ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOPHA149

ACCELERATOR SCHEDULE MANAGEMENT AT CERN

B. Urbaniec, C. Roderick, CERN, Geneva, Switzerland

Abstract

Maximizing the efficiency of operating CERN's accelerator complex requires careful forward planning, and synchronized scheduling of cross-accelerator events. These schedules are of interest to many people helping them to plan and organize their work. Therefore, this data should be easily accessible, both interactively and programmatically. Development of the Accelerator Schedule Management (ASM) system started in 2017 to address such topics and enable definition, management and publication of schedule data in generic way. The ASM system currently includes three core modules to manage: Yearly accelerator schedules for the CERN Injector complex and LHC; Submission and scheduling of Machine Development (MD) requests with supporting statistics; Submission, approval, scheduling and follow-up of control system changes and their impact. This paper describes the ASM Web application (built with Angular, TypeScript and Java) in terms of: Core scheduling functionality; Integration of external data sources; Provision of programmatic access to schedule data via a language agnostic REST API (allowing other systems to leverage schedule data).

INTRODUCTION

In almost any field, effective schedule management is key when it comes to being efficient and maximizing the use of the time available. This also includes the organization of the activities related to the operation of CERN's particle accelerator complex. A lot of effort has always been put into the CERN accelerator schedules, however the schedule data has never been available in a programmatic manner.

Launched in February 2017, the Accelerator Schedule Management project resulted in a new web application that is comprised of three modules to manage:

- The official accelerator schedules.
- Control system changes.
- Detailed planning for Machine Development periods.

Each of the modules is described in more details in the following sections.

SCHEDULE MANAGEMENT

As the name suggests, the Schedule Management (SM) module centralizes the creation, edition and publication of the schedules. In ASM, everything is based on access roles and is fully data driven, therefore, to satisfy the CERN requirement for separate schedules for the LHC and Injector Complex, the person with the role of Schedule Manager has simply configured new schedules accordingly using the forms in the application. Recognizing the utility and ease of use, other types of schedules haven been subsequently added such as for different types of commissioning and facility schedules as shown in Fig. 1.

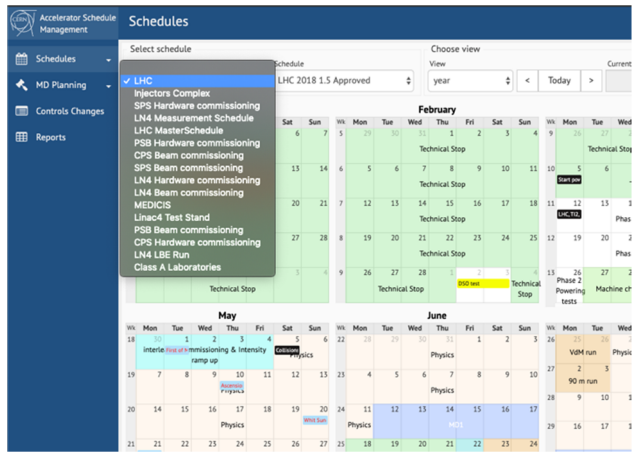

Figure 1: ASM schedules configured for a variety of cases.

The SM module facilities creation and edition of schedules with its point and click user interface allowing to easily add different types of events such as:

- *Background events* – long running periods such as Technical Stops, Physics runs, Machine Development blocks etc.
- *Foreground events* – specific types of events that last for a relatively short time with respect to their corresponding background events e.g. Controls Maintenance Days within an extended Technical Stop.
- *Punctual events* – events that are foreseen to occur at a specific moment in time without a specific ongoing duration e.g. Start of Physics.
- *Floating events* – events for which the exact time and duration are not known in advance, which are therefore scheduled within an approximate time window.

The ASM application validates events as they are scheduled, for example, ensuring they do not overlap. Once a schedule is considered final, the person with the schedule manager role can click to publish the schedule as a new major or minor release. This will automatically update the version number of the schedule and make it available in the overall list of schedules.

Any authenticated user can go to the ASM web application and consult schedules in either yearly (Fig. 2), monthly (Fig. 3) or weekly views (Fig. 4).

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOPHA149

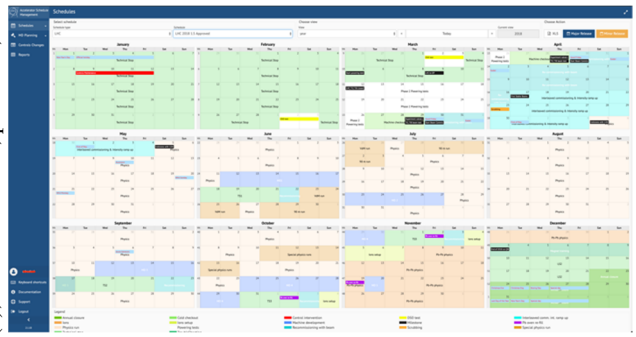

Figure 2: Yearly schedule view with overview and legend.

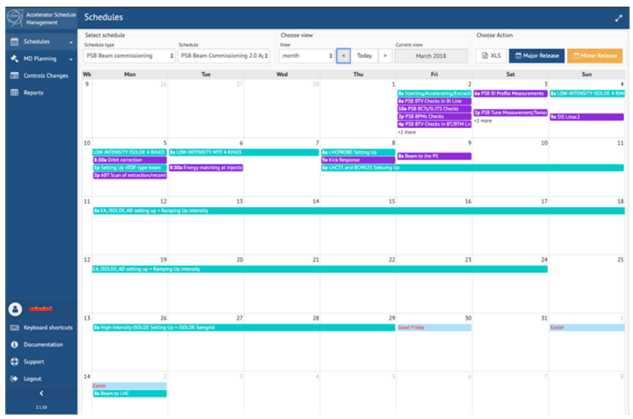

Figure 3: Monthly schedule view.

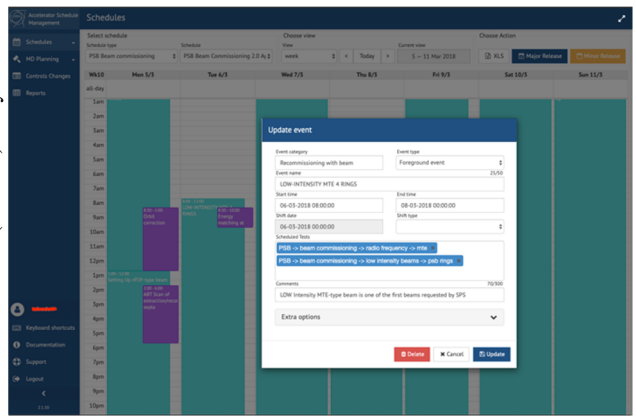

Figure 4: Weekly schedule view with event details.

According to the view, more or less details are displayed. As shown in Fig. 4, the weekly view can list detailed entries for each day that people can easily follow during busy periods such as beam commissioning.

In addition, it is possible to generate a print-view of a yearly schedule which fits on a single page in a format that users are familiar with from the time when the schedules were prepared fully by hand. Such a schedule is shown in Fig. 5 and is typically kept as an on-hand reference by people throughout the year. In the past, generating such a view required time-consuming manual work using an Excel spreadsheet to effectively draw the schedule by colouring and labelling the cells in a worksheet.

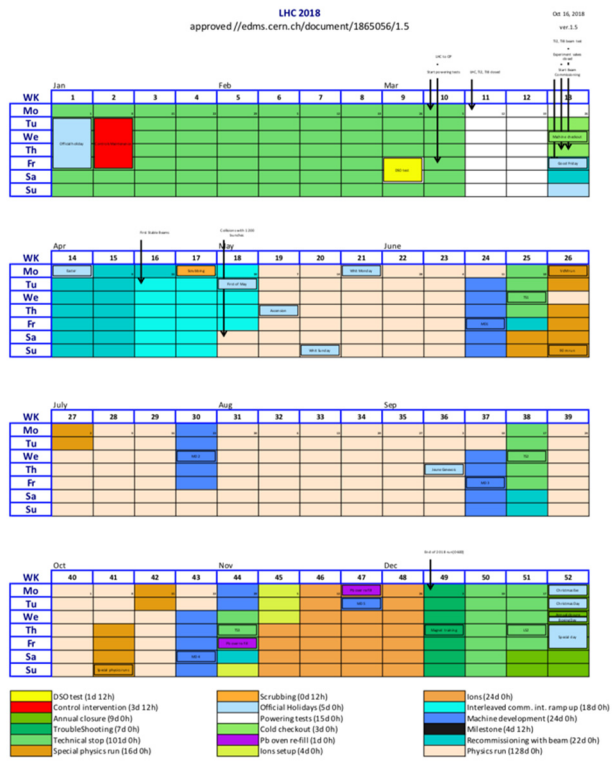

Figure 5: Yearly schedule A4 print view.

Programmatic Access

An important aim at the start of the ASM project was to provide programmatic access to the schedule data. This has been achieved via a publicly accessible, language agnostic REST API which is accompanied by interactive documentation using Swagger as shown in Fig. 6.

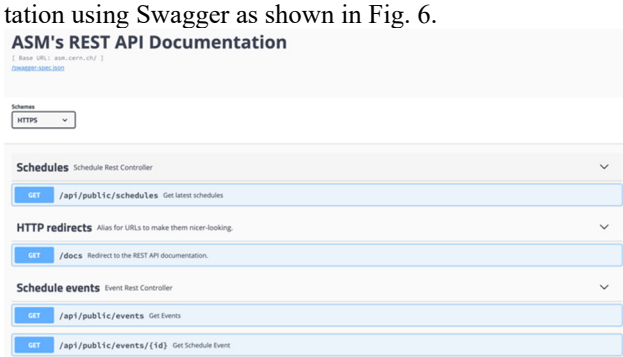

Figure 6: Interactive REST API documentation.

The ASM REST API allows other systems to leverage schedule data to facilitate the tasks of their associated users. As shown in Fig. 7, the CERN Accelerator Fault Tracking (AFT) system [1] already incorporates ASM data to allow users to easily analyse faults or availability in function of the schedule and in an almost natural language style. For example, “show LHC availability between 2018 Technical Stop 1 and Technical Stop 2 excluding Machine Development periods”.

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOPHA149

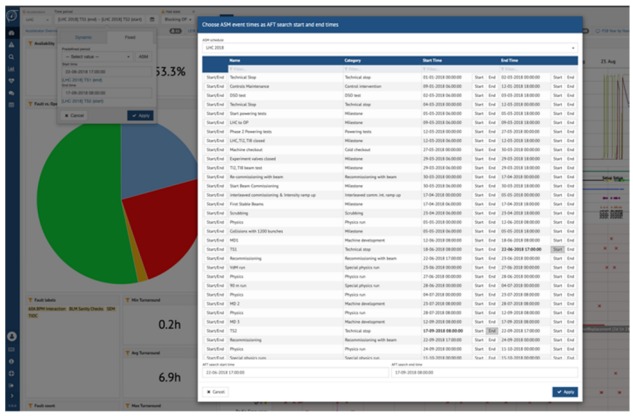

Figure 7: ASM schedules integrated in AFT application.

It is envisaged to incorporate ASM into other systems in the future, including:

- The CERN Accelerator Logging Service [2] to facilitate data extraction and analysis e.g. “extract LHC BPM data during the 2017 LHC MD block 3”, thus avoiding the need for the end-user to know exactly which dates and times to use. Another example is in the new NXCALS system, where schedule data could be used to: condition whether or not data is logged; increase / decrease acquisition filtering according to the schedule. A concrete use case being to store all data from some systems, completely unfiltered during Machine Development blocks.
- The Controls Configuration Service [3] would also benefit for the scheduling of events to automatically migrate Controls devices from one software version to another, during a particular Technical Stop event.

CONTROL CHANGES

Controls Changes (CC) is the second ASM module, which aims to facilitate the so-called “Smooth Upgrades” process to declare changes to the accelerator Control system in advance of when they will be deployed and to follow-up their status afterwards.

The CC module is integrated with the aforementioned SM module and allows users (typically from equipment groups) to declare Controls changes foreseen to occur at different points in the accelerator schedule without having to know the precise date e.g. “during 2020 Technical Stop 1”.

In addition to *what* and *when*, Controls changes are registered with a number of other attributes (Fig. 8) such as:

- Responsible person and people involved.
- Accelerator(s) affected.
- Hard deadline for implementation.
- Deployment risk and recovery strategy.
- Approval process required.
- External links (e.g. to documentation and issue trackers).

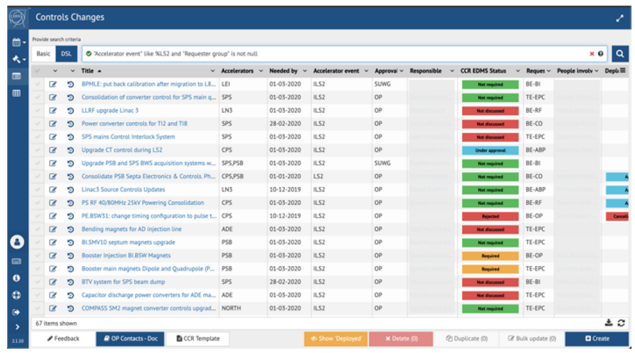

Figure 8: Example controls changes.

Each Controls Change entry also has a deployment status (pending, approved, completed, cancelled), therefore anyone can consult the list of pending or completed changes with respect to one or more schedule events.

According to the approval process required, a different workflow is followed within ASM. For example, for changes posing a risk to operations, the Operations group responsible persons are involved in the process to ensure they understand the planned work and give their approval (or not) for the planned change prior to the foreseen deployment date. Overall the CC module helps streamline the upgrade process and facilitates communication between all parties involved. Furthermore, it captures a traceable record of all changes made over time, which can be referenced in case of subsequent operational issues / degraded performance for which the cause is not clear from the outset.

ASM has been used by the Smooth Upgrades Working Group to successfully plan and follow-up all Controls related changes since Technical Stop 2 in June 2017.

MACHINE DEVELOPMENT SCHEDULES

Machine Development (MD) essentially implies exploring new modes of operation and / or validating new equipment with beam. There are two types of MD scenarios:

- Dedicated MD blocks – when the beam time is only used to perform the agreed development activities.
- Parallel MD blocks – when the development activities take place alongside regular operation for Physics.

In both cases, people wishing to conduct MDs need to submit a request, indicating the type of MD slot they need, together with a lot of other attributes such as type of beam and number of hours required, the people involved, the perceived merit of the MD, operational procedures to be followed, etc. All of this information and more (including accelerator specific attributes) can be submitted via ASM as shown in Fig. 9. The definition of MD requests for a given machine, including the validations to be applied, are fully data driven. This means that adding new attributes to existing MD request templates or configuring new MD request templates for different machines and use cases is relatively straightforward and does not require any additional development.

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOPHA149

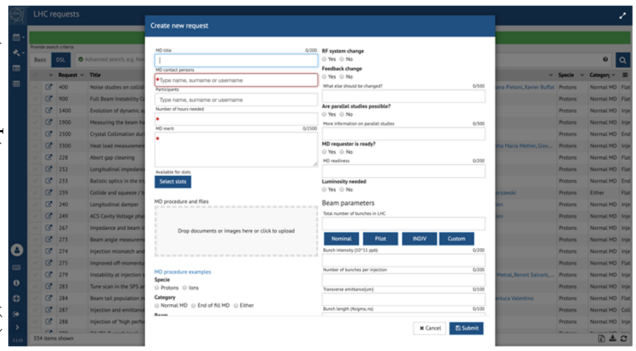

Figure 9: New MD request.

There are typically many more MD requests than there is corresponding allocated beam time, therefore it is important to optimize the available beam time by scheduling the highest priority / most relevant MD activities. This task falls to the CERN MD Coordinators who have a dedicated role inside ASM with elevated privileges allowing them to easily review and schedule MD requests, including sharing notes with other MD Coordinators / Experts (Fig. 10).

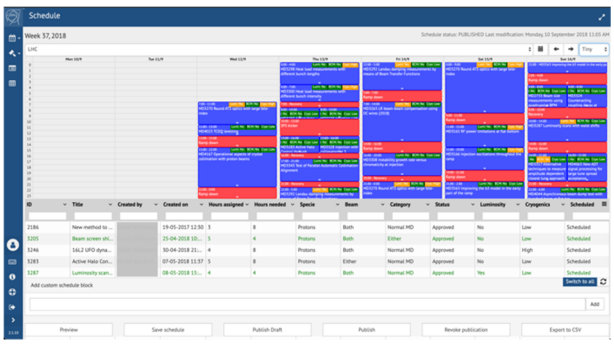

Figure 10: LHC MD Block schedule.

Once MD requests have been scheduled, the requestor together with any authenticated user can easily see what has been scheduled for when.

The ASM MD module was intensively and successfully used throughout 2018 for the LHC and the Injectors, allowing MD coordinators to efficiently schedule, follow-up and report on the MD activities of the year. This was supported by the ASM functionality to quickly produce different types of MD statistics for a given period, as shown in Fig. 11.

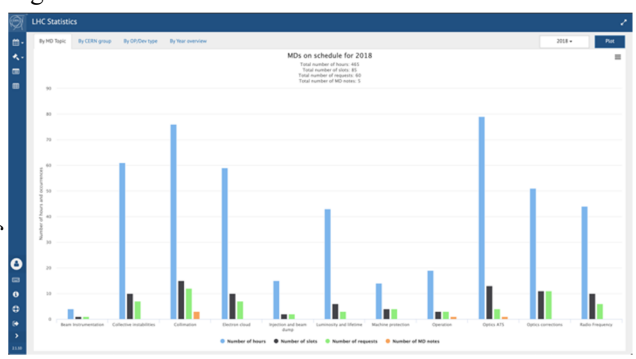

Figure 11: Example LHC MD statistics.

TECHNICAL IMPLEMENTATION

ASM is a web application developed using the common technology stack used for all CERN BE Controls Data Services software:

- Java using the Spring framework (notably Spring Boot) for the stateless backend server processes.
- AngularJS, TypeScript and Bootstrap for the front-end.
- Oracle database for the persistence (note that no Oracle specific features are required for ASM and in theory any relational database could be used).

The common development process relies on Gradle and Webpack for building, Jenkins and Ansible for managing deployment pipelines, integrated with GitLab for source control and automatic provisioning for new merge requests. Monit is used to manage the redundant processes running behind HAProxy for high availability.

CURRENT STATUS

ASM is stable and the overall application has been used in production since mid-2017, with the MD module in use since the start of 2018.

In order to keep up to date with technology, the ASM front-end has just been re-written to use Angular 7 with Material Design. All other BE Controls Data Services applications will soon follow suit.

SUMMARY

ASM brings added value to CERN when it comes to managing the schedules that directly or indirectly impact accelerator operation. With highly usable interfaces, ASM saves people time when it comes to preparing schedules and producing statistical summaries of how time is distributed between activities.

The data driven configuration of ASM makes it relatively low cost to tailor and apply to new use cases. The programmatic access allows to leverage the schedule data in different applications and further facilitate the work of the corresponding CERN experts.

The Controls Changes module helps streamline the evolution of the Control system in a coordinated manner.

The Machine Development planning tool simplifies the task of collecting, sorting and allocating MD requests to MD slots and maximising the use of the precious beam time.

Meanwhile, the use of open source software and a non-CERN-specific design mean that ASM could be ported to fulfil similar schedule management requirements in other institutes and domains.

REFERENCES

[1] C. Roderick *et al.*, "Accelerator fault tracking at CERN", in *Proc. ICALEPCS'17, Barcelona, Spain*, Oct. 2017, doi:10.18429/JACoW-ICALEPCS2017-TUPHA013

[2] C. Roderick, L. Burdzanowski, and G. Kruk, "The CERN Accelerator Logging Service - 10 Years in Operation: A Look at the Past, Present, and Future", in *Proc. 14th Int. Conf. on Accelerator and Large Experimental Control Systems*

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOPHA149

(ICALEPCS'13), San Francisco, CA, USA, Oct. 2013, paper TUPPC028, pp. 612-614.

[3] L. Burdzanowski *et al.*, "CERN Controls Configuration Service - a Challenge in Usability", in *Proc. 16th Int. Conf. on Accelerator and Large Experimental Physics Control Systems (ICALEPCS'17)*, Barcelona, Spain, Oct. 2017, pp. 159-165. doi:10.18429/JACoW-ICALEPCS2017-TUBPL01