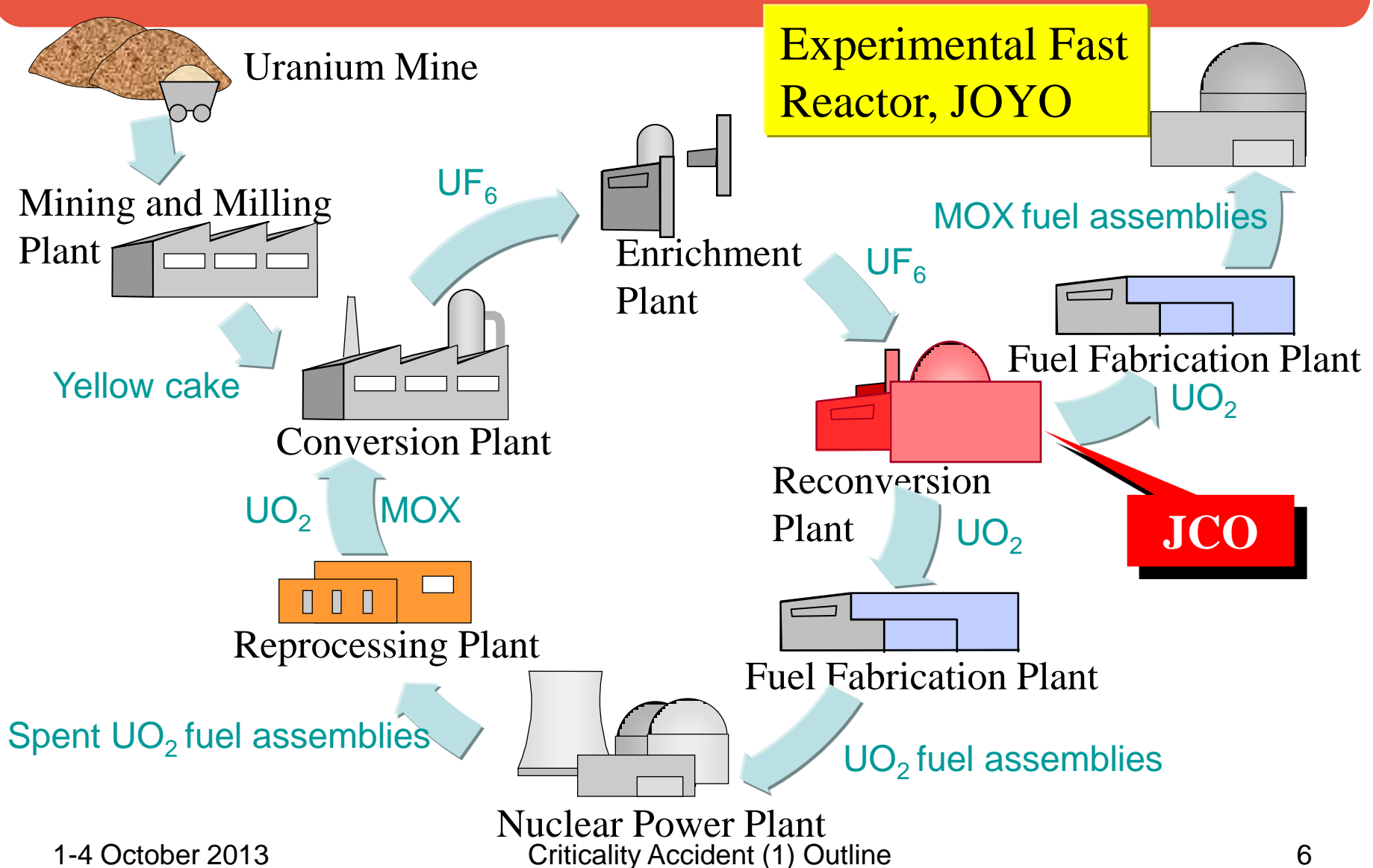
1-4 October 2013

Criticality Accident (1) Outline

JCO Site



Main Role of JCO in Nuclear Fuel Cycle

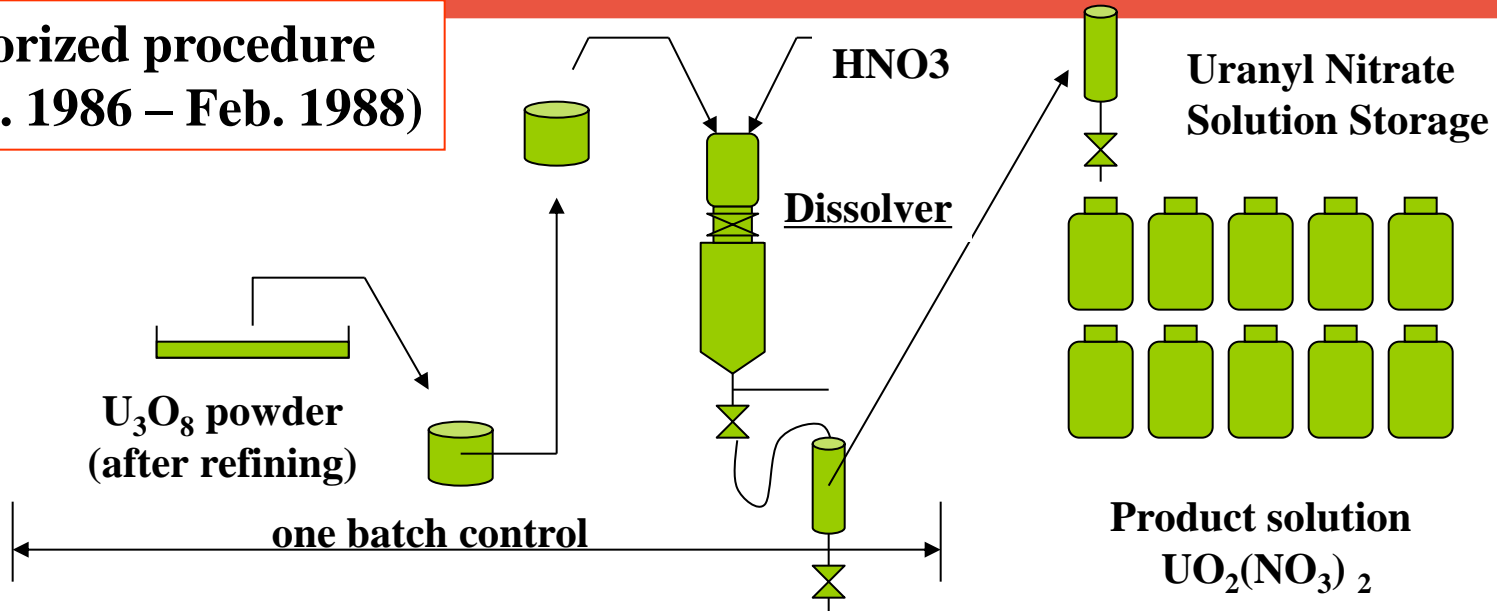


Consignment from Former JNC

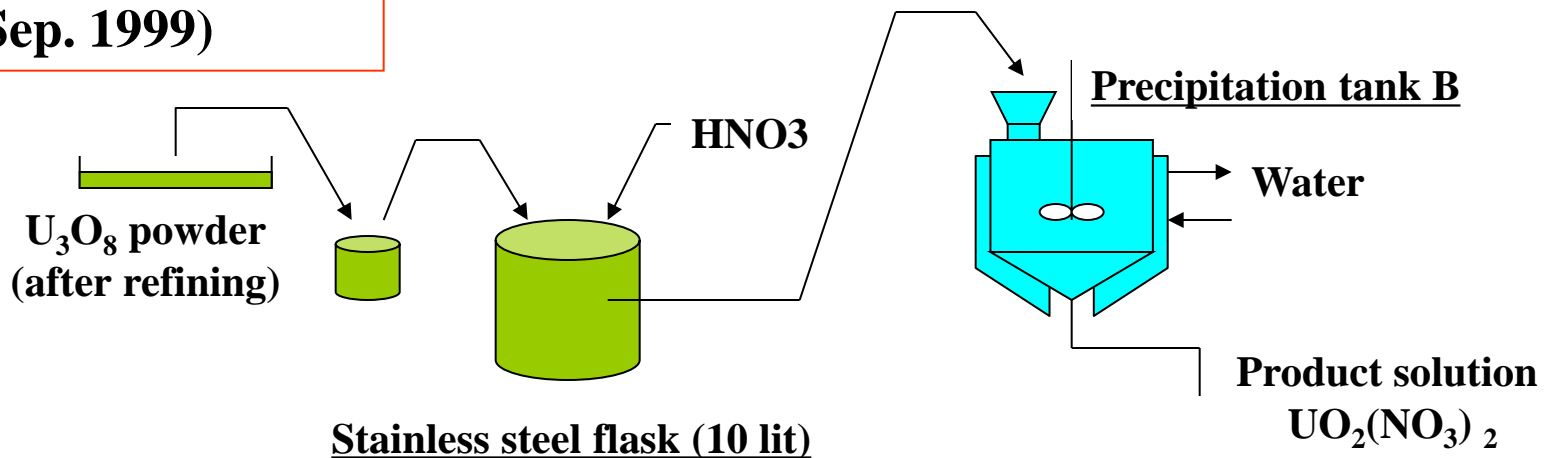
- **To obtain homogeneous uranium nitrate solution from U_3O_8 powder of 18.8 uranium enrichment to make a test fuel for the Experiment Fast Breeder, Joyo of the former Japan Nuclear Cycle Development Institute (JNC).**

Simplified Process

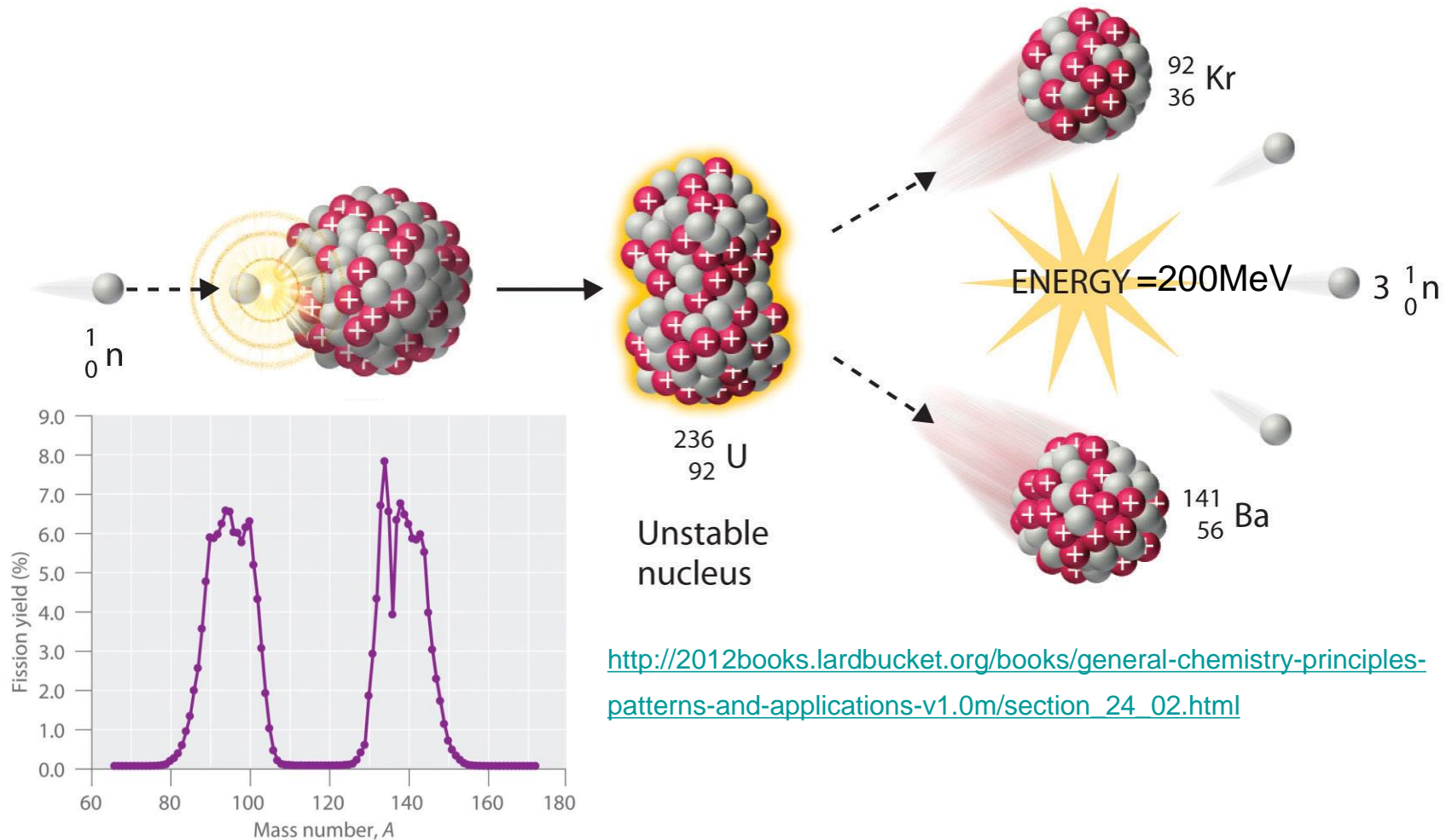
**Authorized procedure
(Oct. 1986 – Feb. 1988)**



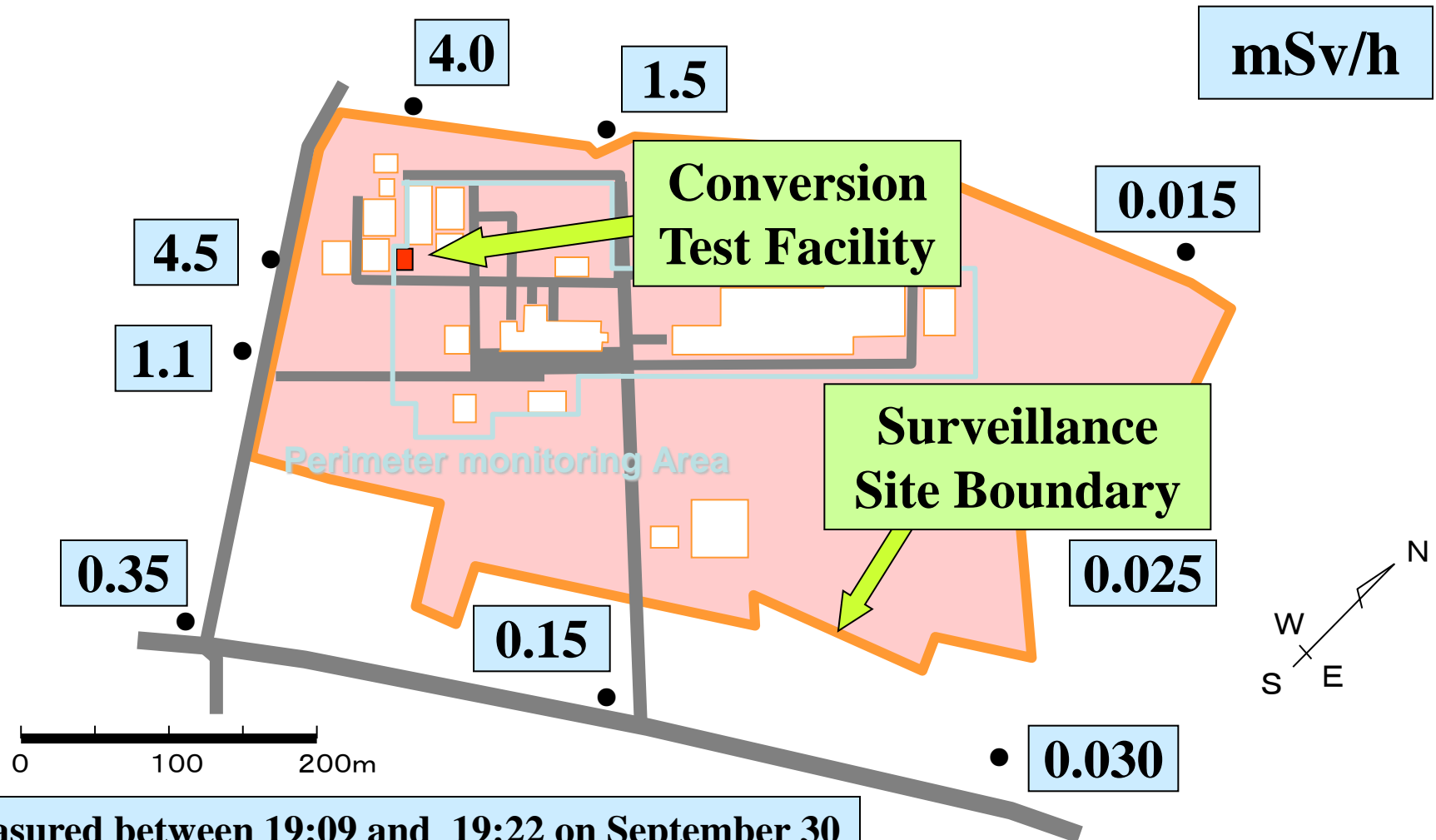
**Actual procedure
(Sep. 1999)**



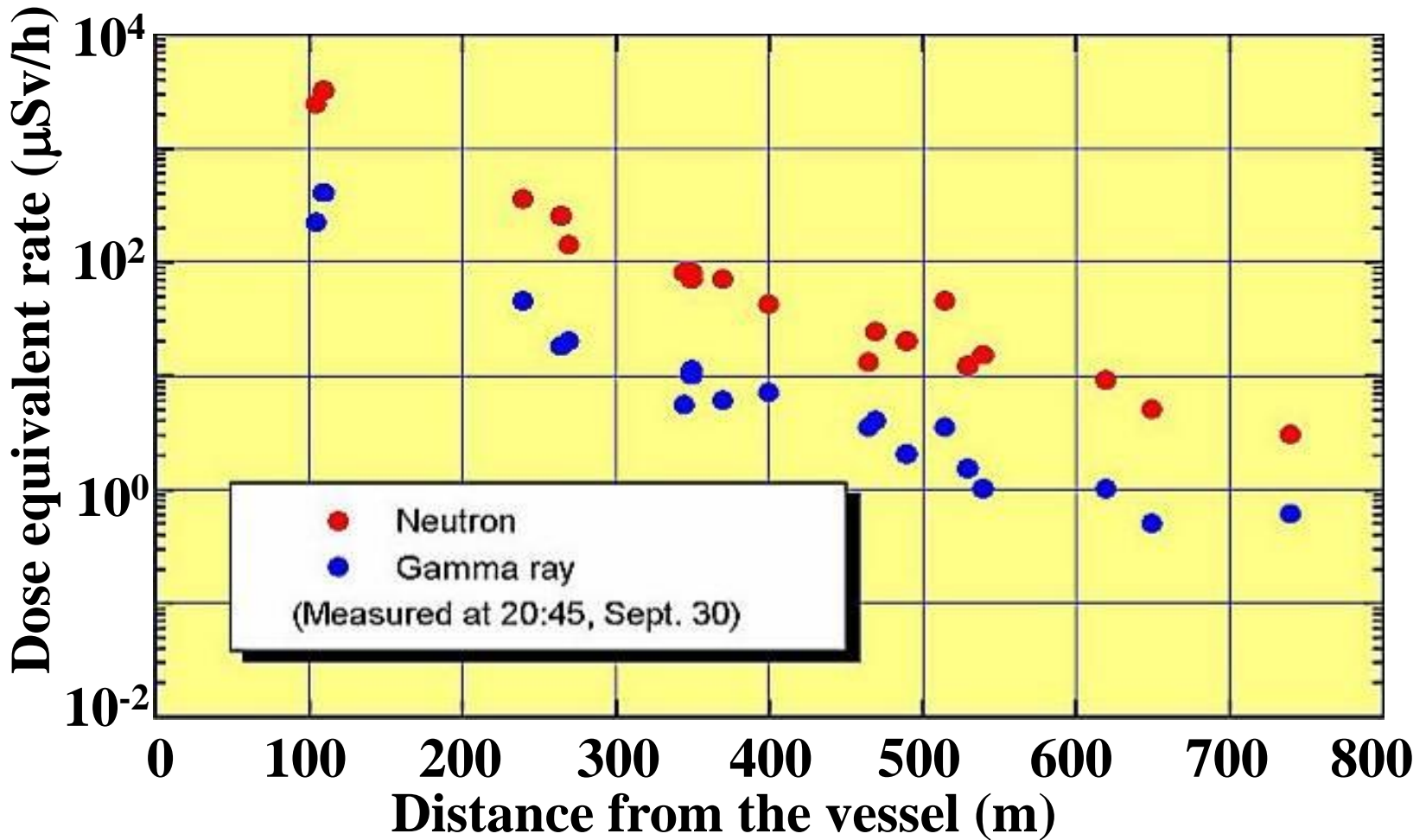
What is Induced by a Fission?



Neutron Dose Equivalent Rate Measured at the Site Boundary

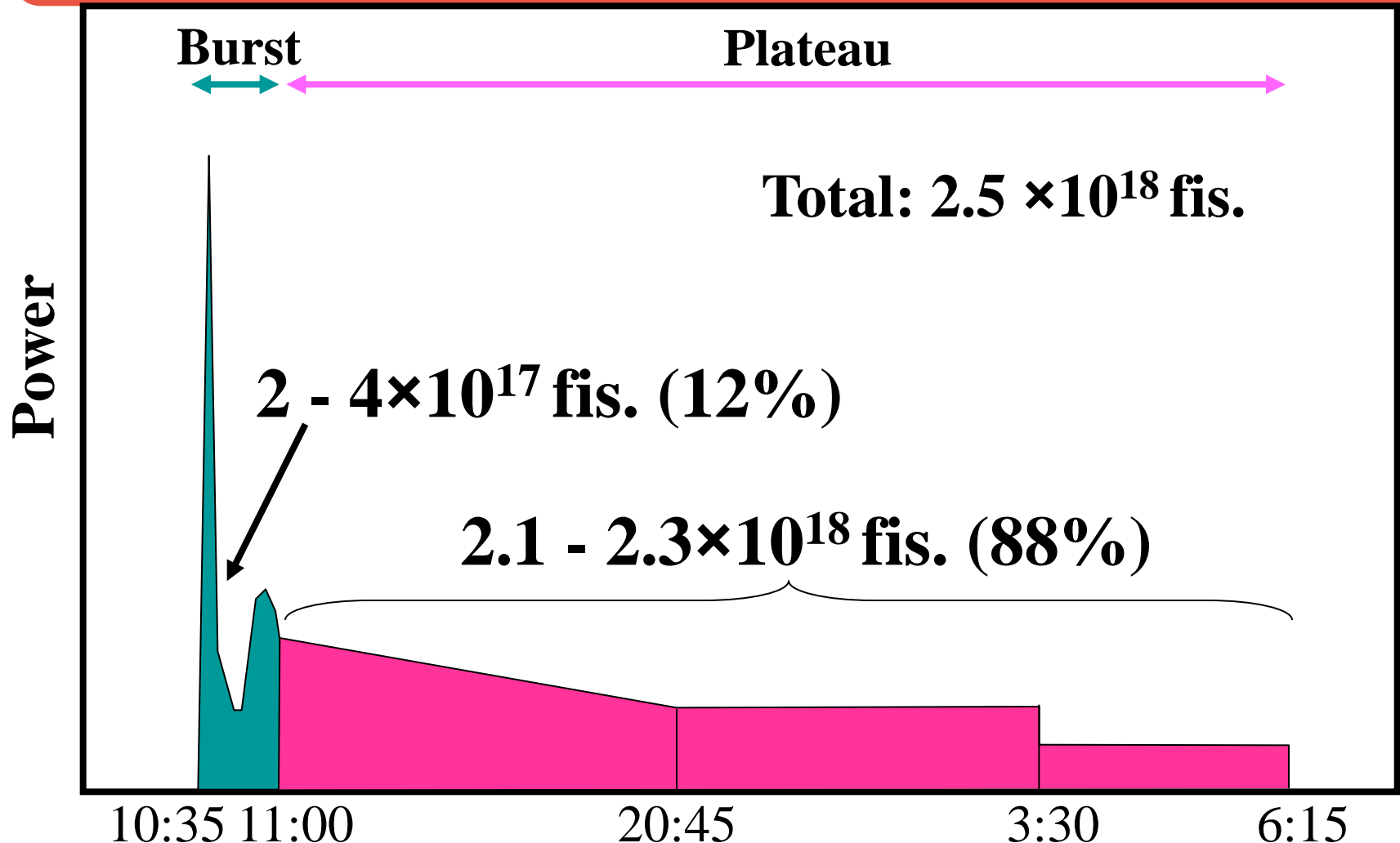


Neutron/Gamma Dose Equivalent Rates Measured near JCO



<http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAERI-Tech-2000-074.pdf> [in Japanese]

Estimation of Fission Behavior



Radioactivity Discharged into the Atmosphere

	Released amount (Bq)
Noble gases	1.6×10^{14}
Iodines	1.3×10^{10}

Emergency Response by JCO

Time	Action
10:35	Gamma-ray area monitors alarmed in JCO.
10:40	Collected workers on the playing ground and called over.
10:43	Called 119, telling “Looks like by <i>tenkan</i>*.”
~11:15	Sent FAX to STA, Ibaraki Pref., Tokai-mura, etc. reporting the event with a comment “nuclear criticality might occur.”
13:56	Visited Tokai-mura and requested evacuation of the nearby residents.
14:40	Same as above.

* In Japanese, both conversion and epilepsy are pronounced *tenkan*.

Emergency Response by Firefighters

Time	Action
10:46	Arrived at the main gate of JCO.
11:02	Informed by JCO that the patients suffered radiation exposure.
11:33	Requested National Mito Hospital (NMH) to accept the radiation casualties.
12:07	Arrived at NMH.
13:02	Requested the police helicopters to transfer the casualties to the NIRS.
13:43	Left the police heliport in Mito.
15:23	The casualties arrived at the NIRS.

Emergency Response by Former JNC

Time	Action
12:30	Received a call for help from JCO.
12:35	Established the JNC Support Headquarters.
After 14:30	Arrived at JCO and made a plan for counter-measuring the event.
16:30	Measured the neutron dose level as 0.6mSv/h in the administrative building of JCO.
19:30	Made gamma screening for JCO workers at Ishigami Community Center.
Next day	A hundred workers participated in making sand bags and piling them up for shielding.

M. Kanamori, "JCO Criticality Accident Termination Operation," JAEA-Technology 2009-079 (2010).

Emergency Response by Former JAERI

Time	Action
12:18	Received a call from STA.
13:10	Established the emergency Headquarters at Tokai Establishment.
14:10	Dispatched specialists in criticality safety and health physics to STA-Tokai.
~18:10	Received information on the precipitation tank of JCO.
~22:00	Estimated that the tank might become subcritical when water would be drained out from the water jacket of the tank.

Emergency Response by Local Residents

Time	Action
12:30	The residents of Tokai-mura were announced over the community system that they should be stayed indoors, because radiological material was seemingly released from JCO where an accident was occurred at 10:35.
~15:00	The residents within 350-m-radius area were requested by Tokai-mura to evacuate.
22:30	The residents within 10-km-radius area were requested by the Governor of Ibaraki-Prefecture to stay indoors.

Lessons Learned (I)

- I. The accident was happened where it was not assumed to happen.**
 - Not at a nuclear power plant nor at a fuel reprocessing plant!**
 - Processing uranium, not plutonium!**
 - Nuclear criticality continued!**
- 2. Emergency response can be made within his/her usual habit and ability.**
 - Many workers for JCO and some first responders did not carry a personal dosimeter.**
 - Criticality calculation was performed by a JAERI researcher who used the code in his research.**

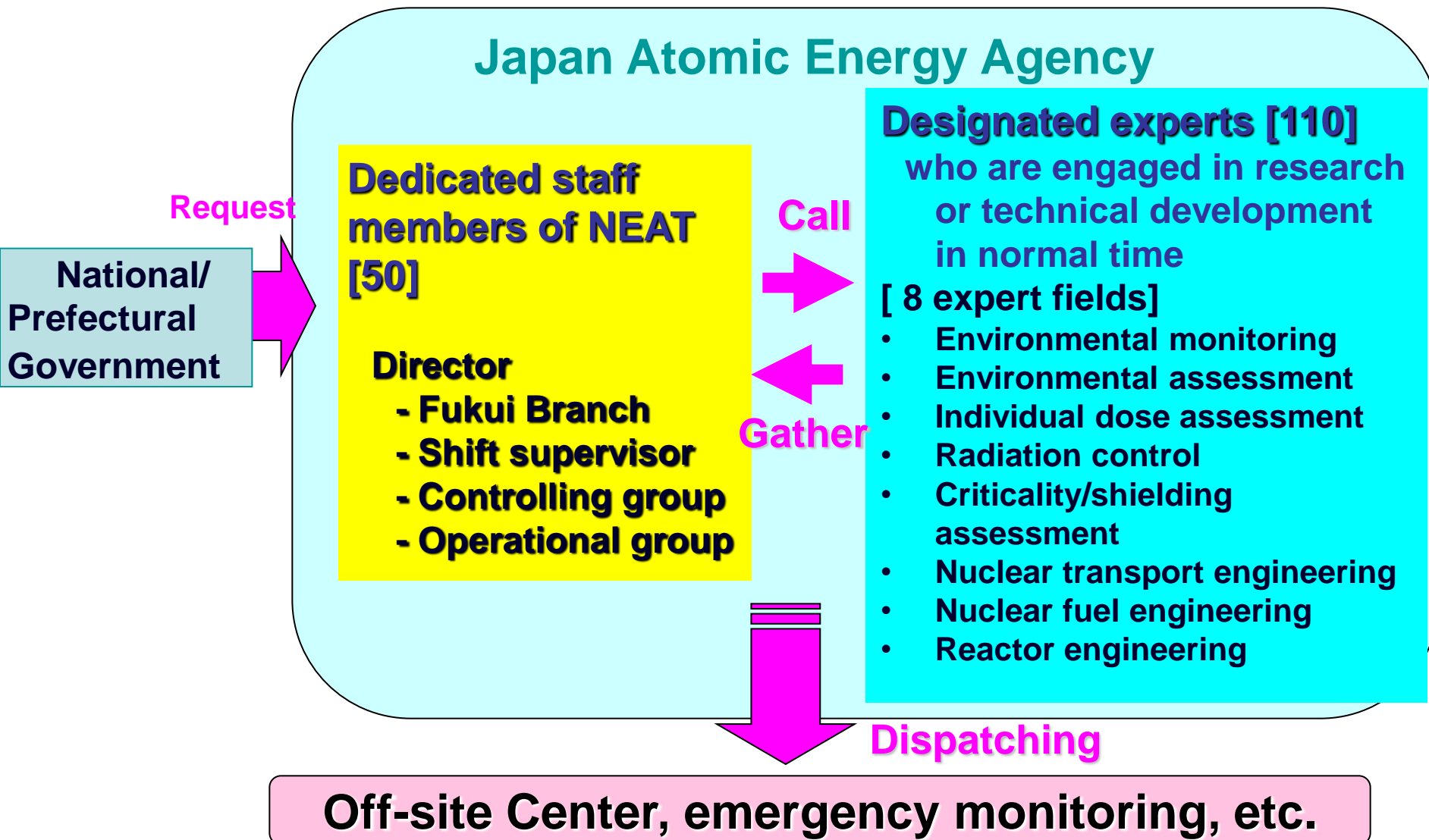
Lessons Learned (2)

- 3. Information sharing among emergency response headquarters is important.**
 - The emergency HQs of Tokai-mura was not informed of the Governor's request.
- 4. Mass communication, esp. TV broadcast, is a fast publication tool in emergency.**
 - JCO workers watched TV during the accident, not knowing what to do.
 - People at the Emergency HQs of Tokai-mura knew the Governor's request through TV news.
 - However, the national broadcast does not join the emergency exercise, because of the independence of mass media.

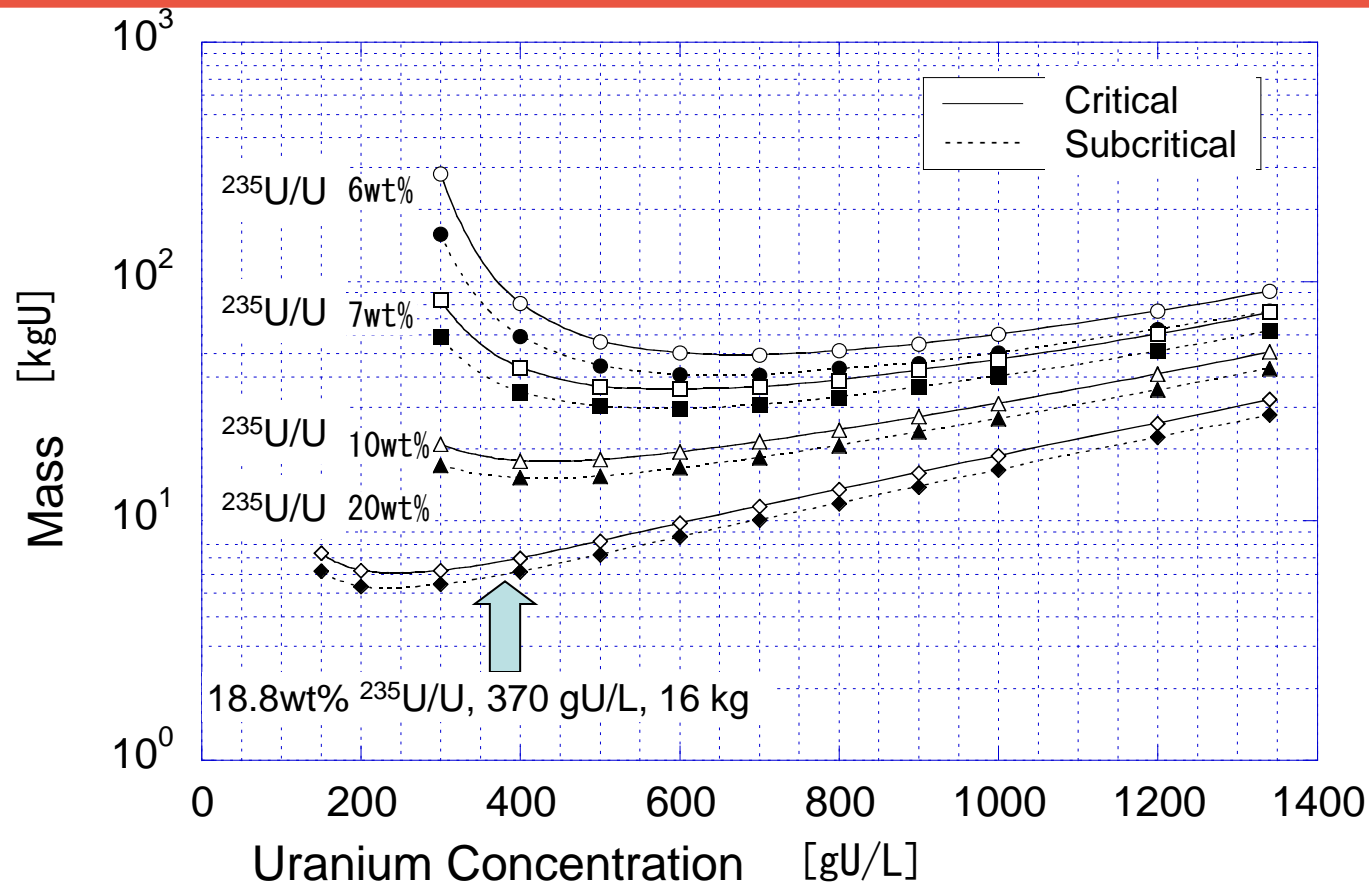
Appendices

- **JAEA/NEAT**
- **Criticality mass curves**
- **Drawing for countermeasure**
- **Memo on calculation results**

Emergency Response Structure of the Japan Atomic Energy Agency as a Designated Institute



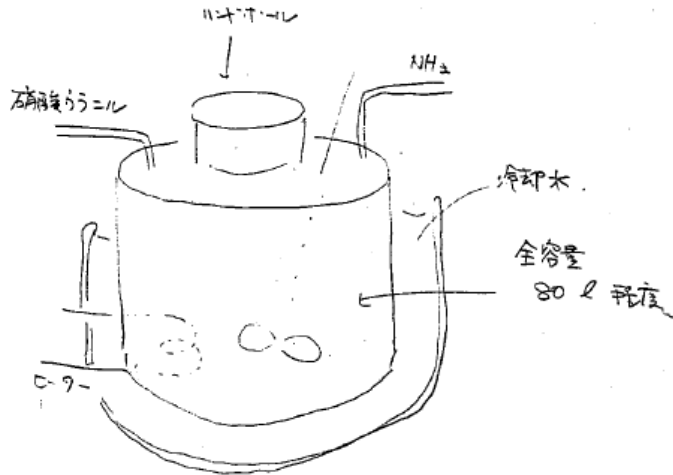
Criticality Mass Curves



Criticality mass curves for uranium nitrate solution

<http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAEA-Data-Code-2009-010.pdf> [in Japanese]

Drawing for Stopping Criticality



1. タンク内で瞬発が起る可能性がある。
2. 本来 26kg 投入するところ、16kg 投入した。
3. 流量は不明。
4. タンク周囲の冷却水が、中性子反射材となってしまう可能性がある。

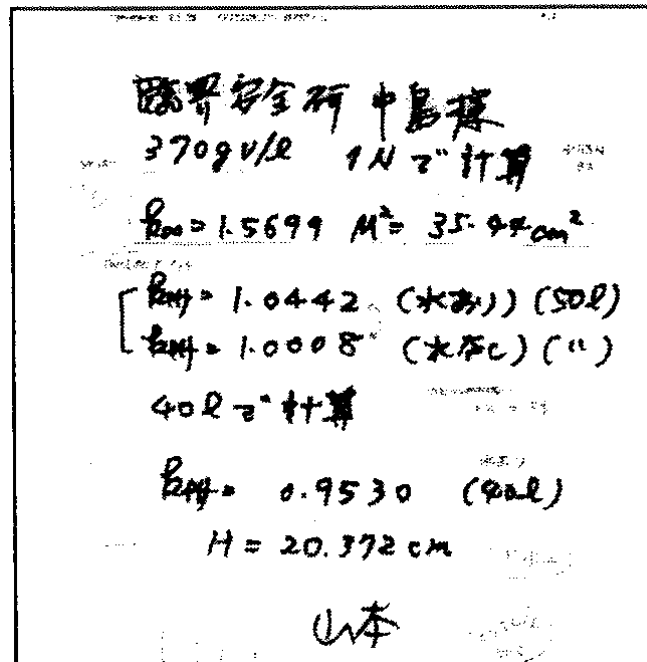
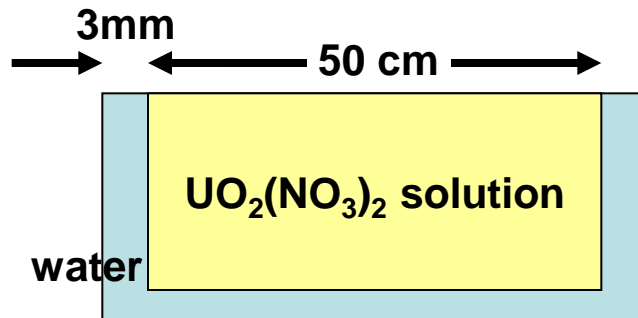
対策

1. 中性子反射材である冷却水を抜く。
2. 中性子吸収剤を含む水（ホウ酸水）をタンク内に入れる。
3. NH3ラインから入れることは可能か？

- **Outline drawing of the precipitation tank and planning of countermeasures to stop criticality**
 1. To draw cooling water outside of tank
 2. To inject neutron absorber into the tank
 3. Is it possible to inject from NH₃ line?
- **The paper was faxed to JAERI's Emergency HQs by the dispatched expert of JAERI.**

<http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JNC-TN8440-2001-018.pdf> [in Japanese]

Criticality calculation made for stopping criticality on 30th September



- **Calculation assumptions**
 - Uranium conc.: 370 gU/L
 - Free nitric acid: 1 N
 - Liquid volume: 50 L
- **Calculation results**
 - Infinite multiplication factor $k_{\infty} = 1.5699$
 - Migration area $M^2 = 35.44 \text{ cm}^2$
 - $k_{\text{eff}} = 1.0442$ w/ water reflector
 - $k_{\text{eff}} = 1.0008$ w/o water reflector

<http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAERI-Tech-2000-074.pdf>
[inJapanese]