CELL-INTEGRATED SENSING FUNCTIONALITIES FOR SMART BATTERY SYSTEMS WITH IMPROVED PERFORMANCE AND SAFETY

GA 957273

D7.4 - FINAL QUALITY ASSURANCE AND RISK MANAGEMENT PLAN

LC-BAT-13-2020 - Sensing functionalities for smart battery cell chemistries

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Summary

This Final Quality Assurance and Risk Management Plan for the SENSIBAT project outlines the followed strategic approach to ensure the highest standards of project quality and effective risk management built upon the foundations laid in the Initial Quality Assurance and Risk Management Plan (deliverable D7.2). The present document summarises our commitment to deliver a project of the highest quality and effectively managed associated risks.

SENSIBAT's journey from the Initial Quality Assurance and Risk Management Plan to this final iteration has been marked by continuous improvement and adaptation. SENSIBAT project partners implemented methodologies and processes detailed in the initial document, and the present updated version reflects the enhancements made based on practical insights and lessons learned throughout the project.

No deviations exist from the description of this deliverable as provided in Annex I of the Grant Agreement.

Table of Contents

Abbreviations

Symbol / Abbreviation	
AB	*Advisory Board*
CSA	*Coordination and Support Action*
EC	*European Commission*
EIS	*Electrochemical Impedance Spectroscopy*
EV	*Electric Vehicle*
DOA	*Description Of Action*
GA	*General Assembly*
IPR	*Intellectual Property Rights*
SOC	*State Of Charge*
SOE	*State Of Energy*
SOH	*State Of Health*
SOP	*State Of Power*
SOS	*State of Safety*
WP	*Work Package*
WPL	*Work Package Leader*

1 Introduction

The deliverable D7.2 (Initial Quality Assurance and Risk Management Plan) represented an essential tool for an effective technical coordination of SENSIBAT. During all phases of the project, this deliverable underwent updates and reviews to culminate in the creation of 'D7.4 - Final Quality Assurance and Risk Management Plan.' This final plan summarises all identified risks throughout the project lifecycle, documenting their impact and the prescribed responses.

As defined in D7.2 the responsibility for technical coordination, quality assurance, and risk management was overseen by the Project Coordinator (IKE) throughout the entirety of the project. Any necessary corrective actions, including potential work reallocation, were efficiently coordinated by the Project Coordinator and approved by the Executive Board, consisting of all WP leaders.

The Quality Assurance procedures (Chapter 3 of D7.2 and Chapter 4 of D7.1) outlined robust procedures that ensured the quality of deliverables, maintaining adherence to deadlines, and implementing a peer review matrix. Moreover, the procedures addressed the processes within SENSIBAT that assured the scientific/technical quality of work and the quality of administrative processes.

The Risk Management Plan (Chapter 2 of D7.2) successfully identified most of the potential risks that could impact the predefined evolution of the project. Its monitoring was monthly overseen by the Executive Board and twice a year by the General Assembly. Finally, this deliverable consolidates all identified risks and associated management details upon project completion.

2 Risk Management

The following section presents an updated, extended, and completed risk analysis, demonstrating SENSIBAT project's proactivity in identifying and addressing potential risks.

SENSIBAT's initial risk identification process laid the foundation, and the extended risk analysis incorporates insights gained from project developments, ensuring a more comprehensive risk profile. As elaborated in D7.2, the Risk Management Plan is not merely a static document; instead, it is conceptualised as a living, iterative tool that continuously evolved throughout the project's lifecycle. This dynamic nature ensured that the project team remained agile and responsive in dealing with emerging risks, contributing to the overall resilience and success of the SENSIBAT initiative.

In deliverable D7.2, the methodology followed by the SENSIBAT project's Risk Management Plan is explained in detail. This methodological approach entails a cyclical process involving risk identification, analysis or evaluation, plan definition, continuous monitoring, and response.

2.1 SENSIBAT Risk Management Register

During the SENSIBAT project, each risk was listed in the Risk Management Register, which is presented below and is available on METT, the online management platform used in the SENSIBAT project. Work Package Leaders collected feedback from the partners involved in their tasks, revised and updated The Risk Management Register before each Executive Board and General Assembly meeting or when requested by the Project Coordinator.

Table 1. Probability of risk occurrence

Risk No.	***WP***	***Descrip-tion***	***Type of Risk***	***Probability***	***Effect***	***Priority***	***Prevention plan***	***Contingency plan***	***Responsible***	***Pe-riod***
XX	***WPx***	*Describe the risk here and, when relevant, refer to the section with related text in the deliverable*	*Indicate type: Tech = Technological, Part = Partnership, Mana = Management, Ext = External*	*Indicate the level 1 = High 2 = Medium 3 = Low*	*Indicate the level 1 = High 2 = Medium 3 = Low*	*Indicate the level Critical High Medium Low*	*Give a description how to avoid the risk and reduce the effect*	*Identify resources, propose a work plan to minimize impact and to oversee the factors that may activate the risk*		

The Risk Management Plan has been implemented in the 40 months of the project, as a result, in addition to the first 12 risks which were included in the proposal of the SENSIBAT project, several risks have been identified. As mentioned above, the Risk Management Register has been a living document continuously under review.

The prevention plan was defined in the cases in which it has been decided to accept the option that the identified risk may affect the project.

Risk No.	WP	Description	Type of Risk[1]	Probability [2]	Effect[3]	Priority[4]	Prevention plan	Final status	Responsible	Period
1	**WP2 WP3**	Sensors cannot withstand adverse environment in battery cell (e.g. may react with electrolyte to produce by-products) and lose sensitivity	Tech	3	1	Medium	A part of task 3.1 is focussed on the encapsulation of the level 1 sensors for chemical resistance against electrolyte. The level 1 sensors will be integrated within a polymer substrate giving them an intrinsic (backside) encapsulation that will protect against (electro-)chemical interference using the appropriate material or additional organic/ inorganic coating. The situation is more delicate on the surface of the sheet, especially for the temperature sensors that have to be equipped with a thermal interface to the environment. The consortium will use appropriate and chemically stable thermal interface materials (e.g. aluminium oxide/nitride) to build the interface, ideally exposing them only partially to the electrolyte by opening "windows" in an additional encapsulation layer. Pressure sensors are less critical to shield because the transduction of the forces can be realised through any sub- or superstrate given appropriate stiffness and thickness. For the level 2 sensors, subtask 2.1.1 is focussed on the selection of electrode-materials that withstand the operation condition of the battery cell	Although the encapsulation nominally protected the sensors from the electrolyte, high temperatures would damage the encapsulation of L1 sensors during sealing of the pouch cells. The electrolyte would then dissolve the feedthroughs, irreversibly damaging them. An alternative solution was found with a double pouch cell sealing wherein neither the sensors nor their encapsulation would be in touch with the electrolyte. The extra layer would act as a barrier layer. L2 sensors printed on the separator had no issues of this sort.	FHG	M1-18
2	**WP2 WP3**	Feedthrough of measurement contacts from the inside to the outside of the cell without leakage is not possible	Tech	3	1	Medium	A new pouch cell design will be developed by introducing a barrier layer near the seal areas to prevent the leakage. In case this is not sufficient, an additional tough polymer (typically polyester) exterior barrier will be introduced to the pouch cell.	This risk partially materialized on L1-5 Ah pouch cells with apparent leaking and drying of the electrolyte close to the feedthrough area. It was resolved by roughening the sealing area surface for better sealing. However, this new sealing damaged the cell after several moths of	AIT/ VAR	M1-40

[1] Tech = Technological, Part = Partnership, Mana = Management, Ext = External
[2] Probability risk will occur: 1 = High, 2 = Medium, 3 = Low
[3] Effect of risk: 1 = High, 2 = Medium, 3 = Low
[4] Priority of risk: Critical, High, Medium, Low

								testing. The alternative solution is explained in risk #r 1. L2 sensors printed on the separator had no issues of this sort.		
3	**WP2** **WP3**	Incompatibility of the sensors with the pouch cell assembly process	Tech	2	3	Low	The level 1 sensors are chosen and designed to be as thin as possible to be compatible during the pouch cell assembly. The level 2 sensors will be printed on the cell separator and therefore it is expected that they will not influence the assembling process.	This risk partially materialized since the design of the L1 sensors was incompatible only with the pouch cell sealing process. Therefore, the solution with the barrier layer was implemented, as described under risk #1. L2 sensors printed on the separator had no issues of this sort.	AIT/ VAR	M1-40
4	**WP2** **WP3**	Integration of sensors without changing the electrochemical behaviour of the battery cell (e.g the transport or transfer of lithium ions between anode and cathode electrodes) is not possible	Tech	2	1	High	The level 1 sensors will be attached to one side of the stacked battery electrode inside the cell where there is minimum flow of lithium ions. In case of conflict with the battery chemistry and/or functional elements several measures can be taken, e.g. a) relocation of sensing layer into different level/to different interface b) Perforation of the sensor sheet to yield a chemically open grid. The level 2 sensors will be printed onto the separator and therefore it is not expected that this will have a negative impact on the electrochemical behaviour of the battery cell. Optimisation of the geometry/shape and/or the position of the electrodes onto the separator will be investigated.	This risk partially materialized since the electrolyte did react with L1 sensors at the sealing area. Nevertheless, from the postmortem and electrochemical studies, the influence on the cell behaviour appears to be minimal. The solution presented under risk #1 was sufficient to finally fully mitigate this risk. L2 sensors printed on the separator had no issues of this sort.	AIT/ VAR	M1-40
5	**WP2** **WP3**	The EIS with internal auxiliary electrodes (level 2) is too complex and expensive (both in extra hardware required and modelling) to be implemented	Tech	2	1	High	The level 2 Electrochemical Impedance Spectroscopy (EIS) may turn out to be too expensive for commercial use in Electric Vehicle (EV) battery systems. However, the developed EIS electrodes printed on the separator, will very likely be useful in development and application laboratories to gain insights about degradation mechanisms, improve battery cells and battery control (state functions)	This risk did not materialize. However, the deliverable D5.2 Cost-Benefit assessment analysed the implementability of the Level 2 sensor.	BDM	M1-31
6	**ALL**	Breach of IPR conditions as per Consortium Agreement	Part	3	1	Medium	The General Assembly, as it will be stated in the Consortium Agreement, will be the main body in charge of monitoring the intellectual property rights (IPR) aspects, the Exploitation Manager will prepare the IPR state of play during the project execution.	This risk did not materialize.	IKE/ POL	M1-40

7	**ALL**	Infringe on existing patents	Mana	3	2	Low	The Exploitation Manager will scan the IP environment worldwide and update the consortium in a timely manner. Risk of infringement could be avoided by adapting project development trajectory.	This risk did not materialize	POL	M1-40
8	**WP 1-5**	Relevant data are not being supplied in time by the partners.	Part	3	1	Medium	The Consortium will specify relevant backup data to work with	This risk did not materialize	IKE/ ABEE	M1-40
9	**WP2 WP3**	Integration effort of the sensors higher than expected	Mana	2	1	High	Within WP2-WP3 the partners are committed to have sufficient PM for the dedicated task, or will make available additional efforts	This risk did not materialize	VAR	M6-31
10	**ALL**	Low level of quality in technical studies. Delays in milestones or deliverables.	Mana	2	2	Medium	The Executive Board will monitor continuously progress and quality of work in accordance to defined work plans	While some deliverables and milestones were delayed, this delay was part of the extension that project got. The only delay that influenced other milestones and works to be done in the project was the one related to the readout circuit of Level 1 sensor and the corresponding BMS slave-master for the development of the module. The quality of technical studies was up to the standard	IKE/ ABEE	M1-40
11	**WP7**	Partners leave or partners become insolvent	Mana	3	1	Medium	Back-up partners list or inside Consortium solution	This risk did not materialize	IKE/ UNR	M1-40
12	**WP7**	Delay in work plan due to COVID-19	Ext	1	3	Medium	Partners will review the schedule and determine if there are areas that can be compressed or consolidated or if there is work that can be done concurrently rather than sequentially. Develop a priority scale for the project and work on deliverables.	This risk did not materialize	IKE	M1-12
13	**WP 1-5**	Delays in providing the components in time for following WPs activities	Part	2	2	Medium	Track development progress and focus efforts especially in the most sensible components.	This risk did materialize in WP4 with the components for demonstrator module, delay in readout circuit for Level1 sensor incorporated cells and BMS slave-master.	IKE/ ABEE	M4-40
14	**WP5**	Testing plan not suited to detect differences between baseline and sensor cells.	Tech	3	2	Medium	Testing plan planned and reviewed by experienced engineers/scientists. Random post-mortem samples of test items to identify.	This risk did not materialize. Nevertheless, some differences in the cells were identified only with post-mortem analysis.	AIT	M6-40
15	**WP4**	Equivalent-circuit type battery models do not allow to adequately describe the link between the battery state (2D heterogeneous SOC and SOH, SOE and SOP) and the 2D	Tech	2	2	Medium	Task 4.4 will assess the level of model complexity required to leverage level 1 sensor information to improve the state estimates. If equivalent-circuit-type models prove inadequate, electrochemical battery models will be considered. In this case, part of the work of task 4.5 will move to task 4.4.	The L1 cells analysis unveiled a significant relationship between mechanical pressure and SOC/SOH/SOS values. In addition, as the cell ages, there is an irreversible increase in thickness, leading to a shift in all pressure measurements towards higher	IKE	M9-40

		temperature and pressure measurements of the level 1 sensors.						values. Among the different possibilities to integrate the 2D temperature and pressure measurements, it has been decided to opt for the method of averaging the 2D measurement data. Therefore, the average temperature and pressure values are used in the state algorithms.		
16	**WP4**	The data coming from the different sensors are not consistent, which hinders their usefulness in improving the state estimation functions.	Tech	2	2	Medium	Tasks 4.4 and 4.5 will investigate the consistency between the various sensor readings using a commercially available EIS measurement device. This will allow the detection of potentially unreliable readings and the ranking of the different sensors according to their usefulness in improving the state estimation functions. If inconsistencies or inaccuracies are observed in the level 1 or 2 sensor measurements, this will be fed back to the relevant sensor development work package(s) for further investigation.	Added a new preconditioning step for the reference electrode to obtain a reference potential as reproducible as possible (Level 2). This does not affect the cell performance.	FM/ IKE	M9-40
17	**WP3**	Pouchbag cells are typically operated between two plates (braced together) – attached sensor may result in additional mechanical stress	Tech	2	2	Medium	Special design of the plates may become necessary, providing additional space for the attached sensor	This risk did not materialize	VAR	M1-40
18	**WP7**	Not detect a risk	Mana	2	3	Low	Monitor risks and try to identify new ones in the corresponding meetings	This risk did not materialize	IKE/ ABEE	M1-40
19	**WP4**	Complexity of the module cooling strategy	Tech	1	2	Low	Keep the design as simple as possible, as long as it does proper cooling. The goal of the project is not to optimize the cooling strategy.	This risk did not materialize	FM	M12-40
20	**WP2 WP3**	The welding of tab to level 2 sensor damages the polymeric separator	Tech	2	3	High	Conventional ultrasonic welding parameters used to connect the tabs to current collectors will be modified to be compatible with polymeric separators	The parameters for ultrasonic welding, traditionally employed for connecting tabs to current collectors, were adjusted to ensure compatibility with polymeric separators.	BDM/ AIT/ VAR	M18-31

3 Quality Assurance

In SENSIBAT project, three distinct dimensions of quality were meticulously addressed: i) the scientific/technical quality of the work, ii) the quality of deliverables and milestones, and iii) the quality of administrative processes.

3.1 Scientific and technical quality of the work

The overall project outcome hinged on the meticulous execution of activities, with the quality of work continually monitored by the General Assembly, the Executive Board, the Project Management Team, and the WP Leaders. Throughout the project, every team member, including the Coordinator, assumed responsibility for critically assessing work quality and striving for optimal results.

3.1.1 External Advisory Board

SENSIBAT featured an external Advisory Board (AB) comprised of 5 external experts (detailed information can be found in D6.4 and D6.5). This board actively supported SENSIBAT by providing feedback, participating in meetings and workshops, and offering insights on exploitation relevant to SENSIBAT.

3.1.2 Internal project monitoring

General Assembly meetings have been held twice a year to facilitate progress monitoring. Next to this, there were monthly Executive Board meetings. In addition to these meetings, all consortium partners were requested to complete a short internal progress report every 6 months. This report indicated any problems regarding meeting deadlines, completion of the work as planned, and budgets. The purpose of the internal progress report was to set up and maintain an 'early-warning' system (for possible technical and financial risks) via clear, simple, and transparent procedures.

3.1.3 Battery 2030+ research initiative

SENSIBAT project collaborated in the Battery 2030+ initiative. This research initiative allowed the collaboration between seven projects; one coordination and support action (CSA) coordinated by UU, Sweden, and six research and innovation projects: BAT4EVER, coordinated by VUB, Belgium; BIG-MAP, coordinated by DTU Denmark; HIDDEN, coordinated by VTT Finland; INSTABAT, coordinated by CEA France; SENSIBAT, coordinated by IKERLAN in Spain, and SPARTACUS, coordinated by Fraunhofer in Germany. The Battery 2030+ initiative facilitated the SENSIBAT project to collaborate on the technical side with two projects financed under the same call (INSTABAT and SPARTACUS) through the creation of multi-project teams on specific topics such as:

- Exchange of battery cells to compare sensor data
- Data from T-sensors – also by optical sensor technologies
- Comparison of data from strain/compression sensor – also by optical sensor technologies
- Comparison of approaches to generate models
- Cost-benefit analysis
- Data management
- Battery management systems
- Aging protocols
- Electronic hardware

In addition, dissemination and networking activities under the umbrella of Battery 2030+ had a great impact on the success of the project that is difficult to match.

3.2 Quality of deliverables and milestones

SENSIBAT consortium finalised and submitted all planned deliverables in ANNEX I of the Grant Agreement. Those documents underwent internal review before submission. This review process involved the Work Package Leader (WPL) of the relevant Work Package (WP) responsible for checking the quality of reporting and consistency within the WP, a member of the Executive Board appointed by the Project Management Team ensuring alignment with the Description of Action (DoA), project objectives, and fulfilment of expectations across all WPs, and the Project Coordinator who ultimately approved the deliverable. At least two different reviewers were involved in each review.

Reviewers have used the standard review form (Annex A of D7.1) to document his/her review findings. After reviewing, the reviewer sent his/her comments to the deliverable authors. The author(s) revised the deliverable according to the quality assurance review. The Coordinator ensured that the requested updates/improvements were implemented by the author(s) and performed the final review.

Once the deliverable was approved by the Coordinator, the Coordinator submitted the deliverable to the EC in electronic form (PDF) via the Participant Portal. The submitted deliverables were stored on Mett. A template for deliverables has been provided on Mett.

Finally, when each milestone had been successfully achieved, the milestone underwent discussion within the EB, and following this, the Project Coordinator reported it to the European Commission (EC) through the designated portal.

3.3 Administrative quality

Quality management extended to the administrative processes of the project, leveraging the extensive experience of the Project Management Team in handling large international research projects funded by the European Commission.

Responsibilities were divided between IKE and UNR. IKE managed the administration of the EU financial contribution, distributing it within the Consortium, and oversaw the technical, financial, and organisational risks in the project. UNR took charge of day-to-day contractual and administrative management, financial management, set-up and maintenance of the web-based communication tool (METT), monitoring project progress, tracking costs and budget, and organising meetings of the General Assembly and the Executive Board. Both IKE and UNR collaborated on monitoring compliance by beneficiaries under the Grant Agreement, arranging the review of deliverables, and maintaining communication with the Commission's Project Officer(s) to update on project progression and relevant matters.

As the project concludes, the effectiveness of this management structure has been evident, contributing to the successful execution of SENSIBAT's objectives.

4 Conclusion

This document captures the Quality Assurance and Risk Management Plan for the SENSIBAT project. These plans have been instrumental in establishing a foundation for maintaining high project quality and implementing effective and up-to-date risk management, despite the challenges faced during the project that forced a four-month extension period.

Notably, the project encountered difficulties, primarily associated with the L1 sensor's interaction with the electrolyte and the associated read-out circuit. These challenges prompted a dynamic approach to risk management, leading to an ongoing and detailed risk analysis.

The document will serve as a valuable resource, providing insights into navigating complexities in future projects within the realm of battery and sensor technologies.

5 Acknowledgement

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

Project partners

#	PARTICIPANT SHORT NAME	PARTNER ORGANISATION NAME	COUNTRY
1	IKE	IKERLAN S. COOP.	Spain
2	BDM	BEDIMENSIONAL SPA	Italy
3	POL	POLITECNICO DI TORINO	Italy
4	FHG	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.	Germany
5	FM	FLANDERS MAKE VZW	Belgium
6	TUE	TECHNISCHE UNIVERSITEIT EINDHOVEN	The Netherlands
7	NXP NL	NXP SEMICONDUCTORS NETHERLANDS BV	The Netherlands
8	NXP FR	NXP SEMICONDUCTORS FRANCE SAS	France
9	ABEE	AVESTA BATTERY & ENERGY ENGINEERING	Belgium
10	VAR	VARTA MICRO INNOVATION GMBH	Germany
11	AIT	AIT AUSTRIAN INSTITUTE OF TECHNOLOGY GMBH	Austria
12	UNR	UNIRESEARCH BV	The Netherlands

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