ANALYSIS OF THE FUKUSHIMA DAIICHI ACCIDENT FROM A HUMAN AND ORGANIZATIONAL PERSPECTIVE

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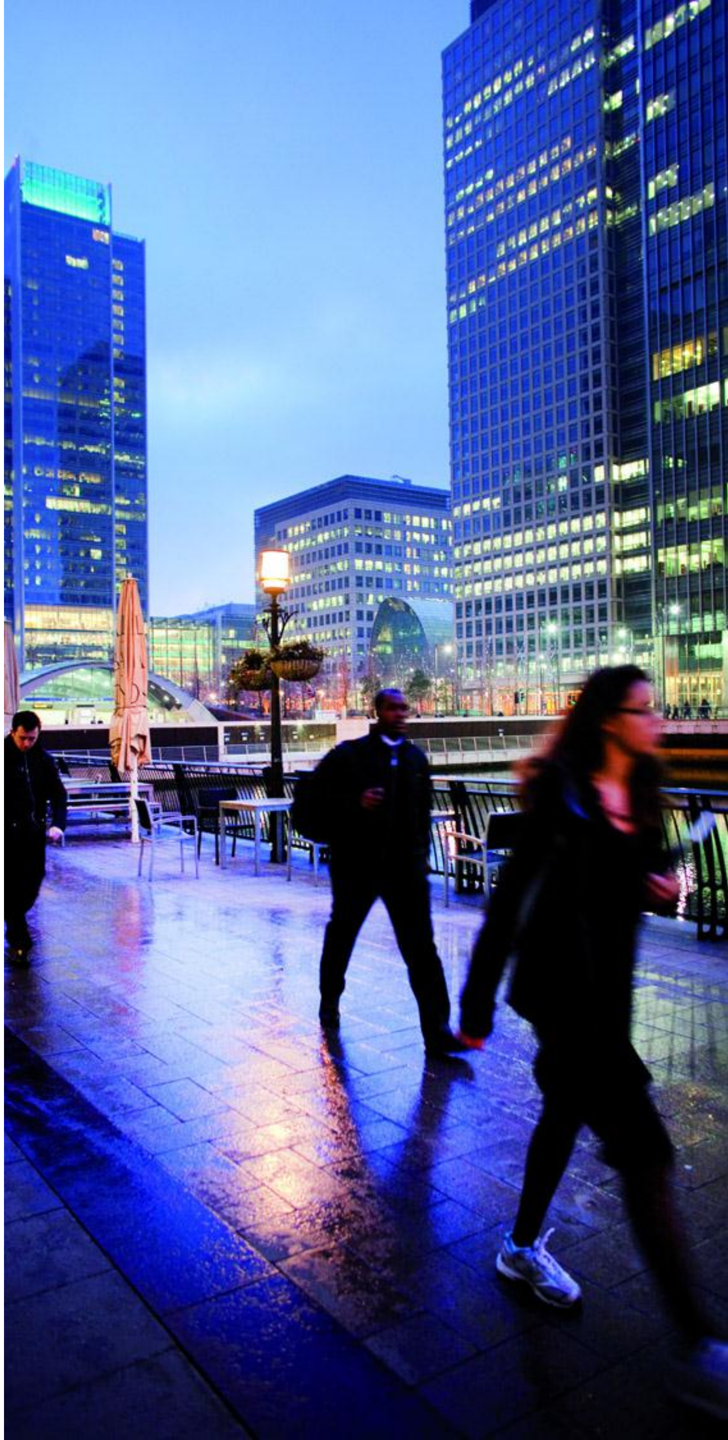

INTRODUCTION : OBJECTIVES

- A new paradigm for HRA?

  Human Factor as the last barrier

  Panel on Fukushima, HRA Society - PSAM11 ESREL12

➢ **Need for an analysis of the accident from a Human and Organizational perspective**

- ☐ Decision making, Actions in the field
- ☐ Insights for PSA, HRA and SAM
- ☐ MONACOS & MERMOS (EDF's methods)
- ☐ New focuses to investigate

SUMMARY

1. WORK METHODOLOGY
2. MULTI UNIT MANAGEMENT
3. FIELD WORK IN EXTREME SITUATION
4. CONCLUSIONS

WORK METHODOLOGY

1. **Bibliography**
2. **The MONACOS model**

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MONACOS MODEL FOR UNIT 3

Timestamp	Events	Operating Strategies		
11/03 – 14:46	**Earthquake** **Reactor SCRAM**	**EOPs applied – Field evacuation to MCR or ERC PS**		
11/03 – 14:46		Reactor parameters control via RCIC		
11/03 – 15:35	**Tsunami**			
11/03 – 15:42	Confirmation of tsunami Loss of AC sources DC, RCIC & HPCI ok	Reactor parameters control via RCIC		Field checks of equipments and power sources status
12/03 – 00:00		Low pressure injection line preparation	P_{PCV} control via S/C then D/W spray Venting line preparation	
12/03 – 11:36	Automatic shutdown of the RCIC	Manual activation of the HPCI		Restoration works
12/03 – 15:36	**H_2 explosion on Unit 1**	Reactor parameters control via HPCI		**Field evacuation**
12/03 – 17:20	P_{PCV} increase because of RCIC & HPCI operation			Damaged equipments restoration
13/03 – 2:42	P_{RPV} below HPCI operating pressure	HP → LP switch preparation		
13/03 – 3:45		RPV depressurization via SRV attempts		
13/03 – 8:35		LP injection attempts SRV restoration and opening	Venting line implementation	
13/03 – 9:08	P_{PCV} high enough for venting LP injection ok	LP injection failure RCIC or HPCI restart failure LP injection attempts		
13/03 – 9:20	Venting failure		Venting line valves restoration Temporary air compressors used to maintain valves opened	Restoration of long term accident control equipments
13/03 – 10:40	**Core damages**			
13/03 – 13:12	Seawater injection	Water sources switch		
14/03 – 6:10	Venting confirmed			
14/03 – 11:01	**H_2 explosion on Unit 3**	**Field evacuation**		
14/03 – 13:05	No cooling			Damaged equipments restoration
14/03 – 15:30	Cooling ok	Seawater injection resumed		
15/03 – 00:00	**End of the analysis** : core damaged, small leaks in PCV and RPV, PCV vented, seawater injection			

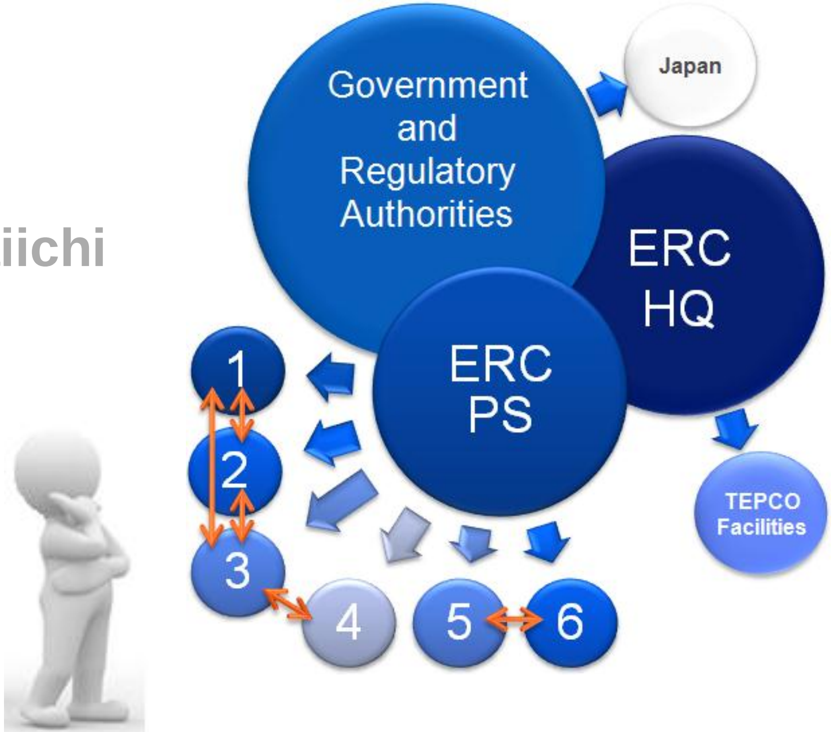
MONACOS MODEL ANALYSIS

- **Analysis of the CICAs allow a good understanding of the situation :**
  - ☐ **Why** → Context
  - ☐ **Who** → Role of teams, decision making process, …
  - ☐ **Where** → Plant architecture, Accessibility and field conditions, …
  - ☐ **When** → Event progression
  - ☐ **How** → Emergency procedures, imagination of teams, …
  - ☐ **What** → Results of the operating actions
- **Performed on most of the CICAs for Units 1, 2 & 3**
- **Further analysis on each "critical points" of the accident :**
  - ☐ IC operation misunderstanding between MCR and ERC at PS on Unit 1
  - ☐ PCV venting failure on Unit 2
  - ☐ High Pressure → Low Pressure switch failure on unit 3

CICA =
Important
Characteristic
for Emergency
Operations

MULTI UNIT MANAGEMENT

1. Situation at Fukushima Daiichi
2. Unit Interactions Analysis



LOCAL TEAMS ORGANISATION

- **Main Control Room :**
  - ☐ Same operation team and MCR for unit **pairs** : 1&2, 3&4, 5&6
  - ☐ 24 persons per pair of MCR :
    - 14 Operators including the shift supervisor
    - 10 Field workers

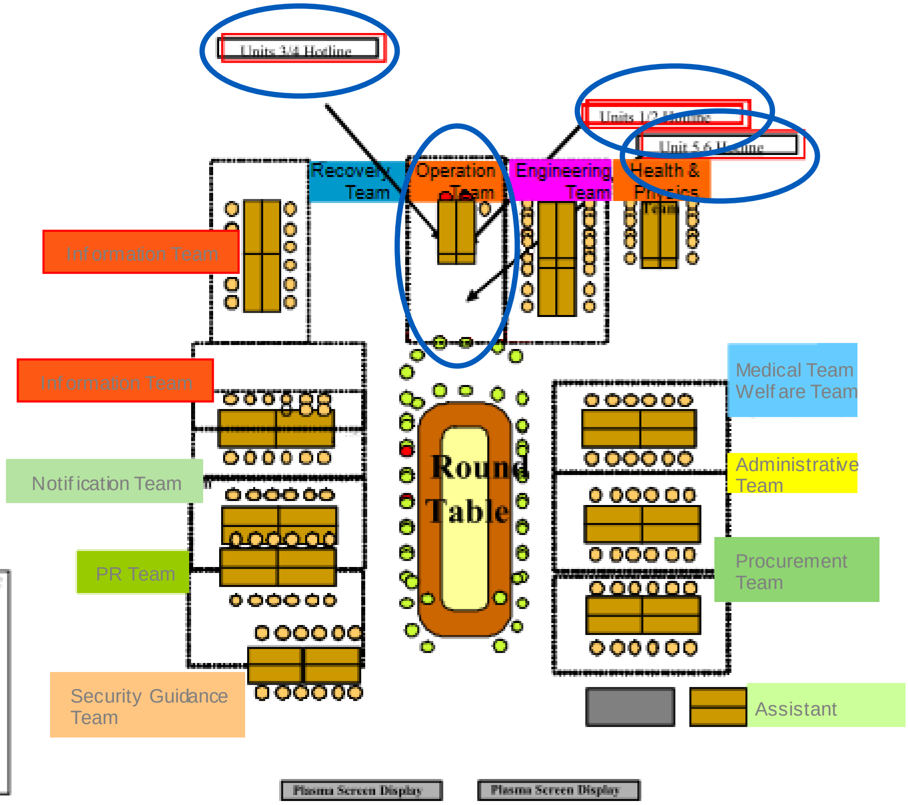
- **Emergency Response Center at the Power Station**
  - ☐ 12 teams ≈ 400 persons including the Site Superintendant
    - Recovery, Health & Physics, Engineering, Operation, …
  - ☐ Located in a seismic isolated building, already on site after the earthquake

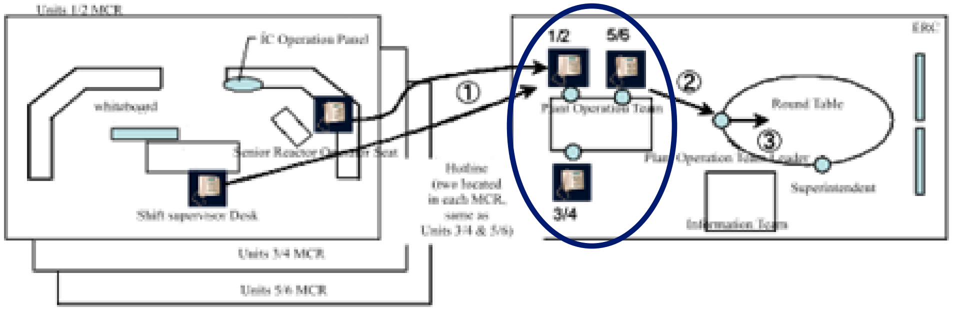
LOCAL TEAMS ORGANISATION

MCR ⇔ ERC PS COMMUNICATION

3 steps chain communication

1) From MCR to ERC PS Operation Team
2) From Op Team to Op Team Leader
3) From Op Team Leader to Site Superintendant and other team leader





MONACOS MODEL FOR THE ERC at PS

CICAs for the ERC at Power Station

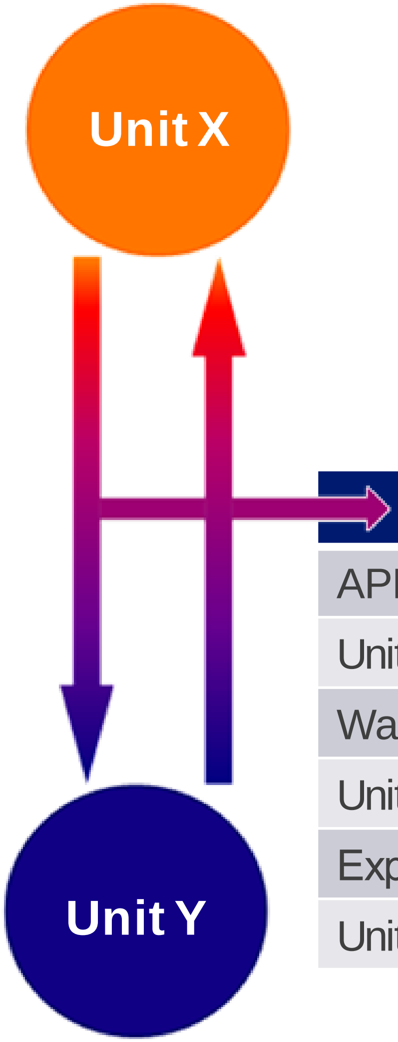
Main points :

- *Different dynamics of the accidents :*
  - ***1*** *: 24 hours before explosion*
  - ***3*** *: 68 hours before explosion*
  - ***2*** *: 87 hours before PCV damages*
- *One specific problem per unit with different priorities :*
  - ***1*** *: IC operation*
  - ***2*** *: PCV Venting*
  - ***3*** *: HP/LP injection switch*
- *Important constraints in the field (explosions, tsunami…)*
  - *Accessibility of equipment locations*
  - *Discontinued field work*
  - *…*
- *Communication and parameters monitoring difficulties*

MULTI-UNIT INTERACTIONS

How can units interact one with another during an accident ?

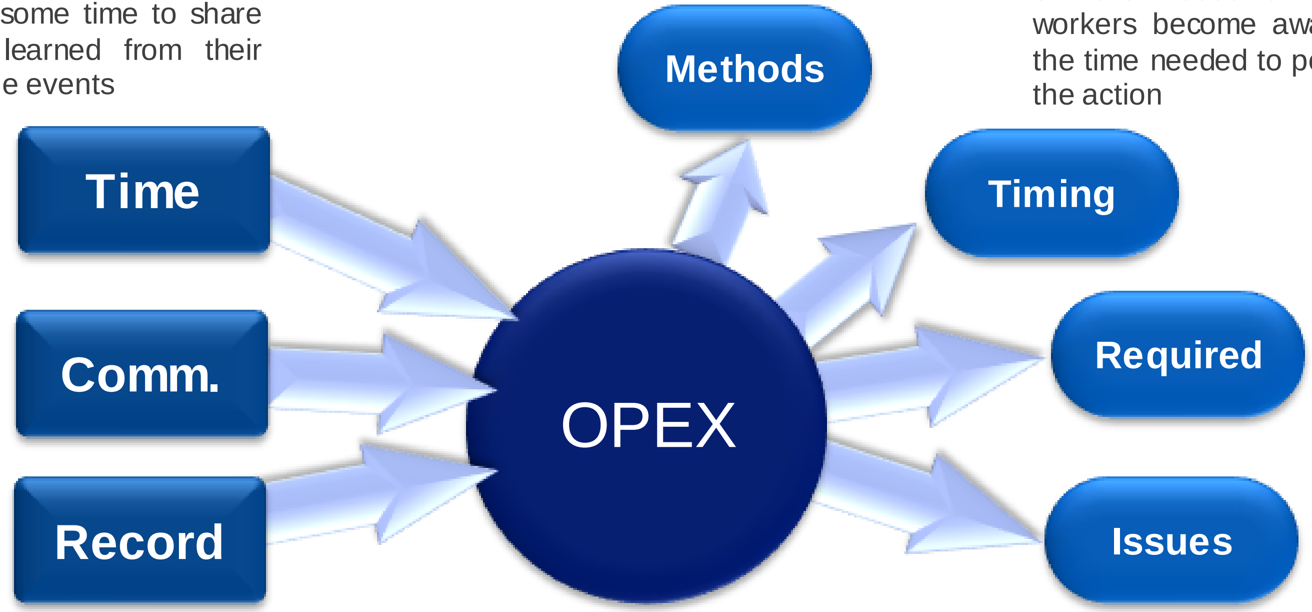
How can units interact one with another during



During
APD used
Unit 2 prioritization at the beginning
Water injection in Unit 1
Unit 3 venting methods applied on Unit 2
Explosions, debris, …
Unit 4 explosion with Unit 3 H_2

Interaction
Equipments (Un)Availability
Staff (Un)Availability
Resources (Un)Availability
Lessons Learned
Work environment modification
Shared circuits

“REAL TIME” LESSONS LEARNED



Teams need some time to share the lessons learned from their actions and the events

Time

Communication means are required between both teams

Comm.

Record

Keeping a communication support (written, audio, drawings, …) is also important for the second team understanding

OPEX

Operating procedures prepared and implemented on SRV opening for Unit 3 were used again on Unit 2 when needed

Methods

After laying power cables or water hoses for a unit, workers become aware of the time needed to perform the action

Timing

After using them on Unit 3, workers know they will need portable air compressors in the field to open SRV on Unit 2

Required

Issues

H_2 explosion on Unit 1 made the ERC conscious of the same risk on the other units of the plant

FIELD WORK IN EXTREME SITUATION

1. Synthesis of difficulties
2. Example
3. Discontinued work

Approximately **1,5km** between Main Control Rooms and the ERC at Power Station. On flat and clear land it takes about **15 minutes** by foot. On the site, the roads were damaged by the earthquake and on slopping ground so the walk would last a bit longer (maybe **20 minutes** ?)

Back and forth from MCR to ERC would take about **40 minutes**, assuming that workers leave as soon as they arrive. In the facts, they had to **confirm their presence** to their team leaders.

Workers often received instruction to evacuate from the field to the ERC at PS, and walk all the way from field to higher ground.

→ This is one of the reasons it takes more than an hour for field checks to start after explosions, alerts, …

WORKING CONDITIONS

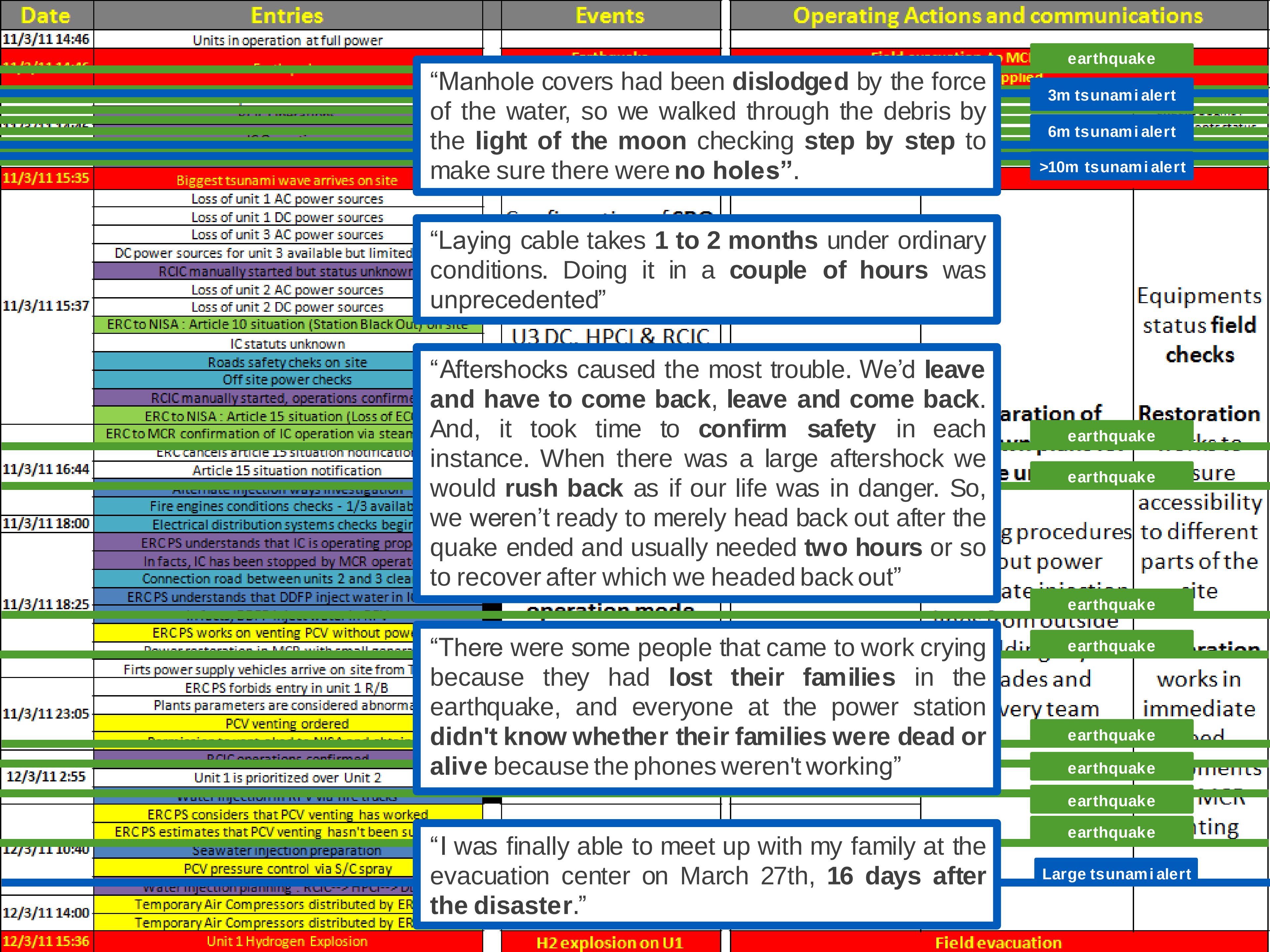
Work in dark places

No means of communication with the ERC at Power Station, Obstacle and debris spread about the field, Shifts needed as work performed wearing protective clothing in high dose environment …

AND

Manhole covers missing underwater

Discontinued work due to aftershocks, tsunami alerts, …



Date	Entries	Events	Operating Actions and communications
11/3/11 14:46	Units in operation at full power		
11/3/11 15:35	Biggest tsunami wave arrives on site		
11/3/11 15:37	Loss of unit 1 AC power sources		Equipments status field checks
	Loss of unit 1 DC power sources		
	Loss of unit 3 AC power sources		
	DC power sources for unit 3 available but limited	U3 DC, HPCI & RCIC	
	RCIC manually started but status unknown		
	Loss of unit 2 AC power sources		
	Loss of unit 2 DC power sources		
	ERC to NISA : Article 10 situation (Station Black Out) on site		
	IC statuts unknown		
	Roads safety cheks on site		
	Off site power checks		
	RCIC manually started, operations confirme		
	ERC to NISA : Article 15 situation (Loss of EC		Restoration
	ERC to MCR confirmation of IC operation via steam		
11/3/11 16:44	ERC cancels article 15 situation notificatio		sure accessibility to different parts of the site
	Article 15 situation notification		
	Alternate injection ways investigation		
	Fire engines conditions checks - 1/3 availab		
11/3/11 18:00	Electrical distribution systems checks begin		
11/3/11 18:25	ERC PS understands that IC is operating prop		
	In facts, IC has been stopped by MCR operat		
	Connection road between units 2 and 3 clea		
	ERC PS understands that DDFP inject water in I	operation mode	
	ERC PS works on venting PCV without powe		
	Firts power supply vehicles arrive on site from T		works in immediate
11/3/11 23:05	ERC PS forbids entry in unit 1 R/B		
	Plants parameters are considered abnorma		
	PCV venting ordered		
	RCIC operations confirmed		
12/3/11 2:55	Unit 1 is prioritized over Unit 2		
	ERC PS considers that PCV venting has worked		
	ERC PS estimates that PCV venting hasn't been su		
	Seawater injection preparation		
	PCV pressure control via S/C spray		
12/3/11 14:00	Temporary Air Compressors distributed by ER		
	Temporary Air Compressors distributed by ER		
12/3/11 15:36	Unit 1 Hydrogen Explosion	H2 explosion on U1	Field evacuation

“Manhole covers had been **dislodged** by the force of the water, so we walked through the debris by the **light of the moon** checking **step by step** to make sure there were **no holes”**.

“Laying cable takes **1 to 2 months** under ordinary conditions. Doing it in a **couple of hours** was unprecedented”

“Aftershocks caused the most trouble. We’d **leave and have to come back**, **leave and come back**. And, it took time to **confirm safety** in each instance. When there was a large aftershock we would **rush back** as if our life was in danger. So, we weren’t ready to merely head back out after the quake ended and usually needed **two hours** or so to recover after which we headed back out”

“There were some people that came to work crying because they had **lost their families** in the earthquake, and everyone at the power station **didn't know whether their families were dead or alive** because the phones weren't working”

“I was finally able to meet up with my family at the evacuation center on March 27th, **16 days after the disaster**.”

earthquake

3m tsunami alert

6m tsunami alert

>10m tsunami alert

earthquake

earthquake

earthquake

earthquake

earthquake

earthquake

earthquake

earthquake

Large tsunami alert

CONCLUSIONS

1. Severe accident management
2. Perspectives

SEVERE ACCIDENT MANAGEMENT

- **Different accidents on each reactor**
- **New issues**
  - Severe accident environment’s impact
  - Multi units interactions
- **Emergency team operation**
- **A very rich feedback**
  - In depth detailed operations’ analysis is very fruitful

PERSPECTIVES

- Clarify unclear points
- Extend the analysis to Units 4, 5 & 6 (work in progress)
- Search for other “site accidents” (Blayais, Oconee, Fukushima Daini,…) to improve the multi unit interactions’ modeling
- Model the organisational resilience
- Insights for HRA

THANK YOU FOR YOUR ATTENTION