Reliability and Availability Working Group

Minutes for the RAWG meeting on 14th August 2024

Present: T. Argyropoulos, S. Bertolasi, M. Blaskiewicz, H. Dostmann, L. Felsberger, J. Heron, M. Hostettler, P. Jurcso, D. Kuchler, K. Li, B. Mikulec, B. Rae, M. Saccani, J. Uythoven, W. Vigano, F. Waldhauser, D. Westermann, D. Wollmann

The slides are available on indico.

Agenda

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1 RAWG Organisational Change and Update on Activities - L. Felsberger

L. Felsberger opened the meeting. The minutes of the RAWG meeting on 18/06/2024 are now available on indico. There were no comments on the minutes. The last meeting was a joint seminar with ICF and ML coffee with no minutes.

Effective 1st of July, the organizational structure of the RAWG has changed with **J. Uythoven** handing over the chairing of the working group to **L. Felsberger**. **B. Mikulec** and **X. Fink** will keep their current roles while **F. Waldhauser** takes over as scientific secretary. **L. Felsberger** thanked **J. Uythoven** for his contribution over the last years. These changes have been presented to the CTTB on 28/06/2024. The announcement of the organizational changes was followed by a summary and update on the RAWG activities. Main topics are the design of dependable systems, the monitoring and optimization of availability of the accelerator complex and availability studies of future accelerators.

2 Accelerator Availability in the First Half of 2024 and AFT Update - B. Mikulec

B. Mikulec presented a mid-year analysis for the availability of the LHC and the injector complex. For each accelerator, the unavailability, weekly fault rate and unavailability by duration was presented and discussed regarding possible explanations for changes with respect to the previous years. All figures can be accessed through GitLab.

For LINAC4, the unavailability increased slightly compared to 2023. The increase seen in the weekly fault rate might be attributed to the split of faults between RF and EPC leading to an increase of the fault number. The unavailability of the PS Booster could be reduced with respect to 2023, partially due to remote checks for water leaks reducing the magnet fault rate. The PS also improved its availability compared to 2023. Possible explanations are improvements in the RF system including automatic cavity resets which also could explain the increased availability even if the weekly fault rate is not significantly lower. **J. Uythoven** asked whether problems seen in the past with the Power for PS (POPS) have been solved. **B. Mikulec** responded that the main problem was solved during the YETS 22/23, but there were still a few POPS issues concerning water leaks in the DC/DC converters observed in 2023. **L. Felsberger** added that this milestone was reached earlier than expected and was initially planned for LS3. **S. Bertolasi** noted that it should be distinguished whether a fault is a problem in the

system or due to a human error. **B. Mikulec** responded that this is already done with human error classified as "Other", as for example done with the AUG button incident.

For SPS, the increase in unavailability can be attributed to many RF cavity issues. **K. Li** added that the problem is not yet fully understood, and the downtime is mainly caused by few very long faults. **M. Hostettler** asked whether it would make sense to introduce a minimum fault duration (e.g., 2 minutes) to reduce the number of automatically recorded faults which are not attributed to systems. **B. Mikulec** responded that this is already realized for the other injectors and **L. Felsberger** added that there was an estimation in 2021 on the resulting error which turned out to be tolerable. **K. Li** agreed that this would be a good idea and **B. Mikulec** suggested to follow up on this offline.

The LHC availability has improved with respect to 2023 with QPS-related unavailability steadily increasing over the last few years. Possible reasons might be R2E effects due to increasing luminosity and/or longer repair times. **D. Wollmann** noted that downtime classified as "Other" was mainly at the beginning of this year's proton run (e.g., heat load recovery). **M. Hostettler** added that accesses are sometimes handled differently which might contribute to increasing unavailability classified as "Other" even if the number of accesses did not increase. **D. Wollmann** noted on slide 17 that the turnaround penalty is naturally more severe for QPS and beam losses due to short faults compared to Cryogenics. **M. Hostettler** commented on the fact that QPS unavailability increased with constant weekly fault rate that there are more QPS faults this year related to R2E, particularly in point 5 which requires RP clearance for access and thus causes longer downtime. **D. Wollmann** responded that there is a uniform distribution of R2E related QPS faults between points 1, 5 and 8 and the increase in unavailability is due to a combination of three effects: doubled luminosity compared to last year pushing R2E faults, many faults requiring physical intervention (replace components or hard reset), efforts in growing a new generation of QPS experts, which adds overhead on intervention time. **B. Mikulec** asked about the expected fault rates for HL-LHC. **D. Wollmann** responded that new BS boards are developed after identification of an issue in 2018, which are currently validated and used in point 1 and will be deployed everywhere. These boards account for 40% of the faults. Improvements on communication boards are ongoing and mitigation measures are evaluated within the next two years of Run 3 with implementation expected in LS3.

Concerning overall availability, the PSB is constantly increasing and LHC also performs better than last year. **M. Hostettler** noted that in 2022 and 2023 the LHC had long faults leading to a schedule update, which is not reflected in the availability figures, and the availability this year might actually be better than 2022. For the availability review at the end of the year it might make sense to correct the overall availability figures for changes in the schedule. **L. Felsberger** confirmed that the proton availability numbers correspond to the latest version of the schedule and not its first version. **D. Wollmann** noted that the improvements from LS2 are slowly phasing out since we are approaching the next LS.

AFT review rates differ significantly between accelerators and are particularly low for SPS, LHC and NA. For SPS, this might be affected by the high number of automatically recorded short faults. **D. Wollmann** asked whether the pending reviews are mainly OP, RAWG or equipment reviews. **B. Mikulec** responded that this would have to be checked again. On slide 23, **L. Felsberger** commented that missing reviews could be due to outdated e-groups, some of which are currently under review.

Automatic fault recording has seen steady upgrades. **M. Hostettler** added that for LHC it is planned to add non-blocking faults and spurious circuit trips during periods without beam.

B. Mikulec updated the slides to include the remark on overall LHC availability and the AFT improvement plans mentioned by **M. Hostettler**.

3 AvailSim4: Open Source Framework For Availability And Reliability Simulations - M. Blaskiewicz

M. Blaskiewicz presented the AvailSim4 simulation framework, which is developed at CERN and in use for reliability and availability studies since 2020. Main benefits are the availability as an open-source tool, the easy integration with other tools, the possibility for parallelization making it useful for large-scale simulations (e.g., on HTCondor), and its flexibility, which comes at the cost of slow convergence. The framework combines Discrete Event Simulation (DES) and Monte Carlo (MC) approaches and allows implementation of complex models. For

performance optimization either Quasi Monte-Carlo (QMC) or Importance Splitting can be applied for better coverage of the problem space or focusing on rare critical events. **M. Blaskiewicz** showed a Demo demonstrating the workflow from definition of the simulation scenarios to evaluation of the results.

B. Mikulec asked how the simulation compare with the availability seen in reality. **L. Felsberger** noted that the results are always only as accurate as the estimations of the failure rates used in the simulations. He cited the previously mentioned example of the new SPS RF systems based on solid-state power amplifiers (SSPAs) where an availability analysis with failure rate estimates from the component suppliers showed that there is sufficient redundancy with a comfortable margin, while it seemed that with the increased operational failure rate in practice the limits of the redundancy are reached. **B. Mikulec** responded that a comparison with actual failure rates would allow an evaluation of the estimations which could help for designing future systems. **J. Uythoven** pointed out that this comparison was done by **A. Apollonio** in the past for the LHC machine protection system's main components. **D. Wollmann** added that the simulation results give important information for system upgrades, e.g., which are the critical components for increased luminosity. **J. Uythoven** added that faults originating outside of the design, e.g., incidents with the electricity grid, are not captured in the simulations.

L. Felsberger closed the meeting. The next RAWG meeting will take place on September 12th.