STATUS OF THE UNCERTAINTY QUANTIFICATION FOR SEVERE ACCIDENT SEQUENCES OF DIFFERENT NPP-DESIGNS IN THE FRAME OF THE H-2020 PROJECT MUSA

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ABSTRACT

The current HORIZON-2020 project on "Management and Uncertainties of Severe Accidents (MUSA)" aims at applying Uncertainty Quantification (UQ) in the modelling of Severe Accidents (SA), particularly in predicting the radiological source term of mitigated and unmitigated accident scenarios. Within its application part, the project is devoted to the uncertainty quantification of different severe accident codes when predicting the radiological source term of selected severe accident sequences of different nuclear power plant designs e.g. PWR, VVER, and BWR.

Key steps for this investigation are: a) the selection of severe accident sequences for each reactor design; b) the development of a reference input model for the specific design and SA-code; c) the selection of a list of uncertain model parameters to be investigated; d) the choice of an UQ-tool e.g. DAKOTA, SUSA, URANIE, etc.; e) the definition of the figures of merit for the UQ-analysis; f) the performance of the simulations with the SA-codes; and, g) the statistical evaluation of the results using the capabilities, i.e. methods and tools offered by the UQ-tools.

This paper describes the project status of the UQ of different SA codes for the selected SA sequences, and the technical challenges and lessons learnt from the preparatory and exploratory investigations performed.

KEYWORDS
Severe accident, modelling, uncertainty quantification, MUSA, source term

1. INTRODUCTION

Recalling the maturity of Severe Accident (SA) codes in terms of phenomena addressed and extensive validation conducted, the H-2020 4-year-project MUSA has been set up to explore uncertainty quantification in the SA domain including accident management (AM) actions [1]. In [2], an Uncertainty Quantification (UQ) approach is compared to conservative methods for the prediction of potential radiological off-site consequences after SAs in different reactor types. [3] introduces uncertainty propagation in the SA context, applying it to thermal-hydraulic phenomena in Reactor Cooling System (RCS) and containment.

The expectable gains from UQ are manifold: in addition to reducing conservatism and getting an idea of uncertainty bands of estimates (Figures of Merit, FoM), it allows the identification of most relevant parameters (input, models, initial and boundary conditions) impacting the prediction of the FoM of interest in a systematic manner. Moreover, the impact of SA Management (SAM) actions (e.g., time of initiation, location, delays, injection rates, pressure set-points) on uncertainty bands and FoM can be quantified.

The overall goal of MUSA is to quantify the uncertainty and sensitivities embedded in different SA codes when predicting the radiological Source Term (ST) for the SA sequences of different NPP designs using various UQ tools. The fact that almost half of the partners are from non-EU countries underlines the large interest in cooperating in this field. The technical work in the project is structured into (i) two preparatory Work Packages (WP) addressing the quantification of uncertainty sources (WP2) and reviewing uncertainty methodology (WP3), and (ii) three application WPs featuring an integral experiment, Phebus FPT1 [4, 5] (WP4), different reactor designs selected by the partners (WP5), and a Spent Fuel Pool (WP6).

This paper describes the status of work in the reactor applications WP, at 30 months into the project. It starts off by describing the organisation of the WP, the choices made by partners for their contributions, and how analyses in the first phase have been set up. It then discusses the results of the first "preliminary" phase of the analyses, i.e. the most important challenges that have been encountered during the setting up and running of the first UQ applications. This is the foundation for progressing to the project stage that is described in the outlook.

2. DESCRIPTION, AND STATUS, OF WORK ON REACTOR APPLICATIONS

WP5 is the largest WP in MUSA, taking contributions from 27 partner organisations and about 30% of the total human resources. It is built on output from MUSA WP2 and WP3, and is greatly supported by experience gained in WP4. Given this interrelation, WP5 started later than these three WPs. Towards the end of MUSA, it is foreseen that experience gained in WP5 will be fed back to WPs 2 and 3.

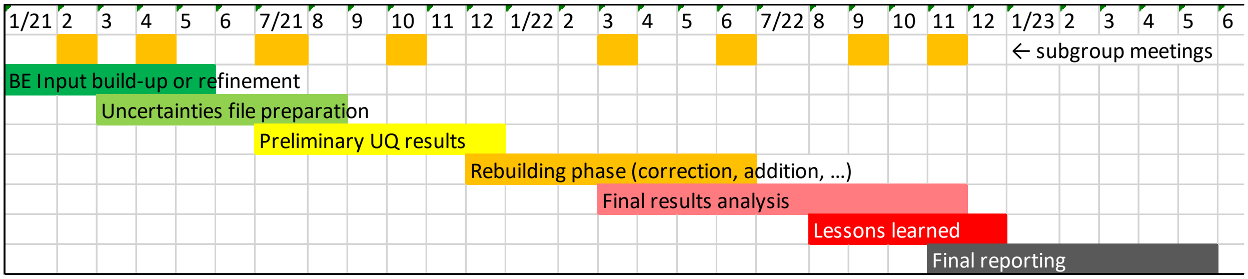

Figure 1 WP5 work phases from January 2021 to the end of MUSA [months].

For a better exchange, partners in WP5 are divided into 4 subgroups according to the reactor type they are investigating: PWR Gen. III (5 partners), PWR Gen. II (10), VVER plus CANDU (6), and BWR (6). **Table II** shows the group make-up in detail.

Figure 1 indicates that 4 subgroup meetings are organised per year where partners present their work and discuss within the group. One of the meetings in 2021 was organised as a plenum meeting with presentations of WP2, 3 and 4 outputs and of US-American ST studies and the state of the art [2].

Figure 1 also highlights the phases that have been proposed for partners' work. Knowing that many partners had to build up their capability for Uncertainty Analysis (UA) in SA modelling, work was initially focussed on a best-estimate base case. The second phase, "uncertainties file preparation", concerns coupling SA codes and Uncertainty Tools (UTs) and creating all files required for the UQ. This step benefitted greatly from work done in WP4, where 21 of the partner organisations have been involved. The third and still ongoing phase, is the running of preliminary cases as proof of concept. The sections below report from the work in these 3 phases.

The year 2022 is foreseen for running the full analyses, and for evaluating and interpreting the results.

It has to be recalled that working together and achieving the common objectives of WP5 is a challenging endeavour. The variation among partners' work is huge owing to differences in reactor types; the codes applied; the power of computing hardware used; previous experience with UQ; and, finally, the research interest selected. The effort to harmonise the outcome rests on several requirements: that ST analyses are to be carried out and ST nuclides to be used as FoM; that risk-dominant scenarios are analysed, i.e. SBO, LOCA and in some cases SGTR; that Uncertain Parameters (UPs) as defined in WP2 are to be used; and, that a best practice for results evaluation will be sought.

2.1. Selection of SA sequences

Any modelling of a SA relies on a large number of choices – e.g. initial conditions, available safety systems, mitigation measures – to reflect the situation in the damaged reactor and to demonstrate how the accident sequence is impacted. In the reactor applications WP of MUSA participants have been able to make these choices according to the reactor type they are investigating, their previous experience, their research interest, etc. However, they have also been committed to common guidelines expressed in the project definition and in recommendations made by the project's End User Group:

- MUSA is oriented towards exploring uncertainties in the ST estimate, implying that any accident sequence considered needs to lead to core damage and the release of Fission Products;
- MUSA aims at analysing risk-dominant and thus highly relevant accident sequences;
- it has been proposed not to feature completely unmitigated scenarios, but rather consider SAM actions with an impact on the ST. Examples for mitigation are late core flooding and, during the ex-vessel phase, water injection into the cavity or filtered containment venting.

It is important to note that the effort for investigating sequences prolonged by mitigating actions tends to be significant. This has been a concern for many partners, in particular where the runtime requirements of the SA code are high and where High Performance Computing (HPC) is not available for the project.

Table I Scenario choices made by the contributors to WP5 for the preliminary analyses

Organisation	Reactor	SA scenario	SAM action
CNPRI	HPR1000	LLOCA	
NPIC	HPR1000	LOCA, SBO	
SNERDI	CAP1400	SGTR, LLOCA, SLOCA	
KAERI	APR1400	SBO leading to SGTR	UA for triggering ADV
CNPE	HPR1000	LB-LOCA	
KIT	KONVOI	MB-LOCA plus SBO	
BelV	PWR-1000	LB-LOCA	
ENEA	PWR-900	SBO	
CIEMAT	PWR (Surry)	SBO	
PSI	PWR-1100	SBO plus SGTR	Fixed-time SG re-flooding
GRS	KONVOI		
IRSN	PWR-900	SBO plus loss of aux. FW	Fixed-time sump flooding, CFVS
EPRI	PWR (Surry)	ELAP w/o+ w/ mitigation	Un-mitigated vs. AC restored at RPV failure
TRACTEBEL	PWR-1000	SBO	UA for triggering CSS, DCIS, PPORV, CFVS
USNRC	PWR (Surry)		
FRAMATOME	KONVOI	MB-LOCA plus SBO	
INRNE	VVER-1000	LB-LOCA plus SBO	Core quenching at SAMG criterion
CNSC	CANDU	LB-LOCA; SBO	
NINE	VVER-1000	LB-LOCA plus SBO	
TUS	VVER-1000	LB-LOCA plus SBO	
SSTC	VVER-1000	SBO	UA for Pressurizer PORVs
Energorisk	VVER-1000	LB-LOCA plus SBO	
LEI	BWR5-LIKE	LB-LOCA plus SBO	
JAEA	BWR4 Mark1	SBO	UA for CFVS, DC water injection
VTT	BWR4 Mark1	SBO	Fixed-time wet-well venting
SAPIENZA	BWR4 Mark1	SBO	Pressure-based wet-well venting
JACOBS	ABWR-LIKE	SBO	UA for triggering/flow rate of High-Pressure Core Flooder

Table I shows the reactor type and the scenario choices made by the contributors to WP5. The SAM actions described have been explored during the preliminary analyses and may still be adapted during the full analyses. Please notice the distinction between SAM actions subject to uncertainty (mostly the timing in initiating the action) and other “hardwired” actions (fixed time, or based on a key parameter reaching a threshold). Please note also that all accident scenarios in the table make assumptions on the availability of a reactor’s safety systems like passive hydro-accumulators or safety relief valves. These assumptions are made by the partners and are not coordinated by the project; they will be important when discussing results, at a later stage of the project.

2.2. Development of a reference input model for the specific reactor design and SA code

One of the first steps taken in WP5 was to invite all partners to complete a functioning input deck, demonstrated by a best-estimate reference case simulation leading to a radioactive release. Technical meetings have shown the effort that has had to be invested in adapting input decks to the UQ exercise.

Table II Hardware/software choices and WP5 subgroup split

Organisation	WP subgroup	SA code	Uncertainty Tool	Computer hardware
CNPRI	PWR Gen. III	ASTEC	SUNSET	no info
NPIC		MELCOR	DAKOTA	no info
SNERDI		MAAP 4.0.7	DAKOTA	PC, 4GB RAM
KAERI		MELCOR 2.2	DAKOTA	HPC, 128GB RAM
CNPE		MELCOR	DAKOTA	no info
KIT	PWR Gen. II	ASTEC	Python-based FTSC	HPC
BelV		MELCOR	URANIE	PC, 8GB RAM
ENEA		MELCOR	DAKOTA	PC, 32GB RAM
CIEMAT		MELCOR	DAKOTA	PC, 8GB RAM
PSI		MELCOR	DAKOTA, Python	PC, 16GB RAM
GRS		AC^2	SUSA	no info
IRSN		ASTEC	SUNSET, Python	HPC, 125GB RAM
EPRI		MAAP 5.05	Python scripts	HPC
TRACTEBEL		MELCOR	Python scripts	HPC, 32GB RAM
USNRC		MELCOR	Python scripts	no info
FRAMATOME		other	Genpara, MOCABA	no info
INRNE	VVER / CANDU	ASTEC	SUNSET	PC, 8GB RAM
CNSC		MAAP	Python scripts	PC, 8GB RAM
NINE		MELCOR	NEMM method	no info
TUS		ASTEC	SUNSET	PC, 4GB RAM
SSTC		MELCOR	SUSA	PC, 32GB RAM
Energorisk		MELCOR	DAKOTA	PC, 128GB RAM
JRC	BWR	-	-	-
LEI		RELAP/SCDAPSIM	SUSA	PC, 16GB RAM
JAEA		MELCOR	RAVEN	HPC, 192GB RAM
VTT		MELCOR	DAKOTA	PC, 8GB RAM
SAPIENZA		MELCOR	RAVEN	PC, 16GB RAM
JACOBS		MELCOR	DAKOTA, Python	HPC

Modifications are required for all partners to automate setting the values of the UPs in the input deck. For their individual reference case scenario, partners were asked to

1. Run the case and show the credibility of the results in terms of characteristic parameters like primary and containment pressure. These transients are well known from previous studies or from literature;
2. Show the evolution of some Fission Products in the ST; and,
3. Record key metadata of the simulation, like (i) scenario duration; (ii) hardware used; and, (iii) runtime required.

At the end of October 2021, 24 of 27 partners have completed the reference case and have established basic data characterising the effort posed by one simulation.
The results confirm that most SA codes require a computing time similar to the simulated time on a local scientific PC; only the fast-running code MAAP is an exception. Depending on their IT boundary conditions, partners favour different approaches to the task of running multiple simulations for uncertainty propagation:

A. For MAAP, large numbers of cases can run with acceptable effort[1], moving the challenge of managing the amount of data created into the foreground.
B. Partners who have access to HPC rely on the parallel execution of multiple runs of the SA code (the software licence permitting).
C. Partners who are limited to local PCs need to economise, and plan to do this in terms of
    - Reduction of the complexity of the reactor description, i.e. input deck simplification;
    - Selection of a less complex SA-scenario;
    - Reduction of the duration of the accident scenario. This can be related to the choice of mitigation action that prolongs the accident scenario, but it also touches on the criterion for the termination of the simulation.

Table II shows SA codes, UQ tools and computing hardware used by the different partners.

2.3. Setting up preliminary uncertainty analysis cases

The UA work in MUSA is organized as a two-staged approach of (i) first setting up all necessary models and tools and demonstrating their functioning; and, (ii) the full-scale analyses according to their individual scientific interest in terms of scenario and mitigation actions. This approach takes account of the fact that few partners have previously carried out UA in the SA context, and of the complexity of setting up the necessary constituents of the analysis described hereafter. The uncertainty application in MUSA's WP4 has been part of developing the collective capabilities and has been very effective in all points discussed below.

The problem definition itself builds on the input deck and the scenario selection that have been described above, and on the definition of ST FoM. Within the early work reported here, partners have experimented with FoM ranging from

- the FP groups provided as output by the SA codes; to
- inventories in the zones of the reactor or releases from them, i.e. RCS and containment; to
- non-ST quantities, e.g. hydrogen in the containment; to also
- time instances of events during the accident sequence, e.g. the creep rupture of hot leg, surge line and SG tubes.

For the full analysis, and considering the overall goal of MUSA, it is foreseen that the FoM will include the total release of radioactive Noble Gases, Caesium and Iodine to the environment.

The choice of the set of UP to investigate is typically driven by the search for the parameters with the highest impact on the FoM during the accident progression (in-vessel, ex-vessel, containment, etc). It also reflects the focus of the investigation, like: (i) the physical models in the SA code that partners want to investigate; (ii) phases of the accident (in-/ex-vessel, containment) of special interest; (iii) SA management and mitigation considerations. For the preliminary analyses partners selected a minimum number of UP, their Probability Density Function (PDF), and their maximum/minimum values. At this stage, the need for justifying assumptions on the PDF (an important aspect in WP2) has been relaxed.

Further steps to be carried out in the context of running a preliminary analysis are:

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[1] It is stressed that this paper is not comparing the modelling approach of different SA codes. The accuracy of the MAAP results in this study is the same as in any other application of the MAAP code.

- The choice and implementation of a UP sampling method. Most partners chose Latin Hypercube Sampling (LHS) which promises the minimum number of runs for a given confidence interval. Even so, a few partners chose the less efficient Monte Carlo (MC) random sampling to avoid making the strong assumptions of parameter independence in LHS. KIT found that taking account of pre-correlations among the selected UP governing the same phenomenon increased the related correlation coefficients between such parameters and the FoMs (up to a factor of four).
- Automation of the analysis: uncertainty propagation requires the SA code to run with a large number of sampled UP sets. Automating the creation of these input deck variations is not only a question of economy; it also helps avoiding typographical errors from manual input. Ideally, the selected UT would already have an interface to the selected SA code that provides this automation and initiates the execution of all simulations. In MUSA, this held only for a few partners; most faced situations like: (i) the interface of SA code and UT needed to be created, or errors corrected; (ii) the interface was reinforced by additional code to meet the requirements of the partner; and, (iii) some partners opted for a self-programmed solution altogether, providing flexibility e.g. with regard to the IT platform and taking advantage of programming languages like Python and statistics software packages.
- Post-processing of the results from the uncertainty propagation runs. Goals reach from checking plausibility of single runs to generating ensemble data that display graphically key messages of the UQ.

2.4. Status of preliminary uncertainty analysis

At the end of October 2021, and thus 29 months into the project, 15 of the partners have achieved a proof of concept for the set-up of their UA. Most others are in the process of solving technical issues related mainly to coupling of SA codes and UT and to frequent code failures.

Many partners have already gone beyond these preliminary analyses by selecting larger numbers of FoM and UP, running a hundred or more simulations, and beginning to perform a critical review of the obtained results in view of MUSA's objectives. A brief overview of these activities will be given in Section 3.

The phase of preliminary UA together with experience gained in WP4 has been very useful in highlighting the challenges met during the UA, and in showing partners' ideas on how to address them:

- The crashing of the SA code during the execution, for some of the UP sets. This is a reminder of codes' sensitivity to the choice of parameter values in the physical models and correlations. The discussion of partners' results in MUSA subgroup meetings provided some interesting insights, e.g.
    a. Code crashes were observed much less when carrying out a pre-correlation analysis of UP – and by this avoiding physically meaningless random combinations of correlated UP
    b. Fewer code crashes seemed to be also observed when sampling with MC rather than LHS method.
    c. One partner observed random code crashes for small variations in the UP. This could mean that a parameter set causing a code crash could be replaced by a set changed by random noise, with a chance of not thrashing. Analyses on the bias this might cause are on-going.
- The overall hardware requirements of the preliminary runs also give an indication of how much time would be required for the full-scale UQ analysis.

3. MAIN RESULTS FROM PRELIMINARY ANALYSES

3.1. Examples of results from Uncertainty Analyses

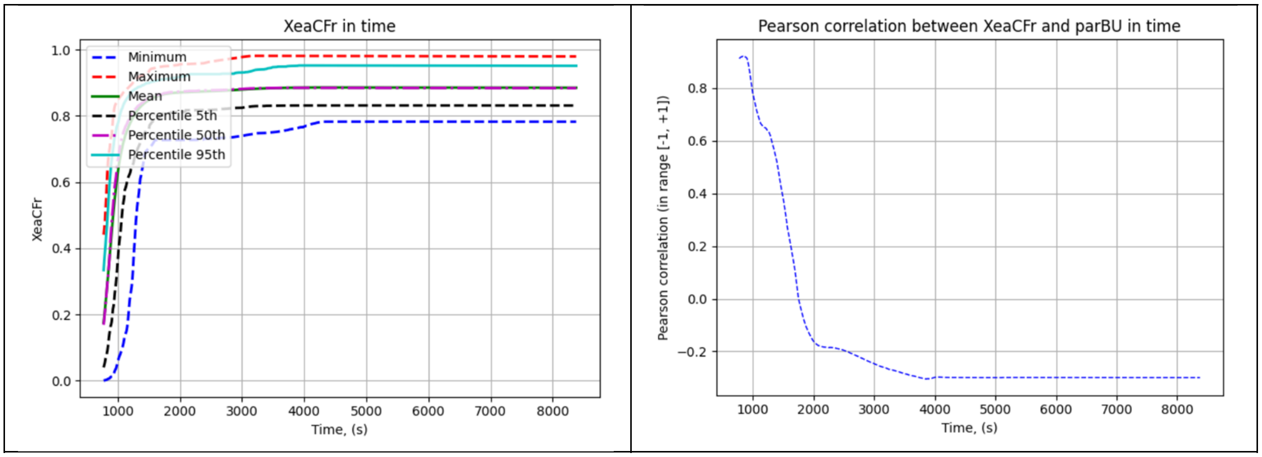

Figure 2 Xe release XeaCFr to containment (left) and correlation of XeaCFr with fuel burn-up (KIT)

During the setting up of their analyses, partners have explored ways of presenting their results. Next to the type of plots in **Figure 2** they have looked at (i) FoM evolution in time, plotted for all simulated cases and thus giving a picture of the FoM ensemble; (ii) values of correlation coefficients for all UP in bar charts or color-coded matrices to highlight dominating uncertainties; (iii) FoM PDF assembled from all simulations and plotted for a given time instant to look for patterns in the statistics of the result; etc. Post-processing will become relevant for the full-sized final analyses.

Figure 2 displays uncertainty bands of a ST FoM, and its sensitivity towards one of the uncertain parameters; see ***Table I*** : KIT for more details on the case. The correlation coefficient as a function of time underlines that the fuel burn-up has a significant impact at the beginning of the scenario and is weakening with time.

3.2. Computational set-up and cost

In MUSA, the computational effort poses the most severe limit to the reactor application of UQ. There is a range of factors that determine the cost of the analyses, with the most influential (i) the complexity of the reactor model; (ii) the complexity and length of the simulated accident scenario; (iii) the runtime requirement of the SA code used; (iv) the complexity/size of the UQ; and, (v) the available hardware to run the analyses. Moreover, the handling and post-processing of huge amounts of data should not be underestimated.

A poll of the computing hardware to be used shows that, out of 20 respondents, 6 are using HPC that run many simulations in parallel and are allowing demanding analyses within, say, a couple of weeks to a couple of months, even for codes that are not fast-running. The remaining 14 partners run PC systems of varying computing power. In terms of runtime requirements for the base case, partners have quoted between 20 minutes and 120 hours – this longest value reflecting a case terminated only after 10 days of problem time. Limits in hardware power lead to a situation where many partners need to make trade-offs between points (i), (ii) and (iv) described above. Even so, computing power is not a pre-condition for making sensible contributions to the methodological questions addressed by MUSA. See **Table II** for details on the hardware.

3.3. SA-codes behaviour during the UQ

Setting up the computational framework for the preliminary UA, see the description in section 3.3, is in itself a process of tracing and correcting faults before the system works well. However, the failure of some SA codes when running with an instance of the set of varied UP is a more complex challenge that may have different root sources, e.g. the selected PDF, the value ranges assigned to each UP (narrow/wide range), the combination of UP for each run, or the numerical stability of the SA-code.
The experiences of partners, for the different SA codes, can be summarised like this:

1. For MAAP, almost no code failure is observed, meaning that the code set-up is resilient towards the variation of selected UP. For MAAP-CANDU, CNSC experienced some problems with UP outliers and proposed using bounded PDF as a fix.
2. For MELCOR, the situation is more varied, judging by the reports of 11 partners:
    a. Two partners report no code failure. One of them (KAERI) was not simulating core slump or RPV failure during the preliminary phase, while the other (Energorisk) was looking at a very short and very severe sequence. All others acknowledge that a small number of code failures is to be expected.
    b. The quality of the model seems to have an impact: SSTC could reduce the number of code failures significantly by changing the resolution of the core model. This point is echoed by other partners who adapted/simplified an existing input deck and who know from experience the need to look for model optimisation.
    c. Several partners report schemes for reducing the minimum time step and restarting simulations. This led to fewer code failures, at the price of increasingly long simulation duration. For code failures after time step reductions, SSTC reports making small changes (1% of the variation range) to some of the parameters related to the core model – which in their case had been identified as the origin for code failure.
    d. Jacobs has performed a study of biases that may result from the absence of failed calculations from the output distribution. A method was developed to automatically rerun failed calculations with reduced time steps around the time of failure, which greatly improved the percentage of successfully completed runs. It was observed the initial failures were unevenly distributed in key output quantities, suggesting bias would have been introduced by omitting calculations that initially failed.
    e. Finally, some partners have included the timing of SAM actions as UP and have shown a large impact on code performance. Jacobs did this for core re-flooding and reports up to 55% of code failures when a narrow band of initiation times was considered during core degradation.
3. Experiences of partners using ASTEC showed few code failures. INRNE reports less than 4% of their simulations, while KIT reported 2 code failures from 300 runs. It is worth mentioning that KIT used pre-correlated UP to minimize unphysical parameter combinations.

3.4. Sampling of uncertain parameters

Practically all partners use the Wilks formula [6] to establish the minimum number of simulations required for achieving FoM estimates with a 95% confidence interval for the 95% probability content. Most of them combine, or intend to combine, this with LHS of the UP, which promises the most efficient coverage of parameters' uncertainty ranges.
First experiences with sampling can be characterised like this:

- Due to code failures, many partners need to run additional cases to arrive at the minimum number of simulations required by Wilks, e.g. by increasing Wilks' minimum number of UP variations with the estimated number of code failures when sampling UP space.

- Just dropping failed runs can injure the mathematical assumptions of the UA and bias the results. Partners have analysed sets of UP in failed cases to detect a causal link for the failure. So far, few cases have been reported where such a link could be detected.
- Dropping cases from a LHS scheme can also lead to an uneven representation of UP. Ways of addressing this problem have been:
    - To re-run failed cases with some parameters in the UP set changed by small systematic or random perturbations. Analyses of potential bias in this case are on-going.
    - To use MC sampling and run significantly more cases than required by the Wilks formula, to make sure that the parameter uncertainty space is well covered
- There are concerns that correlations of UP exist and could be ignored, potentially leading to un-physical choices of parameter combinations. KIT reported positive results for taking into account such pre-correlations.

Finally, it is noted that partners running large numbers of cases typically use MC random sampling and achieve confidences higher than 95%.

3.5. Accident Management and Mitigation

It is an important goal of MUSA to include AM actions in the UA. Such actions are fundamentally different from parameters in the phenomenological models of the SA code: they represent sequence-specific uncertainties. UP in SAM actions are often the time instant of activating a system, e.g. cavity flooding or CFV, but they can also include other parameters of an activated system, such as a flow rate. During the preliminary phase five partners included uncertainty in SAM actions in their analyses, see Table I.

Four partners have analysed SAM action: all for SBO scenario, where 3 have looked at the uncertainty in triggering the depressurization of the RCS and one at high-pressure re-flooding. While these are preliminary results and will not be discussed in detail, there are some observations made to guide other partners in analysing SA actions:

- Triggering the SAM actions does not in itself imply more code failures, but the simulation can indeed react sensitively to the choice of uncertainty interval – in Jacobs' case early core re-flooding starting between 8,000s and 12,000s into the SBO led to significantly more code failures than for later times;
- The SAM triggering time was selected within a larger set of uncertain model parameters and did not upset the uncertainty propagation. Tractebel found a triggering delay strongly correlated with one FoM (CsMb) and weakly correlated with another (CsI), while JAEA and SSTC found such a delay weakly / not correlated with their FoM of choice.

Having made these two points, it should still be clear that any SAM action changing drastically the scenario, e.g. mitigating vessel failure, is likely to have a big impact on FoM.

4. CONCLUSIONS

The paper has given a view of the extent of work to be carried out under WP5 of MUSA, highlighting the large number of partners; the variety of reactor types, scenarios, codes and hardware; and, the organisation of the work.

The reactor applications WP has seen most of the partners concluding the setting up of their analyses with 18 months to the end of the project. In this, the level of progress is wide-ranging, with some partners already running large uncertainty propagation and addressing key questions of applying UA to SA modelling.

Challenges shared by the partners when setting up their UA have been described. The issues identified as a result of this learning process may be regarded as preliminary lessons learnt. They will remain issues during the full-sized analyses in WP5: computational aspects, like effort and code performance; the selection, definition and sampling of uncertain parameters; and particularities of SAM actions. MUSA will support its participants to manage these issues according to their capacity and scientific interest.

Two examples of the results that will be achieved with the uncertainty analyses – uncertainty bands of the FoM and correlation coefficients for UP and FoM – have been shown. Details of these analyses go beyond the scope of this paper and will be addressed in more technical contributions in the future.

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