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
BIBLIOGRAPHY

- Fukushima Nuclear Accident Analysis Report and Attachments, June 20, 2012 (TEPCO)
- Special Report on the Nuclear Accident at the Fukushima Daiichi Nuclear Power Station, November 2011 (INPO)
- Fukushima Daiichi : ANS Committee Report, March 2012 (American Nuclear Society)
- The official report of the Fukushima Nuclear Accident Independent Investigation Commission, 2012 (The National Diet of Japan)
- Le déroulement de l’accident de Fukushima Daiichi, March 2012 (IRSN)
## MONACOS MODEL FOR UNIT 3

<table>
<thead>
<tr>
<th>Timestamp</th>
<th>Events</th>
<th>Operating Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/03 – 14:46</td>
<td>Earthquake Reactor SCRAM</td>
<td>EOPs applied – Field evacuation to MCR or ERC PS</td>
</tr>
<tr>
<td>11/03 – 14:46</td>
<td></td>
<td>Reactor parameters control via RCIC</td>
</tr>
<tr>
<td>11/03 – 15:35</td>
<td>Tsunami</td>
<td>Reactor parameters control via RCIC</td>
</tr>
<tr>
<td>11/03 – 15:42</td>
<td>Confirmation of tsunami</td>
<td>Reactor parameters control via RCIC</td>
</tr>
<tr>
<td>12/03 – 00:00</td>
<td>Loss of AC sources</td>
<td>Low pressure injection line preparation</td>
</tr>
<tr>
<td>12/03 – 11:36</td>
<td>Automatic shutdown of the RCIC</td>
<td>Manual activation of the HPCI</td>
</tr>
<tr>
<td>12/03 – 15:36</td>
<td>H₂ explosion on Unit 1</td>
<td>P&lt;sub&gt;PCV&lt;/sub&gt; control via S/C then D/W spray</td>
</tr>
<tr>
<td>12/03 – 17:20</td>
<td>P&lt;sub&gt;PCV&lt;/sub&gt; increase because of RCIC &amp; HPCI operation</td>
<td>Venting line preparation</td>
</tr>
<tr>
<td>13/03 – 2:42</td>
<td>P&lt;sub&gt;RPV&lt;/sub&gt; below HPCI operating pressure</td>
<td>HP → LP switch preparation</td>
</tr>
<tr>
<td>13/03 – 3:45</td>
<td></td>
<td>RPV depressurization via SRV attempts</td>
</tr>
<tr>
<td>13/03 – 8:35</td>
<td></td>
<td>LP Injection attempts</td>
</tr>
<tr>
<td>13/03 – 9:08</td>
<td>P&lt;sub&gt;PCV&lt;/sub&gt; high enough for venting</td>
<td>SRV restoration and opening</td>
</tr>
<tr>
<td>13/03 – 9:20</td>
<td>Venting failure</td>
<td>Venting line implementation</td>
</tr>
<tr>
<td>13/03 – 10:40</td>
<td>Core damages</td>
<td>LP injection failure</td>
</tr>
<tr>
<td>13/03 – 13:12</td>
<td>Seawater injection</td>
<td>RCIC or HPCI restart failure</td>
</tr>
<tr>
<td>14/03 – 6:10</td>
<td>Venting confirmed</td>
<td>LP injection attempts</td>
</tr>
<tr>
<td>14/03 – 11:01</td>
<td>H₂ explosion on Unit 3</td>
<td>Venting line valves restoration</td>
</tr>
<tr>
<td>14/03 – 11:01</td>
<td></td>
<td>Temporary air compressors used to maintain valves opened</td>
</tr>
<tr>
<td>15/03 – 00:00</td>
<td></td>
<td>Restoration of long term accident control equipments</td>
</tr>
<tr>
<td>14/03 – 13:05</td>
<td>No cooling</td>
<td>Damaged equipments restoration</td>
</tr>
<tr>
<td>14/03 – 15:30</td>
<td>Cooling ok</td>
<td></td>
</tr>
<tr>
<td>15/03 – 00:00</td>
<td></td>
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</tr>
</tbody>
</table>

**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 = ImportantCharacteristic for Emergency Operations
MULTI UNIT MANAGEMENT

1. Situation at Fukushima Daiichi
2. Unit Interactions Analysis

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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 Superintendent and other team leader
Main points :

- **Different dynamics of the accidents**:
  - 1: 24 hours before explosion
  - 2: 87 hours before PCV damages
  - 3: 68 hours before explosion

- **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?

Unit X

Unit Y

Interaction

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

During:

- APD used on Unit 3
- 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 H₂

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"REAL TIME" LESSONS LEARNED

- **Methods**: Operating procedures prepared and implemented on SRV opening for Unit 3 were used again on Unit 2 when needed.

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

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

- **Issues**: H₂ explosion on Unit 1 made the ERC conscious of the same risk on the other units of the plant.

- **Time**: Teams need some time to share the lessons learned from their actions and the events.

- **Comm.**: Communication means are required between both teams.

- **Record**: Keeping a communication support (written, audio, drawings, ...) is also important for the second team understanding.

- **OPEX**: Communication means are required between both teams.
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, …
“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**.”
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
- 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