ROAD SHOW ACCADEMICO 2010 / 2011

Enel EDF POLITECNICO DI MILANO

ENERGIA
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LA TECNOLOGIA NUCLEARE

ENERGIA,FUTURO, RICERCA
La tecnologia Nucleare

Le verifiche di sicurezza post-Fukushima; le indicazioni delle organizzazioni sovranazionali

Politecnico Milano, 03/05/2011

Giancarlo Aquilanti
Ingegneria e Innovazione
Enel-Area Tecnica Nucleare

The Fukushima event as of April 30th, 2011

AFFECTED PLANT

Fukushima Daiichi – Japan: Units 1 to 6

ACCIDENT CLASSIFICATION

International Nuclear Event Scale (INES)
NISA(*) provisional rating

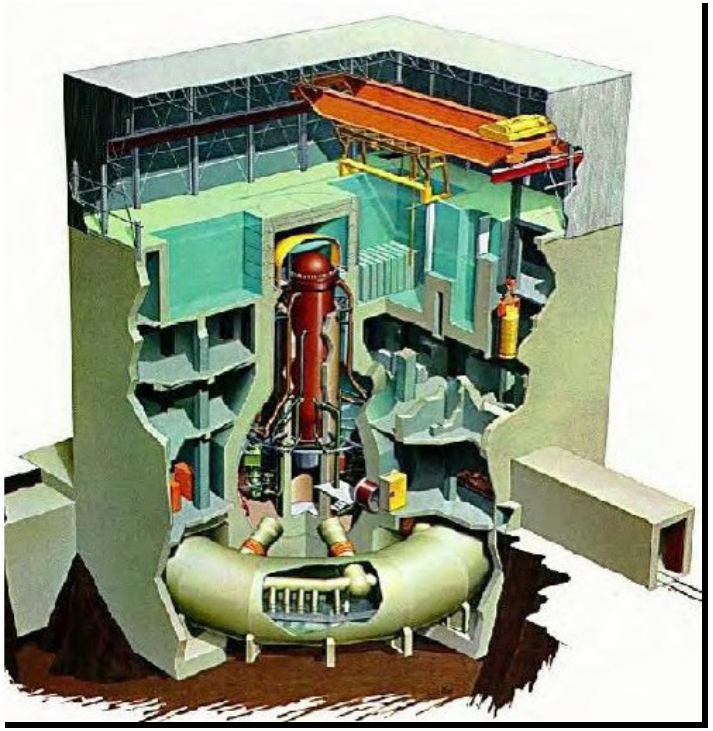
Units 1-2-3: **As single event INES 7**
(same as Chernobyl, Ukraine 1986)

Unit 4: **INES 3**
(same as Sellafield event, UK 2005)

ACCIDENT PRESENT STATUS

- **Units 1 to 3**: **Core damaged** (from ≈ 55% in Unit 1 to ≈ 30% in Unit 3) and **fuel partially exposed**; **reactor pressure vessel integrity unknown**; fresh water injection by MD pumps
- **Reactor buildings severely damaged** (Units 1,3,4) by H2 explosions; steam like smoke arising from bldg
- **Reactor containment potentially damaged** in **Unit 2**; **pressure stable** and **venting stopped** in **Units 1 and 3**; **containment flooding** and **N2 injection** in progress in **Unit 1**
- **Fresh water injection/spray** in all **spent fuel pools**; **possible damages** of **spent fuel** in **units 3 and 4**; **concerns** about **spent fuel pool structural integrity** in **Unit 4**
- **Units 5 and 6 in safe shut-down conditions**

(*) NISA = Nuclear and Industrial Safety Agency -Japan



	CRITERIA OR SAFETY ATTRIBUTES		
	OFF-SITE IMPACT	ON-SITE IMPACT	DEFENCE IN DEPTH DEGRADATION
7 MAJOR ACCIDENT	MAJOR RELEASE: WIDESPREAD HEALTH AND ENVIRONMENTAL EFFECTS		
6 SERIOUS ACCIDENT	SIGNIFICANT RELEASE: LIKELY TO REQUIRE FULL IMPLEMENTATION OF PLANNED COUNTERMEASURES		
5 ACCIDENT WITH OFF-SITE RISK	LIMITED RELEASE: LIKELY TO REQUIRE PARTIAL IMPLEMENTATION OF PLANNED COUNTERMEASURES	SEVERE DAMAGE TO REACTOR CORE/RADIOLOGICAL BARRIERS	
4 ACCIDENT WITHOUT SIGNIFICANT OFF-SITE RISK	MINOR RELEASE: PUBLIC EXPOSURE OF THE ORDER OF PRESCRIBED LIMITS	SIGNIFICANT DAMAGE TO REACTOR CORE/RADIOLOGICAL BARRIERS/FATAL EXPOSURE OF A WORKER	
3 SERIOUS INCIDENT	VERY SMALL RELEASE: PUBLIC EXPOSURE AT A FRACTION OF PRESCRIBED LIMITS	SEVERE SPREAD OF CONTAMINATION/ACUTE HEALTH EFFECTS TO A WORKER	NEAR ACCIDENT NO SAFETY LAYERS REMAINING
2 INCIDENT		SIGNIFICANT SPREAD OF CONTAMINATION/ OVEREXPOSURE OF A WORKER	INCIDENTS WITH SIGNIFICANT FAILURES IN SAFETY PROVISIONS
1 ANOMALY			ANOMALY BEYOND THE AUTHORIZED OPERATING REGIME
0 DEVIATION	NO	SAFETY	SIGNIFICANCE

The Fukushima event as of April 30th, 2011

MANAGEMENT OF RADIOACTIVE EFFLUENTS AT SITE

- **Highly radioactive water** found in **turbine building** of Units 1-3 **transferred to**:
  - **Condensate Storage Tanks**, after emptying CST to Suppression Pool Surge Tanks,
  - **Waste Disposal Facility**, after emptying WDF by discharging low radioactivity water at sea (≈10.000 cu.m.)
- **Additional storage** (tanks and floating) and **waste water treatment** being **implemented** at **site** for low radioactive water

RADIOLOGICAL PROTECTIVE MEASURES

- **Evacuation**: **20 km** from the **Daiichi Plant** and 10 km from the Daiini Plan;
- **Sheltering**: **20 km to 30 km** from **F-Daiichi**
- **Evacuation prepared** area: **20 km to 30 km** from **F-Daiichi**
- **Planned evacuation area**: **hot spots** in areas **further than 20 km** from **F-Daiichi**

ACCIDENT CONSEQUENCES ON PLANT WORKERS

- **Conventional**
  - 2 people dead from earthquake (stack cabin)
  - 2 people dead from tsunami
  - 15 people injured from hydrogen explosions
  - approx. 6 people injured from other causes
- **Radioactivity related**
  - 28 worked received a dose higher than 100 mSv
  - None has received a dose higher than 250 mSv

Lethal dose [1]: 5000 mSv

Extended TEPCO limit: 250 mSv

Initial TEPCO limit: 100 mSv

Maximum allowed: 50 mSv/a

Natural background: 2.5 mSv/a

1) 50% of mortality rate for short term exposure

First appraisal of the Fukushima event

Evaluation of causes

Probably **several thorough analyses** on the **Fukushima accident** will take place **after the event is finished**; **these analyses** will **take months to be completed** and many information, now not available, will be required.

The **need** to **check immediately** each **individual Plant safety** against the most evident **criticalities** which **emerged** so far **from the Fukushima accident**, thus providing also **immediate answers** to the **public** about the **safety of NPP's** has pushed **Nuclear industry**, the **Safety Authorities** and the **Political level** to define a **first level of actions** based on the **major evidences** of the accident.

Event initiation

- **Inadequate design basis** for the **tsunami event** (*) (external natural hazard) (design)
- **Loss of all safety trains** and of **all lines of defenses in depth** for **multiple Nuclear Units** due **one single event** (design)
- **Flooding of all electrical systems** (safety and non safety related) for **one single event** (design)

Event degradation

- **No power back-up system available for days** after the initiating event (all battery capacity discharged and then total loss of any plant instruments, control, protection, operability) (emergency procedures; preparedness for extreme events; organization)
- **No immediate prompt action to bring on-site needed equipment to restore vital safety functions** during the first phase of the events (emergency procedures; preparedness for extreme events; organization)

(*) The **tsunami wave height** of the **present Tohoku** pacific ocean **earthquake** has been of **approx. 14 m** in F-Daiichi. The tsunami wave **design height is 5.7 m** for Daiichi and 5.2 m for Daiini; **the site level of Daiichi is 10 m** (turbine and reactor bldg and 4 m (seawater pumps). The tsunami wave design height has been taken on the basis of historical values (confirmed by Japan Society of Civil Engineers in 2002); it seems that **tsunamis** of **similar heights** than Tohoku were produced **in 1896** (Meiji Sanriku earthquake) and **in 869** (Jogan tsunami) (Advanced Industrial Science and Technology report to METI in 2009).

First appraisal of the Fukushima event

Evaluation of causes

Event degradation

- **Much delayed reaction to extreme plant conditions** (emergency procedures; preparedness for extreme events; organization)
- **Delayed or wrong Containment venting** (Emergency procedures, organization, design)
- **No proper hydrogen management** (Emergency procedures, design)
- **Inadequate spent fuel cooling** in the spent fuel pool (even with fuel probably submerged)

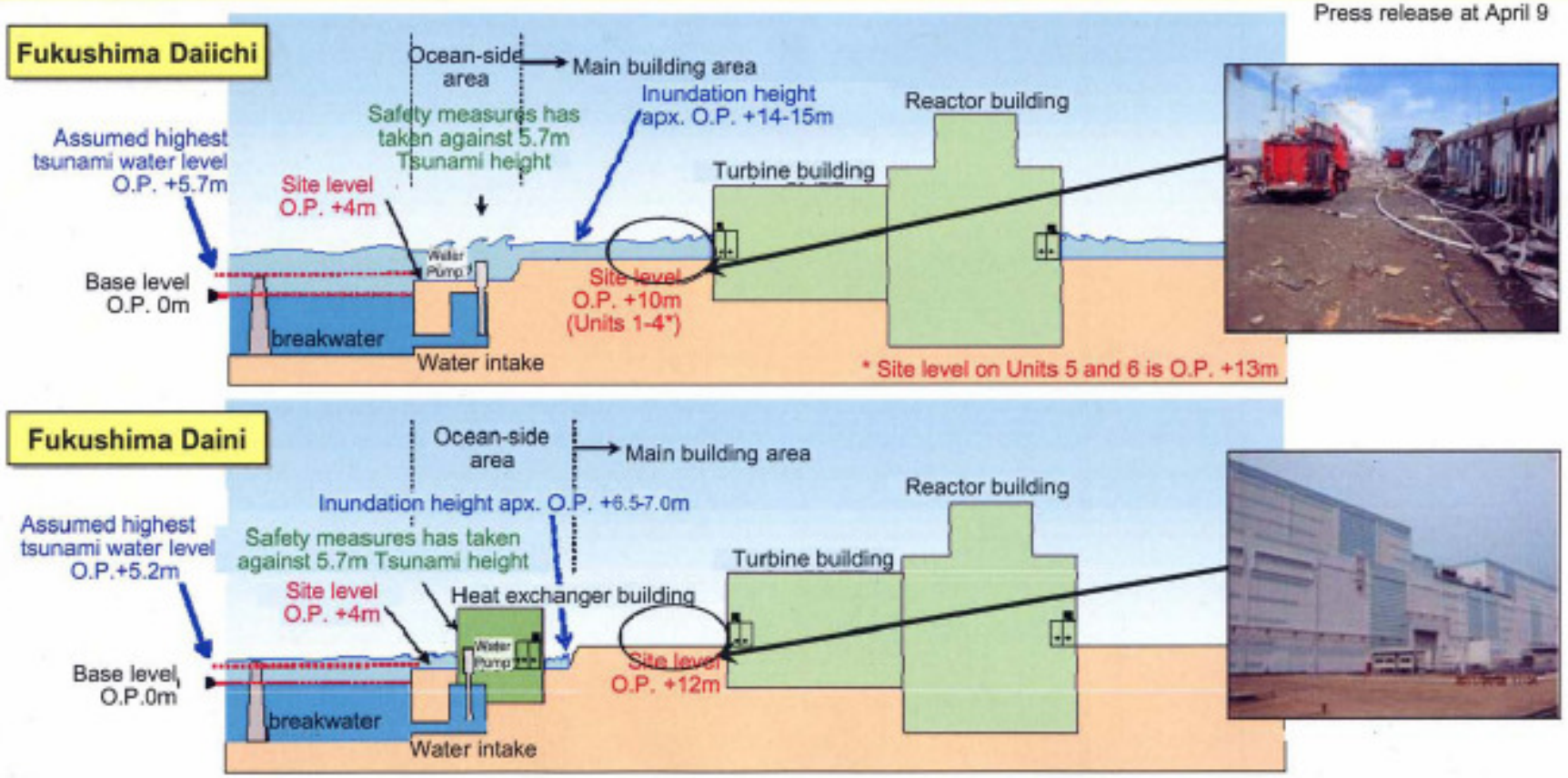
Important contributors to the **accident degradation** appear to be:

- the **reactive response** to the events by TEPCO,
- **shortfalls** in the **implementation** of **safety upgrades** for GE BWR Mark I reactors vs sister units in US and and of **proper Severe Accident Management Procedures**

[Reference] Height of Tsunami

- Based on the evaluation method by the Japan Society Civil Engineers revised on 2002, we conducted an assessment regarding Tsunami of O.P. 5.1～5.7m, and based on this evaluation, we have taken safety measures.
- At Fukushima Daiichi Nuclear Power Station, inundation with inundation height of approximately O.P. + 14 to 15 meters and inundation depth approximately 4 to 5 meters occurred in most of the area.
- At Fukushima Daini Nuclear Power Station, inundation with inundation height of approximately O.P. + 6.5 to 7 meters occurred in the ocean-side areas, however, only surrounding areas of Unit 1 and 2 buildings and the south side of Unit 3 building was inundated within the main building area.
- **Accordingly, we have confirmed that the impact of tsunami was relatively larger in Fukushima Daiichi Nuclear Power Station than Fukushima Daini Nuclear Power Station.**

Press release at April 9

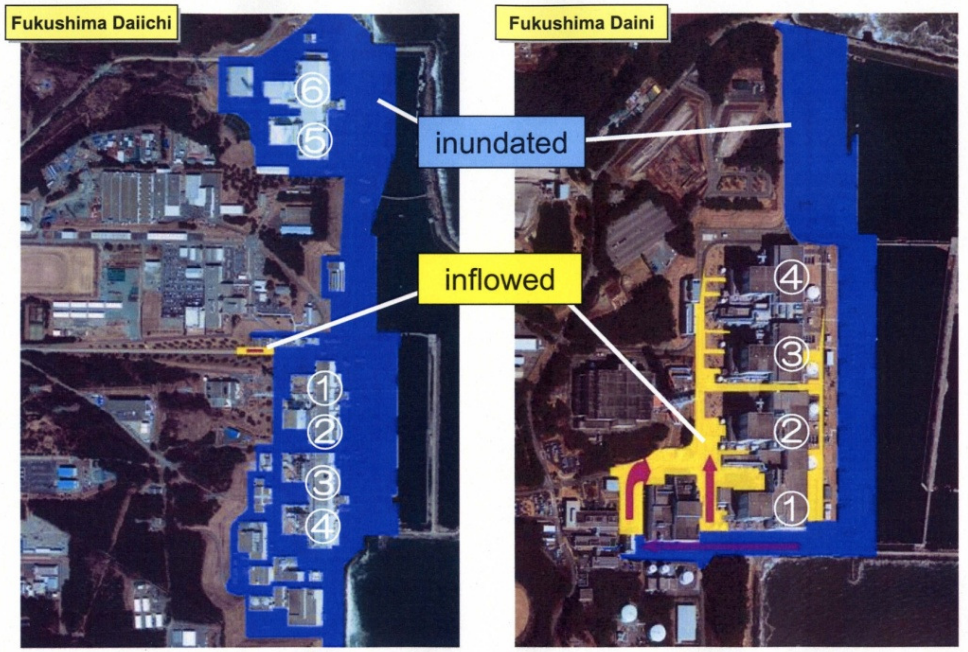


O.P. : Onahama bay construction base level

Fukushima Daiichi
Tsunami effects

Tsunami wave approaching Fukushima Daiichi

[Reference] Inundated and Inflowed Area at Fukushima Daiichi and Daini Site



(C) GeoEye

Fukushima Daiini

Tsunami effects

Fukushima Daiini

Tsunami effects

Fukushima Daiini

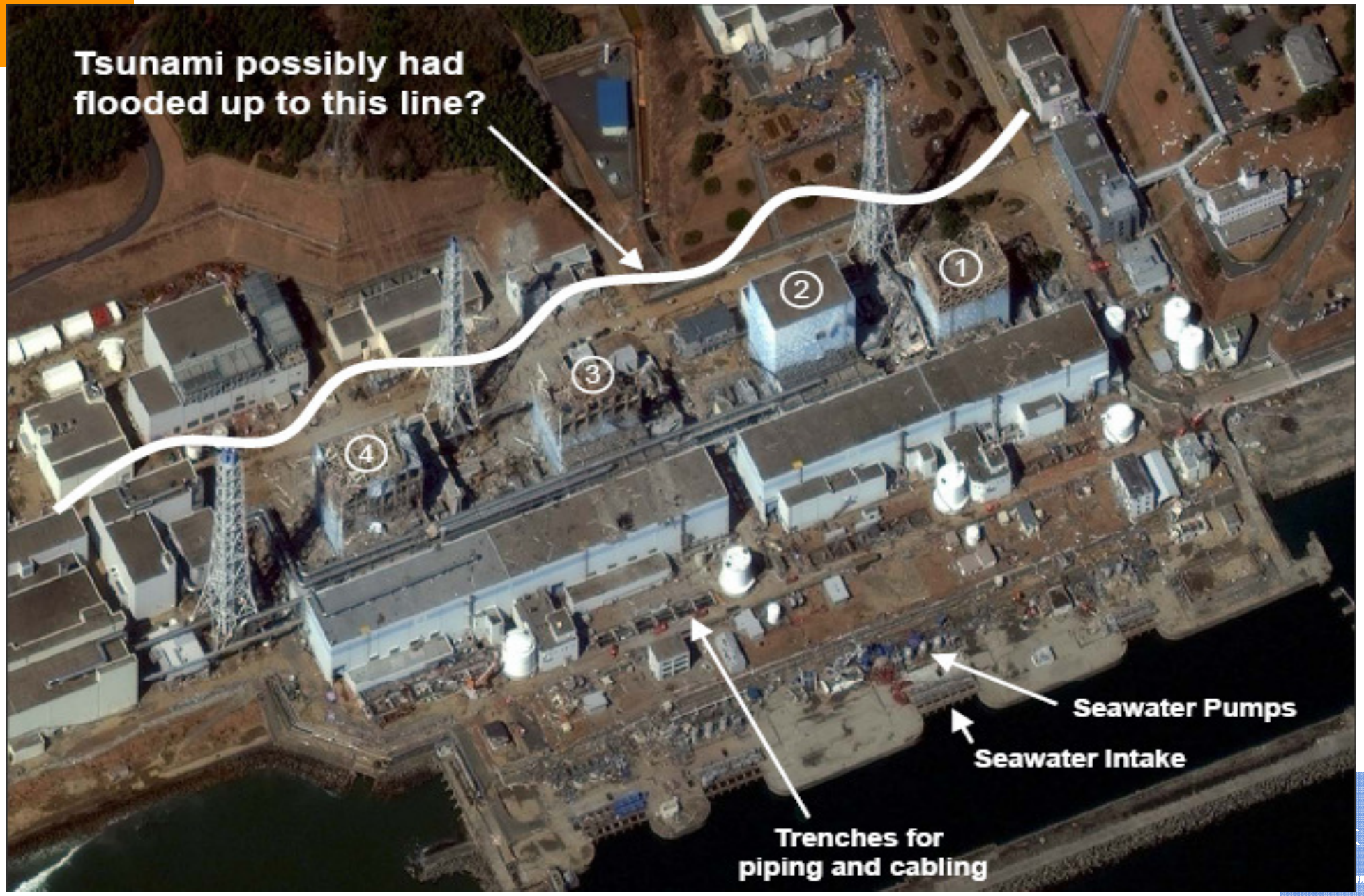
Tsunami effects

Fukushima Daiini

Tsunami effects

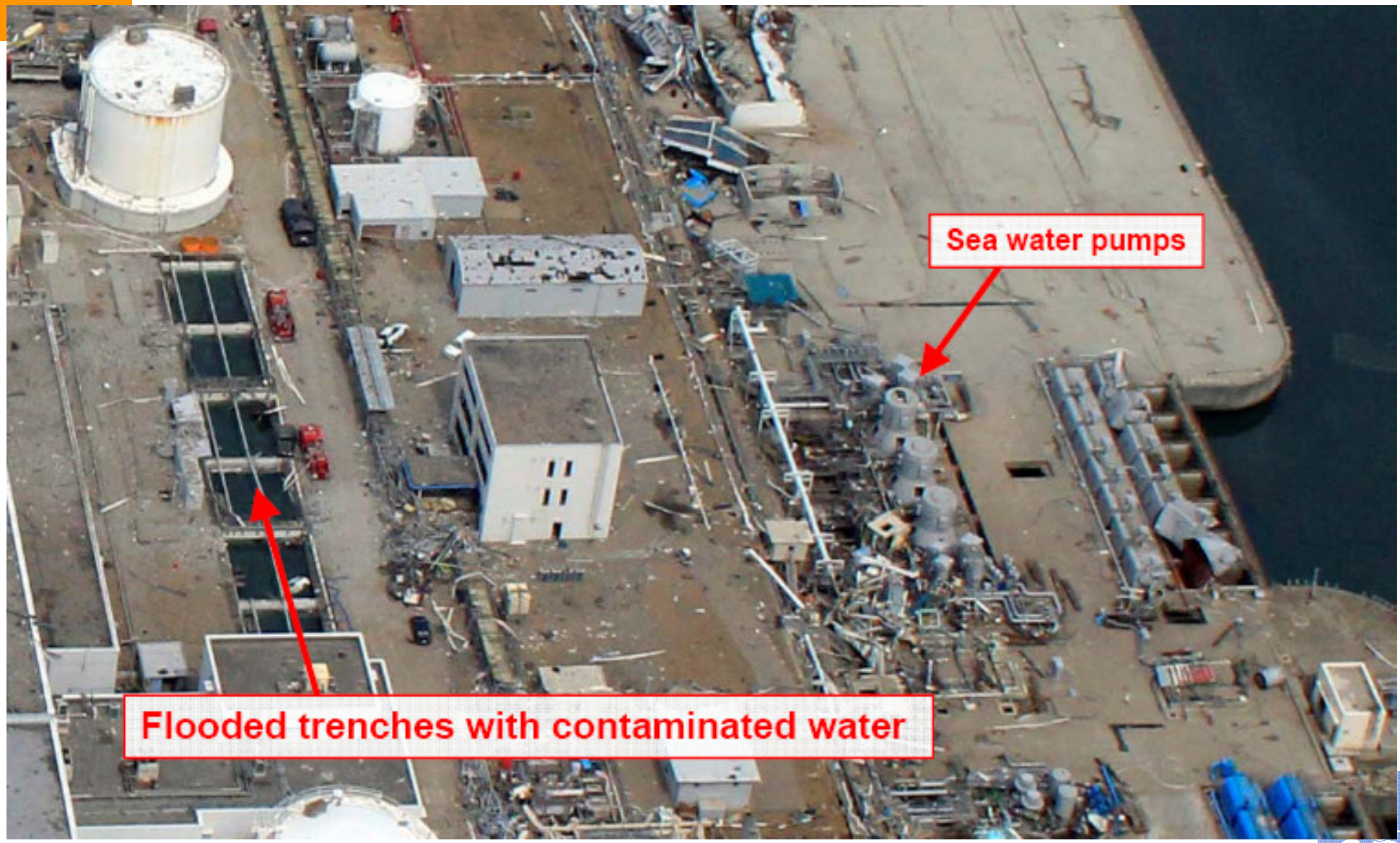
Fukushima Daiichi

Tsunami effects



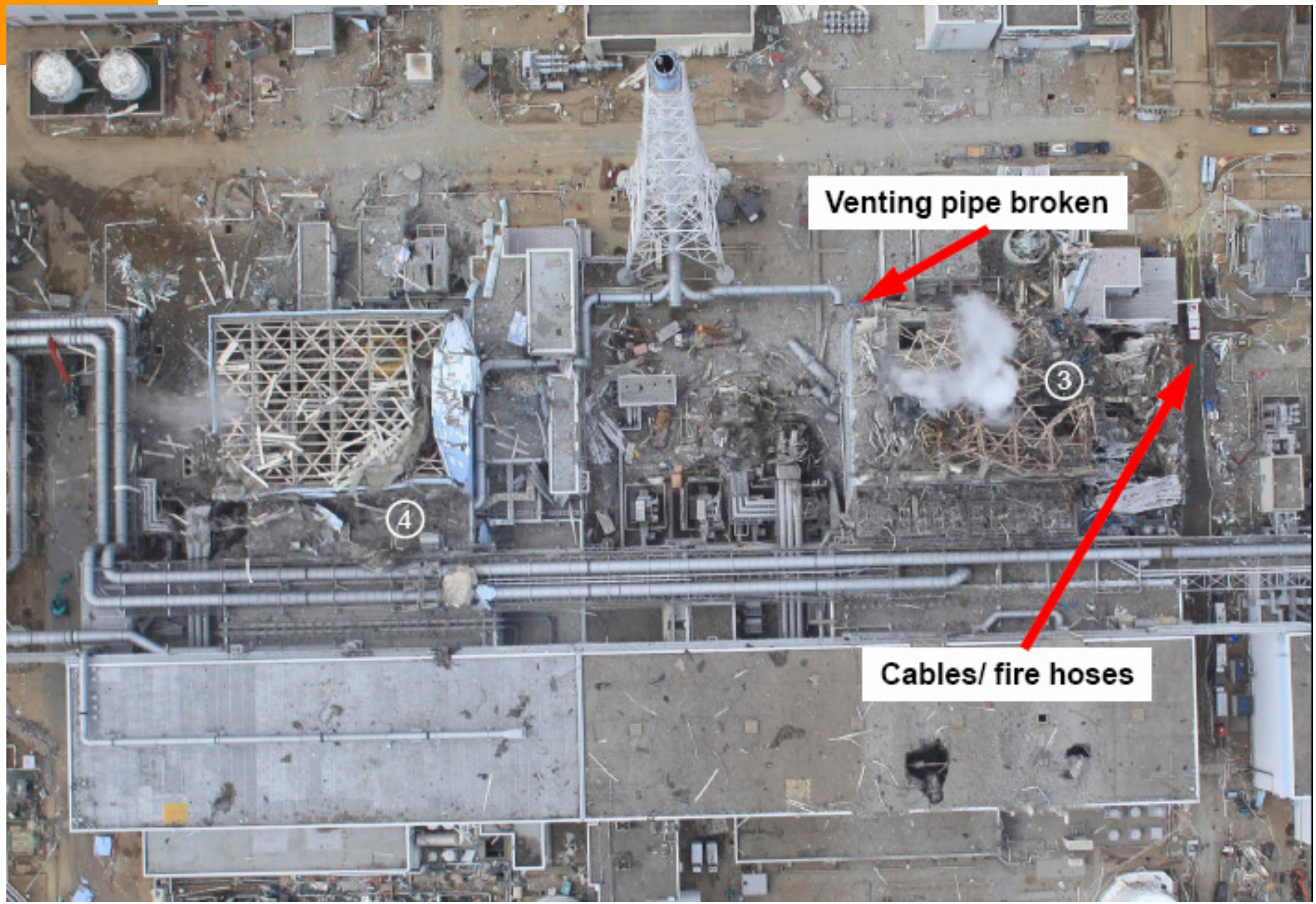
Fukushima Daiichi

Tsunami effects



Fukushima Daiichi

Tsunami effects



Fukushima Daiichi

Tsunami effects

First analysis of lessons learnt from the Fukushima event

INITIATING EVENTS

- The **external natural hazards** are very critical for Plant safety (e.g.: earthquake, flooding, extreme weather conditions) since they can jeopardize all Plant safety-and-non safety features; the **design values** should be **adequately assessed against site data** (WENRA)
- **Combination** of **correlated low probability severe events** must be properly addressed in siting and design (tail risks)
- Adequate **evaluation** should be made for the **potential** of **beyond design basis external events** to **affect any Plant safeguard** (NEI)
- **Multiple Nuclear Units** should be adequately analyzed for the **potential of events affecting all Units** (WENRA)

LOSS OF SAFETY FUNCTIONS

- **Total loss of Power supply events** to be **re-evaluated** to verify time limits and scenarios for alternate source of power (WENRA, WANO, NEI)
- **Total loss of cooling capability events** to be **re-evaluated** to verify time limits and scenarios for copying with such events (WENRA)
- **Degraded conditions in spent fuel** to be re-evaluated (also effect of loss of radiation shielding) (WENRA)

ACCIDENT MANAGEMENT

- **Highest level of preparedness** for **Severe accident conditions** is required (WENRA, WANO) and to **cope with beyond design events** (flooding, fire) , also considering multiple failures (WANO, NEI)
- **Plant extreme conditions** should be **analyzed** in order to **define measures** to cope with such scenarios (NEI)

WENRA = Western European Nuclear Regulators' Association
WANO = World Association of Nuclear Operators

NEI = Nuclear Energy Institute (US)

Post Fukushima scenario on Nuclear Power generation
NPP's in Operation: Europe and North America

The **two major areas** on **Nuclear Generation**: **North America** and **Europe** can be **impacted in a different way** by the **Fukushima event**

Europe has **certain gaps** compared to **North America** situation, that will have probably **to be bridged after Fukushima**

	North America	Europe	Probable post-Fukushima action (Europe)
SAFETY REQUIREMENTS: ▪ **EQUALIZATION** ▪ **ENFORCEMENT**	▪ **Same safety requirements** ▪ **One strong independent Safety Authority** ▪ Strong level of enforcement	▪ **Different level of safety requirements for the different Countries**	▪ **Harmonization** of safety standards and requirements ▪ **Strong coordination of Safety Authorities** (short) ▪ **Possible supra-national Safety Authority** (long)
PROCEDURES AND HARDWARE FOR SEVERE ACCIDENTS AND EXTREME PLANT CONDITIONS	▪ **General implementation of Severe accident management strategies** ▪ Post 9-11 requirements has led to preparedness for extreme degraded conditions (off-site, ready to use equipment)	▪ **Non homogeneous implementation of Severe accident management strategies** ▪ **No guaranteed preparedness** (except UK) **for extreme degraded conditions** (off-site, ready to use equipment)	▪ **Equalization of stronger Severe accident management strategies** ▪ **General implementation of preparedness for extreme degraded conditions**

Post Fukushima scenario on Nuclear Power generation
NPP's in Operation: Europe and North America

CONTROL ON NUCLEAR OPERATORS

North America

- **North America Nuclear Operators** have given **INPO strong contro**l and **significant empowerment** about monitoring Operators Safety performances

Europe

- **WANO** is more a **worldwide consultant** with very **limited empowerment** in case of Safety deficiencies

Probable post-Fukushima action (Europe)

- **Stronger enforcement** and **control** capability given to WANO
- Possible creation of a supra-National entity to check safety on Nuclear Operators

Requirements by WANO: World Association of Nuclear Operators on 23 March 2011

SOER[1)] 2011-2: verification of the capability to mitigate conditions resulted from beyond design basis events

1st deadline for completion: April 8th, 2011

- Verify the **capability** to **mitigate conditions** resulting from **beyond design Basis Events**:
  - Equipment are available and functional
  - Procedures are in place and executable
  - Operators and support staff are qualified
  - Agreements and cotracts for external support are in place and are adequate

2nd deadline for completion: April 15th, 2011

- Verify the capability to **mitigate station blackout conditions**
  - Verify through walk-downs and inspections that all **required materials are adequate and properly staged,**
  - Demonstrate through walk-downs that **procedures for response to an SBO are executable**

3rd deadline for completion: May 6th, 2011

- Verify the capability to **mitigate internal and external flooding** events required by station design

4th deadline for completion: May 13th, 2011

- Perform walk-downs and inspections of important equipment needed to **mitigate fire and flood events**
  to identify the potential that the equipment's function could be lost during seismic events appropriate for the site
- Develop **mitigating strategies for identified vulnerabilities**.
  Perform walkdowns and inspection of important equipment (permanent and temporary) and develop mitigating strategies

1) Significant Operating Experience Report

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Requirements at European level

The European Commission and WENRA

Background

March 15: "Stress Test" announced by the Commissioner **G.Oettinger** to the Press as a follow up of the European meeting of the stakeholders held in **Brussels on March 15**; meeting stated the need to:

- ***Promote the highest safety standards in Europe in the nuclear business***
- ***Develop a coherent safety assessment process in the EU***

March 21: Immediately after, the EU Atomic Group convened an extraordinary **Council Meeting** on **March 21**, which stated that the Safety assessment should follow:

- ***…an European approach, based on a common approach, borderless (involving neighboring Countries), including at least earthquake, flooding, station blackout, etc.***

March 23: **EU ministers** have agreed to launch a **safety assessment** of **Europe's 143 nuclear** power reactors (nuclear "stress tests"), re-checking their safety in the light of the Fukushima nuclear accident. The assessment should be underway before the end of the year and cover countries neighboring the EU.

March 23: The **WENRA meeting** on March 22 and 23 drafted some preliminary criteria

Players and Roles

ENSREG
European Nuclear Safety Regulators Group

Nuclear Regulators from the EU 27 + EC representatives - **Advises the EC** on Nuclear Safety Standards.

Western European
WENRA
Nuclear Regulators' Association

Nuclear Regulators of EU countries – **not a EU consultation body**

European Nuclear Energy Forum
Bratislava - Prague

European Institutions, nuclear industry– **EU platform to discuss on transparency issues**

ENISS : European Nuclear Installations Safety Standards

FORATOM
for nuclear energy in Europe

EU Nuclear utilities and operating companies: **represents nuclear utilities interests at EU level**

ENSREG will endorse the set of criteria issued by WENRA and help the EU in the harmonization of "Stress Test" results coming from each European state members.

WENRA is in charge of issue a detailed proposal for "Stress Test" *criteria* for the EU: definition, objective, technical scope, methodology and time frame.

The EU intends to use the ENEF platform, which involves all the stakeholders, for the broadest possible consensus on potential assessment actions to be performed at the European level.

ENISS is going to play a key role inside ENEF in the development of the proposal

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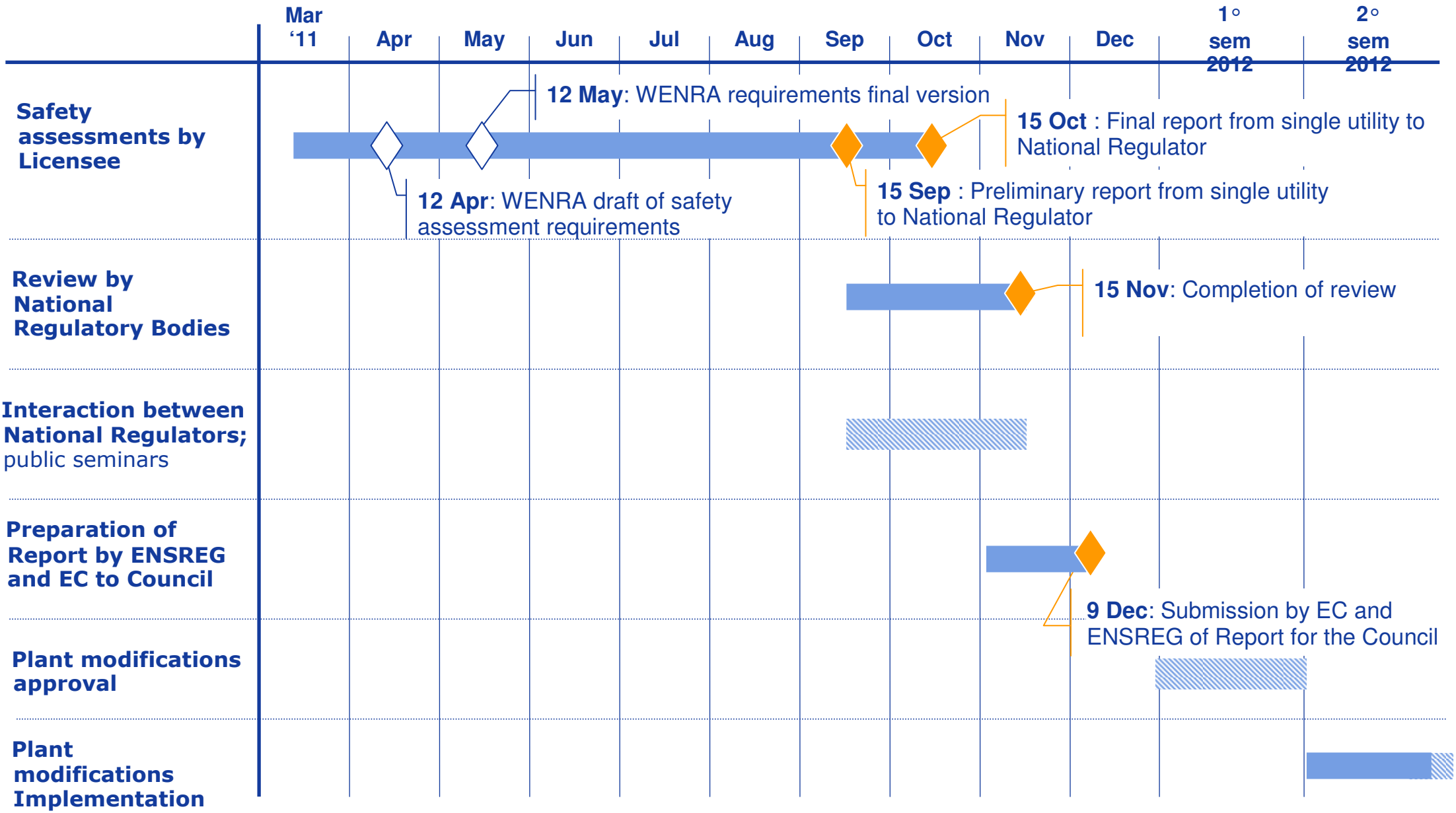
Stress test external timing

WENRA time schedule, to be confirmed by the 12nd of May



WENRA "stress test" specifications

General aspects

Definition

Stress tests **are a targeted reassessment of safety margins of NPP's in the light of the events of Fukushima: extreme natural events challenging the safety functions and leading to a severe accident**

Objective

Evaluation of Plant response to a set of extreme situations

Verification of preventive measures following Defense in depth logic

Requirements

Sequential loss of lines of defense should be assumed, in a deterministic approach, irrespective of the probability.

All reactors at a site shall be supposed to be affected at the same time

Technical scope

A ***Initiating events***

Earthquake, Flooding, Combination of Earthquake and Flooding, other extreme natural events

B ***Consequential loss of safety functions***

Loss of off-site power (LOOP), Station black-out (SBO), Loss of ultimate heat sink (UHS), combination of SBO and UHS loss

C ***Severe accident management issues***

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WENRA "stress test" specifications

A Initiating events

Earthquake and Flooding

Evaluation of Design Basis

- Design Basis Earthquake (DBE) and Flooding (DBF) and assessment of their adequacy
- Provisions to protect the plant against DBE and DBF
- Verification of Plant compliance with licensing basis

Evaluation of the margins

- **Evaluation** of the **range** of **earthquake** and **flooding severity above which loss** of **fundamental safety functions** or **severe damage to fuel** occur (weak points, **cliff edge effects**, possible provisions to avoid cliff edge effects)
- Evaluation of the **range of earthquake severity** the plant **can withstand** without losing confinement integrity

Combination of earthquake and flooding exceeding DBE and DBF

- **Indication of severe damages, weak points, cliff edge effects, possible provisions to avoid cliff edge effects**

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WENRA "stress test" specifications

B

Consequential loss of Safety Functions

Situations to be addressed

- **Loss of off-site power (LOOP)**
- **LOOP and loss of on-site back-up sources (both ordinary and diverse back-up sources) (Station Black-Out – SBO)**
- **Loss of main Ultimate Heat Sink (UHS)**
- **Loss of UHS with SBO**

For each of these situations

- **Indicate for how long the site can withstand without any external support before severe damage to the fuel becomes unavailable**
- **Specify which actions are foreseen to prevent fuel degradation**
- **Indicate if any provisions can be envisaged to prevent cliff edge effects or to increase robustness of the plant**

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WENRA "stress test" specifications

C

Severe Accident Management

Describe the accident management measures (organization, equipment, mobile devices, management of supplies, communication and information systems) in the following scenarios:

- **Loss of core cooling functions**
- **Loss of cooling functions in fuel storage**

Possible situations on site:

- **destruction of infrastructures,**
- **impairment of work performance due to high doses,**
- **unavailability of power supply,**
- **potential failure of instrumentation,**
- **potential effects from the other neighboring plants**

At each stage of previous scenarios

- **Identify any cliff edge effect and the time before it**
- **Assess the adequacy of the existing management measures**

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