



Magic-RR

D5.1 – Detailed Work Plan

WP5 – Task 5.1

Version n°1

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Authors

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Table of contents

Summary	6
Keywords	6
Abbreviations and acronyms	6
Introduction	8
1. WP1 actions: Irradiation damage of Research Reactor materials at high fluences	10
Task 1.1: Irradiation damage mechanisms in RR materials	10
Task 1.1a: Literature study	10
Task 1.1b: High fluence irradiation effects on mechanical properties	10
Task 1.1c: Irradiation damage on microstructure	10
Task 1.1d: Predictive models for irradiation damage	11
Task 1.2: Corrosion behaviour of Al alloys: Prevention and mitigation strategies (NRG)	13
WP1 Deliverables	14
WP1 Milestones	15
Interaction with other WPs	16
Risks of WP1	16
2. WP2 actions: Validation of miniature specimens for surveillance testing of Research reactors..	17
Task 2.1: Experimental validation of sub-size specimens for surveillance programs (NRG)	17
Task 2.2: Numerical modelling to account for size effects on fracture toughness determination (CEA)	18
WP2 Deliverables	19
WP2 Milestones	20
Interaction with other WPs	20
Risks of WP2	20
3. WP3 actions: Ageing management and structural integrity of Research reactors	21
Task 3.1: Ageing management methods of RRs to support LTO (HUN-REN-CER)	21
Task 3.2: Best practice guidelines on ageing management and structural integrity (HUN-REN-CER)	22
WP3 Deliverables	23
WP3 Milestones	23
Interaction with other WPs	23
Risks of WP3	23
4. WP4 actions: Communication, Dissemination, Education and Training	24
Task 4.1 Public Communication	24
Task 4.2 Dissemination plan, interaction with stakeholders and publications	25

Task 4.3 Dissemination, Education and Training.....	26
WP4 Deliverables	26
WP4 Milestones	27
Interaction with other WPs	27
Risks of WP4	27
5. WP5 actions: Project coordination and management	27
Task 5.1 Project coordination.....	28
Task 5.2 - Project office	28
Task 5.3 Scientific Advisory Board	29
WP5 Deliverables	30
WP5 Milestones	30
Interaction with other WPs	30
Risks of WP5	31
Conclusion	31

List of figures

Figure 1. High level objectives (HLOs) and specific objectives (SOs) of Magic-RR	8
Figure 2. PERT chart showing WP structure of Magic-RR Project	9

List of tables

Table 1. List of actions within T1.1a	11
Table 2. List of actions within T1.1b	11
Table 3. List of actions within T1.1c	13
Table 4. List of actions within T1.1d	13
Table 5. List of actions within T1.2	14
Table 6. List of deliverables within WP1	15
Table 7. List of milestones within WP1	16
Table 8. Interactions between WP1 and other WPs	16
Table 9. Anticipated risks in WP1	17
Table 10. List of actions within T2.1	18
Table 11. List of actions within T2.2	19
Table 12. List of deliverables within WP2	20
Table 13. List of milestones within WP2	20
Table 14. Interactions between WP2 and other WPs	20
Table 15. Anticipated risks in WP2	21
Table 16. List of actions within T3.1	22
Table 17. List of actions within T3.2	22
Table 18. List of deliverables within WP3	23
Table 19. List of milestones within WP3	23
Table 20. Interactions between WP3 and other WPs	23

Table 21. Anticipated risks in WP3	24
Table 22. List of actions within T4.1	25
Table 23. List of actions within T4.2	26
Table 24. List of actions within T4.3	26
Table 25. List of deliverables within WP4	27
Table 26. List of milestones within WP4	27
Table 27. Interactions between WP4 and other WPs	27
Table 28. Anticipated risks in WP4	27
Table 29. List of actions within T5.1	28
Table 30. List of actions within T5.2	29
Table 31. List of actions within T5.3	30
Table 32. List of deliverables within WP5	30
Table 33. List of milestones within WP5	30
Table 34. Interactions between WP5 and other WPs	31
Table 35. Anticipated risks in WP5	31

Summary

This deliverable details the detailed work plan of the Magic-RR project. The proposed technical work from the Description of the Action (DoA) from GA, has been divided into several actions to realise the project objectives. For every action, at least one responsible person or organisation has been appointed. This document is intended to be used by the coordination team to follow-up the project activities and by the Magic-RR consortium. This document shall be updated along the project duration in case of delay in the action implementation and/or identification of new actions.

Keywords

Keywords of the GA - Irradiation damage in Al alloys, Corrosion, Transmutation, Ageing of research reactors, Small specimen techniques, Surveillance testing, continued safe operation (CSO), Multi-scale modelling.

Abbreviations and acronyms

Acronym	Description
AMR	Ageing Management Review
APT	Atom Probe Tomography
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATR	Advanced Test Reactor
CMOD	Crack Mouth Opening Displacement
CSO	Continued Safe Operation
CT	Compact Tension
DBTT	Ductile to Brittle Transition Temperature
DoA	Description of the Action
DMP	Data Management Plan
E&T	Education and Training
EDM	Electrical Discharge Machining
EDX/EDAX	Energy Dispersive X-Ray Spectroscopy
EU	European Union
EUG	End-User Group
FAIR	Findability, Accessibility, Interoperability and Reusability data principles
FEM	Finite Element Modelling
FIB	Focused Ion Beam
FMEA	Failure Mode and Effects Analyses
FRANCESUS	FRacture mechanics TESting of irradiated RPV steels by means of SUB-sized Specimens
FT	Fracture Toughness
GA	Grant Agreement
GB	Grain Boundary
HCL	Hot Cell Laboratory
HFR	High Flux Reactor in Petten

HLOs	High Level Objectives
IAEA	International Atomic Energy Agency
LCF	Low Cycle Fatigue test
LEU	Low Enriched Uranium
NPP	Nuclear Power Plant
OM	Optical Microscopy
PIE	Post-Irradiation Examination
PKAs	Primary Knock-on Atoms
PM	Person Month
PQP	Project Quality Plan
R&D	Research and Development
ROLT	Recommended Operation Lifetime
RPV	Reactor Pressure Vessel
RRs	Research Reactors
RVE	Representative Volume Element
SAB	Scientific Advisory Board
SANS	Small angle neutron scattering
SCC	Safety Critical Components
SEM	Scanning Electron Microscope
SICs	Structural Integrity Calculations
SKPFM	Scanning Kelvin Probe Force Microscopy
SNETP	Sustainable Nuclear Energy Technology Platform
SOs	Specific objectives
SRS	Savannah River Site reactors
STEM	Scanning Transmission Electron Microscopy
SURP	HFR Vessel Surveillance Programme
TEM	Transmission Electron Microscope
TFR	Thermal-to-Fast Fluence Ratio
TLAA	Time Limited Ageing Analysis
TRL	Technology Readiness Level
TSOs	Technical and scientific support organizations
NRC	U.S. Nuclear Regulatory Commission
XPS	X-Ray Photoelectron Spectroscopy

Introduction

Many of the existing Research Reactors (RR) in Europe are very old (>60 years operation). Only a few initiatives have been taken (PALLAS and JHR) to partially replace this capacity. Continued operation of these RRs is mandatory (at least until the new reactors come to operation) to maintain the EU excellence in development and qualification of nuclear materials for advanced reactor concepts and to maintain the supply of medical isotopes. License extensions for continued safe operation (CSO) requires ageing management review (AMR) and time limited ageing analysis (TLAA) of critical structures and components. However, there is limited understanding of damage mechanisms and lack of materials data on RR materials at relevant operating conditions for long term operation of RRs. In addition, there is a shortage of surveillance specimens for extending the operational life for some RRs. Lastly, sharing of knowledge and operational experience is crucial in this relatively small RR community.

To address the aforementioned open issues in RRs, three high level objectives (HLOs) and 9 specific objectives (SOs) are defined in Magic-RR (Figure 1).

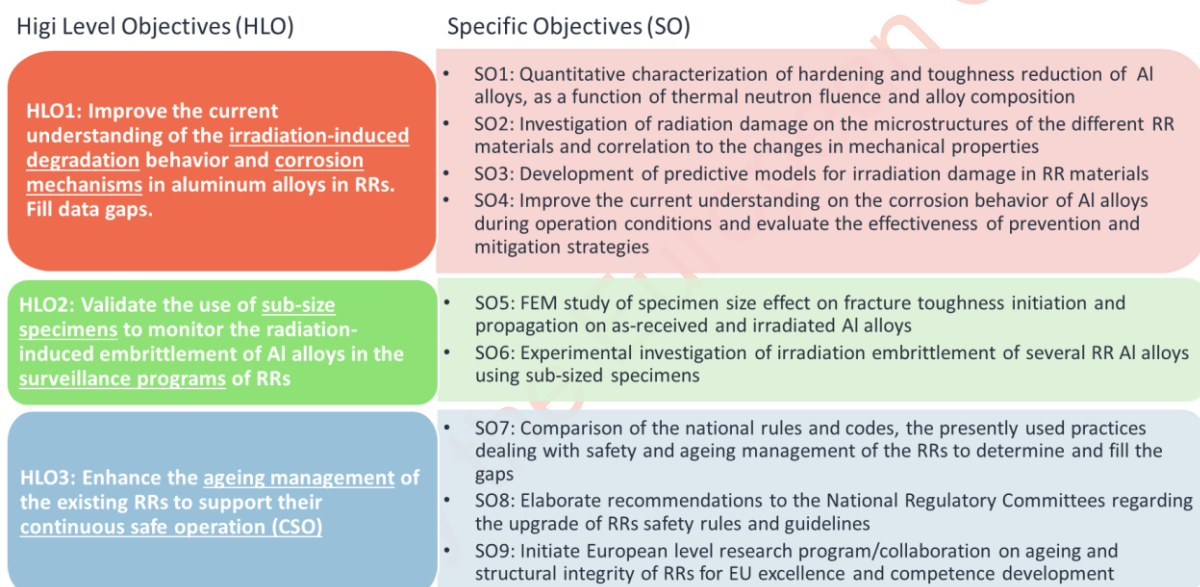


Figure 1. High level objectives (HLOs) and specific objectives (SOs) of Magic-RR

Magic-RR realises these objectives by leveraging (1) available archive materials and data from the existing research reactors, e.g. from surveillance programs and shut down reactors, (2) operational experience of research reactor operators and (3) advanced characterisation and modelling techniques at universities and nuclear research centers. The following work package (WP) structure (Figure 2) is defined to achieve the forementioned objectives of Magic-RR.

This deliverable describes a detailed action list for every task in each of the 5 work packages including the start and end dates, action responsible and contributors.

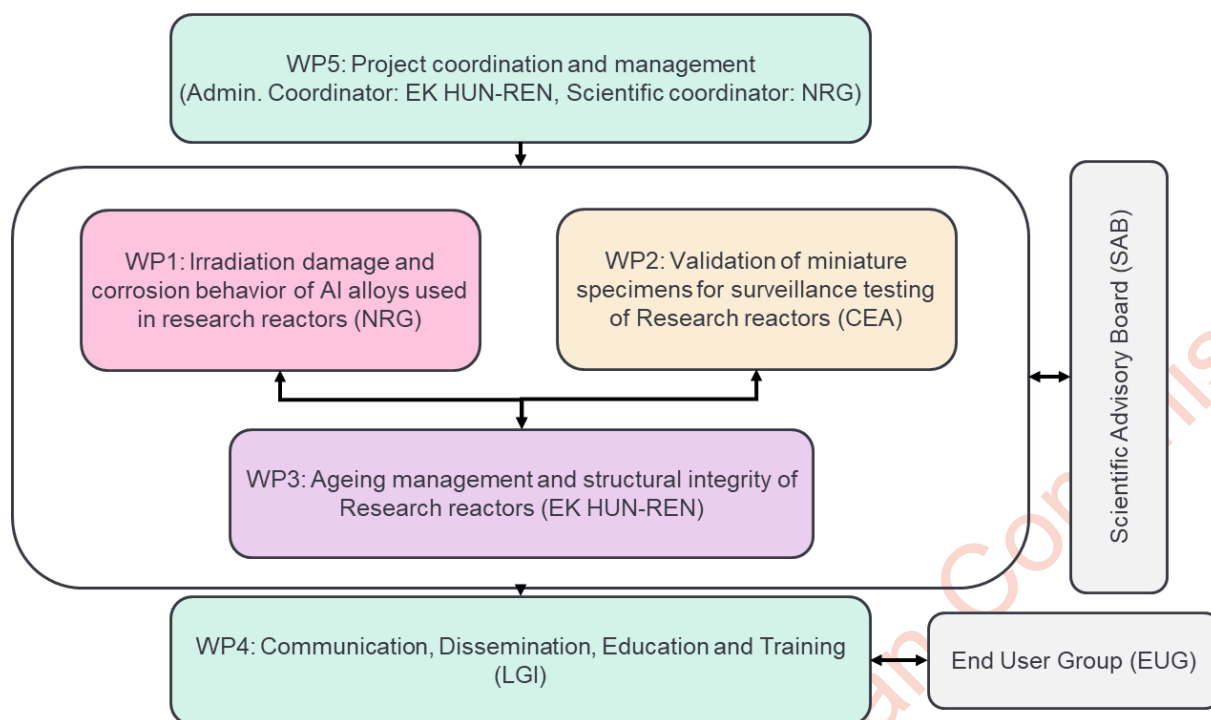


Figure 2. PERT chart showing WP structure of Magic-RR Project

1. WP1 actions: Irradiation damage of Research Reactor materials at high fluences

Work Package Leader: Kiki Naziris (NRG)

Duration: M01 – M36

Objectives: WP1 is dedicated to performing the reference and PIE testing, microstructural characterization of selected Al alloys used in RRs, corrosion testing and multiscale modelling of irradiation damage in Al alloys. The results will be directly useful to achieve the specific objectives 1 and 4 (SO1 & SO4) of the Magic-RR (see Figure 1). WP1 has the following 2 tasks.

Task 1.1: Irradiation damage mechanisms in RR materials

Task Leader: Kiki Naziris (NRG)

Contributors: HUN REN-CER, CEA, CNRS, UR, UKAEA, CNL, Oxford, TU/e, TU Delft

Duration: M01 – M42

Description of activities: Task 1.1 is divided into the four sub-tasks.

Task 1.1a: Literature study

A literature study will be performed on the irradiation damage of RR materials. This study will serve as a starting point for this WP. The knowledge gaps in the degradation behaviour of RR materials as function of fluence will be identified among the current predictive models of radiation damage. Additional literature data on mechanical properties of RR materials as function of fluence will also be collected. A report will be written by the contributing partners.

Task1.1b: High fluence irradiation effects on mechanical properties

This sub-task aims to collect the mechanical properties (tensile properties and fracture toughness) of RR materials at different fluence values. As input for this task, already existing data from HFR SURP materials, 5154-O Al alloy with wide range of thermal fluences ($E < 0.414$ eV; $0 - 26 \times 10^{26}$ n/m²) will be used. Microhardness measurement will be performed on samples used for APT needles preparations to improve microstructure / mechanical properties correlation. New tests on other RR materials will be performed: 6061-T6 alloy irradiated in HFR to low fluence, two specimens of 6082 Al grade for corrosion studies which have been irradiated in the HFR (for one of the two specimen a hydrothermal treatment has been applied), AA6061 (non-irradiated, neutron irradiated & Si-implanted), BKR reactor archive materials; AlMg1Si and AlMg2.5Si, CNL: I-rod 2 (5052-O grade) from NRU reactor – high fluence.

Task 1.1c: Irradiation damage on microstructure

This sub-task aims to study the changes in the microstructure of the RR materials during operation conditions. Several of the RR materials, which have received a wide range of neutron fluences and have been studied in the first sub-task of 1.1, will be selected for microstructural investigation. Within this sub-task, microstructural characterisation techniques such as optical microscopy (OM), scanning electron microscopy (SEM), transmission electron microscopy (TEM), atom probe tomography (APT) and small angle neutron scattering (SANS) will be applied to investigate the irradiation damage mechanisms of RR materials at different fluence values. Finally, the observed microstructural changes will be correlated to the changes in mechanical properties studied in the previous sub-task.

Task 1.1d: Predictive models for irradiation damage

A framework for modelling of microstructure evolution under neutron loads, and the irradiation hardening and embrittlement due to this microstructure evolution under general mechanical loads will be developed. A multi-scale approach will bridge the physical processes that occur at the scale of the crystalline lattice and its defects, to mechanical failure at the macroscopic application scale.

A detailed list of actions in each of these sub-tasks is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Writing of literature study on radiation damage in Al 5xxx and 6xxx alloys and collect available HFR SURP data	M01	M08	M. Kolluri (NRG)	Kristóf Andor Csikós (HUN-REN-CER)
2. Literature Collection and exchange	M01	M05	Lajos Berzy HUN-REN-CER	F. Gillemot HUN_REN-CER

Table 1. List of actions within T1.1a

Actions	Start Date	Due Date	Responsible	Contributors
3. Preparation of test matrix (MS1)	M01	M03	K. Naziris (NRG)	M. Kolluri (NRG), F. Gillemot (HUN-REN-CER), Joël Ribis, Jérôme Garnier (CEA), B. Radiguet (CNRS), A. London (UKAEA), H. Namburi (CNL), P. Bagot (Oxford)
4. Irradiated material harvest from the disassembled parts of the BKR reactor (AlMgSi and AlMg2.5) & providing list and service history of RR surveillance specimen	M01	M18	F. Gillemot (HUN-REN-CER)	
5. Machining mechanical testing specimen from irradiated RR materials	M03	M18	M. Kolluri, K. Naziris (NRG)	F. Gillemot (HUN-REN-CER)
6. Tensile, notch tensile, hardness testing on reference & irradiated RR materials (AlMgSi and AlMg2.5 alloys, 6061-T6 alloy irradiated in HFR to low fluences)	M03	M24	M. Kolluri, K. Naziris (NRG)	F. Gillemot (HUN-REN-CER)
7. Report on high fluence irradiation effects on the mechanical properties of RR materials	M18	M24	M. Kolluri, K. Naziris (NRG)	F. Gillemot (HUN-REN-CER)

Table 2. List of actions within T1.1b

Actions	Start Date	Due Date	Responsible	Contributors
8. Transport of high-fluence neutron irradiated I-rod material (Al-5052) from CNL to NRG	M03	M09	H. Namburi (CNL)	K. Naziris, M. Kolluri (NRG)
9. Transport of small volume reference & irradiated 5154-O, 6061-T6 and 5052-O materials from NRG to Oxford, UKAEA CNRS for microstructural investigation	M03	M09	K. Naziris, M. Kolluri (NRG)	A. London (UKAEA), B. Radiguet (CNRS) & P. Bagot (Oxford)
10. Collection of existing TEM data on the 5154-O Al alloy from the HFR SURP program (NRG)	M03	M12	V. Marques Pereira (NRG)	
11. OM, SEM & SANS measurements on AlMgSi and AlMg2.5 alloys	M12	M38	Dávid Cinger (HUN-RENCER)	
12. Prepare samples for atom probe tomography by the lift-out technique for volume reduction.	M06	M10	A. London (UKAEA)	
13. XRD for line-profile analysis of defects			A. London (UKAEA)	
14. Micro-scale mechanical testing (cantilever/micro-tensile)			A. London (UKAEA)	
15. APT measurements on selected RR materials	M10	M038	B. Radigue (CNRS)	B. Radiguet (CNRS)
16. FIB, SEM, TEM measurements on high-fluence neutron irradiated I-rod material from NRU reactor	M03	M038	H. Namburi (CNL)	
17. TEM sample preparation & measurements on selected RR materials (5154-O at reference state & 3 different fluence values)	M06	M038	V. Marques Pereira (NRG)	
18. FIB lamellas and electro-polishing thin foils preparation of the non-irradiated AA6061	M01	M12	Joël Ribis, Jérôme Garnier (CEA)	
19. TEM observations of non-irradiated and neutron irradiated AA6061	M12	M24	Joël Ribis, Jérôme Garnier (CEA)	
20. FIB lamellas preparation and TEM observations of the Si-implanted AA6061	M24	M36	Joël Ribis, Jérôme Garnier (CEA)	

21. In situ annealing of the Si-implanted AA6061 and deliverable redaction	M36	M38	Joël Ribis, Jérôme Garnier (CEA)	
22. Report on irradiation damage on microstructure of RR materials. Correlation will be made with observed changes in mechanical properties.	M24	M38	B. Radigue (CNRS)	P. Bagot (Oxford), Joël Ribis, Jérôme Garnier (CEA), V. Marques Pereira (NRG), Dávid Cinger (HUN-REN-CER), A. London (UKAEA)

Table 3. List of actions within T1.1c

Actions	Start Date	Due Date	Responsible	Contributors
23. Development of models for microstructure evolution (under long-term neutron fluence, including lattice defects and transmutation Si in the form of precipitates and at grain boundaries.) & micromechanical model (full field crystal plasticity-based model for the mechanical response of neutron irradiation-induced microstructures)	M01	M33	Hans van Dommelen (TU/e)	PhD student (TU/e)
24. Development of framework for prediction failure probability and understanding the role of the microstructure for brittle failure	M12	M34	Hans van Dommelen (TU/e)	PhD student (TU/e)
25. Upscaling of the material behaviour to mechanical test geometries and validation of the modelling framework with experimental data for different fluence values	M24	M42	Hans van Dommelen (TU/e)	PhD student (TU/e)

Table 4. List of actions within T1.1d

Task 1.2: Corrosion behaviour of Al alloys: Prevention and mitigation strategies (NRG)

Task Leader: Mathilde Laot (NRG)

Contributors: TU Delft, HUN-REN-CER

Duration: M01 – M44

Description of activities: The main aim of this task is to study the corrosion behaviour of core components of RRs. A literature study on corrosion behaviour of RR materials will be performed. Prevention and mitigation strategies will be investigated: hydrothermal treatments on Al alloys will be performed and the corrosion resistance of treated Al alloys under irradiation will be investigated. The

influence of time/temperature on the effectiveness of the hydrothermal treatment and the corrosion behaviour of untreated vs treated Al alloys under irradiation will be the main objectives of this task.

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Preparation of test matrix	M02	M06	M. Laot (NRG)	TU Delft
2. Provide literature study	M02	M16	D. Cinger (HUN-REN-CER)	Mathilde Laot (NRG), Post-doc (TU Delft),
3. SEM and XRD of historic irradiated corroded HFR materials	M03	M12	M. Laot (NRG)	
4. SEM and XRD of historic hydrothermally treated and irradiated Al alloys	M06	M12	M. Laot (NRG)	
5. Perform hydrothermal pre-treatments on Al alloys for corrosion studies with varying parameters (i.e. temperature, hold time, ...)	M03	M10	M. Laot (NRG)	
6. Study the water corrosion resistance of Al alloys samples (non-irradiated) with microscopy and electrochemical experiments.	M06	M24	Post-doc (TU Delft), Y. Gonzalez-Garcia (TUD)	
7. Study the protection performance of pre-treatments on Al alloys corrosion behaviour	M06	M24	Post-doc (TU Delft), Y. Gonzalez-Garcia (TUD)	
8. Perform irradiation of samples in gamma field for hydrolysis studies	M10	M36	Mathilde Laot (NRG)	
9. Perform irradiation on anodised samples for corrosion resistance studies	M10	M36	Mathilde Laot (NRG)	
10. Perform microscopy of anodised samples after neutron and gamma irradiation	M40	M44	Mathilde Laot (NRG)	

Table 5. List of actions within T1.2

WP1 Deliverables

Number	Title	Due Date	Responsible
D1.1	Report of literature review on irradiation damage of RR materials	M08	M. Kolluri (NRG)
D1.2	Lists and service history of the irradiated samples	M18	F. Gillemot (HUN-REN-CER)
D1.3	Report on mechanical tests of RR materials	M30	F. Gillemot (HUN-REN-CER)

D1.4	Report on microstructural characterisation of RR materials and correlation to the mechanical properties as function of fluence and chemical composition	M38	B. Radiguet (CNRS/UR)
D1.5	Report on computational model for microstructure evolution & computational micromechanical model	M40	Hans van Dommelen (TU/e)
D1.6	Report on prediction of failure probability and understanding of the role of the microstructure for brittle failure	M42	Hans van Dommelen (TU/e)
D1.7	Report on corrosion mechanism, corrosion performance under pool water exposure & the evaluation of the corrosion protection efficiency of the mitigation strategies	M44	Mathilde Laot (NRG)

Table 6. List of deliverables within WP1

WP1 Milestones

Number	Title	Verification mean	Due Date	Responsible
MS1	Definition of final testing matrix	Report	M03	K. Naziris (NRG)
MS2	Harvesting of materials from old BKR reactor & preparation of mechanical testing samples	Note	M18	F. Gillemot HUN-REN-CER
MS3	Completion mechanical testing (tensile & fracture toughness) of RR materials planned in WP1	Report	M24	K. Naziris, M. Kolluri (NRG)
MS4	Transport of irradiated RR materials for microstructural characterisation	Note	M06	K. Naziris, M. Kolluri (NRG)
MS5	Completion of PIE microstructural characterization	Report	M24	V. Marques Pereira (NRG)
MS6	Completion of in-situ TEM investigations	Report	M33	Joël Ribis, Jérôme Garnier (CEA)
MS7	Completion of models for microstructure evolution & micromechanical model	Report	M33	Hans van Dommelen (TU/e)
MS8	Framework for prediction failure probability and understanding the role of the microstructure for brittle failure	Report	M38	Hans van Dommelen (TU/e)
MS9	Completion of macroscopic loading geometry	Report	M42	Hans van Dommelen (TU/e)
MS10	Completion of microscopy analysis of corrosion samples	Report	M15	Post-doc (TU Delft), Y. Gonzalez-Garcia (TUD)
MS11	Completion of studying the effect of pH on corrosion kinetic & mechanism	Report	M24	Post-doc (TU Delft), Y.

				Gonzalez-Garcia (TUD)
MS12	Completion of irradiation of anodized coupons as well as irradiation of Al alloys in gamma field	Report	M36	Mathilde Laot (NRG), Léa Maillot (NRG)
MS13	Screening of the protection/mitigation strategies based on the corrosion protection efficiency	Note	M36	Post-doc (TU Delft), Y. Gonzalez-Garcia (TUD)
MS14	Completion of microscopy analysis on anodized coupons and Al alloys irradiated in gamma field	Report	M44	Mathilde Laot (NRG)

Table 7. List of milestones within WP1

Interaction with other WPs

Number	Interaction description	Responsible
1	Provide data to WP2	F. Naziris (NRG)

Table 8. Interactions between WP1 and other WPs

Risks of WP1

Contractual risks (number, description, risk-mitigation), probability (1=low; 5=high) that the risk occurs and impact (1=low; 5=high) if the risk occurs. Other risks (not in GA) can be added so they can be followed during the project. Risk mitigation: P=preventive actions / C=contingency actions.

Number	Risk description	Risk mitigation	Prob.	Impact
1 ¹	Key partner leaves the consortium	Redistributing tasks to remaining partners with associated resources necessary	1	3
2 ¹	Pandemic, wars.	Adapt planning and redistribute tasks if required to partners.	1	1
3	Lack of experimental input for the selected material system for modelling work	Model choices will be made based on existing experimental data from previous projects and literature, possibly for a slightly different material system.	1	3
4	Equipment failure/Unavailability due to technical issue	Regular maintenance, Repair machine, contact partners with similar set-up to perform tests in case the reparation will take too long.	1	1
5	Alteration of irradiated thin foils by oxidation	Use of FIB to lift out the non-oxidised layers and prepare TEM lamella.	1	3
6	Difficulties in transport to different partners of samples after irradiation	Establish good communication with partners. Use of personnel with	3	1

¹ Applicable to all WPs

		previous experience in arranging these kinds of transport.		
7	Difficulties in preparing the APT samples for Irradiated materials to be tested at CNRS	NRG is investigating if the rods can be produced in Petten. Another option is that the samples are prepared by UKAEA, this will require an additional transport.	2	4
8	Difficulties in finding a suitable post-doc for the project	Work will be delayed in case the post-doc starts later than planned. Impact on other sub-tasks is deemed minimal.	1	3
9	Unforeseen issues at HFR causing delays in irradiation or preventing irradiation from being performed.	Planning will be adapted if needed.	2	4
10	Missing specific skills due to leaving of employees from company (e.g. preparing FIB lamellas etc.)	A replacement personnel will be trained/recruited. Planning will be adapted if needed and any resulting delays will be communicated to PO	4	2

Table 9. Anticipated risks in WP1

2. WP2 actions: Validation of miniature specimens for surveillance testing of Research reactors

Work Package Leader: Pierrick Francois (CEA)

Duration: M01 – M48

Objectives: WP2 is focused on an experimental – numerical approach for validation of sub-size specimens for surveillance testing of RRs to achieve SP5 and SO6.

Task 2.1: Experimental validation of sub-size specimens for surveillance programs (NRG)

Task Leader: Murthy Kolluri (NRG)

Contributors: HUN-REN-CER, CEA

Duration: M01 – M48

Description of activities: Three grades of Al alloys (6061-T6, 5154-O, 5051) irradiated over a wide range of thermal neutron fluences will be studied. Sub-size specimens will be manufactured in hot cells from remnants of irradiated RR surveillance samples. Pre-cracking and tests on sub-size specimens will be performed by using available and qualified experimental devices. Displacement will be measured by an extensometer to assess the CMOD (Crack mouth opening displacement). Temperature and specimen orientations will be chosen according to samples from which sub-size specimens will be machined.

The task will be divided in two parts:

- Assessment of hardening based on sub-sized tensile specimens. Tensile specimens (Smooth and notched) will be used to perform tensile testing. Sub-size tensile test results will be compared with surveillance data on larger specimens.
- Assessment of fracture toughness based on sub-size C(T) specimens. Fracture toughness determined using sub-size C(T) specimens will be compared with data obtained on standard C(T) specimens. Fracture toughness values from standard C(T) specimens are already available for irradiated 6061-T6 and 5154-O Al alloys (CEA and NRG). For as received and irradiated 5051, HUN-REN-CER will perform fracture toughness tests on sub-size as well as standard specimens for the comparison.

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Specimen preparation and testing of 0.5T-CT	M12	M36	F. Gillemot (HUN-REN-CER)	
2. Specimen preparation and testing of 0.4T-CT	M03	M36	M. Kolluri (NRG)	
3. Specimen preparation and testing of 0.16T-CT	M05	M36	P. Francois (CEA)	S. Saanouni, B. Tanguy (CEA), F. Gillemot (HUN-REN-CER), M. Kolluri (NRG)
4. FT assessment based on notched tensile specimens	M04	M36	F. Gillemot (HUN-REN-CER)	
5. Mini-tensile specimens' fabrication and testing	M03	M38	F. Gillemot (HUN-REN-CER)	M. Kolluri (NRG)
6. Results comparison and analysis between tensile and mini-tensile specimens	M27	M40	M. Kolluri (NRG)	F. Gillemot (HUN-REN-CER)
7. Results comparison and analysis between CT specimens	M27	M40	P. Francois (CEA)	S. Saanouni, B. Tanguy (CEA), M. Kolluri (NRG), F. Gillemot (HUN-REN-CER)
8. Synthesis of experimental and numerical results	M40	M46	P. Francois (CEA)	

Table 10. List of actions within T2.1

Task 2.2: Numerical modelling to account for size effects on fracture toughness determination (CEA)

Task Leader: Pierrick Francois (CEA)

Contributors: TU/e

Duration: M01 – M48

Description of activities: Simulation of standard and sub-size CT specimens will be performed in order to evaluate the effect of size on the ductile fracture initiation toughness, which is a property that may be influenced by the reduction of specimen size. Finite element simulations based on standard plasticity as well as based on micromechanical modelling of ductile fracture will be combined to provide accurate assessment of the size effect on the critical fracture toughness that correspond to the initiation of ductile fracture. In a second step, the size effect on the full crack resistance (J-R) curve will be evaluated.

Non-linear finite elements modelling (FEM) will be performed using Cast3M FEM software. FEM will be performed on sub-size CT specimens as well as on 0.5T-C(T) specimens. The design of the sub-size CT specimen will be studied and validated. Size effect on local mechanical fields, the resistance curve and the fracture toughness at crack initiation will be assessed. A dialogue with experimental results on both types of specimens will be set up in order to quantify a size-effect correction from the finite element simulations based on physically-based modelling.

Evaluation of the size effect on the critical fracture toughness will be based on elasto-plastic flow theory whereas ductile damage behaviour will be used to study the size effect on the J-R curves. With the objective to dialogue with the tests that will be performed in the experimental task on irradiated Al 6061, the material laws established at CEA will be provided and used. These laws have been validated for the simulation of plastic and damage behaviour of the non-irradiated as well as the irradiated Al 6061 alloy that will be tested.

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Set-up simulation and meshes	M04	M16	P. Francois (CEA)	B. Tanguy (CEA)
2. Elasto-plastic simulations	M09	M22		
3. Ductile fracture initiation model implementation and validation	M09	M22		
4. Ductile fracture micromechanical model (GTN) implementation and validation	M17	M28		
5. Simulation of experimental data base	M10	M28		
6. Comparison and analysis of the results between specimen geometries	M10	M32	Hans van Dommelen (TU/e)	Hans van Dommelen (TU/e)
7. Model brittle failure and compare the results between specimen geometries	M06	M32		

Table 11. List of actions within T2.2

WP2 Deliverables

Number	Title	Due Date	Responsible
D2.1	Report on the design of sub-size specimens, and test matrix	M14	F. Gillemot (HUN-REN-CER)

D2.2	Intermediate report on the design and the simulation of sub-size CT specimen	M24	P. Francois (CEA)
D2.3	Intermediate report on tensile specimens testing	M30	M. Kolluri (NRG)
D2.4	Intermediate report on CT specimen testing (sub-size and standard)	M36	M. Kolluri (NRG)
D2.5	Final report on finite element simulations to assess size effect on fracture toughness at crack initiation and J-R curve of sub-size CT	M36	P. Francois (CEA)
D2.6	Report on the comparison of fracture toughness and notch/yield ratio	M40	F. Gillemot (HUN-REN-CER)
D2.7	Final report on the use of sub-size tensile and fracture toughness specimens to assess irradiation embrittlement of several RR Al alloys	M46	P. Francois (CEA)

Table 12. List of deliverables within WP2

WP2 Milestones

Number	Title	Verification mean	Due Date	Responsible
MS15	Final design of the specimens (tensile, CT, sub-size tensile and sub-size CT)	Note	M12	P. Francois (CEA)
MS16	End of set up of the simulation and meshes elaboration	Report	M18	P. Francois (CEA)
MS17	End of elasto-plastic simulations	Report	M24	P. Francois (CEA)
MS18	End of machining of sub-size specimens in hot cell	Note	M24	P. Francois (CEA)
MS19	End of J-R simulations	Report	M30	P. Francois (CEA)
MS20	End of tensile and fracture toughness tests	ReportM40	P. Francois (CEA)	

Table 13. List of milestones within WP2

Interaction with other WPs

Number	Interaction description	Responsible
1	Transfer fracture toughness data to T1.1d	P. Francois (CEA)
2	Compare the hardening assessment obtained with sub-size tensile, and tensile specimens	M. Kolluri (NRG)

Table 14. Interactions between WP2 and other WPs

Risks of WP2

Contractual risks (number, description, risk-mitigation), probability (1=low; 5=high) that the risk occurs and impact (1=low; 5=high) if the risk occurs. Other risks (not in GA) can be added so they can be followed during the project. Risk mitigation: P=preventive actions / C=contingency actions.

Number	Risk description	Risk mitigation	Prob.	Impact
1	Unavailability of researchers to perform the simulation	Allocate resources in advance and have redundancy in knowledge.	1	3
2	Difficulties in harvesting historic materials	Materials from different partners will be used for redundancy and ensure availability of materials of interest	3	3
3	Pre-fatigue of mini CT-s could be difficult. No prior experience.	Pre- fatigue technology development	2	2

Table 15. Anticipated risks in WP2

3. WP3 actions: Ageing management and structural integrity of Research reactors

Work Package Leader: Ildiko Szenthe (HUN-REN-CER)

Duration: M01 – M48

Objectives: WP3 is focused on ageing management methods of RRs.

Task 3.1: Ageing management methods of RRs to support LTO (HUN-REN-CER)

Task Leader: David Cinger (HUN-REN-CER)

Contributors: NRG, NECSA

Duration: M01 – M48

Description of activities: A survey of the existing age management methods at the participant and in the literature will be performed. An evaluation of the safety related, or life-limiting factors of RRs SCCs will be done. It is also aimed to study the existing practices of use of AMR, TLAA and FMEA and determine the typical life limiting factors such as increase of the silicon content by transmutation in the aluminium structures and causing embrittlement.

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Questioner on existing ageing management and structural integrity methods	M01	M04	F. Gillemot HUN-REN-CER	
2. Provide information on ageing and structural integrity management methods	M04	M10	L. Hasa, S. van Doorene (NRG)	All + RR operators from EUG members
3. Information on SAFARI1 ageing management and structural integrity methods	M04	M10	J. Mostert (NECSA)	

4. Information on BRR ageing management and structural integrity methods	M01	M10	F. Gillemot (HUN-REN-CER)	
5. Information on other sources ageing management and structural integrity methods	M04	M10	L. Berzy (HUN-REN-CER)	All
6. Survey of existing RR FMAE	M03	M28	D. Cinger (HUN-REN-CER)	All
7. Report on existing practices of use AMR, TLAA, FMEA and life limiting factors	M15	M30	D. Cinger (HUN-REN-CE)	All

Table 16. List of actions within T3.1

Task 3.2: Best practice guidelines on ageing management and structural integrity (HUN-REN-CER)

Task Leader: F. Gillemot (HUN-REN-CER)

Contributors: NRG, NECSA, All partners

Duration: M01 – M48

Description of activities: Based on the knowledge collected in WP1, WP2, and in Task 3.1, elaboration a recommended guide-line of ageing management for RR operators (including periodic check of structural integrity), and a list of recommendation for extensions of the RR safety rules (if necessary) to the NRC-s. Based on the TLAA or FMEA elaborated in Task 3.1 selection of the SCC-s and prepare the list of risks of structural integrity. Collect the available structural integrity knowledge for the selected SCC-s and summarize the mitigation methods applied at the different RR-s. The study will be focused on the information collected from the participating RRs, but other available sources also will be considered.

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Elaboration list of critical components	M01	M10	L. Berzy HUN-REN-CER	All partners
2. Literature survey of mitigation methods for irradiation ageing	M01	M26	L. Berzy HUN-REN-CER	All partners
3. Literature survey of mitigation methods for corrosion	M03	M26	L. Berzy HUN-REN CER	M. Laot (NRG) All partner
4. Collecting information for best practice	M03	M42	L. Berzy HUN-REN-CER	All partner
5. Analysis and Report on best practices	M24	M46	F. Gillemot HUN-REN CER	L. Hasa, S. van Doorene (NRG), J. Mostert (NECSA)

Table 17. List of actions within T3.2

WP3 Deliverables

Number	Title	Due Date	Responsible
D3.1	Report on existing ageing management methods	M12	L. Hasa, S. van Doorene (NRG)
D3.2	Report on FMAE results	M30	D. Cinger (HUN-REN-CER)
D3.3	Best practice guide of ageing management of structural SCC-s of RR-s	M46	I. Szenthe (HUN-REN-CER)

Table 18. List of deliverables within WP3

WP3 Milestones

Number	Title	Verification mean	Due Date	Responsible
MS21	Completion of Survey of existing ageing management methods	Note	M12	I. Szenthe (HUN-REN-CER)
MS22	Completion of FMEA analyses	Note	M30	I. Szenthe (HUN-REN-CER)

Table 19. List of milestones within WP3

Interaction with other WPs

Number	Interaction description	Responsible
1	Ageing management data from WP1, WP2	L. Berzy HUN-REN-CER
2	Paper on ageing management and information to WP4	L. Berzy HUN-REN-C

Table 20. Interactions between WP3 and other WPs

Risks of WP3

Contractual risks (number, description, risk-mitigation), probability (1=low; 5=high) that the risk occurs and impact (1=low; 5=high) if the risk occurs. Other risks (not in GA) can be added so they can be followed during the project. Risk mitigation: P=preventive actions / C=contingency actions.

Number	Risk description	Risk mitigation	Prob.	Impact
1	Delayed response from RR operators on existing practices of use of AMR, TLAA and Structural integrity procedures	Take proactive approach and maintain good communication with RR partners	3	3
2	In consistence responses due to large variability in ageing management and structural integrity procedures	Design a structured survey template with right questions.	3	3

3	Pandemia, loss of responsible employee	Secondary person involvement into the task	1	1
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Table 21. Anticipated risks in WP3

4. WP4 actions: Communication, Dissemination, Education and Training

Work Package Leader: Clea Prieto (LGI) / Anne-Charlotte Costabadie (LGI)

Duration: M01 – M48

Objectives: This WP will ensure a proper communication and dissemination of the project results.

Task 4.1 Public Communication

Task Leader: Clea Prieto (LGI) / Anne-Charlotte Costabadie (LGI)

Contributors: NRG

Duration: M01 – M48

Description of activities: The main objective of this task is to communicate the activities and the achievements of the project, and to interact with different groups of interest. To achieve this, Magic-RR will implement a series of communication tools and actions define a Communication Plan (D4.1, M03), including the goals and timing, key messages, communication platforms and target audiences for the defined actions.

The plan will include information on:

- The project brand (logo and visual identity), which will be designed and applied to all communication actions.
- Presentation (template and in-depth presentation) and document templates
- Brochure and a roll-up banner (including electronic versions) so as to promote the project at both, in-person and online events.
- The project website. The website will provide visitors with general information about the project. Partners will provide updates for the website regularly throughout the project with news about their results and information on related events.
- A LinkedIn account will be created to grow a community of interested stakeholders and communicate with them on project happenings.
- The final results will be presented in an easy-to-understand manner. A short video, infographics, factsheets, visuals are some of the formats that are considered.
- The project brand will also be applied to four project newsletters, where Magic-RR stakeholders can learn more about project events, publications and results.
- Yearly newsletters summarising the project results and advanced made in Magic-RR

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Creation of the visual identity,	M01	M02	Anne- Charlotte Costabadie (LGI)	All partners
2. Setting up of the LinkedIn account	M01	M01	Anne-Charlotte Costabadie (LGI)	
3. Creation of deliverable and presentation templates	M01	M01	Anne-Charlotte Costabadie (LGI)	M. Kolluri (NRG)
4. Setting-up of the website	M01	M03	Anne-Charlotte Costabadie (LGI)	M. Kolluri (NRG)
5. Communication and dissemination plan (D4.1)	M01	M03	Anne-Charlotte Costabadie (LGI)	All partners
6. Creation of communication materials (brochure, roll-up, print and digital)	M01	M03	Anne-Charlotte Costabadie (LGI)	M. Kolluri (NRG)
7. Creation of communication materials to present results	M36	M48	Clea Prieto (LGI)	All partners
8. Publication of the four newsletters	M10	M48	Clea Prieto (LGI)	All partners

Table 22. List of actions within T4.1

Task 4.2 Dissemination plan, interaction with stakeholders and publications

Task Leader: Murthy Kolluri (NRG)

Contributors: LGI, HUN-REN-CER, CEA

Duration: M01 – M48

Description of activities: This task is aimed to develop dissemination strategy and a procedure for dissemination activities (Dissemination Plan, DP) to disseminate the knowledge and results of the work carried out in Magic-RR to the project's stakeholders:

- Coordinating the participation of partners in conferences and events
- Coordinating publications, including in magazines, open access journals and online repositories when possible. Gold Open access will be preferred whenever possible, including the new opportunities provided by Open Research Europe. Partners' repositories will also be used to archive and make publications accessible. Furthermore, all project publications will be made available through the project website.
- Establishing close collaboration and strengthening ties with related projects, networks, clusters and initiatives at European and national/regional level to share information and exploit synergies and additional dissemination channels. Magic-RR will participate in the international conference focussed on nuclear materials and testing (e.g. NuMat, ASME PVP) and in events with the Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA).

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
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1. Continued monitoring of relevant events, publications and collaborations	M01	M48	M. Kolluri (NRG)/ All partners	All partners
2. Coordination of participation of events	M04	M48	M. Kolluri (NRG)?	All partners
3. Coordination of publications	M01	M48	M. Kolluri (NRG)?	All partners
4. Coordination of participation of partners in networks and initiatives	M01	M48	M. Kolluri (NRG)?	All partners

Table 23. List of actions within T4.2

Task 4.3 Dissemination, Education and Training

Task Leader: Ildikó Szenthe (HUN-REN-CER)

Contributors: LGI, NRG, TUD, UR, CEA, TU/e

Duration: M06 – M48

Description of activities: The goal of this task is to disseminate the results of work carried out in Magic-RR to the project's stakeholders, scientific community and to ensure the platform for training and education. The task activities will include the following actions.

- Publication/presentation of the project results in international journals and meetings
- A Summer school will be organized in the project framework (target groups: Students, young researchers), location: TU Delft premises, The Netherlands, M36)
- Final seminar and workshop will be organized for target groups defined in the dissemination strategy in framework of dissemination (for project participants, end users, researchers, location: NRG premises, the Netherlands, M48)

Participation of Ph.D. students, postdoctoral researchers and trainees will be supported (partially) by student grants. One of the goals of these seminar/workshop and summer school are to spread knowledge and know-how towards PhD students and young researchers, in order to encourage research in the field and to train the younger generation. Dissemination of results to End Users is another prime goal.

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Publication/presentation of the project results in international journals and meetings	M01	M48	I. Szenthe (HUN-REN-CER)	All partners
2. Summer school organisation	M24	M36	Y. Gonzalez-Garcia (TUD)	All partner
3. Final seminar and workshop organisation	M36	M48	M. Kolluri (NRG)	All partner

Table 24. List of actions within T4.3

WP4 Deliverables

Number	Title	Due Date	Responsible
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D4.1	Communication and Dissemination Plan	M03	Anne-Charlotte Costabadie (LGI)
D4.2	Four newsletters	M48	Clea Prieto (LGI)

Table 25. List of deliverables within WP4

WP4 Milestones

Number	Title	Verification mean	Due Date	Responsible
MS23	Social and Scientific profiles available	LinkedIn Page	M02	Anne-Charlotte Costabadie (LGI)
MS24	Website Open	Website url	M03	Anne-Charlotte Costabadie (LGI)
MS25	First Magic-RR newsletter released	Newsletter sent and available on the website in pdf	M12	Clea Prieto (LGI)
MS26	Magic-RR Summer School	Agenda and Minutes	M36	Y. Gonzalez-Garcia (TUD)
MS27	Magic-RR final seminar and workshop completed	Agenda, Minutes, and attendant list?	M48	M. Kolluri (NRG)

Table 26. List of milestones within WP4

Interaction with other WPs

Number	Interaction description	Responsible
1	Collection of information of all WPs for the communication materials, news and newsletter	Clea Prieto (LGI)
2	Coordination of partners for participation in events, networks and initiatives, and coordination of publications	M. Kolluri (NRG)

Table 27. Interactions between WP4 and other WPs

Risks of WP4

Contractual risks (number, description, risk-mitigation), probability (1=low; 5=high) that the risk occurs and impact (1=low; 5=high) if the risk occurs. Other risks (not in GA) can be added so they can be followed during the project. Risk mitigation: P=preventive actions / C=contingency actions.

Number	Risk description	Risk mitigation	Prob.	Impact
1	Low engagement of partners on communication activities	Continued communication with the consortium	1	4

Table 28. Anticipated risks in WP4

5. WP5 actions: Project coordination and management

Work Package Leader: (HUN-REN-CER)

Duration: M01 – M48

Objectives: This WP will ensure a proper management of the project.

Task 5.1 Project coordination

Task Leader(s): Akos Horvath (HUN-REN-CER) – Administrative coordinator, Murthy Kolluri (NRG) – Scientific coordinator

Contributors: CEA, LGI

Duration: M01 – M48

Description of activities: This task groups the coordinator's activity of organization and monitoring of the work progress:

- Elaboration of the detailed work plan, established at the beginning of the project, defining with precision the activities of each partner within each task and identifying the involved persons. This will be mainly done with the partners during the kick-off meeting.
- Supervision of project deliverables, progress milestones, and planning.
- Risk analysis and management plan throughout the project.
- Performance indicators identification and follow up.
- Continuous monitoring of partners' scientific achievements.
- Scientific review of the work and deliverables performed by the partners.
- Project Quality Plan and Data Management Plan (DMP).

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Project coordination (Administrative part)	M01	M48	A. Horvath (HUN-REN-CER)	I. Szenthe (HUN-REN-CER)
2. Project coordination (Scientific part)	M01	M48	M. Kolluri (NRG)	F. Naziris (NRG)
3. Lead and coordinate activities in WP2	M01	M48	Pierrick Francois (CEA)	
4. Support the coordinator in the following actions (T7.1a-f), in initializing the tools/templates, continuously collecting the information, consolidating the outputs.	M01	M48	M. LAZAREVIC, M. TERREROS LOZANO (LGI)	M. LUX (LGI)
5. Write project quality plan (T7.1g)	M01	M03	M. TERREROS LOZANO (LGI)	M. LUX (LGI)
6. Write data management plan (T7.1g)	M01	M06	M. LAZAREVIC, M. TERREROS LOZANO (LGI)	M. LUX (LGI)

Table 29. List of actions within T5.1

Task 5.2 - Project office

Task Leader: Mina LAZAREVIC, Mariana TERREROS LOZANO (LGI)

Contributors: Marine LUX (LGI)

Duration: M01 – M48

Description of activities: This task includes the following sub-tasks.

- a. Quality management
 - Elaboration and application of a project quality plan, internal guideline detailing project procedures (quality assurance, document management, document templates, etc.).
 - Private web collaborative platform to share information, document, including a deliverable & milestone monitoring and validation workflow.
 - Set up and maintain the project mailing lists.
- b. Project secretariat and meetings organization
 - Pre-and post-processing of all the project meetings (kick-off, executive committee, governing board, plenary meetings).
 - Support to project partners upon request.
 - More generally, ensuring that all partners share the same level of information.
- c. Contractual & Financial Management
 - Maintenance of the grant and consortium agreements.
 - Management of funds and maintenance of budget files.
 - Coordination of the periodic (M18, M36 and M48) and final (M48) reports to the EC.

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Quality management	M01	M48	M. LAZAREVIC (LGI)	M. TERREROS M. LUX (LGI)
2. Project secretariat and meetings organization	M01	M48	M. LAZAREVIC (LGI)	M. TERREROS M. LUX (LGI)
3. Contractual & Financial Management	M01	M48	M. LAZAREVIC (LGI)	M. TERREROS M. LUX (LGI)
4. Coordination of Periodic Report 1	M17	M18	M. LAZAREVIC (LGI)	M. TERREROS M. LUX (LGI)
5. Coordination of Periodic Report 2	M35	M35	M. LAZAREVIC (LGI)	M. TERREROS M. LUX (LGI)
6. Coordination of Periodic Report 3	M47	M48	M. LAZAREVIC (LGI)	M. TERREROS M. LUX (LGI)

Table 30. List of actions within T5.2

Task 5.3 Scientific Advisory Board

Task Leader: Ferenc Gillemot (HUN-REN-CER)

Contributors: NRG, LGI

Duration: M01 – M48

Description of activities: The scientific advisory group (SAG) will be constituted of high-ranking scientists from organizations in and/or outside Europe. It will advise on specific questions raised by the project and provide its assessment of the scientific activities based on international trends and

scientific developments in the fields of the project. The detailed terms of reference will be established at the beginning of the project.

A detailed list of actions in this task is given below.

Actions	Start Date	Due Date	Responsible	Contributors
1. Questionnaire for SAB Names	M3	M3	F. Gillemot (HUN-REN-CER)	
2. Selecting SAB members and Invitation of SAB members	M3	M4	F. Gillemot (HUN-REN-CER)	M. Kolluri (NRG)
3. First SAB video meeting to introduce project	M4	M4	F. Gillemot (HUN-REN-CER)	M. Terreros Lozano (LGI)
4. SAB meetings connected with the consortium meetings	M12	M48	F. Gillemot (HUN-REN-CER)	M. Terreros Lozano (LGI)
5. Information on SAB recommendations during EXCOM meetings, and on the project web	M6	M48	I. Szenthe (HUN-REN-CER)	M. Terreros Lozano (LGI)

Table 31. List of actions within T5.3

WP5 Deliverables

Number	Title	Due Date	Responsible
D5.1	Detailed Work Plan	M03	M. Kolluri (NRG)
D5.2	Project Quality Plan	M03	M. Terreros Lozano (LGI)
D5.3	Data management Plan	M06	M. Terreros Lozano (LGI)

Table 32. List of deliverables within WP5

WP5 Milestones

Number	Title	Verification mean	Due Date	Responsible
MS28	Kick-off meeting	Meeting minutes	M01	M. Kolluri (NRG)
MS29	Constitution and first meeting of the SAB	Meeting minutes	M04	F. Gillemot (HUN-REN-CER)

Table 33. List of milestones within WP5

Interaction with other WPs

Number	Interaction description	Responsible
1	Collecting suggestions for the name SAB members	F. Gillemot (HUN-REN-CER)

2	Information on SAB suggestions to EXCOM and project web	I. Szenthe (HUN-REN-CER)
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Table 34. Interactions between WP5 and other WPs

Risks of WP5

Contractual risks (number, description, risk-mitigation), probability (1=low; 5=high) that the risk occurs and impact (1=low; 5=high) if the risk occurs. Other risks (not in GA) can be added so they can be followed during the project. Risk mitigation: P=preventive actions / C=contingency actions.

Number	Risk description	Risk mitigation	Prob.	Impact
1	Delay since late responses	Good communication between the participants and SAB members	2	3

Table 35. Anticipated risks in WP5

Conclusion

This deliverable is concerned with the detailed work plan of the Magic-RR project. The proposed technical work from the Description of the Action (DoA) from the GA has been divided into several actions to realise the project objectives. For every action, at least one responsible person or organisation has been appointed. This document is intended to be used by the coordination team to follow-up the project activities and by the Magic-RR consortium. This document shall be updated along the project duration in case of delay in the action implementation and/or identification of new actions.



Magic-RR

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