IROS 2012
Vilamoura, Oct. 8, 2012

Robot & Remote-Controlled Machine Technology for Response against Accident of Nuclear Power Plants and toward Their Decommission

Hajime ASAMA
Dept. of Precision Engineering, The University of Tokyo, Japan
Robotics Task Force for Anti-Disaster (ROBOTAD), Chairman
Remote Control/Robotics Project Team, Member
Council on Competitiveness-Japan, Project on Disaster Response Robots and Their Operation System, Project Leader
Japan Atomic Energy Commission, Advisory Committee on Medium-range and Long-range Measures for Fukushima Daiichi NPP, Member
Japanese Government and TEPCO: Headquarter of Mid-term and Long-term Research and Development Promotion, Member
Task Force for Remote Control Technology, Chairman
NEDO Anti-disaster Unmanned System R&D Project, Project Leader

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Thank you for your great support!

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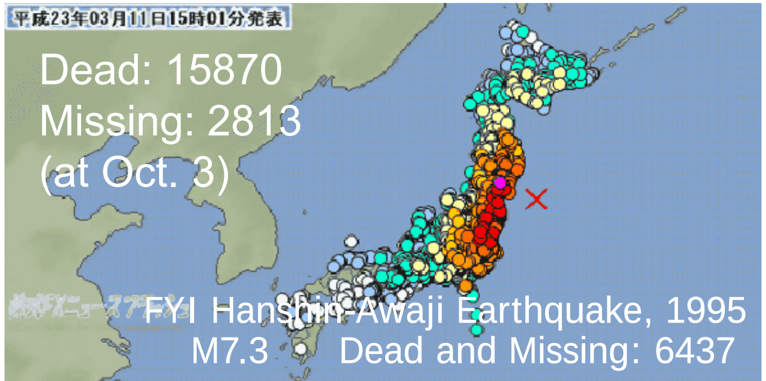
The Great Eastern Japan Earthquake and the Tsunami

Earthquake
- 14:46, Mar 11, 2011
- Magnitude: M9.0
- Maximum Seismic Intensity Scale: 7



Dead: 15870
Missing: 2813
(at Oct. 3)

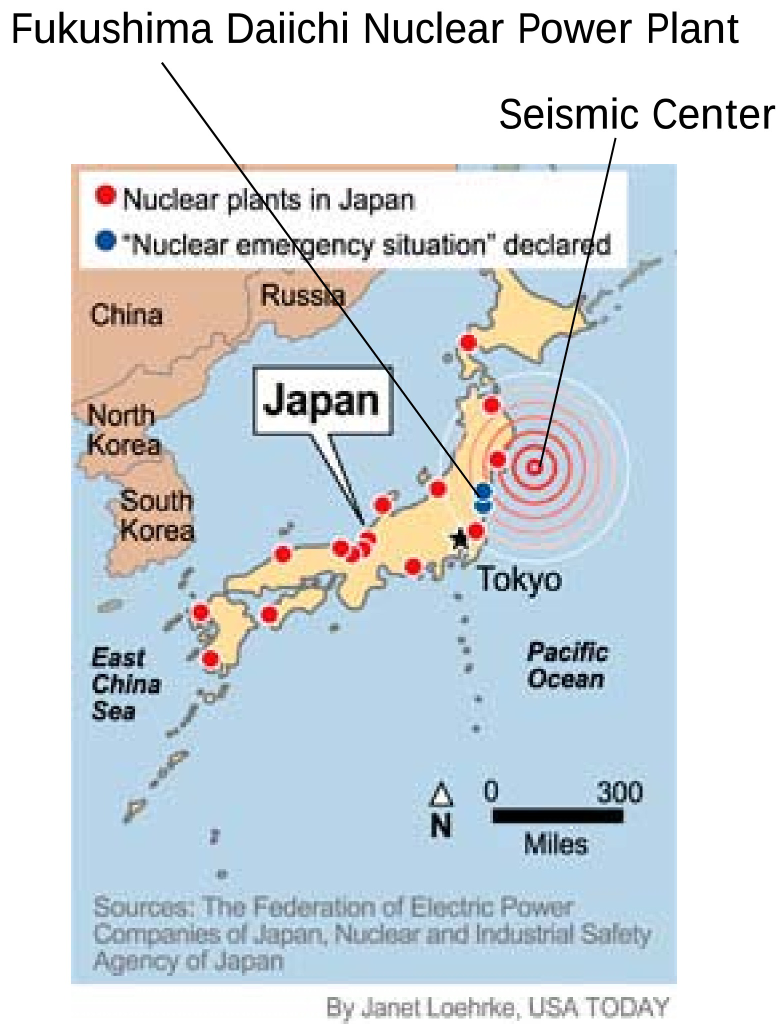
FYI Hanshin-Awaji Earthquake, 1995
M7.3 Dead and Missing: 6437

Tsunami
- 30-60 min later
- Maximum Wave Height: 40.5[m]

neering

Accident of Fukushima Daiichi Nuclear Power Plant

- Earthquake (14:47)
- Loss of Power Supply
- Activation of Emergency Diesel Generator
- SCRAM
  Stop Reactors
- Tsunami
- Damage of Fuel Tanks and Generators
- SBO (Situation of Black Out) (15:39)
- Failure of Cooling System of Reactors and Fuel Storage Pool
- Loss of Cooling Water
- Melt down
- Hydrogen Explosion (Mar. 12-15, Unit 1, 2, 3, 4)



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Major Accidents of Nuclear Facilities

- Three Mile Island
  - Mar. 28, 1979
  - Level 5 (Accident of coolant loss)
- Chernobyl
  - Apr. 26, 1986
  - Level 7
- Tokai
  - Sep. 30, 1999
  - Level 4 (Criticality accident in fuel processing)
- Fukushima
  - Mar. 12-15, 2011
  - Level 7

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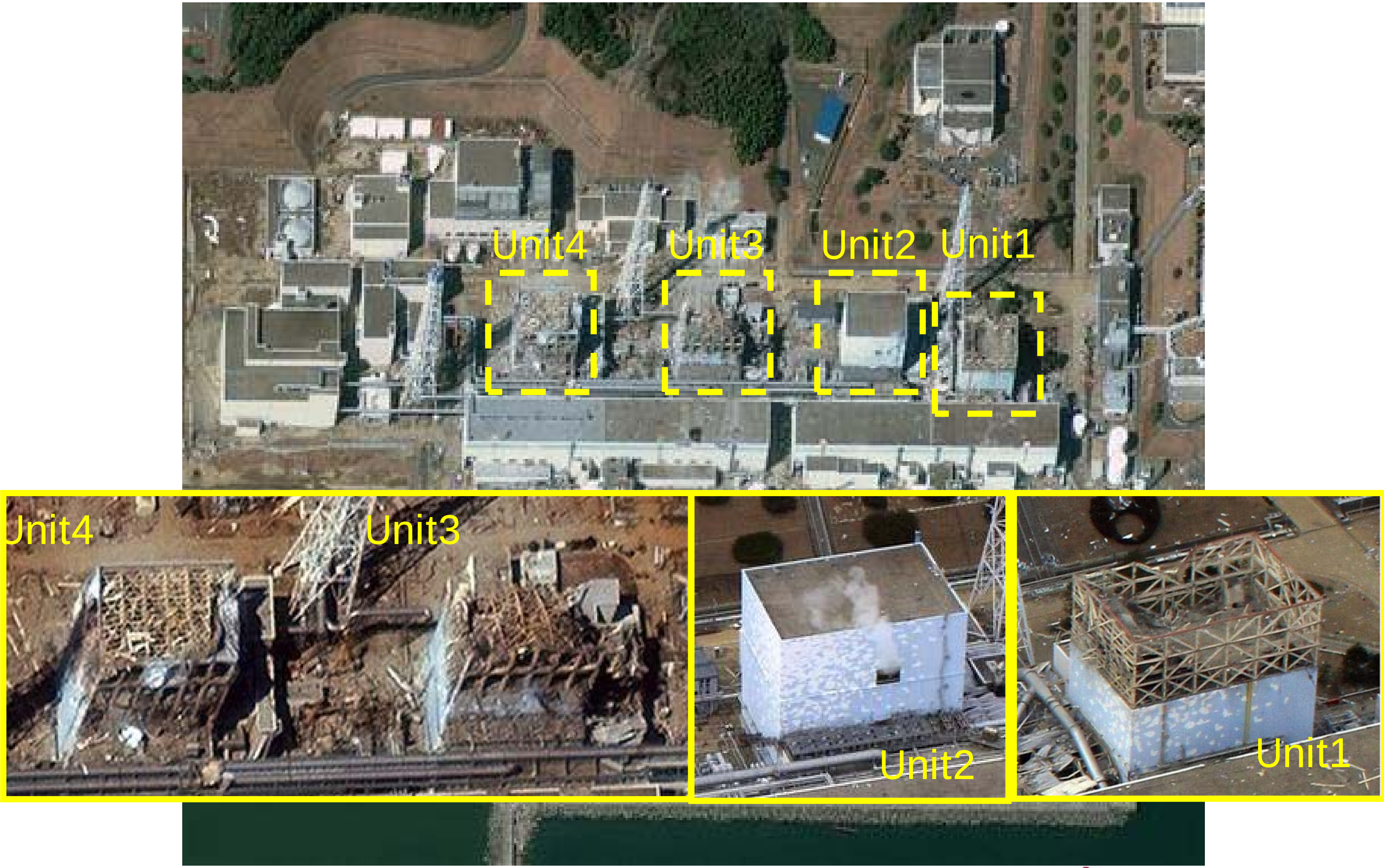
Explosion of the Reactor Building



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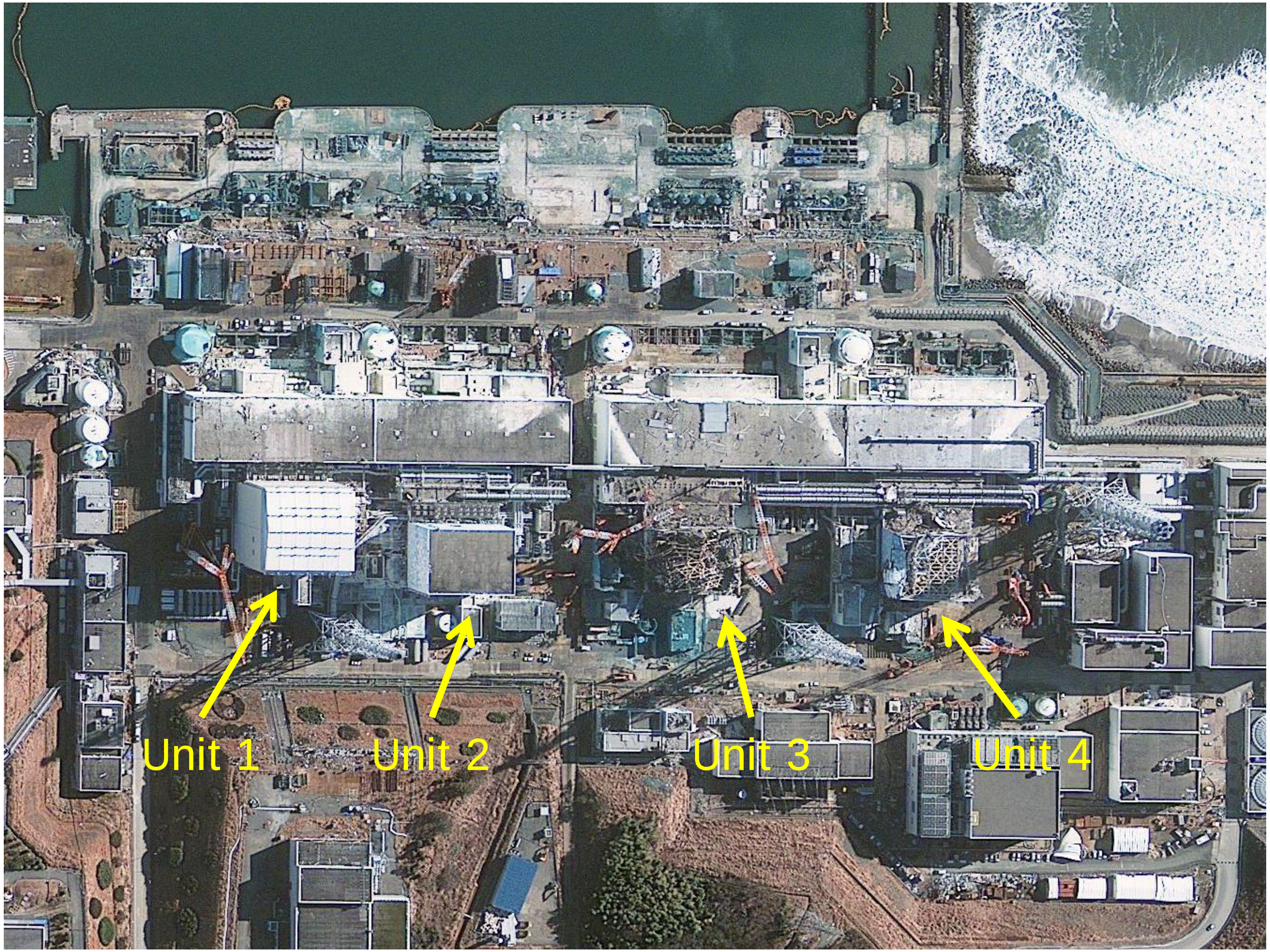
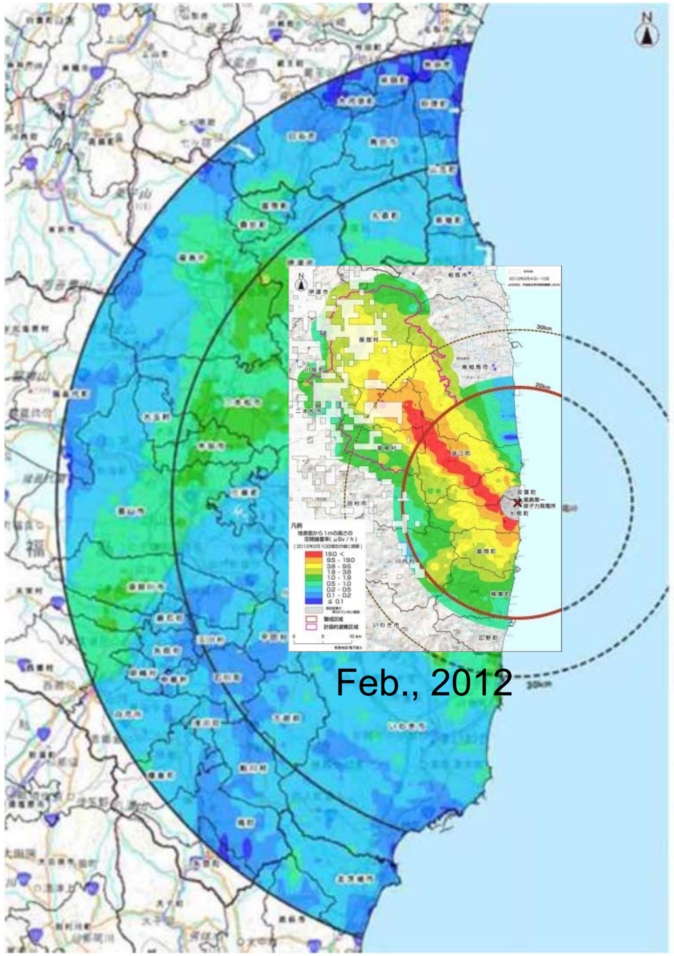
Recent View of Fukushima Daiichi (Units 1 to 4)

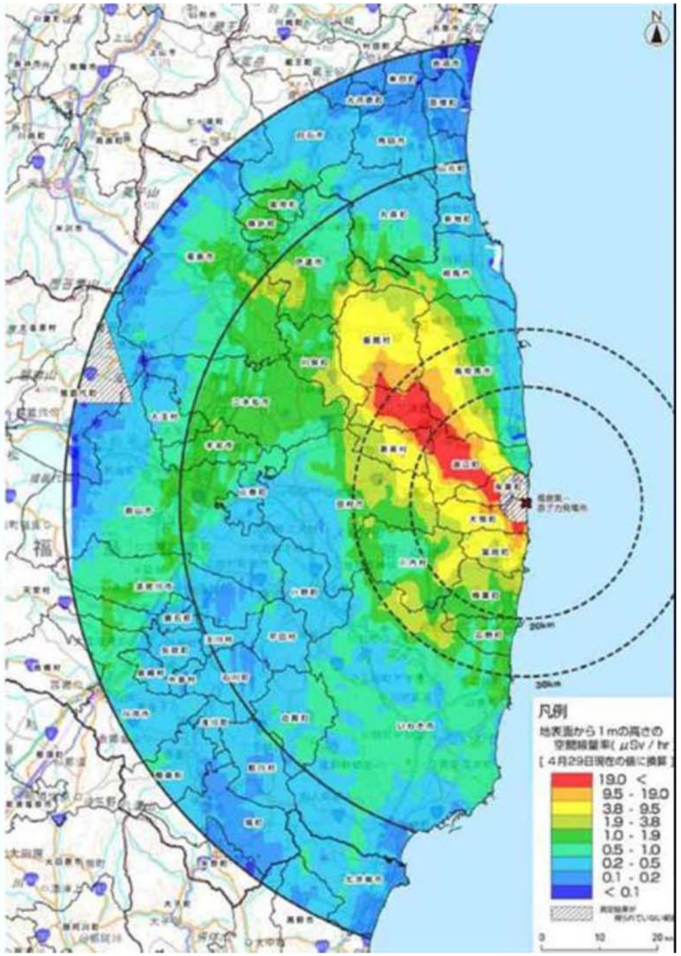


As of 1/31/2012 10:24 (C)GeoEye / 日本スペースイメージング

Radiation level



July, 2011



April, 2011

(MEXT)

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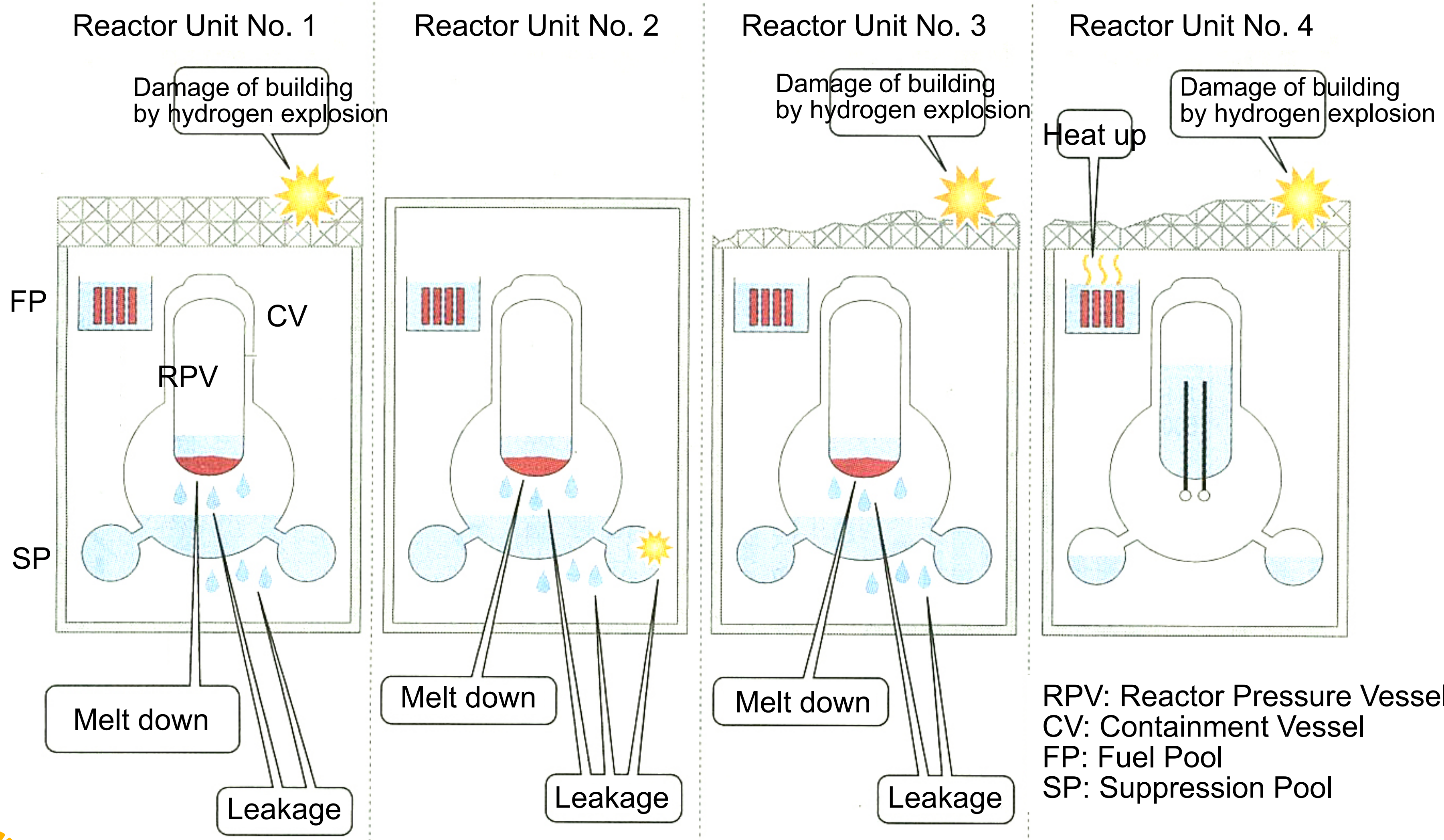
Current situation of units

Nikkei Newspaper



RPV: Reactor Pressure Vessel
CV: Containment Vessel
FP: Fuel Pool
SP: Suppression Pool

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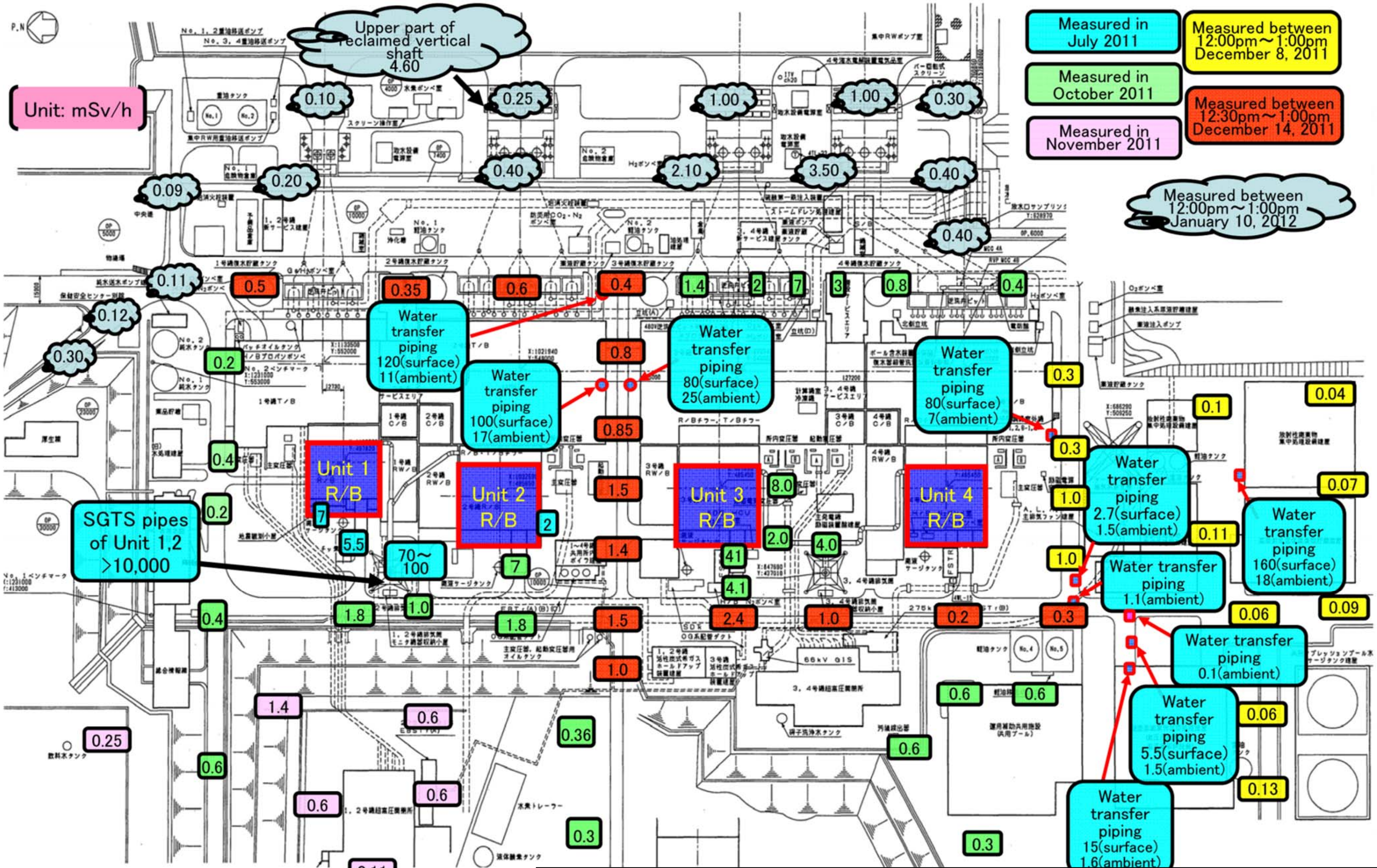
Dose Rate Map of Fukushima Daiichi Site (As of 5:00PM Jan.10, 2012)



Basically < 2mSv/hr except for some hot spots

Special Project Teams (Japanese Gov. and TEPCO)

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Appendix 3

Current Status of "Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station, TEPCO" (Revised edition)

October 17, 2011
Nuclear Emergency Response Headquarters
Government-TEPCO Integrated Response Office

Red colored letter: newly added to the previous version, ☆: already reported to the government, Green colored shading: achieved target

Issues		As of Apr. 17	Step 1 (around 3 months)	Step 1 target	Step 2 (through the end of this year) current status (as of Oct. 17)	Step 2 target	Mid-term issues (around 3 years)
I. Cooling	(1) Reactor	Fresh water Injection	Cooling by minimum injection rate (injection cooling) Consideration and preparation of reuse of accumulated water Circulating water cooling (start) ☆ Nitrogen gas injection ☆ Improvement of work environment ☆	Stable cooling	Circulating water cooling (continued) Nitrogen gas injection (continued)	Cold shutdown condition	Continuous cold shutdown condition Protection against corrosion cracking of structural materials* *partially ahead of schedule
	(2) Spent Fuel Pool	Fresh water injection	Reliability improvement in injection operation / remote-control operation *ahead of schedule Circulation cooling system (installation of heat exchanger) ☆ *partially ahead of schedule	Stable cooling	Remote-controlled injection operation Consideration / installation of heat exchanging function	More stable cooling	Start of removal work of fuels
II. Mitigation	(3) Accumulated Water	Transferring water with high radiation level Storing water with low radiation level	Installation of storage / processing facilities ☆ Installation of storage facilities / decontamination processing	Secure storage place	Expansion ☆ / consideration of full-fledged processing facilities Decontamination ☆ / desalination processing (reuse), etc Storage / management of sludge waste etc. ☆ Mitigation of contamination in the ocean	Reduction of total amount of accumulated water	Installation of full-fledged water processing facilities Continuous processing of accumulated water Storage / management of sludge waste etc. Research on processing of sludge waste etc. Mitigation of contamination in the ocean
	(4) Ground water		Mitigation of contamination in groundwater Consideration of method of impermeable wall against groundwater	Mitigate ocean contamination	(Restoration of sub-drainage pumps with expansion of storage / processing facilities) Design / implementation of impermeable wall against groundwater	Mitigate ocean Contamination (continued)	Mitigation of contamination in groundwater Establishment of impermeable wall against groundwater
	(5) Atmosphere / Soil		Dispersion of inhibitor Removal / management of debris	Mitigate scattering	Dispersion of inhibitor (continued) Removal / management of debris (continued) Installation of reactor building cover (Unit 1) ☆ Removal of debris (top of Unit 3&4 R/B) Consideration of reactor building container Installation of PCV gas control system	Mitigate scattering (continued)	Dispersion of inhibitor Removal / management of debris Removal of debris / installation of reactor building cover (Unit 3&4) Start of installation work of reactor building container Installation of PCV gas control system

Current Status of "Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station, TEPCO" (Revised edition)

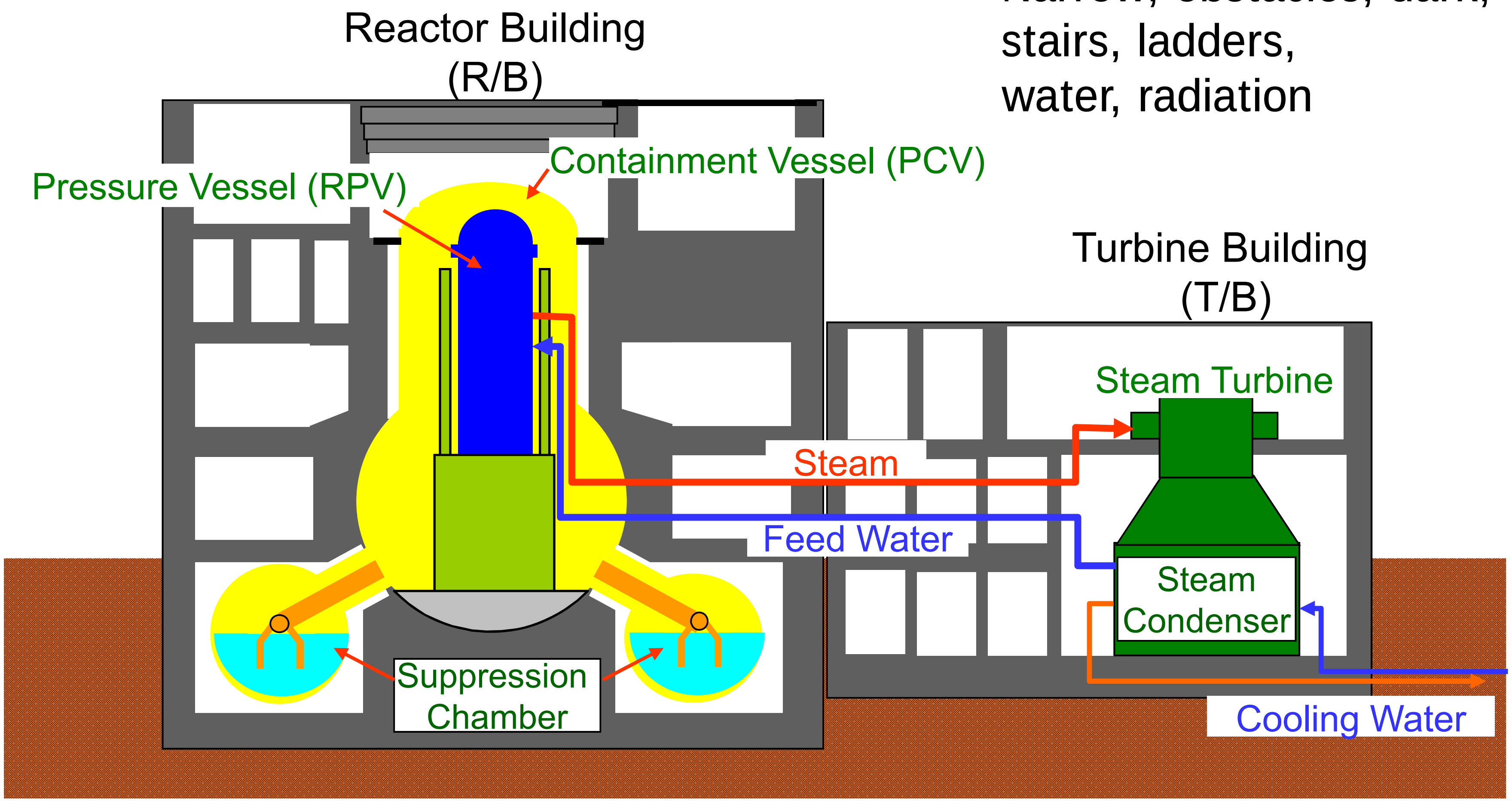
October 17, 2011
Nuclear Emergency Response Headquarters
Government-TEPCO Integrated Response Office

Red colored letter: newly added to the previous version, ☆: already reported to the government, Green colored shading: achieved object

Issues		As of Apr. 17	Step 1 (around 3 months)	Step 2 (through the end of this year) current status (as of Oct. 17)		Mid-term issues (around 3 years)
III. Monitoring/ Decontamination	(6) Measurement, Reduction and Disclosure	Expansion, enhancement and disclosure of radiation dose monitoring in and out of the power station		Consideration / start of full-fledged decontamination	Decontamination	Continuous environmental monitoring Continuous decontamination
IV. Countermeasures fort aftershocks, etc	(7) Tsunami, Reinforcement, etc	Enhancement of countermeasures against aftershocks and tsunami, preparation for various countermeasures for radiation shielding	(Unit 4 spent fuel pool) Installation of supporting structure ☆	Consideration of reinforcement work of each Unit ☆	Mitigate disasters	Continue various countermeasures for radiation shielding Reinforcement work of each Unit
V. Environment improvement	(8) Living/working environment		Improvement of workers' living / working environment		Enhancement of environment Improvement	Improvement of workers' living / working environment
	(9) Radiation control / Medical care		Improvement of radiation control / medical system		Enhancement of Healthcare	Improvement of radiation control / medical system
	(10) Staff Training / personnel allocation			Systematic implementation of staff training / personnel allocation	Exhaustive radiation dose control	Systematic implementation of staff training / personnel allocation
Action plan for mid-term issues				Government's concept of securing safety Establishing plant operation plan based on the safety concept		Response based on the plant operation plan

Overview Image of BWR-4

Narrow, obstacles, dark,
stairs, ladders,
water, radiation



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Needs for Robots

- For Operation in Nuclear Power Plants
  - Missions
    - Stabilization of the cooling systems
    - Containment (Coverage of Reactor Buildings)
    - Decommission (Extraction of Nuclear Fuels)
    - Reduction of radiation exposure of workers
  - Tasks
    - Debris clearing
    - Surveillance and mapping outside and inside of the buildings (Images, radiation, temperature, humidity, oxygen concentration, etc.)
    - Instruments setup, sampling
    - Shield and decontamination
    - Material transportation
    - Construction of pipes and equipments , etc.

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Needs for Robots

- For Other Disaster Response
  - Victim search and rescue
  - Inspection, diagnosis and recovery of plants and facilities
  - Surveillance of coast underwater
  - Mapping of the damaged area
  - Power assist for heavy load tasks
  - Mental care of evacuees

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ROBOTAD

ROBOtics Task force for Anti-Disaster
(ROBOtics - Temporary Active Duty)
http://roboticstaskforce.wordpress.com/

Anchorman: Yoshihiko Nakamura
Chairman: Hajime Asama

- Established on Mar 31, 2011
- Group of scientists and engineers on robotics
- Objective:
  - Propose and introduce solutions for the disaster response and measures by applying robot technologies
- Main activities: (Quick action required)
  - Assist remote control/robotics PT
  - Propose and introduce solutions for the disaster response and measures by applying robot technologies
  - Support technically in mobilization and operation of robot systems including modification and reinforcement
  - Maintenance of database on applicable robot technology and achievement records
  - Broadcast technical information
- Association
  - RSJ, JSME Robomec Div., SICE SI Div., IEEE RAS Japan Chap., IFToMM Japan Council
  - Science Council of Japan
  - Japan Robot Association and companies
  - IRS (NPO, International Rescue System Institute)

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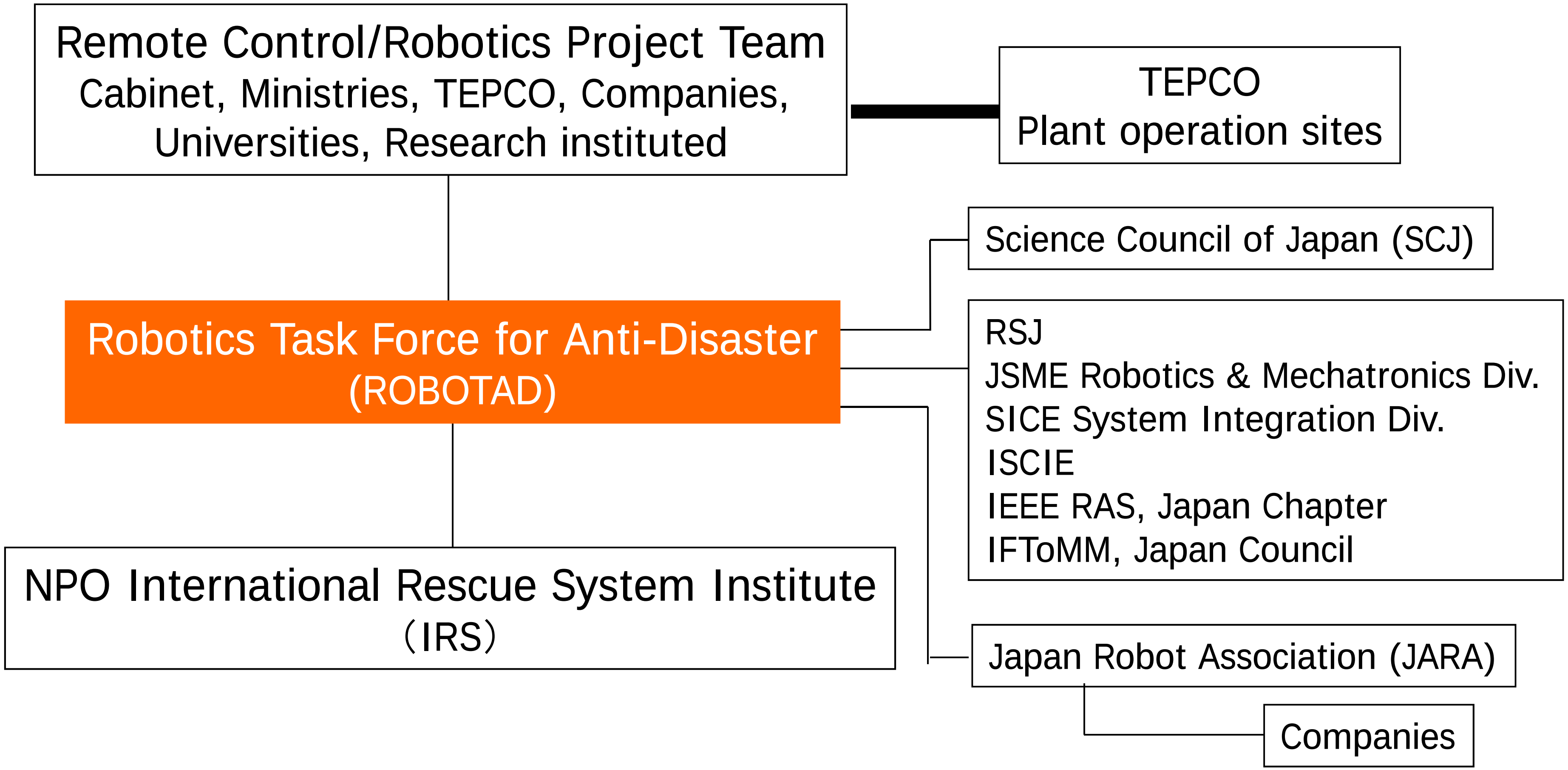
Structure of ROBOTAD



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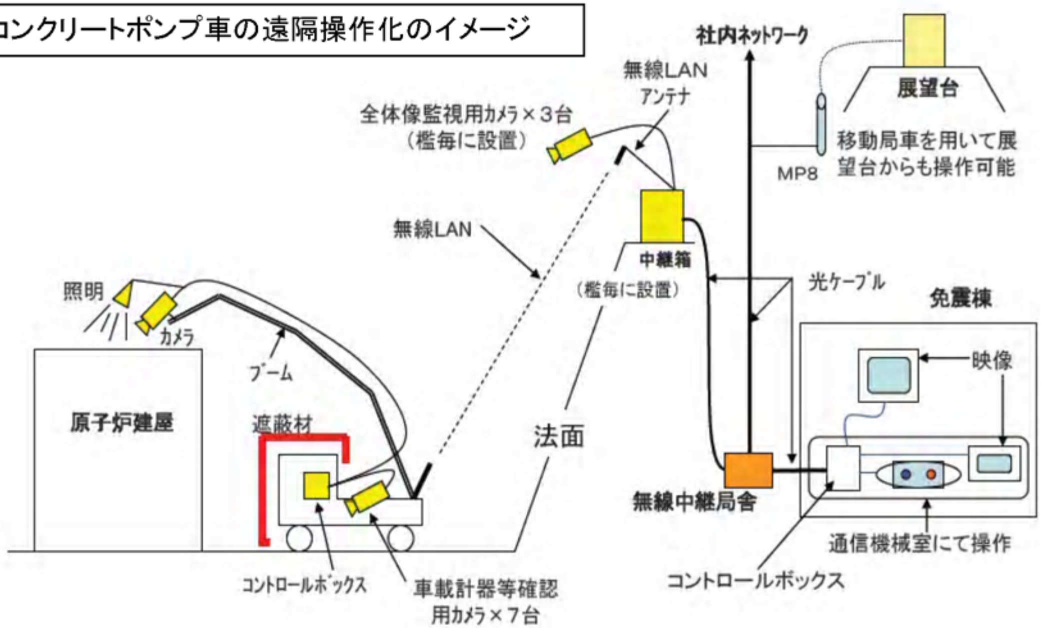
Automated watering by concrete pumping truck

From Mar. 22, 2011

(TEPCO)

コンクリートポンプ車の遠隔操作化のイメージ



ブーム先端へのカメラ等の設置

Remotely controlled Unmanned Construction System for Debris Clearing-up
From Apr. 6, 2011

TEPCO

処理前

コンテナ１個分の処理後

ガレキ積み

コンテナふた

Crawler dumps

仮置き

ナ周辺約 2.5mSv/h)

Backhoes & Iron Forks

積み込み時配置

定置時配置

遠隔操作重機によるガレキ撤去作業

（コンテナ：3.2×1.6×1.1m、約4m^3）

1号　原子炉建屋周辺

（撤去前）

（撤去後）

（仮置の瓦礫収集コンテナ）

（東京電力提供）

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Unmanned Construction System

Used in response against explosion of volcano (Unzen-Fugen Mt.), in 1991
- Pyroclastic flow (Flow of heated rocks and volcanic ash)
- Avalanche of earth and rocks (Flow of debris)

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Unmanned Aerial Vehicles T-Hawk (Remotely controlled)
From Apr. 10, 2011

TEPCO

T-Hawk (Honeywell)

Landing

Operation Room

Top View of R/B Unit 1

Top View of R/B Unit 3

Top View of R/B Unit 4

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Mobile Robots (Remotely controlled)
From Apr. 17, 2011

TEPCO

Packbot

Entering from the doors

Near Doors

1st floor of R/B Unit 1

1st floor of R/B Unit 2

1st floor of R/B Unit 3

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Operation Vehicle（TEAM NIPPON）

JAEA (Japan Atomic Energy Agency)

- Radiation measurement and robot teleoperation
- Operation box shielded by iron plate of 80mm thickness
- Equipped with Gamma camera, monitoring camera, lightening devices, tele-operated survey meter
- Localization of radiation source by the Gamma Camera
- Confirmation of safety by measuring radiation level

(↑)ロボット操作車の外観

(←)ロボット操作車の装備

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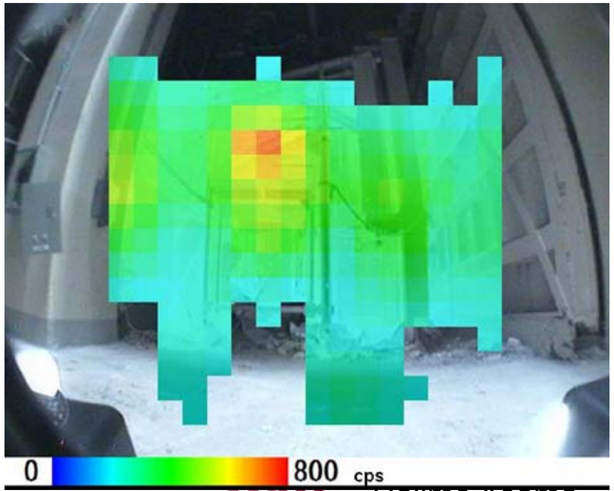
Localization of radiation source and measurement of radiation level by the Gamma Camera

May 22, 2011

(TEPCO)



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Sampling of contaminated water and setting up of water level gauge by Quince from June 24, 2011

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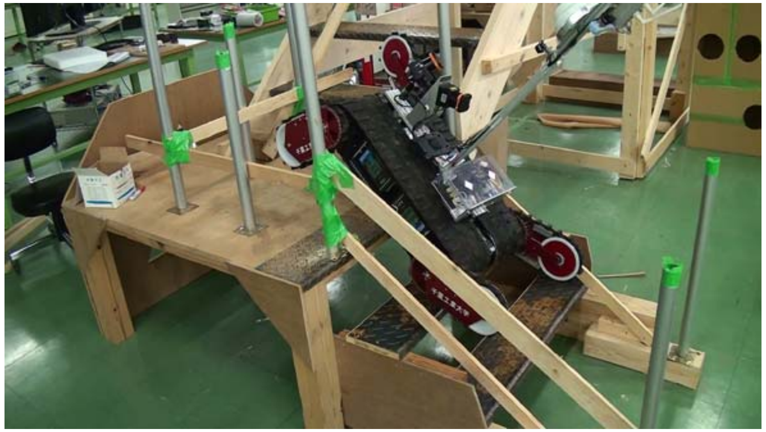
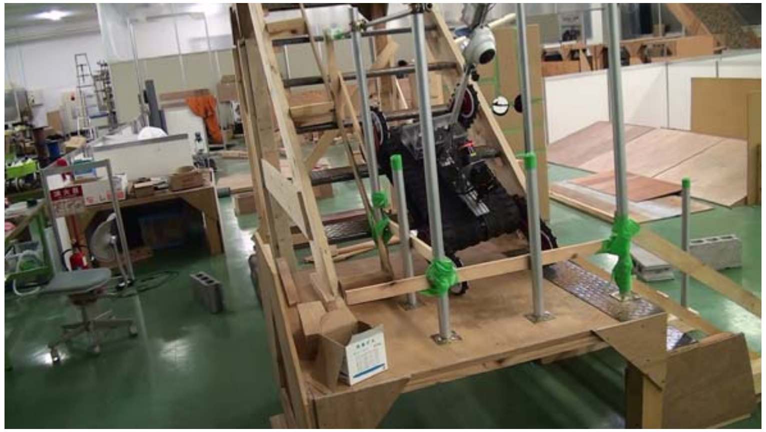
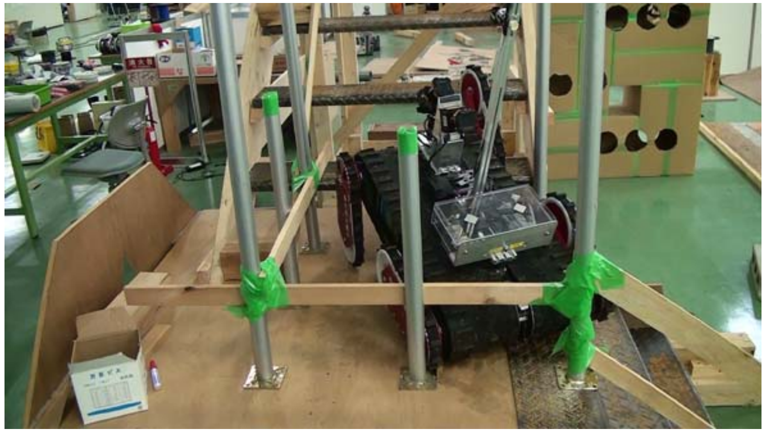
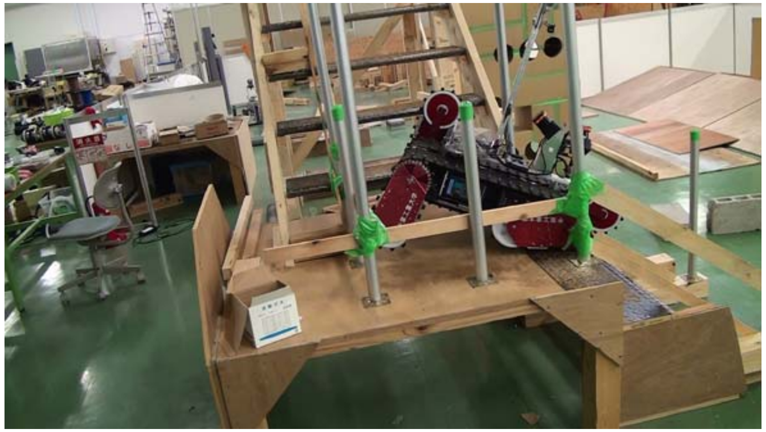
Operator Training of Narrow Stair Climbing by Quince

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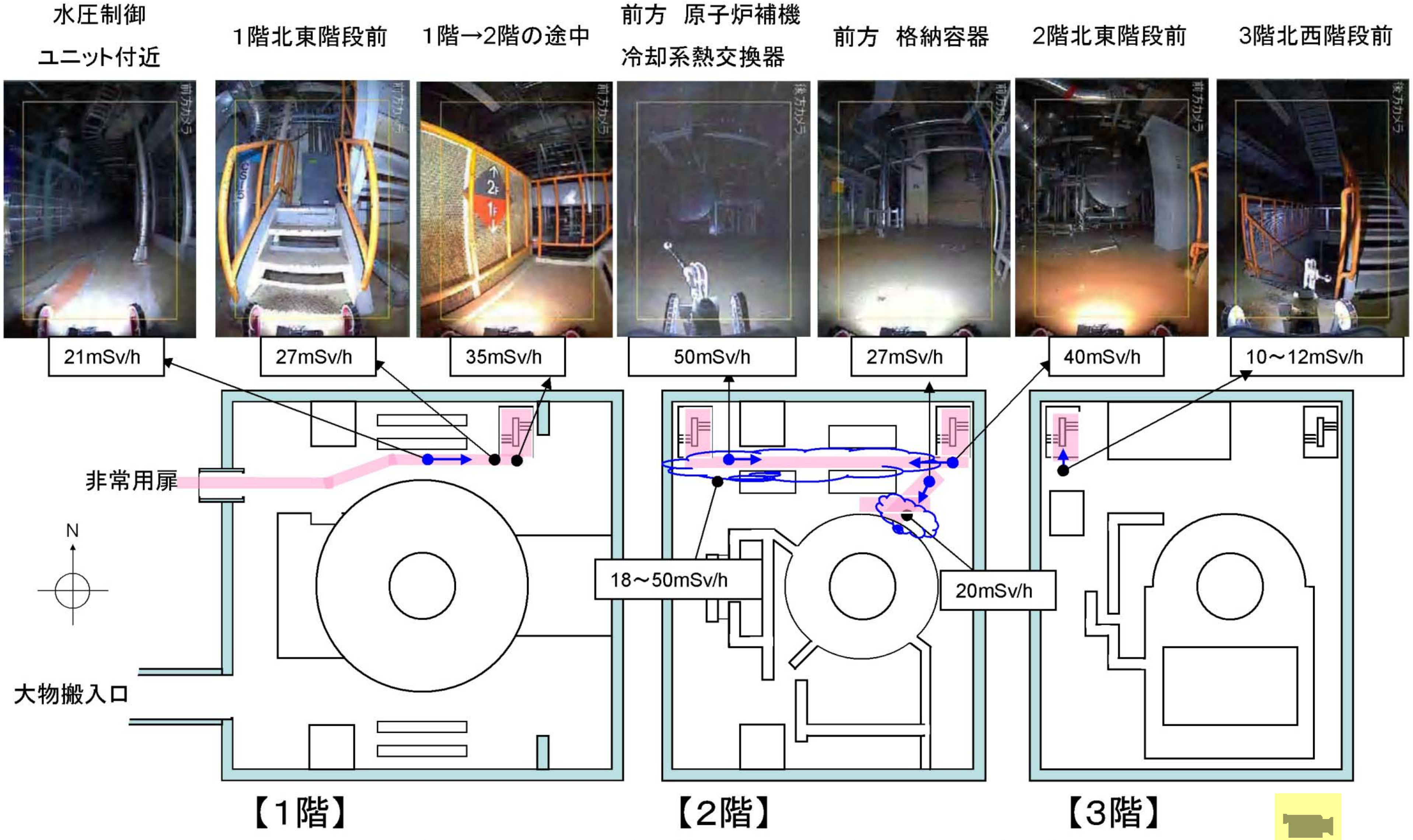
Investigation inside R/B unit 2 on July 8 by Quince

TEPCO
July 11, 2011

ロボットの移動経路
カメラの方向



建屋配置はイメージ（縮尺や配置などは正確ではありません）

Investigation of 1st-5th floor inside Unit 2 R/B on Oct. 20, 2011 by Quince

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Cleaning inside of reactor building unit 3 using the Warrior

July 2, 2011

TEPCO

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Debris Removal
inside of Reactor Building Unit 3
May 10-June, 2011

Talon
(QinetiQ)

Brokk-90
(Brokk)

Bob Cat
(QinetiQ)

Brokk-330
(Brokk)

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Inspection inside of Reactor Building Unit 3 (2 Packbots and 1 Warrior)

Nov. 16, 2011

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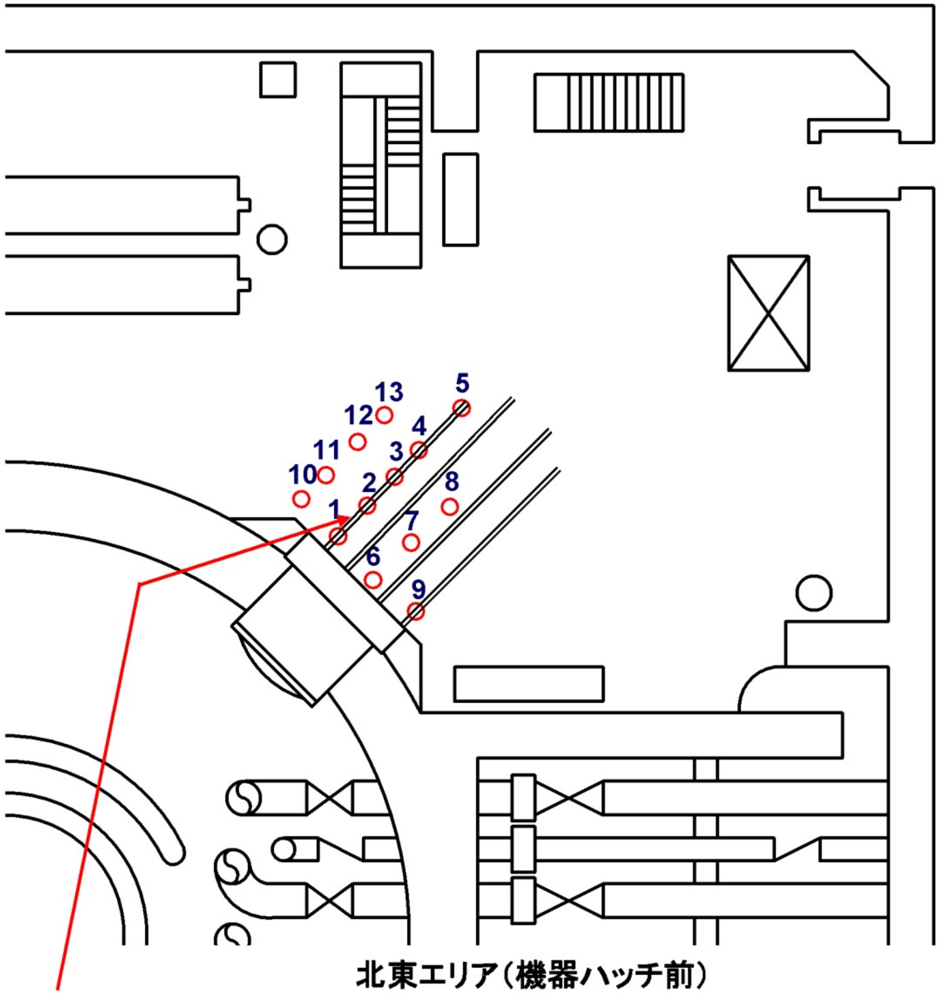
Results of Radiation Measurement at 1st floor of Unit 3

TEPCO
Nov. 16, 2011



北東エリア（機器ハッチ前）

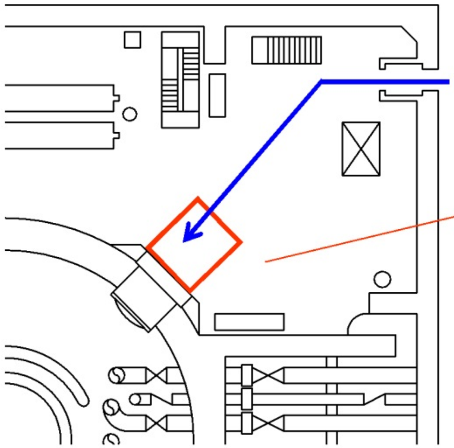
※レール溝内の水有無確認作業時に北側レール表面近傍において約1,300mSv/hを確認

測定点	測定高[m]		
	0.4	1.2	1.7
1	870	370	255
2	800	415	290
3	750	420	280
4	650	410	270
5	380	200	130
6	180	190	180
7	170	190	180
8	145	180	180
9	120	105	105
10	180	200	200
11	180	220	210
12	190	210	205
13	170	190	185

雰囲気線量測定結果[mSv/h]

Wiping Floor by a Robot

ロボット進入経路



機器ハッチ前エリア

床面は乾燥

機器ハッチレール

表面がスラッジ状

レール溝　拭き取り前

拭取り

水面が露出

レール溝　拭き取り後

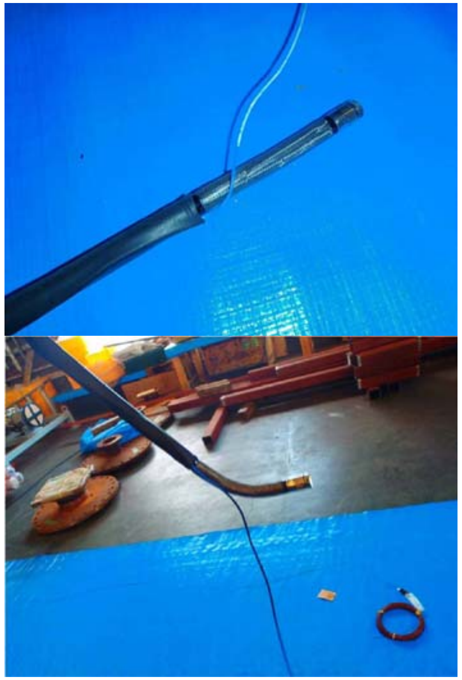
水濡れ

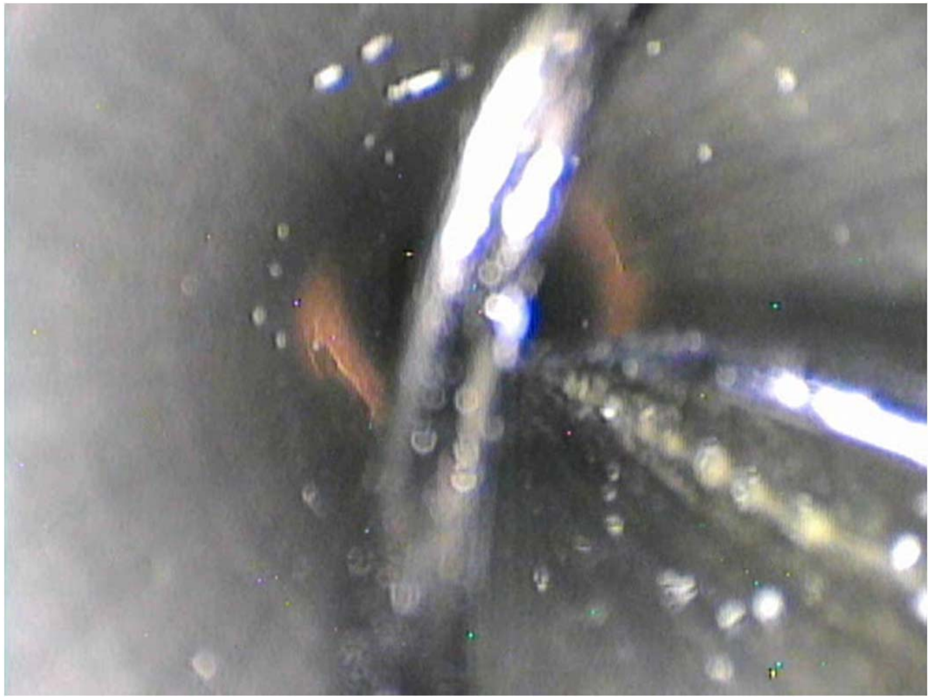
拭き取り後のウェス

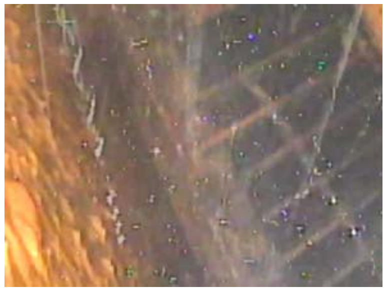
Inspection inside PCV of Unit 2

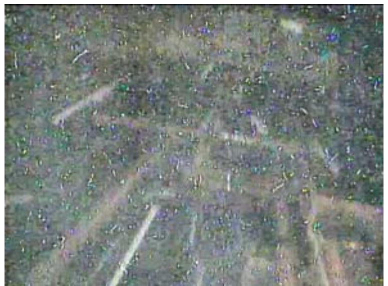
Jan. 20

TEPCO









Industrial Endoscope
and Thermocouple

72.9Sv/h was observed
At the 2nd entry in Mar. 27, 2012

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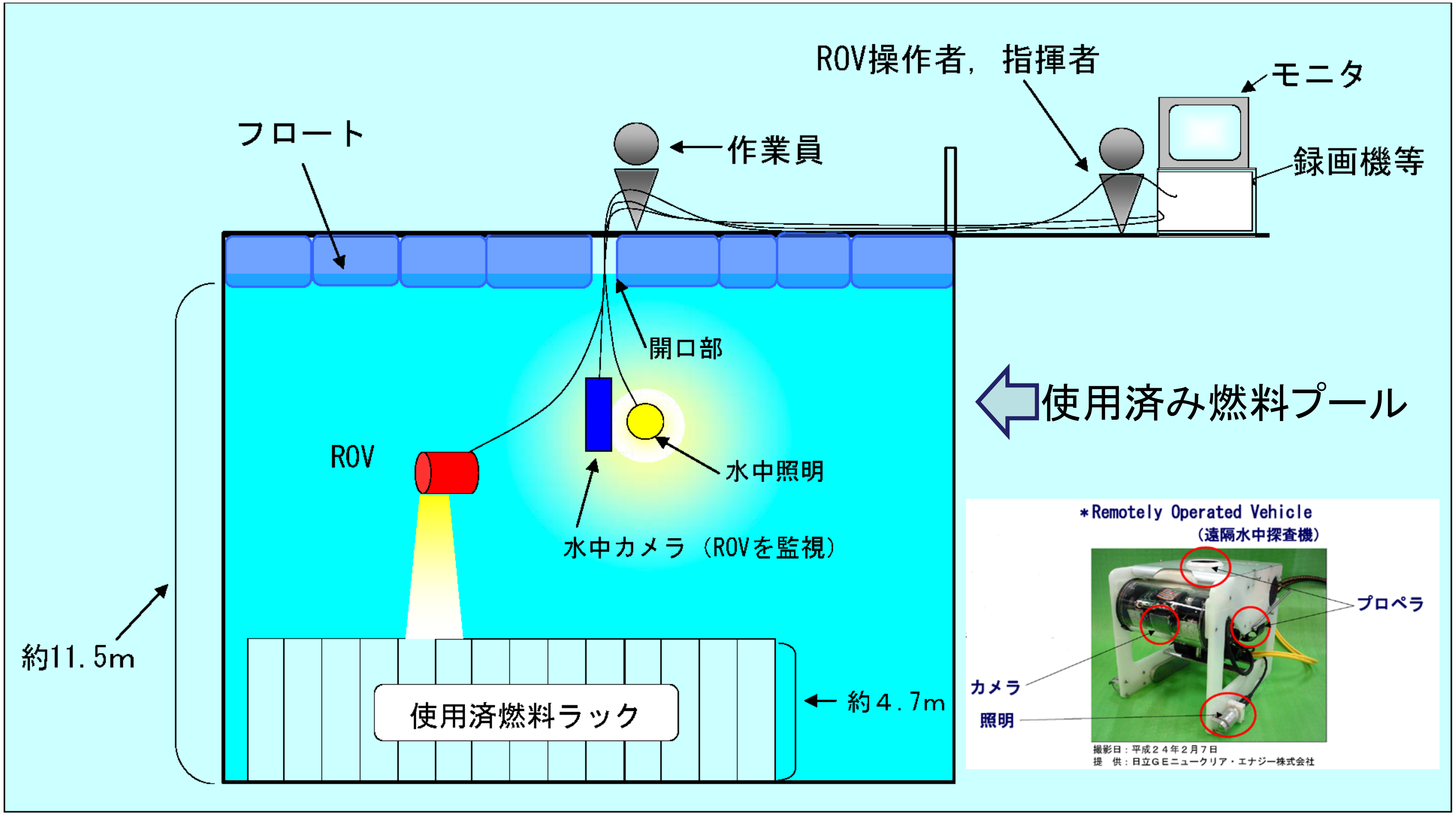
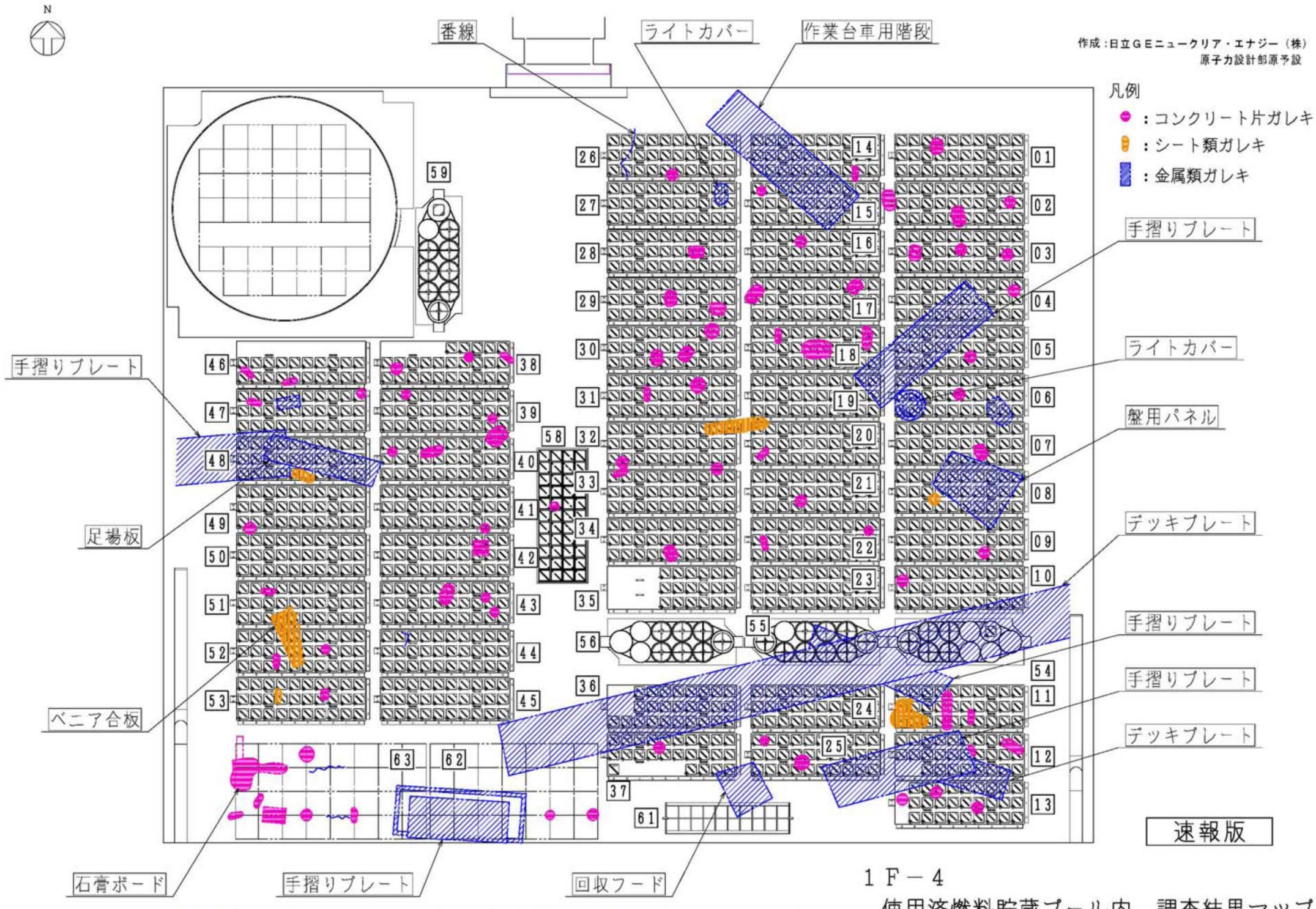
Mapping of Debris in the Fuel Storage Poon in Unit 4

使用済燃料プール上を覆っているフロート養生の開口部からROV※を使用済燃料プール内に投入し、オペレーティングフロア上で操作を実施。

※ROV：Remotely Operated Vehicle（遠隔水中探査機）



Mapping of Debris in the Fuel Storage Poon in Unit 4



1Ｆ－４
使用済燃料貯蔵プール内　調査結果マップ

燃料上部に堆積している砂状のガレキは，本ガレキ分布マップには反映していない。

Investigation of Suppression Chamber Room in Unit 2

Apr. 18, 2012

Survey Runner
TOPY Industries

Radiation dose: 186mSv
For three hours mission

Suppression Chamber SE

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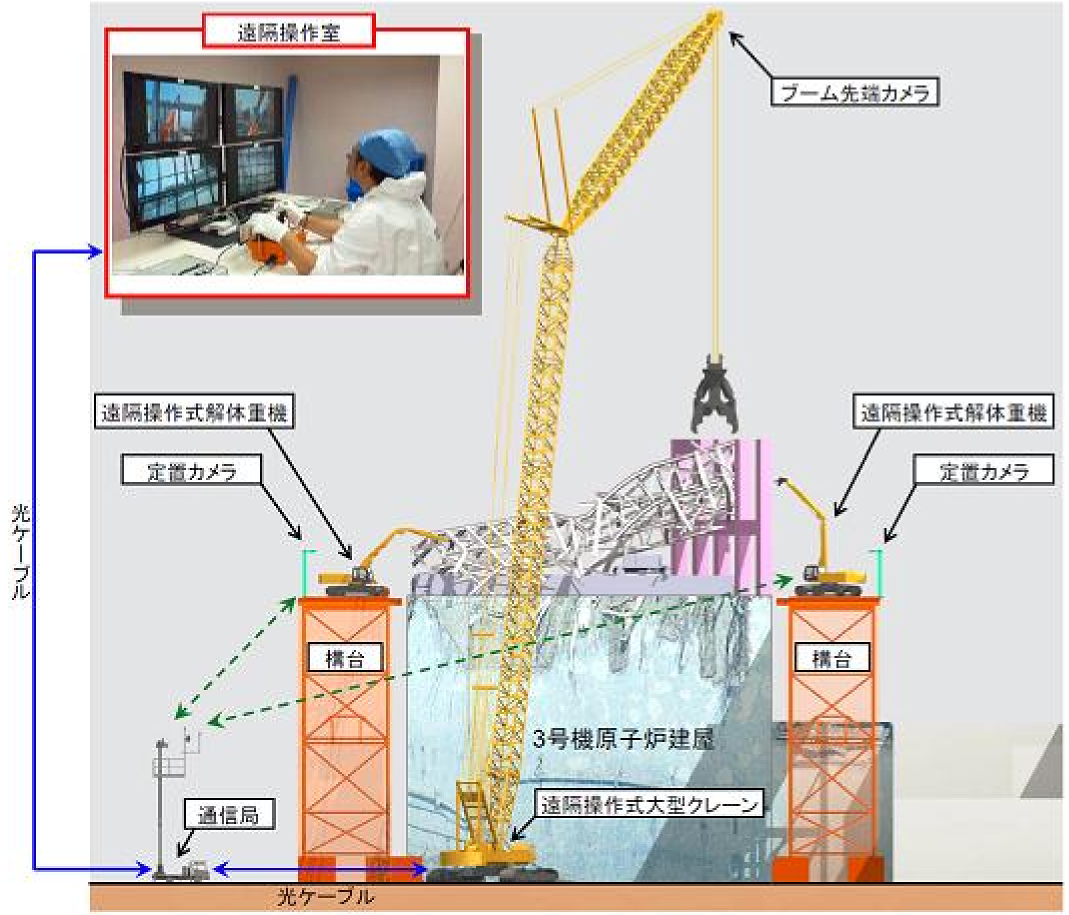
Debris Clearing-up of Operation Floor Using Remotely-controlled Machines



Debris Clearing-up of Operation Floor of Unit 3

Clearing-up on the ground

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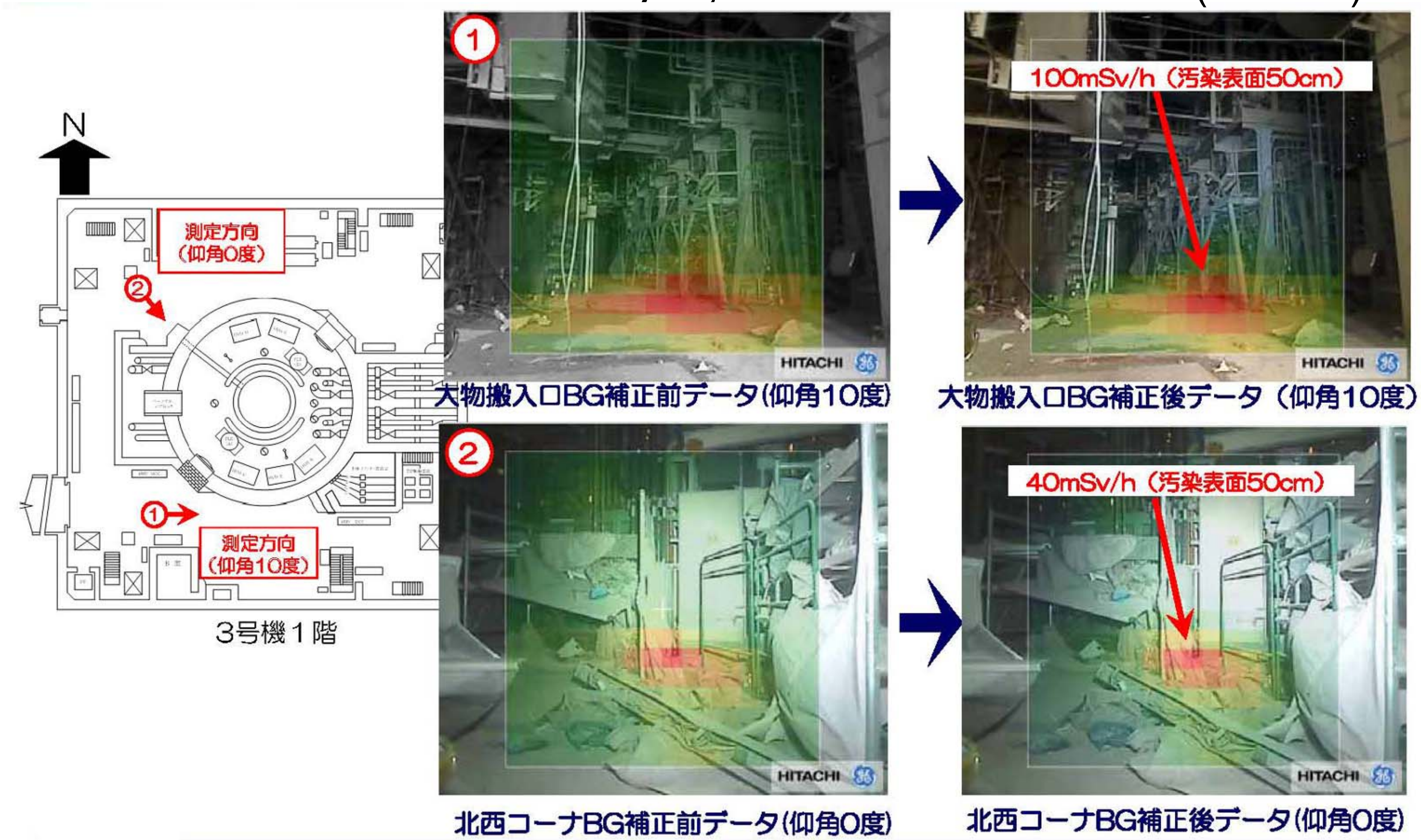
Radiation Source Localization & Radiation Measurement of Unit 2 and 3 Using γ Camera and Dosimeter

July 5, 2012 (TEPCO)



Packbot＋ Hitachi γ Camera

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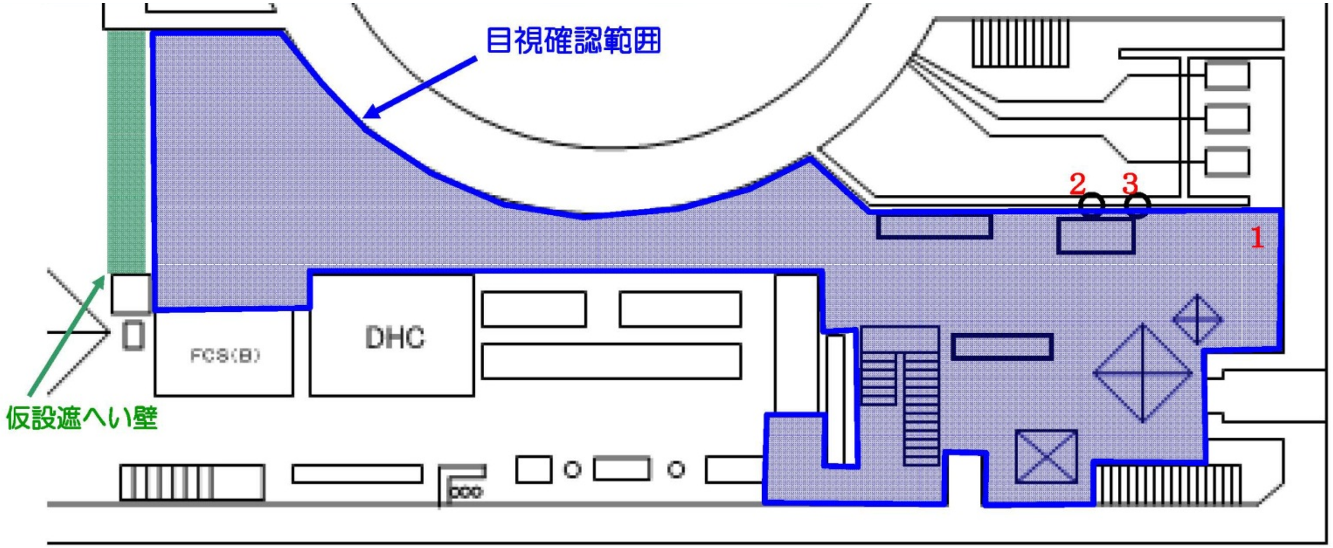
Investigation inside R/B unit 1 (1^{st} floor)
TIP Room and South Area
July 5, 2012

(TEPCO)



1．ＴＩＰ室扉鍵開け作業

2．機器ファンネル

3．床貫通部

Packbot＋Quince2

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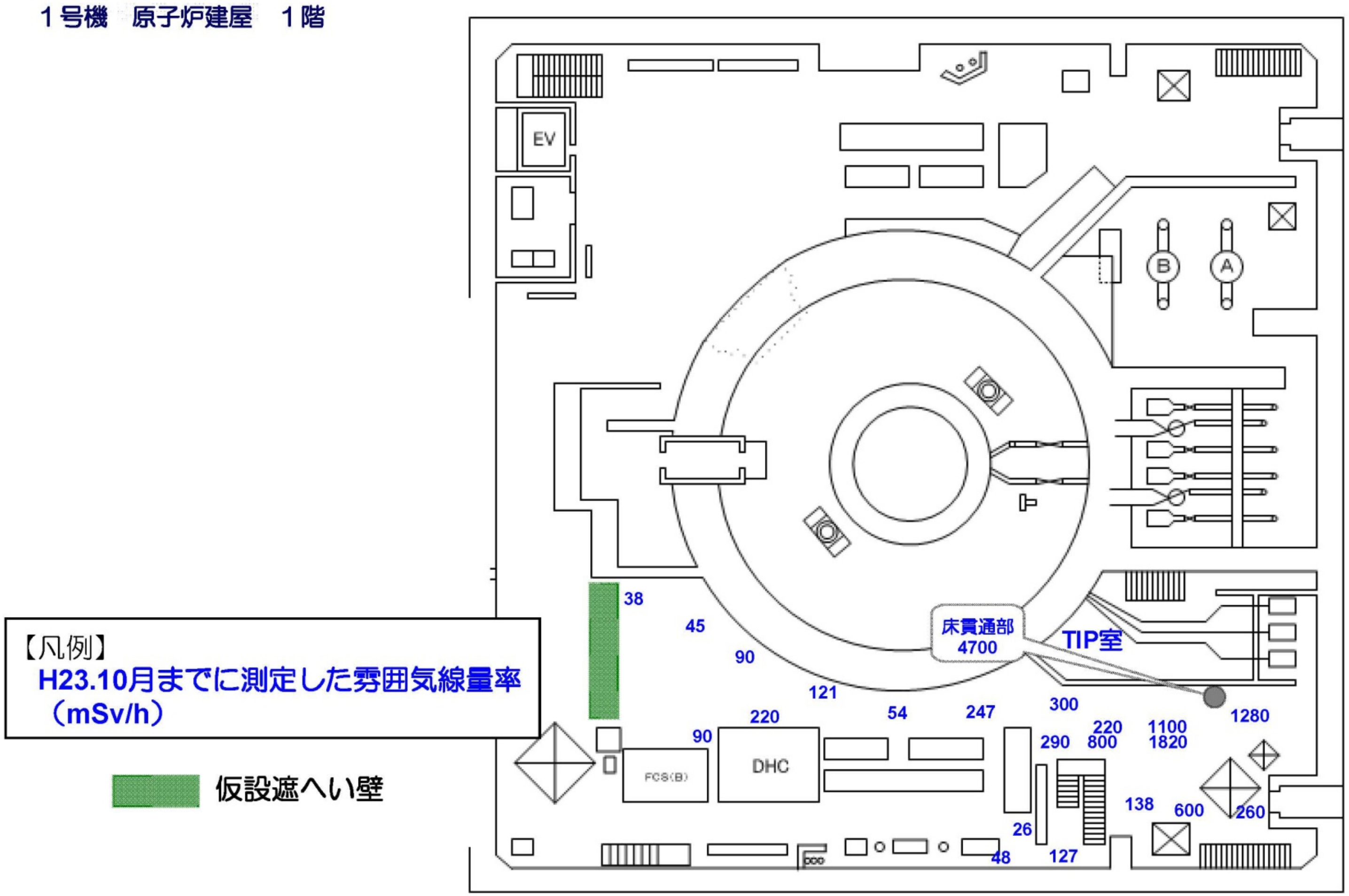
Investigation inside R/B unit 1 (1^{st} floor)
TIP Room and South Area
July 5, 2012

(TEPCO)



Packbot＋Quince2

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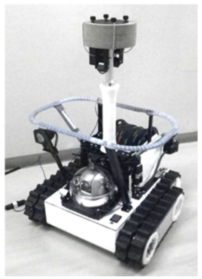
Operational Robots (at July, 2012)

Name	manufacturer	Photo	Nr. Posession (Operational)	Use
Packbot	iRobot		4 (3)	Investigation Radiation measurement Light work, etc. (inside buildings)
Quince	- Chiba Inst. Tech. - Tohoku Univ. - IRS		3 (2)	Investigation Radiation measurement Dust sampling (Q2) 3D mapping (Q3) (Operatable by wireless even if cable amputation)
Survey Runner	TOPY Industries		1	Investigation Radiation measurement (in underground level such as suppression chamber) (Operatable by wireless even if cable amputation)

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Achievements of Robot Operation in R/B Unit 1, 2, 3 (at July, 2012)

Investigation (Acquisision of visual images, measurement of radiation etc.)		
Date	Location	Robots
Apr. 17, 2011	1u 1F	Packbot
Apr. 17, 2011	3u 1F	Packbot
Apr. 18, 2011	2u 1F	Packbot
Apr. 26, 29, 2011	1u 1F	Packbot
May 10, 2011	3u 1F N	Packbot
May 13, June 3, 2011	1u 1F S	Packbot
June 24, July 2, 2011	3u 1F S	Packbot
July 8, 2011	2u 1～3F	Quince
July 22, 2011	3u 1F NE	Packbot
July 26, 2011	3u 1～2F	Quince
Sep. 22, 2011	2u 1F S	Quince
Sep. 24, 2011	3u 1F	Quince
Oct. 13, 2011	1u 1F S	Packbot
Oct. 20, 2011	2u 1～5F	Quince
Nov. 3, 2011	3u 1F	Packbot
Nov. 14, 19, 2011	3u 1F NE	Packbot
Feb. 27, 2012	2u 5F	Quince2
Mar. 21, 2012	2u TIP Rm.	Quince2
Apr. 18, 2012	2u Sup.Cham.	Survey Runner
May 23, 2012	3u 1F TIP Rm.	Quince2
June 13, 2012	2u 1～5F	Quince2
July 4, 2012	1u 1F S	Packbot Quince2,3

Decontamination, Work Monitoring			
Date	Location	Robot	Use
July 1, 2011	3u 1F S	Warrior	Cleaning
July 6, 2011	3u 1F S	Warrior	Work monitoring
July 6, 2011	3u 1F S	Packbot	Work monitoring
July 8, 2011	3u 1F S	Packbot	Working site inspection
July 12, 2011	3u 1F S	Packbot	Work monitoring
Sep. 23, 2011	2u 1F	JAEA3 Packbot	Inspection by camera and γ camera
Sep. 23, 2011	3u 1F	Packbot	Inspection by camera
Nov. 2, 3, 2011	3u 1F	Warrior Packbot	Obstacle transportation
Nov. 14, 17-19, 2011	3u 1F NE	Packbot	Rag wiping
May 2012- (on going)	1～3u 1F	Packbot	Inspection by γ camera

Light work by Packbot

Cleaning by Warrior

5000mSv/h was recorded in the inspection of 1u T/B2F SGTS Rm. by Packbot in Aug. 2, 2012

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Achievements of Disaster Response Robots

Investigation of Building
(Kohga3: Matsuno, Kyoto U.)

Investigation under Water
(Anchor Diver III: Hirose, TITech.)

Investigating under Water
(Remote-Controlled ROV: Ura, U. Tokyo)

Mapping of the Destroyed Area
(Omni-directional Camera on a Vehicle
Ikeuchi, U. Tokyo, Deguchi, Tohoku U.)

UAV
(Nonami, Chiba Univ.)

Assist of Heavy Load Task
(Smart Suit Light:
Tanaka, Hokkaido U.)

Mental Care in Refuge
(Paro: Shibata, AIST)

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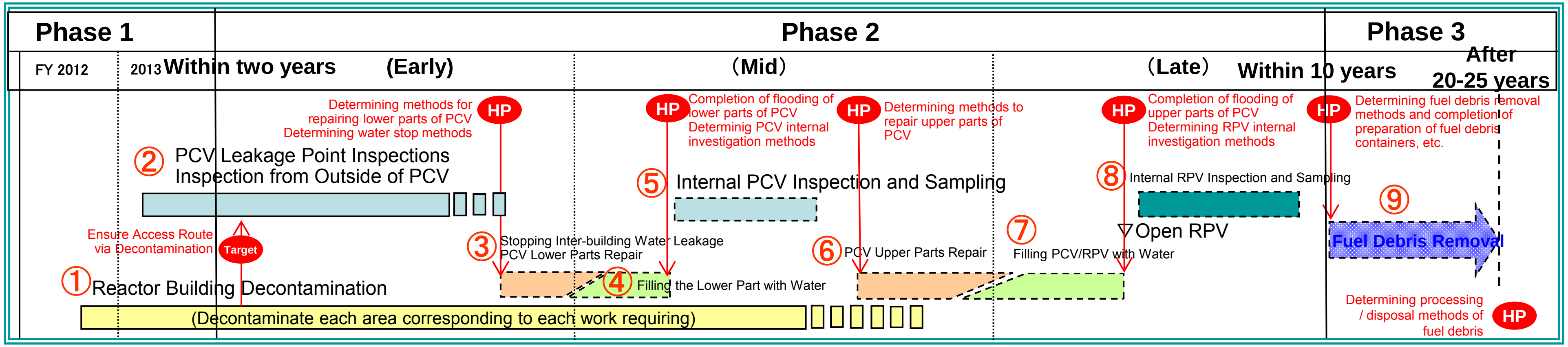
Recovery Operation using Dual Arm Machine

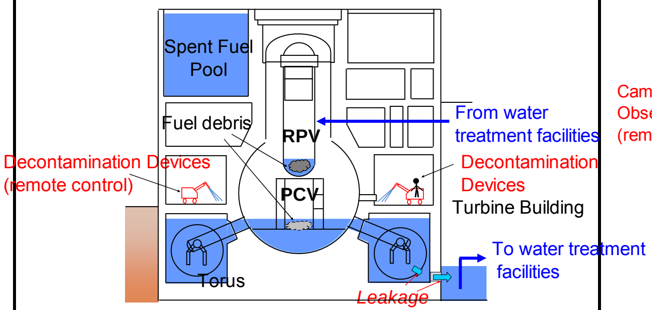
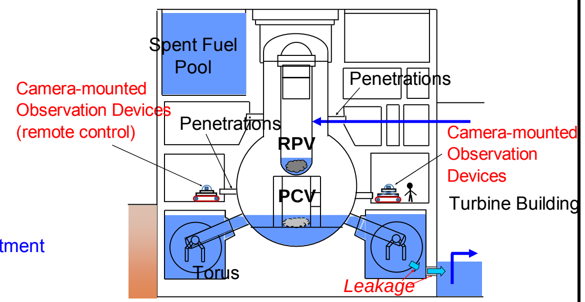
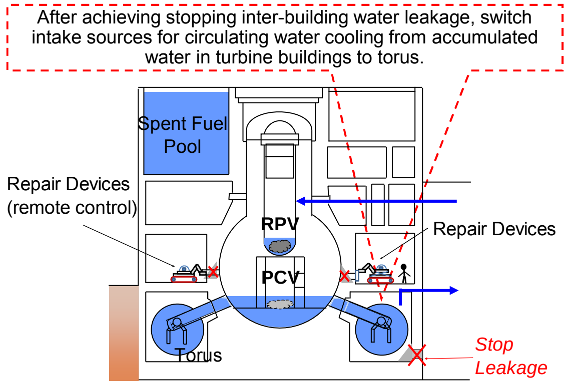
Mid-and-long-Term Roadmap Summary
(TEPCO)

Present (Completion of Step 2)	Within 2 Years	Within 10 Years	After 30-40 Years
Step 1, 2	**Phase 1**	**Phase 2**	**Phase 3**
<Achieved Stable Conditions>	Period to the start of fuel removal from the spent fuel pool (Within 2 years)	Period to the start of fuel debris removal (Within 10 years)	Period to the end of decommissioning (After 30-40 years)
-Condition equivalent to cold shutdown -Significant Suppression of Emissions	-Commence the removal of fuels from the spent fuel pools (Unit 4 in 2 years) -Reduce the radiation impact due to additional emissions from the whole site and radioactive waste generated after the accident (secondary waste materials via water processing and debris etc.) Thus maintain an effective radiation dose of less than 1 mSv/yr at the site boundaries caused by the aforementioned. -Maintain stable reactor cooling and accumulated water processing and improve their credibility. -Commence R&D and decontamination towards the removal of fuel debris -Commence R&D of radioactive waste processing and disposal	-Complete the fuel removal from the spent fuel pools at all Units -Complete preparations for the removal of fuel debris such as decontaminating the insides of the buildings, restoring the PCVs and filling the PCVs with water Then commence the removal of fuel debris (Target: within 10 years) -Continue stable reactor cooling -Complete the processing of accumulated water -Continue R&D on radioactive waste processing and disposal, and commence R&D on the reactor facilities decommission	-Complete the fuel debris removal (in 20-25 years) -Complete the decommission (in 30-40 years) -Implement radioactive waste processing and disposal

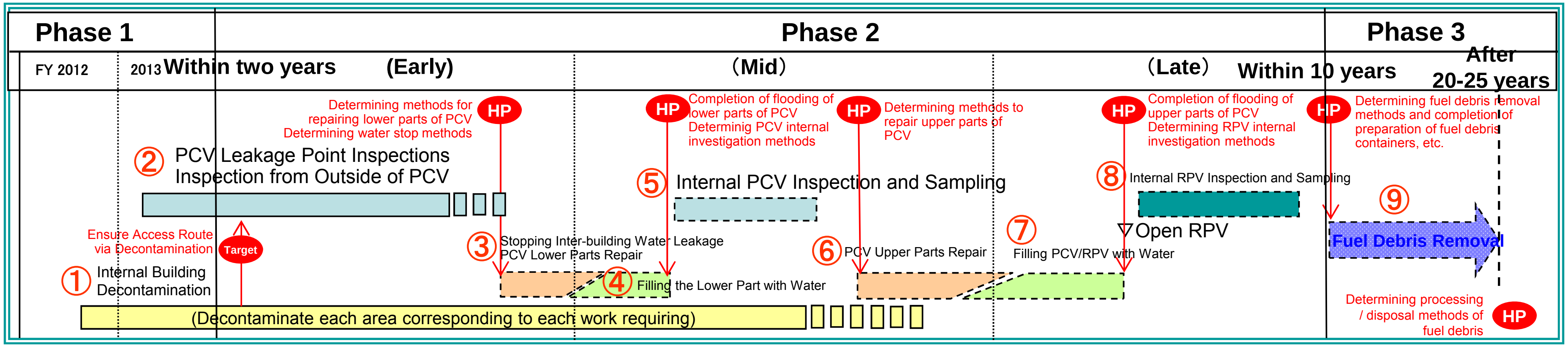
Actions towards systematic staff training and allocation, improving motivation, and securing worker safety will be continuously implemented.

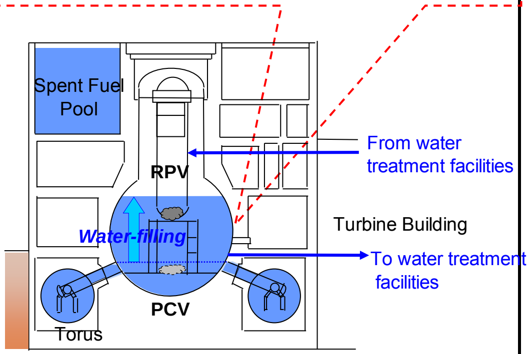
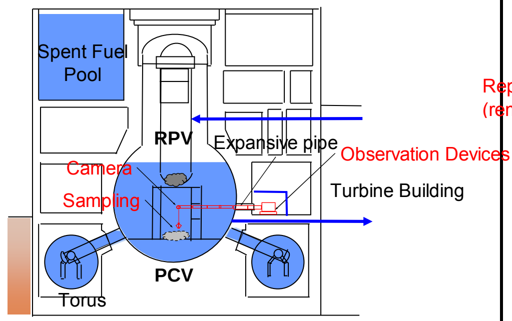
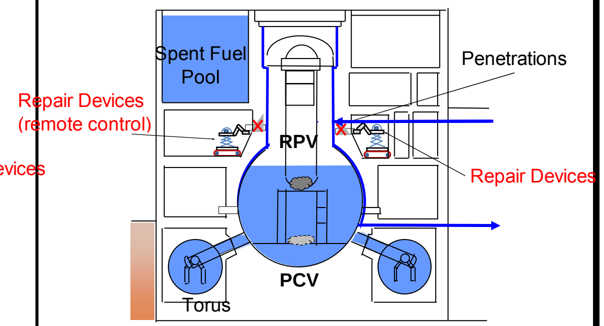
Work Steps Involved in Fuel Debris Removal（1/3）



Steps	① Reactor Building Decontamination **(Decontaminate each area corresponding to each work following ② sequentially)**	② PCV Leakage Point Inspections Inspection from Outside of PCV	③ Stopping Inter-building Water Leakage PCV Lower Parts Repair
Images			
Contents	In order to easily access PCVs, decontaminate work area via high-pressure washing, coating, and scraping, etc.	Inspect leakage points in the PCV and reactor building via manual or remote dose measurement, and camera, etc. Estimate and inspect the status of PCV inside via measurement of gamma ray from outside of PCV, and acoustic inspection, etc.	Repair PCV leakage points and then stop water leakage because it is believed that removing debris while underwater due to the excellent radiation shielding afforded will be the reliable method. First, repair points at lower parts of PCV for internal inspection.
Points to Note on Development	**◆The existence of areas of high dosage (several hundred to 1,000 mSv/h).** **◆Access restriction due to rubble scattered about inside R/B.** ・Remote decontamination methods corresponding to the above need to be considered and established.	**◆Inspection areas may be located in highly radioactive environments, under contaminated water, and in narrow parts.** ・Develop leakage point inspection methods and devices. ・Develop methods and devices for internal inspection from outside of PCV.	**◆While continuing water injection for circulating water cooling, stop water leakage under highly radioactive and water running conditions.** ・Develop technologies and methods to repair leakage points and stop water leakage. ・Consider and develop alternatives.

Work Steps Involved in Fuel Debris Removal（2/3）



Steps	④ Filling the Lower Part with Water	⑤ Internal PCV Inspection and Sampling	⑥ PCV Upper Parts Repair
Images	After achieving construction of boundaries at the lower parts of PCV, switch intake sources for circulating water cooling from torus to PCV. 		
Contents	Partially fill the lower parts of PCV with water before starting PCV internal inspection.	Ascertain distributions of fuel debris flowed from RPV by internal PCV inspections and samplings etc.	In order to fill the PCV full with water, repair leakage points at the upper parts of PCV by manual or remote methods.
Points to Note on Development	**◆Same as ③** ・Place top priority on the construction of boundaries at the lower parts of PCV (including filling torus with grout materials).	**◆ Access restriction due to high radioactive conditions and unknowing PCV internal conditions (thickness of internal water, existence of debris, etc.)** ・Develop remote inspection methods and sampling methods corresponding to the above.	**◆ Same as ②** ・Develop technologies and methods to repair PCV leakage points and stop water leakage (same as ③).

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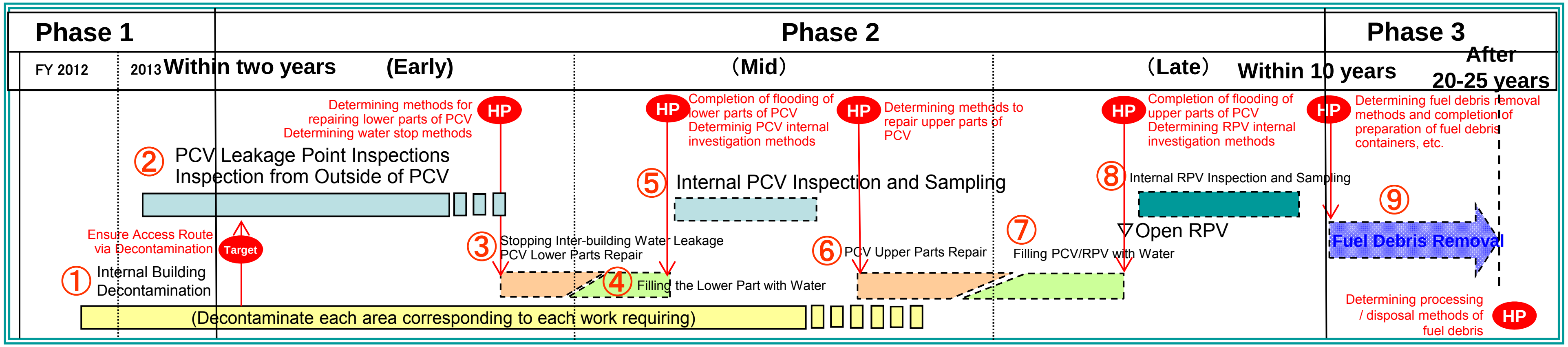
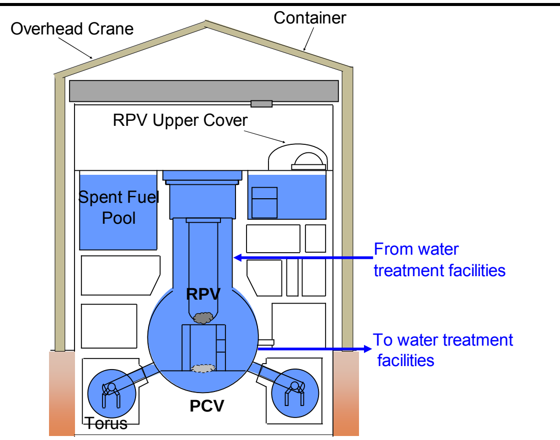
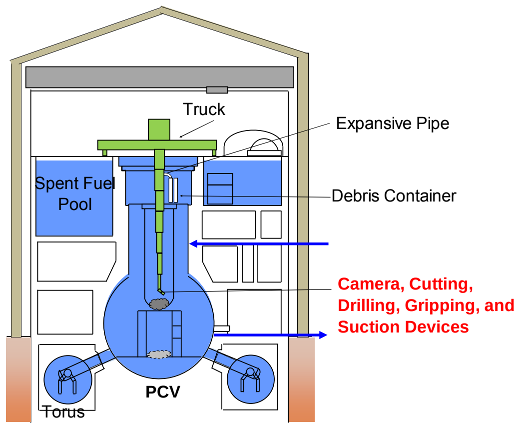
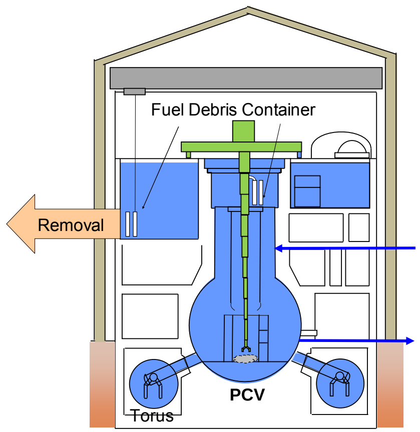
Work Steps Involved in Fuel Debris Removal（3/3）



Steps	⑦ Filling PCV and RPV with Water ⇒ Open the upper cover on RPV	⑧ Internal RPV Inspection and Sampling	⑨ Fuel Debris Removal
Images			
Contents	After filling PCV/RPV with water enough to ensure shielding, open the upper cover on RPV.	Ascertain conditions of fuel debris and internal RPV structures by internal RPV inspections and samplings etc.	Remove debris inside RPV and PCV
Points to Note on Development	(Place top priority on the construction of PCV boundaries as per ⑥)	◆Restricted access route due to high radioactive conditions and unknown internal RPV conditions (thickness of internal water, existence of debris, etc.) ・Develop remote inspection methods and sampling methods based on the above.	◆Expand technology development scope depending on distribution status of fuel debris (No experience of fuel removal of inside PCV at TMI) ・Develop more sophisticated technologies and methods than those of TMI

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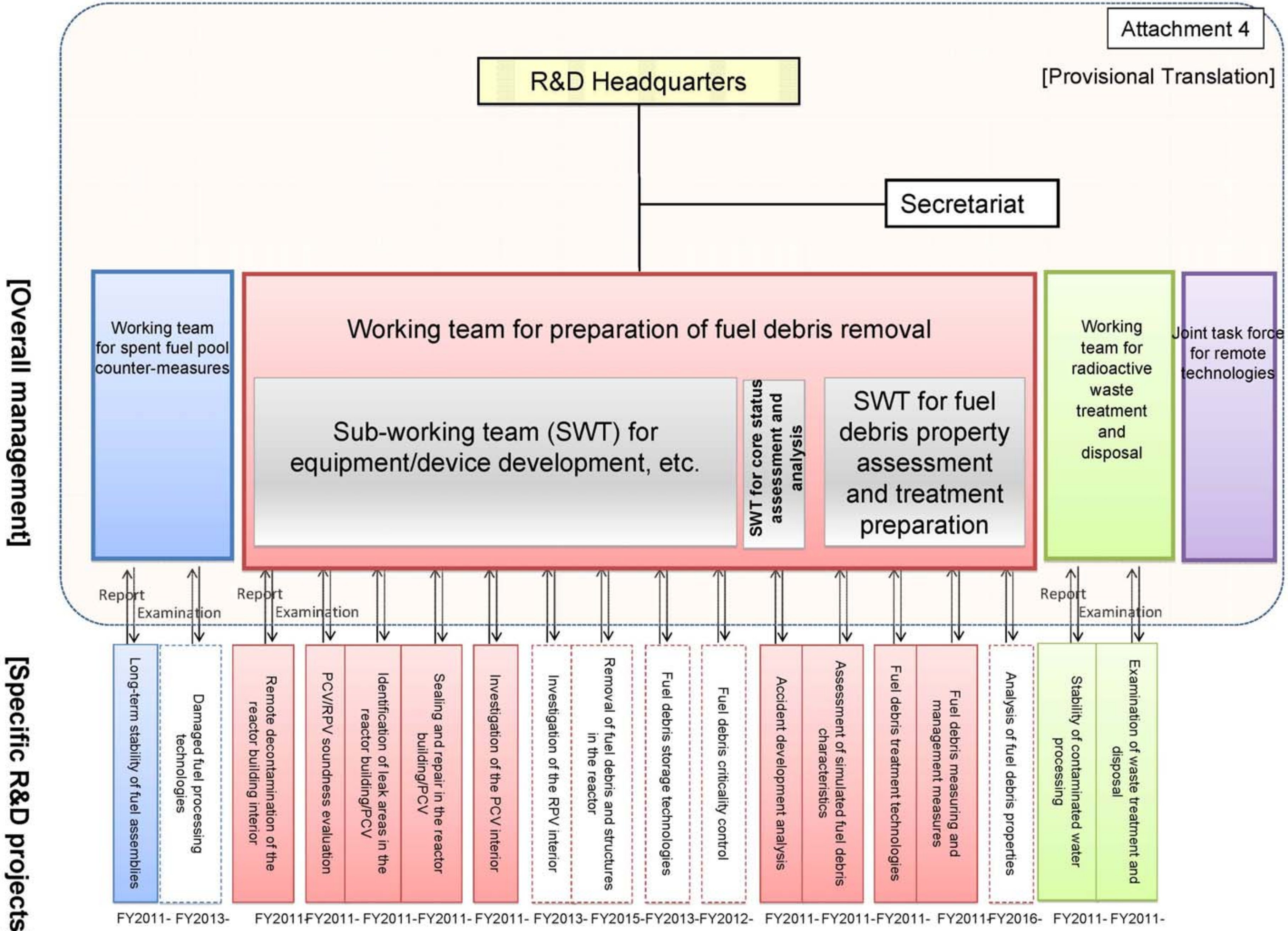

Attachment 4
[Provisional Translation]
R&D Headquarters
Secretariat
[Overall management]
Working team for spent fuel pool counter-measures
Working team for preparation of fuel debris removal
Sub-working team (SWT) for equipment/device development, etc.
SWT for core status assessment and analysis
SWT for fuel debris property assessment and treatment preparation
Working team for radioactive waste treatment and disposal
Joint task force for remote technologies
Report
Examination
Report
Examination
Report
Examination
[Specific R&D projects]
Long-term stability of fuel assemblies
Damaged fuel processing technologies
Remote decontamination of the reactor building interior
PCV/RPV soundness evaluation
Identification of leak areas in the reactor building/PCV
Sealing and repair in the reactor building/PCV
Investigation of the PCV interior
Investigation of the RPV interior
Removal of fuel debris and structures in the reactor
Fuel debris storage technologies
Fuel debris criticality control
Accident development analysis
Assessment of simulated fuel debris characteristics
Fuel debris treatment technologies
Fuel debris measuring and management measures
Analysis of fuel debris properties
Stability of contaminated water processing
Examination of waste treatment and disposal
FY2011- FY2013- FY2011-FY2011- FY2011-FY2011- FY2011- FY2013- FY2015-FY2013-FY2012- FY2011-FY2011-FY2011- FY2011-FY2016- FY2011- FY2011-

R&D Projects for Fuel Debris Removal

■ Remote Decontamination Technology

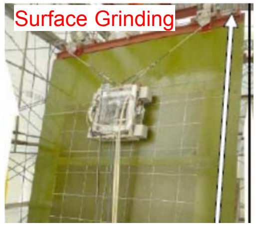
◆ **Purpose**

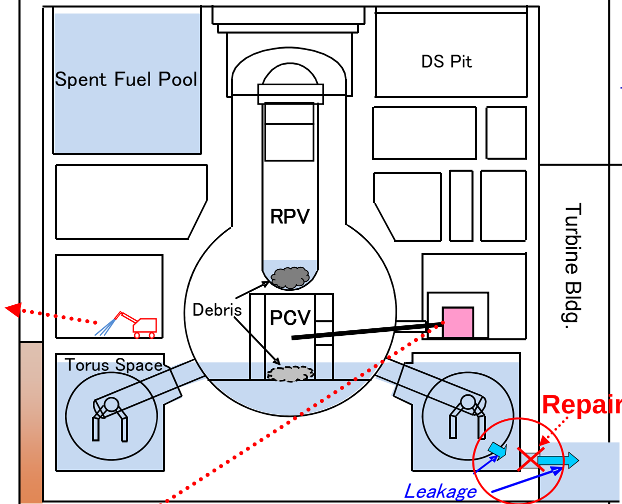
Reduce the radiation dose for following surveys and repair works

◆ **Challenging Points**

・Optimal decontamination way for each situation
・Remote control tech. for high radiation or restricted work space

Existing Techniques





■ Leakage Detecting Technology

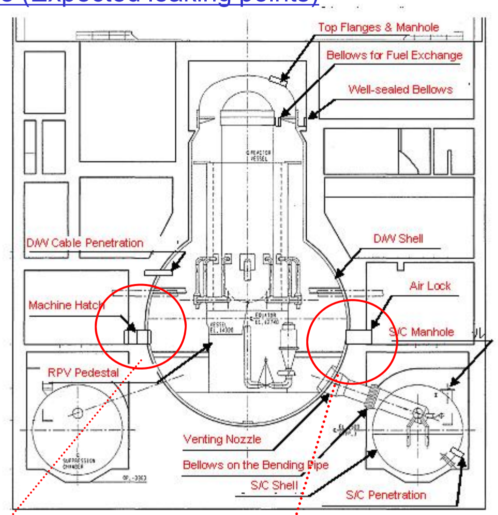
◆ **Purpose**

Detect the leaking points w/o high exposure

◆ **Challenging Points**

・High radiation, little space
・Remote checking/control system

Example (Expected leaking points)



■ Inner PCV Survey Technology

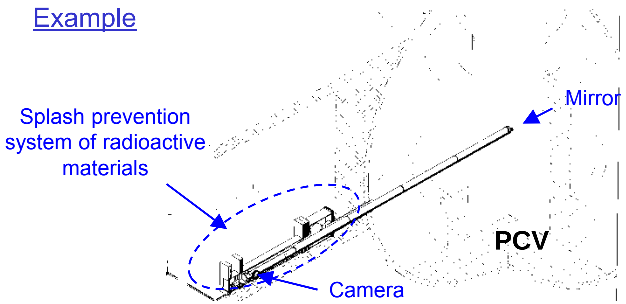
◆ **Purpose**

Survey the condition of PCV and RPV, and the location and property of debris

◆ **Challenging Points**

・Measuring instruments with remote control system under high temp., high humidity, and high radiation
・Splash prevention system

Example



■ Leakage Mending Technology

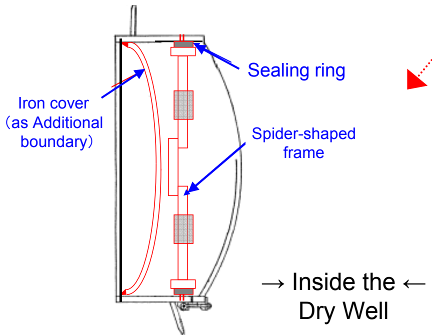
◆ **Purpose**

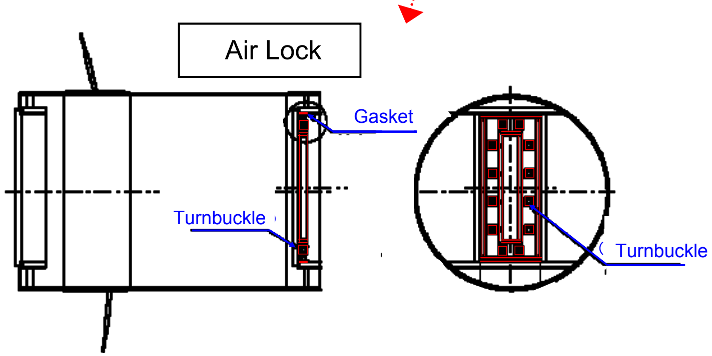
Develop the waterstops and leakage mending methods for various leakage points

◆ **Challenging Points**

・Availability in the contaminated water
・Remote procedure/control

Example





Toshiba/Hitachi GE Nuclear Energy/Mitsubishi Heavy Industries

Technical Catalogue

Investigation of applicable technologies toward accomplishment of removal of fuel debris and decommission.

- Decontamination technology and remote-control technology for decontamination work
- Remote-control operation machine and measurement equipment for Primary Containment Vessel inspection and repair.

395 proposals

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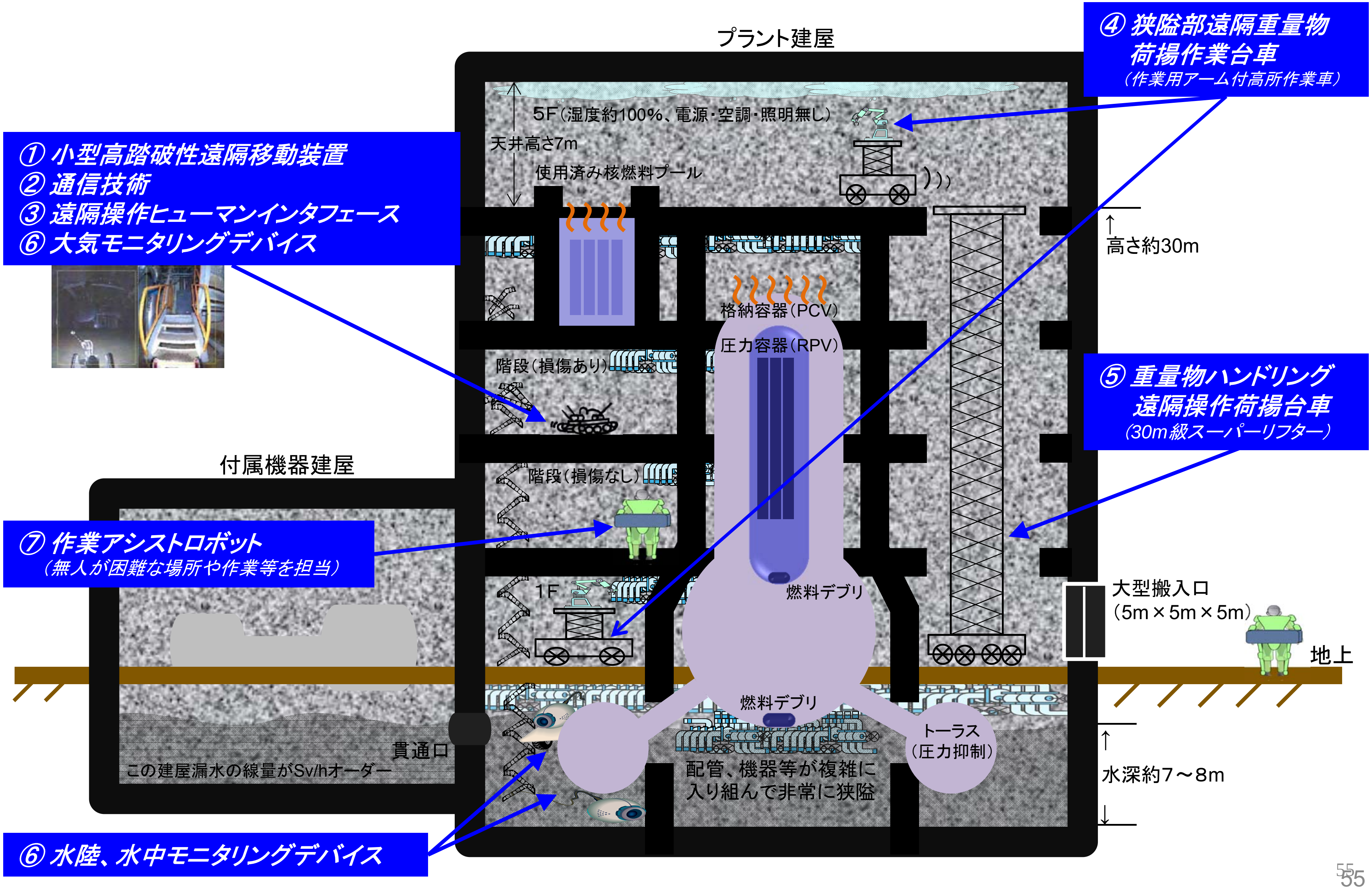
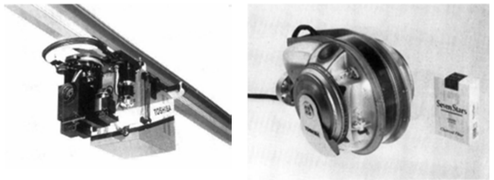
Image of system application to the accident of NPP



Robots developed in projects for nuclear facilities

For Maintenance

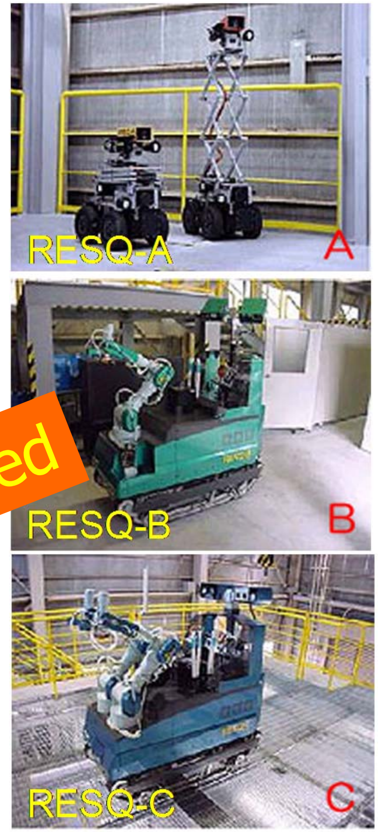


Inspection Robots (for specific use)

Hazard Environments Robot

Maintenance Robot (for general use)

For Emergency Response
(JCO Criticality Accident)



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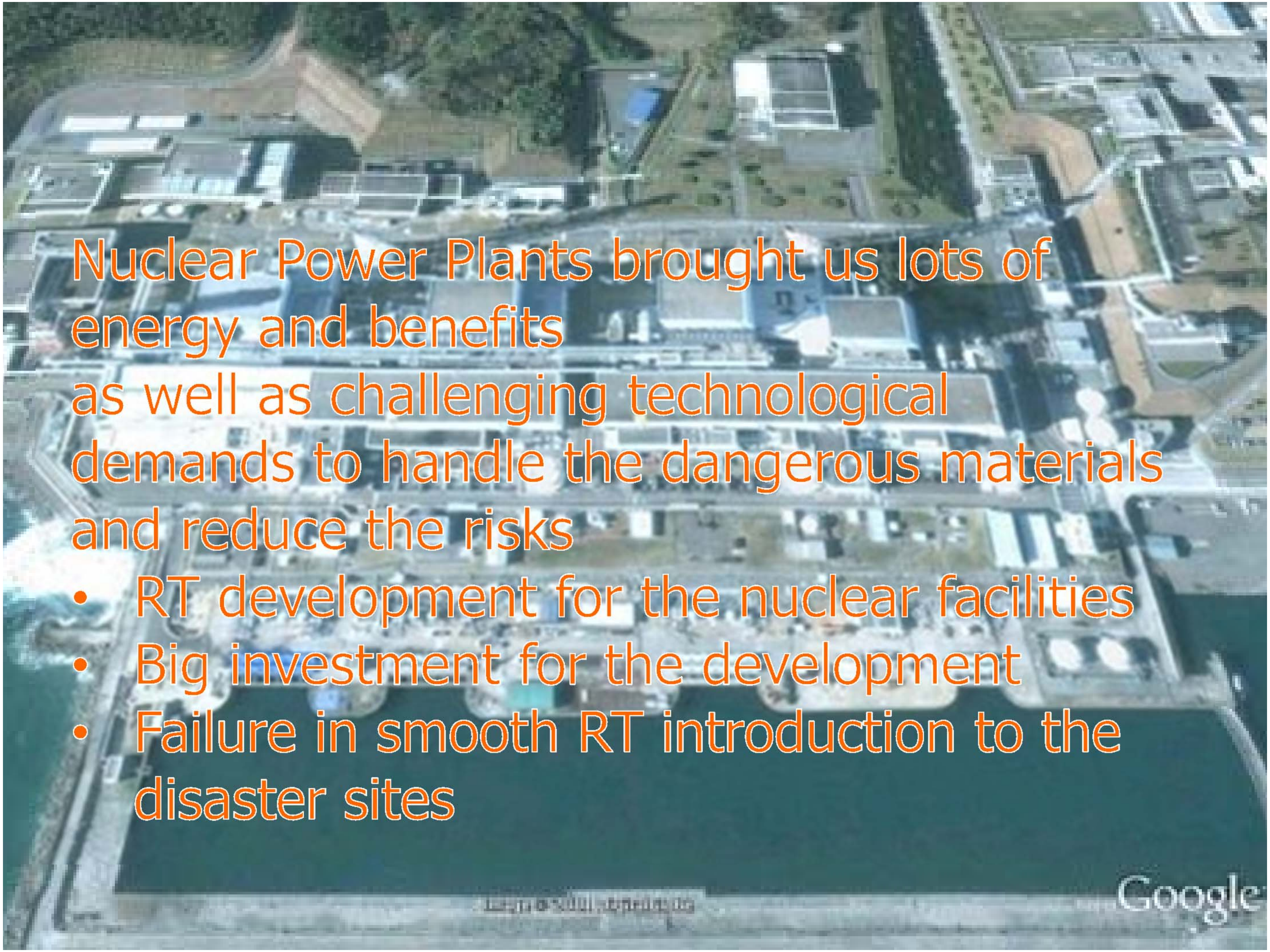
Considerations



Nuclear Power Plants brought us lots of energy and benefits
as well as challenging technological demands to handle the dangerous materials and reduce the risks

- RT development for the nuclear facilities
- Big investment for the development
- Failure in smooth RT introduction to the disaster sites

The World's Window on Japan
The Japan Times ONLINE

Friday, Jan. 6, 2012

NUCLEAR AWAKENING

Domestic robots failed to ride to rescue after No. 1 plant blew

By **HIROKO NAKATA**
Staff writer

Last of five parts

After the March 11 tsunami slammed into the Fukushima No. 1 nuclear plant and wrecked three reactors, many people expected the nation's cutting-edge robotic technologies to come to the rescue.

That, however, turned out to be wishful thinking, and the public was left wondering why Japanese robots, such as Honda Motor Co.'s Asimo humanoid, weren't sent to the power plant to assist firefighters and workers trying to bring the crippled reactors under control.

In the early stages of the nuclear crisis, many people actually sent messages to the Asimo Twitter account run by Honda Motor Co., asking why the robot wasn't participating in recovery efforts led by the government and plant operator Tokyo Electric Power Co.

The reply they received, however, said only that

Slinky move: Quince moves down stairs at Chiba Institute of Technology in June. CHIBA INSTITUTE OF TECHNOLOGY

- Indication of the responsibility of robot scientists
- Why Honda Asimo not used?
- Disappointment to know RT is not useful in real situation when it is demanded

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Expectation to Robot Technology

Gap

Reality

- There are few robots and remotely controlled machines which have sufficient function to be used in the real disaster sites.
- Most of the robots developed in Japan were just prototypes developed by researchers, and there are few products.

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- Confusion in information sharing between users and providers (developers)
  - Users
    - What kind of robots and remotely controlled machines are existing?
    - How useful they are in the disaster sites?
  - Providers
    - Where are the needs?
    - What are the needs and requirements?

- It was difficult to introduce RT to the disaster sites smoothly.

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Questions in responsibility of scientists

1. Did we make sufficient effort to translate and transmit the real information on RT to the public?
   - Mass media has reported only on the strong points of Robot Technology and not much on the technological limitation in function.
   - We should review if we have made sufficient effort to translate and transmit the information on the reality on RT to the public.

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Questions in responsibility of scientists

2. Did we make sufficient effort to develop practical technology for implementing the technology in the society?
   - Difficulty in implementing the technology in the society
   - Decision making of technology utilization is heavily dependent on the dynamics of politics and economics
     - Any systems are imperfect in the indefiniteness of the real world (artificial systems and even humans)
     - Risk reduction vs. cost and efficiency
   - Necessity of efforts to develop practical technologies
     - Effort to develop practical technology should be responsibility of scientists
   - Reliable and dependable technology development led by the hard experience and failures

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Lessons learned and future issues

- Necessity to construct international network and framework for cooperation in knowledge sharing and technology transfer
- Examination of the political strategy
  - Sustainability of technology for possible disasters
  - Limitation of demand and market
  - Combination with maintenance use
- Necessity of projects to develop practical technologies usable at first-hand by involving users
- Necessity of site and organization for practical technology development , testing, and quick response to possible emergency and disaster
- Necessity of conservation of technology and knowledge for long-life artificial systems

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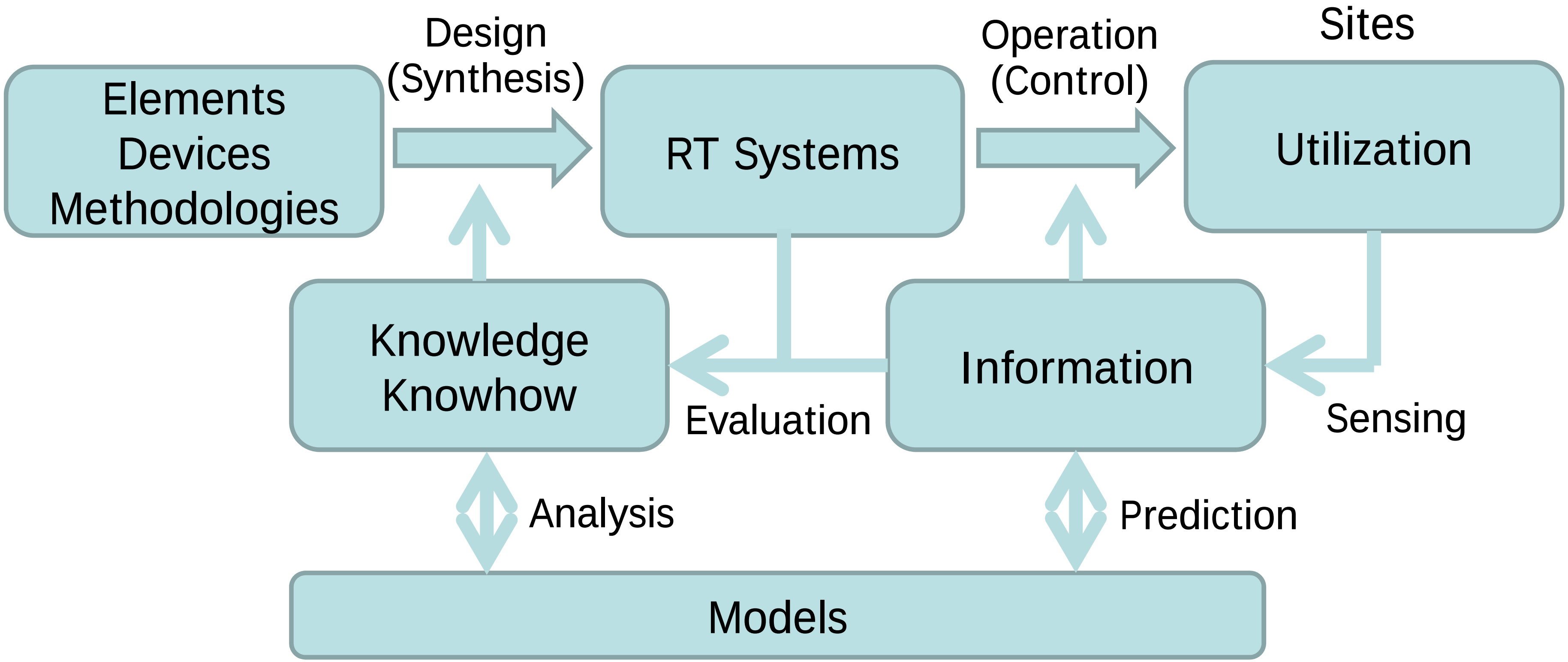
RT System Design & Operation



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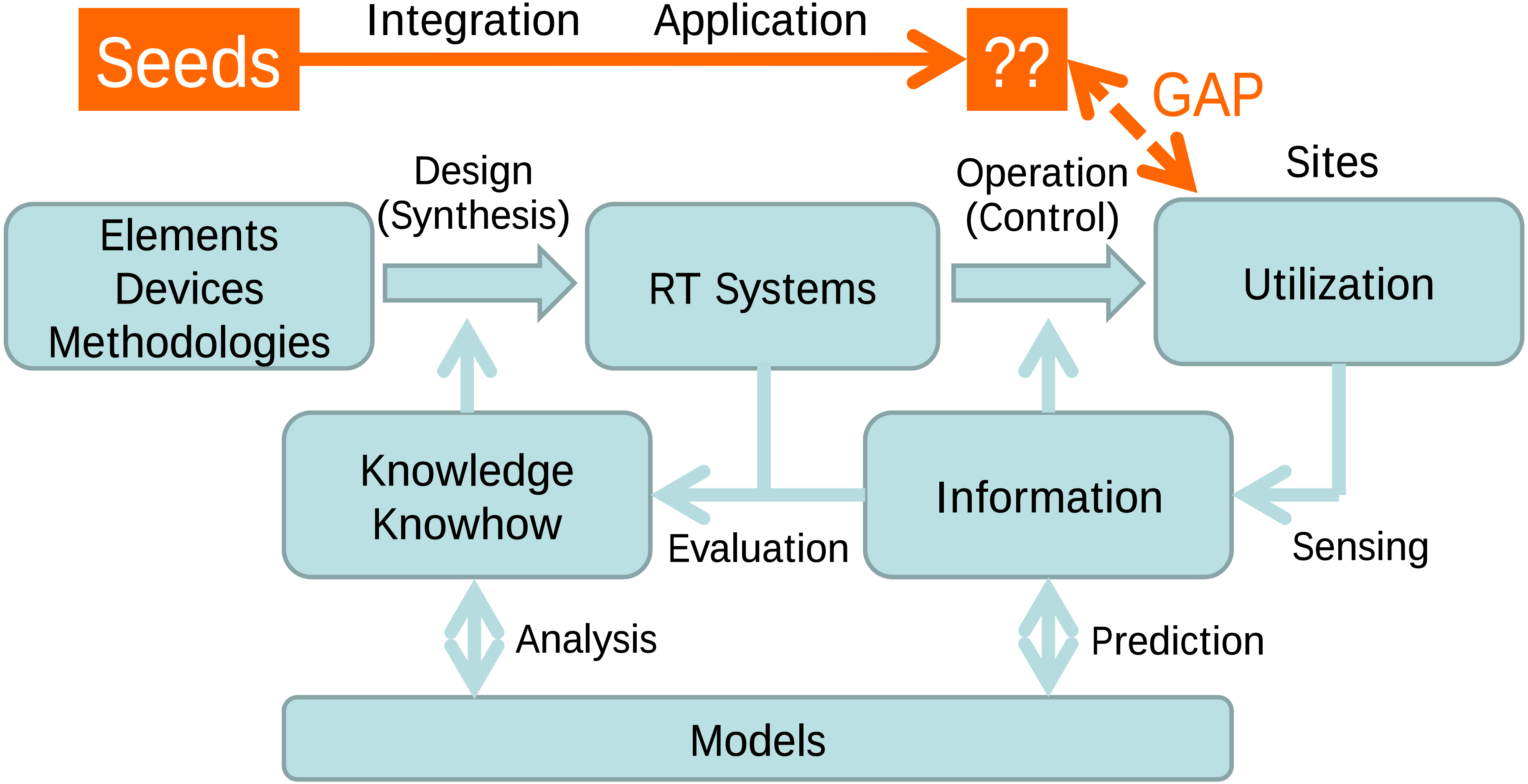
Seed-driven approach



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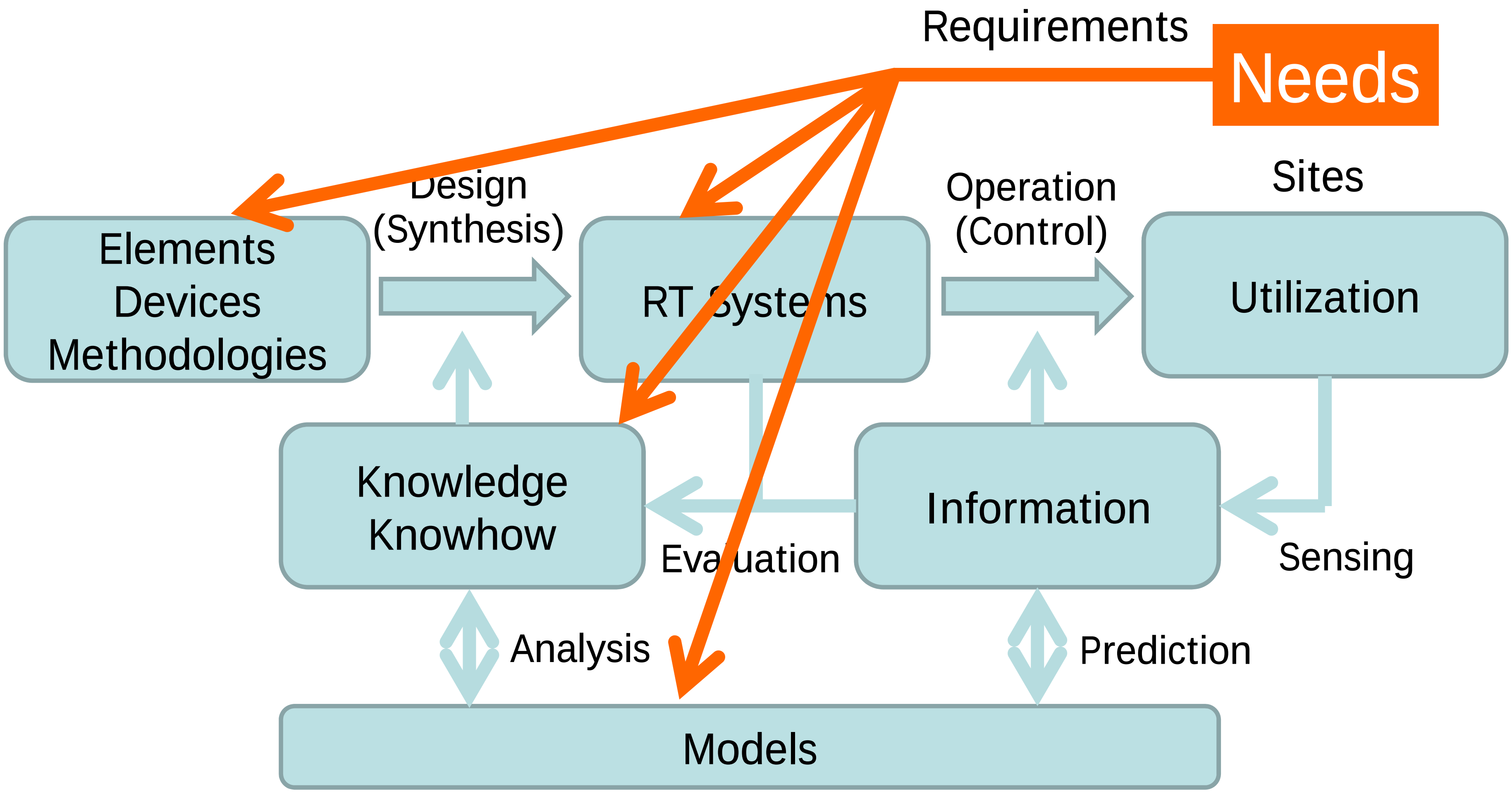
Need-driven approach



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For Future

- Transform the bitter experience to the chance for the technological advancement by developing more dependable and demanded technology for safe and secure society
- Develop young human resources and keep the knowledge and technology beyond the generation

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I extend my sincere condolences
for all the victims, and
express my hearty sympathy to
all the evacuees
due to the Earthquake

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Thank you for your attention!

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