FAIR Commissioning & Control WG
Strategy & Concepts

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FAIR Main Control Room
WG Restructuring & Extended Mandate

Separate previous activities into two new working groups:

- *FAIR Main Control Room WG – building specific Aspects* (PSP 2.14.10.10 & 4.6.1)
  (membership composition: “Bau”, CSCO, LOAO, ...)
  - Prepare requirements and follow-up new common control room for all GSI/FAIR accelerators
  - Develop and coordinate a migration concept for the existing GSI→FAIR MCR

- *FAIR Commissioning & Control WG (FC^{2}WG)– accelerator specific topics*
  (membership composition: MPLs, equipment groups, accelerator-experts, …)
  - prepare 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.
  - prepare 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.)
  - prepare 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
    - Includes interfaces between accelerators, transfer-lines and to experiments

Vision for FAIR*

Become the world leading accelerator-based research facility for a versatile research programme covering atomic, nuclear and bio-medical applications

Derived mission:

FAIR provides the enabling platform, with direct impact on the research outcome → paramount: commission, operate, and further develop the facility as efficient as possible.

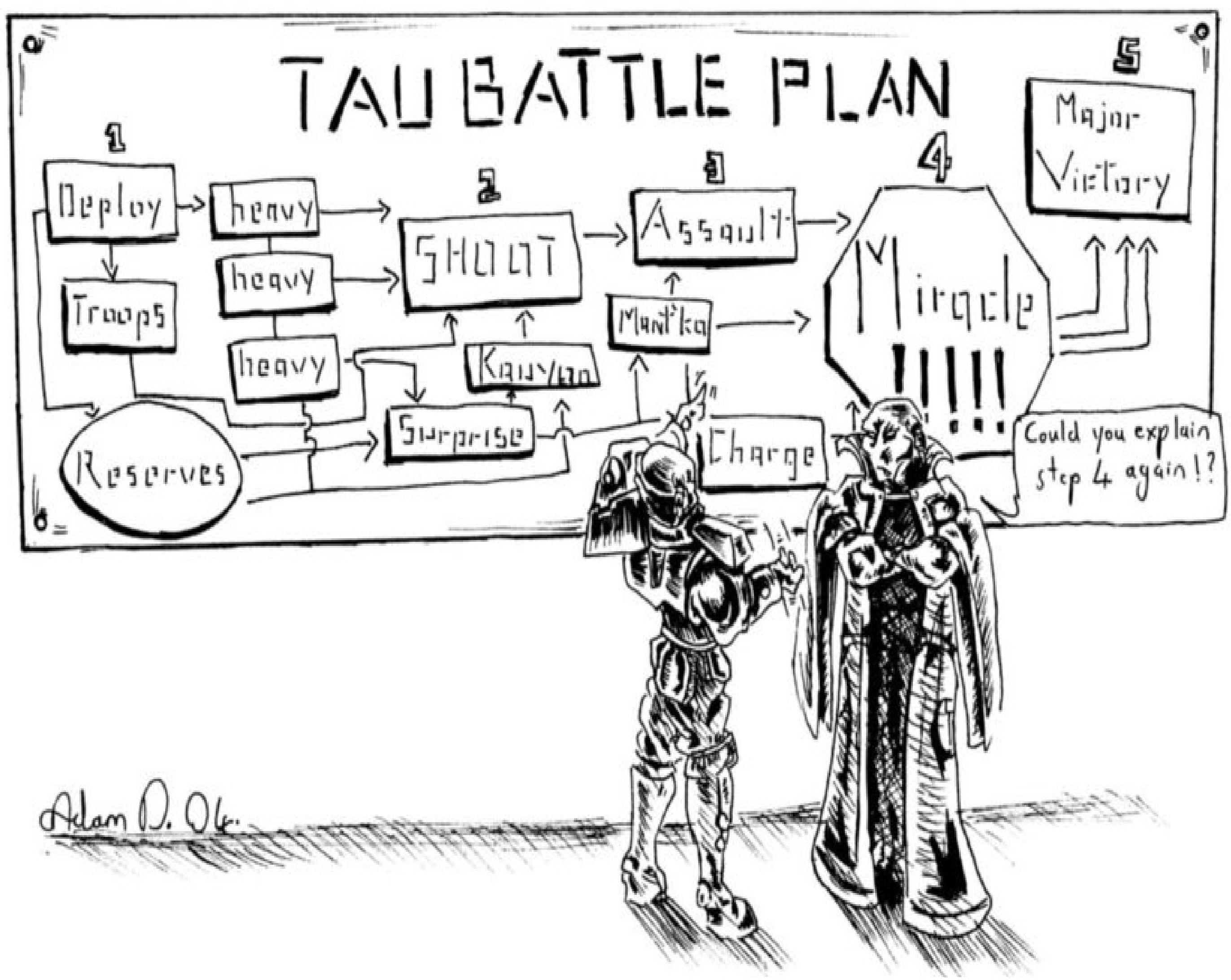
*my understanding

Global Requirements & Constraints

- Much larger facility, cannot reliably extrapolate from present 'UNILAC→SIS18→ESR' operation to requirements for FAIR (9+ resp. 13 accelerators, higher/unsafe intensities, more users)
- Will be in a constant flux of frequent adaptations to new cycles/beam parameters, etc. present estimate:
  - avg. experiment run: ~ 1-2 weeks + many new storage rings and transfer lines with high(er) complexity → machine setup time-scale
  - high-intensity operation requires more and better fine-tuning
    - dynamic vacuum, activation & machine protection (mainly septa, instrumentation, etc.)
  - limited operator resources: 4-5 (beam operation) + 1 (infrastructure, cryo)

→ need to be smart and develop an efficient commissioning procedure, training and tools to facilitate fast turn-around and maintain (or improve) present operational efficiency

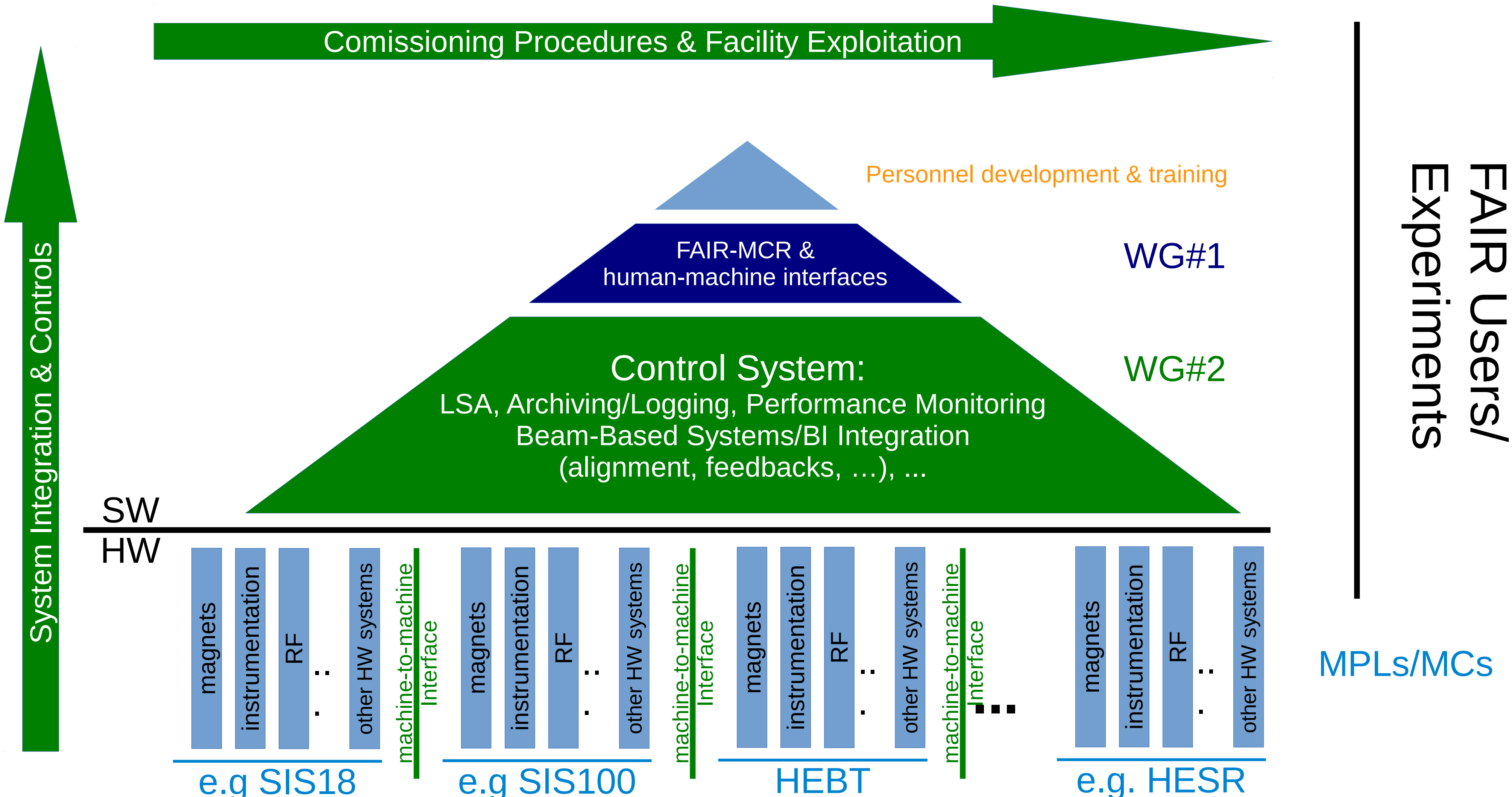
Plan of Action



Need to be more explicit w.r.t. 'item 4' for commissioning and operation of FAIR.

Fundamental Axiom

An accelerator is more than the sum of its parts:



Re-working, re-optimisation is inefficient and costly

Proposal to follow a long-term strategy and 'lean principles':

- Continuous improvement
  - Right processes to produce right results and for getting it right the first time
    - *commissioning procedures as evolving operation standard*
    - system integration: definition of what, how and when (prioritisation) is needed
  - Prevention of inefficiencies, inconsistencies & waste by design
    - 'poka-yoke' or 'error proofing' principle – culture of stopping and fixing
      1. early, when and where they occur (at the source)
      2. with low-intensity beam rather than with high-intensity beam
      3. addressing first basic parameters before complex higher-order effects
    - Example #1: first fix injection, trajectory, orbit, Q/Q' before addressing space-charge or slow-extraction problems
    - Example #2: important losses for low-intensity beam have larger impact for high-intensity beam (↔ activation)

- Respect for people – "develop people, then build products"→ talk by S. Reimann
  - optimise operation ↔ smart tools & procedures, e.g. beam-based feedbacks, sequencer, …
    - automate routine task so that operator talents are utilised and focused on more important tasks
  - training, investment in and development of people – minimise overburden/strain of personnel

FAIR Commissioning Procedure I/II

- Develop a (initial/re-)commissioning and operation strategy:
  - MoU between various stake-holders (AP, BI, CO, RF, ...)
    - define when, where and how the individual accelerator systems should fit in
  - Identify and define missing procedures, equipment and tools, e.g.:
    - define, check the need or priority of applications vs. 'use cases'
    - define, check integration and interface between specific equipment and CO/OP environment
  - Focus first on commonalities across then specifics within individual accelerators
    - MPLs/MCs define pace & resources of how fast to achieve the above
  - Dissemination/knowledge transfer from groups that constructed and performed the initial HW commissioning to the long-term operation
    - training of operational crews (physics, operation, tools, ...)
  - Scheduling tool for technical stops to follow-up possible issues found

*Procedure aims not only at the initial first but also subsequent re-commissioning
e.g. after (long) shut-downs, mode of operation changes and/or regular operation

FAIR Commissioning Procedure II/II

- Distinguish two forms of 'commissioning':

  A) Hardware Commissioning (HWC)

  - Formal functional checks and acceptance tests of the physical objects
  - Done during initial commissioning and as part of the 'machine check-out' after every (longer) technical stops (e.g. annual shut-down)

  B) Commissioning with Beam (BC)

  - thread, inject, capture, accelerate and extract through the accelerator chain
  - commissioning of beam-dependent equipment

Hardware Commissioning

- Covers two aspects:

1. Initial hardware acceptance tests
   - Checks conformity with contractual design targets
   - Done once, or after major upgrade or modifications
     - mainly done by system responsible/experts
     - coordinated by machine project leaders

   } covered by present project structure

2. 'Machine Checkout' – presently not covered (yet)
   - Checks conformity of system's controls integration and readiness for beam commissioning/operation
     - Checked during 'dry-runs' – periodic (partial) facility tests coordinated by CO/OP
   - Needs to repeated after every shut-down or longer technical stop
     - Presently done on a system-by-system basis
     - Would benefit from a more global approach

Commissioning with Beam

- Split Beam Commissioning into three phases:
  I. Pilot beams/"easily available" ions (e.g. U28+, Ar)
    - basic checks: threading, injection, capture, acceleration & extraction
    - always done with 'safe' ie. low-intensity/brightness beam
      - Ions: simpler optics, beam dynamics → Protons: transition crossing

  II. Intensity ramp-up & special systems
    - commissioning of e.g. e-cooler, slow extraction, transverse fast feedbacks
    - commissioning and validation of machine protection & interlock systems
    - Possibly unsafe operations always preceded by checks with safe beam

  III.Production operation with nominal intensities
  (N.B. first time counted as 'commissioning' → later: 'regular operation')
    - push physics and beam parameter performance
    - identify and improve upon bottlenecks impacting FAIR's 'figure-of-merit

Commissioning Phases* Example I/II

Phase	Description
A.1	Injection and first turn: transfer lines, injection commissioning; threading, initial commissioning beam instr.
A.2	Circulating pilot: establish circulating beam, closed orbit, tunes, RF capture
A.3	injection initial commissioning: initial commissioning of beam instrumentation cont'd, beam dump
A.5	Ramp: transition crossing (protons), control of orbit, Q/Q', ...
A.6	Injection & Extraction optics: beta beating, dispersion, coupling, non-linear field quality, aperture
A.7	Special aspects: special machine functions, e.g. e-cooler, slow-extraction, bunch merging/splitting schemes
A.8	Preliminary physics runs: “physics” with intermediate safe beam parameter (experiment detector setup etc.)

*inspired by commissioning and SW analysis efforts for LHC:
http://lhccwg.web.cern.ch/lhccwg/overview_index.htm
http://lhccwg.web.cern.ch/lhccwg/Bibliography/background-material.htm
http://proj-lhc-software-analysis.web.cern.ch/proj-lhc-software-analysis/
http://lhc-commissioning.web.cern.ch/lhc-commissioning/machine-checkout.htm

Commissioning Phases* Example II/II

- Defined for each phase:
  - Short description of should be achieved
  - Entry and Exit conditions – clear definition of handover specs
    - definition of must-have systems,
    - op. procedures (e.g. machine patrol)
    - List of systems to be considered “operational” afterwards
  - Machine setup:
    - optics, beam type, MP equipment in place
  - Procedure:
    - detailed 'cookbook': check list of individual steps (settings, gains, …)
    - Optional items e.g. for night-time shift or delayed by another item
  - List of possible problems and first-order remedies
  - Open questions/action items
  - References (!!) & Acronyms

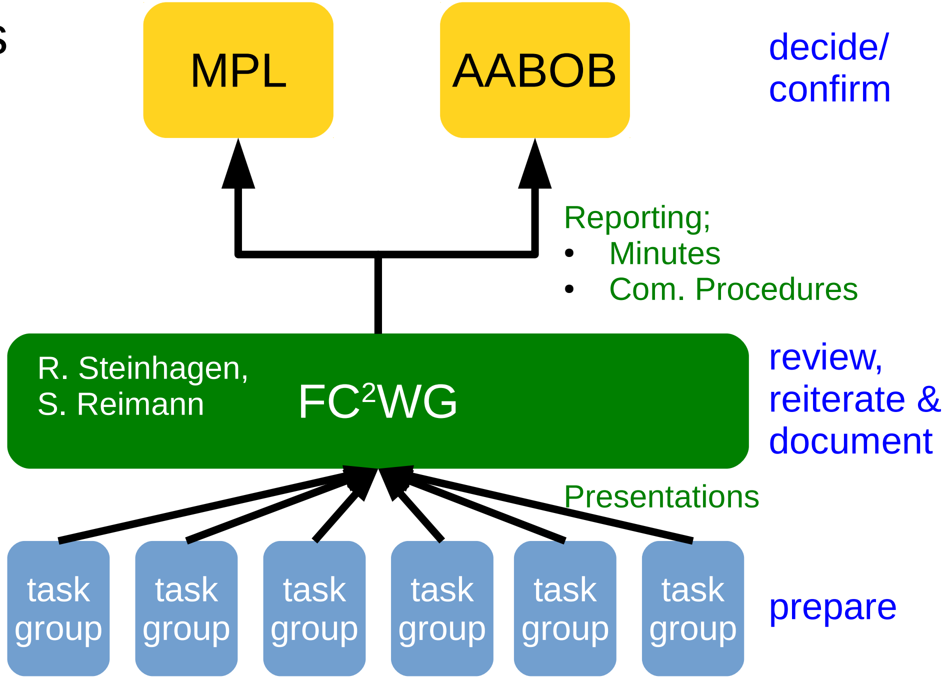
*for examples (LHC context) see e.g:https://edms.cern.ch/cedar/plsql/project.info?proj_id=1027639877

Example: Injection and First Turn

- Need – entry conditions
  - HW/SW conditions: full machine check-out, dry-runs performed, technical services available, ...
  - Machine state: ion optics, beam parameters to be used, ...
- Procedure:
  - Injection preparation: check transfer line settings, timing, kicker & power supply statuses, ...
  - Commission last meters of transfer line: check magnet & pick-up polarity, rough optics checks, commission beam instruments, ...
  - ...
- Potential Problems & Mitigation:
  - Cannot thread beam (beam lost somewhere) → Causes: … Diagnostics: ... Remedies: ...
- Open Questions:
  - UNILAC to SIS18 timing: first turn definition, ...
- Have – exit conditions:
  - Fully commissioned screens/IPMs, can exclude BI/kicker polarity errors, ...

FC²WG Working Group Organisation I/II

- Composition – key stake-holders: MPLs/MCs, BI, CO, RF, PB, LOAO, other equipment groups and experiments
- Frequency: bi-weekly → recognition as core activity
  - individual topics prepared within existing task groups
- Documentation & Reporting
  - minutes, commissioning procedures (first wiki → EDMS)
    - Docs in English ↔ ext. review/partners
    - Meetings: German/English as needed
  - Reporting: PBL-JF & AABOB
    - decisions affecting finance/ resources remain with MPL/MCs!



FC^{2}WG – Nominal Membership

- **Machine Project Leader/Coordinators:**
  - R. Brodhage (p-Linac), P. Spiller + Jens Stadlmann (SIS18 / SIS100), F. Hagenbuck (HBET), K. Knie (pbar separator) A. Dolinskii (CR), Dieter Prasuhn (HESR, FZ Jülich), M. Winkler, S. Pietri (SFRS), M. Steck (ESR), C. Kleffner (HEST), R. Hollinger (Sources), P. Gerhard (UNILAC), F. Herfurth (CRYRING)
  - *<check: missing MPL / MCS?>*
- **Equipment Groups** (main focus on beam commissioning / regular operation):
  - Marcus Schwickert → Andreas Reiter (BI), O. Boine-Frankenheim, V. Kornilov (BP), R. Baer → Jutta Fitzek & Christian Hilbricht (CO, also: vacuum & cryo controls), David Ondreka (System Planning), Harald Klingbeil → Ulrich Laier (RF), Stephan Reimann (OP), U. Blell → Jürgen Florenkowski (HV pulsed power, TFS), C. Dimopoulou (Stored Beams, Beam Cooling)
  - <check: missing equipment group?>
- **Machine-experiment link person**: Inti Lehmann
- Please feel free to propose further participants you consider pertinent or whom it may concern
  - N.B. open membership but participation should be coordinated with group leaders

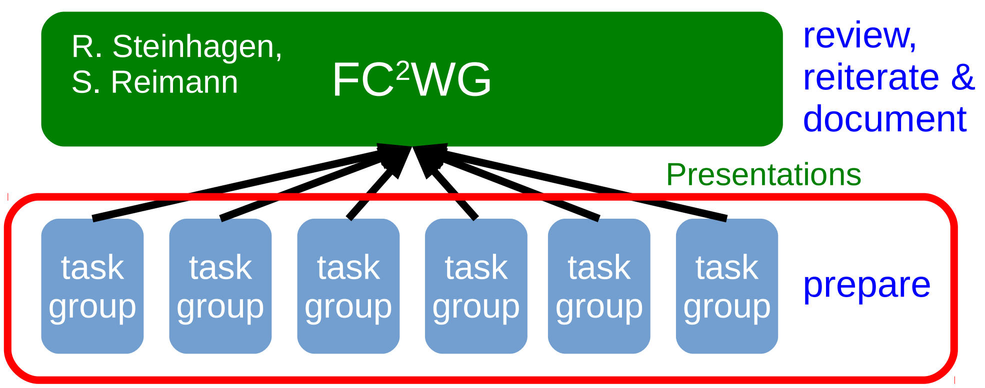
System Analysis & Topics to be covered

- Facility & Interface Analysis
  - Procedures: HWC, HWC-'Machine Check Out', BC-I, BC-II, BC-III
  - Beam parameters, FAIR performance model and optimisation
- Beam Instrumentation & Diagnostics – System Integration
  - Intensity (DCCTs, FBCT), trajectory & orbit (BPMs), Q/Q', optics (LOCO & phase-advance), longitudinal & transverse emittance (WCM, screens, IPM, etc.), beam loss (BLMs), Δp/p, long. bunch shape, abort gap monitoring, long. Tomography, aperture model, ...
- Accelerator Hardware – System Integration
  - Power converter, magnets, RF, injection/extraction kicker, tune kicker/AC-dipole, beam dump, collimation/absorbers, cryogenics, vacuum, radiation monitoring, magnet model, k-modulation, ...
- Control System
  - Archiving, analog signal acquisition, test-beds, timing, bunch-to-bucket transfer, cyber security & role-based-access, middleware, RT & Feedbacks, daemons, semi-automated procedures, …
- Components
  - Post-mortem, safe-beam settings management, machine protection ↔ interlocks, beam quality checks
- Applications
  - Sequencer, GUIs, fixed-displays

FC²WG Working Group Organisation II/II

- FC2WG reviews,reiterates & documents the various topics the 'actual work' is prepared in small “task groups”
  - Topics typically organised > 4 weeks
  - Related equipment experts, CO + <u>others</u>
    - Please feel free to step-up and announce your interest/willingness to contribute
    - Please contact R.Steinhagen | S.Reimann to facilitate coordination

- FC²WG web-site (wiki): http://fair-wiki.gsi.de/FC2WG/
  - copy of minutes, presentations, open action
  - Documentation
    - commissioning procedures
    - controls concepts
  - next agenda & planning



FCWG – Topics 1st meeting (20th May)

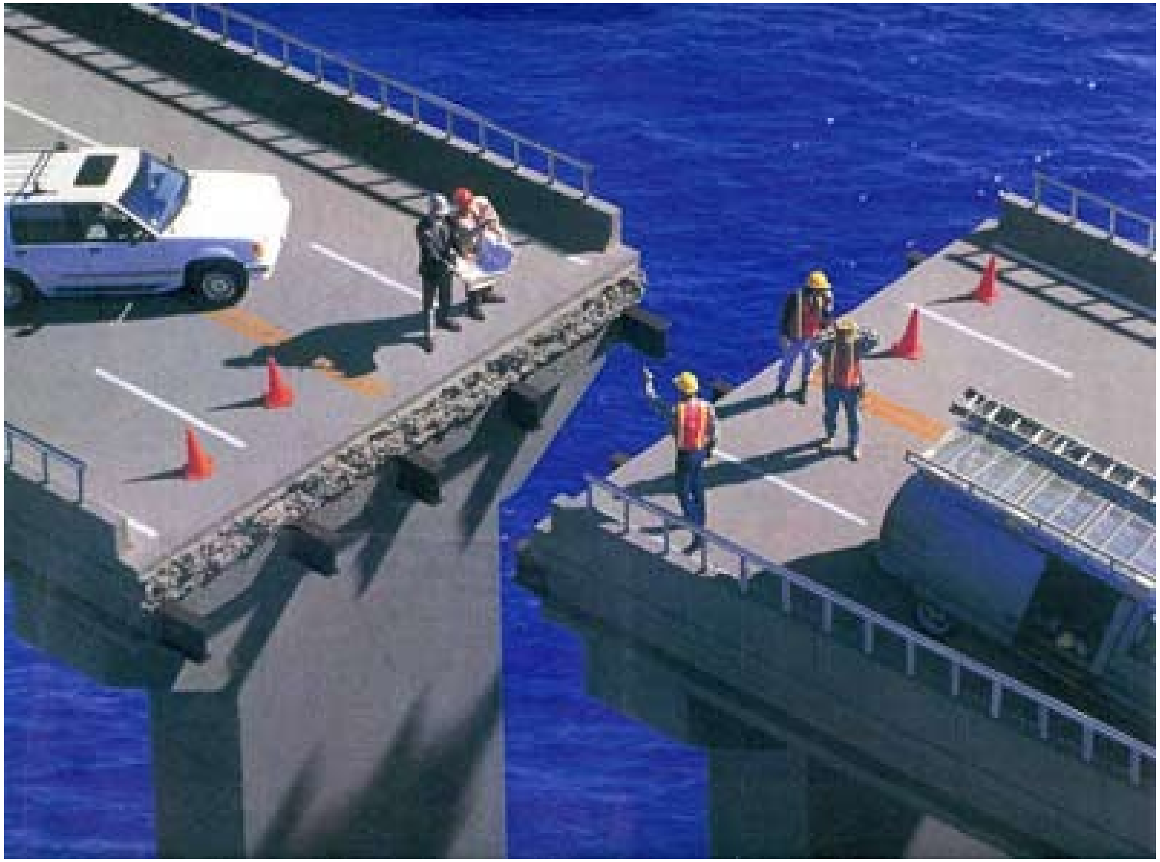
- General Strategy & Purpose (R. Steinhagen)
  - Staged commissioning approach
  - Documentation of procedures and user-requirements
- Beam parameter & planned base-line Facility Operation (D. Ondreka)
  - What's old → what's new
  - Constant flux of commissioning (~ every 2 week)
  - Uncharted/new territory for GSI: high-intensity protons
  - Performance indicator/targets
- FAIR Accelerator Operation Paradigms (S. Reimann)
  - 'one operator per experiment' vs. 'one operator per accelerator' paradigm
  - One common vs. many decentralised control rooms
    - Issue of responsibility, day-to-day efficiency/hand-over issues, long-term sustainability/costs
  - Necessity of ongoing personnel development & training
    - Peak efficiency: good tools & people that know how to use them efficiently

Next Meetings

- Wednesday 3rd June 2015, 15:00-17:00 (SE 1.124c)
  - SIS18 controls retrofitting & re-commissioning (R. Bär)
  - Overview of Beam Instrumentation for FAIR (M. Schwickert)
  - Data Archiving & Post-Mortem – First Iteration (R. Steinhagen)
- Wednesday 17th June 2015, 15:00-17:00 (SE 1.124c)
  - FAIR High-Intensity Operation: Between Poka-Yoke and Machine Protection (R. Steinhagen C. Omet?)
  - Interlock System (Frederic Ameil)
  - Fast Beam Abort System (Marko Mandakovic)
- Wednesday 1st July 2015, 15:00-17:00 (SE 1.124c)
  - Transmission Monitoring and Performance Optimisation (R. Steinhagen)
  - Beam Intensity Measurements (BI, tbc.)
  - Longitudinal Diagnostics (RF, tbc.)

Questions?

- N.B. following is work in progress and intended as a basis for further internal discussions



FCWG – Topics cont'd

- Commissioning in Stages:
  - HWC – Stage I: HWC & Machine Check-Out (S. Reimann/P. Schütt?)
    - power converter, RF, dry-runs, ...
  - HWC – Stage II: test-beds and what can we check w/o beam (J. Fitzek)
  - BC – Stage I: rough machine checkout (tbd.)
    - from injection through extraction, done with “pilot”/“probe”/safe beam intensities only:
      - “easily available” ions (U28+, Ar, etc.) – get particles through the chain (UNILAC→SIS18→SIS100)
      - protons: check transition crossing/avoidance scheme, etc.
  - BC – Stage II: higher intensities
    - e-cooler, space-charge effects, intensity ramp up
    - slow extraction, other machine specific features
    - Secondary particle recapture ($\bar{p}$ & SFRS targets) into CR → HESR
  - BC – Stage III: increasing intensity/high-intensity proton operation
    - Tighten screws on interlocks, collimation and OP procedures
    - fine-tuning of working point
    - Shift to regular day-to-day operation

FCWG – Topics cont'd

- General idea: alternate between presentations on requirements & system/equipment provider
- Beam-Instrumentation
  - Overview and strategy (M. Schwickert and/or P. Forck)
    - MP relevance, OP robustness/reliability, nice-to-have
  - Group I: Intensity monitoring across transfer lines & rings
  - Group II: Orbit/Trajectory & Q/Q'
  - Group III: Beam Loss & Vacuum
  - Group IV: longitudinal diagnostics (bunch shape/length, splitting/merging, abort gap monitoring, tomography, ...)
  - Group V: emittance diagnostics and preservation (after optics)
- Beam Control:
  - Trajectory and Orbit Control (Bernd?)
  - Tune and Chromaticity Measurement & Control (P. Kowina?)
  - RF capture and (later) RF gymnastics
  - Transfer line & ring optics measurement & control (Peter?)
  - Transverse and longitudinal feedbacks (RF: ???)

Critical Systems – CO

- Critical systems that need to be defined as soon as convenient
  - Data archiving paradigm, requirements & specs ↔ post-mortem
    - Storage by cycle, as 'function of time' or both (e.g. snapshots of accelerator states after injection, start ramp and before extraction)
    - Data extraction: online tool to make simple 1st-order correlation, other extraction options (C/C++, Java, Matlab, Mathematica, … ?)
    - How to ensure complete coverage: tree structure to be defined globally but individual variables (leafs) need to be defined by system experts (↔ human readable naming convention)
  - Remote acquisition of analog signals (↔ CERN's Oasis)
    - "online scopes" management framework (fixed signals vs. ad-hoc measurements)
    - Mandatory analog input protection: low-noise amplifiers needed for ions but may be destroyed by high-intensity proton signals ↔ passive protection + active settings driven and feedback if things go unexpected
  - Test-beds for each and every accelerator equipment
    - Equipment need to provide (simulated, stored, etc) data with the same interface as the operational (future) device in the machine
    - Mandatory for quality assurance and long-term maintenance
    - Allows development of tools prior to/without the availability of the underlying equipment
      - Important for pre-commissioning and during operation (for safety reasons)

Critical Systems cont'

- Deriving from HWC and machine check-out:
  - LSA providing test function for system acceptance tests (not beam-hierarchy driven)
  - Context-based monitoring of
    - electrical power network & power converter infrastructure
    - Cryogenics & vacuum
    - other facilities: water, personnel safety radiation monitors, ...
  - Controls and accelerator infrastructure monitoring
    - controls and timing network (latencies, instantaneous/avg. bandwidth load)
    - FE CPU/temperature loads,
  - Tools for check-out test analysis (passed, in-progress, fault)
  - Tools for availability analysis → interface with logbook?
  - Bunch-to-bucket transfer paradigm – proof of concept? (use-case, specification, ...)
  - Video/image distribution and analysis (↔ IPMs, transfer line screens)
    - bandwidth, latency control, post-processing infrastructure, …

Control Room Application

- Crucial, missing tools:
  - Performance indicators:
    - Overall transmission performance (short-, medium- and long-term)
    - Total up-time, beam-delivered-on-target

    Already important for SIS18 restart In 2017-Q1
  - Beam parameter control
    - (Semi-)Automated Transfer-line Steering – priority for SIS18 restart
    - Closed-Orbit Control (circulating beam) – priority for SIS18 restart
    - Q/Q' and Coupling Control
    - TL & ring optics measurements and control
  - Transverse and Longitudinal emittance monitoring?
    - emittance preservation across UNILAC → SIS18 → SIS100

Cybersecurity

- Aim:
  - Protect the accelerator against accidental or unauthorised access/protect the facility's availability
  - ensure the integrity of interlock and machine protection settings
  - Allow/manage safe and transparent accelerator modifications by experiments/operators (tracking)

- Separation of 'technical' from 'office' network
  - Bandwidth control, control of cross-talk of accelerator and non-accelerator activities
  - Need for 4+ priority queues: (0: net management, 1: real-time feedbacks, 2: OP critical data e.g. linked to SW interlocks, 3: others – video streaming, user communication outside of control room etc.). Assume Orbit-FB uses its own dedicated network.

- Role-Based-Access
  - Need to restrict unauthorised access that may compromise machine operation or protection
  - No generic accounts (pwd issue), but needs simple procedure through e.g. badge system.
  - Need to develop and roll-out role model soon

Miscellaneous Items

- Dry-runs, precursor to check-out for beam operation
  - Identifies bugs, errors, missing functionality early on
- E-logbook & error/fault/down-time tracking
  - needed to improve availability of individual systems → facility
- LSA question: intensity/beam parameter effects on magnet settings?
  - cycles with same optics but different magnet/BI/RF settings depending on beam parameters
  - Example: injections of pilot (low-intensity), magnetic field checks → injection of nominal beam (high-intensity) keep fields (or with simple scaling) but change intensity settings of BPM & RF front-ends.
- OP/CO/.. training on tools & accelerator concepts (shut-down lectures)
- Fixed displays – applied KISS principle
  - N.B. needs to be properly elaborated

Machine Protection I/II

- MP & FMECA (Failure-Mode-Effects-and-criticality-analysis)
  - not primary function of FCWG but needs to be synchronised and scheduled within overall commissioning and operating strategy:
  - Set limits on how far we can push intensities before MP elements need to be commissioned: optics checks, absorber/collimation setup, interlocks, ...)
    - Operate within envelope set by MP (interlocks, SBF).
  - operational integration across accelerators?
    - KISS – keep it simple, keep it safe → 'Safe-Beam-Flag' concept for FAIR?
  - Need clearer view of criticality and safety requirements for SIS100
    - What's at stake: human safety, machine HW protection, equipment protection (RF AFE), SEUs & overall Availability, ALARA,
    - Impact of HW failure and beam loss:
      - Destruction potential for major components:
        - Steel vacuum pipe, Cu coating, Al flanges
        - sector valves, BI beam screens
      - Residual beam vacuum (cycle-to-cycle contamination)
      - Residual activation & ALARA
      - SEU and machine availability

Machine Protection II/II

- BI Instruments
  - Ionisation Profile Monitor
    - Need to inject gas? yes/no? Species dependent?
    - Cycle-to-cycle IN → OUT → IN possible?
    - Centre beam position available (→ steering)?
    - Online emittance monitoring?
    - Damage thresholds (higher-beam losses due to pressure rise)?
  - Beam Screens
    - Cycle-to-cycle IN → OUT → IN possible?
    - Damage thresholds?
  - BPMs & RF AFE front-ends
    - How robust w.r.t. intensity/bunch length changes? Margin?
    - Can they adapt to the varying conditions during the ramp? Bunch compression, cooling, etc....
  - Can one use beam instrumentation for MP? 'reliability vs. availability' question

- Beam-Quality-Checks
  - Longitudinal profile recorded/analysed systematically?
  - Emittance monitoring and e-blow-up tracking across chain?
  - Reliability and redundancy of beam current transformer
    - Source for MP interlocks and interlocks protecting upstream equipment (e.g. TFB, BPMs, screens, ..)
  - Definition of 'safe-beam'?
- Reliability and integrity of BPM readings
  - Every-n-cycle or on-demand 'as good as new' checks?
  - checks via k-modulation? → if yes, need address winding/PC soon
  - Low-level RF signal commutation switches?
- Reliability and integrity of Q/Q' diagnostics
  - Can it be improved? CERN model?

Beam Instrumentation cont'd

- MP & beam instrumentation
  - Sufficient redundancy/robustness?
  - SIL specification possible (mainly FBCT)?
- Integration of beam instrumentation into operational CO/OP environment
  - big subject, …
- Bunch-to-bucket transfer and BST
  - Bunch #1 & abort gap definition?
  - Can we trigger specific bunches?

Operational Items

- Operational paradigm: operator tends to the whole beam production chain for a given specific experiment rather than a single set of accelerators
- How to keep OP “fit” for beam recommissioning
  - Is an early restart of UNILAC→SIS18→ESR sufficient?
- MCR level interaction/integration of exp. user in beam operation
  - easier for 'target' experiments (e.g. SFRS)
  - How often and what type of interactions are foreseen for storage ring experiments
- Some things that may need to be formalised:
  - Lad-laden control room → should encourage (/enforce) more gender balance
  - The matter of “language of the organisation”
    - International contributions and collaborators that would like to participate
    - IMHO: we need to become a bit more hospitable for non-german speakers

FAIR Operation/Control Paradigm

- 'One Operator per Accelerator Domain' vs. 'One Operator per Experiment':