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REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

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Content

Abbreviations

AI	Artificial Intelligence
ATF	Accident Tolerant Fuel
BWR	Boiling Water Reactor
CETAP	Communication, Education and Training Action Plan
CSS	Containment Spray System
DBA	Design Basis Accident
DEC-A	Design Extension Conditions-A
EC, EU	European Commission, European Union
EPR	European Pressurised Reactor
EP&R	Emergency Preparedness and Response
ETSON	European Technical Safety Organisation Network
EUG	End User Group
FP	Fission Product
GA	Grant Agreement
LOCA	Loss Of Coolant Accident
MT	Management Team
NEA	Nuclear Energy Agency
PC	Project Coordinator
PWR	Pressurized Water Reactor
RC	Radiological Consequences
RCS	Reactor Coolant System
SEG	Senior Expert Group
SGTR	Steam Generator Tube Rupture
SNETP	Sustainable Nuclear Energy Technology Platform
TL	Task Leader
VVER	Vodo Vodianoï Energetitcheskyi Reactor
WPL	Work Package Leader
WP	Work Package

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1. Introduction

The main objectives of the R2CA project, dedicated to the Reduction of Radiological Consequences of Accidents with design basis and design extension conditions for Gen II, III and III+ Nuclear Power Plants, are:

- to consolidate assessments of radiological consequences of two categories of selected bounding accidental scenarios (Loss-Of-Coolant Accidents and Steam Generator Tube Rupture accidents) within the Design Basis (DBA) and Design Extension (DEC-A) domains for PWRs, EPR, BWR & VVERs;
- To propose improvements for NPP management strategies and devices to reduce the radiological consequences of these accidents.

To meet these objectives several specific actions will have to be performed:

- Make a review and collection of the existing experimental data that will be used to verify and calibrate the updated/improved models and/or advanced simulations tools developed during the project for LOCA and SGTR accidental transients ;
- Make a comparative assessment of the existing methodologies used in different countries to evaluate the radiological consequences experimental results as well as the assumptions/hypotheses, models and simulation codes that are applicable to evaluate the safety margins of the considered reactor models within DBA & DEC-A conditions, through the RC of bounding scenarios ;
- To provide advanced simulation tools and calculation schemes allowing to assess the degree of conservatism in order to be able to derive more realistic safety margins through the RC of bounding scenarios within the DBA & DEC-A domains ;
- To elaborate updated and harmonized methodologies for the evaluation and the reduction of those RC in the different kinds of operating and foreseen reactors in Europe and implemented in various code ;
- To derive from these methodologies some rationales for the optimisation of EP&R actions ;
- To provide analytical rationales for the development of innovative measures, devices and tools that could be used for the anticipated diagnosis but also for the management and mitigation of those accidents.

To this end the project is divided into four different technical Work-Packages whose specific objectives are:

- WP2-METHOD: propose harmonized methodologies for the evaluation of the RC as a marker of safety margins of both LOCA and SGTR bounding scenarios for DBA and DEC-A conditions and perform reactor case calculations
- WP3-LOCA: develop accurate evaluation tools for the evaluation of the RC of LOCA bounding scenarios by improving the existing tools for both accidental progression in the core and release/transport of fission products up to the environment
- WP4-SGTR: develop accurate evaluation tools for the evaluation of the RC of SGTR bounding scenarios by improving the existing tools for both accidental progression and release/transport of fission products up to the environment
- WP5-INNOV: identify and evaluate the gains using the developed evaluation tools of potential new accident management procedures/devices including Accident Tolerant Fuels but also explore the capabilities of prognosis evaluation tools to anticipate accidental configuration through Artificial Intelligence functionalities.

The work performed during the 1st project year in WP2 will be reported as well as the work foreseen for the coming year in WP3, WP4 and WP5 that have only started in July 2020. In addition, will be also reported the work dedicated to the project management (WP1) as well as in WP6 where more details will be given regarding the dissemination/communication activities and the education/training program (mobility program between different organizations in the consortium, training perspectives and provisional list of Phd/post docs).

2. Work progress (WP1-MANAG, WP2-METHOD & WP6-DISSE)

The project was officially launched on September 2019. During this first year of the project, as initially planned, the technical work was essentially done within WP2 (METHOD) and focussed on knowledge synthesis & reactor case selection.
WP2, dedicated to release evaluation methodologies, started by a synthesis of existing knowledge and an inventory of available tools and data. This work divided in three different sub-tasks and completed in September 2020 consisted in:

- A review on existing methodologies used in different countries for licensing procedures of different kinds of reactor configurations for release evaluations during LOCA and SGTR scenarios where the main hypotheses and assumptions depending on regulatory practices were collected;
- An analysis of the capabilities of the available codes including both system codes, tacking globally the overall accidental phenomenology, and more detailed or mechanistic codes focussing on a part of the phenomenology only but also the combined use of these codes in implementation of the evaluation methodologies ;
- An identification and selection of available experiments dedicated either to fuel rod behaviour, cladding rupture or fission product release and transport up to the environment which will be used to verify and validate the improvement of the corresponding tools for LOCA and SGTR bounding scenarios within DBA and DEC-A domains. The corresponding metadata were collected and gathered in a report

The corresponding reports have been finalised and submitted to the European Commission in September.
A major effort has also been devoted to the selection of a set of reactor configurations and accident scenarios. To this end a Senior Expert Group meeting was held in conjunction with the kick-off meeting and several other dedicated meetings have been organized afterwards. The contribution of each of the 13 organisations participating to the reactor calculations are detailed in a dedicated technical report to be issued very soon indicating the reactor case configuration chosen by each partner, describing the different scenarios and giving details on the main assumptions and hypotheses considered. Those reactor configurations both include different reactor-types (PWRs, BWR, EPR & VVERs) and different bounding scenarios of DBA and DEC-A domains. In addition, a simple methodology for the evaluation of the radiological consequences from a given environmental source term was also proposed and detailed in this report.

2.1. WP1-MANAG (lead: IRSN)

2.1.1. Objectives

WP1 is dedicated to the overall project management. Its main objectives are to ensure an efficient scientific, administrative and financial follow-up of the project during its four year duration. Regarding the technical coordination, the WP1 will that all the produced scientific work will be implemented in compliance with the quality standards and with respect to the planned time schedules, delivery tables and budget. It will also verify that the produced work meet the project main and specific objectives.
During the first year, the management team will have to foster the interactions between the partners and to initiate the collaborative performance of the work in agreement with the project guidelines for the achievement of the planned first deliverables and milestones.

2.1.2. Overview of the main advances

A kick-off meeting, gathering about 40 European experts from the 17 organisations participating to the project, was held in Fontenay-aux-Roses in November 2019, where the main objectives of the project were recalled as well as the associated work plan. It has allowed converging on the first studies of interest to be launched.

The quality management report was issued describing:

- The project overall organisation, the project bodies and actors ;
- The management of the documentation that will be produced ;
- The deliverable issuing and validation process for periodic reports to EC, contractual as well as non-contractual reports and publications.

A preliminary list of 12 performance indicators to assess the progress and success of the project activities, help to monitor its results and to propose corrective actions for reaching the initial objectives was also established and detailed in this report.
Finally the consortium agreement was also drafted.

2.2. WP2-METHOD (lead: Tractebel)

2.2.1. Objectives

The main objectives of WP2 are:

- Propose harmonized methods for evaluation of the radiological consequences of both SGTR and LOCA categories of DBA and DEC-A accidents;
- Perform best estimate evaluations of reactor case configurations for PWRs, BWRs, VVERs and EPR by using improved calculation schemes;
- Analyse the potentiality of accident management measures and devices, including innovative actions to reduce the radiological consequences of those accidents.

The work-package is subdivided into 8 tasks. In the first year the focus was on the 5 first tasks (task 2.1.1, task 2.1.2, task 2.1.3, task 2.2 and task 2.3). The first 4 tasks were all finalised by the end of the first year (with the exception of some deliverables which were slightly adapted as a result of the comments from some contributors).

The specific objectives for the 4 first tasks are:

- Task 2.1.1 - The objective for this task is to make a review of the different evaluation methodologies used by the different partners for the calculations of the radiological consequences following a LOCA or a SGTR. This review has to be included in a summary report by the end of august 2020;
- Task 2.1.2 - The objective for this task is to make a review of the different simulation codes and calculation schemes used by the different partners. This review has to be included in a summary report by the end of august 2020;
- Task 2.1.3 - The objective for this task is to make a review of the experimental database (available experiments including the experiments targeting the fuel rods and/or cladding rupture, the fission products release and transport up to the environment). This review has to be included in a summary report by the end of august 2020;
- Task 2.2 – The objectives for this task are:
    - Agree in collaboration with the SEG and the different partners on a minimum set of reactor configurations that will be analysed in task 2.3 and in task 2.5;
    - Propose simple methodology for the evaluation of the radiological consequences from a given environmental source term.

The objective for task 2.3 is to make a simulation of the reactor case determined in task 2.2. This simulation will be used as a starting point in task 2.5.

2.2.2. Overview of the main advances

At the moment of drafting of this document the PoW was still not finished. Moreover since the first 3 tasks are finished at this moment they will not be included in the PoW.
As explained in the following paragraph (§2.2.3) the first 3 tasks used questionnaires in order to obtain the necessary information from the different partners. The information obtained in this way is processed and is included in a document which presents the final deliverable for this task.

- Task 2.1.1: Review of the RC evaluation methodologies (IRSN);
- Task 2.1.2: Review of simulation codes and methodologies for LOCA and SGTR;
- Task 2.1.3: Report on SGTR and LOCA available experimental data.

The information obtained in these documents does not lead to new insights or conclusions but does present a very useful source of information for the Work-packages 3 and 4.

For task 2.2 an agreement was reached during the SEG meeting on the use of separate hypotheses and model for all different partners. This is included in the Minutes of meeting from the SEG. In addition to this minutes a working document has been created that contains information on the scenario's for all partners. In addition a proposal for a simple methodology for the evaluation of the radiological consequences from a given environmental source term is included in this document. However this proposal is not yet definite and several comments on the proposal have to be discussed/processed.

Task 2.3, which consists of a simulation of the scenario presented in task 2.2, has started but has not yet been finished. An agreement was reached on the content of a template document which will be used by every partner to document the results from their simulations. At this stage there has not been any communication between the different partners on the progress of their modelling.

2.2.3. Details of the activities performed

2.2.3.1. Task 2.1.1: Review of release evaluation methodologies (lead: IRSN)

Within the task 2.1.1, 6 partners (IRSN, Tractebel, Bel V, SSTC NRS, ARB, LEI) have shared their various methodologies to evaluate the radioactive release due to a Loss Of Coolant Accident (LOCA) or a Steam Generator Tube Rupture in a PWR, VVER or BWR. Due to the very different context, regulatory practices and licensing procedures in the different countries, major differences in the methodologies are observed, leading to one to two order of magnitude discrepancies for the radioactive releases of some major isotopes such as Xenon and Iodine.
For the LOCA scenario, the differences start at the isotopic inventory definition. Both deterministic and Monte-Carlo methods are used to establish the fuel composition. In terms of burn-up, realistic, maximum as well as average values are used. The assumed rate of failed fuel rods is also different among the participants, ranging from 33% to 100%. However there is an agreement regarding the core discretization: most methodologies consider several different types of similar fuel assembly based on irradiation and core management.
Concerning the elements volatility, the list of considered FP is different for each project partner. Also the definition of semi-volatile and low-volatile varies for several elements.
Regarding the release of FP, two approaches exist: the conservative 100% release, employed mainly by Tractebel and Bel V for noble gases and iodine, and a less conservative release model, which considers only the gap release. In terms of FP release to the containment, all the participants consider a 100% release of the

FP the containment, and thus no RCS retention. However, the FP distribution between the liquid and gas phases of the containment is modelled following two approaches: a conservative 100% distribution of all FP into the gas phase and a more realistic distribution of elements between the two phases according to their chemistry. In terms of FP chemistry in the containment, three approaches are considered: time-dependent modelling of iodine chemistry (IRSN and LEI), instant modelling (ARB and SSTC NRS) and no modelling of iodine speciation (Tractebel and Bel V). The hypotheses regarding the impact of the Containment Spray System also vary: either the CSS operation is not considered at all or it is considered with varying degrees of efficiency.
All the methodologies consider unfiltered gas releases to the environment, with leak rates that are sensibly the same. Liquid leaks outside the containment are considered only by IRSN and Tractebel and Bel V. There are differences concerning the filtered releases, specifically the efficiency of filtering systems towards the considered iodine species (molecular iodine, organic iodine and particulate iodine).
For the SGTR scenario there are also differences in the approaches for evaluating the RC. Tractebel and Bel V only consider 131I for RC evaluation, whereas IRSN computes the equivalent 131I activity, which is the weighted sum of the most important iodine isotopes present in the RCS. In addition IRSN, ARB and SSTC NRS consider the presence of other isotopes in the primary coolant, although the activity values vary. The iodine form in the RCS is also different: Tractebel and Bel V do not discriminate between iodine species, while the other methodologies consider molecular and particulate iodine. Moreover, ARB and SSTC NRS also consider organic iodine. For the distribution of iodine species between the liquid and gas phase of the steam generator, Tractebel and Bel V use a realistic approach based on phenomena such as isenthalpic flashing and droplet atomization, whereas the other participants consider partitioning coefficients with a varying degree of conservatism. Regarding the retention in the secondary loop, only Tractebel and Bel V consider any for iodine, while the other methodologies assume no iodine retention.
This work will establish a first picture of the different methodologies. It will be updated throughout the project enabling to evidence the improvements performed within the project in particular through the reduction of some of the conservatisms.

2.2.3.2. Task 2.1.2: Review of simulation tools and calculation schemes (lead: VTT)

In R2CA project, dedicated computer programmes are used to perform assessments of radiological consequences in LOCA and SGTR conditions. In the course of the project, the codes and the methods how those codes are applied will be upgraded. Fission product release from the fuel rods in LOCA and SGTR, transport in the primary and secondary circuit, release to the containment and further into the environment will be modelled. Often more than one code is needed in order to take into account the different modelling scales, resulting in calculation chains in which data is passed from one code to another. In addition, as various organizations use different codes for the simulation of one specific domain, the number of codes becomes large. Task 2.1.2 was set with the following specific goals: to understand the current status of modelling capabilities of LOCA and SGTR and to facilitate the comparison of various codes, to pinpoint the required development needs of each code, and to provide a base document that can be used later on to highlight the gains achieved by the code and methodology improvements during the project.

Task 2.1.2 had 10 participating organizations: VTT (task leader), IRSN, BEL V, ENEA, SSTC-NRS, ARB, BOKU, EK, UJV, and HZDR. Furthermore, TRACTEBEL, LEI, CIEMAT and JRC provided contributions. The selection of codes covered fuel performance (inc. two steady-state codes), sub-channel and system thermal hydraulics, radionuclides behaviour and integral system behaviour: CATHARE, GENFLO, RELAP5, RELAP5-3D, DYN3D, FRAPCON, FUROM, SHOWBIZ, TRANSURANUS, DRACCAR, FRAPTRAN, FEMAXI-6, MFPR-F, TSKGO, RING, AC2 (ATHLET, ATHLET-CD, COCOSYS), APROS, ASTEC, MELCOR, and JRodos. While there exist a number of other codes for LOCA and SGTR analyses, this review focused on the codes used in this project. The group of codes includes established codes that originate from the development work done for decades, as well as newer codes that have been developed just recently.

In order to facilitate the code comparisons, questionnaire tables were formulated, consisting of various models to be compared between the codes, with an emphasis on fission product behaviour. As there are codes with different modelling scales, the comparison of codes was divided into two tables: integral system codes, and fuel performance/radionuclides behaviour codes. Short code descriptions were written by the code owners or users. In the code descriptions, general overview of modelling capabilities and possible interlinkages to other codes in the specific radiological consequences evaluation method were brought out, as well as how fission product release and transport is considered in the code, how data is passed in the calculation chain, what boundary conditions are needed, and can the code use the output of a code with more detailed modelling as its input.

The deliverable report helps to achieve an understanding on the current capabilities of each of the applied code. The report summarizes also the general development items for the codes, as well as those items intended to be addressed in the R2CA project. Many codes will gain significant improvements for modelling the phenomena addressed in the project, while some of the codes are not planned to be improved but are used in the development of radiological consequences evaluation methodologies. In the latter case, code development items may rise during the project. The development items identified during Task 2.1.2 can be grouped as follows: 1) cladding modelling, 2) fuel and fission product modelling, 3) codes coupling, and 4) the whole core modelling and nodalization.

The deliverable report was finished during the first project year as planned.

2.2.3.3. Task 2.1.3: Review of experimental database (lead: EK)

In the framework of the Task 2.1.3 of R2CA project the available experimental databases were reviewed focusing on fuel failure, on fission products release from the fuel rods and on activity transport up to the environment during LOCA and SGTR events. The review also included available information obtained from the monitoring of normal operation and transients in NPPs and from some accidental situations. It is expected that this review will cover all important LOCA and SGTR phenomena by experimental data and will support code validation activities in the R2CA project.

In order to specify the content and for of the review document and to identify the responsible R2CA partners for each test series a topical meeting on “Task 2.1.3 Review of existing experimental database” was held on 15 January, 2020 in Budapest.

Deliverable D2.1.3. with the title “Review of experimental database” was produced by the following group of experts: Zoltán Hózer (EK), Adam Kecek (NRI Rez), Katia Dieschbourg (IRSN), Tatiana Taurines (IRSN), Martina Adorni (Bel V), Nikolaus Müllner (BOKU), Mattia Massone (ENEA), Matthias Jobst (HZDR), Asko Arkoma (VTT), Péter Szabó (EK), Ruslan Lishchuk (ARB), Stanislav Sholomitsky (ARB), Michael Schöppner (BOKU), Cedric Leclere (IRSN), Luis E. Herranz (CIEMAT), Rafael Iglesias (CIEMAT) and Vincent Busser (IRSN)

The report includes the description of each test series in individual chapters. Short summaries were produced to identify the test objectives, introduce the tested materials, test facility, measured parameters and PIE data, and present the general conclusions drawn after the completion of the tests. The main characteristics a test series are summarised in form of matrices, which are shown in the Appendix of the report. Three large matrices have been compiled to support detailed discussions on

- Phenomena,
- Test characterization and
- Data availability.

The users of the database can find more information on the given test series in the references, which are grouped into special directories. In some cases, the data available for the test series inside of R2CA project are also given in these directories. The data files are available in their original format as provided by the data owner. It was intended to include all available information on the related experiments and NPP measurements, even if the data are not available for the project.

The R2CA project partners reviewed the experimental database taking into account the following sources:

- Tests and measurements in national or institutional projects,
- OECD State-of-the-art Report on Nuclear Fuel Behaviour in Loss-of-coolant Accident (LOCA) Conditions,
- OECD and EU projects,
- Publications in scientific journals, conference materials and other open libraries (IAEA and NUREG reports).

In most of the cases some experts were involved in these tests series or participated in the evaluation of the data.

The preliminary list of tests was agreed during topical meeting in January 2020. During the screening process several severe accident type experiments were removed from the list, for the R2CA will deal with DBC and DEC-A conditions only. Furthermore, some additional items were added. The final list included 43 test series (Table 1).

Table 1: Test series reviewed for R2CA activities

No.	Test series	Responsible organisation for the related chapter in database report
1	Edgar tests	IRSN
2	COCAGNE tests	IRSN
3	REBEKA tests	HZDR
4	AEKI/MTA EK burst tests	EK
5	JAERI and JAEA burst tests	IRSN
6	UK burst tests	HZDR
7	MRBT (ORNL) burst tests	IRSN
8	Russian burst tests	EK
9	ANL burst tests	IRSN
10	EDF burst tests	IRSN
11	PBF tests	EK
12	FR-2 tests	IRSN
13	PHEBUS-LOCA test	IRSN
14	Halden LOCA tests	VTT
15	ACRR (SNL) tests	BOKU
16	NRU MT-4 test	IRSN
17	LOFT LP-FP tests	HZDR
18	FLASH tests (Grenoble, Siloe)	IRSN
19	GASPARD tests	IRSN
20	VERCORS tests	IRSN
21	VERDON tests	IRSN
22	Studsvik LOCA test	VTT
23	CORA tests	HZDR
24	QUENCH-LOCA integral tests	ENEA
25	CODEX-LOCA integral tests	EK
26	PARAMETER tests	EK
27	Halden FGR tests	ARB
28	FIRST-Nuclides leaching tests	EK
29	MTA EK H uptake test	EK
30	DEFECT tests with defective fuel	IRSN
31	DEFEX secondary defect test	IRSN
32	Halden IFA-631 secondary degradation test	ARB
33	BIP	UJV, BEL V
34	MARVIKEN FSCB	UJV
35	THAI	UJV, BEL V
36	ARTIST	CIEMAT
37	STEM	UJV
38	VVER NPP iodine spiking	EK
39	PWR NPP iodine spiking	EK
40	VVER NPP SG collector cover lift-up	ARB
41	VVER NPP non-closure of the pressurizer safety valve	ARB
42	OECD-IAEA Paks Fuel Project	EK
43	PSB-VVER and other TH loops	BOKU

The review of experimental databases covered a large number of tests, which characterizes the phenomena taking place during LOCA and SGTR events in PWRs and VVERs. Among the tests several separate effect tests and integral tests were listed, and some NPP measurements were also included.

- **Fuel failure during LOCA** is well covered by experiments, since many teste series were carried out under different conditions with all important cladding types. Beyond the burst type failure – which took place in more than twenty reviewed test series –, the brittle failure of Zr alloy claddings was observed in some tests. The fuel pellet fragmentation and dispersal was indicated by several tests (PBF, FR-2, ACCR, ANL, FLASH, Halden LOCA, Studsvik LOCA).
- **Fuel failure during SGTR** normally is not expected for intact fuel rods. The related experiments simulate the behaviour of defective fuel rods, which may suffer from secondary defects during the accident. The available experimental data characterise the hydrogen uptake by Zr alloys in the defective fuel rods and its embrittlement effect. The behaviour of water logged fuel under transient loads is not covered by the current database.
- **Activity release from fuel during LOCA** conditions is was simulated in several separate effect tests (VERDON, VERCORS, GASPARD) and also by integral test (ACRR, FLASH, Halden-LOCA, LOFT LP-FP). The available experimental data cover wide range of parameters for different fission products. The Halden FGR tests are also important for this topic, for they may provide part of the gap source term in case of fuel failure.
- **Activity release from fuel during SGTR** conditions is supported by iodine spiking experience at PWR and VVER NPPs and by separate effect tests on leaching fuel pellet samples. The DEFECT and DEFEX test series simulated the behaviour of defective fuel rods in research reactor conditions and provided valuable information on secondary defects and water logged fuel rod phenomena.
- **Activity transport during LOCA** includes several phenomena in the primary circuit and containment, which were investigated in the VERCORS, VERDON, BIP, THAI and STEM projects. The ARTIST project focused on aerosol trapping in steam generators. Some important data can be drawn from the OECD-IAEA Paks fuel project and from NPP event with non-closure of pressurizer safety valve.
- **Activity transport during SGTR** is characterised by complex path configurations, which were studied in the VERCORS, VERDON, BIP, THAI, ARTIST and STEM projects. The BIP, MARVIKEN FSCB and STEM test series simulated fission product transport in the steam generator, too. The primary-to-secondary phenomena were also observed in an NPP event with steam generator collector cover lift-up.

The project partners indicated that at least 18 test series was already used earlier for code validation purposes and there are intentions to use at least 21 tests series for further validations activities within the R2CA project. The experimental data can be used for the support R2CA tasks in several areas including model development and validation activities:

- Burst tests data can be used for the improvement and validation of transient fuel behaviour codes,
- Integral LOCA tests allow us to carry out further validation of fuel behaviour codes,
- Fission product test data are crucial for the testing of severe accident codes,
- Fission product transport experiments provide unique possibilities for severe accident code validation,
- Iodine spiking data can be used to develop and improve activity release models which can be applied in SGTR analyses,
- Hydrogen uptake data are useful for the simulation of secondary degradation in defective fuel rods,
- The learning from thermal hydraulic experiments can support the optimisation of accident management strategies.

The common use of data from small scale separate effect test and integral tests provides possibilities for the improved simulation of several phenomena (e.g. cladding burst, oxidation, hydrogen uptake, activity release and transport) under very different conditions. Most of these conditions can be considered typical for LOCA and

SGTR event, and some of them cover even wider parameter ranges than those that can take place in these accidents.

The experimental data from 12 test series are included in the present version of the database. Data for other 24 test series are accessible for some of the project partners, but cannot be shared within the project with all partners for different reasons. Some of the experimental data are stored in international databases (e.g. IFPE of OECD NEA, OECD projects, IAEA FUMEX), while some others are stored by the owners of data in private databases. The data of some old test series or experiments carried out outsides of Europe (USA, Russia) are not accessible for the project, but are listed in the database as significant contributions to our knowledge on the SGTR and LOCA related phenomena.

2.2.3.4. Task 2.2: Identification of reactor cases (SEG)

Prior to the SEG meeting, a questionnaire was sent to all partners involved in the R2CA project. This questionnaire was set up in order to obtain information on the analyses and tools the different partners intended to perform in task 2.3 (and task 2.5).
During the SEG meeting which took place on November 27, 2019 a summary of the information obtained was presented to the different members of the SEG. It was decided on the bases of this presentation that no attempt would be made to use a common reactor configuration for the different partners. Every partner has the freedom to use his own model/configuration.

Over the course of the first half of 2020, dedicated meetings were organised in which the different partners could discuss and adjust their hypotheses and their models. These meetings were organised by reactor type (PWR or VVER) and by accident type (LOCA or SGTR). For BWR and EPR no such meetings were organised since for both only one participant is going to work with these in task 2.3 and task 2.5.
As a result of these meetings a document was drafted which contains all information on the scenario's/models which was sent to all partners. This document will be used as a working document and is not intended to be publicised.

In addition a first proposal has been made for a simple methodology for the evaluation of the radiological consequences from a given environmental source term. This methodology is not yet finished but will be further elaborated and converted to a simple tool in the last months of 2020.

2.2.3.5. Task 2.3: Reactor test case simulations (lead: LEI)

During this year, the templates for the LOCA and for the SGTR accidents which should be used for communication of the results in the framework of Task 2.3 were developed. In order to do this, two video-conferences with the different partners were organized in which the structure and content of the templates were drafted (April 21st, and September 9th of 2020). Following the the first meeting a general structures (table of content) of the template was agreed upon. The second meeting was held in order to establish the detailed content of the template and in order to discuss specific some more specific points related to presentation of the results.

The different partners of the R2CA project all worked on their models/calculations in the framework of task 2.3. However at the moment of writing these models are not yet finished. This does not pose a problem since the deadline for task 2.3 is at the end of February 2021. Table 2 presents the progress of all partners in the T2.3.

Table 2: Progress of all partners for initial reactor test case simulations

Partner	Transient conditions	Model development	steady-state calculations	Transient calculation		
				Thermo-hydraulic analysis	Thermo-mechanics and core degradation analysis	Fission product behavior
LOCA						
ENEA	DBA	Developed	Finished	Ongoing	Ongoing	Ongoing
	DEC-A	Developed	Ongoing	Ongoing	Ongoing	Ongoing
HZDR	DBA	Developed	Finished	Ongoing	Ongoing	Ongoing
	DEC-A	Developed	Finished	Ongoing	Ongoing	Ongoing
IRSN	DBA	Developed	Finished	Ongoing	Ongoing	Ongoing
	DEC-A	Developed	Finished	Ongoing	Ongoing	Ongoing
VTT	DBA	Developed	Finished	Ongoing	Ongoing	Not planned
ARB	DBA	Developed	Finished	Ongoing	Not planned	Ongoing
	DEC-A	Developed	Finished	Ongoing	Not planned	Ongoing
MTA EK	DBA	Developed	Finished	Finished	Not planned	Not planned
SSTC-NRS	DBA	Developed	Finished	Finished	Finished	Finished
	DEC-A	Developed	Finished	Finished	Finished	Finished
UJV-NRI	DBA	Developed	Finished	Ongoing	Ongoing	Ongoing
LEI	DEC-A	Developed	Finished	Finished	Finished	Finished
SGTR						
Bel V	DBA	Developed	Finished	Ongoing	Not planned	Not planned
	DEC-A	Developed	Finished	Ongoing	Ongoing	Ongoing
TRACTEBEL	DBA	Developed	Finished	Finished	Not planned	Not planned
	DEC-A	Developed	Ongoing	Ongoing	Not planned	Not planned
ARB	DBA	Developed	Finished	Ongoing	Not planned	Ongoing
	DEC-A	Developed	Finished	Ongoing	Not planned	Ongoing
MTA EK	DBA	Developed	Finished	Finished	Not planned	Finished
BOKU	DEC-A	Developed	Finished	Ongoing	Ongoing	Not planned
UJV-NRI	DBA	Developed	Finished	Ongoing	Ongoing	Not planned
CIEMAT	DBA	Developed	Finished	Ongoing	Ongoing	Ongoing
	DEC-A	Developed	Finished	Ongoing	Ongoing	Ongoing
IRSN	DBA	Developed	Finished	Ongoing	Ongoing	Ongoing
	DEC-A	Developed	Finished	Ongoing	Ongoing	Ongoing
SSTC-NRS	DBA	Developed	Finished	Finished	Finished	Finished
	DEC-A	Developed	Finished	Finished	Finished	Finished

* Included release, transport and physico-chemical behaviour in containment or failed Steam Generator

2.3.WP6-DISSE (lead: ENEA)

2.3.1. Objectives

Informing society about the project and its results, going beyond the project's own community, is one of the key elements of H2020 projects. The communication, together with the dissemination and exploitation, is necessary to demonstrate and maximize the societal and economic impact of Project and shows the impact and benefit of European Research and Innovation funding. The main target of the communication activity is to communicate and promote the project by informing about the project itself and its results. The main target of the dissemination activity is to describe and make results available for use. The main target of the exploitation activity is to make use of the project results. As stated in the R2CA Grant Agreement (GA), the dissemination of knowledge and of the Project results will be performed through three main axes:

- Communication between partners within the project (intranet website, yearly technical workshops, etc);
- Education and training (Phds, mobility programme of young researchers and PhDs);
- Dissemination of knowledge (public web site, electronic newsletter, external end-users group, organisation of 2 international workshops, publication of papers, contribution to international conferences, database for IAEA).

In order to promote the project action and its results, several communication actions and activities are planned inside the project, as stated in the GA, and are described in the Communication Education & Training Action Plan (CETAP), Table 3.

Table 3: Main actions for communication and dissemination in the R2CA project and exploitation of its results

Action	**Comment**	**Type (E: External, I: Internal)**
Logo and document template	Action initiated by PC and WP6 Leader. Already done at the beginning of the project, this action is necessary to identify and give visibility to the project.	I,E
Design Material to support project Communication	Action initiated by the WP6 Leader with the support of the PC and WPLs. The brochure and poster will be created and shared with Partners, and then displayed or distributed at various events to promote the project and increase its visibility.	E
R2CA web site	Action is initiated and monitored by the PC. Creation and maintenance of a public R2CA website, with both open and restricted access.	I,E
Social Network accounts	Action monitored by WP6 Leader and PC. The creation of an account on social media can contribute to the public communication of the project (informing mass media about the project) and to the activities developed like workshops, training activities and mobility program. It can be also useful to support the communication between the Partners.	I,E

Participation to public events	Action monitored by PC, WP6 Leader and MT members. Participation to public events is encouraged. The European researcher night is one example of the public event where the project and its results can be presented.	E
Participation in side-events	Action monitored by PC, WP6 Leader and MT members. Some specific topics dealt within the project can be subject of several side-events (e.g. SNETP, ETSON, OECD/NEA, IAEA, etc.)	E
Electronic-newsletter	Action by WP6.3 leader with the support of PC and WPLs. This will be issued once or twice a year and will inform the stakeholders of the project advancement and the main activities/results.	I,E
Organization and implementation of communication activities towards international organizations and networks	Action monitored by PC, WP6 Leader and MT members. This WP will organize the communication with international organizations and networks (e.g. SNETP, ETSON, OECD/NEA, IAEA, etc.) in order to update periodically about the project status and the main achievements. At the end of the project a database will be created gathering the reference reactor case simulations to be shared with IAEA. The action related to the creation of database will be discussed along the project development.	E
Peer-reviewed scientific publications	Action monitored by PC, WP6 Leader and MT members. Journals dedicated to the nuclear community and to the academic community will be considered. Journal with open access will be considered as far as possible.	E
Conference publications	Action monitored by PC, WP6 Leader and MT members. General conferences (e.g. EUROSAFE, NURETH, NUTHOS, etc.) as well as more specific conferences dedicated either to nuclear fuel (NUMat, NUFuel, TopFuel, etc.) or will be attended by R2CA Partners	E
International Open Workshops	Action monitored by PC, WP6.3 leader. Two international workshops will be organized to disseminate among the international scientific community the main achievements and results of the project, one at the end of second year and one around the end of the project.	E
Organization of trainings on codes	Action monitored by WP6.1 leader, with the support of the PC and MT members. In order to involve effectively students and young researchers in the R2CA community but also beyond, specific training sessions on the computational tools used in R2CA will be organized in order to disseminate their use and the associated best-practices.	I,E
Creation of EUG	Action monitored by WP6.3 leader, with the support of the PC and MT members. EUG will be constituted of researchers from institutions not participating in R2CA but with a strong interest in the scientific results of the project, other stakeholders and who can directly or indirectly benefit from the project itself. Members of the EUG will be	E

	officially invited to the international workshops and trainings.	
Exploring the possibility to consolidate project results in international recognized report	Action monitored by WP6.3 leader, with the support of the PC and MT members. After the end of the project, the main results for the methodologies of best estimate evaluation of releases for DBA and DEC-A conditions can be consolidated under two possible internationally recognized reports (or even both): o OECD “State of the Art Report”; o IAEA “Safety Guides” edited by IAEA.	E
Partner activity report	All the Partners of the project are supposed to contribute to the implementation of the CETAP, considering different actions and opportunities available within their very same organizations.	I,E

Considering that the project will be developed along 48 months in order to promote and highlight all the results, different temporal actions are considered along the project duration. Considering the GA and the CETAP, the WP6 specific objectives for the 1st year are:

- Creation of logo and document template;
- Design of material to support project dissemination and communication activities;
- Creation and maintenance of a public R2CA website, with both open and restricted access;
- Creation of an account on social media that can contribute to the public communication of the project (informing mass media about the project) and to the activities developed like workshops, training activities and mobility program. It can be also useful to support the communication between the Partners.
- Distribution of project newsletter to inform the stakeholders of the project advancement and the main activities/results;
- Creation of the End-User Group (EUG) profile;
- Organization of trainings on codes;
- Collect through the Partners a first list of mobility, master thesis and training session proposals.

2.3.2. Overview of the main advances

Considering the previous objectives, the following activities have been done along the first year of activity:

- Logo and document template have been created and used for the projects presentations, reports and communication activities;
- The material to support project dissemination and communication has been created. In particular a project brochure, a poster and a project presentation have been created and are available in the project SharePoint platform.
- R2CA website, have been created. Restricted access is already in operation and has been developed at the very beginning of the project; the open access part (http://www.r2ca-h2020.eu/) is still under construction;
- Social network account has been created (LinkedIn Group and ResearchGate Project)
- R2CA electronic newsletter template has been drafted and validate and the first newsletter has been issue and distributed through the R2CA H2020 EURATOM PROJECT LinkedIn group and the Researchgate R2CA H2020 EURATOM PROJECT.
  - To promote the diffusion of scientific results and of the harmonized methodology developed within the project a EUG profile has been created. In the first newsletter interested parties have been encouraged to contact the project Coordinator through email or the project website.

- Education and training needs have been collected through the Partners and a first list of mobility, master thesis and training sessions proposals is available;
- Along the R2CA 1st Yearly Progress Meeting, a training course about the SCIANTIX code is planned. Due to the COVID 19 issues, it will be a virtual training.

Considering the COVID-19 issues and the consequent restrictions, participation at public event and to side events, have not been done during the first year activity.

In the relation to the WP6 deliverable:

- D6.1 "Communication Education & Training Action Plan (CETAP)" has been released;
- D6.2: "R2CA public website" draft design was done, work is still on-going to complete it with the necessary information.

In relation to the WP6 milestone, the MS9 and MS10 (due date: month 44) are not part of this reporting period.

2.3.3. Details of the activities performed

2.3.3.1. Task 6.1: Education & Training (lead: POLIMI)

In relation to the education and training task, education and training needs have been collected through the Partners and a first list of mobility, Table 4, master thesis, Table 5, and training session proposals, Table 6

, are available. Along the R2CA 1st Yearly Progress Meeting, a training course about the SCIANTIX code is planned (October 16, 2020). Due to the COVID 19 issues, it will be a virtual training.

2.3.3.2. Task 6.3: Communication Activities (lead : ENEA)

Along this first reporting period, the following activities have been done:

- A communication action plan including also the training action plan has been released and have been called Communication Education & Training Action Plan (CETAP);
- Logo, Figure 1, and document templates for reports and presentations, **Erreur ! Source du renvoi introuvable.** and
- Figure 3 respectively, have been created and consolidate;
- Project brochure, Figure 4 and Figure 5, and poster, Figure 6, have been prepared and are available in the project SharePoint platform;
- H2020 EURATOM PROJECT LinkedIn group (https://www.linkedin.com/groups/12404880/),
- Figure 7, and ResearchGate R2CA H2020 EURATOM PROJECT (https://www.researchgate.net/project/R2CA-H2020-EURATOM-PROJECT), Figure 8, have been created.
- First Electronic newsletter (5 pages newsletter) have been issued and also distributed through R2CA H2020 EURATOM PROJECT LinkedIn group and the ResearchGate R2CA H2020 EURATOM PROJECT. The first page of the newsletter is shown in Figure 9.
- To promote the diffusion of scientific results and of the harmonized methodology developed within the project, an EUG has been created, open to safety authorities, technical support organizations, NPP owners, Vendors, thermal-hydraulics, fuel and source term experts, and Universities with curricula in nuclear reactor safety. EUG members may express their needs and opinions in the field of thermal-hydraulics, fuel and source term, will approach the methods developed during the project, will become familiar with them, and will present their approach to project results thus showing its exploitation. They

will participate in the periodic workshops, training courses and summer school foreseen for the future.. Applications will be approved yearly by the project Steering Committee. The EUG candidate profile is shown in Figure 10. Three Organization currently applied to be part of R2CA EUG:

- Vattenfal (Sweden);
- Sapienza Università di Roma (Italy);
- Politecnico di Torino (Italy).

The first year of the project has been dedicated to developing digital tools of the project which will allow communication between partners (a SharePoint platform) and presentation of the project for the scientific community (a Website). The SharePoint platform has been developed at the very beginning of the project. This website has been presented to partners at the Kick-Off-Meeting in November 2019. The aim of this SharePoint platform is to collect and share with all partners useful documents of the project: publications, deliverables. This platform has been designed to upload 5 000 documents and less than 20 Go as total size of all uploaded documents. A registration procedure is required to access to the page and it is possible for each partner to access to this site. Each participant is classified into groups providing specific rights following their role in the project. The base group is the 'contributors' with read and modification rights. There is also an 'approvers' group (same rights and access to the Workflow) constituted by the Management Team of the project. A Workflow for the validation of the documents of the project is also planned but this module is not fully operational. The platform, Figure 11, has been built with many folders in order to structure:

- Consortium Agreement
- WP1
- WP2
- WP3
- WP4
- WP5
- WP6
- SEG
- Deliverables
- Publications
- Project Meetings
- Project Library
- Templates

Major information concerning the project was also published on the Home Page of this site (meeting announcements). The project coordination encouraged each participant and in particular Task-Leaders and Work-Package Leaders to contribute and to upload/download in this platform.

The second digital tool of the project is the Website of the project, which will be accessible at the following address http://www.r2ca-h2020.eu/. This HTML website is still under construction and it will be dedicated to the dissemination of the project information to the scientific community. A short description of the project is provided and a focus is done on the dissemination activities of the project (training schools, mobility programs). A draft has been recently designed and the production step of the Website is now in progress, Figure 12.

Table 4: Mobility proposal collected

#	WP / Task	Duration	Staff involved	Envisaged period	Home organization	Host organization	Supervisor home organization	Supervisor host organization	Contact	Scientific objective	Justification for mobility
1	4.2	3 months	Post-doc	*To be defined*	POLIMI	JRC-Ka	Lelio Luzzi	Paul Van Uffelen	lelio.luzzi@polimi.it paul.van-uffelen@ec.europa.eu	1) Finalize the interface between SCIANTIX and TRANSURANUS and adapt code for inclusion of the new ANS5.4 model in the code 2) Model benchmarking (with MFPR-F, ANS5.4, FISPRO2)	1) Direct interaction with TRANSURANUS developers allows for speed up in identification of needs and problem solving 2) additional experimental data available at JRC can be used for code validation
2	4.3	1 month	PhD/Post-doc	*To be defined*	POLIMI	CIEMAT	Lelio Luzzi	Luis E Herranz	lelio.luzzi@polimi.it luisen.herranz@ciemat.es	Couple SCIANTIX with FRAPCON/FRAPTRAN for the fuel performance code to benefit from the envisaged work on fission gas behaviour modelling	Direct interaction with the users of FRAPCON/FRAPTRAN allows for speed up in identification of needs and problem solving
3	2.6	1 to 3 months	MSc student	*To be defined*	POLIMI	Bel V	Lelio Luzzi	Albert Malkhasyan	lelio.luzzi@polimi.it martina.adorni@belv.be	Fuel behaviour calculations with TRANSURANUS/ SCIANTIX of Belgian PWR-1000 fuel to complement CATHARE and MELCOR calculations performed by Bel V	Evaluation of interest and feasibility of proposal of new simulation strategies and best practices proposals for safety assessments
4	3.2	2 months	PhD student	*To be defined (2021)*	LEI	IRSN	Tadas Kaliatka	Francois Kremer	tadas.kaliatka@lei.lt francois.kremer@irsn.fr	Evaluation of thermo-mechanical and thermo-chemical property evolution of BWR fuel by means of MFPR-F, which will be coupled with TRANSURANUS	Direct interaction with the developers of the MFPR-F code allows for speed up in identification of needs and problem solving, especially when coupling with the TRANSURANUS code (under development at IRSN and JRC)
5	4.2	1 - 2 months	PhD/Post-doc	*To be defined*	BOKU	NINE	Nikolaus Müllner	Marco Cherubini	nikolaus.muellner@boku.ac.at	Reevaluation of the fission product transport SGTR transient	Direct access to expertise. Feedback and improvement of the developed models.
6	5.1	1 - 2 months	PhD/Post-doc	*To be defined*	BOKU	NINE	Nikolaus Müllner	Marco Cherubini	nikolaus.muellner@boku.ac.at	Optimization of accident management, evaluation of measures and benefits.	Direct Interaction with the task leader, feedback on and discussion of AM measures

Table 5: Thesis proposal collected

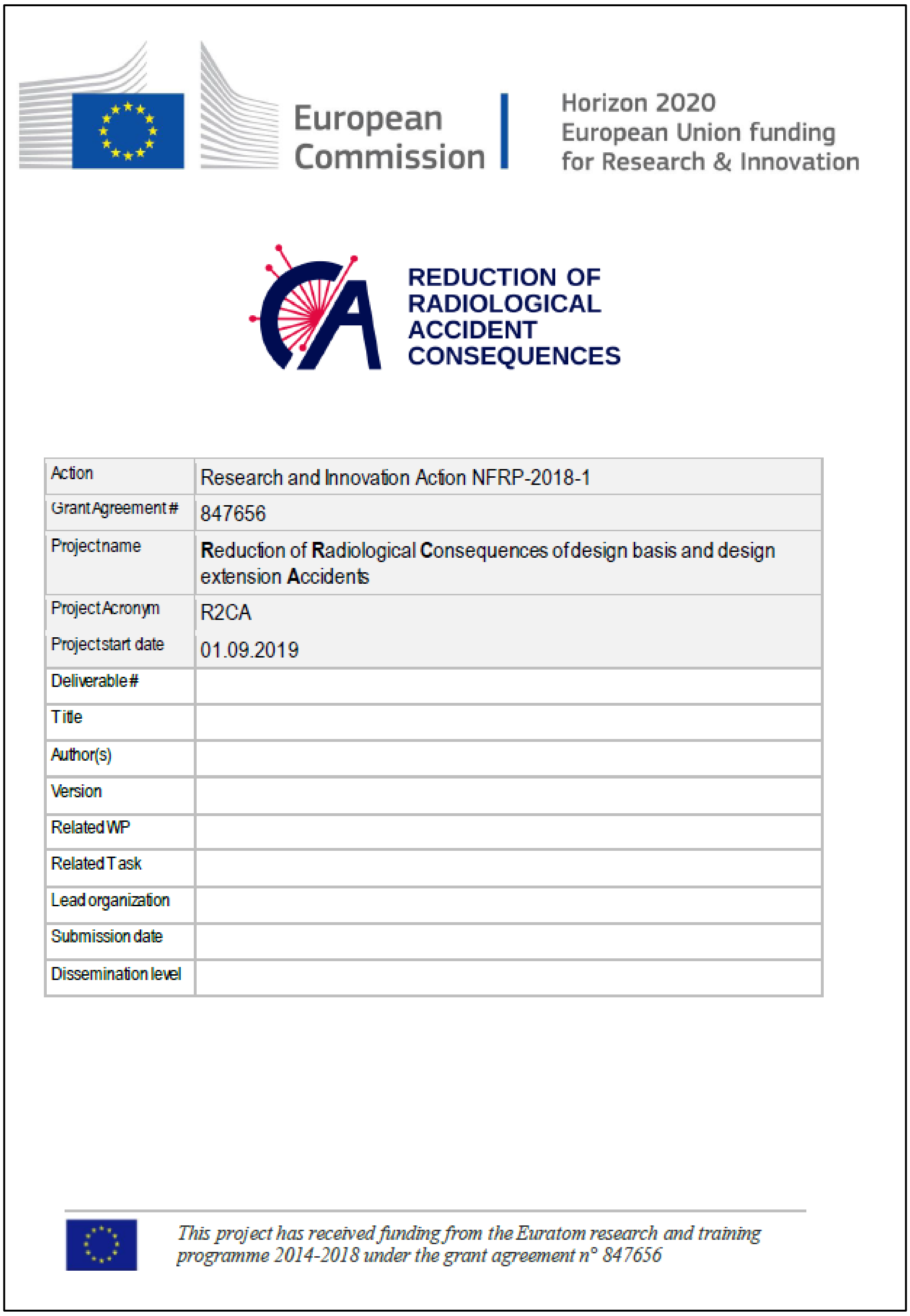
#	WP / Task	Duration	Envisaged period	Supervisor	Contact	University	Scientific objective
1	4.2	9 months (MSc)	Nov. 2020 - July 2021	Lelio Luzzi	lelio.luzzi@polimi.it	POLIMI	Include a new model for radioactive fission product release (new ANS5.4) in the SCIANTIX code. Improvements to the model are going to be considered along the thesis work, along with benchmarking
2	5.2	24 months (post-doc)	2021-2022	Karine Chevalier	karine.chevalier-jabet@irsn.fr	*not yet known*	Quantify uncertainties related to the FP behavior in fuel/primary circuit. Build and validate a fast physical model for the behaviour of contamination in fuel/primary circuit aggregating the results of detailed codes and their uncertainties

Table 6: Training proposal collected

#	Code / subject	Duration	Envisaged period	Host organization	Lecturer/Tutor	Proprietary issues for training purpose (Yes/No)	Contact	Other Notes
1	TRANSURANUS / fuel performance code	1 week	*not yet defined*	JRC-Ka	P. Van Uffelen, A. Schubert, Z. Soti (JRC)	Yes, organization sending trainee must have a TRANSUNANUS user license agreement	paul.van-uffelen@ec.europa.eu	Laptops of JRC are made available for trainees during course
2	SCIANTIX / meso-scale code for fission gas behavior modelling	half day	R2CA 1st progress meeting (On-line, October 16, 2020)	ENEA-POLIMI	D. Pizzocri L. Luzzi (POLIMI)	No (SCIANTIX is open source software)	lelio.luzzi@polimi.it	Training sessions can be organized/carried out using participants' laptops
3	DRACCAR/ 3D Thermo-mechanical code	3 days	R2CA 2nd progress meeting (October 2021)	*not yet defined*	S. Belon T. Glantz (IRSN)	Yes, organization sending trainee must have a DRACCAR user license agreement	gaetan.guillard@irsn.fr	IRSN laptops or participant laptops if trainees have a DRACCAR user license agreement

REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

Figure 1: R2CA LOGO.



European Commission

Horizon 2020
European Union funding
for Research & Innovation

REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

Action	Research and Innovation Action NFRP-2018-1
Grant Agreement #	847656
Project name	**R**eduction of **R**adiological **C**onsequences of design basis and design extension **A**ccidents
Project Acronym	R2CA
Project start date	01.09.2019
Deliverable #	
Title	
Author(s)	
Version	
Related WP	
Related Task	
Lead organization	
Submission date	
Dissemination level	

This project has received funding from the Euratom research and training programme 2014-2018 under the grant agreement n° 847656

Figure 2: R2CA Report template (front page)

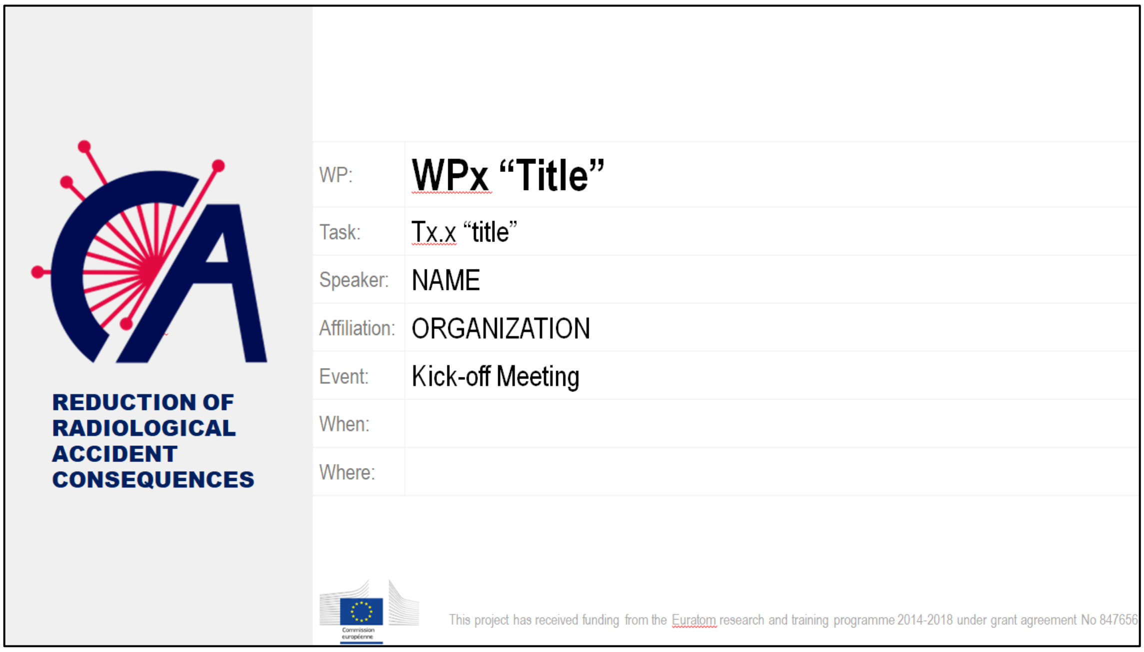


Figure 3: R2CA presentation template (front page).

Figure 4: R2CA project brochure page 1.

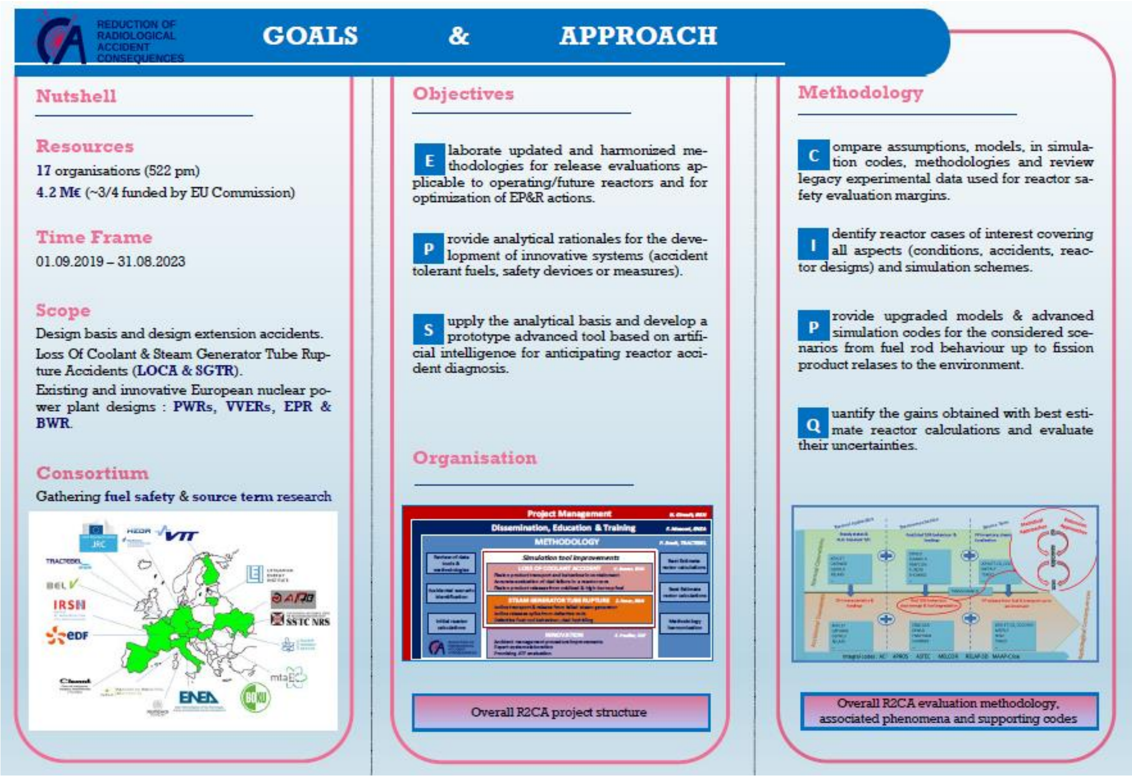


Figure 5: R2CA project Brochure page 2

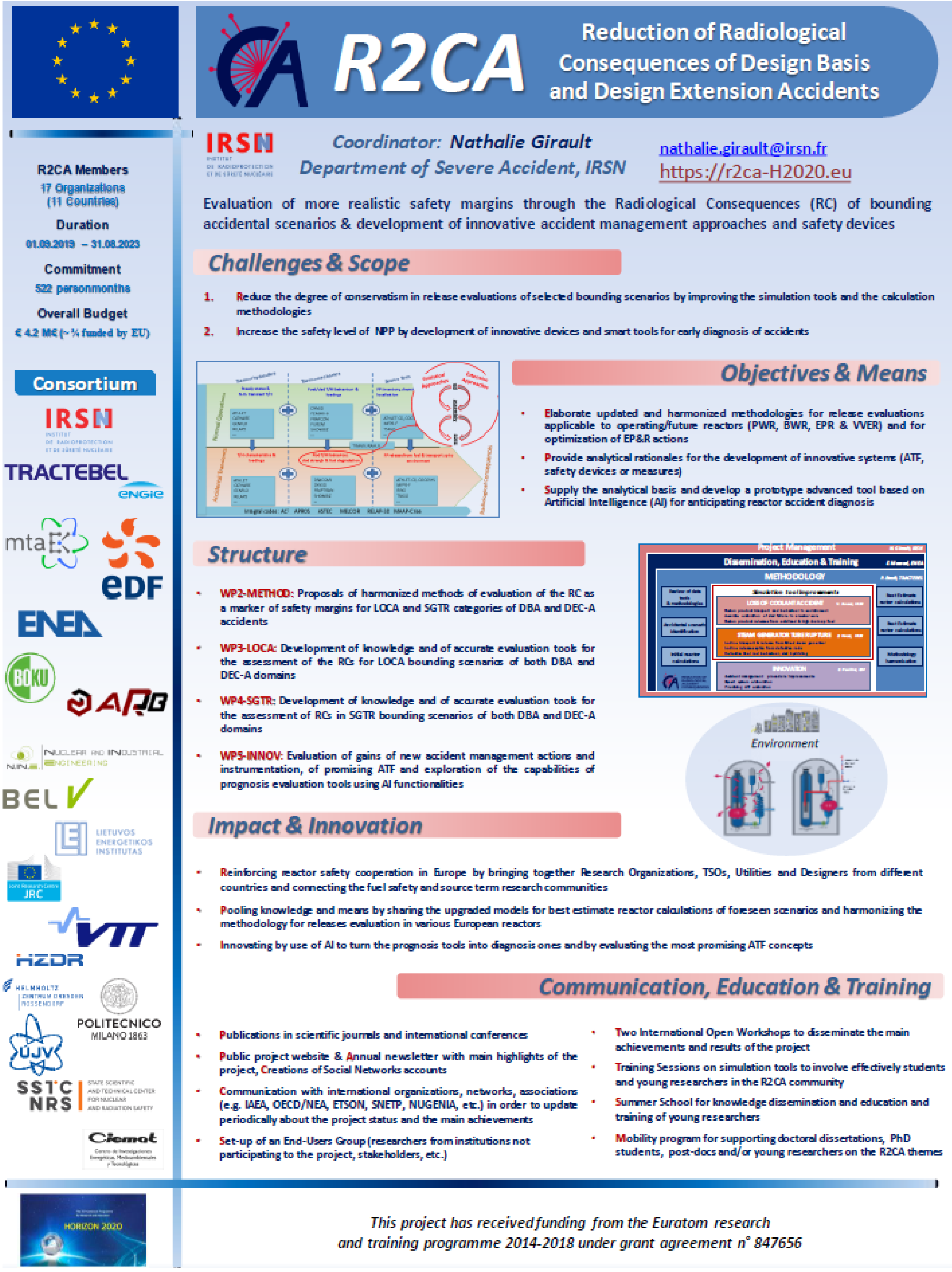


Figure 6: R2CA Poster

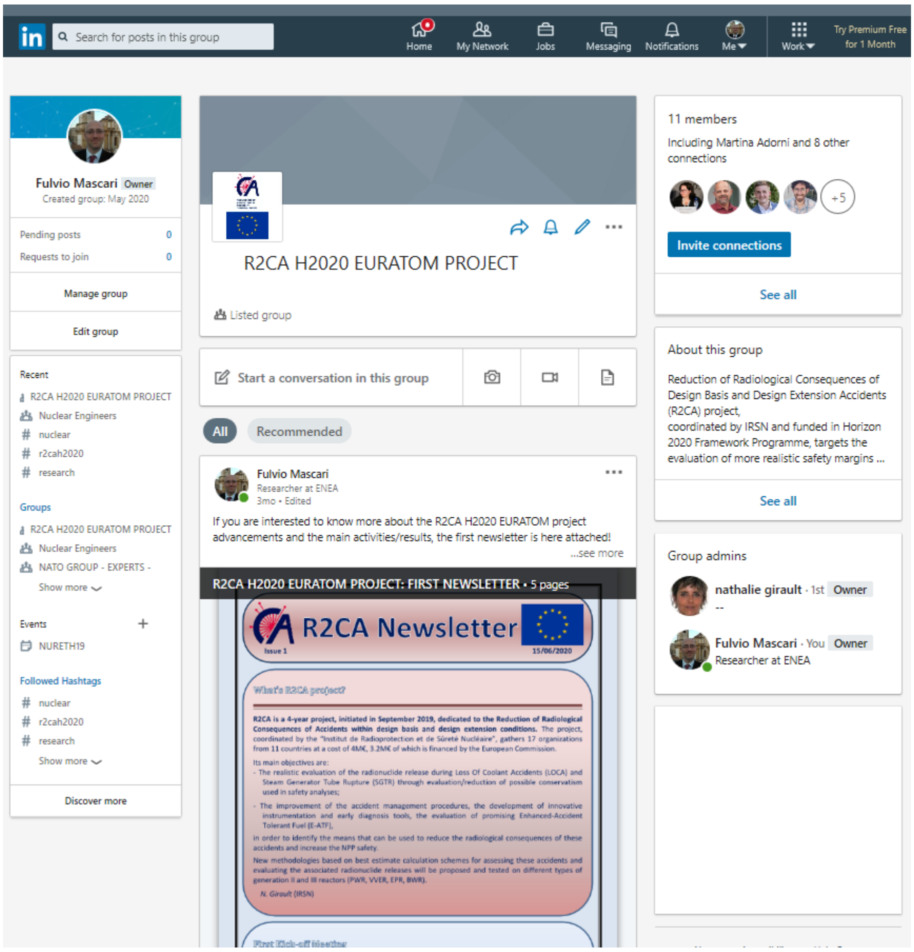


Figure 7: R2CA H2020 EURATOM PROJECT LinkedIn Group view

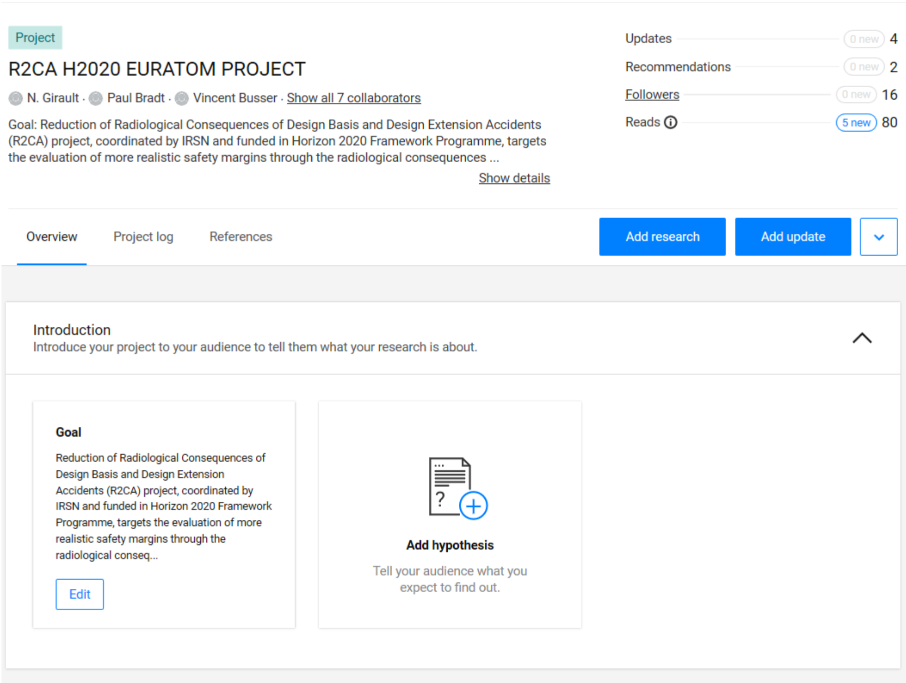


Figure 8: R2CA H2020 EURATOM PROJECT ResearchGate Project view

R2CA Newsletter

Issue 1

15/06/2020

What's R2CA project?

R2CA is a 4-year project, initiated in September 2019, dedicated to the Reduction of Radiological Consequences of Accidents within design basis and design extension conditions. The project, coordinated by the "Institut de Radioprotection et de Sûreté Nucléaire", gathers 17 organizations from 11 countries at a cost of 4M€, 3.2M€ of which is financed by the European Commission.

Its main objectives are:

- The realistic evaluation of the radionuclide release during Loss Of Coolant Accidents (LOCA) and Steam Generator Tube Rupture (SGTR) through evaluation/reduction of possible conservatism used in safety analyses;
- The improvement of the accident management procedures, the development of innovative instrumentation and early diagnosis tools, the evaluation of promising Enhanced-Accident Tolerant Fuel (E-ATF),

in order to identify the means that can be used to reduce the radiological consequences of these accidents and increase the NPP safety.

New methodologies based on best estimate calculation schemes for assessing these accidents and evaluating the associated radionuclide releases will be proposed and tested on different types of generation II and III reactors (PWR, VVER, EPR, BWR).

N. Girault (IRSN)

First Kick-off Meeting

The First kick-off meeting of the European project R2CA was held in Fontenay-aux-Roses from 20 to 22 November 2019. It gathered about 40 European experts and allowed to converge on the first studies of interest to be launched.

On this occasion, the first advances were also shown mainly concerning the reviews of the methodologies used in different countries for evaluating the radionuclide releases, of the various simulation tools and calculation schemes that will be used during the project, and of the experimental data available for the analysis of the two transients of interest (LOCA & SGTR).

V. Busser (IRSN)

Figure 9: Front page of the R2CA Newsletter (issue1).

REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

End Users Group (EUG) candidate profile

EUG will be constituted of researchers from institutions not participating in R2CA but with a strong interest in the scientific results of the project and harmonized methodology developed, other stakeholders and who can directly or indirectly benefit from the project itself.

Mission

During the course of the project, their mission is mainly dedicated to the exploitation of the results and the continuos involvement and participation to the Project. EUG members should:

- Express their needs at the project's start and be kept informed on the progress of activities all along the project;
- Participate to project initiatives like workshops, training sessions and summer school. These events will allow them to approach the methods developed during the project, become familiar with them, and to present their approach to project results thus showing its exploitation;
- Evaluate the pertinence and applicability of the harmonized methodology developed for release evaluations for operating/future reactors and for optimization of EP&R actions through the cross-analyses with the Senior Expert Group members.

Required profile

Any organization interested in the involvement and participation to the R2CA project initiatives and in using the methodologies developed in the project, including, for example:

- Safety authorities,
- Technical support organizations,
- NPP owners,
- Vendors,
- Research institutes with interest in thermal-hydraulics, fuel and source term;
- Universities with Curricula in nuclear reactor technology.

Support documents	
Web site	

Application

The organization can send its application by Email to the Project Coordinator, Nathalie Girault (nathalie.girault@irsn.fr) arguing the interest on the EUG mission and highlighting the consistency between its profile and the required profile. The selection is based on the application and falls within the Steering Committee's abilities. Approval of the inclusion in the EUG will be done once per year.

Figure 10: EUG candidate profile

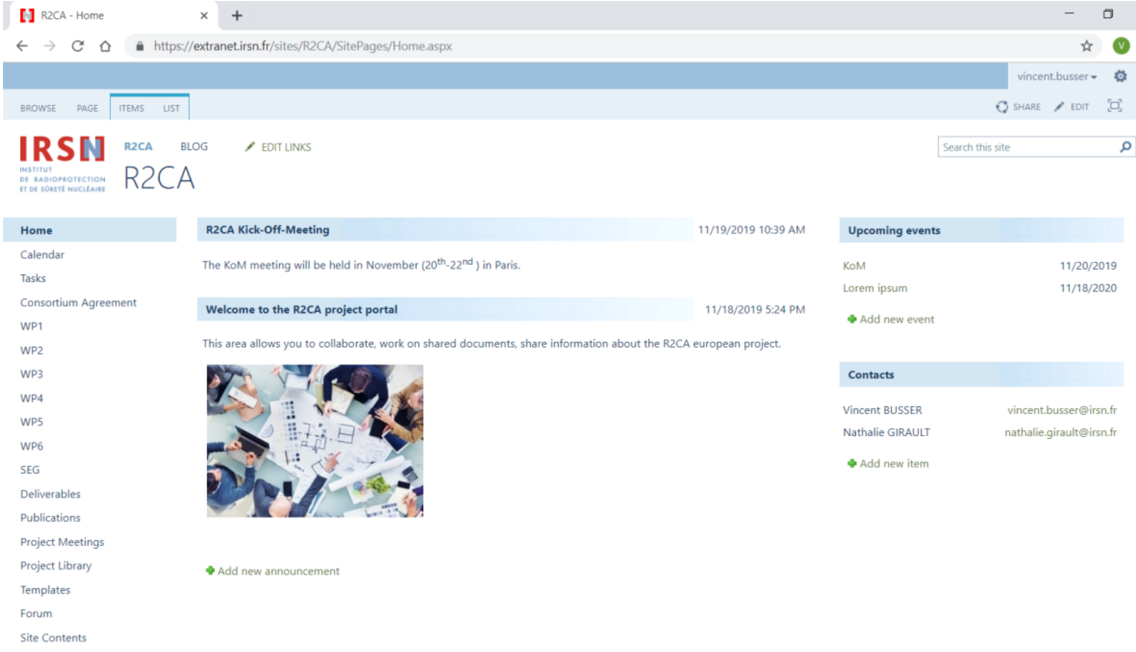


Figure 11: R2CA SharePoint platform view

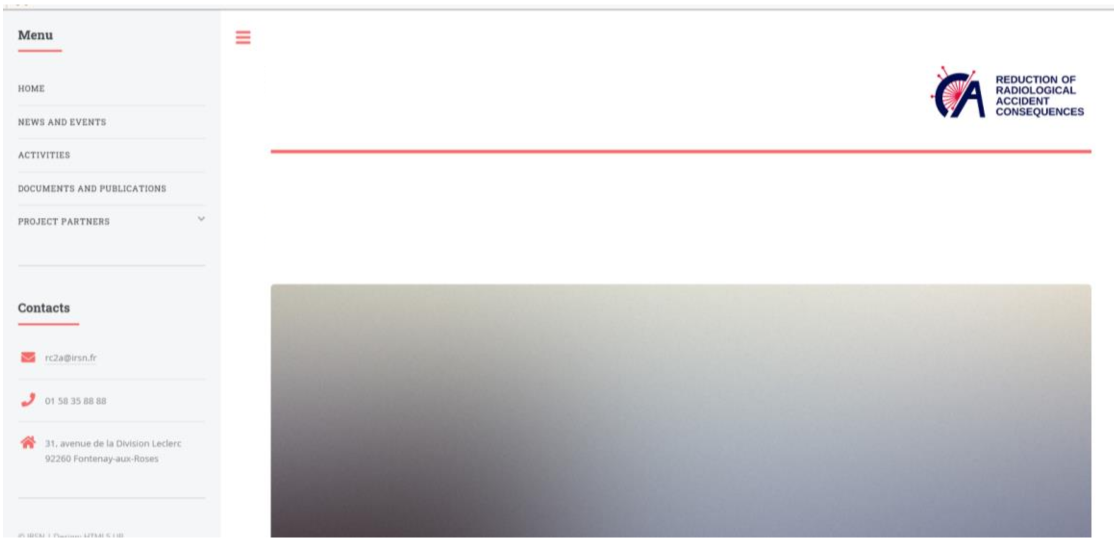


Figure 12: Draft view of the Website of the project

3. PERSPECTIVES

As work for WP3, WP4 & WP5 only started in July 2020 and was impacted by the COVID-19 situation, only a recall of general objectives together with an overview of the work planned focused on the coming year will be described in this section based on the “Programs of Work” issued for each of those WPs after the Kick-off meeting.

3.1.WP3-LOCA (lead: IRSN)

This Work Package aims to improve the different simulation tools and models used to analyse to the LOCA transients and to evaluate the corresponding releases. It will focus on modelling fuel rod cladding failure and calculating the quantity of failed cladding in the reactor core, evaluating releases of fission products into the RCS and their transport to the environment.

It is planned to develop the knowledge and the accurate evaluation tools dealing with the evaluation of the radiological consequences of loss of coolant conditions for bounding scenarios of both DBA and DEC-A domains. To that extent, existing databases and models will be revisited and existing codes will be enriched and adapted. Code improvements will be on both accident progression and source term up to the environment related phenomena.

Concerning WP3, as this work package is planned to start in July 2020, the project coordination takes profit of this first year to define more precisely the proposed work in this frame. To that extent, each partner was asked to contribute to an additional report: Program of Work WP3 regarding to final allocated budget for each task. This report was issued in February 2020 as an internal confidential report of the project.

The management of the project has concentrated efforts on the coordination of the different actions of partners. Indeed, some actions are intrinsically linked because they require identical tools and developments performed by some partners will benefit others.

The first perspectives for the WP3 within each task are respectively described below.

3.1.1. Task 3.1: Fission product transport and release from the primary circuit to the environment (lead: UJV_NRI)

The main objective of Task 4.1 is to improve models and codes for the simulation of fission products behaviour during a LOCA transient. It concerns:

- Reassessment of the database (FP transport up to environment) constituted in the frame of task 2.1.3,
- Review of the functionality of the codes: ASTEC/ELSA, TRANSURANUS, MELCOR
- First developments in the codes: ATHLET-CD.

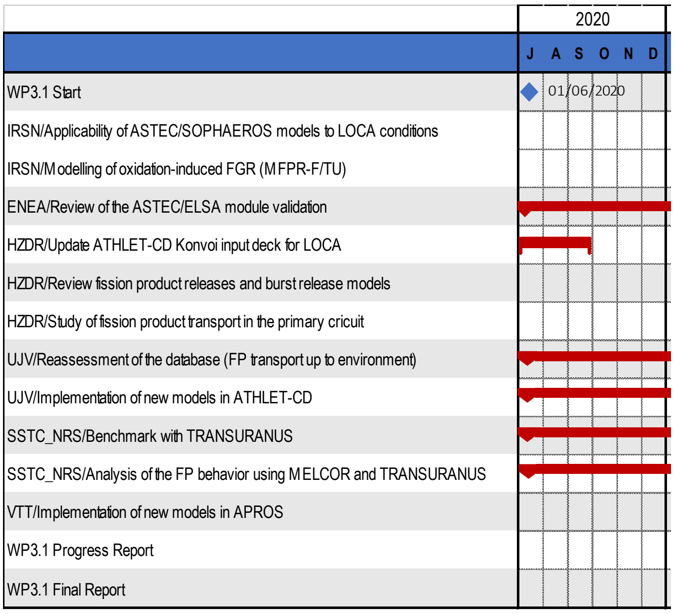


Figure 13: WP Task 3.1 activities during the first year

3.1.2. Task 3.2: Evaluation of the failed rod number (lead: IRSN)

The main objective of task 3.2 is to better predict the number of failed rods during a LOCA transient at the whole reactor core scale. It concerns:

- Clad burst reassessment and new clad burst models development following the work performed in the frame of task 2.1.3,
- Definition of a strategy to model the whole core of the reactor (IRSN/LEI/JRC/VTT/UJV/SSTC_NRS),
- First developments in the codes: TRANSURANUS.

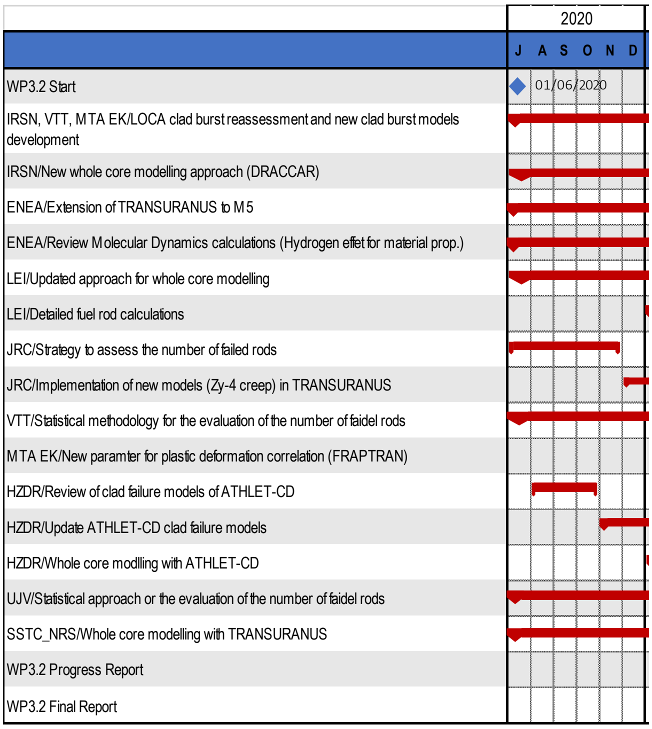


Figure 14: WP Task 3.2 activities during the first year

3.1.3. Task 3.3: Fuel rod behavior during LOCA transient (lead: JRC)

The main objectives of task 3.3 are to better simulate the fuel rod behavior during a LOCA transient and the associated fission gas and fission product releases. It concerns:

- Reassessment of experimental database for fuel rod behavior following the work performed in the frame of task 2.1.3,
- Definition of new models: transport of the gas in the rod,
- Review of the functionality of the codes: FRAPTRAN
- First developments in the codes: DRACCAR, SCIANTIX, FRAPTRAN.
-

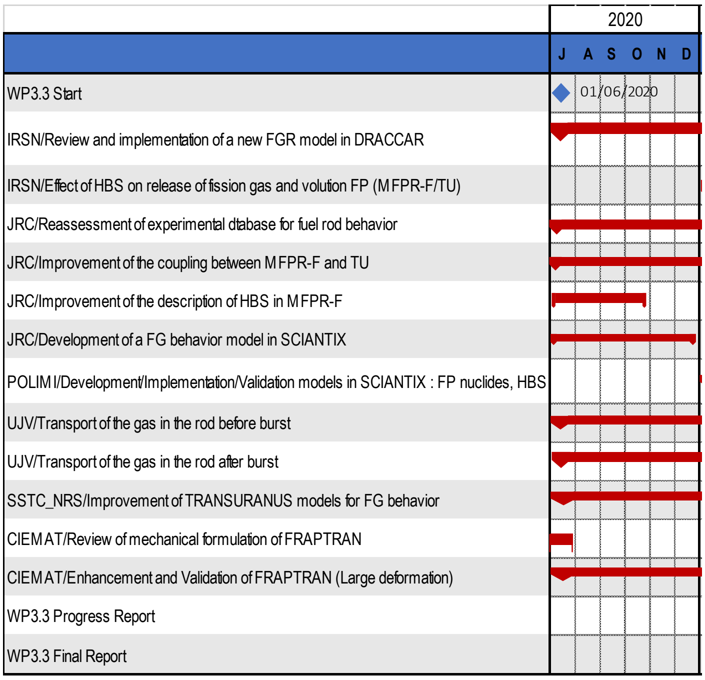


Figure 15: WP Task 3.3 activities during the first year

3.2. WP4-SGTR (lead: EK)

During the first year of the project the detailed work plan for each task and for each partner were identified and summarised in the document “Detailed Program of Work for WP4”.
Seven WP4 deliverable documents were specified, but it is expected that WP4 partners will produce a significant number of technical reports beyond the deliverables.

The work package is divided into 3 tasks.

3.2.1. Task 4.1: Fission product transport and release from the primary circuit to the environment (lead: CIEMAT)

The main objective of Task 4.1 is to improve models and codes for the simulation of fission products behaviour during a SGTR transient. It concerns:

- Fission product transport and behaviour (especially for iodine) in the primary circuit,
- Fission product behaviour in failed steam generator, release to the secondary side and environment

The models of fission product release and transport in integral and stand-alone codes (ASTEC; AC; MELCOR; MAAP and others) will be revisited and their applicability to SGTR DBA and DEC-A conditions assessed. To do so, the database of fission product release and transport will be gathered and their suitability to the conditions of interest assessed. Proposals, if necessary, for improvement/adaptation of integral computer codes (such as ASTEC or MELCOR) are foreseen. The potential optimization of EP actions by accounting for the enhancements achieved in an EP&R dedicated tool (MAAP-crisis) is also considered.

The planned activities of each partner are shown in Figure 16. It can be noted that several activities were launched in 2020. At the time of writing this document the contribution was not specified by BOKU.

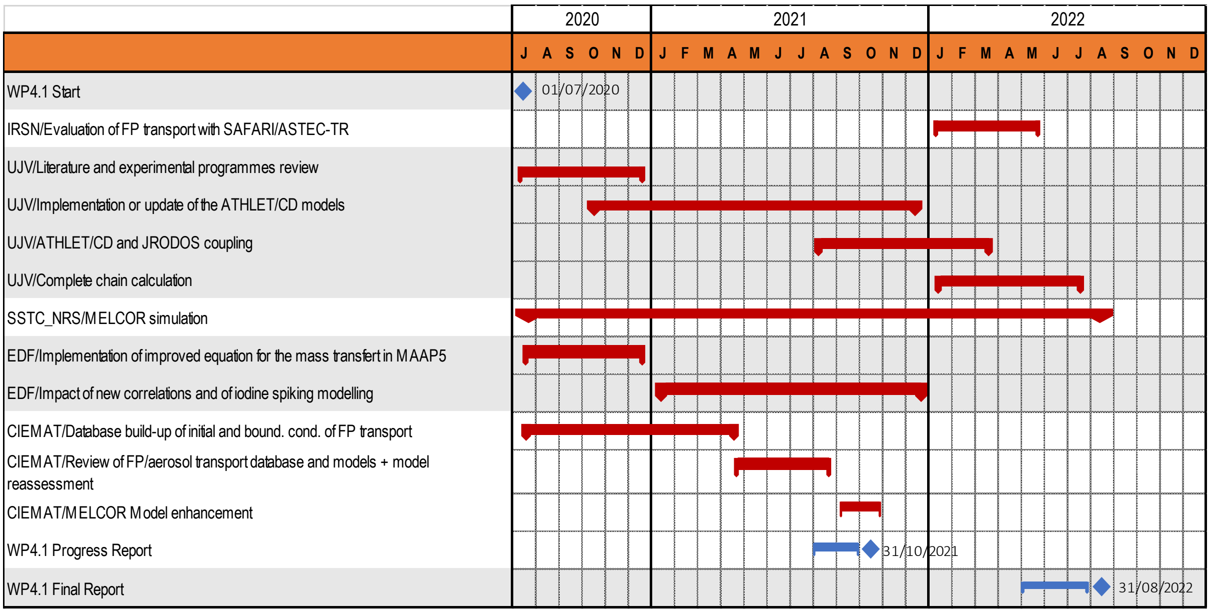


Figure 16: Summary of WP Task 4.1 activities

3.2.2. Task 4.2: Fission product releases from defective fuel rods during SGTR transient (lead: POLIMI)

The main objectives of task 4.2 are to better predict the complex fuel pellet behaviour of defective rods during a SGTR transient and the iodine spiking phenomena. It concerns:

- Fission product releases, especially iodine from defective fuel rods during SGTR transient;
- Complex fuel behaviour in defective fuel rods (especially oxidation, secondary hydriding...).

The planned activities of each partner are shown in Figure 17. It can be noted that most of the partners started their activities in 2020.

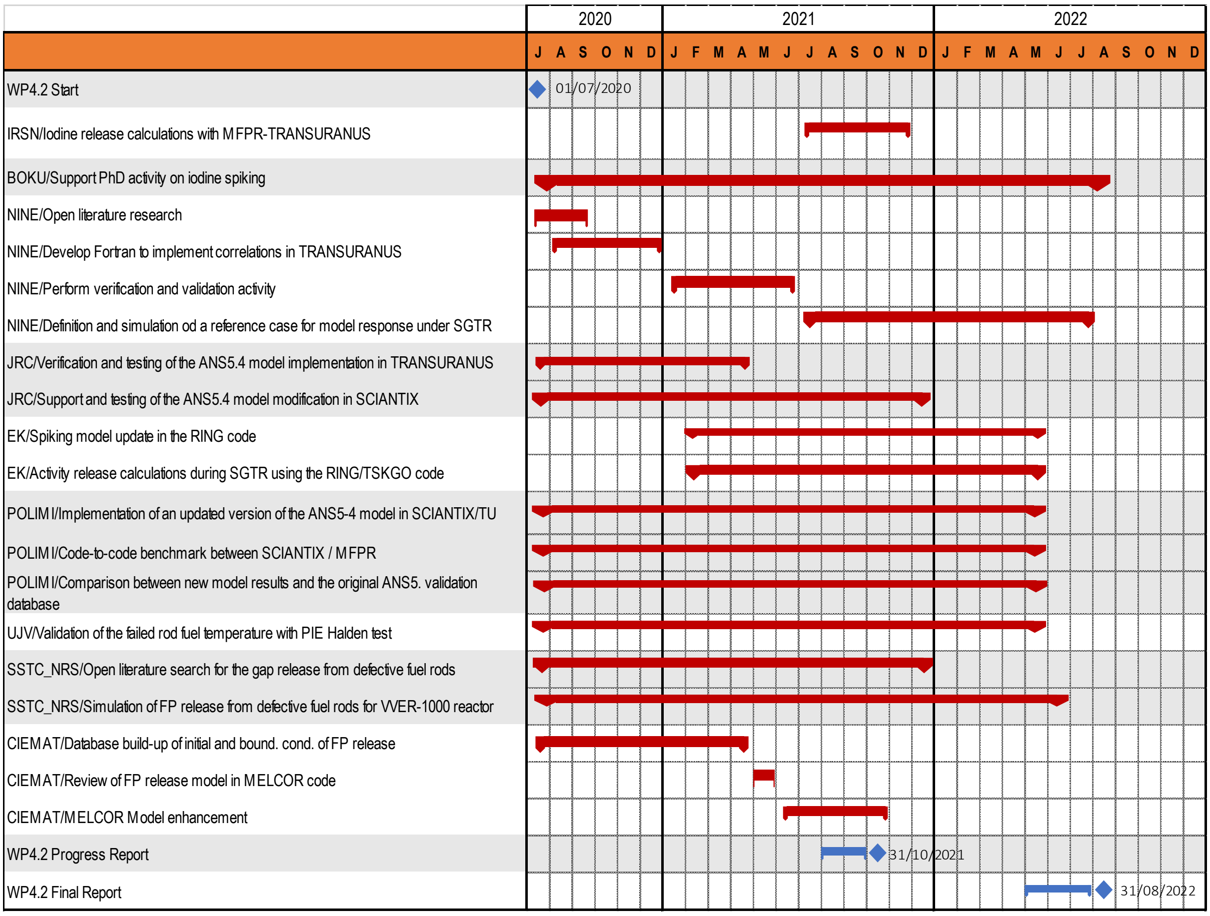


Figure 17: Summary of WP Task 4.2 activities

3.2.3. Task 4.3: Secondary hydriding phenomena of defective fuel rods and its impact on failure behaviour (lead: IRSN)

The main objective of task 4.3 is to study the secondary hydride formation on the inner clad part of defective fuel rods during an in-reactor operation and SGTR transient and its impact on fuel rod failure. It concerns:

- Identification of the secondary hydriding process
- Evaluation of the associated clad mechanical embrittlement
- Determination of a failure criterion for defective fuel rods

The planned activities of each partner are shown in Figure 18. It can be noted that several activities were launched in 2020. At the time of writing this document the contribution was not specified by BOKU.

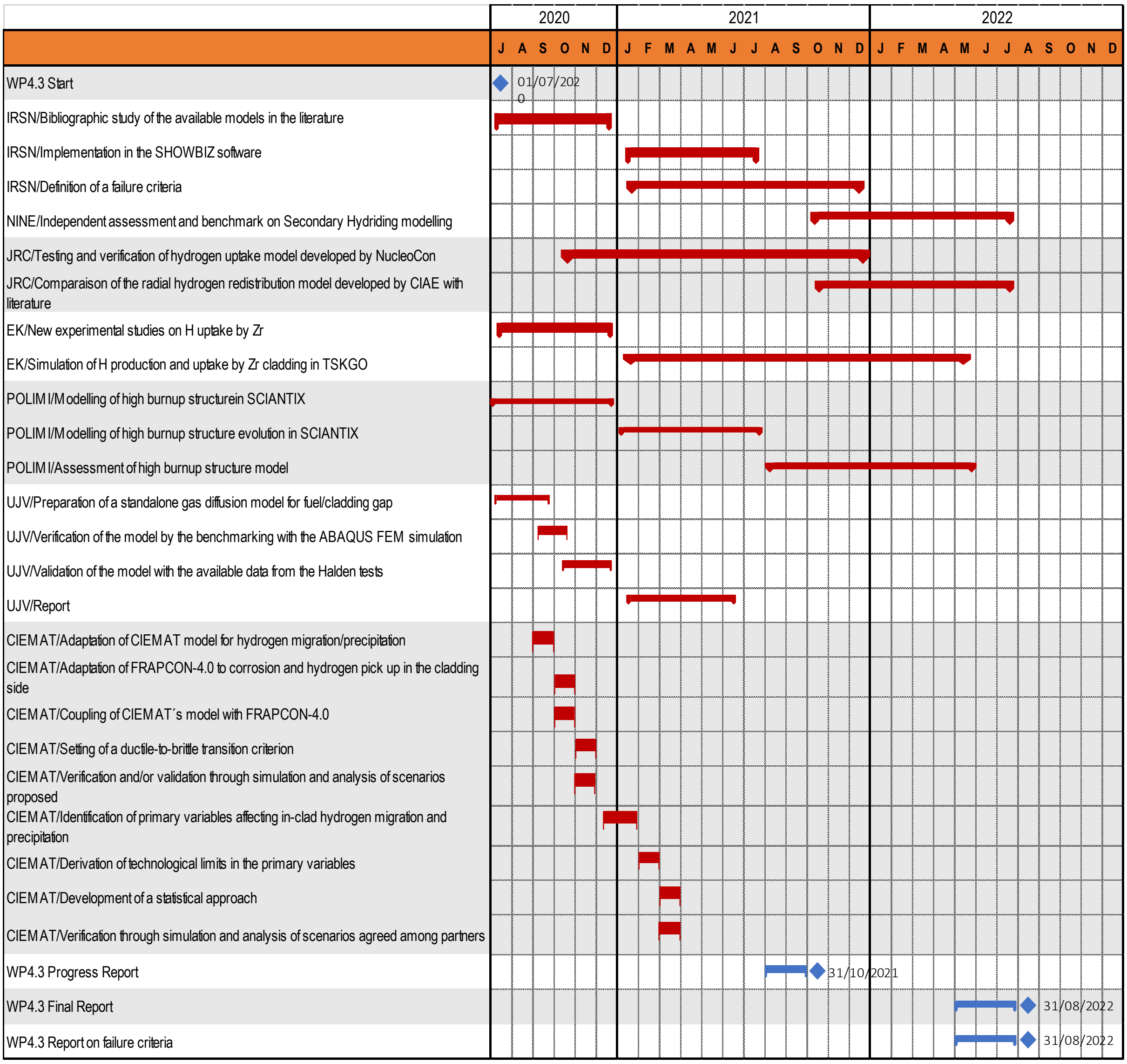


Figure 18: Summary of WP Task 4.3 activities

3.3. WP5-INNOV (lead: EDF)

3.3.1. Task 5.1: Report on pro and cons of innovative devices and management approaches (lead: NINE)

Within the Task 5.1, the approach for the needed innovative devices has been further developed.
The innovative devices and procedures are particularly relevant for these three elements

- Predictive. This element is related to the prediction of the plant behaviour as a consequence of an action of the user or the intervention of a system. Prediction quality and prediction validity time interval can be improved by the availability of suitable devices fully integrated with tool for analysis and calculation. In a plant the instrumentation is generally strongly oriented to plant management during normal operation (basically focused on power management) and safety management. However, a set of new and innovative devices should be necessary to make available proper quantities more suitable for the analysis tools in general having specific requirement for the input data

- Preventive. This element is partially related to the previous one (prediction). However, in this framework, this aspect is more focused on the analysis of the conditions due to specific consequence. The set of devices and tools used for the prevention covers conditions more complex and possibly more severe than the conditions object of the prediction. The adverse consequence of the actions of the operator and systems actuation are evaluated together the possible failure of some systems and the occurrence of external events. That analysis includes more powerful tool and the availability of the effective status of the plant in each time. In this case also, dedicated innovative devices should be properly designed and implemented.
- Mitigation. This element implies an accident is occurred. The main aspects are constituted by:
    - Availability of devices capable to work in the harsh environmental conditions occurring during an accident. Those devices include sensors and actuators of systems and components
    - Availability of the necessary data to feed the tools for the analysis
    - Availability of innovative tools capable to reproduce with the needed accuracy the conditions of the plant and to simulate all the relevant phenomena occurring during the accident

  If these prerequisites are fulfilled, more specific and more effective procedures can be developed.

The first element (predictive) is only partially covered by the goal of the project. But it is important to put in evidence that this element can be a relevant interface for the preventive element. The actions performed in the normal management of the plant can have consequences that are relevant for the preventive aspects e.g. the proper definition of the status of the plant evaluated by the predictive aspect should be used an input for the preventive aspect.

As a main consequence of the above discussion, the identification of innovative devices (both hardware and software) which should assist and help the operator in increasing the understanding on potential progression of an accident (e.g. DEC category accident originated by (LOCA or SGTR) with the main focus on the source term, is necessary.
The above subdivision in three main aspects helps in define the specific requirements for the innovative devices to have a better fit to the considered final use and related implementation. Of course each possible solution has advantages and drawbacks to be evaluated.

A questionnaire is under preparation to collect the suggestions and opinions of plant operators either directly participating in the project and/or that can be reached out by the project participants in order to address the following aspects:

- The data, related instrumentation and environmental conditions of working for it, needed and expected to provide the operator with a comprehensive view of the plant status to evaluate the possible source term.
- Software tools capabilities to inform the operator about the consequences resulting from the actions of the operator and systems actuation during the accidents. This includes data acquisition, data processing and data presentation.

From the above discussion derives that a larger amount of data will be managed. This implies some analyses processes and decision systems could be necessary to work in an automatic way. Those processes can be based on the development of suitable Artificial Intelligences or based on the analysis of large DB, or any other similar approach. It is important to note that those elements are not analysis tools offering some results, but they are systems capable to take decisions with a certain degree of independence from the operator. The operator could be moved to a supervisor position giving only the final consensus or having the role to set the initial parameters to regulate processes and systems especially for the case of fast reactions demand, overcoming the operator capacity (e.g. in analogy with Automatic Driver Systems in automotive).
All those aspects will be included in the questionnaire under preparations.

3.3.2. Task 5.2: Report on innovative diagnosis tools and devices (lead: IRSN)

Within the Task 5.2 IRSN work has started. The following subjects are currently being addressed:

- A specification of the tool is in progress and more specifically a state of the art survey of existing defect diagnosis tools as well as;
- A bibliographic study on AI techniques dedicated to fault detection.

In parallel, the NINE support on the following items is in progress. The current work is performed focusing on:

- Definition of the concepts of "artificial intelligence" and of its possible strategy of application in the safety nuclear environment.
- Definition of the fundamental requirements of such a tool: main functions to be included and expected results to be produced. On this respect NINE will synthetize partners' suggestions who wishes to contribute.

Taking into account those elements an important preliminary aspect has been identified: overview of the comparison between Artificial intelligence (AI) and Natural Intelligence and interfaces between the AI and human operator. This has been identified as a basic aspect to understand the possible role of the AI, taking as reference the performance of a human operator.
Developing this aspect, the AI applied to the nuclear field should include:

- Intuitive problem-solving approach: capability to solve problem not only based on algorithms and without all the need data.
- Representation of the knowledge. capability to represent and to link different concepts
- Set of goals; awareness, setting and evaluating priorities
- Learning: capability to modify and/or to introduce new elements and capabilities not previously included

One important issue is constituted by the validation of the proposed AI tools. The principles for the methods and procedures for the Verification and Validation (V&V) of such a tool will be identified taking into account regulatory requirements and restrains. However new approaches and procedures should be properly designed for those advanced tools.

3.3.3. Task 5.3: Report on pro and cons of Accident Tolerant Fuels (lead: EDF)

The different steps for the final evaluation of promising ATF concepts (claddings and fuels) have been identified and a clear roadmap elaborated consisting in:

1/ A bibliographic review
2/ Implementations of sensitivity analysis capabilities into fuel performance codes
3/ Sensitivity analyses with fuel performance codes
4/ Benchmarking ATF against standard UO_2/Zr concept

During the first year the bibliographic survey of various concepts of Accident Tolerant Fuels (ATF) has just started. The main objectives are:

- To collect the main differences between each specific ATF within one concept as they are described in the literature. Some of the work performed is partly based on experiences gained in the frame of the Il Trovatore project.
- To get material properties needed for an accurate modelling and simulations.

4. CONCLUSIONS

The first year of the project was essentially devoted to making review and collection of the experimental data available for LOCA and SGTR DEBA and DEC-A bounding scenario analyses as well as to make a comparative assessment of the existing methodologies used to evaluate the radiological consequences and the available simulation tools that will be used by the different partners in the projects to perform their reactor calculations.
The methodology review highlighted major differences, leading to one to two order of magnitude discrepancies for the radioactive releases of some major isotopes such as Xenon and Iodine depending on the regulatory practices and licensing procedures used in the different countries. This work will be updated at the end of the project taking into account the improvements that will be performed within the consortium in calculation tools for the reduction of some conservatisms.

The review focussed on the 20 different codes that will be used in the project including either established codes that originate from the development work done for decades, as well as newer codes that have been developed just recently. It covers fuel performance (inc. two steady-state codes), sub-channel and system thermal hydraulics, radionuclide behaviour and integral system behaviour. Two different questionnaire tables were built separating integral system codes from fuel performance/radionuclide behaviour codes. In addition a short description of the codes was also provided. The report helps to achieve a better understanding of the current capabilities of the codes that will be used within the project as well as to pinpoint their required development needs.

A data base collecting the metadata of 43 legacy and past experimental programs have been built; some of them having already been used earlier for code validation purposes. It includes a large number of tests that can be used for model development and validation activities related to clad failure & secondary hydriding, fuel behaviour (oxidation…), fission product releases and behaviour in the RCS, iodine spiking behaviour….
Three large matrices have been compiled to support detailed discussions on phenomena, test characterization and data availability.

In parallel the different reactor scenarios have been identified and the first set of calculations initiated for PWR 900, 1000 and 14000 MW, VVER 440 & 1000, BWR-4 and EPR 1600 MW. A common model for the calculation of the corresponding radiological consequences from releases into the environment was also proposed.
The different Work Programs for WP3-LOCA, WP4-SGTR and WP5-INNOV were built for a better planning, coordination and interlinkage of the different technical actions.
Finally all the material to support the project dissemination and communication (logo, brochure, poster, presentation) has been created and the first newsletter was released. A dedicated project sharepoint with restricted access was built and social network accounts created. Also, first lists for mobility, master thesis and training sessions have been proposed.
Thus despite a late launch of the project through the kick-off and the COVID-19 crisis occurrence, the main objectives of the project for the first year have been more or less met.