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Always On, Always Safe: The engineering challenge of Continuous Operation in the IFMIF-DONES fusion neutron source

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Large scientific infrastructures increasingly depend on availability-driven Operations & Maintenance (O&M) models, where every additional hour of uptime translates directly into scientific output. In IFMIF-DONES, this link is especially explicit: higher infrastructure availability enables longer irradiation time and therefore greater throughput and quality of materials data for fusion-relevant qualification campaigns.

Achieving sustained high availability is, however, far from a conventional O&M problem. Key systems will operate in radiological environments where direct human intervention is constrained, access windows must be minimized, and maintenance actions must be carefully planned, executed, verified, and documented. This creates a demanding operational paradigm: maximize continuity of operation while preserving strict safety, traceability, and configuration control.

This presentation outlines an O&M approach tailored to IFMIF-DONES, focused on “availability without compromising safety.” A central pillar is the design and integration of remote handling capabilities for inspection, maintenance, rescue and recovery tasks, enabling effective interventions in contaminated or high-dose areas and supporting maintainability as a design requirement rather than an afterthought.

Building on this foundation, we discuss how data-driven and AI-enabled methods can further reduce unplanned downtime and optimize maintenance scheduling. Examples include predictive maintenance to anticipate degradations before failure, and reinforcement learning-inspired strategies to support complex operational decision-making and robotic task execution, always under rigorous supervision and interlock logic.

The talk concludes with a practical view of how these elements—remote maintainability, predictive analytics, and intelligent assistance—can be combined into a coherent O&M concept for IFMIF-DONES that is measurable, auditable, and aligned with the facility’s core mission: delivering maximum irradiation availability in a controlled and safe manner.

Presenter: WEBER, Moisés (Consorcio IFMIF-DONES España)

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