

# MARP MANDATE UPDATE – 13/01/2021

The Machine Availability and Reliability Panel (MARP) is active since 2017, analysing the current status of the studies and initiatives in the field of reliability engineering in the departments of the A&T Sector. The minutes of the meetings can be found [here](#).

During this period of time, the panel identified seven areas of long-term interest for further development of ongoing activities, profiting from experience of the involved groups at CERN. The panel proposes to continue the development in the following areas, with each activity being coordinated by one contact person within the MARP. The contact person serves as an interface for people who are or will be involved in the area of interest, providing references, material and advice for new studies.

- 1) *Design of dependable electronic systems*
- 2) *Availability tracking and availability-driven performance optimization*
- 3) *Machine learning applied to the reliability analysis of complex systems*
- 4) *Reliability analysis & risk assessment for HL-LHC accelerator systems*
- 5) *Risk assessment for consolidation requests*
- 6) *Collaborations in the field of reliability*
- 7) *Development of availability/reliability analysis tools and methods*

A detailed explanation of the scope and plans for each of these points is provided below:

1) **Design of dependable electronic systems**

Electronics development is at the core of many of the critical systems of the CERN accelerator complex, including, amongst others, power converters, quench detection, machine interlocks and beam instrumentation. Following several requests from the community of electronics designers, so far treated on a case-by-case basis by a team of experts, the panel identified the need to develop a set of guidelines and good practices that should constitute the reference for the design of dependable electronic systems. The panel proposed to establish a team of experts to serve as contacts for design reviews for electronic systems within the A&T Sector.

2) **Availability tracking and availability-driven performance optimization**

Availability is one of the key performance indicators of the LHC. Operating the CERN accelerator complex with high availability will become even more challenging following the LS2 considering the upgrades deployed in the framework of the LIU project. The need of luminosity levelling further shifts the focus of operation on maximizing LHC availability in order to increase the luminosity production. This will become even more relevant in the HL-LHC era. LHC availability is tracked since 2015 by means of the Accelerator Fault Tracker (AFT). Following recommendations from the CMAC in Chamonix 2016, the tool was extended to the injector chain in 2017. The Availability Working Group (AWG) has been responsible for fault tracking since 2015 and is consistently reporting on the performance of the LHC to the LMC. It is proposed that:

1. The MARP gives recommendations on the priorities for development of the AFT.
2. Fault tracking is organized and streamlined across CERN machines, involving machine supervisors and relevant experts (e.g. from technical infrastructures)

3) **Machine learning applied to the reliability analysis of complex systems**

Future generation colliders will push the limits of today's technologies to unprecedented levels of complexity. Ensuring reliable operation of such systems will be one of the major challenges of these future projects. Ongoing studies for CLIC and FCC reveal that only a systematic optimization of current failure diagnostic techniques can ensure the required level of reliability of future systems. The use of machine learning for the identification of system trends to anticipate failure occurrence or for the discovery of hidden dependencies among systems is a powerful tool that opens the path for redefining current failure prediction and maintenance methods. Ongoing activities in this domain are being developed in several groups in the A&T Sector, with collaborations with the CERN knowledge transfer group (e.g. SMART Linac project) and the IT department. Their coordination would be beneficial to efficiently share tools, methods, computing resources and experience in the AT Sector. The panel proposes to serve as an interface for topics related to predictive maintenance and failure prognostics.

4) **Reliability analyses and risk assessment for HL-LHC accelerator systems**

The HL-LHC project aims at delivering to the LHC experiments an integrated luminosity of 3000 fb<sup>-1</sup> by 2040, targeting a total time with beam collisions above 50% of the scheduled time for physics production. This challenging integrated luminosity goal can only be achieved thanks to the introduction of new key system technologies (such as crab cavities, Nb<sub>3</sub>Sn magnets, superconducting links, hollow e-lenses, etc). The HL-LHC project is entering the transition phase from design to construction and testing. In this context, it is very important to minimize the risks for the project, both from a technological and schedule points of view. This possibly includes also the optimization of spare parts for HL systems. A systematic assessment of the risks associated to the impact of new technologies on LHC operation, including possible failure scenarios and related back-up options should be carried out in order to timely identify possible design changes or failure mitigation strategies.

The panel proposes to coordinate the activities related to reliability analyses and risk assessment for HL-LHC systems.

5) **Risk assessment for consolidation requests**

In order to reach the challenging goals of the CERN scientific programme in the coming years, a targeted consolidation of existing systems and infrastructures is vital to ensure high reliability. In this context, it is fundamental to correctly identify the most critical areas for consolidation, ensuring the highest return of investment while minimizing the impact of potential failures on the CERN scientific programme. This is not trivial, as it is often difficult to compare systems of different nature, belonging to different groups, experiments and test areas.

The panel proposes to provide inputs for these activities, working on standardized risk and reliability assessment forms and providing support for the analysis of the related results.

6) **Present and future collaborations in the field of reliability**

Reliability engineering is a relatively new discipline in the particle accelerator domain, which developed consistently from the LHC design stages. Over the last years, CERN established itself as a reference in this domain for the accelerator community, thanks to the participation of key members to international conferences and workshops (e.g. the Accelerator Reliability Workshop – ARW).

CERN is active and provides support, through expert supervision and testing, to a number of collaborations, e.g. with GSI and MYRRHA. These collaborations are defined in the scope of dedicated collaboration agreements and addenda.

In addition, CERN has active contacts with relevant institutes in the field of reliability, for continuous exchange and follow-up of latest technologies and methods (e.g. with IMA Stuttgart and Politecnico di Milano)

The panel proposes to coordinate the ongoing collaborations, keeping the links to relevant partners and institutes.

7) **Development of availability/reliability analysis tools and methods**

Ongoing studies in the field of reliability engineering are mainly carried out at CERN by students and fellows in different departments of the A&T Sector under the supervision of experienced staff members. Methods such as Failure Mode and Effect Analysis, Fault Trees, System-Theoretic Process Analysis, Discrete Event Monte Carlo simulations, and tools (Isograph, AvailSim) are nevertheless often shared. Providing a forum for sharing experience and bringing together the knowledge developed over the years in this domain is highly beneficial for people working in the field, facing the challenge of modelling accelerator systems with expert tools. The panel proposes to continue with the activities of the Reliability and Availability Studies Working Group (RASWG), to establish and document a medium-to-long term record of methods and tools developed at CERN for analysis of accelerator dependability.

**MANDATE:**

- 1) Share experience, tools and methods for analysis of system reliability/availability across departments in the A&T Sector (covered by points 1 and 6 of the above list)
- 2) Propose a consistent approach for reliability/availability studies within the A&T Sector (covered by points 2, 3, 4 of the above list)
- 3) Promote the reliability/availability culture at CERN through the organization of trainings, workshops, participation to European projects (covered by point 5 of the above list)

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The panel will meet about once per month, giving the opportunity to discuss the status and follow-up of the six activities described above about twice per year.