International Workshop on Robot use
in Nuclear Facilities at Nist
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Radiation Tolerance of Robots

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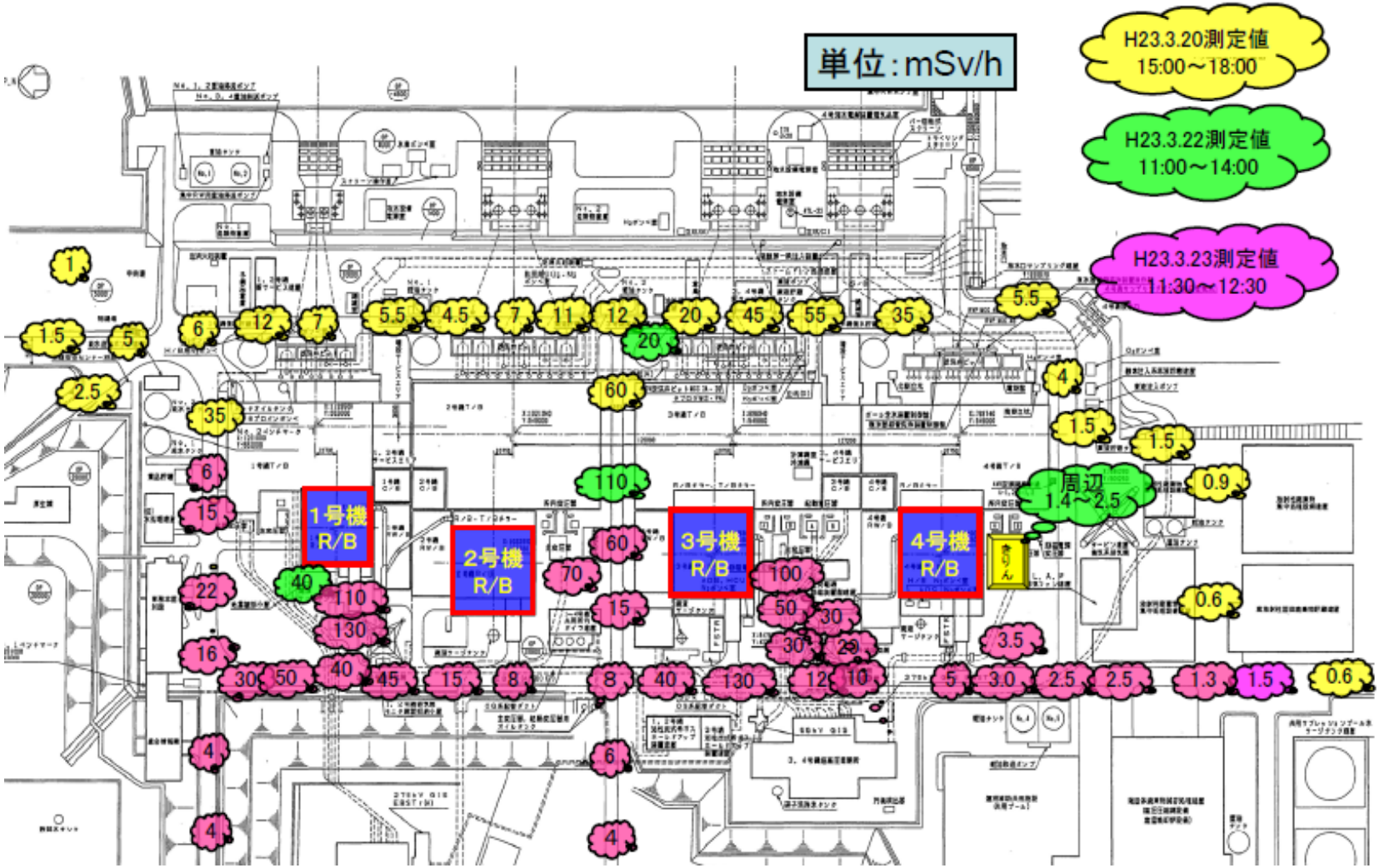
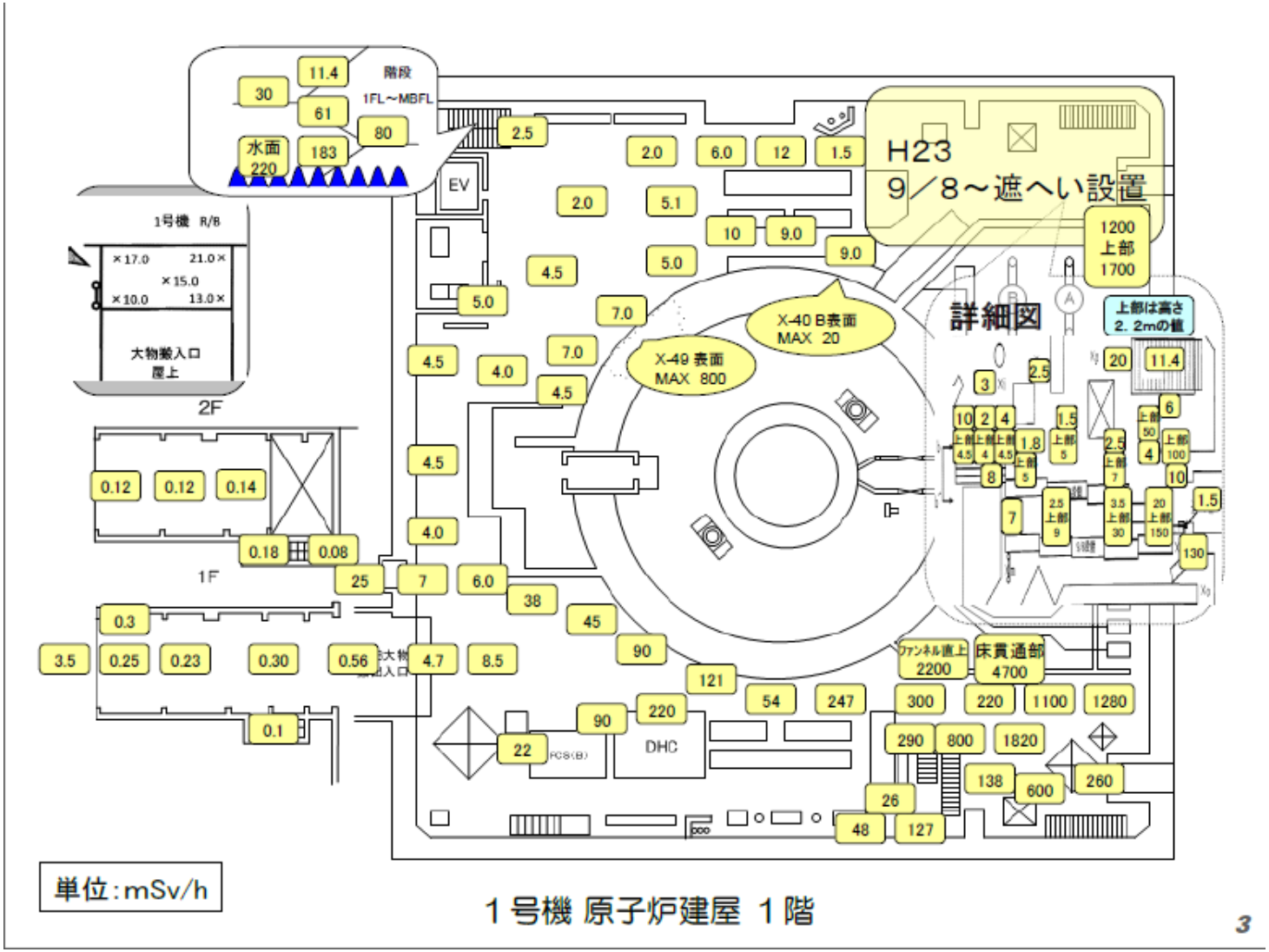
Features of Robots in nuclear facilities

- Not robots but System
- Remote operation (Man Machine Interface)
- Real-time Signal Transmission
- Signal Transmission surrounded by shielding wall and many heavy equipment
- Radiation Tolerance
- Decontamination
- Mobility for emergency logistics
- Maintainability with short time
- Conformity power : Customizing or optimizing for each situation

Radiation Map in the Fukushima daiichi NPPs site at March 23, 2011



Radiation Map in the unit 1 of Fukushima daiichi NPPs



Guideline of Radiation Tolerance

- To be established
- It was required to be up to Several tens Sv in outside and most of inside of Reactor buildings
- It should be required to be much more for going to some parts of the buildings
- It is desired to be much more for going up to upstairs, because dose rate could not estimated.

Radiation Tolerance of components of the robots

Table 1 Rough Evaluation of Radiation Tolerance of Parts for robots and heavy machines

Semiconductors	10-100k Gy
Cable	1M-100M Gy
Oil	-10k Gy

Developed based on [3]

Semiconductors is critical !

Radiation Tolerance of components of the robots

Table 2 Rough Evaluation of Radiation Tolerance of Semiconductors on the shelf

Bipolar transistor	10k Gy
Bipolar Op Amp	100k Gy
CPU	20-100 Gy
CCD	10-100 Gy

Developed based on [3]

Among Semiconductors,

CPU and CCD are Critical !

Radiation Tolerance of components of the robots

JAEA established the guideline and reported to “remote control project team of Government and TEPCO, according to the data of 1980-90’s.

- It was evaluated the CPU and CCD has around 50 Sv radiation tolerance.

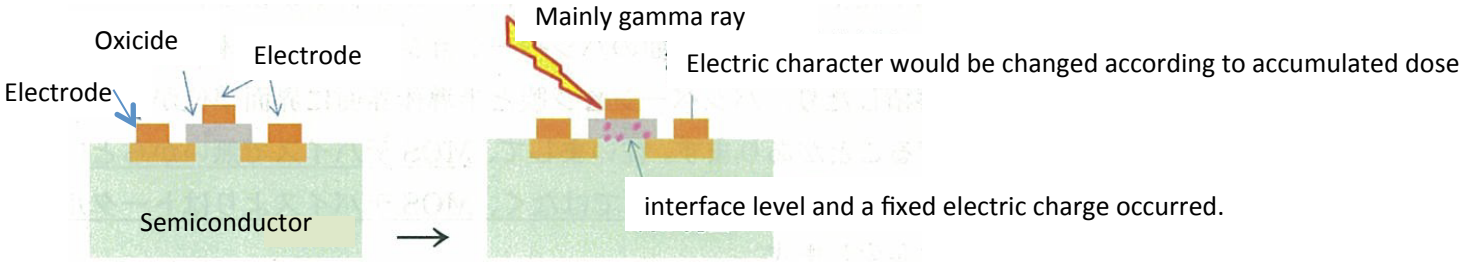
- Management Level was determined 20Sv for heavy construction machines
- Management Level was determined 30Sv for heavy construction machines
- In case, radiation test done, and Management Level of Quince was determined around150Sv.

“Guideline on Rad-Hardness Estimation and Management for Robotics, Unmanned Construction Machine and others”

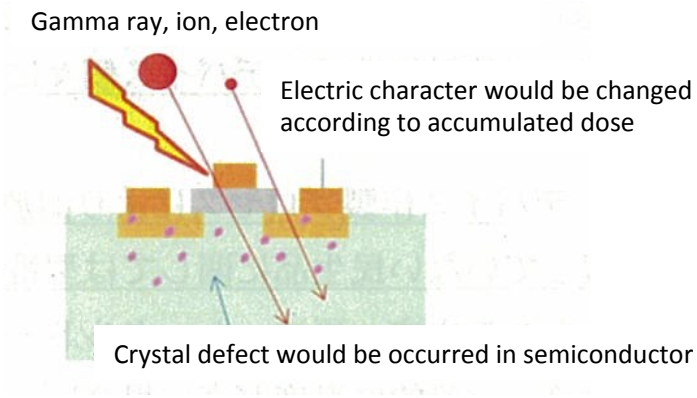
http://roboticstaskforce.files.wordpress.com/2011/05/20110427-rcpt-radiation.pdf

Mechanism of radiation damage of semiconductor

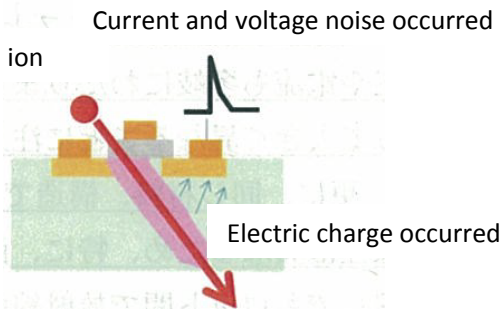
Total Dose Effect



Calculates effect



Single event effect



Total dose effect could be critical causes, because ion or electron could not attack directly to semiconductor in the robots.

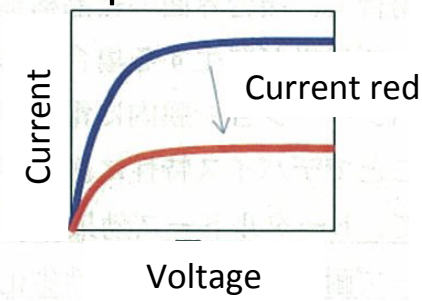
Radiation hardening

Option 1 :

- Develop and Use radiation hardening semiconductor

Option 2 :

- Identify radiation resistance level of COTS(*) and develop Data base
  *COTS : Components On The Shelf
- Select higher radiation resistance level COTS
- Develop and add compensation circuit



- For analog, boost up
- For digital, border change ?

- Develop management(replacing) plan on circuits

Option 3:

- Move semiconductors to lower dose level area

Practice experience

- As for BSM,
  - Servo drivers moved to lower dose area,
  - Sensor circuits were added compensation circuits.

- As for Unmanned construction machines
  - Radiation resistance level of semiconductors were evaluated
  - Management plan was developed
  - The machines were deployed according to the management plan.

- As for QUINCE
  - Irradiation tests were conducted for optimize (expand) the management plan

We shall overcome !!