Fukushima & Three Mile Island Accidents & Spent Nuclear Fuel

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Disclaimer: Fukushima Information is preliminary especially regarding interpretation of events; opinions expressed are mine and mine alone.

Three Mile Island Units 1 &2

March 28, 1979

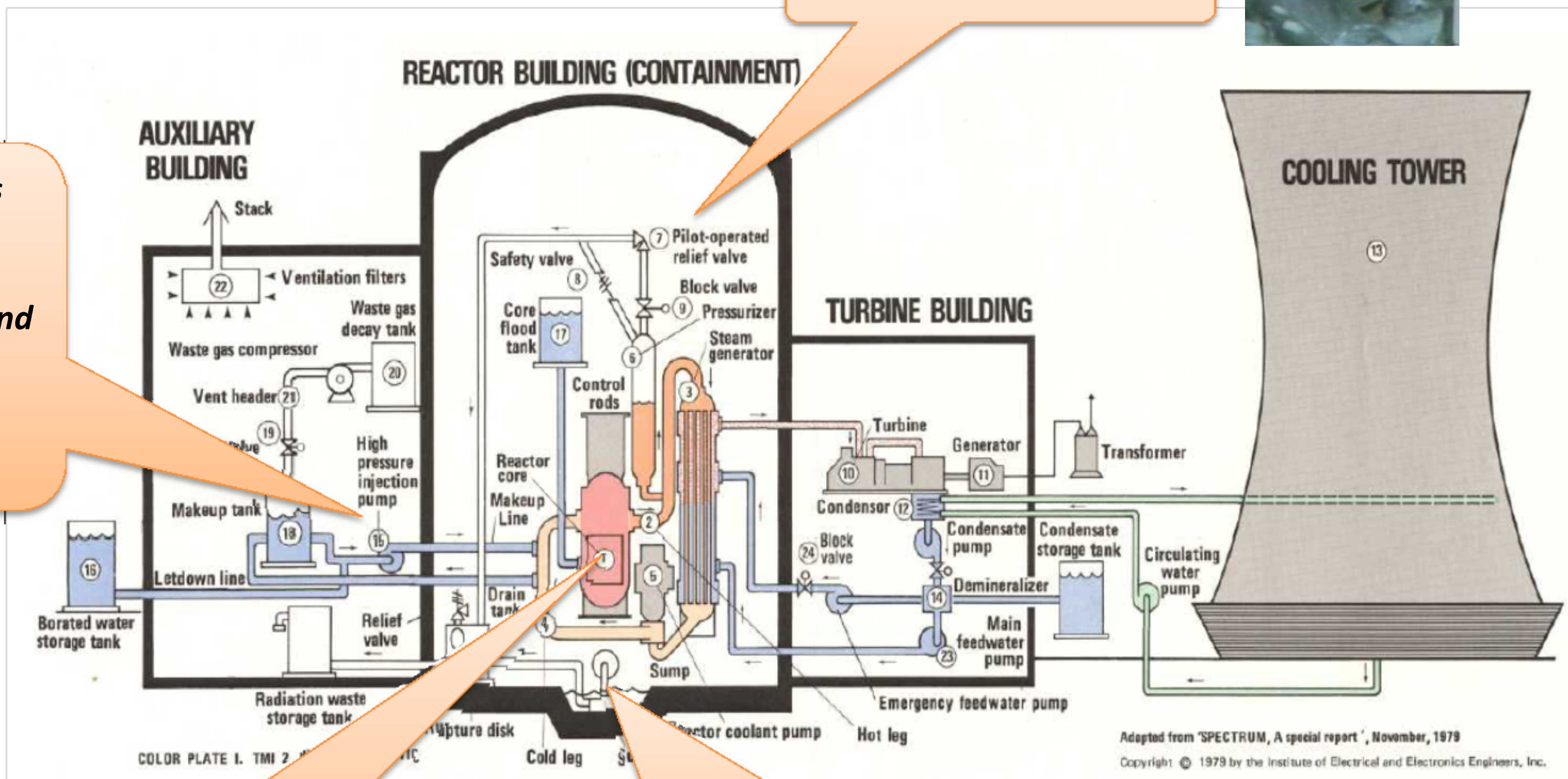
Three Mile Island Unit-2 Accident

March 28, 1979

PORV

Relief Valve fails to close

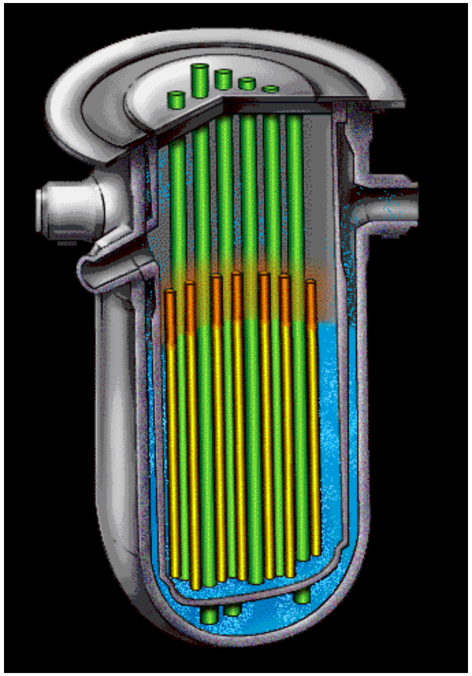
Operators Believe Reactor Overfilled and Turn Off Injection Pumps

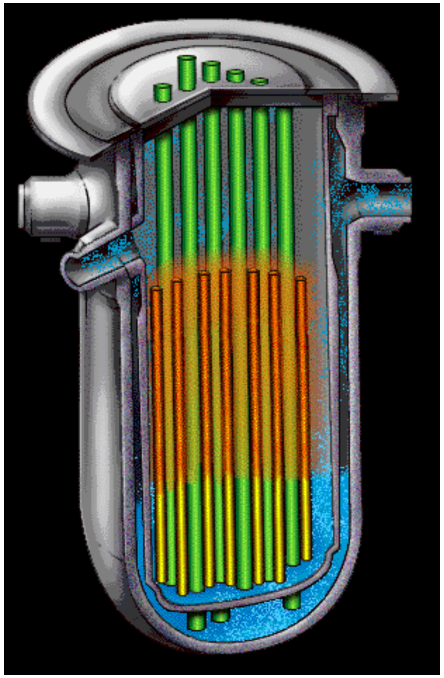


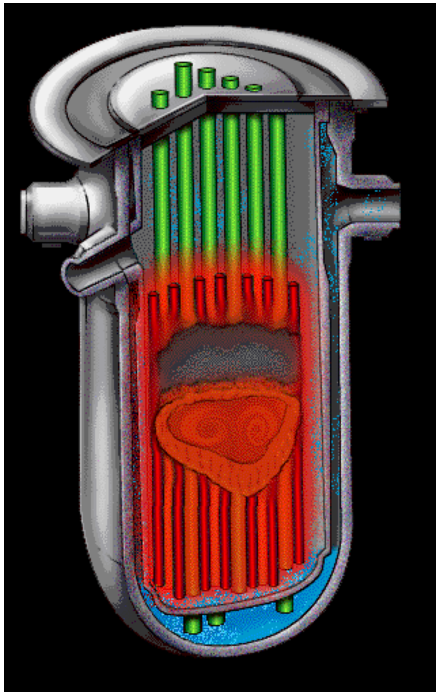
Core is uncovered Fuel overheats/fails/~50% Melt

650,000 gallons of highly radioactive water collects

TMI Core Damage Sequence

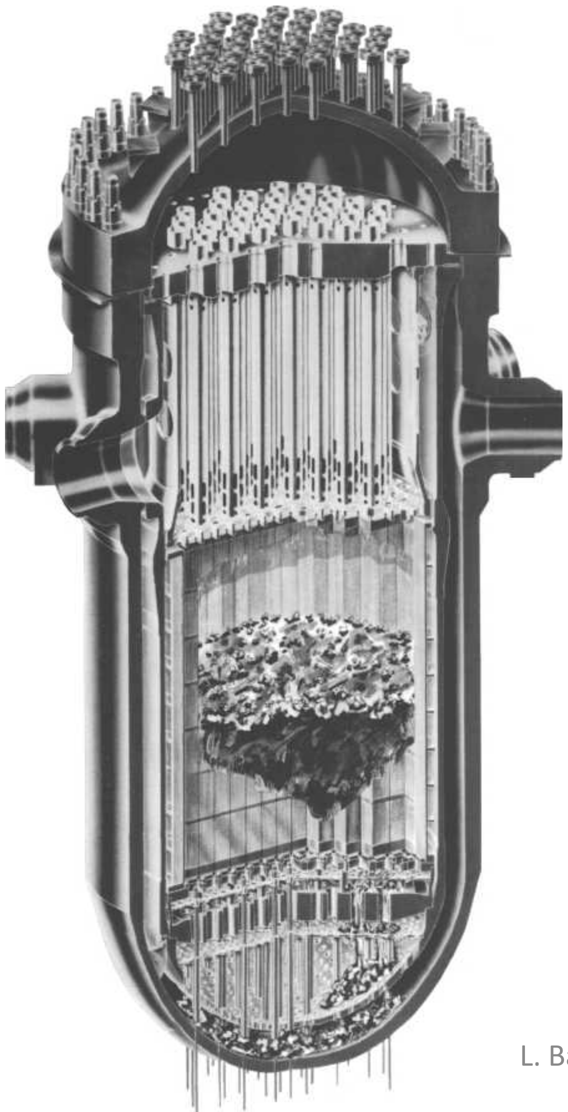






TMI Core Configuration

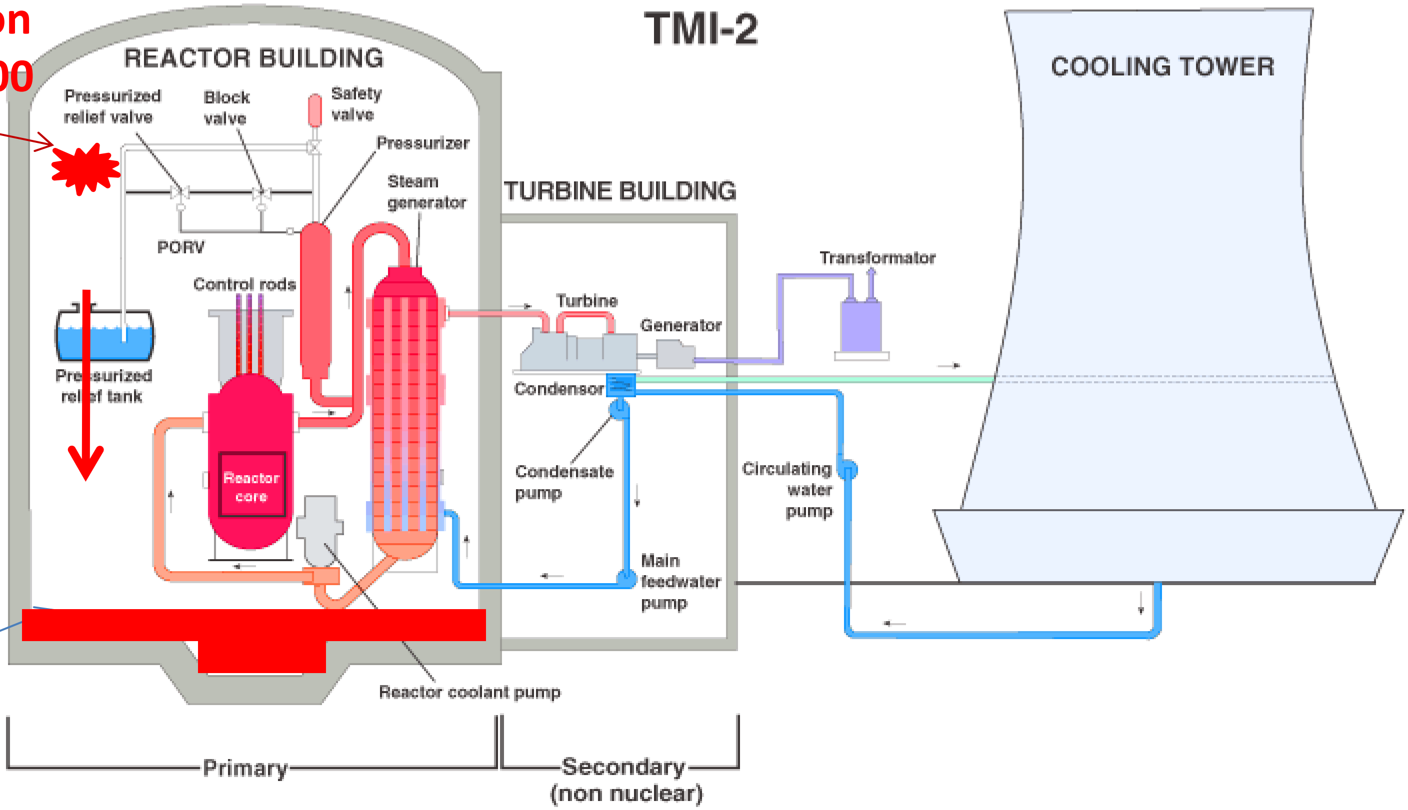
~Evening 3/28/1979



Damaged Fuel Rods

Three Mile Island
March 28, 1979

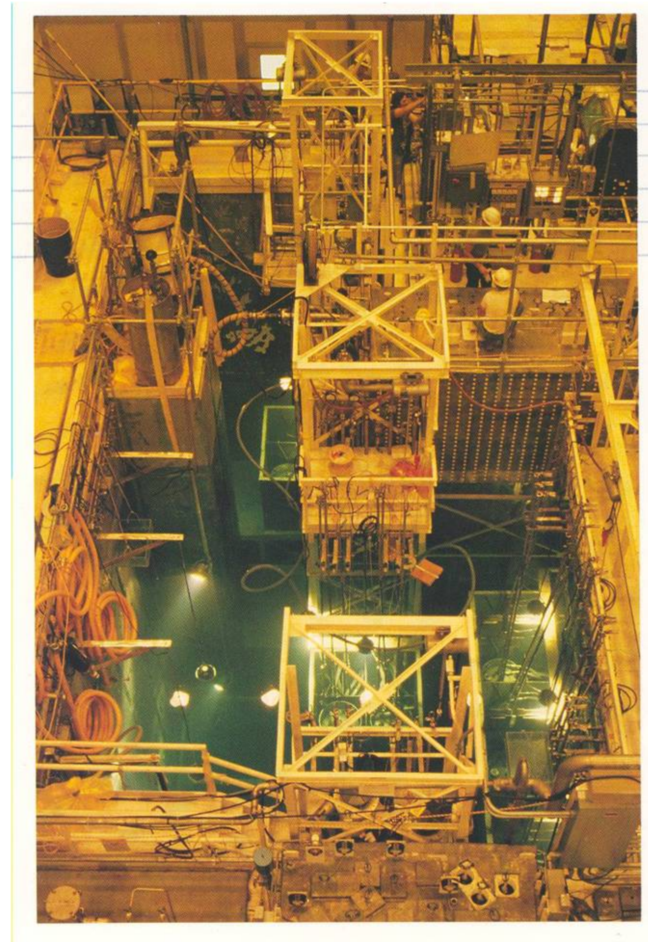
Hydrogen Deflagration 28psig 13:00



~3M deep water 1000R/hr

Recovery Cleanup Actions

Building Remediation to Gain Core Access (Barrett Entry)

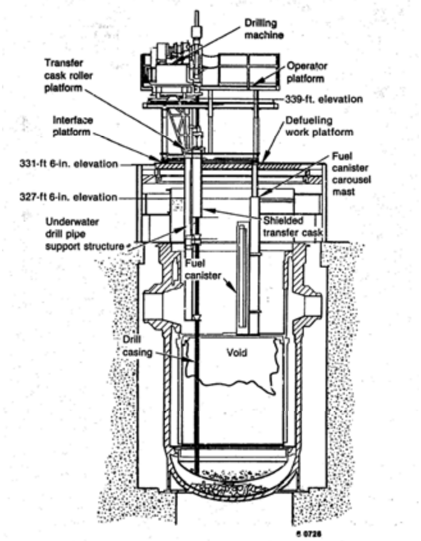


Phased Unique Air and Water Cleanup Systems Created Based on Best Available Technology

TMI Damaged Core Removal

~1985-1990

TMI Defueling Sequence



Core Bore Machine

Defuel Can Loading

Can Transfers

Shipping Cask

Transport

Core Debris Storage

Three Mile Island History

- Reactor Scram: 04:00 3/28/79
- Core melt and relocation: ~ 05:00 – 07:30 3/28/79
- Hydrogen Deflagration: 13:00 3/28/79
- Recirculation Cooling: Late 3/28/79
- Phased Water Processing: 1979-1993:Removed ~1.2MCi Cs137
- Containment Venting 43KCi Kr-85: July 1980
- Containment Entry: July 1980
- Reactor Head removed and core melt found: July 1984
- Start Defuel: October 1985
- Shipping Spent Fuel: 1988-1990
- Finish Defuel: Jan 1990
- Evaporate ~2.8M gallons Processed Water: 1991-93
- Cost: ~$1 Billion

Fukushima Daiichi Nuclear Power Station

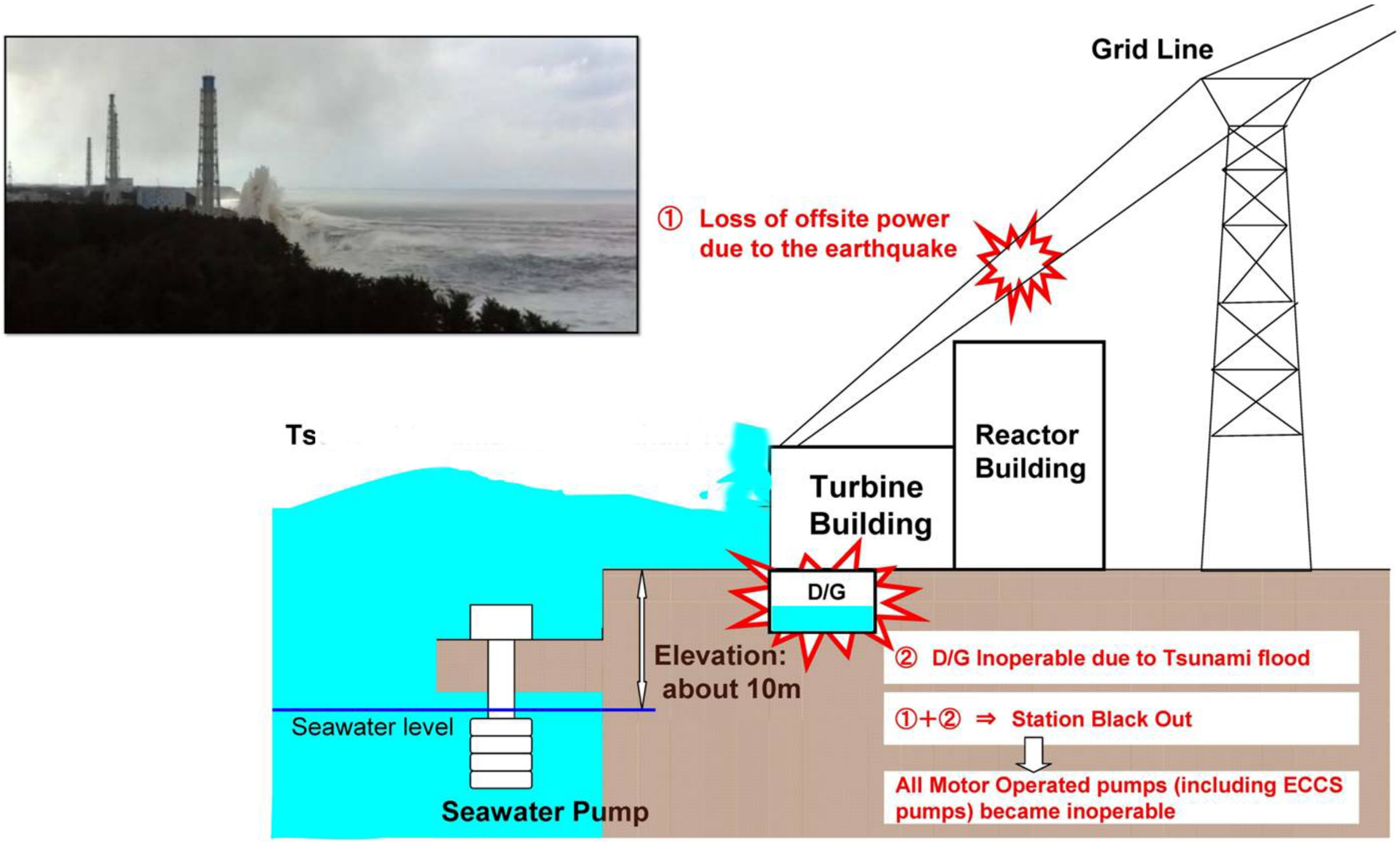
Units 5 &6

Dry SNF Storage

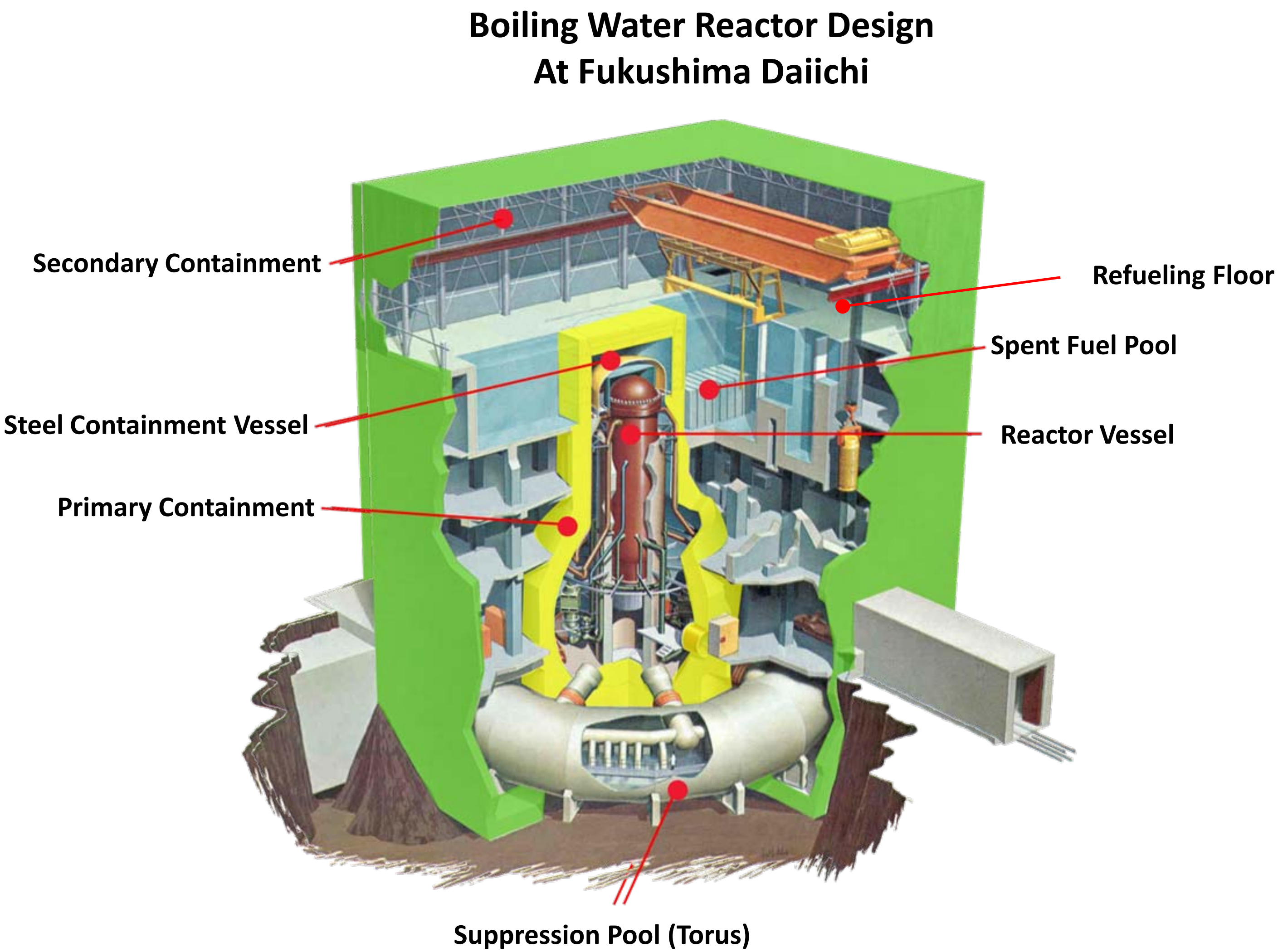
Common
Spent Fuel
Pool

Units 1-4

Tsunami Size: Main Safety Factor
3/11 15:45

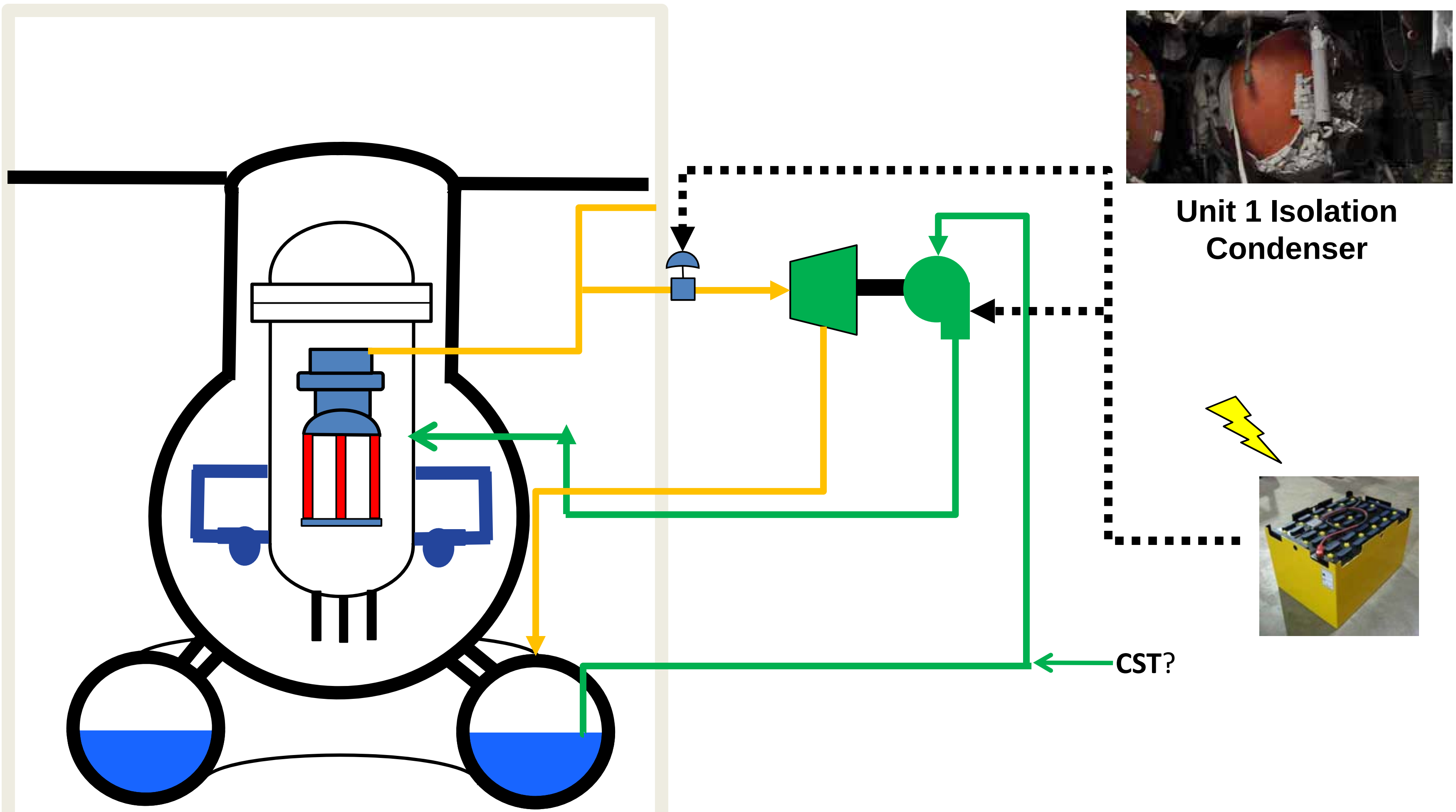


GE Mark I Reactor Building



Browns Ferry Primary Containment

Battery Power Control of Steam-Driven Reactor Core Isolation Cooling System In Units 2 &3 (Unit 1 Had Isolation Condenser which Operators Stopped)



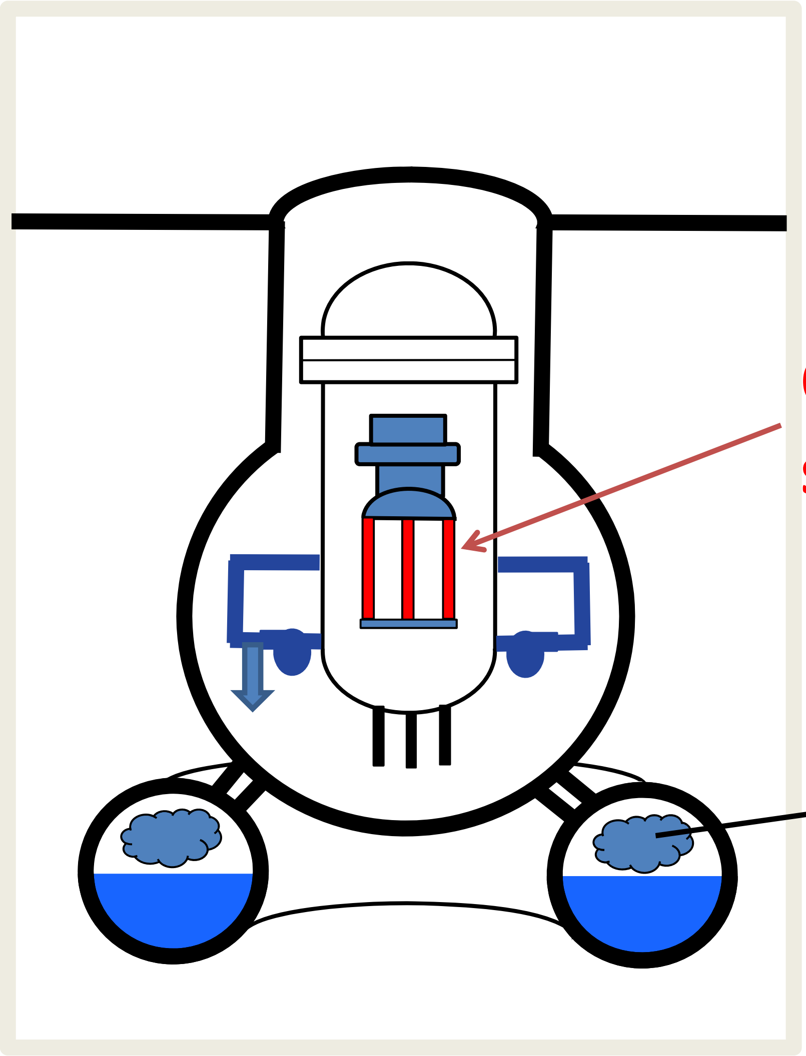
3/11 15:45 to ~ 3/11 24:00 JST

Actions to Extend DC Power For Control

Scavenged Truck Batteries To Maintain Reactor Instrumentation

Control Room Operator During Black Out

Battery Power Exhausted

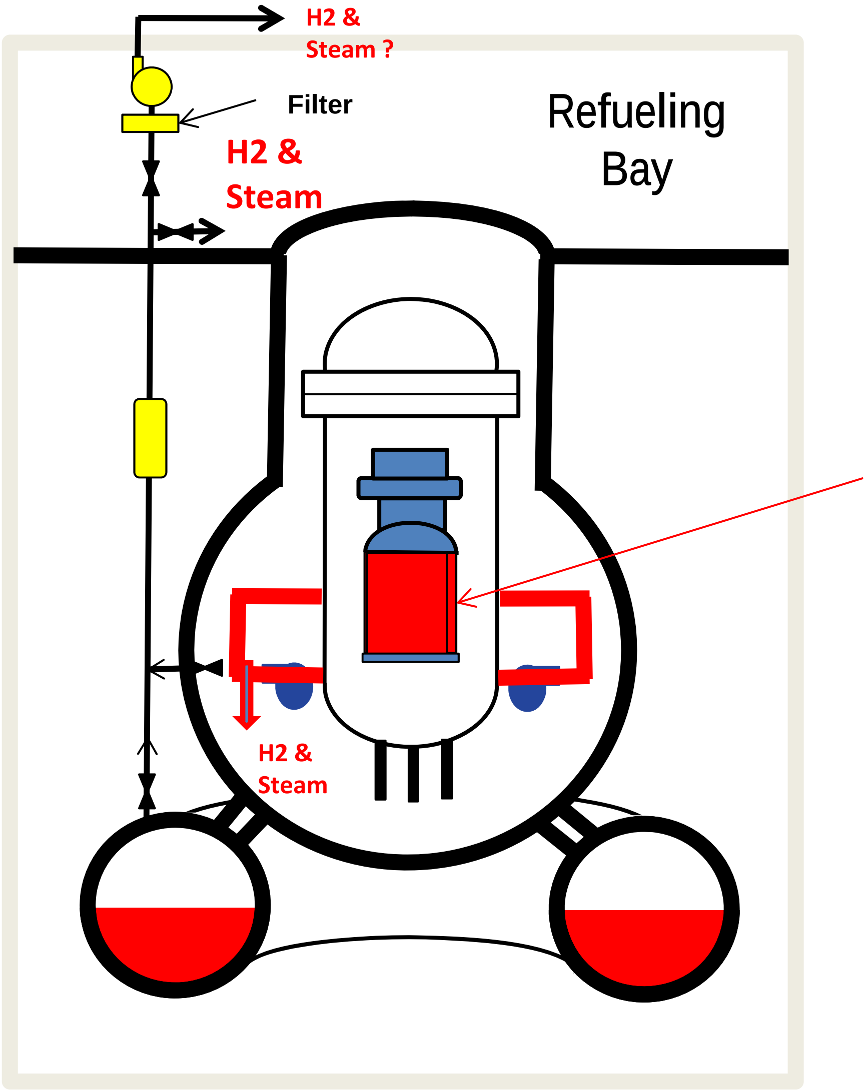


Core Uncovers and starts to overheat

Suppression pool (wet well) becomes saturated

3/12 ~02:00 JST

Venting Primary Containment



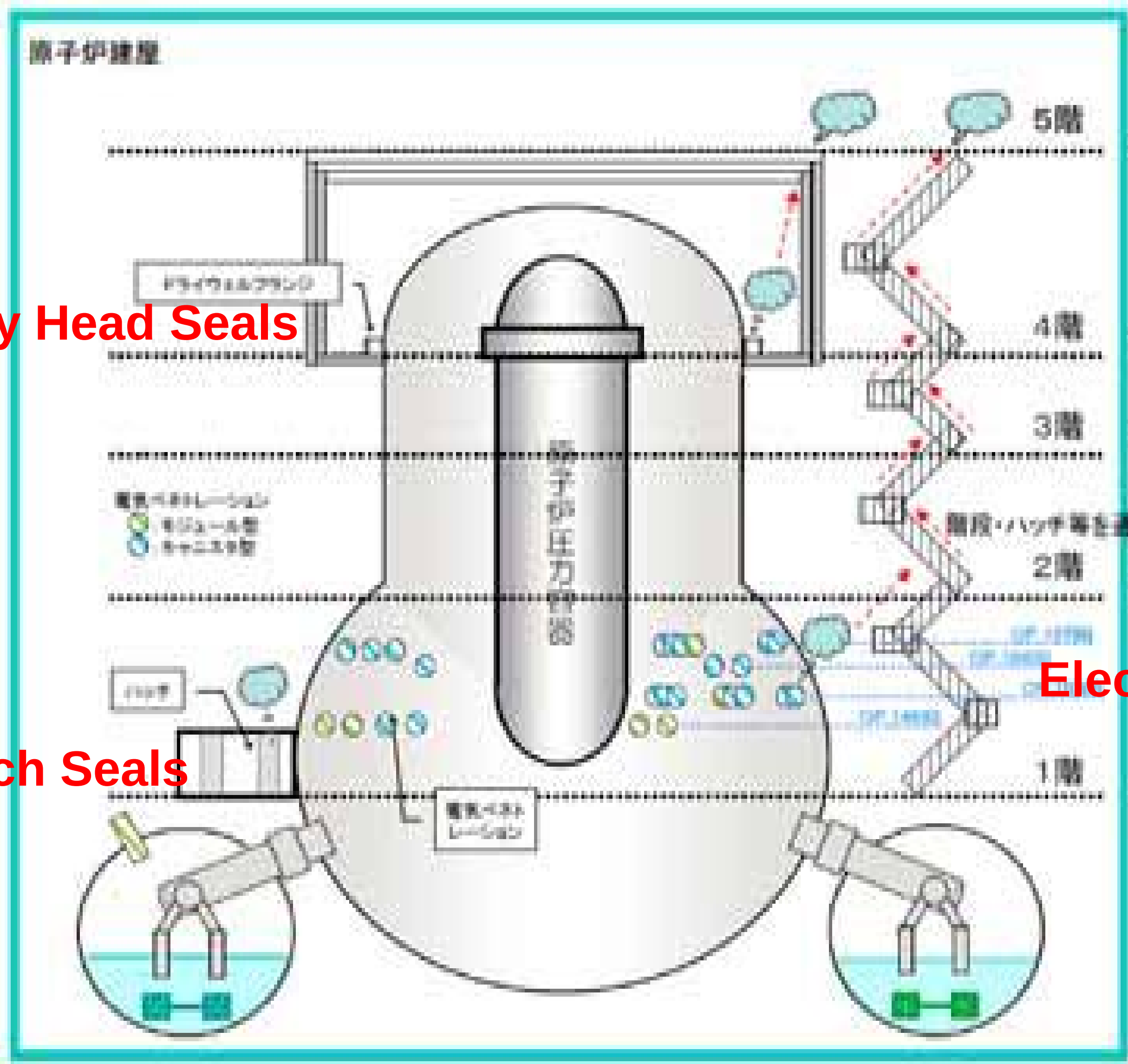
Core Overheated

Primary Containment Pressure~ ~90psia @02:00 3/12

Uncertain Command & Control Actions & Unit 1 Vent Valve Operability

3/12 ~05:30 U1
3/13 ~ 00:00 U2
3/13 ~ 08:40 U3

Hydrogen Leakage Paths



Unit 1 Reactor Building Explosion

3/12 15:31

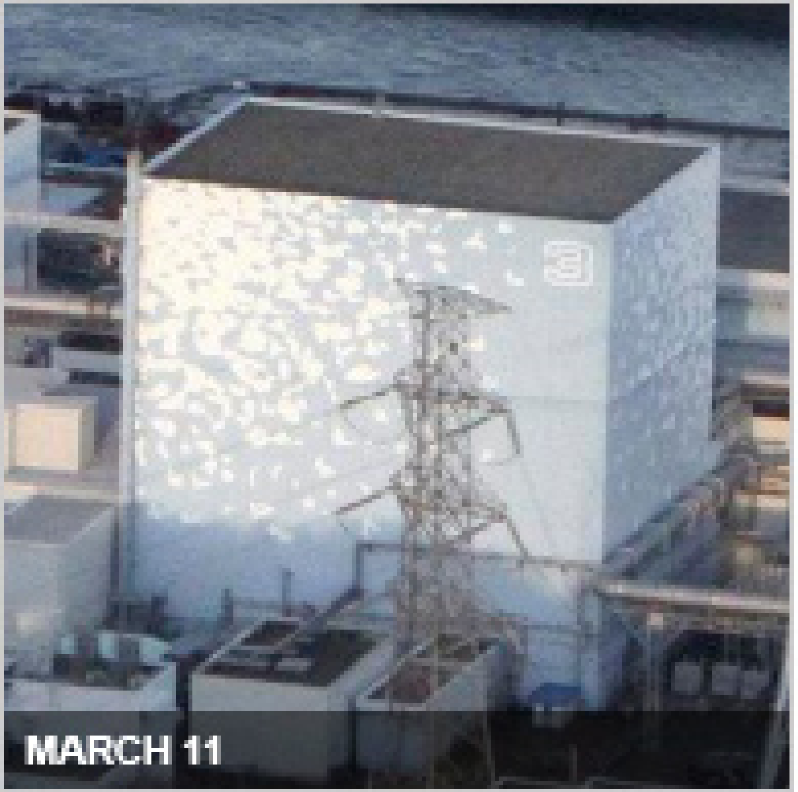
Unit 3 Reactor Building Explosion

3/14 11:15

Unit 1 Reactor Building

Unit 3 Reactor Building

Before



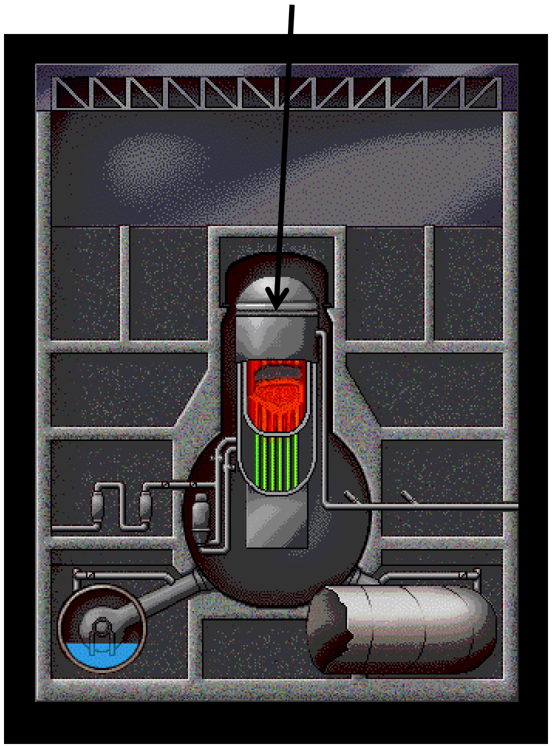
Reuters

After

TEPCO

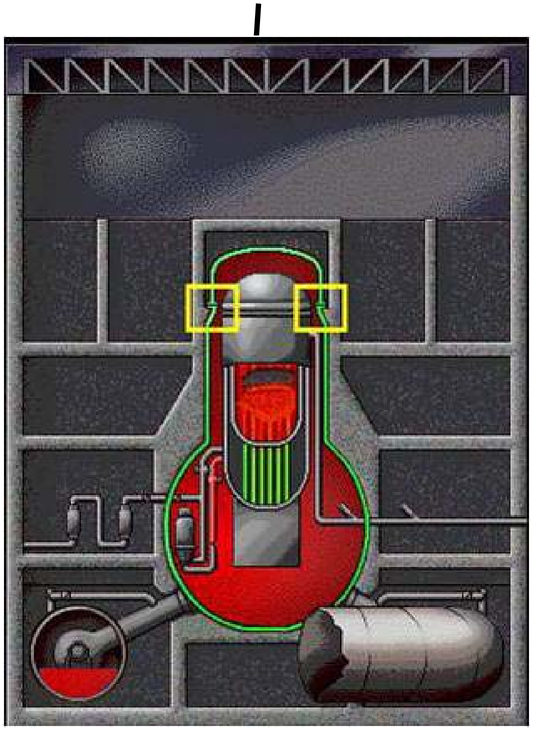
Fukushima: Reactor Vessel-Primary-Secondary Containment Sequence

Primary Coolant System



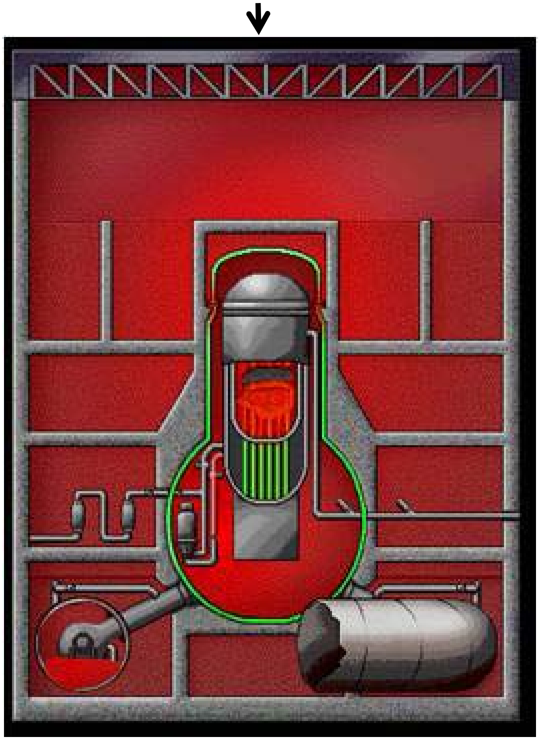
Core Over Heats
-Clad Burst ~900C
-Clad Oxidize ~1200C
-H2 Release
-Partial Melt~1800C-2700C
-Primary Coolant System Overpressure

Primary Containment



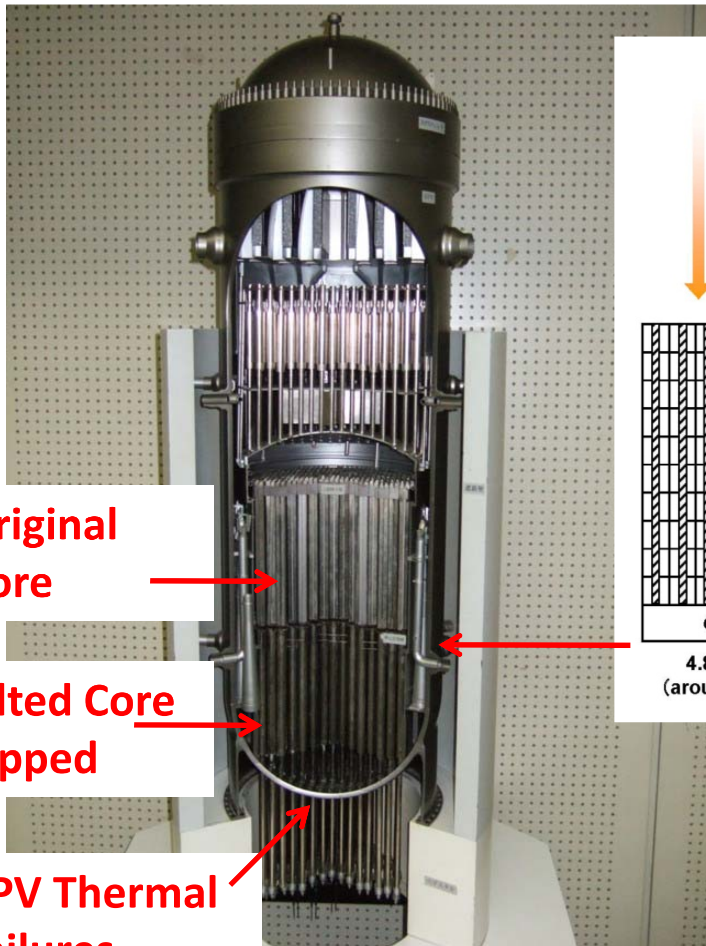
Vent from Primary Coolant Sys to Primary Containment- H2, Steam, & Fission Products (Xe, Kr, I, Cs etc)

Secondary Containment



No Primary Containment Cooling therefore Primary Containment Overpressure-Vent to Secondary Containment

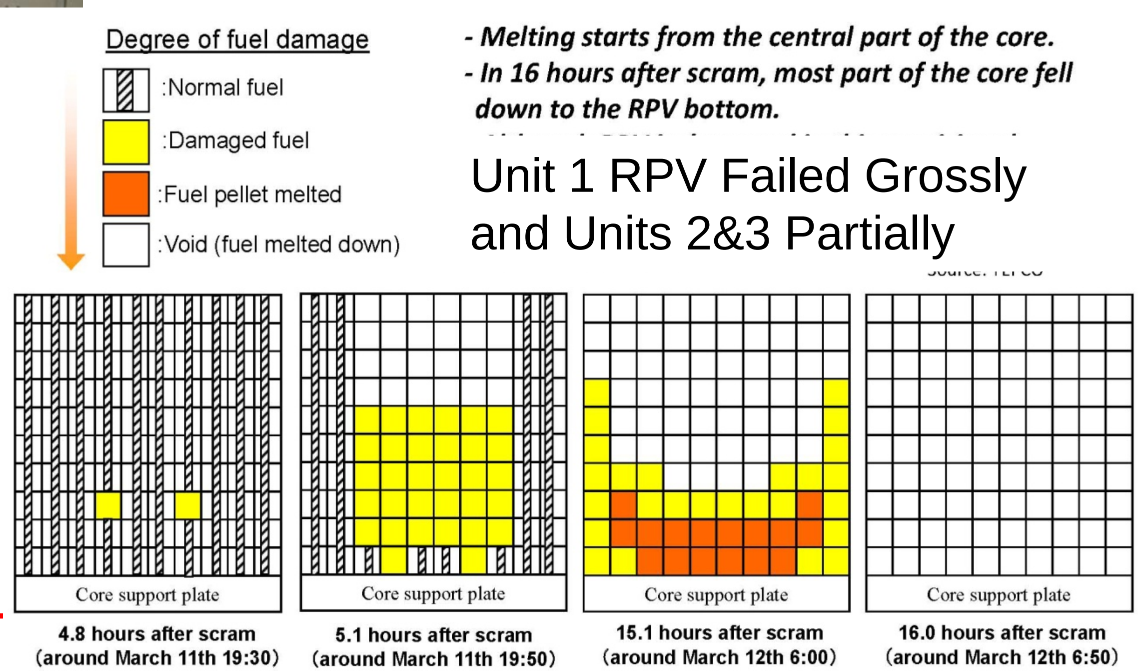
Cores Melted, Slumped Into Lower Head& Likely Failed Some CRD Penetrations



Original Core

Melted Core dropped

RPV Thermal Failures



Unit 1 RPV Failed Grossly and Units 2&3 Partially

Unit 1 Melt: 3/11~19:00 RPV Fails ~3/12 ~15:00

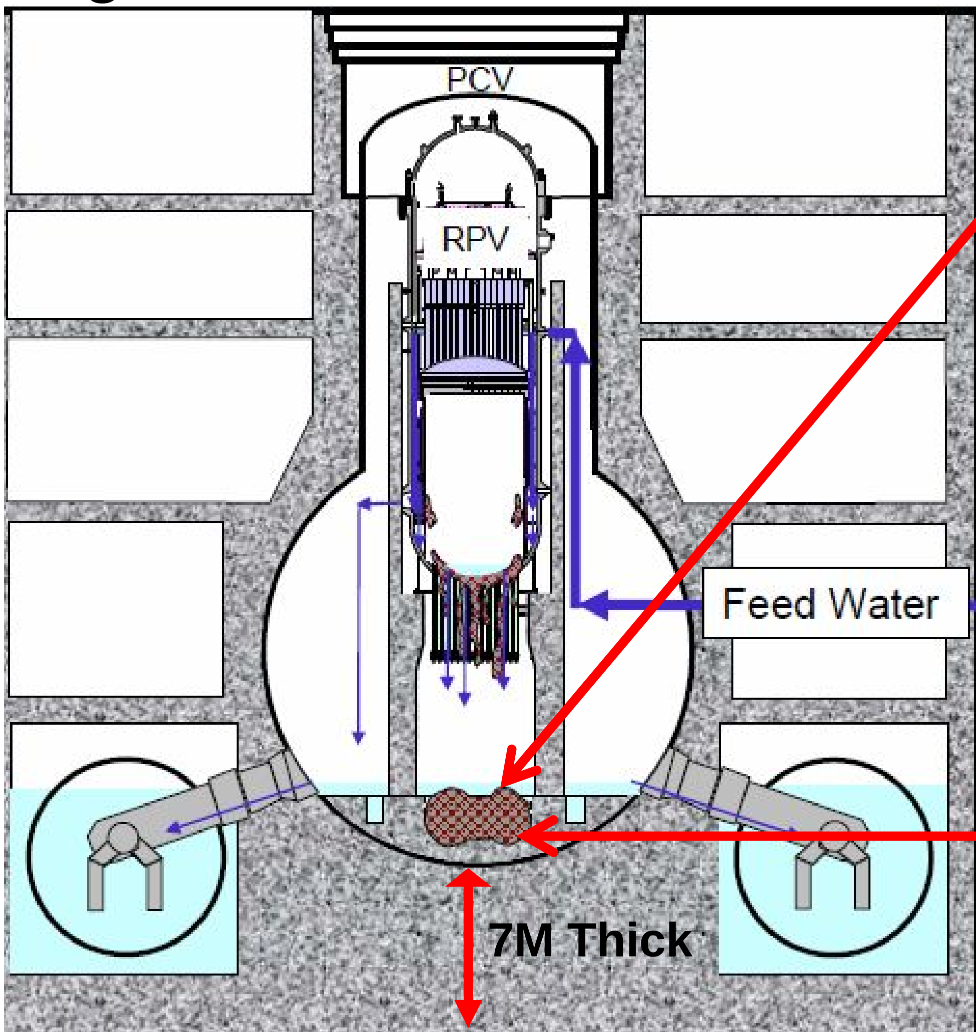
Unit 2 Melt: 3/14 ~20:00

Unit 3 Melt: 3/13 ~09:00

Core on Floor

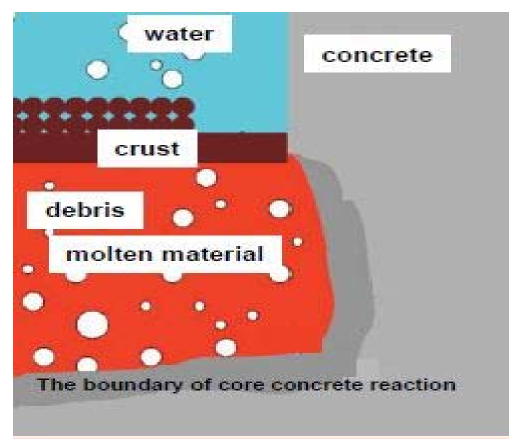
Unit 1 Core Melt to the Floor

Loss of Isolation Condenser Cooling: Early Core Melt & Significant Vessel Penetration & Core Drop

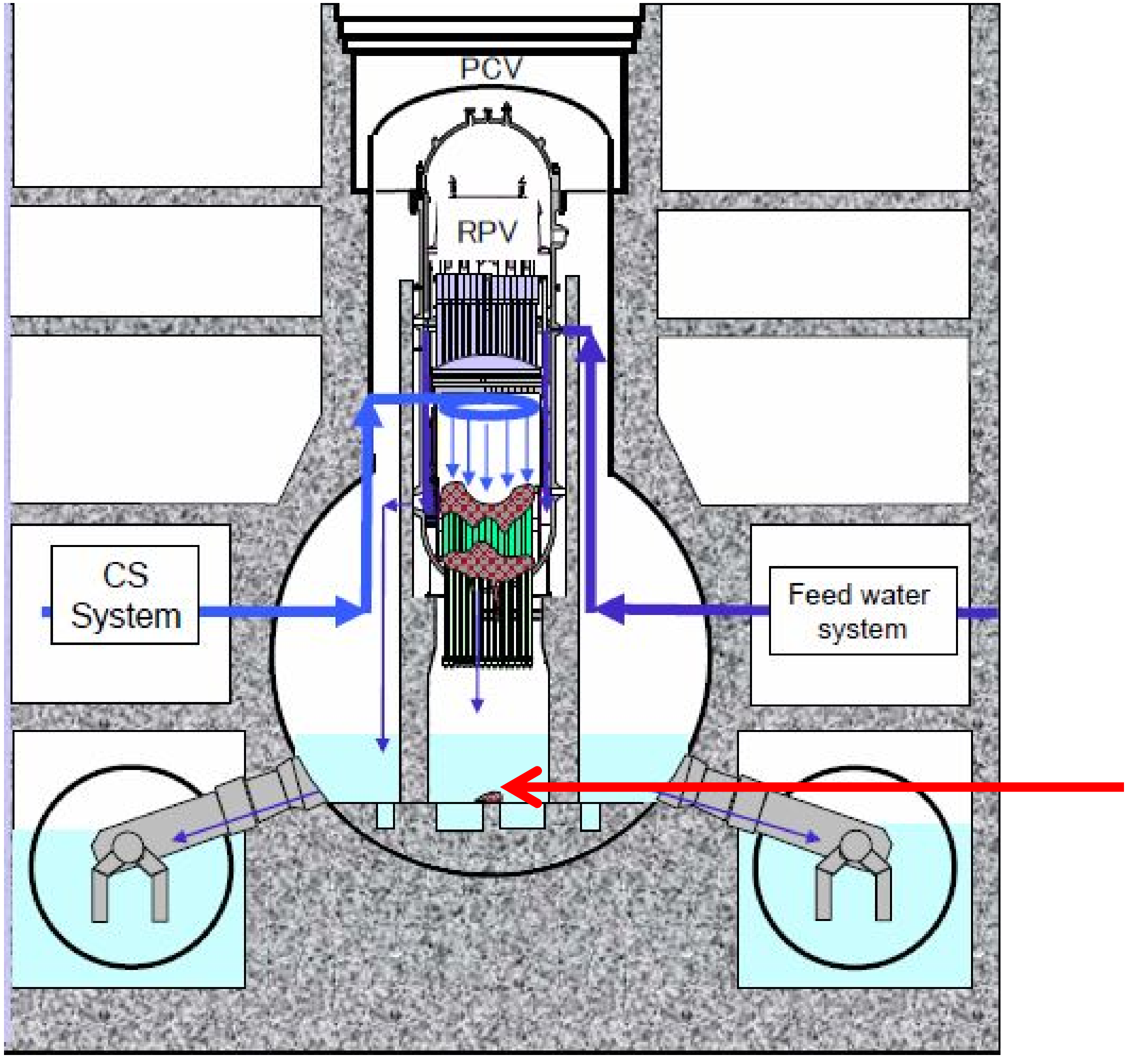


Unit 1 Corium Penetrated ~70cm (30%) of the 260cm thick floor concrete Above the 4cm steel liner plate.

There is 7M of base mat concrete below the liner plate



Unit 2 & 3 Core Melt In Vessel



Longer Core Cooling With Turbine Driven Pumps Resulted in Less Aggressive Core Melting

Projected Vessel Breach with some Melted core on the floor

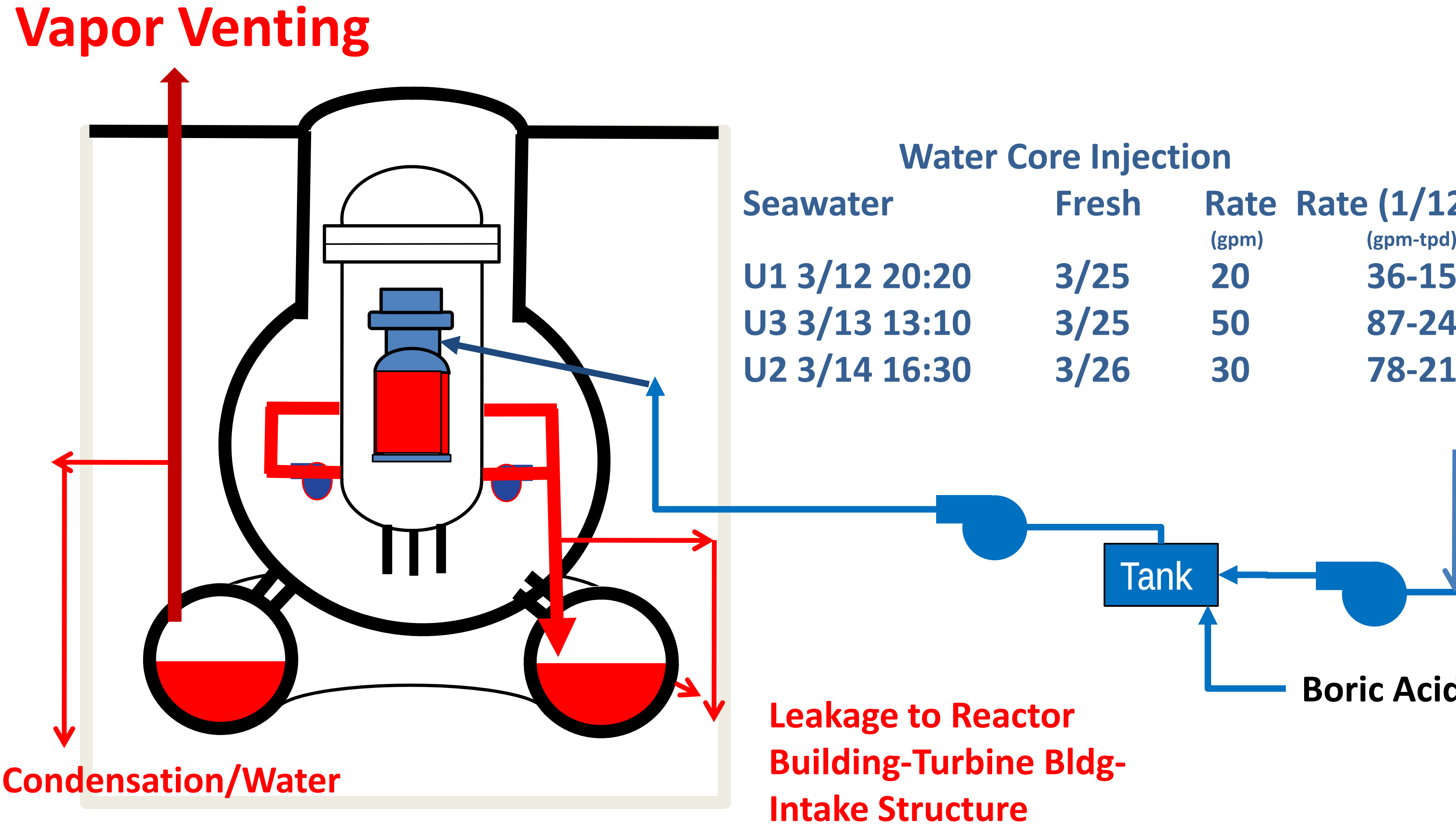
Minor Concrete Penetration (if any) due to low Melted Core Mass and Flooded Drywell Floor

Core Cooling Established With Fire Truck Sea Water Injection

Bleed & Feed Core Cooling Established

Seawater Injection Started Using Fire Engine Pump

Shift to Fresh Water Injection: To Dissolve Possible Salt Cakes



Water Core Injection

Seawater	Fresh	Rate (gpm)	Rate (1/12) (gpm-tpd)
U1 3/12 20:20	3/25	20	36-156
U3 3/13 13:10	3/25	50	87-240
U2 3/14 16:30	3/26	30	78-216

Immediately After Unit 3 Explosion

3/14/11 ~10:00AM JST

Spent Fuel Pool in Reactor Building

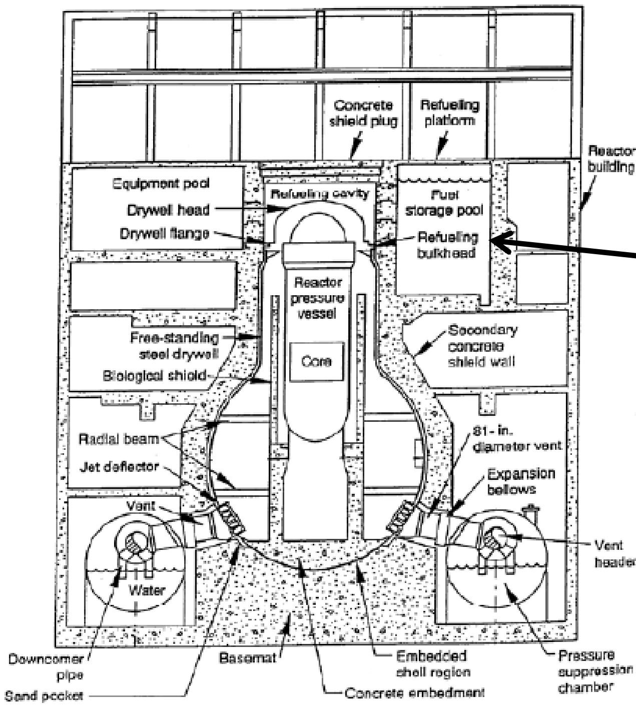
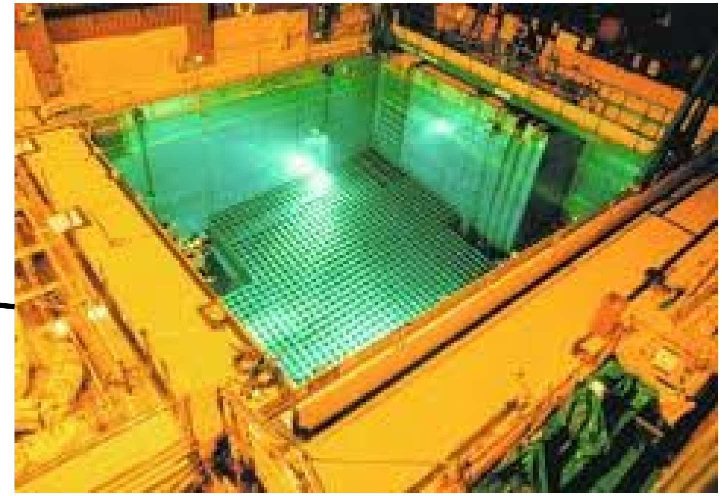
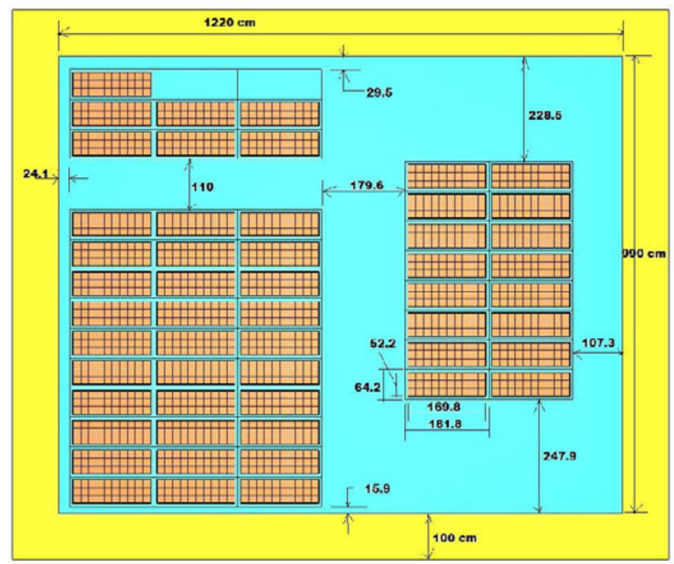


Figure 20. Mark I General Electric,GE BWR Containment.

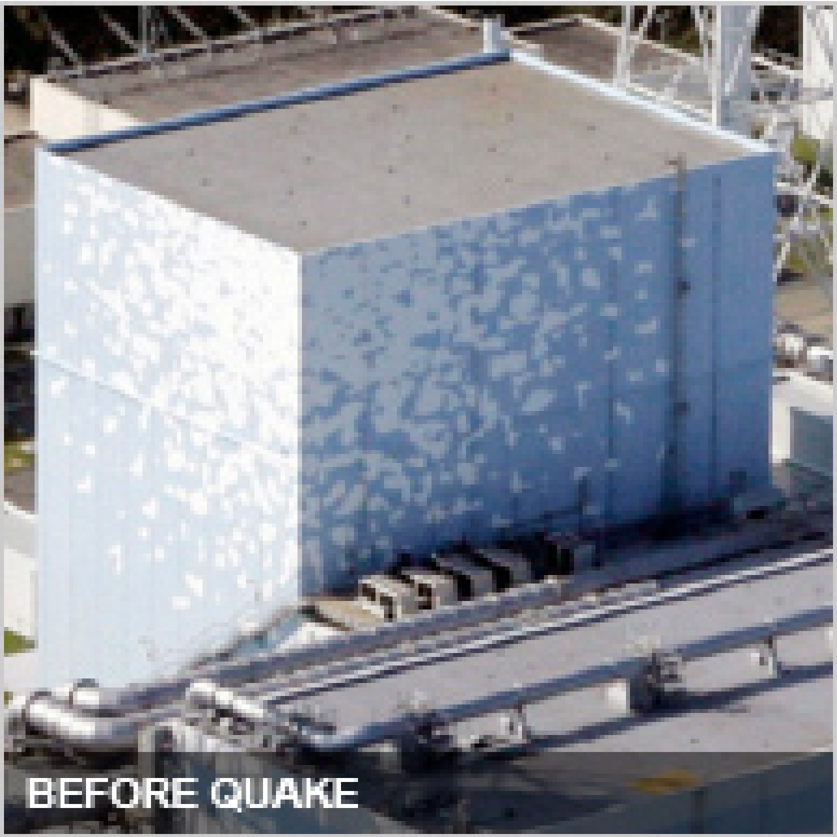


Unit 4 Pool

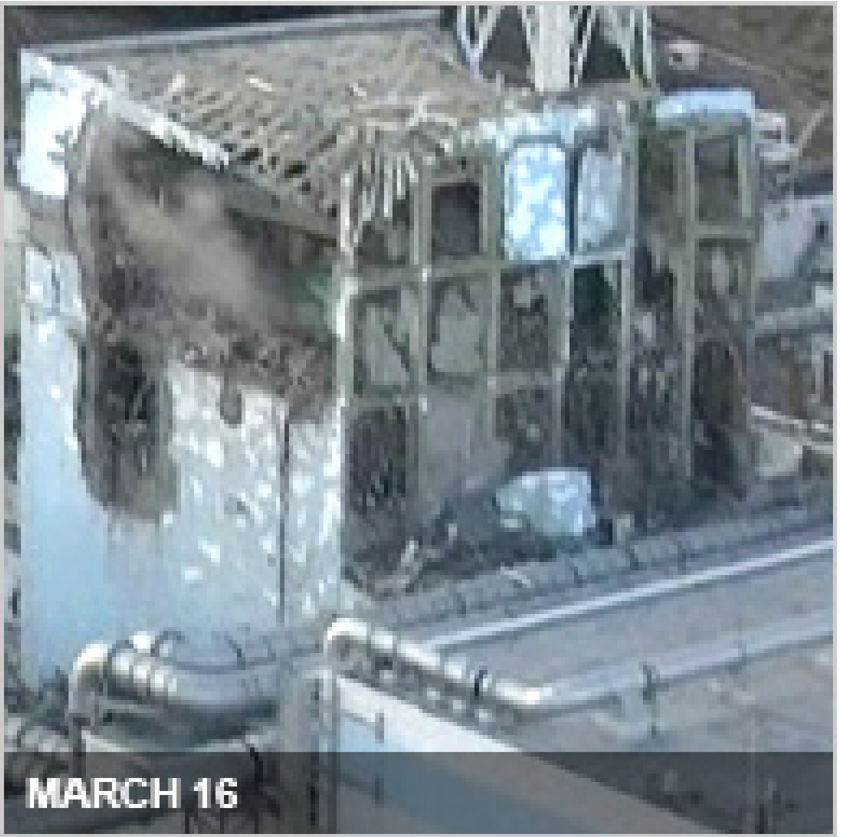


~350,000 Gal
U4:1331 Assemblies SF ~100 day old
U3:514 Assy SF~ 200 Days old
U2: 587 Assy SF ~120 Days Old

Unit 4 Reactor Building

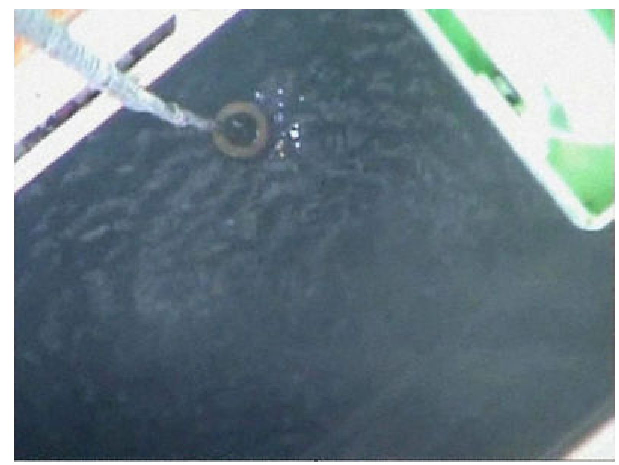


Reuters



TEPCO

Unit 4 Spent Fuel Pool Water Sampling



Boom Inserting Probe
~11-04-11

400ml Sample Probe
~11-04-11

Unit 4 Spent Fuel Pool

Sampling Indicates Little If Any Fuel Damage

Low Cesium Levels in 90Bq/ml

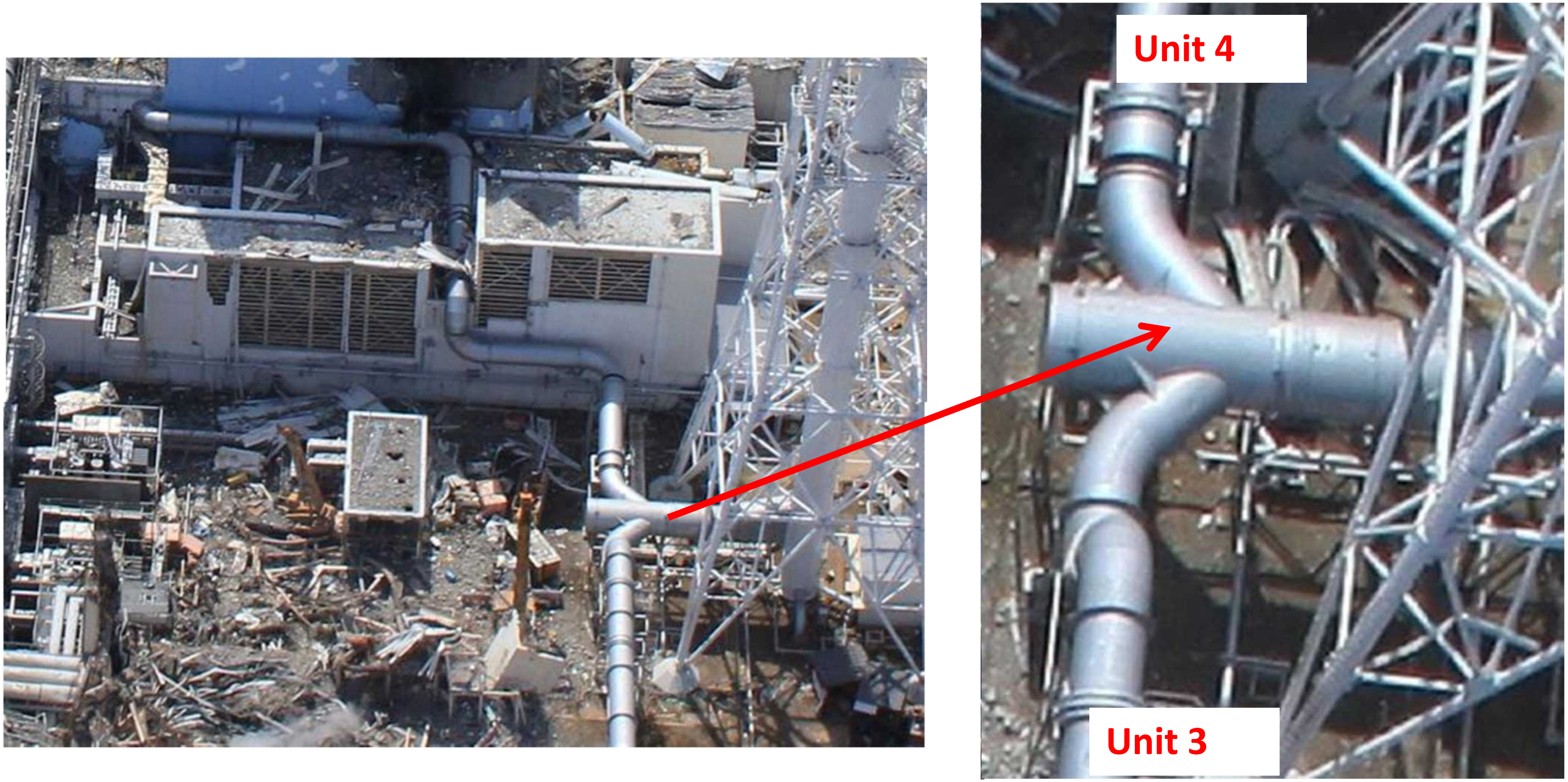
Water Level Lowered For Seismic Safety

Units 2 & 3 Pools Have Some Damaged Fuel- Not Melted

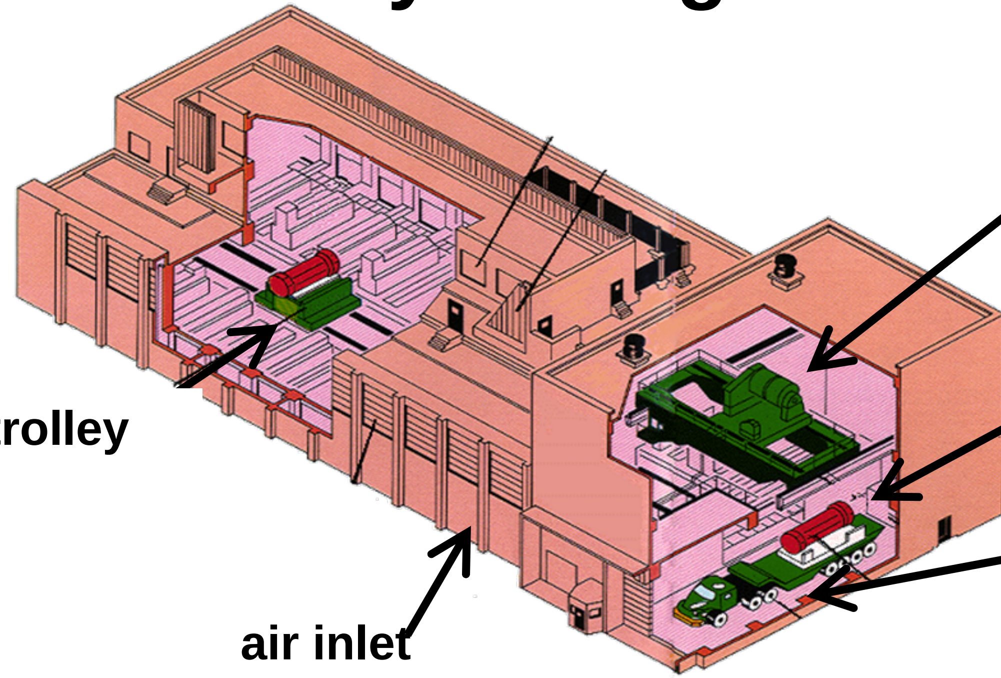
-Cesium 137 Levels in 150,000 Bq/ml
-Low Iodine, indicative of older stored fuel
-High Ph ~11.3
-Al Rack Corrosion
-Adding Boric Acid

Building Debris In Unit 3 Pool
~ R/Hr at U3 Refueling Floor

Unit 4 Explosion: H2 From Unit 3

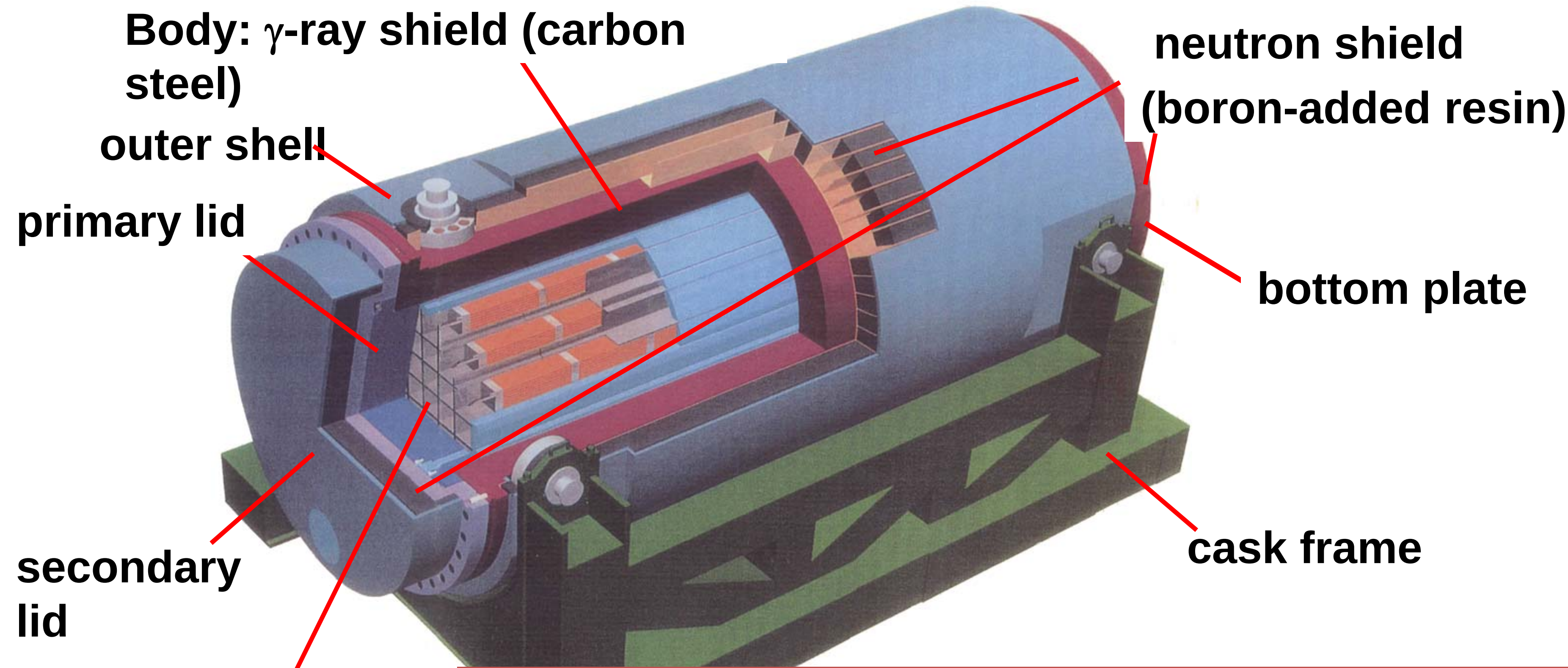


Dry Storage Cask Facility



**Relative
Low Elevation**

Storage Only Metal Cask



Main features

- Cylindrical forged carbon-steel casks
- Similarity with transport casks
- 5-115T 52 Assy Casks & 4-96T 37 Assy Casks
- Helium filled
- Steel for γ-ray shield/ resin for neutron shield
- Borated-aluminum alloy basket for sub-criticality

Dry Storage Facility Was Flooded But All 9 Casks Intact

Fukushima Stabilized

- Established Recirculation Core Cooling
  - Damaged Pressure Vessel(s) & Containments
- Mitigating Airborne Releases
- Mitigating Water Releases
- Gaining Building Access to Start Recovery Activities
- Managing Solid Wastes
- Maintain Personnel Safety: High Rad Areas
- Addressing Evacuation Zone Situation

Units 1-4 After U4 Building Explosion 3/16

Units 3, 2, & 1 Looking Down

Units 4 & 3 Looking Down

Unit 4 Fuel Pool-Side

Unit 3 & Unit 4

Unit 3 Spent Fuel Pool

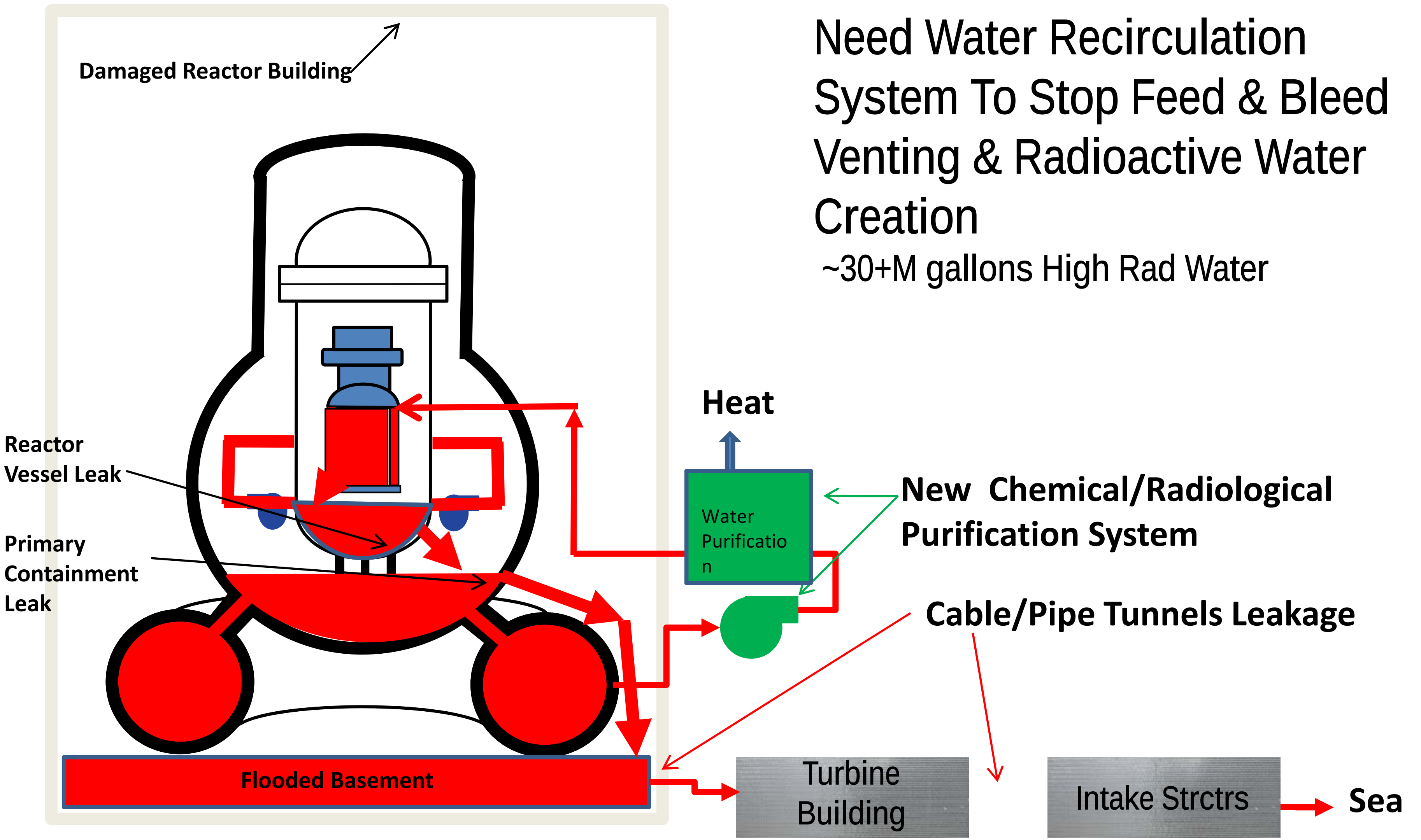
3/16

福島第一原子力発電所 3号機(3/16 PM撮影)

Water Spray to Unit 3 Pool Area

Unit 4 Reactor Building
Water Injection Boom To Spent Fuel Pool

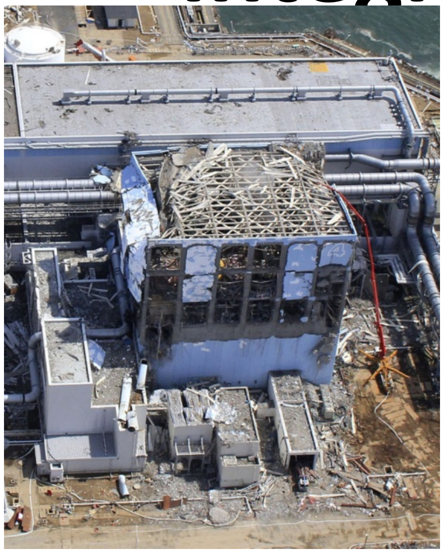
Established Core Recirculation Cooling Once Water Processing Started: July



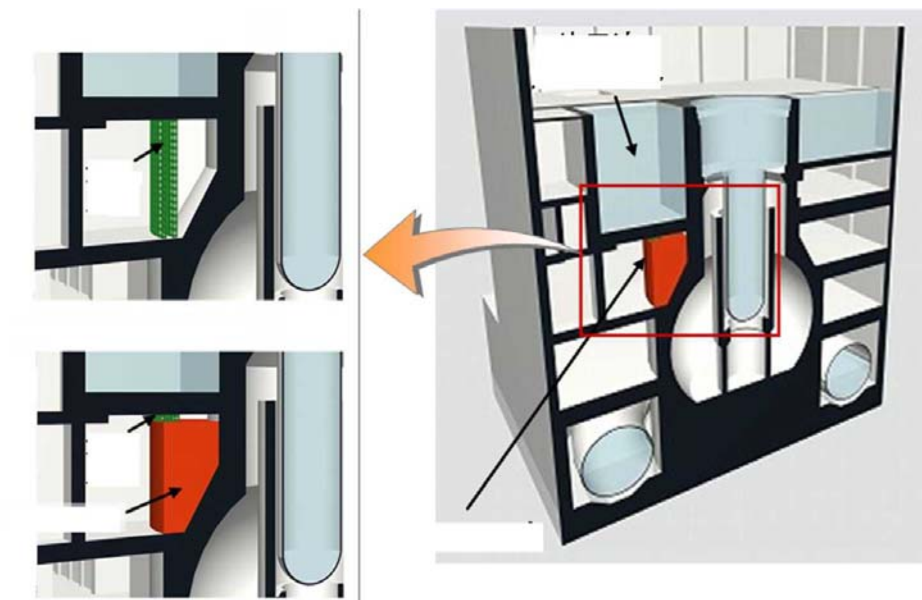
Need Water Recirculation System To Stop Feed & Bleed Venting & Radioactive Water Creation

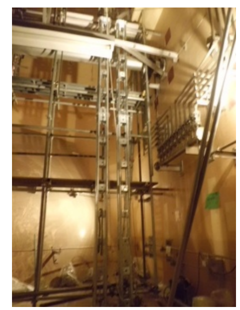
~30+M gallons High Rad Water

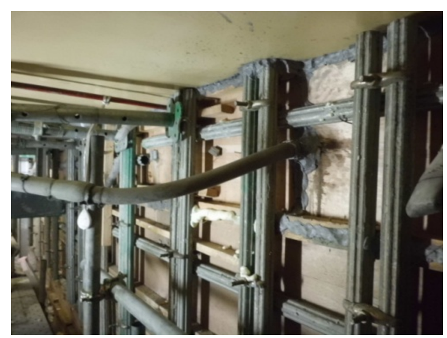
Unit 4 Reactor Building Structural Integrity Seismic Risk Reduction



- Explosions Weaken RB Structure
- A Large Earthquake Aftershock May Cause Building Failure
- Structurally Strengthen Building







- Adding Steel & Concrete under Pool

Working Conditions are Challenging

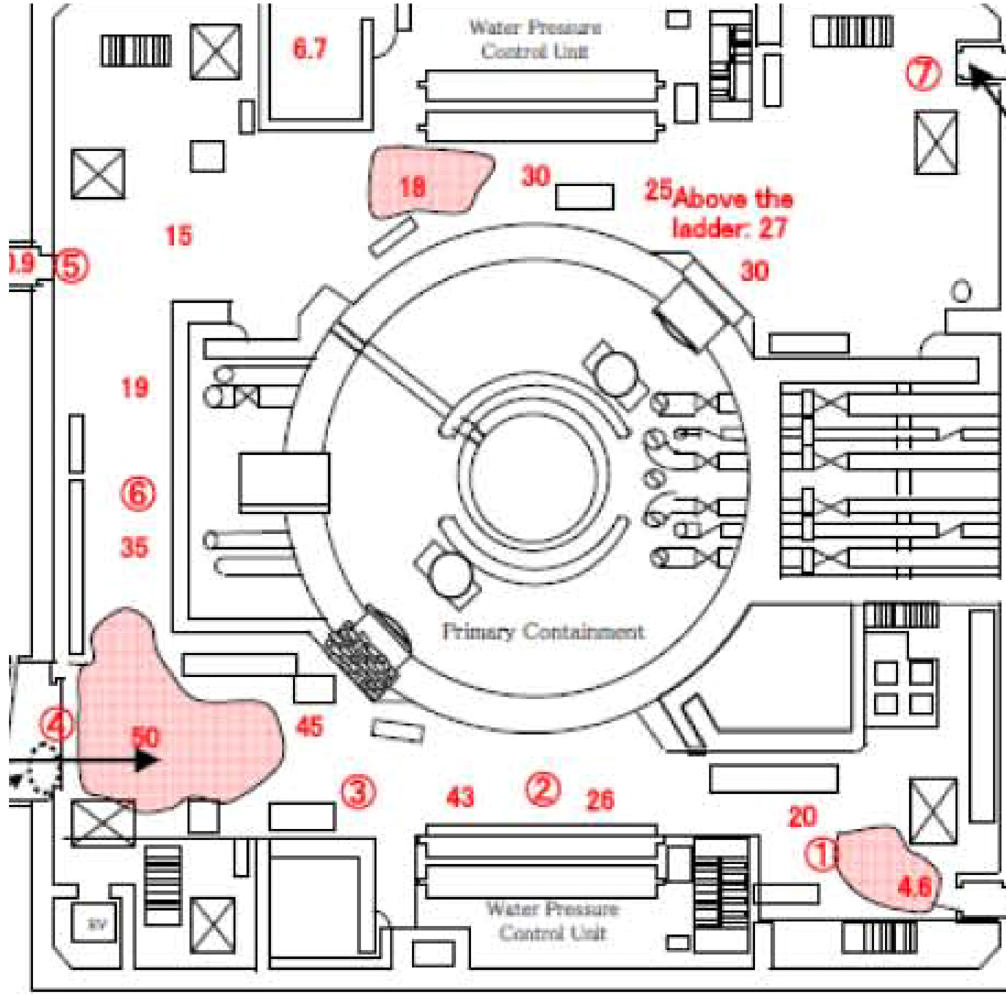
Restoring Power In High Radiation & Contaminated Areas

U2 Reactor Building Conditions

Robots First

Personnel Second

Ground RB Floor



Water 4M deep in Basement

Site Airborne Dust Mitigation

Dust Fixation Resin Application

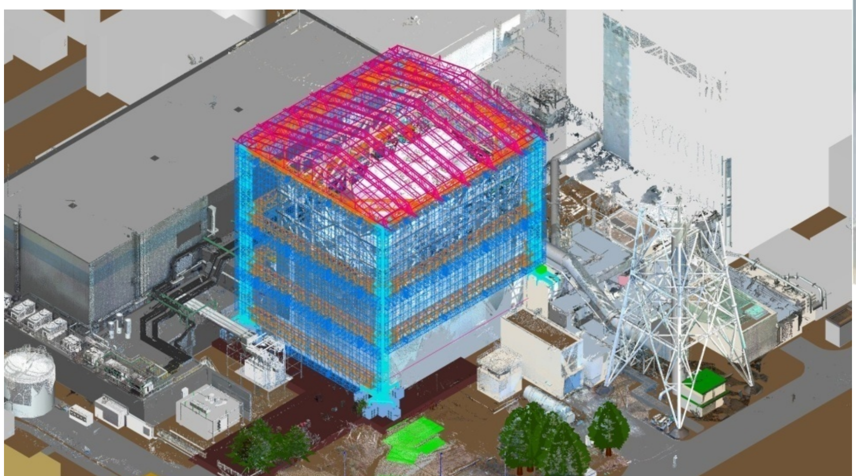
Dust Vacuum Filter/Collection Unit

Before

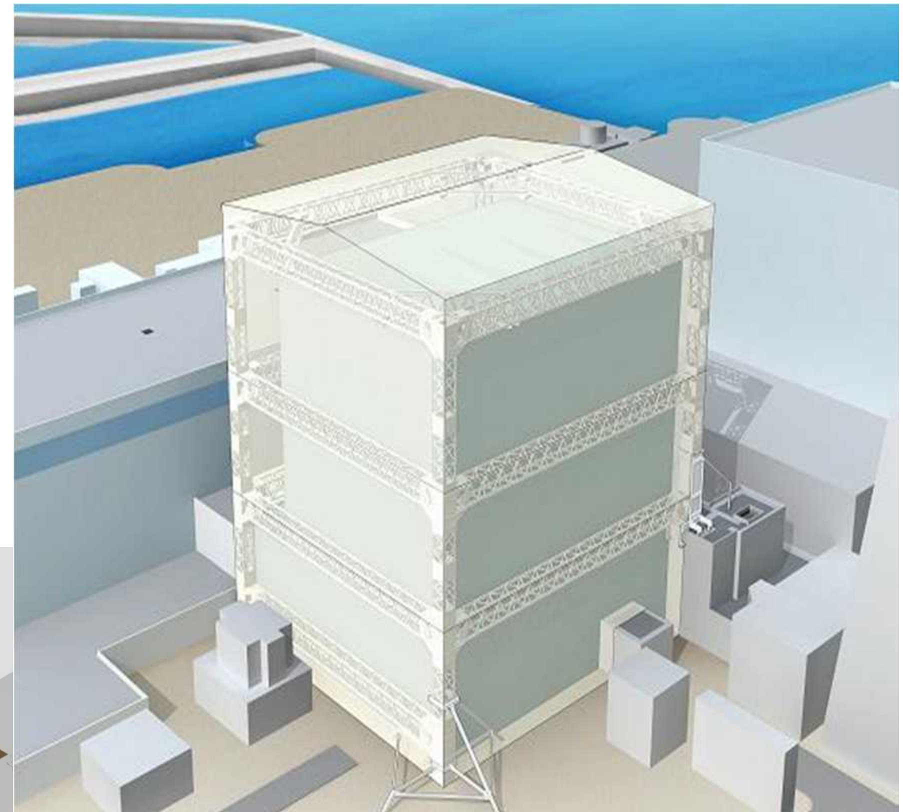
After

RB Airborne Mitigation Containment Canopy Concept Design-1

Fast Remote Construction Design Concept



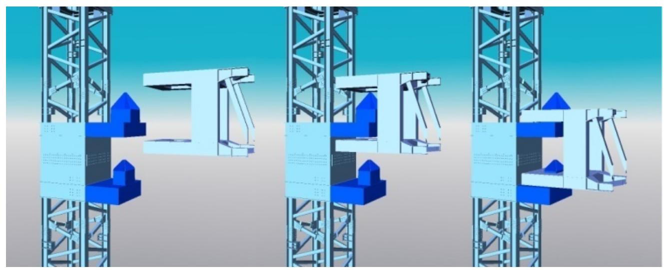
Laser Image New Enclosure



Unit 1 RB Filtered Enclosure
55M High & 47M X 42M

Unit 1 Canopy Detailed Design-2

Construction Sequence Planning



Creative Remote Construction Concepts

Mockup Const Training

Unit 1 Canopy Construction-3

Foundation Clearing

Frame Assembly

Unit 1 Canopy Construction Step-4

Wall Panel Emplacement

Enclosure Completed: Oct

HVAC Fan/Filter/Monitor Equipment Installed

Contaminated Water Containment

Overflow from U2 Reactor Bldg to Turbine Bldg to Intake Structure Wall Crack to Sea

27,000 Ci Cs-137 Released this Path 4/1-6

-Reference Chernobyl was 2MCi Cs-137 released

Non-Safety Grade intake Structure

Radioactive Water Leak 11-04-02

Leak Reduced 11-04-04

Leak Sealed 11-04-06
Sodium Silicate Injection

Sealing Other Leakage Paths to Sea

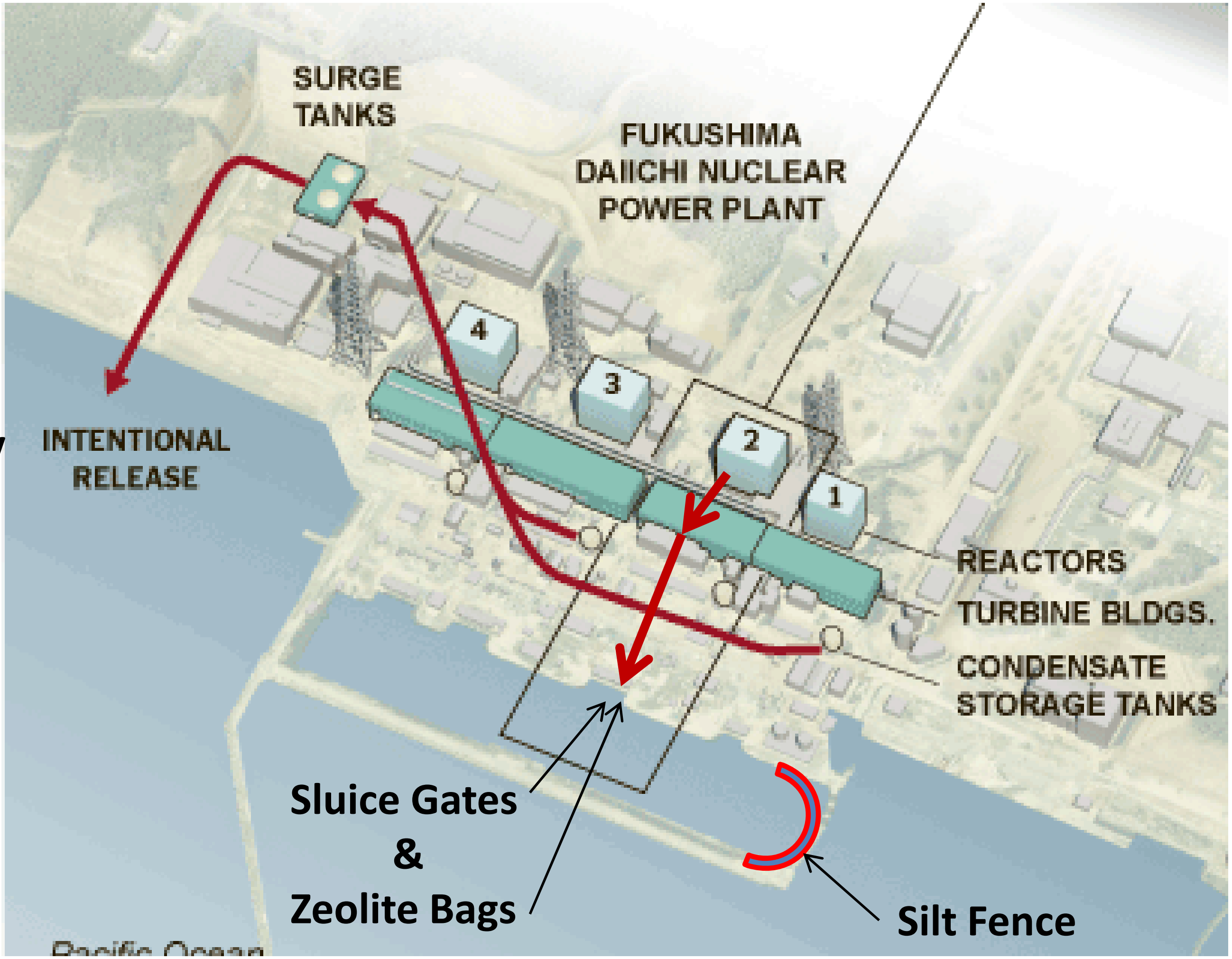
Concreting One of ~37 Cable & Pipe Chase Paths

Water Retention Tank Farms

Underground Tanks Under Construction

Accident Water Management

Relative
Low Activity
Released



20-50 Million Gallons Of Highly Radioactive Water To Be Transferred To Onsite Tankage

Water Release Mitigation

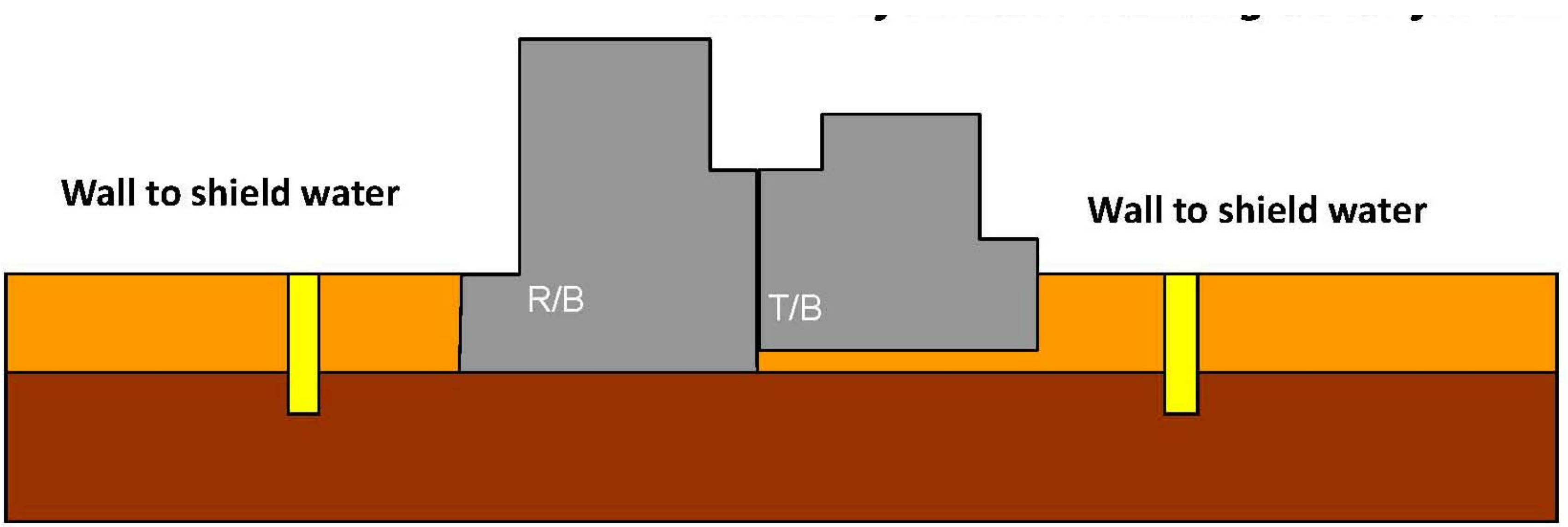
Contain/Retard Intake Structure Cs/Sr Contamination

Sluice Gate to Minimize Outflow To Ocean

Zeolite Bags To Adsorb Cs/Sr

Water Release Mitigation
Silt Fence to Retard Cs/Sr Release to Sea

Mitigate Basement Leakage Into Groundwater Paths To Sea



Planning Underground Barrier Walls to Bed Rock

Improved Contaminated Water Drainage Retention Wall

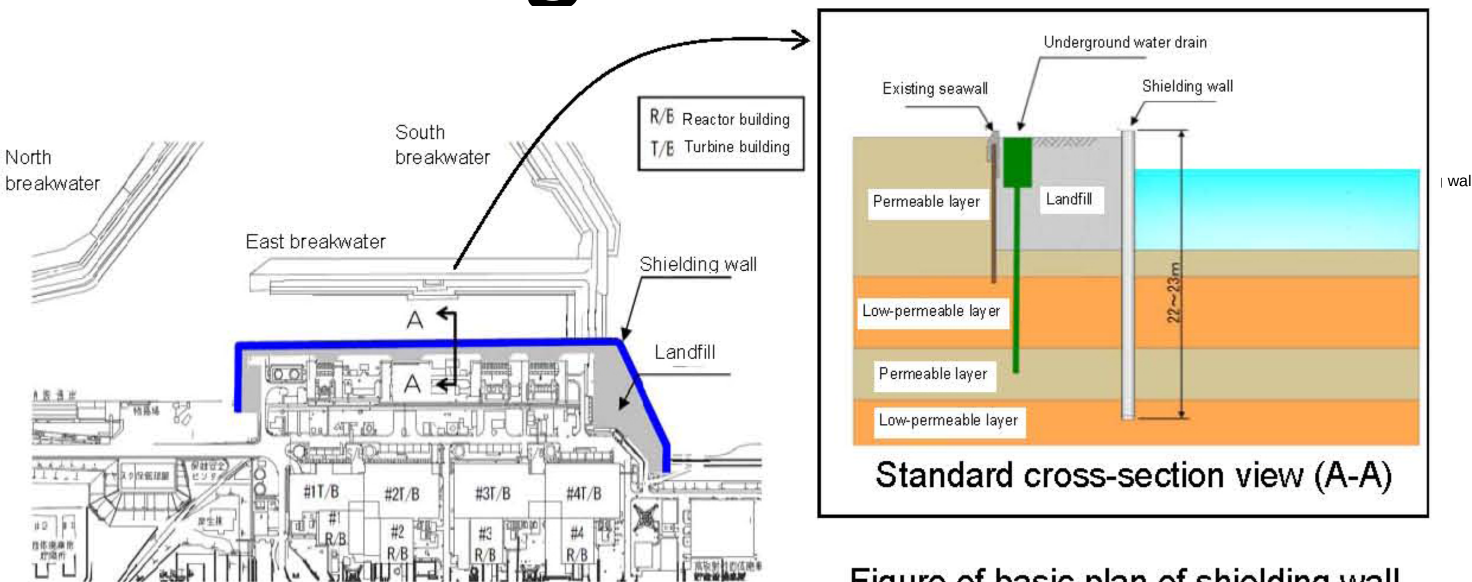


Figure of basic plan of shielding wall

US Fresh Water Barge On Site-April

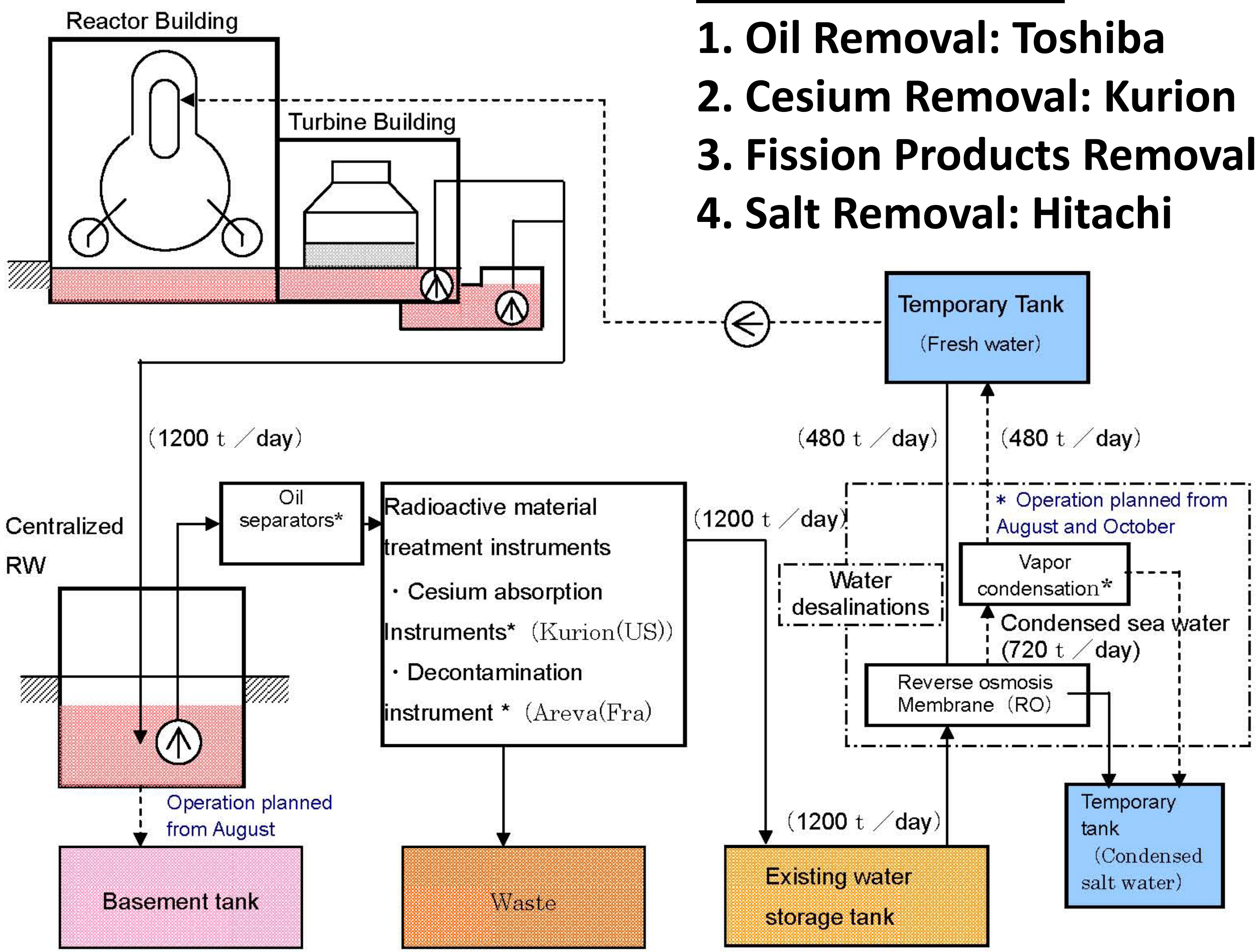
Japanese ship hauling US Navy water barge

Japanese Tow Operators

Water Recirculation Processing Plan

<u>**Four Stage System**</u>

1. **Oil Removal: Toshiba**
2. **Cesium Removal: Kurion**
3. **Fission Products Removal: AREVA**
4. **Salt Removal: Hitachi**



* oil separators, radioactive material treatment instruments… Installed within the Process Main Building,

Cesium absorption Instruments… Installed within the Incineration Workshop Building

Oil Removal

Separator Unit

Separator Internals

Cesium Removal Stage

Shielded Skids

Individual Zeolite Beds

Salt Removal Stage

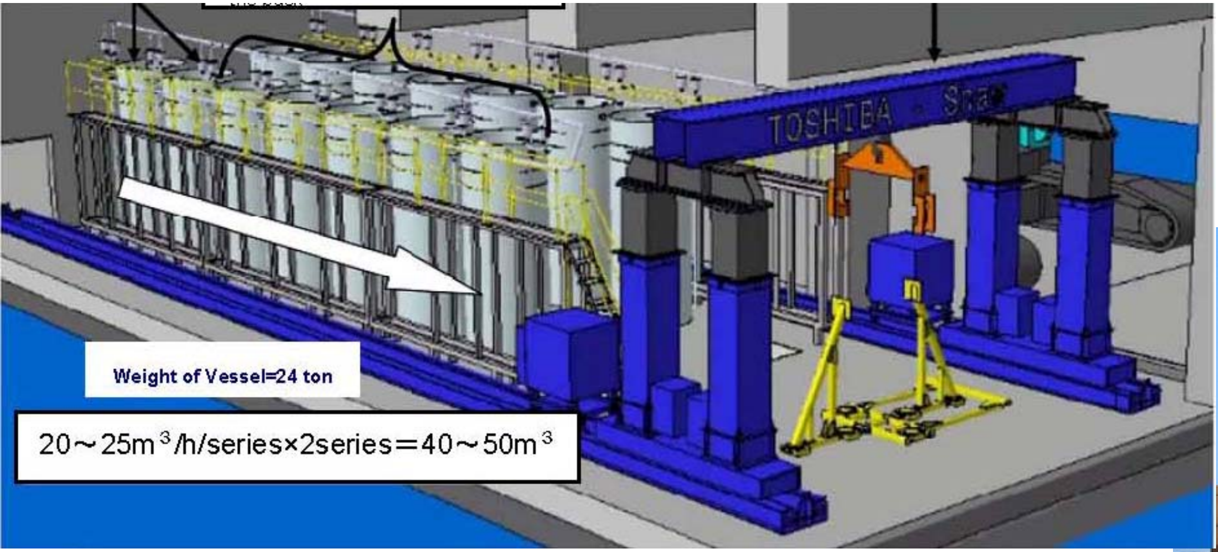
U4 Reverse Osmosis Unit

Evaporator Unit

Underground Tanks for High Activity Liquid Wastes

New Water Processing System

Simplified Active Water Retrieve and Recovery System (SARRY)



Toshiba Lead

2 Lines of 8 Larger (24Ton) Zeolite/Silicate Filter Beds to Augment Initial Kurion/AREVA System -200gpm capacity

September Operation

Wastes From Water Treatment

- Water Treatment Systems Produce High Cs-Sr Wastes
  - ~200 Kurion Zeolite Canisters (90cm dia X 2.3M high, 300M3)
  - ~580M3 of AREVA Precipitation Sludges
  - ~150 SARRY (1.4M dia x 3.5 M high) Zeolite Canisters
- Onsite High Radiation Storage Area

High Radiation Demineralizer Storage

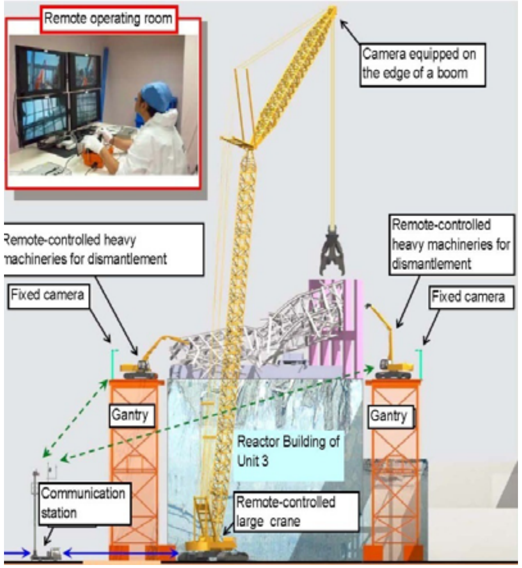
744 Canister Storage Facility

~330 Cans January 2012
1.4M Dia & ~3M high each
~1,000rRHr

Reactor Defueling Plans

Cleanup-Defueling Process
Step wise Access Toward Core Internals

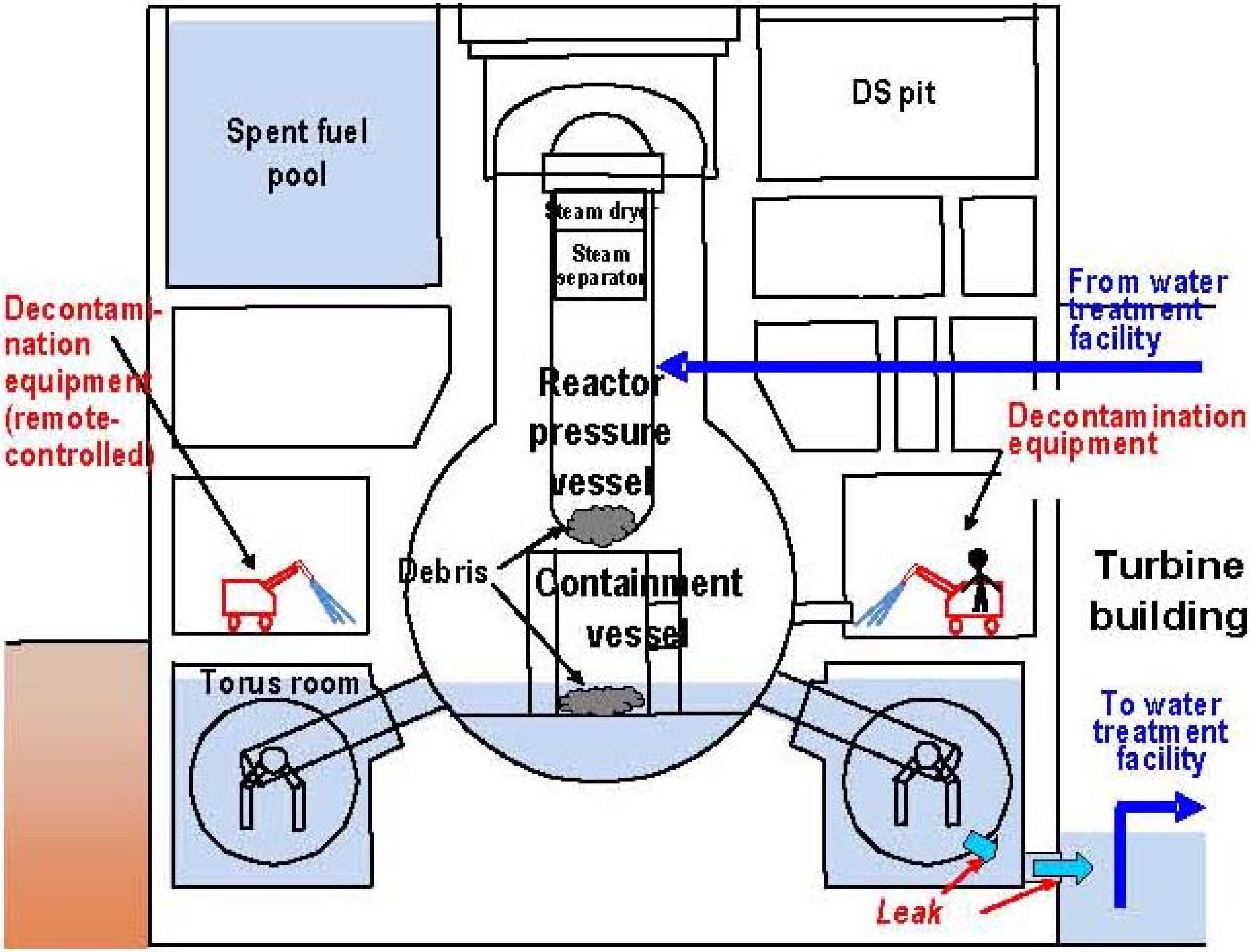
Initial Building Cleanup Robotic Equipment



Planned Steps Toward Defueling Access with Robotic Cranes- High Gamma Fields

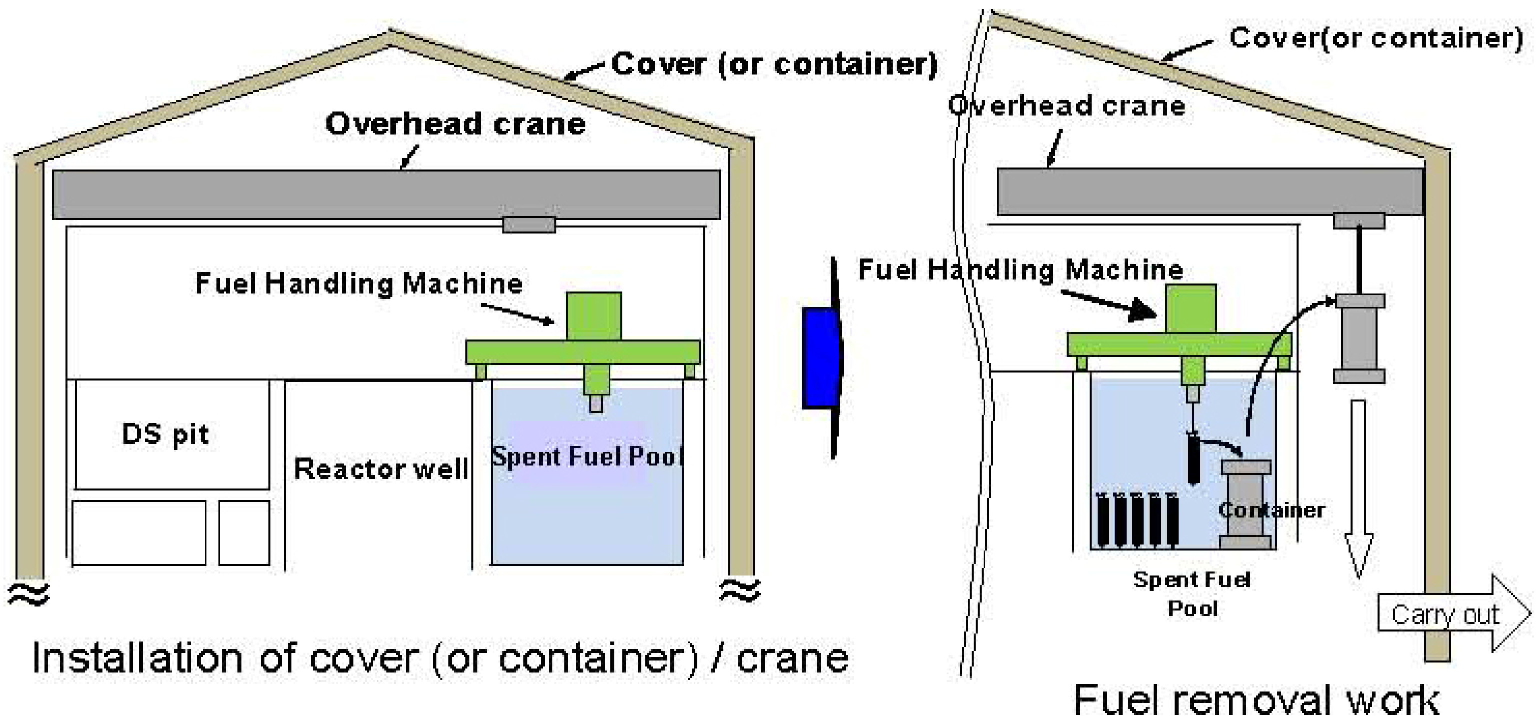
Restore Building Infrastructure, e.g. Crane Capacity

1. Gain Building Access
Decon & Build Infrastructure



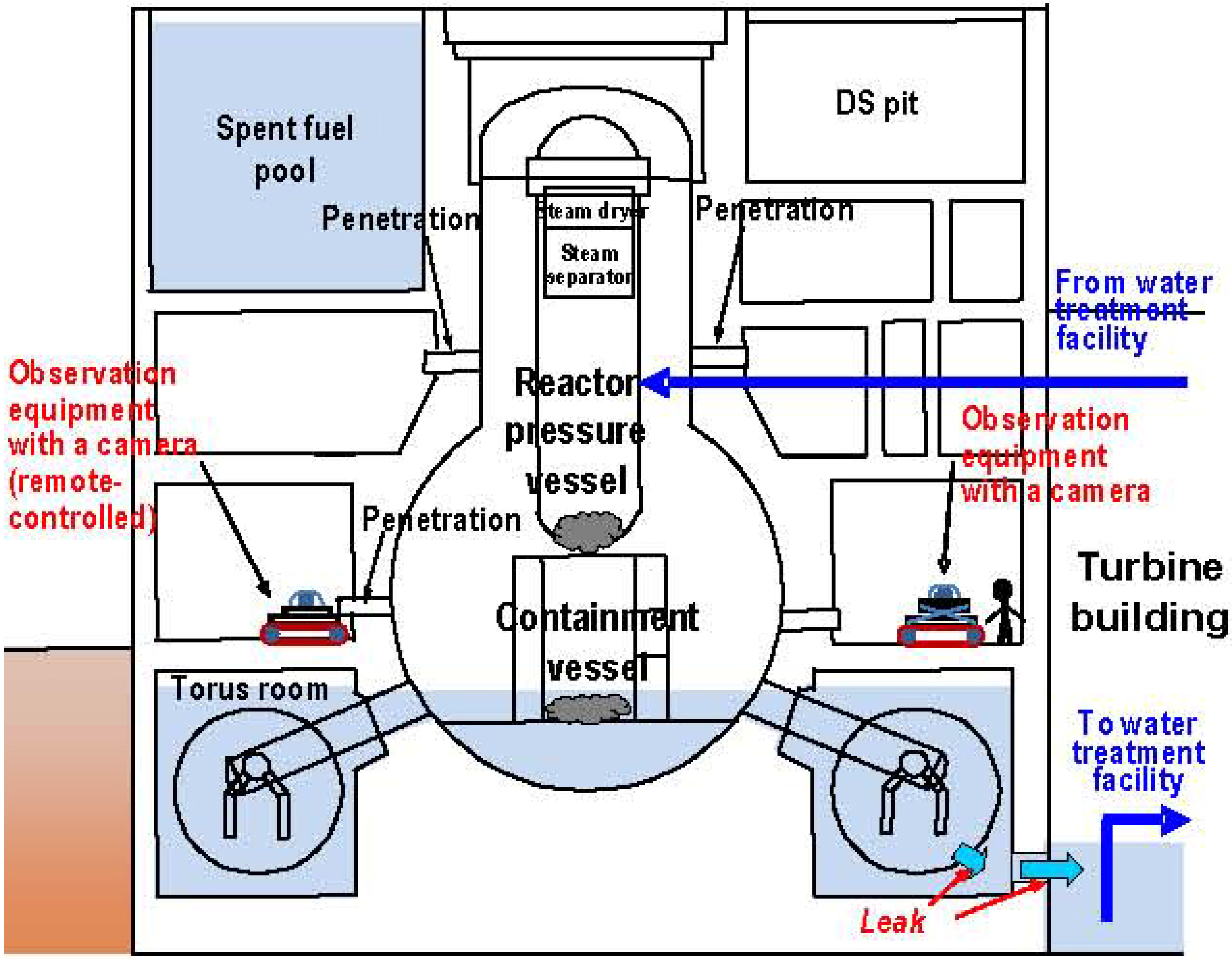
2. Remove UnDamaged Spent Fuel From Reactor Building Storage Pools

Near Conventional Fuel Handling

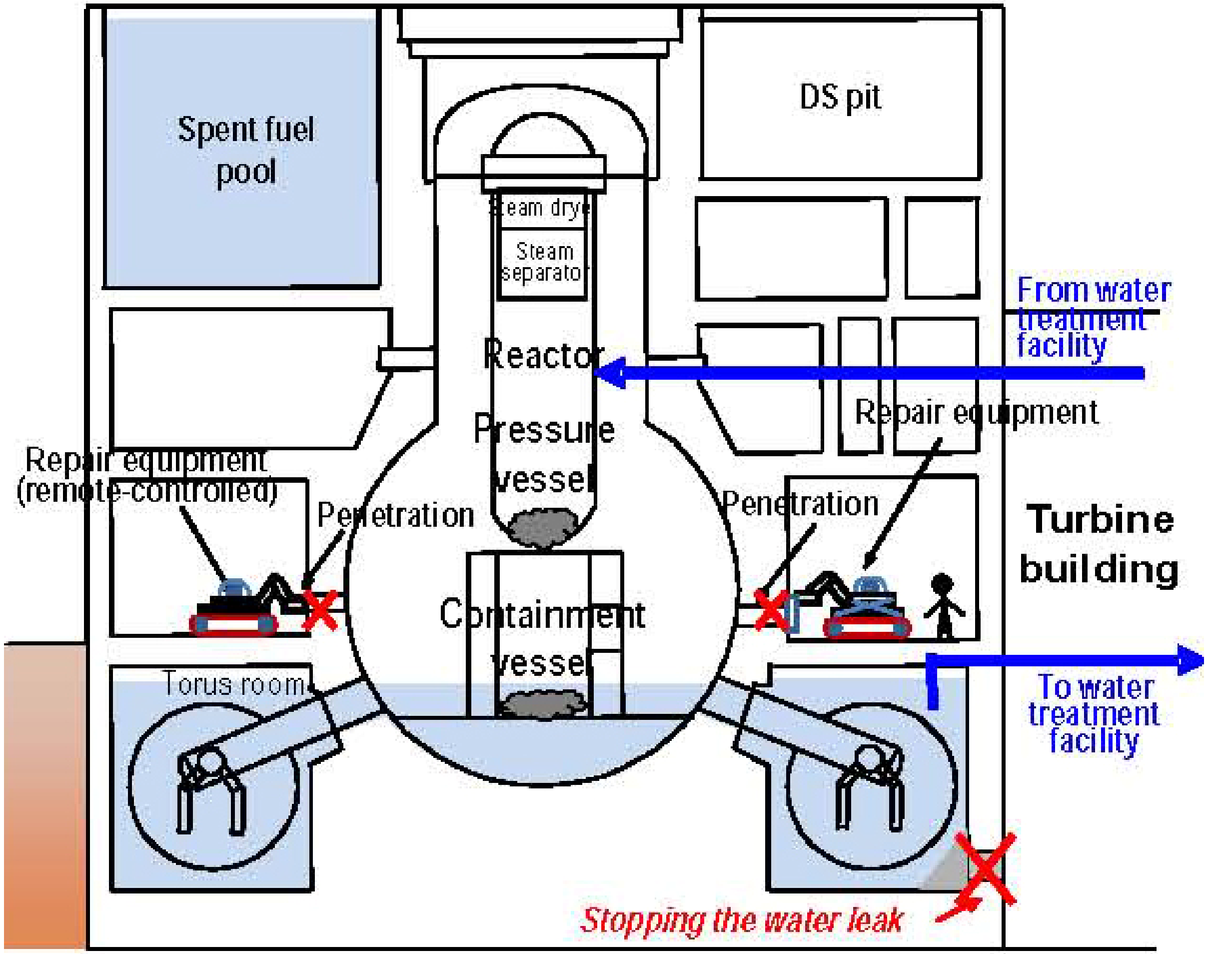


Unit 4 First Followed By Units 1-3 Pools
Start in 2 Years & Finish in 10 Years

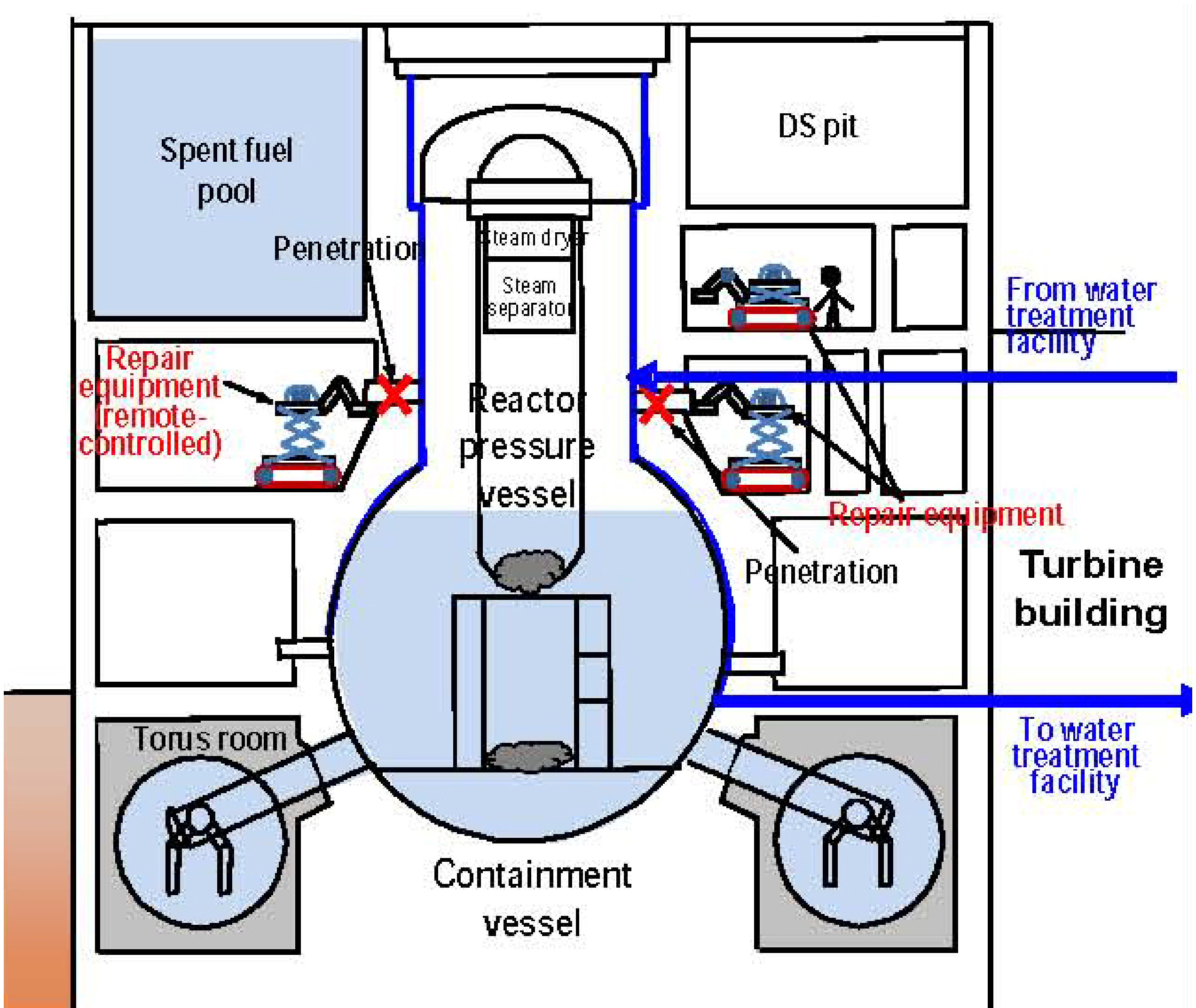
3. Find Containment Leakage Paths



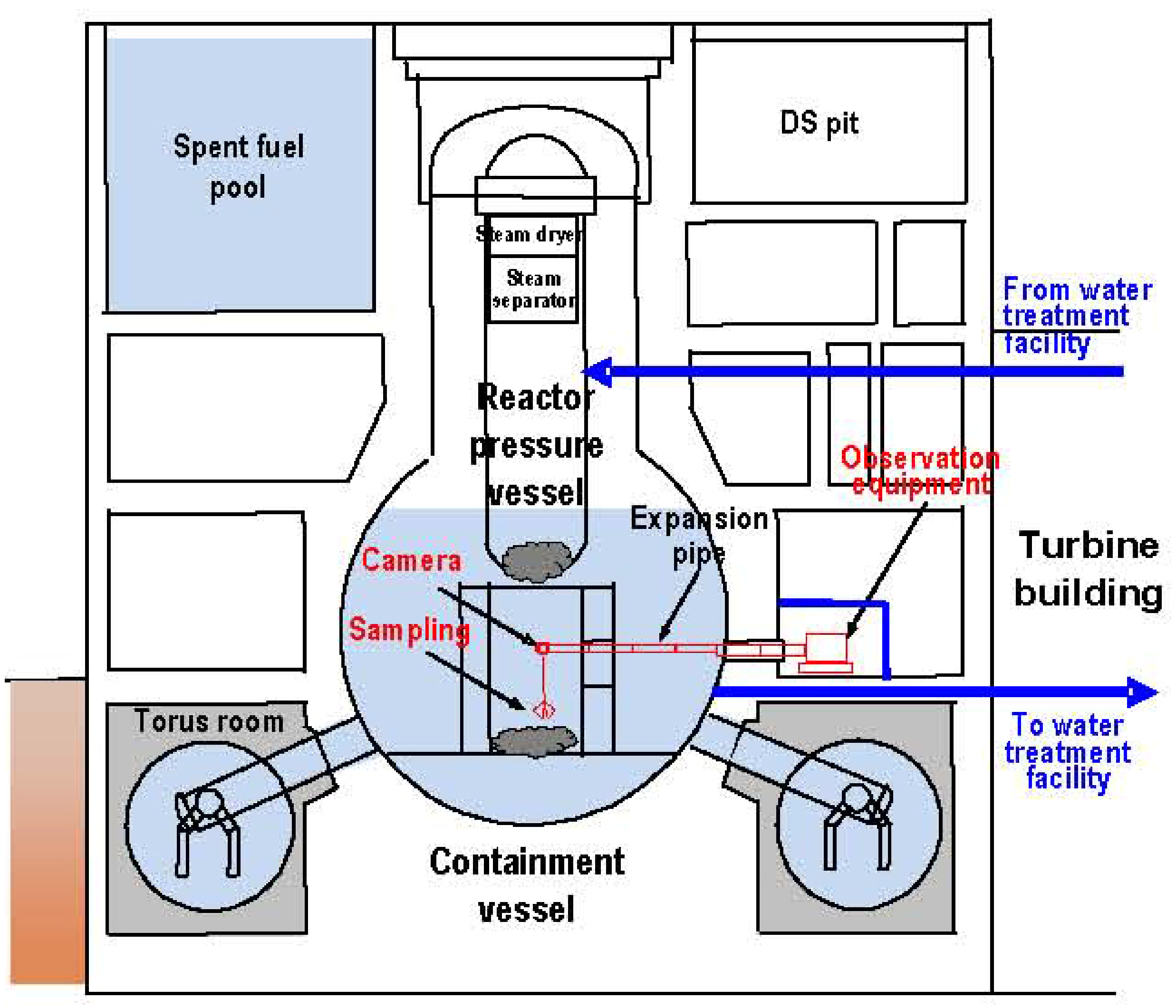
4. Seal Water Leakage Paths From Containment



5. Flood Containment & Work Upwards



6. Flood Further & Evaluate Internal Conditions

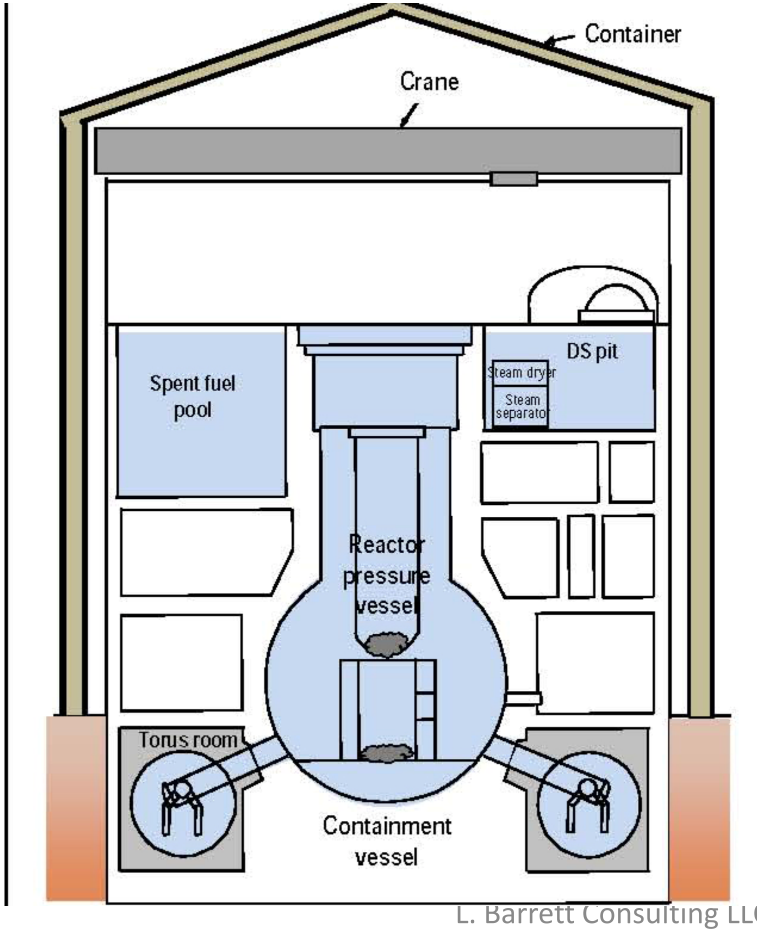


7. Preparing For Melted Core Removal

Secondary Containment Established

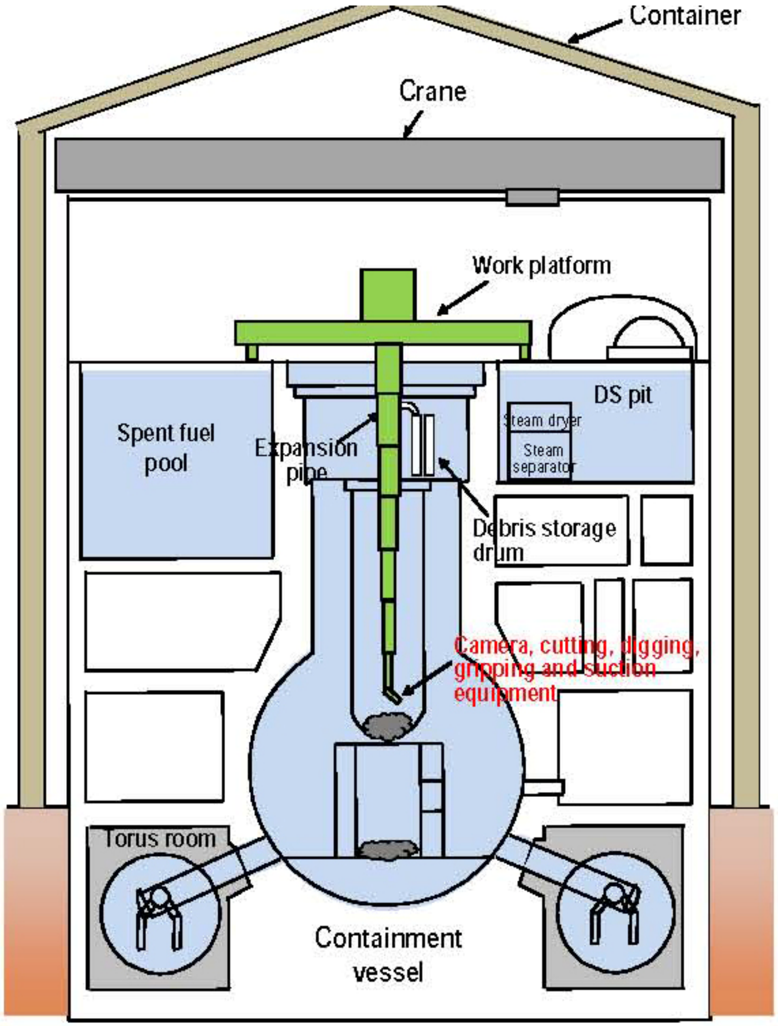
Remove Containment & Vessel Heads

Build Core Debris Canister Loading System



Finish in 10 Years

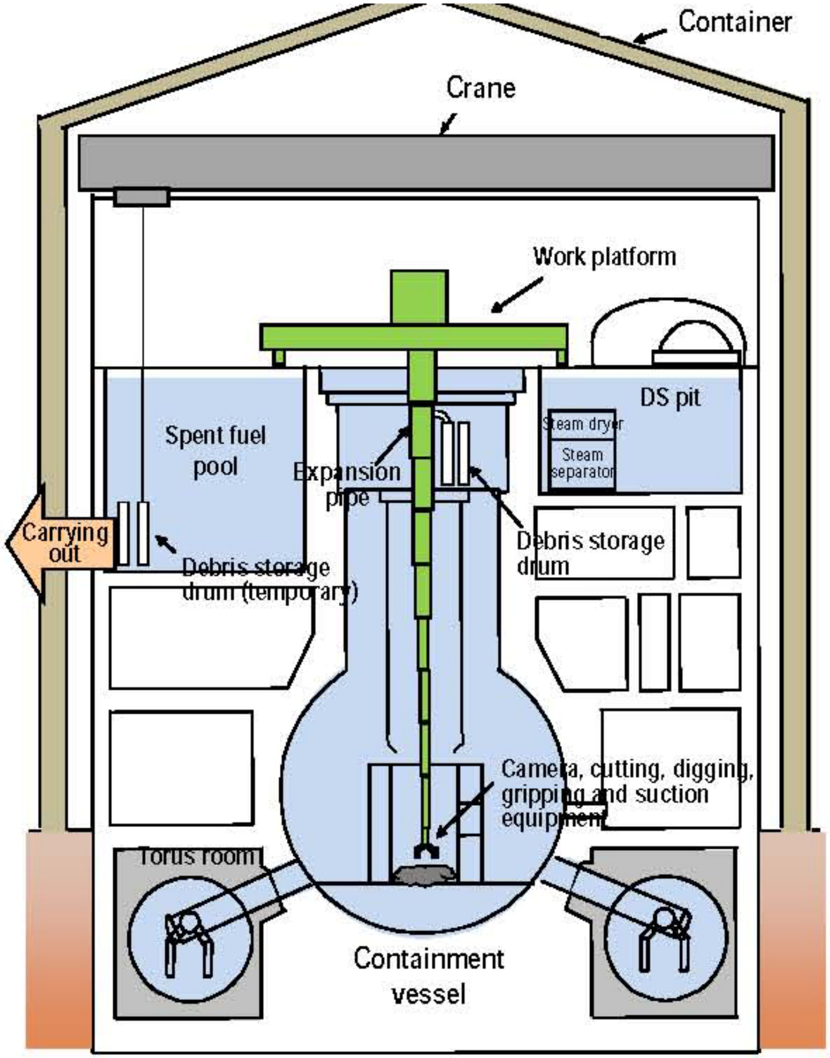
8. Remove Melted Core Debris From Reactor Vessel



Start in 10 Years

9. Remove Melted Core from Floor

Drill/Burn Down Through Reactor Vessel



Complete in 20 to 25 Years

10. Store Core Debris For Final Disposition e.g. TMI Experience

Spent Fuel Can Transfer Cask

TMI Transport Cask

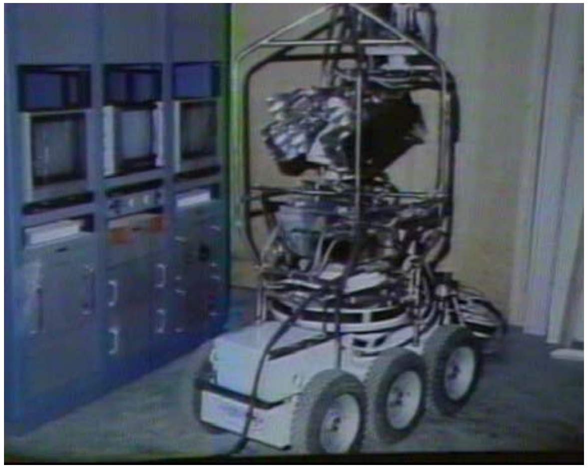
Dry Cask Storage

TMI Core Debris In Idaho

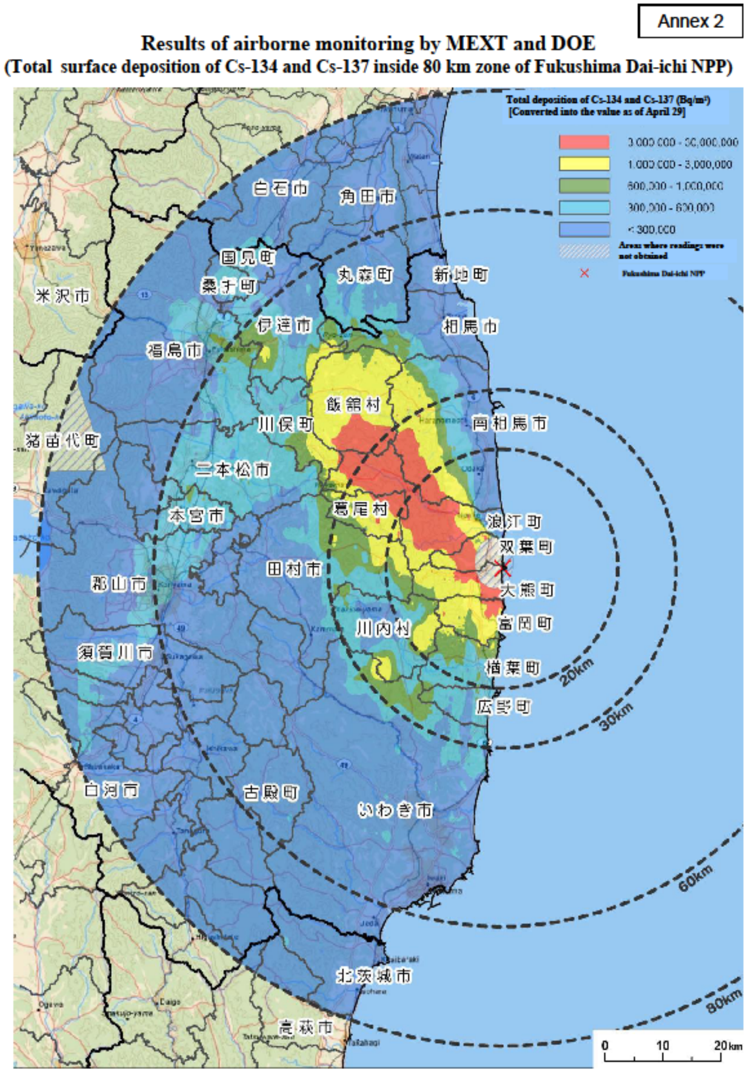
11. Decontaminate & Decommission Buildings

Example of TMI Decontamination Operations (Took ~10 Years)

Fukushima: Complete 30 to 40 Years (2040-2050)



Offsite Contamination Impacts



Offsite Cs/Sr Contamination

-Multi Billion Dollar Government Sponsored Cleanup for Areas > 1uSv/hr above background (~>870mr/yr & 500mr/yr)

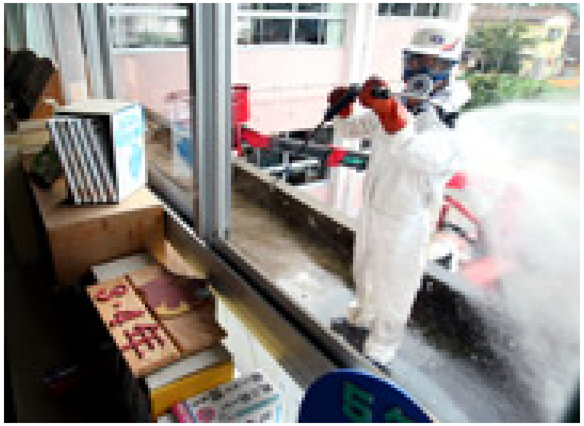
-Limits of 500Bq/kg foods

-Impacts large areas:
~1,800 Km2 @ 5mSv/yr (500mr/yr)
~13,000Km2@1mSv/yr (100mr/yr)
-High Cost: $3B +

Offsite Decontamination

House Roofs

Parking Lots



School Buildings

Children’s Playgrounds

Decontamination Solid Waste Management

Temporary Storage of School Playground Dirt

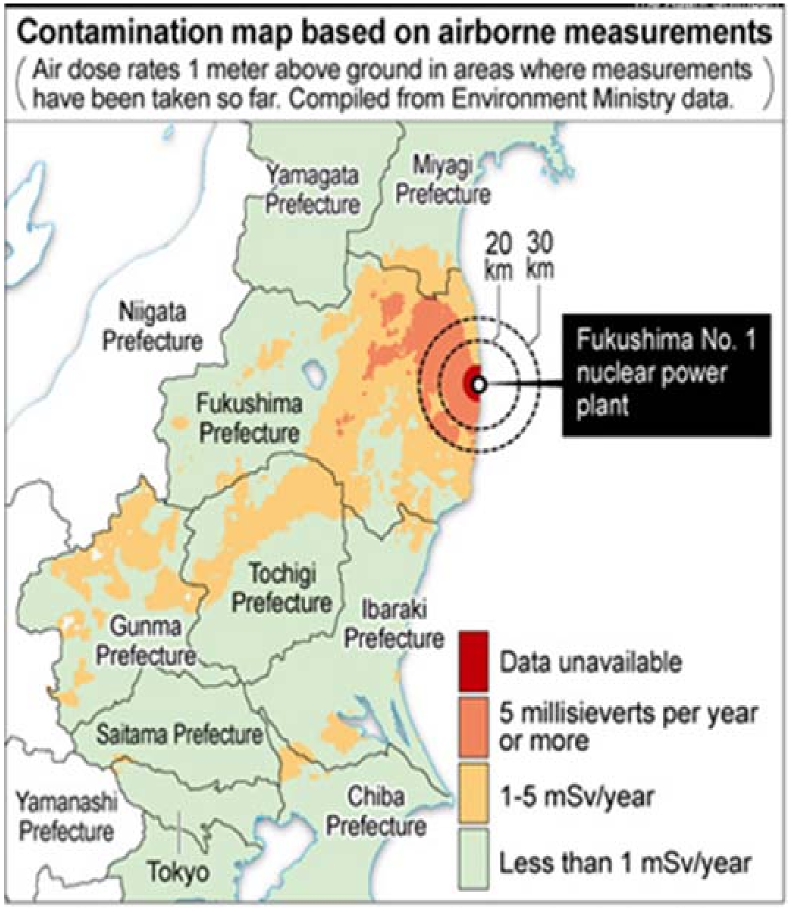
Expecting 29 Million M3 LLW(9KM2 10M deep volume) of Offsite Contaminated Soil to be Managed

-State Owned Forests & Voluntary Storage Sites Planned

Difficult Siting Issues Ahead for Final Disposal Facilities For High Level Waste, Intermediate Wastes, and Low Level Wastes

Human Feelings & Reactions

Cleanup Standards Have Significant Resource Requirement Variations



Cleanup Level at 1 mSv/y:

- 13,000 km^2, or
- 3% of Japan's land mass, or
- About the size of Connecticut
- Costs at $15.6 B

@1msv/yr
Contaminated Area
Is about the size of
Connecticut

Government/Society Decisions

- **National Energy Policy & Implementation**
  - Balance Impacts, Risks, Benefits & Costs of Energy Supplies With Actions
- **Regulatory Policy & Organizational Structures**
- **Resource Allocation**
  - How Clean?
  - What Acceptable Impacts & Risks?
  - How Much?
  - When?
  - Where?
  - Who?

Personal Conclusions

- Fukushima Was an Industrial Catastrophe Caused By an Unexpected Huge Tsunami
- Plant Staff Established Control Under Great Duress
- Public Health Impacts Are Very Low
- Societal Impacts and Costs are Very High
- Japan Faces Many Societal Challenges Ahead
- The US Cleaned Up, Learned, and Became Stronger After Three Mile Island
- Japan Can Also With Fukushima

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Lake Barrett is a part time independent consultant in the energy field. He has worked in the nuclear energy and nuclear materials management areas for over 4 decades, most recently as the former head of the US Department of Energy's Office of Civilian Nuclear Waste Management which is responsible for implementing the United Sates' programs for spent nuclear fuel and high-level radioactive waste, as mandated by the Nuclear Waste Policy Act. In that capacity, he led the complex scientific Yucca Mountain Geologic Repository program through the statutory site selection process culminating with the Presidential site designation and following successful House and Senate votes.

He also served at U. S. Nuclear Regulatory Commission, where he was directly involved with the early response to the Three Mile Island reactor accident and became the Site Director, responsible for regulatory programs during the stabilization, recovery, and cleanup of the damaged reactor. He also has had extensive managerial and engineering experiences in DOE's Defence Programs and private industry at both Bechtel Power Corporation, with commercial nuclear power plants, and Electric Boat Division of General Dynamics with nuclear reactor and submarine systems design, operation, and decommissioning.

Backup Slides

Cold Shutdown Safety Plan

Countermeasures for protecting Core Damage

(1) Flooding Protection Countermeasures for sites and buildings

Installation of tidal embankment, board, and wall and flood protection of door and penetration

(2) High Pressure Cooling Water Injection Facilities (Required within 1-hour)

Concepts

-High pressure injection is initially required due to high reactor pressure in the case that the plant experiences an abnormal shutdown.

-During the accident, some motor-driven equipments were inoperable due to the station black out (SBO). Hence, a steam-driven high pressure facility is the key issue.

-Furthermore, when choosing motor-driven high pressure cooling water injection facilities, it is important to select equipment with minimum operating requirements.

		SBO
RCIC	steam-driven	○
SLC or CRD	motor-driven	×
HPCS		

Reactor Core Isolation Cooling System (RCIC)

Necessary Equipment	Flooding Countermeasure for system	Countermeasure in a flexible manner
Pump/Turbine	Flood protection for the RCIC Room	Establishing manual activation procedures
DC Power Supply (Battery, switchgears, etc.)	Flood protection for the battery room and the area where the main bus panel is located or considering rearrangement)	Preparing Power-Supply cars

Stand by Liquid Control System (SLC) or Control Rod Drive (CRD)

Necessary Equipment	Flooding Countermeasure for system	Countermeasure in a flexible manner
SLC pump or CRD pump	-	Flooding protection for the pump area
Water Source	-	Establishing water supply procedure from the purified water tank
AC Power	-	Flooding protection for power supply equipment, including Emergency D/G(EDG), deploying power-supply car, securing an outside power source as an alternative to the EDG

(3) Depressurizing Equipment (Within 4-8 hours)

Concepts

-Depressurization of the rector pressure vessel is essential in order to remove heat and bring it to a cooling stage

-During the Fukushima accident, the DC power necessary to operate the main steam safety relief valve for depressurizing was insufficient. In addition to securing N2 for valve operations, securing a power source is necessary.

Necessary Equipment	Flooding Countermeasure for system	Countermeasure in a flexible manner
N2 tanks	-	Preparing spare tanks
DC power supply (Battery, switchgears, etc.)	Flood protection for the battery room and the area where the main bus panel is located (or considering rearrangement)	Preparing portable batteries

(4) Low Pressure Water Injection Facilities (Within 4-8 hours)

Concepts

-Low pressure cooling water injection equipment consists of an emergency system, a make-up water condensate system (MUWC) and a fire protection system. In the case of the SBO, only the diesel-driven fire pumps (DDFP) of the FP will be operable.

-Preparing reliable low pressure injection equipment is important including the fire-engine used.

		SBO
DDFP	diesel-driven	○
MUWC	motor-driven	×

Fire Protection System (FP)

Necessary Equipment	Flooding Countermeasure for system	Countermeasure in a flexible manner
Diesel-driven fire pumps	Flood protection for the pump room	Preparing fire engines and constructing water transfer lines, and establishing procedure for seawater injection
Batteries	Flood protection for the battery room	Preparing portable batteries
Diesel fuel	Fuel deployment (including delivery logistics)	-

Make-up Water Condensate system (MUWC)

Necessary Equipment	Flooding Countermeasure for system	Countermeasure in a flexible manner
MUWC pump	Flood protection for the pump room	Establishing procedures for supplying of water among tanks
AC power	Flood protection for power supply equipment, including EDG or considering rearrangement	Preparing power-supply cars, securing an outside power source as an alternative to the EDG

(5) Heat Removal/Cooling Facilities

1) PCV venting (Within 1-2 days)

Concepts

-In the case that seawater cannot be used as a cooling source, suppression chamber venting that utilizes air as a cooling source is necessary.

-In order to conduct suppression chamber venting, opening motor-operated (MO) valves as well as air-operated (AO) valves are necessary.

Necessary Equipment	Flooding Countermeasure for system	Countermeasure in a flexible manner
AC power (MO-valve, solenoid valve for AO-valve)	Flood protection for power supply equipment including EDG or considering rearrangement	Preparing power-supply cars, portable AC generator or portable batteries
Compressed air (For AO-valve operation)	Portable air compressor (or tank preparation)	Remodeling AO-valve so that it can be operated manually

2) Heat removal via Shutdown Cooling Mode (Within 3-7 days)

Concepts

-Shutdown cooling mode procedures by residual heat removal system (RHR) that utilizes sea water as a cooling source is necessary.

-Thus, in addition to ensuring a power source, restoring the seawater system utilized as the ultimate heat sink for preparing alternative pumps, or motor repairs is necessary.

Necessary Equipment	Flooding Countermeasure for system	Countermeasure in a flexible manner
AC power (RHR pump)	Flood protection for power supply equipment including EDG or considering rearrangement	-Preparing alternative pump -Preparing mobile heat exchangers
RCW/RSW pump	Preparing spare motor	
AC power (RCW/RSW)	Flood protection for power room	Preparing Power-Supply cars, maintaining an outside power source as an alternative to the EDG

3) Heat removal from spent fuel pool (Within 7-10 days: Depending on decay heat from spent fuels)

Concepts

-Spent fuel pool cooling and cleanup system (FPC) is basically tsunami-resistant since it is located inside the reactor building. Hence it is important to maintain the power source.

-Furthermore, in light of having a sufficient a amount of time to respond, monitoring utilizing the instruments is important.

Necessary Equipment	Flooding Countermeasure for system	Countermeasure in a flexible manner
FPC pump	Flooding protection for the pump room Installation of water level detection instruments or a thermometer inside the pool	-Preparing fire engines -To establish redundancy with fire protection piping
AC power	Flooding protection for power supply equipment or considering rearrangement	Preparing Power-Supply cars

(6) Ensuring power supply to the monitoring instruments (Required within 1 hour)

Concepts

-During the Fukushima accident, the monitoring instruments were rendered inoperable and restoring power to the instruments took time.

-Thus ensuring immediate power supply for instruments is important.

Necessary Equipment	Flooding Countermeasure for system	Countermeasure in a flexible manner
DC power	Waterproofing the battery room and the area where the main bus panel is located (or considering rearrangement)	-Preparing portable batteries -Preparing Power-Supply cars and portable battery chargers

(7) Mitigation measures following reactor core damage

Concepts

-During the accident, not only was the containment function lost, but also restoration efforts were seriously hampered due to the hydrogen explosion caused by the possible leak of hydrogen from the primary containment vessel to the building.

-In light of defense in depth, it is important to establish countermeasures in the case of the reactor core damage, which happened at Fukushima Daiichi

Items	Countermeasure
Hydrogen Accumulation Prevention	Installing equipment or establishing procedures for drilling holes through the roof or opening the blow-out panels in order to improve reactor building ventilation.
Mitigation of Radioactive Material release	Establishing the water injection procedures to the PCV via fire engines etcetera as is being done with the suppression chamber venting. (Established for smooth venting via water filtering)

(8) Common Countermeasures

- In addition to implementing each countermeasure, it is important to reinforce the supporting work and auxiliary equipment for safe and efficient activity in order to achieve the aforementioned countermeasures effectively.

Items	Countermeasure
Outside Power Source	Reviewing the seismic improvement for the substation facilities, assessing the destruction of the embankment that could lead to transmission tower damage, and setting up facilities that will contribute to power transmission reliability.
Debris Removal Equipment	Preparing equipment to remove debris hampering restoration activity.
Securing communication tools	Establishing flexible communication measure such as the preparation of walkie-talkies or satellite phones as well as ensuring a power source
Securing Lighting Equipment	Preparing high power lighting equipment and headlights that will allow workers free use of both hands so that they will be ready to respond safely, quickly and precisely.
Health Protection Equipment	An abundant supply of protective gear, masks, APDs, portable air refreshers, etc. should be on hand along with the deployment of the power supply car in order to ensure that workers will be able to restore the main control room ventilation system promptly.

Other mid and long-term Technical Issues

-In this study, the aforementioned core damage countermeasures have been established. In addition, mid and long-term technical issues such as those listed in the right-hand table should be considered

-These technical issues will be considered separately.

Items	Action Plan
Isolation Signal Review	During the Fukushima accident, the loss of the isolation condenser cooling function was caused by the valve closing up due to loss of DC power. Hence, the concept concerning the isolation signal should be reviewed.
Venting line improvement	In order to improve venting that is able to significantly filter out radioactive materials, measures such as the aggressive activation of the Rupture Disk will be looked into while taking the accidental release of radioactive materials into consideration
Mitigation measures for radioactive material release during venting	The design of a filter vent to mitigate the release of radioactive materials will be considered
Surveillance Instrument Improvements	Given that the water level gauge measurements deviated greatly from the actual value at the power station, research and development in this area will be developed.

Defueling Plan