FAIR Commissioning & Control Working Group

Notes from the meeting held on 20th May 2015

e-mail distribution: FAIR-C2WG-ALL at GSI.de, participants list

Agenda:

- FAIR Commissioning & Control – WG Strategy & Concepts (jump below), Ralph J. Steinhagen
- FAIR Operation: Experiments, Beam Parameters, and Challenges (jump below), David Ondreka
- FAIR Accelerator Operation Paradigms (postponed), Stephan Reimann

1. FAIR Commissioning & Control WG – Strategy & Concepts, Ralph J. Steinhagen

In his presentation (see slides), R. Steinhagen reminded that the efficiency of the FAIR facility as an enabling platform has a direct impact on its research outcome, and that thus it is also paramount to commission, operate, and further develop the present and future accelerator chain as efficient as possible.

Being not a mere extension, the new facility nearly quadruples the size of the present GSI infrastructure and substantial increases the operational complexity that (in addition) has to be tackled with limited resources (only 4-5 operators for beam operation, further elaborated by S. Reimann and D. Ondreka below). In order to facilitate a fast machine turn-around and to maintain (or even improve) on the present operational efficiency under these conditions, a smart and more holistic approach is needed to develop efficient commissioning procedures, software tools, and the training of personnel.

To address the above mentioned issues more efficiently and inclusively, the previous efforts related to the 'FAIR Main Control Room work package' have been reorganised into a new 'FAIR Commissioning & Control Project' that will be reported at the level of the other machine projects. Within this project, the previous activities have been split into two working groups:

- *FAIR Main Control Room WG:* treating primarily building specific aspects related to the preparation and follow-up of requirements on the new common GSI/FAIR accelerator control room, as well as the migration concept from the existing room.
- 'FAIR Commissioning & Control Working Group (FC^{2}WG or FCWG)', that shall coordinate, prepare and review:
  - a detailed and complete commissioning, operating and controls concept for all FAIR accelerators including the GSI injectors including interfaces between the accelerators, transfer lines and experiments.
  - functional specifications for the accelerator control system (e.g. archiving system; tools related to: post-mortem, accelerator/facility performance monitoring & optimisation, beam-based systems, human-machine-interfaces, etc.)

- functional specifications for the integration of technical systems and equipment into the accelerator controls environment;
- identify and define potentially missing procedures and tools required for the efficient operation of FAIR

The aim is to follow a *lean-based* approach that acknowledges that commissioning and operation of the facility is not static but a continuous improvement process, focuses on long-term strategies and prioritisations, the concept that the right processes will produce the right results, that aims at getting implementations right the first time, and to prevent inefficiencies, inconsistencies and waste during the commissioning and operation of FAIR by proper design. Efficient operation cannot be limited to the development of efficient tools and procedures but also extend to the efficient use, training and development of personnel (see presentation of S. Reimann in the next FC²WG meeting).

While the FC²WG reviews, re-iterates and documents the various topics, the 'actual work' is prepared in the (often already existing) small task groups that present their solutions during the meeting for review. While a bi-weekly meeting schedule is envisaged, the individual topics are organised with the presenters at least four weeks in advance and the topics distributed such that the work-load for preparation is evenly spread.

It is important to note that both groups prepare recommendations and propose prioritisation from a technical point of view between the various stakeholders. Decisions affecting finance or resources that define the pace at which the above are implemented remain with the established management structure, and thus this WG ultimately reports to the machine project leaders, machine coordinators and the GSI Machine Meeting (GMM).

A record and copy of the minutes, presentations, documentation, open action, questions, working copy of the commissioning procedures (wiki), control concepts, next agenda and tentative future planning will be kept at the FC²WG web-site: http://fair-wiki.gsi.de/FC2WG/

Concerning the actual specific topics (see slides, no. 6 & 17), the FC²WG will address two orthogonal tracks: 'commissioning[1] procedures' and 'system integration' of the (already specified) specific equipment into the controls and operational environment. The emphasis is put on the optimisation across accelerators, interfaces between accelerators and – where possible – on creating common solutions to common accelerator problems (e.g. archiving, beam steering, management of critical settings, interlocks, etc.).

The commissioning procedures define as de-facto a shared MoU between various stake-holders (equipment groups, machine experts, operation, ...) of when, where and how the individual accelerator systems should fit in and which order they are being boot-strapped. These procedures will be divided into 'hardware commissioning' (HWC, further divided into 'initial hardware acceptance tests' and 'machine check-out') and 'commissioning with beam' (Beam Commissioning, BC).

1 In this context, 'commissioning' refers not only to the 'initial-' but also subsequent 're-' commissioning of the facility as well as assisted operation during phases while the accelerators are setup for new beam requirements or experiments.

The Beam Commissioning is divided into three phases:

1. 'Pilot Beams': dealing with fundamental aspects such as threading, injection, capture, acceleration, extraction, verification of basic beam parameters (orbit, tune, chromaticity, ...) with “easily available” ions (e.g. U28+, Ar) and with always 'safe' ie. low-intensity and low-brightness beams. The aim of this phase are basic checks that verify the correct functioning (polarities, settings) of the accelerator, provides initial calibration of devices needed for the next phases, and first simple physics events to the experiments to calibrate and setup their detectors.
2. 'Intensity ramp-up': dealing with the commissioning and optimisation of special systems such as e.g. the e-cooler, slow extraction, transverse fast feedbacks, commissioning and validation of machine protection and interlock systems as a prerequisite of operation with possibly unsafe beams. As a general policy: unsafe or untested operations will always be preceded by checks with safe low-intensity beam. These checks will need to be repeated during regular operation to ensure a safe and reliable intensity ramp-up for new experiments or beam conditions.
3. 'Production operation with nominal intensities': dealing with establishing a reproducible nominal operation, pushing physics and beam parameter performance, while identify and improve upon bottlenecks impacting FAIR's 'figure-of-merit' within safe limits. N.B. larger optimisation or new concepts will need to be addressed through stepping back and reiterated during the 'intensity ramp-up' phase.

Each of the phases are broken down into more manageable 'steps' covering:

- a short description of what should be achieved,
- entry and exit conditions (clear definition of handover specs, definition of must-have systems, operational procedures (e.g. machine patrol), list of systems to be considered “operational” afterwards),
- machine setup of pre-conditions (e.g. optics, beam type, which machine protection equipment needs to be in place),
- actual procedure (detailed 'cookbook': check list of individual steps (settings, gains, ...),
- list of possible problems and first-order remedies),
- Open questions/action items.

A Wiki system was chosen for the first iteration of developing the commissioning procedures to facilitate and nurture a wider collaboration and faster and more efficient documentation of the various topics. These efforts cannot be stemmed by single individuals but everyone involved, interested and who can contribute to these matters should feel compelled to discuss, add and complete these procedures as a working document. In the future, the more complete procedures shall be transferred to a more permanent document management system for a more formal approval by the existing management structure.

Discussion:

W. Geithner and A. Adonin asked about how controls is being integrated within the different phases and whether this WG is only about controls and nothing else? R. Bär while many fundamental concepts and implementations are carried out by CSCO (e.g. Archiving), the specific system integration aspects also touch other equipment groups. Control system hardware is not explicitely discussed, but included in the concept. The functional requirements for the specific systems need to be collected in the context of this working group.

D. Ondreka and R. Bär iterated and stressed that there are still many gaps w.r.t. integration and exploitation of equipment, e.g. beam-based feedback and diagnostics systems that combine equipment from different groups and domains [post-meeting comment: we should make more clear, that FCWG is not only about controls]

M. Steck asked about concept for parallel operation. R. Steinhagen replied that this is being addressed in the second talk (below) by D. Ondreka.

W. Geithner asked how the 'continuous improvement' and lean culture change is being induced. R. Steinhagen replied that this cannot be imposed, but has to be lived by all within the organisation, and hopes that this may be a side-effect of the discussions and jointly solving problems within the working group.

P. Spiller asked whether a biweekly schedule wouldn't be too much and whether one would run out of topics very soon. R. Steinhagen commented that we need to be prepared for SIS100 commissioning and operation within about 5 years and that a similar approach w.r.t. system integration and commissioning at CERN for LHC alone required about 7-8 years – besides many topics probably requiring several iterations!

F. Herfurt and A. Adonin hinted that there will be only two years until the SIS18 restart! R. Bär replied that even before, concepts and systems for FAIR will be tested at CRYRING. The CSCO strategy for CRYRING and SIS18 recommissioning will be presented in two weeks. [post-meeting comment: presentation scheduled for 17th of June]

Both, I. Lehmann and R. Steinhagen stressed that the 'actual' work should not be done during the WG meeting but prepared in small task groups beforehand. The topics are only reviewed within the WG meeting, documented for the future and distributed afterwards.

R. Steinhagen added, that an important output of the working group is the definition of milestones through the definition of commissioning procedures and requirements for specific systems.

P. Spiller commented that a plan of transforming the initial commissioning to routine production operations needs to be devised.

C. Omet emphasised the positive aspect of getting away from the current prevailing 'island structure' towards an integrated system and change in mindset.

2. FAIR Operation: Experiments, Beam Parameters, and Challenges, David Ondreka

D. Ondreka started his presentations (see slides) with a brief review of the 11 baseline experiments[2] presently considered for the initial operation of FAIR in 2022. Out of these experiments, NUSTAR provides the most demanding requirements on U^{28+} beam parameters that exemplify the main FAIR operation challenges: achieving highest design intensities, handling of high stored beam energies, tight loss and emittance budgets, and the control of dynamic vacuum necessary to achieve the targeted intensities. Other beam types or ion species are considered either similar or less demanding.

Similar to the present GSI operation, FAIR will also need to maximise its duty cycle and at the same time to provide a similar flexibility w.r.t. mixed mode operation of running periodic (e.g. NUSTAR fixed target or ring) as well as non-periodic (e.g. PP, APPA in (H)ESR) experiments in parallel (some parallel operation examples are given on slide no. 6). It is expected that the operational complexity increases due to among other things longer accelerator chains per experiments and more complicated setup processes.

D. Ondreka provided some more specific examples where the present operation merits some improvement and motivates why we do need a change of culture in order to maintain similar accelerator efficiencies for FAIR as for GSI:

- Experimental setup: the setup of UNILAC+SIS18 requires presently about 1.5 shifts, implies the interruption of other experiments, and due to little direct integration of beam instrumentation requires (less efficient) manual optimisations. For FAIR this would extend the setup time by at least one shift per experiment due to the additional accelerators, transfer lines and storage rings (e.g. SIS100, Super-FRS, CR, HESR) and block other scheduled long-running experiments more substantially if the setup is not done in parallel.
- Operational robustness: the present setup and optimisation procedures depend on a few experienced operators and machine experts, with little standardization, few performance indicators and no performance history. D. Ondreka emphasises that the future FAIR operation should aim at higher targets of verifying not only whether the achieved performance corresponds to the design but also whether it can be improved upon based on comparison with past performance!
- Error prevention and analysis: the most severe risks are presently mitigated by UNILAC pulse time shortening, but no particular further measure is taken in SIS18 (“Operators will ‘play’ with every beam!”). Data history is not kept systematically for later analysis or improvements. D. Ondreka points out that some failures may be too frequent to ignore but difficult to reproduce. Blind knob turning may lead to unnecessary activation, quenches or even machine damage. He suggests that a reduction of setup time, consequently increase

2grouped into three pillars: APPA, CMB and NUSTAR of beam on target, could be achieved for example through standardised setup routines and beam based tools guiding operators through set-up procedures (instead of knob turning).

Focusing on machine protection, D. Ondreka emphasises that high intensity SIS100 beams do not possess the same destructive potential of those in the Large Hadron Collider (LHC) at CERN. Nevertheless, they may still

- destroy sensitive equipment such as the SIS100 electro-static septum wires, intercepting beam instrumentation devices in HEBT (grids, screens), Super-FRS target for a single compressed bunch, etc.
- quench superconducting SIS100 magnets with beam, that in turn – even though the equipment itself is protected through a quench protection system – may cause significant recovery times after such an event and thus reduces the machine availability.
- may pose problems for hands-on maintenance through excessive losses activating the machine [violation of the ALARA principle].

Most of these risks could be provided and mitigated by hardware interlocks (SIS100: Fast beam abort system; SIS18, Super-FRS: extraction inhibit; detection of intercepting BI devices) and through control software support (e.g. transmission control switching beam off, radiation monitoring, protection of critical settings, tools for reliable and robust set-up procedures) and implementation of a 'no-playing-around' or 'no-sloppy-handling' policy with high intensity beams. As a consequence: a) the control system would need to be aware when beam intensities and conditions become dangerous, and b) the interlock system would need to receive reliable data on beam intensities (e.g. through the fast current transformers, FCTs).

Concerning machine performance, D. Ondreka emphasises that in order to optimise the duty cycle the setup of new beams must become a routine operation (especially with the increased complexity of long accelerator chains) and (ideally) not influence other experiments running in parallel. Besides machine protection, the prominent incentive is challenging beam parameters that need to be achieved for the experiments. In addition, he highlights that this and an optimal beam quality also increase the performance and consequently maximise useful events for the experiments. He underpins the importance of monitoring and control of the tight budgets on emittance (/brilliance) as the dilution may impact the beam size and ultimately increase the probability of beam loss. Tools to routinely monitor transverse emittance (e.g. injection mismatch, non-linearities) as well as longitudinal emittance (e.g. stripper foil degradation, injection mismatch) are needed. D. Ondreka gives some further examples of some of the possible improvements that should be addressed:

- concept of pattern and chains, applications for handling them
- machine protection by hardware and software interlock systems
- setup beam concept and intensity ramp-up procedures
- protection of operator from accidentally applying dangerous settings

- reliable and reproducible set-up procedures implemented in software
- beam based set-up preferred over ‘knob turning’
- data archiving for long-term analysis and analysis of unexpected events

These would need to be followed up with a corresponding console concept that focuses on following the beams through the accelerator chain rather than the individual accelerator on a one-by-one basis, as well as allowing simultaneous manipulation of different beams in the same accelerator or transfer line.

He concluded his presentation with: “while there are strong expectations about the FAIR accelerator's behaviour, that they [accelerators] are still partly ’aliens’". While many assumptions (hopefully) may turn out to be largely true, D. Ondreka proposes that one should be prepared for the unknown and thus for example log data as much as possible to reveal hidden ‘features’. He illustrates this by some past experiences with SIS18 operation (see slides, p. 14 for details):

1. Mysterious reduction of SIS18 current:
   - No transmission change in UNILAC
   - By accident UNILAC profile grids had been printed
   - Vertical beam position changed
   - Traced to change of beam request timing
2. Sudden pressure rise in SIS18 extraction sector
   - All vacuum valves closed (logged, but no timely ordering nor source of vac. Interlock)
   - FRS suspected guilty, but no hard evidence
3. Unexpected activation of H=2 cavity in SIS18
   - Comparison of beam loss patterns might help chasing down the source, but no data available
4. Dynamic vacuum questions
   - Topic often comes up in analysis of MD studies
   - Of course, nobody thought about recording…

Discussion:

P. Spiller agrees with the general concept but considers loss minimisation more of a driving factor than e.g. emittance preservation since the required low losses (3%) have an impact on the tunnel shielding. He considers destruction of individual equipment or the machine as a whole more of an exception, but acknowledges that sensitive equipment could be endangered. C. Omet stresses that minimisation of the activation of the machine is equally important and that quenches should be minimised. While single isolated quenches could be accepted, repeated quenching would unnecessarily stress and damage the magnet on the long-term (and also reduce availability of SIS100 for physics). P. Spiller replied that quenches are not as dramatic. D. Ondreka iterates that losses should be controlled and kept in check well before radiation protection limitations become an issue.

P. Spiller asked why the presentation focused mainly on SIS18 and SIS100 and less on the linac and storage rings. D. Ondreka replied that the choice of focus was rather motivated by his direct operational experience with these machines, and that these concepts should of course also be extended to linacs and storage rings.

It has been suggested that the WG should also ask users about their input on the requirements for accelerator operation. I. Lehmann commented and offered to redistribute and inform what is being done in the accelerator sector to the experiments when applicable. I. Lehmann further pointed out that there is no single representative use-case, but that the experiments have very diverse requirements on the accelerator chain. P. Spiller commented that in most cases the operation already knows the 'common complains' from the experiments, and that they are usually related to the variability of beam properties. J. Stadlmann suggested that many special requests are also often driven by users depending on the 'therapy mode' of operation. I. Lehmann stresses that while there is an important overlap of the experimental communities of GSI and FAIR, that they are not the same and include other new international partners with possibly new requirements.

In the line of 'continuous improvement', W. Geithner asked about what needs to be optimised and what are the targets on a more global scale. R. Steinhagen replied that there are various 'figures of merit' and that some depend on the given specific experiment (e.g. protons on target, luminosity, spill quality/flatness, etc.). There are many options, but one needs to agree on the definition of the more important ones.

3. FAIR Accelerator Operation Paradigms (postponed), Stephan Reimann

Due to the length of the previous discussions, this presentation has been postponed to next meeting.

The next meeting is planned for: Wednesday 3rd June 2015, 15:00-17:00 (SE 1.124c)

Reported by J. Fitzek, S. Reimann, R. J. Steinhagen