# FUTURE REPAIR AND MAINTENANCE FOR AEROSPACE INDUSTRY

**Deliverable 9.4** **Technology roadmap with tasks to increase TRL further to reach the overall goals by 2020**

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## Executive summary

At the beginning of the project, the RepAIR consortium analyzed the MRO activities and proposed some technological innovations, in order to strengthen the European MRO services market, since the huge inherent cost of the MRO activities is producing the moving of the activity outside Europe. The innovations presented by the consortium have some objectives, i.e. reduce repair and overhaul costs and the turnaround time, automated spare parts production process by integrating production and supply chain, reduce scrap and toxic chemicals in the repair process, apply innovative solutions and increase their technology readiness levels, decrease the certification effort, reducing the inspection time, strengthen the business model of MRO service providers within Europe, and increase the competitiveness of AM technologies.

In order to achieve the objectives of the project, the partners proposed seven systems, components or technologies:

- ER1: Health condition monitoring component.
- ER2: Decision component.
- ER3: High batch repair system.
- ER4: 5-axis direct metal deposition system.
- ER5: Post-process and supply chain management.
- ER6: Management and integration system.
- ER7: Qualification component.

Deliverable D2.7 [R.2] evaluated the technology readiness level (TRL) of ER1, ER3 and ER4 at the beginning of the project, but also provided an estimation of the most plausibly TRL at the end of the project of the same components and systems.

Now, this document evaluates also the achieved TRL of ER1, ER2, ER3, ER4 and ER6. In order to achieve that, the document makes use of deliverables D2.7 (TRL assessment), D9.2 [R.4] (KPIs assessment) and D9.3 [R.5] (objectives evaluation).

The TRL of ER7 has not been evaluated since it is related to validation and qualification processes of materials and manufacturing technologies and to certification of airframe components. Similarly, the technology readiness level of ER5 has not been evaluated, due to the fact that the post-process activities are considered as an existent and mature technology that need to be adapted to the needs of AM. Therefore, with respect to ER5 and ER7, RepAIR only increases the know-how of handling, post-processing and qualifying parts manufactured with AM technologies.

The achieved TRL is summarized in the following table:

| ID | Element to be assessed | TRL start [acc. D2.7] | Plausible TRL at end [acc. D2.7] | Actual TRL at end [acc. D9.4] |
|---|---|---|---|---|
| ER1 | Health condition monitoring | 2 | ≤ 4 | 5 |
| ER2 | Decision component | - | - | 4 |
| ER3 | High batch repair system | 2 | ≤ 5 | 4 |
| ER4 | 5-Axis direct metal deposition system | 2 | ≤ 4 | 4 |
| ER5 | Process and supply chain management | - | - | N/A |
| ER6 | Management and integration system | - | - | 4 |
| ER7 | Qualification component | - | - | N/A |

From TRL 4 to TRL 6 the technology grows from an experimentally validated process to a product prototype shown to work in a relevant environment. This transition is frequently complicated and is commonly known as the *death valley* of technologies, since only a few technologies succeed to be fully implemented in the industry. In order to avoid these technologies to fade, some further steps and milestones are provided:

- ER1. Next step would require demonstrating performance for the operational environment on the ground or in the aircraft. Additionally, in order to extend the application and exploit the HCM it is required to demonstrate the component in a wider range of rotational and non-rotational parts.
- ER2. Increasing the TRL would require developing a complete database including real costs and functionality demonstration in a MRO partner.
- ER3. In order to overcome TRL5 it will be required to demonstrate the capability of repairing parts without defects in the interface between the machined part and the added layers.
- ER4. Reaching TRL 4 requires machine subsystems completion and functional performance demonstration.
- ER6. Increasing the TRL would require demonstrating its functionality in a pilot program comprising diverse partners with different roles. Also it would be necessary to develop a complete database including all the required information about internal processes of each partner, a catalogue of parts and materials, etc.

Finally, some lessons learned have been derived from diverse surveys and interviews sent to partners, stakeholders and AB members. The lessons learned are summarized in the following table:

| Successes / Shortcomings | Comments |
|---|---|
| All the interviewees agree with many proposed scenarios within RepAIR. | RepAIR has defined real needs within MRO activities. |
| Higher expectation in manufacturing than in repair with AM technologies has been reached. | Benefit of applying RepAIR solutions to repair parts should be better explained. |
| The decision component is highly valuated by interviewees. | The decision component has generated great expectations, due to the fact that the decision component proposes the most cost-effective solution when repairing a part, and that the cost is an important driver in MRO activities. |
| The IT platform has not generated great expectations. | The benefit of adopting the IT platform should be explained in more depth. |
| The 5-axis multi-purpose machine has generated great expectations. | Most of the interviewees consider that they would benefit of the 5-axis machine. |
| 5-axis machine objectives too ambitious. | Despite the efforts done in RepAIR the readiness level of the 5-axis machine has not increased much. |
| The SLM machine is accepted as a repair solution. | Many interviewees accept SLM not only for manufacturing, but also as a repair technology. |
| Potential AM users expect higher effort in qualifying light metals | Aluminium is rated as the most desired material after titanium. |
| The interviews and questionnaires have not reached a wide spectrum of profiles. Most of the interviewees have a research role and many others a management role. | Most of the interviewees are researchers and they are prone to adapt new technologies. It could bias the result of the questionnaires.<br>In the future it will be important to interview a higher number of managers, engineers and operators. |