The Effect of Fukushima on Research Activities in CIEMAT related to Severe Accidents

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OUTLINE

- ***BACKGROUND***
- ***OBJECTIVE & SCOPE***
- ***OVERVIEW of ACTIVITIES***
- ***THE EU-PASSAM PROJECT***
- ***THE OECD-BSAF PROJECT***
- ***FINAL REMARKS***

BACKGROUND

The Fukushima-1 Accident

A new way to "look at" severe accidents !!

Specific Issues

H_2 mitigation

Source term mitigation

A huge dataset

Analytical tools assessment

(strengths & weaknesses)

OBJECTIVE & SCOPE

Objectives

- *To describe major research activities in CIEMAT resulting from the accident.*
- *To briefly sum up some on-going international projects.*

Scope

- *Restricted to the Unit on Nuclear Safety Research (15 people; 11 scientists).*
- *Restricted to activities directly-related to severe accidents.*

OVERVIEW of ACTIVITIES

- *Modeling the Spanish BWR3 Mark-I → Updating (MELCOR 2.1) and upgrading*
- *H_2 distribution studies (stratification break-up) → 3D simulations of HYMERES tests*
- *Generic modeling Mark-I containments → ASTEC input deck build-up (CESAM)*
- *Simulation of pool scrubbing tests → SPARC-B (ASTEC) assessment (CESAM)*
- *Simulation of SFP fire tests → Out-of-reactor application of ASTEC (CESAM)*
- *Experimentation on pool scrubbing → Measurement of pool DFs (PASSAM)*
- *Experimentation on mitigation → Acoustic agglomeration efficiency (PASSAM)*
- *Modeling the Fukushima accidents → MELCOR 2.1 analyses of units 1-3 (BSAF)*

THE EU-PASSAM PROJECT

Key Project Features

- ***Duration:*** *January 2013 – December 2016*
- ***Effort:*** *390 person-month (≅ 9 researchers/year x 4 years)*
- ***Total Cost:*** *5.1 M€*
- ***Project nature:*** *Experimental (74% of the effort on testing)*
- ***Partners:*** *IRSN; CIEMAT; CSIC; EDF; PSI; RSE; VTT; AREVA; U. Lorraine*

Objectives

- ***Explore potential enhancement of existing source term mitigation devices.***
  - *Aqueous ponds.*
  - *Sand bed filter (metallic pre-filters) source term attenuations.*

- ***Demonstrate the ability of innovative systems to achieve even larger source term attenuations.***

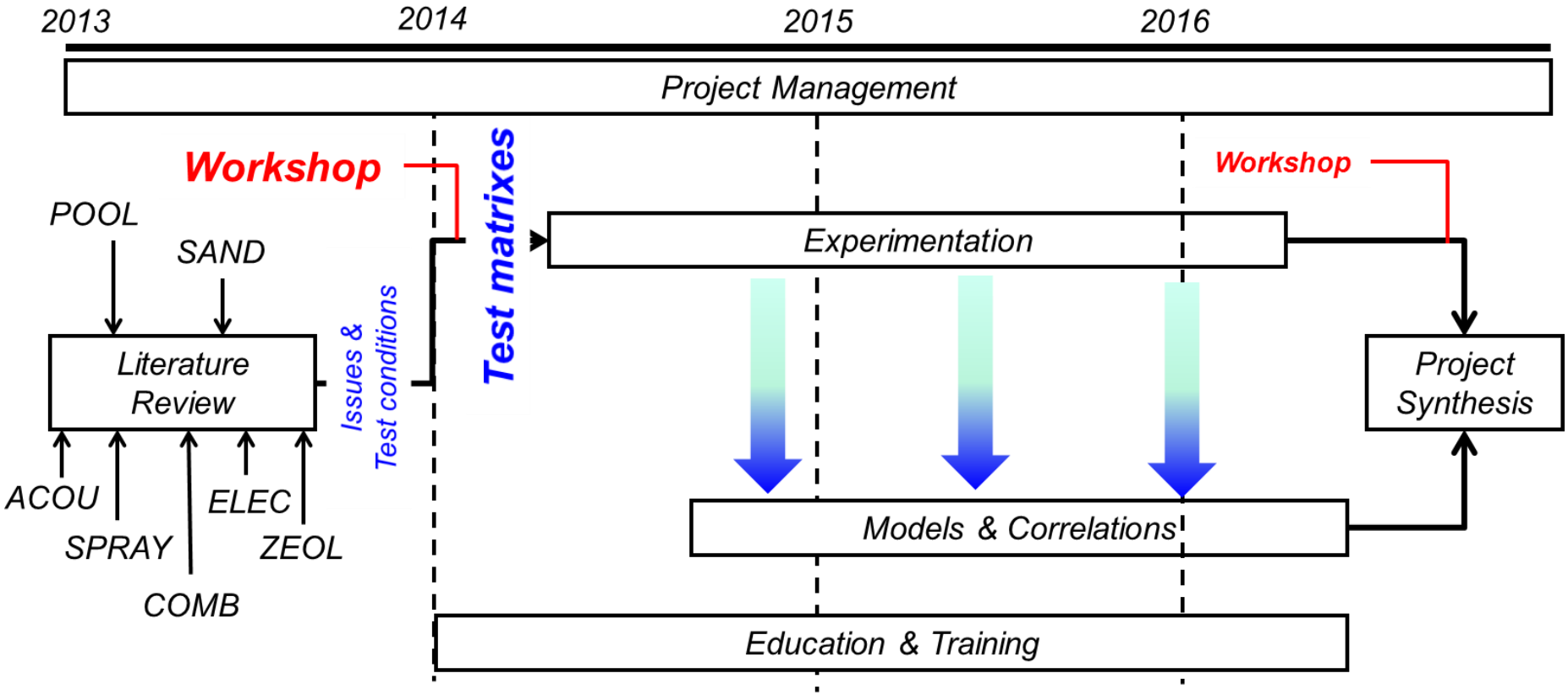
Preconditioning stage

- *Acoustic agglomerators.*
- *High pressure sprays.*

Filtering stage

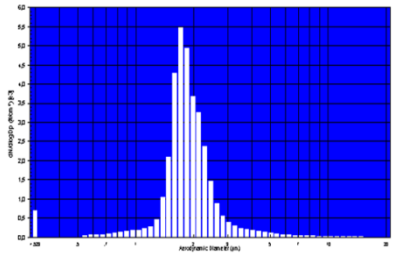
- *Electrostatic filters.*
- *Improved zeolites.*
- *Dry & wet combined filters.*

Planning



← ***ACOU*** → ← ***POOL*** →

The ACOU Tests: The PECA-AAA Facility



Particle size characterization inlet

Particle generation

Stainless steel vessel (~ 8 m³)

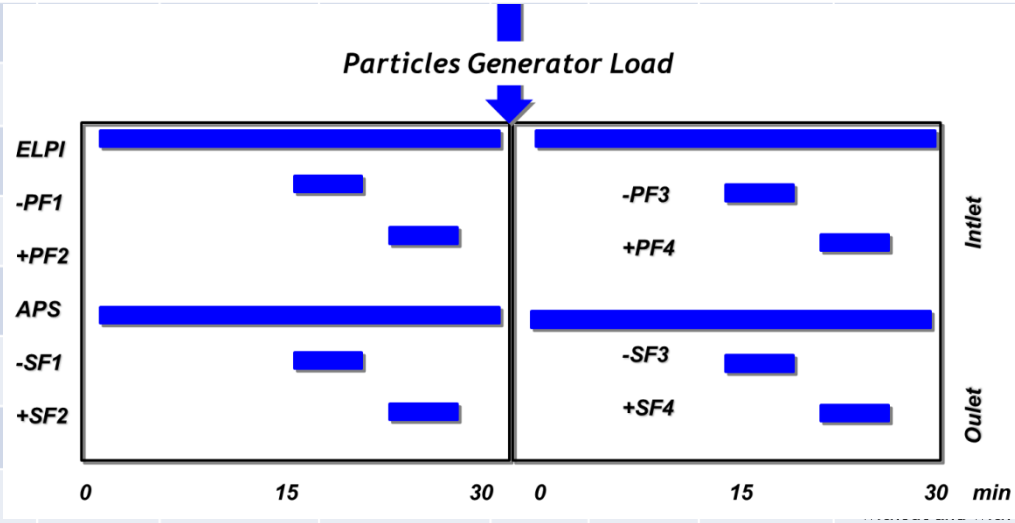
Particle size characterization outlet

The Acoustic Chamber ***(CSIC)***

The ACOU Tests: Experimental Matrix

Test	US Frequency (kHz)	Power Applied (W)	Gas Composition	Temperature (°C)	v_{gas} (m/s)	$C_{aerosol}$ (g/Nm^3)	d_{part} (µm)	Remarks
T01	21	300	Air	T_{room}	0	0.1-1	~0.1	Static test without and with ultrasonic field
T02	21	300	Air	T_{room}	0	0.1-1	~1	Static test without and with ultrasonic field
T1	21	300	Air	T_{room}	0.05	0.01	~0.1	High gas velocity/High concentration (hgv1) without and with ultrasonic field
T2	21	300	Air	T_{room}	0.05	<0.01	~0.1	High gas velocity/Low Concentration (hgv2) without and with ultrasonic field
T3	21	300	Air	T_{room}	0.025	0.02	~0.1	Low gas velocity/high concentration (lgv1) without and with ultrasonic field
T4	21	300	Air	T_{room}	0.025	<0.02	~0.1	Low gas velocity/Low Concentration (lgv2) without and with ultrasonic field
T5	21	300	Air	T_{room}	0.05	<0.01	~1	Particle size effect (hgvp1) without and with ultrasonic field
T6	21	300	Air	T_{room}	0.025	<0.02	~1	Particle size effect (lgvp1) without and with ultrasonic field
T7	21	300	Air	T_{room}	0.05	0.01	~1	Particle size effect (hgvp2) without and with ultrasonic field
T8	21	300	Air	T_{room}	0.025	0.02	~1	Particle size effect (hgvp2) without and with ultrasonic field
T9	21	300	Air	T_{room}	0.05	<0.01	~0.1	Relative humidity effect (hgvrh1) without and with ultrasonic field
T10	21	300	Air	T_{room}	0.05	0.01	~1	Relative humidity effect (hgvrh2) without and with ultrasonic field
T11	21	300	Air					Reproducibility test - TBD without and with ultrasonic field
T12	21	300	Air					Reproducibility test - TBD without and with ultrasonic field

The ACOU Tests: Experimental Matrix



Test	US Frequency (kHz)	Power Applied (W)	Gas Composition	Temperature (°C)	v_{gas} (m/s)	$C_{aerosol}$ (g/Nm^3)	d_{part} (µm)	Remarks
T01	21							st trasonic field
T02	21							st trasonic field
T1	21							ty/High (hgv1) trasonic field
T2	21							ty/Low (hgv2) trasonic field
T3	21							concentration trasonic field
T4	21							Concentration trasonic field
T5	21							ct (hgvp1) trasonic field
T6	21							ct (lgvp1) trasonic field
T7	21	300	Air	T_{room}	0.05	0.01	~1	Particle size effect (hgvp2) without and with ultrasonic field
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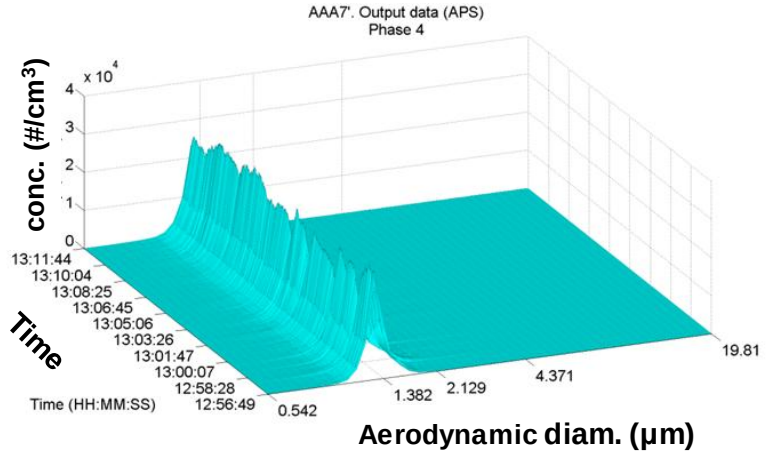
T11	21	300	Air					Reproducibility test - TBD without and with ultrasonic field
T12	21	300	Air					Reproducibility test - TBD without and with ultrasonic field

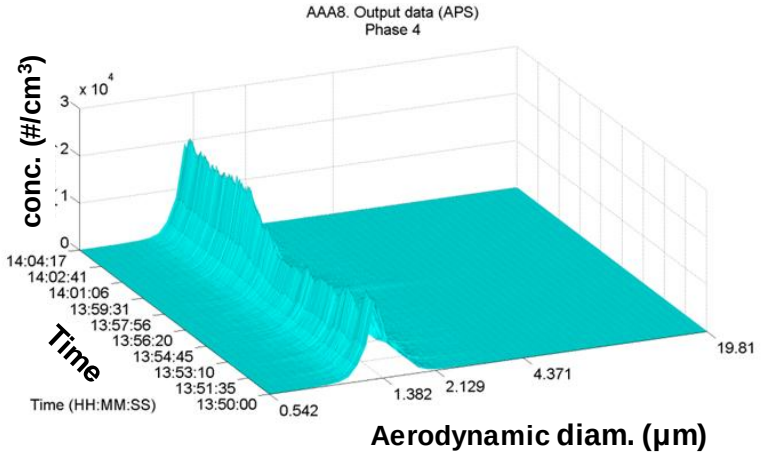
The ACOU Tests: *Preliminary Results*

Mass distribution

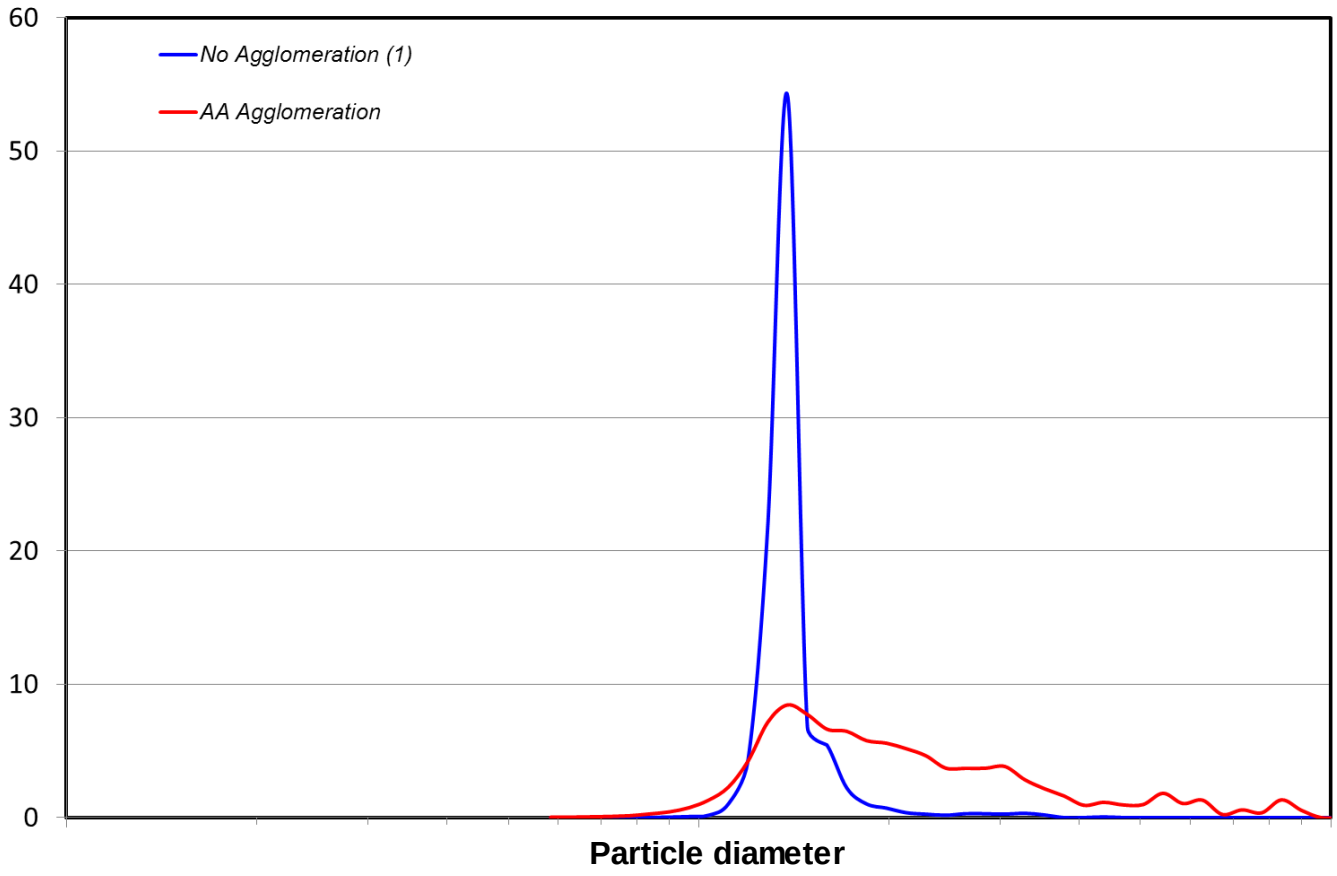
Time	Experiment	Phase	US	Input Mass (mg)	Input air flow (l/min)	Output Mass (mg)	Output air flow (l/min)	Corrected Ouput (mg)	Mass Retention Increase (%)
10:33	T7´	1	No	3,950	35	4,200	29,1	5,052	38,5
10:41	T7´	2	Yes	4,550	35	3,450	29,7	4,066	
12:10	T7´	3	No	5,500	35	4,550	29,3	5,435	44,7
12:19	T7´	4	Yes	28,000	35	12,900	29,8	15,151	
10:49	T8	1	No	6,100	35	4,900	28,6	5,997	28,8
10:57	T8	2	Yes	7,300	35	4,250	29,3	5,077	
12:31	T8	3	No	9,750	35	8,100	28,5	9,947	40,7
12:39	T8	4	Yes	11,550	35	5,950	29,4	7,083	

Outlet Particle Size





The ACOU Tests: *Anticipated Results*



THE OECD-BSAF PROJECT

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

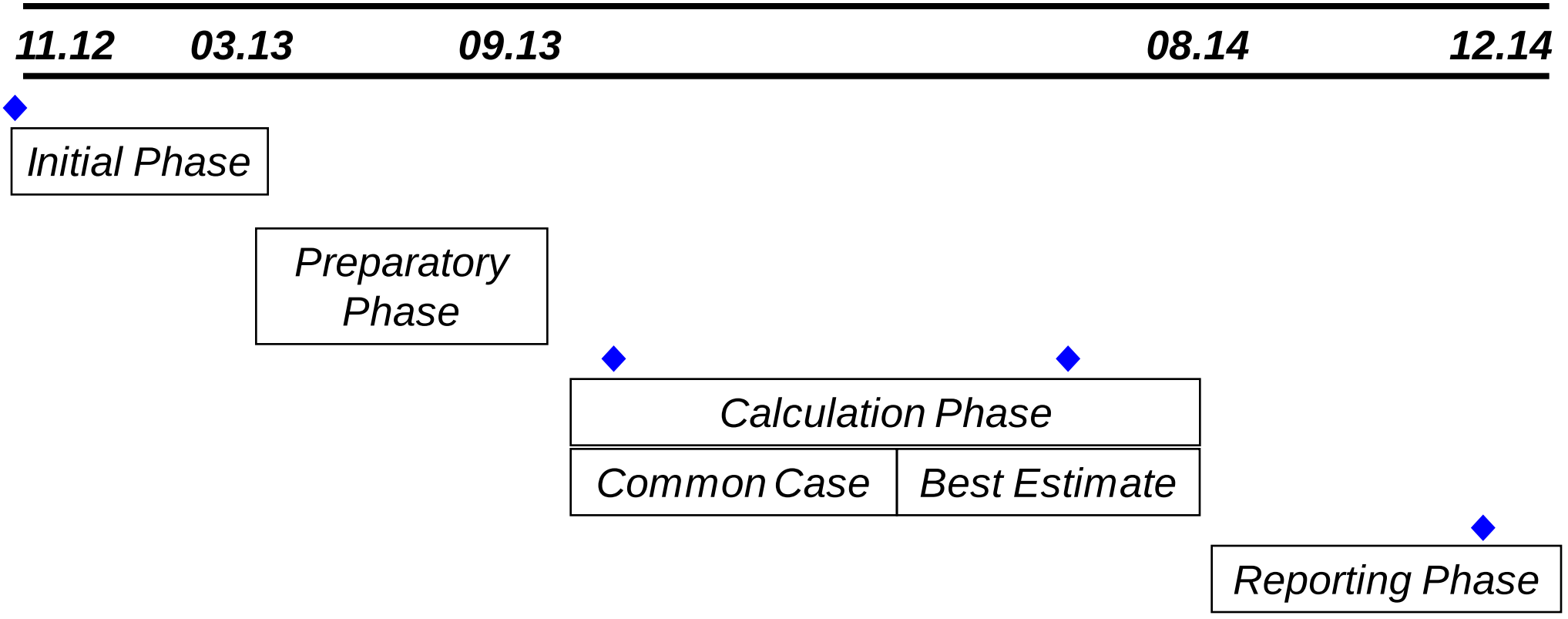
- *Pressure evolution*
- *H_2 pathways*
- *Pedestal and cavity integrity*
- *…*

Amount & distribution of fuel debris

Decommissioning

SA Codes Validation

Project Unfolding



Current Status

- ***Final reporting OECD-BSAF*** *Jan. – March 2015*

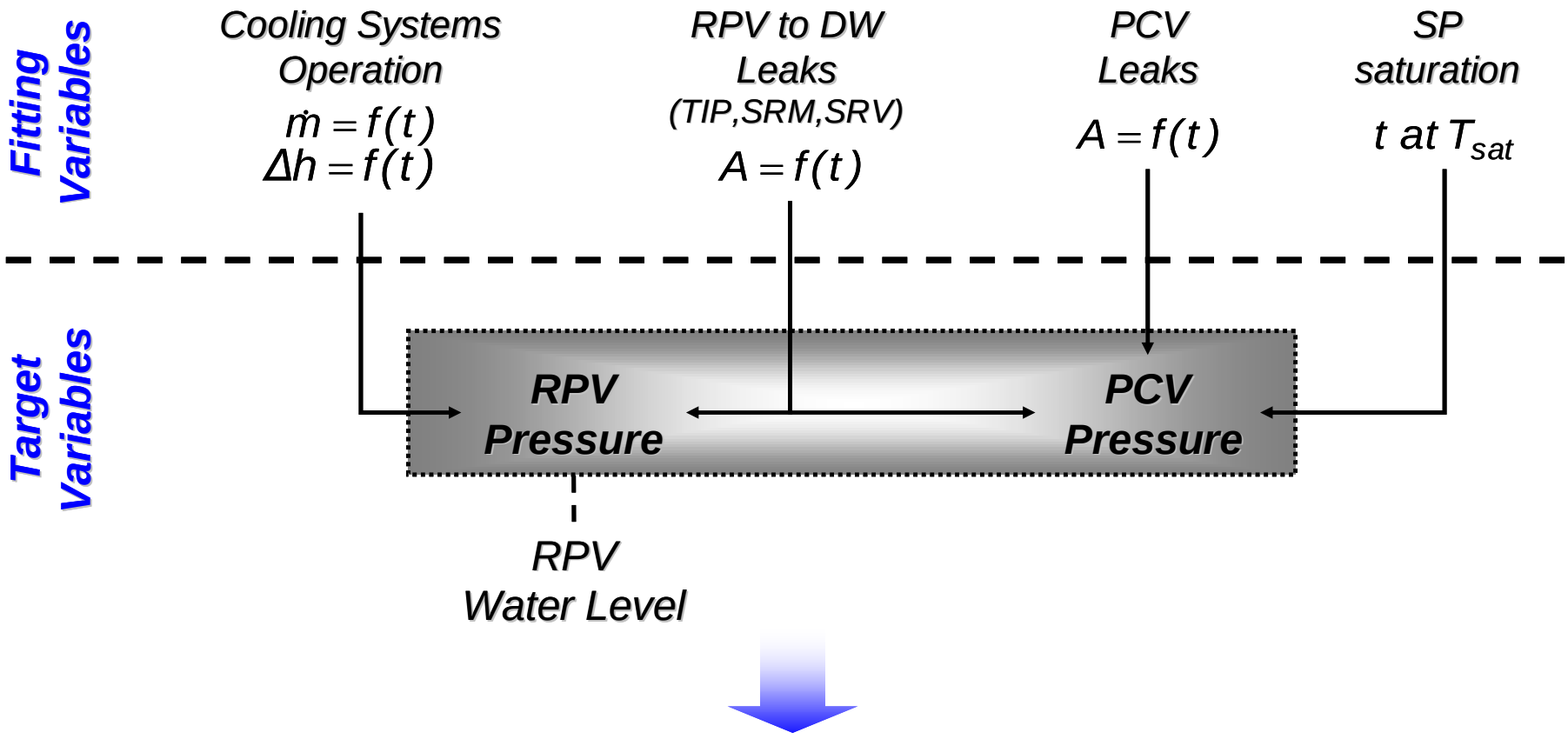
- ***Discussion of OECD-BSAF II*** *Jan. – March 2015*

  - *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

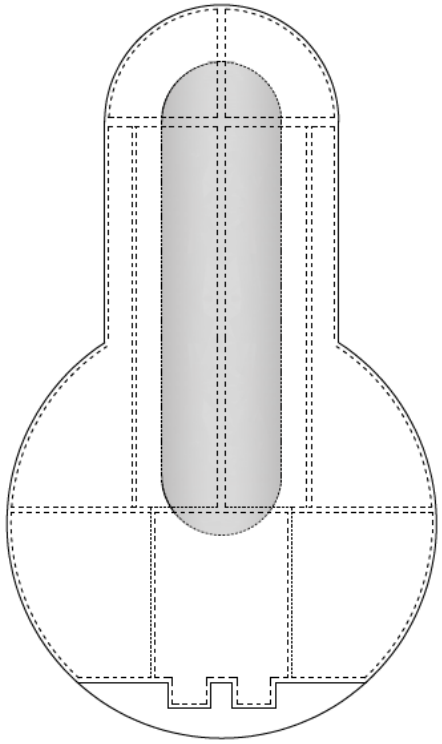
  - *Time span of analyses: 21 days*

CIEMAT Overall Approach



A number of "feasible" scenarios in each unit

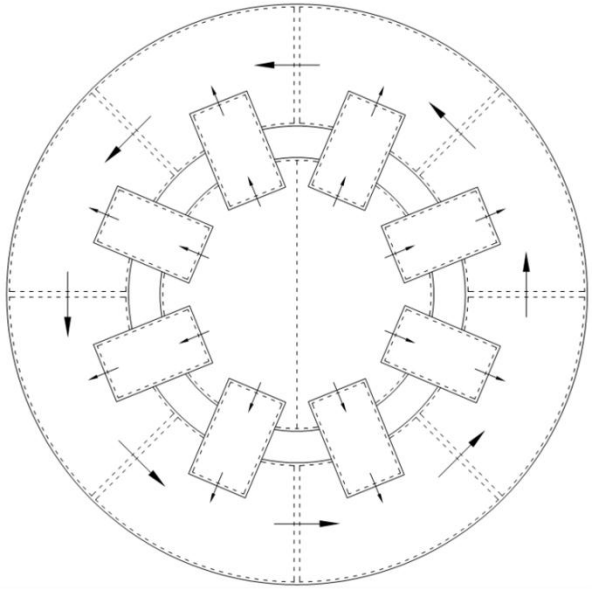
Generic Plant Modeling: PCV Nodalisation



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

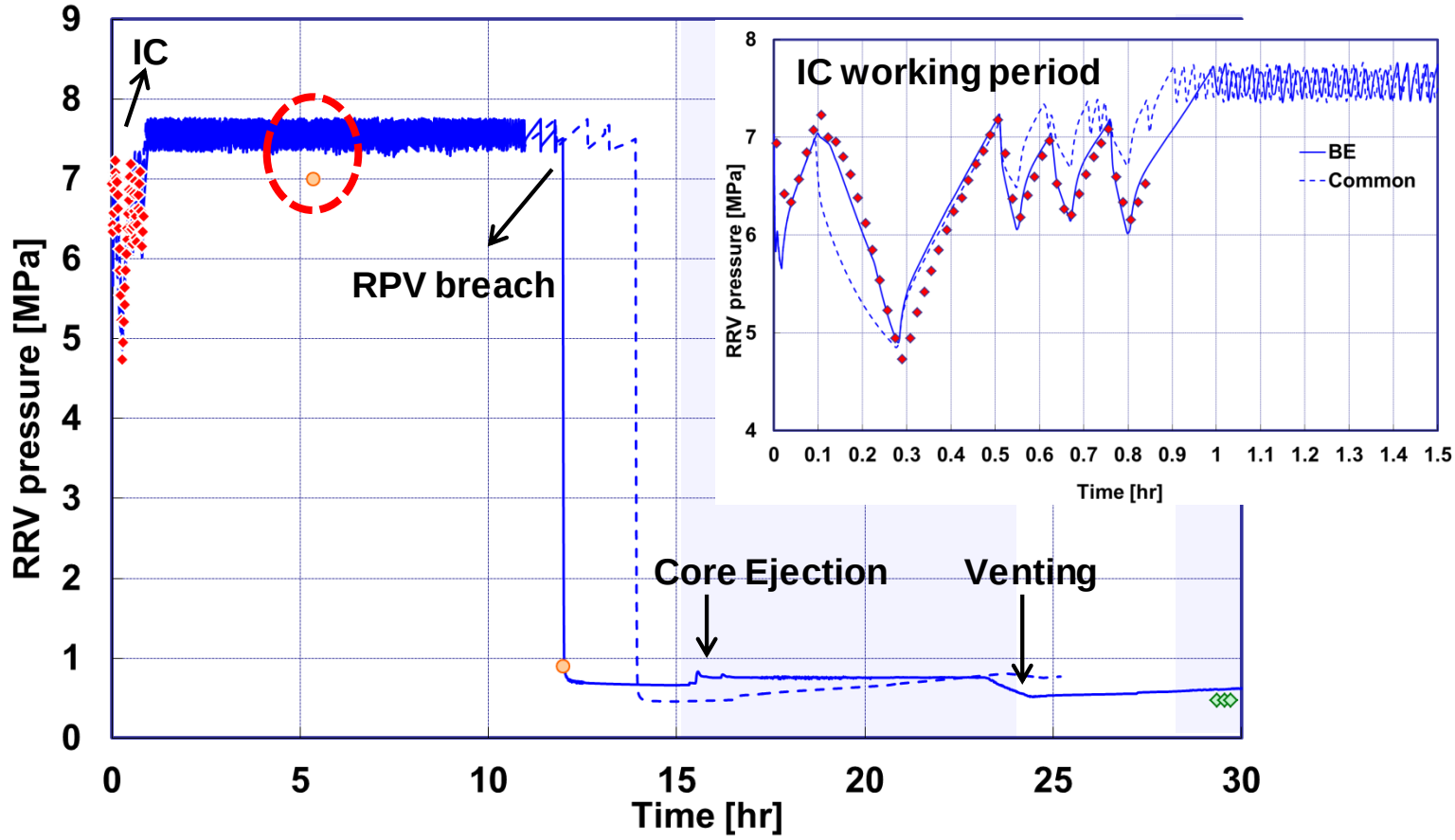
		1F1	1F2	1F3
Power [MW_{th}]		1380	2381	2381
Systems	IC	☑	–	–
	RCIC	–	☑	☑
	HPCI	–	–	☑
	SRV	☑ (4; 1 on)	☑ (8; 1 on)	☑ (8; 1 on)
	$Sprays_{PCV}$	–	☑	☑
Venting		☑ (1)	–	☑ (6)
External Water Injection		☑	☑	☑
Torus Room		Dry	Flooded	Dry

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])*

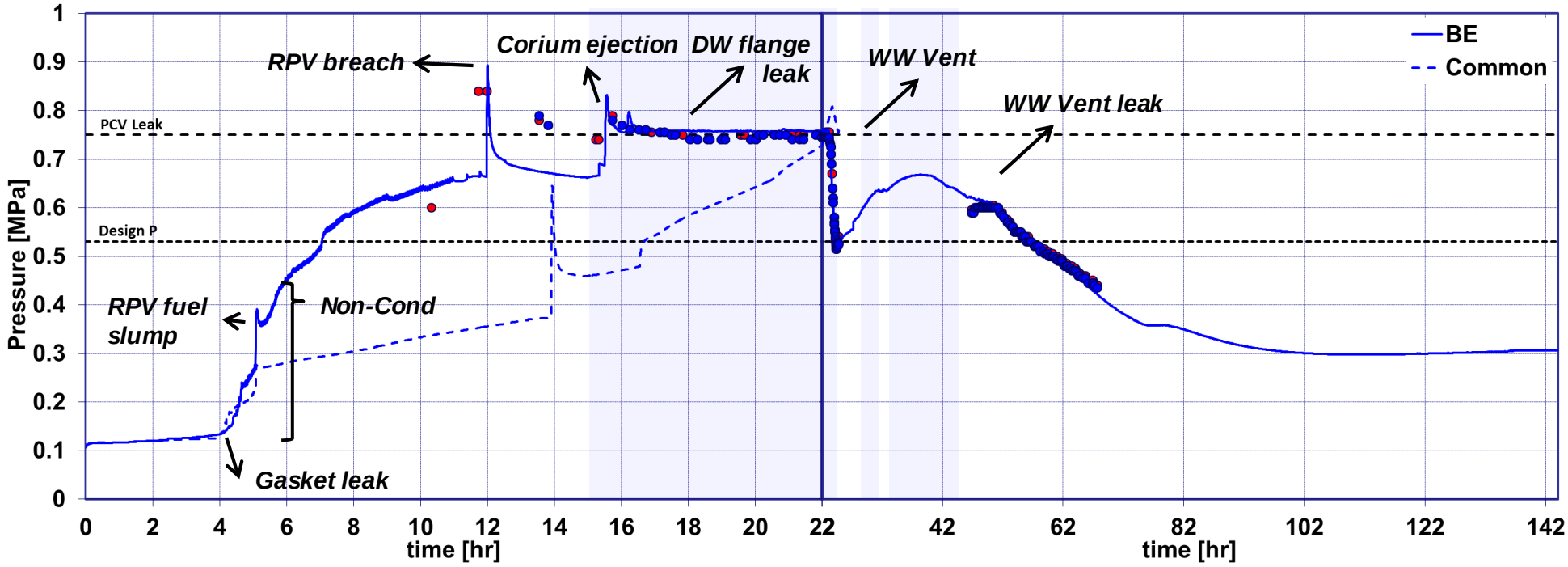
Results (I): Unit 1

RPV Pressure

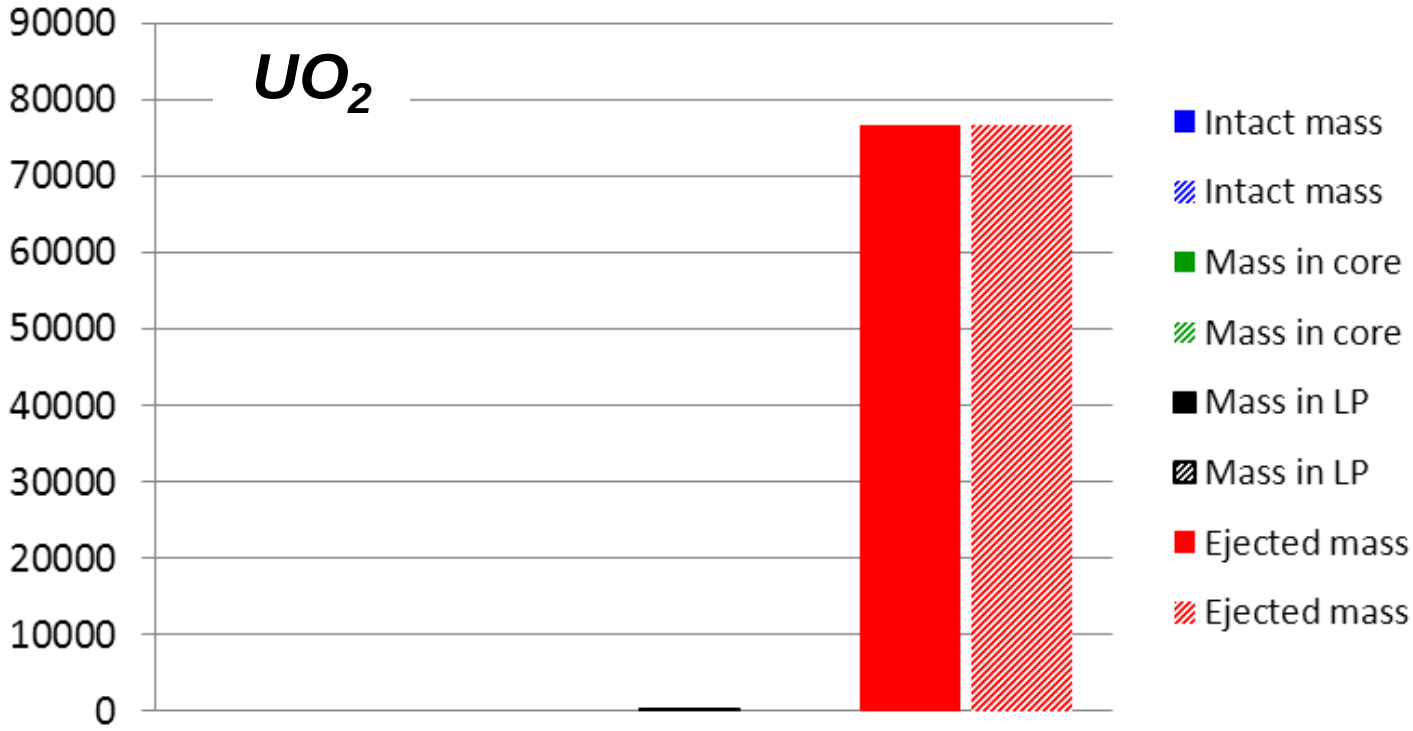


Results (II): Unit 1

PCV Pressure



Results (III): Unit 1



Preliminary 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.

FINAL REMARKS

- *Upon the Fukushima accident,* ***CIEMAT fitted its research on severe accidents according to major international trends.***
  Additionally, CIEMAT has kept its own domestic activities.

- ***Experimental and analytical Fukushima-related research*** *has been conducted since.*

- *Major Fukushima-related research focus on****: Source Term mitigation and forensic accidents analysis.***

- *Within EU-PASSAM contribution is being made to database on* ***pool scrubbing under jet injection and particle growth by acoustic fields.***

- *Within OECD-BSAF,* ***potential accident scenarios are being proposed****; nevertheless, these analyses are far from being the finals.*

Thank you for your attention!

Any questions?

Acknowledgments to EU and CSN
who provided financial support for the work here presented.