The OECD-BSAF Project:

The Spanish Involvement

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BACKGROUND

- ***CIEMAT and CSN closely collaborate on severe accident research.***

- ***A number of issues have been/are being addressed:***

  - *Fission products retention in meltdown SGTR sequences (ARTIST).*
  - *Fuel degradation in SFP under complete LOCA conditions (OECD-SFP).*
  - *Hydrogen distribution in containment (OECD-HYMER).*
  - *In-Containment Source Term (iodine chemistry) (PHEBUS-FP).*
  - *Pool scrubbing (EU-PASSAM).*
  - *Spanish NPP modeling with the MELCOR code.*
  - *Uncertainty analysis in severe accident simulations.*
  - ***The Fukushima accidents analyses (OECD-BSAF)***

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THE OECD-BSAF PROJECT

Unit of Nuclear Safety Research
CSN (Madrid), Jan. 15th, 2015

Overall Description

- ***Restricted-participation project under the frame of the OECD-NEA.***
- ***A 2-year project:*** *Nov. 2012 – 2014.*
- ***Operating agent:*** ***JAEA*** *in collaboration with IAE, JNES, CRIEPI and supported by TEPCO.*
- ***Participant countries:*** *France, Germany, Japan, Rep. Of Korea, Russian Fed., Spain, Switzerland and USA.*

Objectives & Scope

TH analysis of 1F1 – 1F3 Accidentes *(6 d)*

RPV

- *Core degradation*
- *H_2 production*
- *Safety systems performance*
- *…*

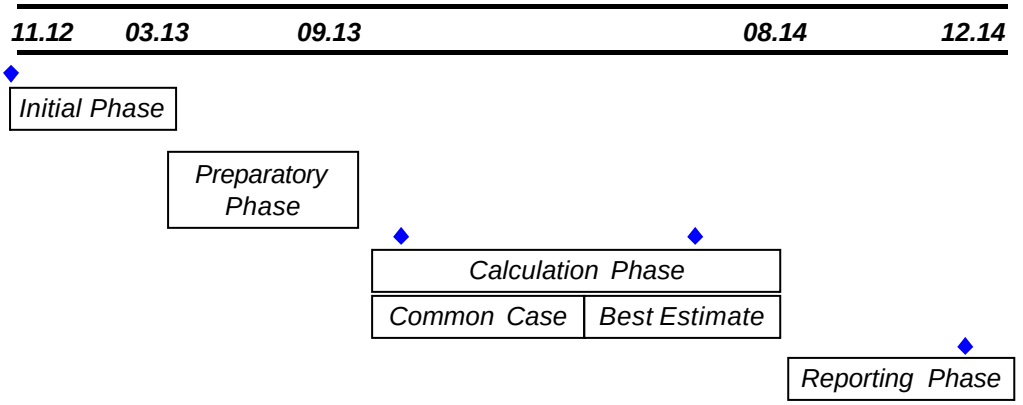
PCV

- *Pressure evolution*
- *H_2 pathways*
- *Pedestal and cavity integrity*
- *…*

Amount & distribution of fuel debris

Decommissioning ***SA Codes Validation***

Project Unfolding



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Current Status

- ***Final reporting OECD-BSAF*** *Jan. – March 2015*
- ***Discussion of OECD-BSAF II*** *Jan. – March 2015*

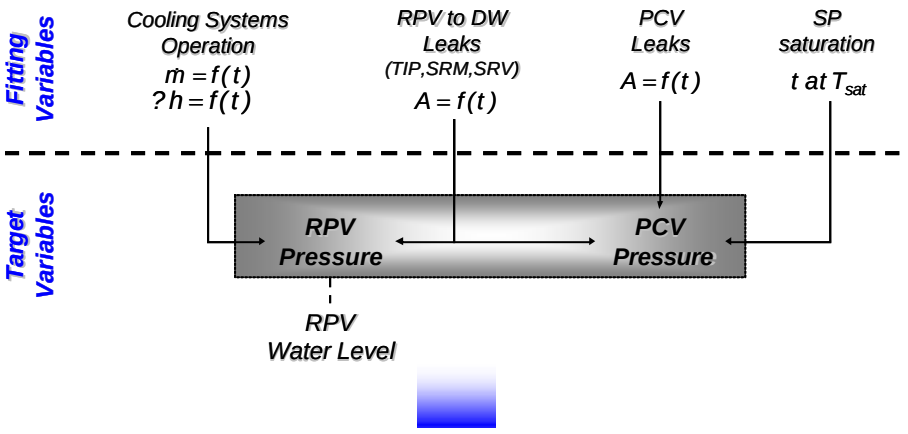
  - *3-year project.*
  - *Technical focus:*

    a. Distribution of FPs and contaminated debris in the units.
    b. Evaluation of source term
    c. Review of OECD-BSAF I modeling

  - *Time span of analyses: 21 days*

THE CSN-CIEMAT CONTRIBUTION

Approach



A number of "feasible" scenarios in each unit

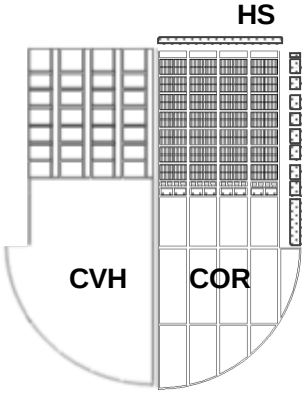
Fundamentals

- **The tool:** **MELCOR 2.1.4803, PC version**

	1F1	1F2	1F3
Simulation time	144 h	144 h	144 h
CPU time	7 h	19 h	16 h

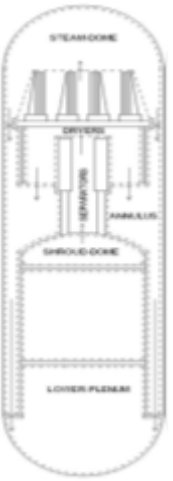
- **Key references:**
  - **IAE, "Common case specifications". Jan 2014**
  - **IAE, "BSAF non-proprietary data". Dec. 2012**
  - **JAEA, "Plant design". March 2013**
  - **"Kick-off meeting releases". Nov. 2012.**
  - TEPCO – "Fukushima nuclear accident analysis report". June 2012
  - SAND2012-6173, "Fukushima Daiichi Accident Study". April 2012.
  - Spanish NPP BWR3-Mark I (1400 MW_{th})

Generic Plant Modeling: RPV Nodalisation

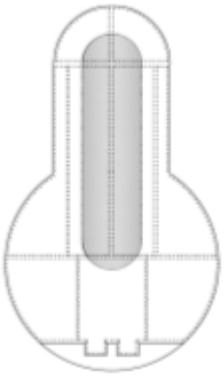


	CORE & LP	Rest of RPV
COR	49	-
CVs	33	5
FLs	40	6

	1F1	1F2	1F3
SRV	4	8	8
SV	3	3	3



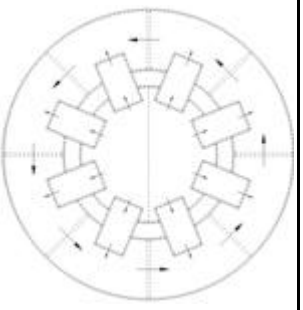
Generic Plant Modeling: PCV Nodalisation



DW **WW**

	DW	WW	Vents	VBs
CVs	9	8	8	-
FLs	16	8	8	8

Volume	1F1	1F2	1F3
DW (m^3)	3000	3770	3770
WW (m^3) (pool)	4370 (1750)	6140 (2980)	6140 (2980)



RB

Boundary Conditions

		1F1	1F2	1F3
Power [MW_{th}]		1380	2381	2381
Systems	IC	☑	-	-
	RCIC	-	☑	☑
	HPCI	-	-	☑
	SRV	☑ (4; 1 on)	☑ (8; 1 on)	☑ (8; 1 on)
	$Sprays_{PCV}$	-	☑	☑
Venting		☑ (1)	-	☑ (6)
External Water Injection		☑	☑	☑
Torus Room		Dry	Flooded	Dry

Systems Modeling

- ***Systems (IC, RCIC, HPCI):*** *Modeled "to effect" (i.e. source/sink)*
- ***Systems (SRV):*** *Nominal setpoints*
  - *Relief mode bf. SBO*
  - *Safety mode af. SBO*
- ***RPV leakages:*** *Best fit*
- ***PCV leakages:*** *Best fit*
- ***PCV ventings:*** *Best fit (t [s] & A [m^2])*
- ***External water injections:*** *Best fit (t [s] & m [kg/s])*

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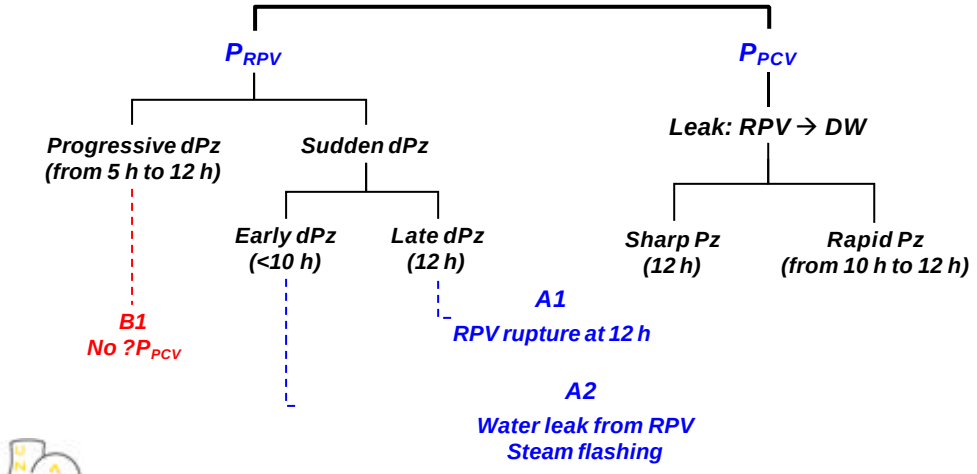
Phenomena-Related Approximations

- *Default values in Flow Paths definition.*
- *No specific model for eutectic formation.*
- *Simplified B_4C oxidation model.*
- *One-layer model for molten material in cavity.*
- *The recirculation loop not modeled.*
- *HPCI & RCIC exhaust modeled as sources in the WW pool (h_{steam}).*

Strategy of Pre-Analysis



Matrix of Scenarios

RPV failure										
Type	SRV_{gasket}		$CORE_{SRM/IRM/TIP}$			LP_{leak}		$SRV_{failedOpen}$		
Fail	N	Y	N	1-Ring	4-Rings	N	Y	N	Y	
1		☑	☑			☑		☑		A1
2		☑		☑		☑		☑		
3		☑			☑	☑		☑		
4		☑	☑				☑	☑		A2
5	☑		☑				☑	☑		
6	☑		☑			☑			☑	
7	☑		☑			☑		☑		

Specific Approximations

RPV:

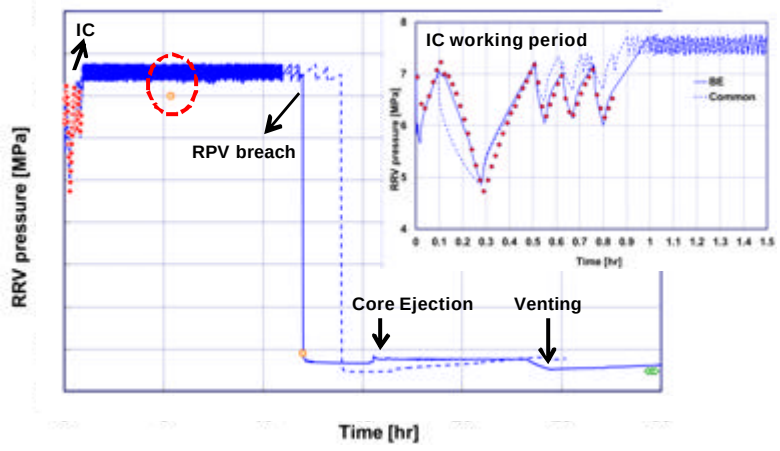
IC	*Energy sink in dome*	*BE: adjusted to follow P_{RPV}*
Water inj.	*Source to downcomer*	*BE: adjusted to follow P_{PCV}*
SRVs	*Relief mode (bf. SBO)* *Safety mode (af. SBO)*	*P_{open} / P_{close} : 7.38/ 7.01 MPa* *P_{open} / P_{close} : 7.75/ 7.36 MPa*
"RPV Leaks"	*From RPV to DW (SRV gasket)*	*BE: T> 723 K ; A=32.6·10^{-4} m^2*

PCV:

Venting	*WW → Environment*	*BE: t = 23.2 – 24.4 h; A=0.016 · A_{tot}* *t > 24.4 h; A* = 0.14 – 0.02·A_{tot}*
DW flange failure	*DW → Environment*	*BE: P > 0.75 MPa; A=f(P)*

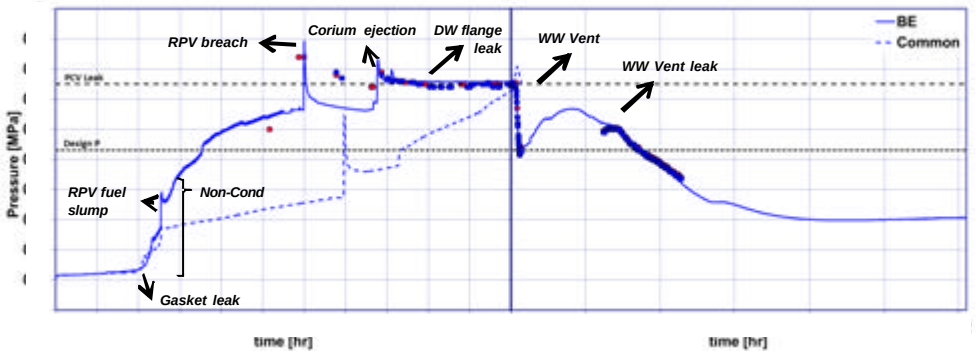
Results (I)

RPV Pressure



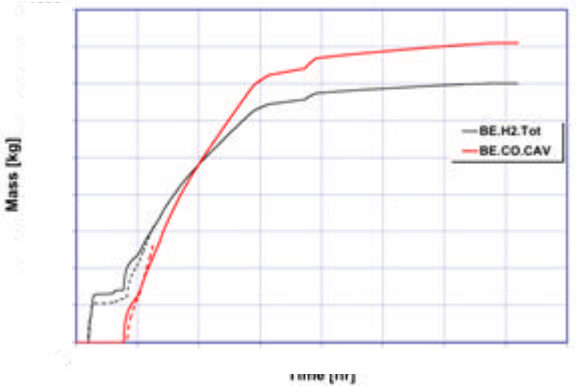
Results (II)

PCV Pressure



Results (III)

H_2 & CO Generation



Results (IV)

Mass Distribution

"Best Estimate" — *Solid color columns*

"Common Case" — *Stripped color columns*

The Color code

	(Zr/SS Oxides)
Intact mass	
Degraded in-core	
Degraded in-LP	
Ejected mass	

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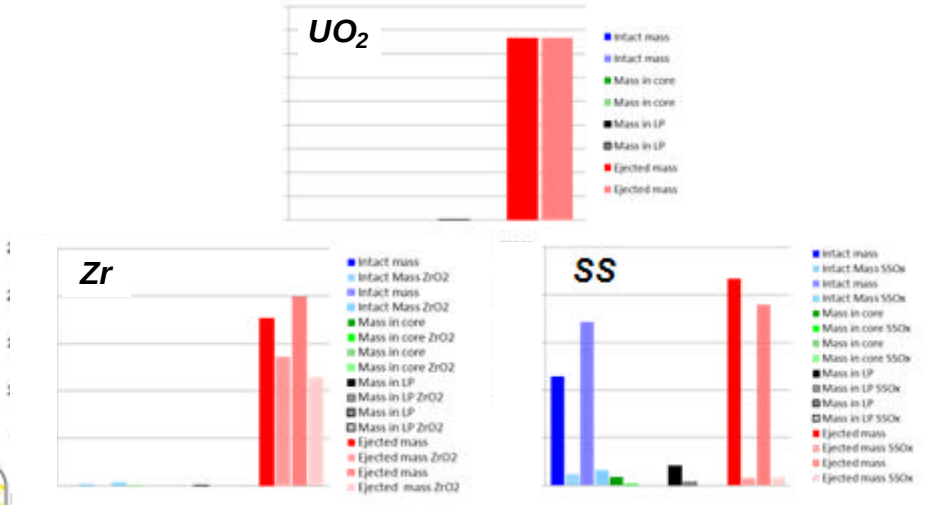
Results (IV)



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Major Insights

- ***Final status of 1F1:***
  - *Massive core degradation.*
  - *RPV failed in the first 12 h.*
  - *Most core materials slumped into the cavity.*
  - *More than 7000 kg of H_2 & CO (most from MCCI).*
- ***Detailed evolution of 1F1 highly uncertain! – No proper BE***
  - *RPV and PCV data inconclusive.*
  - *Multiple RPV scenarios feasible.*
  - *Suppression pool thermal stratification might play a role.*

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- ***"BE cases" is probably not the right way to call them!***
- ***"BE scenarios" are highly uncertain.***
  - *Boundary conditions ? Scarcity of data to set cross-correlations.*
  - *Modeling (physical & scenarios) ? Enhancement indispensable!*
- ***Major modeling uncertainties come from:***
  - *Cavity modeling (1F1).*
  - *Containment modeling (i.e., SC nodalization)*

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- ***"BE Scenarios" vs. "Common Case":***
  - *Consistency in major accident signatures.*
  - *Substantial differences in some variables unfolding.*
- ***"BE Insights":***

  1F1 - Core massively degraded and poured into PCV cavity. More than 7000 kg of H_2 + CO generated. Potential for liner failure.

  1F2 - Half of the core in LP; no RPV failure predicted. About 600 kg of H_2 generated.

  1F3 - Half of the core relocated in LP; no RPV failure. More than 1000 kg of H_2 generated.

- ***Refined "BE cases" being calculated.***

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Thank you for your attention!

Any questions?

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