



FAIR Sequencer

- computerized system validation -

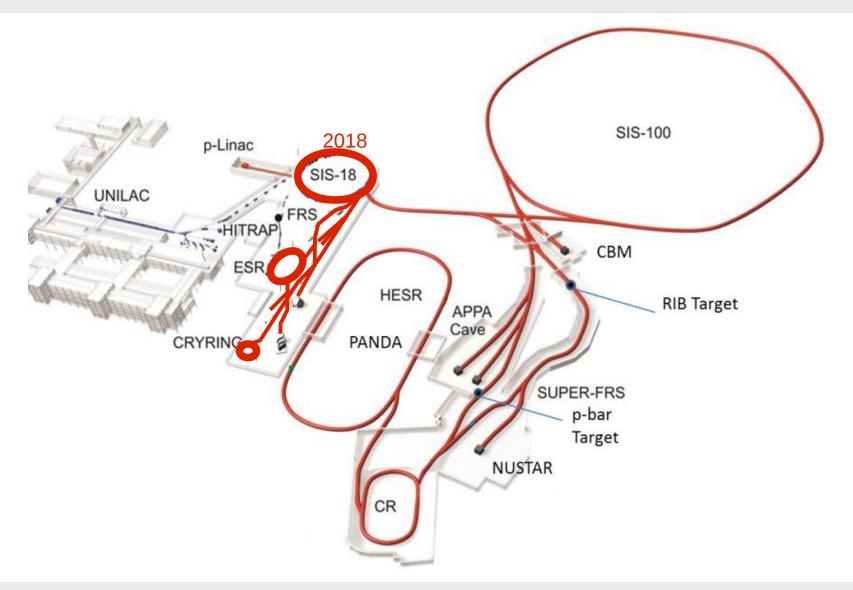
Preliminary Concepts and first Prototype

Ralph J. Steinhagen, R. Mueller

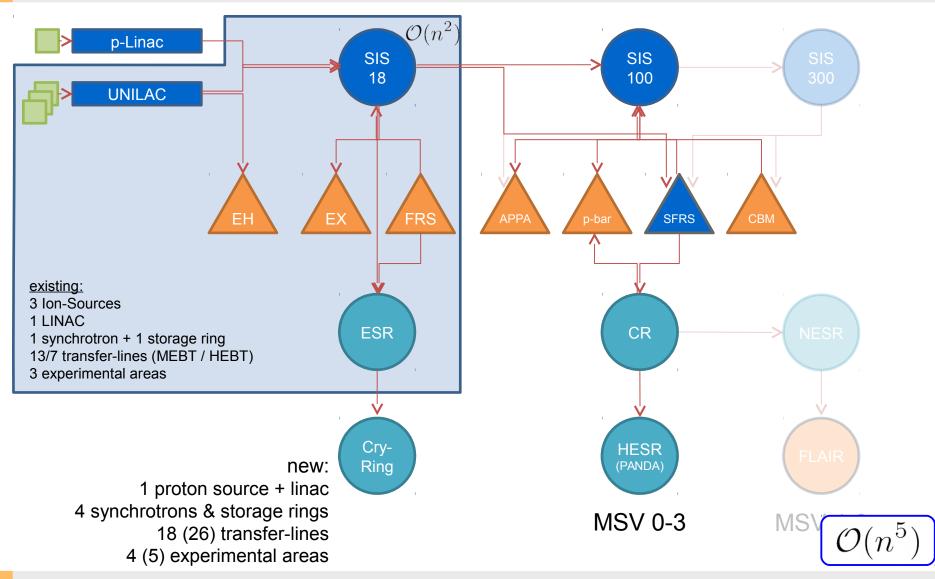
* based on 2015/16 FC2WG presentations & meeting minutes

FAR Accelerator Controls Retrofitting GSI \rightarrow FAIR Transition in 2018





FAR Migration Strategy GSI 3 \rightarrow FAIR 8¹/₂ (11+) accelerator(-like) machines

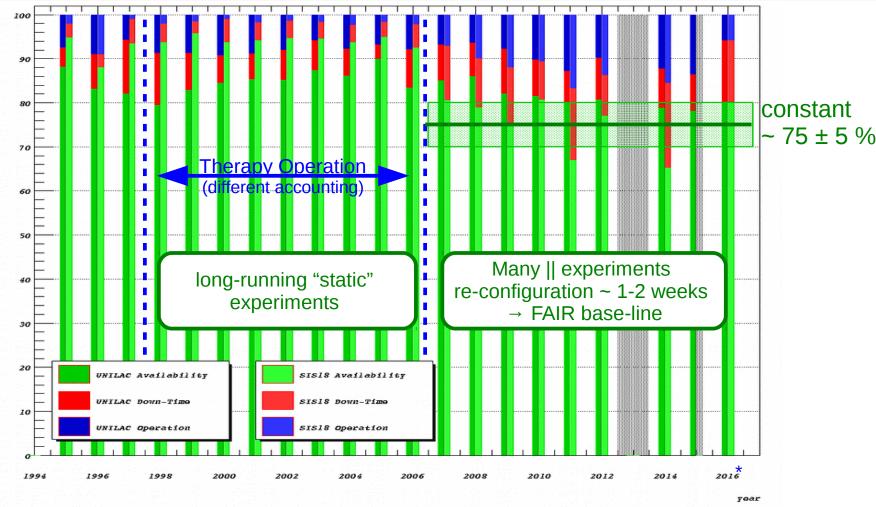


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FAR Accelerator Experience & Efficiency 1995-2016: U. Scheeler, S. Reimann, P. Schütt et al.





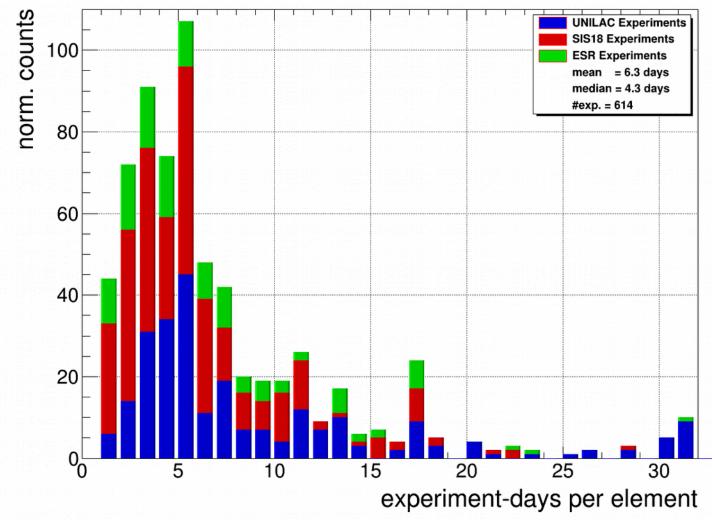
Based on: U. Scheeler, S. Reimann, P. Schütt et al., "Accelerator Operation Report", GSI Annual Scientific Reports 1992 – 2015 + 2016 (D. Severin) https://www.gsi.de/en/work/research/library_documentation/gsi_scientific_reports.htm N.B. ion source exchanges are factored out from UNILAC & SIS18 data (~ constant overhead) Availability: experiments + detector tests + machine development + beam to down-stream accelerators; Down-time: unscheduled down-time + standby; Operation: accelerator setup + re-tuning

* 2018 operation limitations:
• only ½ UNILAC (w/o A3 & A4)
• only 1 element in SIS18

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FAR Accelerator Experience & Efficiency a closer look on Exp. Statistics 2006-2016*





*see GSI annual reports 2015/16 data courtesy D. Severin

FAIR Commissiong &Controls Recap: 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 → 5-6 days 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) + 1-2 (infrastructure, cryo)

 \rightarrow 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

FAR Fundamental FC²-Principles: Reworking, 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
 - Examples:
 - first fix injection, trajectory, orbit, Q/Q' before addressing space-charge or slow-extraction problems
 - important losses for low-intensity beam have larger impact for high-intensity beam (+ activation)
 - pilot-beam concept: <u>always</u> verify machine safety with low-intensities before moving on to high-intensity beams
- Respect for people "develop people, then build products"
 - optimise operation \leftrightarrow 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 is a large facility and needs wider support: communicate concepts and strategy to broader base \rightarrow FC²WG

- SIS18 profile grid connectors
- Procedures: e.g. ATM machine: need to retrieve card before money is released (\leftrightarrow prevents missing card)

- to avoid (yokeru) inadvertent errors (poka)

etc. affecting machine performance and

industrial processes designed to prevent human errors

Concept by Shigeo Shingo: 'Toyota Production System'

minimise common mistakes, procedural errors,

Polarity protection of electrical plugs Ethernet cable)

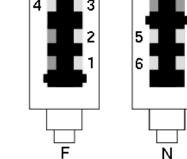
Real-World Examples:

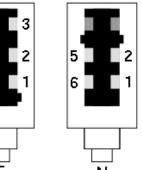
(TPS, aka. 'lean' systems)

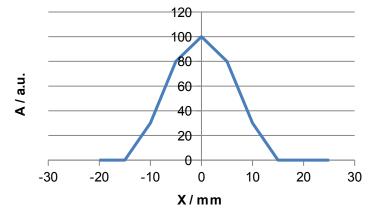
Origin:

protection

(e.g. phone,









✔ Poka-Yoke(ポカヨケ)– 'Mistake-Proofing'



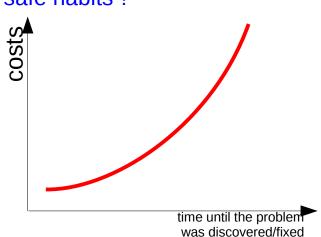
Reaction-Time and Cost \rightarrow "fix" errors early

Fix problems early, when and where they occur

• Minimises procrastination of errors: "Safety starts with safe habits"!

Poka-Yoke (ポカヨケ) – 'Mistake-Proofing'

- big losses with big intensities \rightarrow bad (activation)
- large losses with small intensities \rightarrow probably OK? ... No!
 - requires paradigm change!
- Interdependence between beam parameter & systems
- Early indication of developing/not-yet-critical faults:
 - Post-Mortem analysis ('as good as new' SIL assurance)
 - Preventative maintenance → Sequencer
 - fix "domino effect" problems at the source not its symptoms
 - e.g. fix problems with low-intensity beam rather than with high-intensity beam (avoids revalidation of loss patterns, MPS setup, ...)
 - e.g. fix basic accelerator parameters before moving on to higher-order effect (e.g. extraction/injection energy/trajectory → orbit → tune → chromaticity → optic → ... → driving term s





FAIR Commissioning & Control WG Ghttp://fair-wiki.gsi.de/FC2WG/ An accelerator is more than the sum of its parts: Commissioning with Beam Comissioning Procedures & Facility Exploitation Personnel development & training Commissioning w/o Beam (HWC/Dry-Runs) Experiments FAIR Users, Controls FAIR-MCR & FAIR-MCR human-machine interfaces ("HKR") Control System: ∞ŏ FC²WG System Integration LSA, Archiving/Logging, Performance Monitoring Beam-Based Systems/BI Integration (alignment, feedbacks, ...), ... SW System Integration ЧW other HW system achine-to-machin trum entatio other HW syster trum entati agnets magnets magnets Stripper magnet nterface nterface nterface ₹ MPLs/MCs e.g SIS100 e.q SIS18 HEB⁻ e.g. HESR

FAIR Commissioning & Control Working Group

- ¹ platform to discuss, coordinate and work-out FAIR commissioning and operation
- ¹ open to all who can participate and contribute to this subject!

Example: FAIR Commissioning Procedures



FAI

Ew BeamCommissioning - Beam ×								
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Apps GSI CERN-LHC	🖬 CERN-TEMP 🐚 Misc 🌑 Optics 🌑 3D Printing 🐚 RF-Components 🐚 Kickstarter 🐚 Wiki 🐚 RF 🚺 Imported 🚺 Maple 🚺 Jobs 🏠 New folder 🏠 Living 🏠 Print							
		Log in						
FAR Commiss	ioning & Control Group (FC²WG)	search						
I VIII VVOIKing V								
Home Minutes Next	Agenda Dry-Runs Commissioning Procedures Control Topics Admin							
BC Overview	You are here: FC2WG > BeamCommissioning	Log in						
Stage A - Pilot Beams Phase A.1 - Injection and First	Hardware Commissioning Commissioning with Beam Assisted	or Register						
Turn Phase A.2., Circulating Pilet	Machine Checkan	Toolbox						
Phase A.3 - Injection initial								
Commissioning Phase A.4 - Ramp	- 6 months - 2 weeks Stage A Stage B Stage C							
Phase A.5 - Injection &	~3-6 months							
Phase A.6 - Extraction	The Commissioning with Beam (BC) for FAIR is grouped into the following three stages:	Changes						
Phase A.7 - Final	Stage A - Pilot Beams Main focus for 2018	Notifications						
Phase A.8 - Preliminary	main aim: (re-commissioning, new CO) ofrive the beam expeditiously through the BeamProductionChain (BPC): from the sources, through the synchrotrons, beam transfers, up to the							
Physics runs Phase A.9 - Special aspects								
Stage B - Intensity Ramp-up	experimental targets/storage rings check basic 'accelerator mechanics': threading, injection, capture, cool, convert, acceleration/decelerate, stripping & extraction 							
Phase B.1	 identify beam-related limitations: polarities, RF, beam instrumentation, machine alignment, effective physical machine aperture, always done with 'safe' resp. low-intensity/brightness beam 							
Stage C - Production	 initially with 'easily available' ions (e.g. U28+, Ar -> simpler optics, beam dynamics, etc.), then protons (tests transition crossing, etc.) 							
Operation with nominal Intensities	Stage B - Intensity Ramp-up & Special Systems							
Phase C.1	• main aim:	Webs						
μα	 achieving and maintaining nominal machine performance for a limited number of reference beam 	FC2WG						
	 check that the accelerator design and systems can achieve (near) nominal beam parameters, e.g. beam intensities, nominal transmission and beam losses for e.g. U28+ & proton beams, etc. 	BeamCommissioning						
	 commissioning of e.g. e-cooler (if not needed earlier), slow extraction, transverse fast feedbacks 	HardwareCommission						
	 commissioning and validation of machine protection & interlock systems possibly unsafe operations always preceded by checks with safe beam 	Main Sandbox						
	Stage C - Production Operation with nominal Intensities							
							 main aim: make fast setup and switch-over between different <u>BeamProductionChains</u> routine 	

FAI Example: FAIR Commissioning Procedures

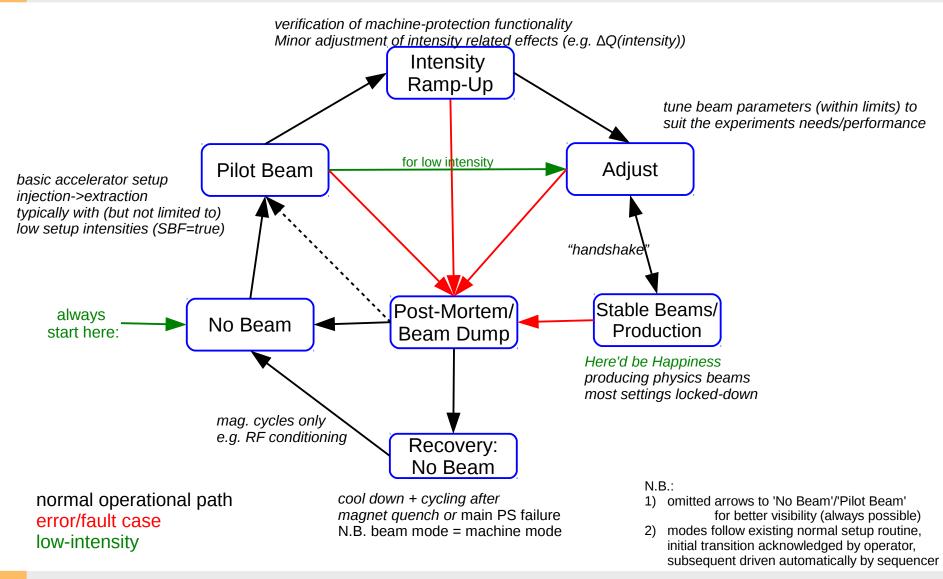


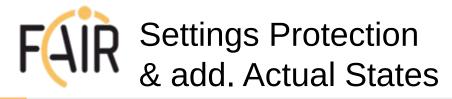
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	Group (FC ² WG)		
Home Minutes Next	Agenda Dry-Runs Commissioning Procedures Control Topics Admin		
C Overview	You are here: FC2WG >> BeamCommissioning >> BeamCommissioningStageA >> BCStageA1		Log in
age A - Pilot Beams hase A.1 - Injection and			or Register
rst Turn hase A.2 - Circulating Pilot	FAIR Commissioning Phase A.1) - Injection and First Turn	initial test in 2018	Toolbox
hase A.3 - Injection initial	Last modified by WolfgangGeithner on 07 Mar 2016 - 09:29 - r11		Greate New Topic
ommissioning hase A.4 - Ramp			i≣ Index
nase A.5 - Injection & traction Optics	+ Description		Search
ase A.6 - Extraction	Entry Conditions Machine Setup		Changes
ase A.7 - Final ous/Target Steering	Procedure Details of activities		Notifications
hase A.8 - Preliminary hysics runs	+ Problems		RSS Feed
ase A.9 - Special aspects	Exit conditions Open Questions & Action Items		Statistics
age B - Intensity Ramp-up	↓ References ↓ Acronyms		Preferences
age C - Production			. interestinger
ensities	Description		
	Commissioning of the last section of the preceding transfer line (matching section + few metres before) and th		Webs
	 First commissioning of key beam instrumentation 	FC2WG	
	 Commissioning of the trajectory acquisition and correction Threading the ring (first turn) 	BeamCommissioning	
	 Closing the orbit to be ready for phase <u>A.2 Circulating Pilot Beam</u> 		Hardware Commissionin
	Entry Conditions		Main
	Show		Sandbox
			System
	Machine Setup		
	Show		
	Procedure		
	1000000		
	Step Activity	Who Priority Special Procedures YR GS GE 1S CR HR	
	A.1.1 Commission Injection Region (1 Pilot Bunch) .01 Commission final metres of preceding TL	1 🕹	
	.02 Setup injection elements with beam	1	
	.03 Beam commissioning injection screens & grids .04 Detailed steering onto moved-in injection collimator (if available -> otherwise vacuum chamber)	1	
	.05 Power injection kickerbumper	1	
	.06 Check stability of transfer lines and trajectory without injection kicker/bumper	2	
	.07 Check stability of injected trajectory with injection kicker/bumper ON, measure kicker/bumper wavefo .08 Beam commissioning Software-Interlock-System (parasitic)	2 2	
	.08 Beam commissioning Software-Interlock-System (parasitic) .09 Perform aperture scan at magnetic/electro-static injection septa	2	
	A.1.2 Threading Beam around the Ring	-	
	.01 Open injection absorber/collimator (if applicable, or not dumped onto vacuum chamber)	1	
	.02 Coarse beam commissioning of BPMs (asynch. acquisition/narrow band, if available)	1	
	.03 Commission trajectory acquisition and correction .04 Threading around ring	1	
	.04 Inreading around ing .05 First measurement of energy mismatch (correction if needed)	1	
	.06 First BPM and corrector polarity checks and repairs	1	
	.D7 Beam commissioning of DCCTs & ICT	1	

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FAIR Beam Modes – State Diagram







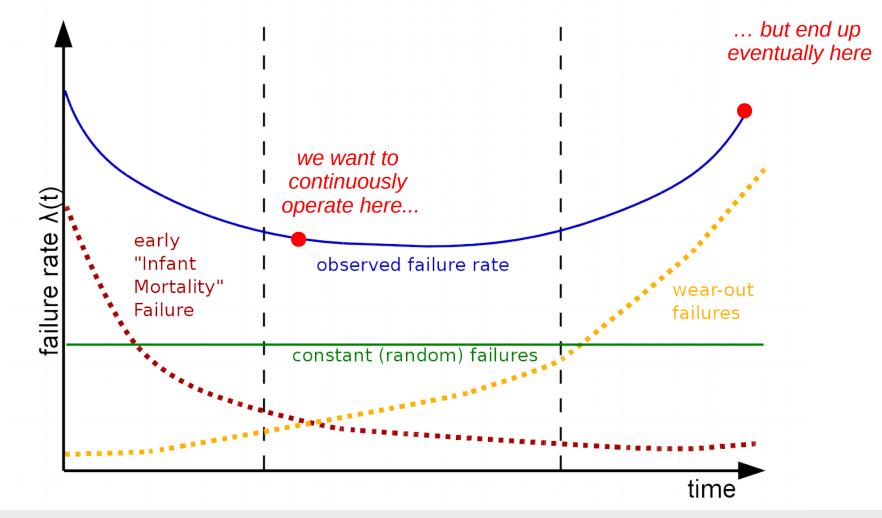


- Management of Critical Settings lock-down of critical machine settings depending on OP/MP scenario
 - tolerance bands depending on 'Accelerator' & 'Beam Modes': e.g. 'Pilot': fully open
 → 'Intensity Ramp-up' (limited 'safe range'. e.g. ΔQ < 0.01) → 'Adjust' (more stringent limits, e.g. only exp. target parameter) → 'Stable Beams' (only agreed settings, e.g. "beam-on-target position on 100 um level")
- Beam Presence Flag (BPF) indicates that cycle/settings have been validated with Pilot- or Physics-Beam in the recent past (< days, tbd.)
 - main usage: prevent high-intensity injections into an 'empty' machine with new untested magnetic settings or modified machine conditions
 - defined per accelerator or transfer-line segment (where necessary)
- Setup Beam Flag (SBF) indicates beam used to setup the beam production chain (typically lowintensity)
 - defined per accelerator or transfer-line segment (where necessary)
 - SBF provides flexibility of masking interlocks during setup (e.g. MWPC/screen protection)
 - Used to enforce interlocks with high-intensity (primary) beam (↔ prevents the 'forgotten interlock syndrome')
- Injection/Extraction Permit indicates if subsequent accelerator chain is ready (safe) to receive beam (→ fast beam aborts, discussed later)





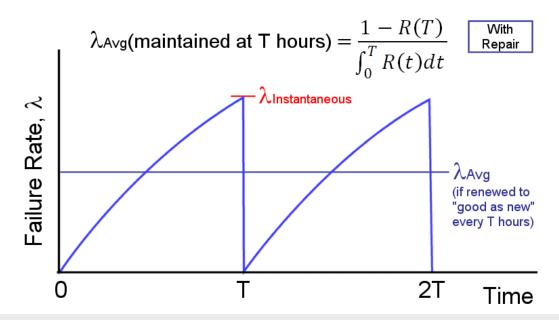
Problem definition: classical bath-tub curve – in an ideal/naïve world:







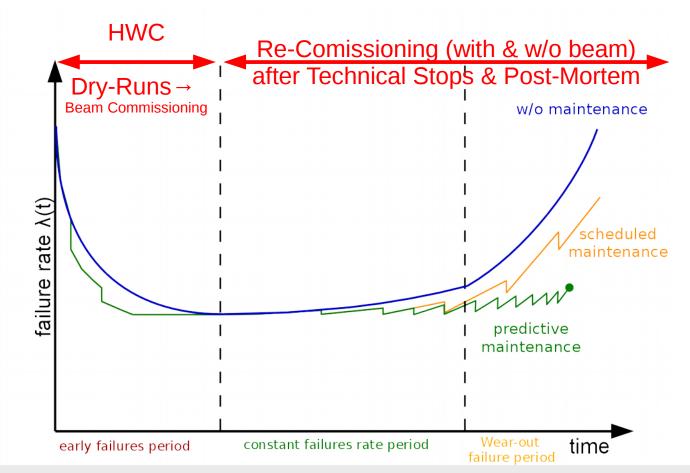
- Common improvement options: choice of materials, safety margin in material/parameter properties & adding redundancy
- However: redundancy provides only limited reliability gain
 - \rightarrow key to high reliability: performance surveillance + checks
 - → 'as good as new' system validation
 - technical implementations at FAIR: Sequencer & Post-Mortem System







• Sequencer (OP triggered) and Post-Mortem (MP triggered) checks



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 Kahneman studies¹ famously described the two different ways of our brain works and forms thoughts (N.B. → warded the 2002 nobel prize):

- System 1: "Fast", automatic, frequent, emotional, stereotypic, subconscious.
 - role: assess the situation, deliver updates
 - based on past experience, intuition and learned experience

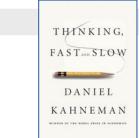
¹Daniel Kahneman, "Thinking, Fast and Slow", Farrar, Straus and Giroux, 2011

- prone to cognitive bias, logic faults
- Saves "mental energy"
 → usually preferred

- System 2: "Slow", effortful, infrequent, logical, calculating, conscious.
 - role: seeks new/missing information, makes decisions
 - Can keep only up to five aspects in active memory
 - Requires (sometimes significant)
 'mental energy' → unfavoured

... performing multiple complex, high-risk tasks is a actually very bad idea \rightarrow unnecessary strain on operators, machine experts and operational risk

Facility Complexity & the Human Factor Thinking Fast and Slow & "Human Multitasking"

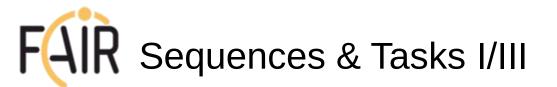




FAIR Sequencer & Post-Mortem or: 'Computerized System Validation'



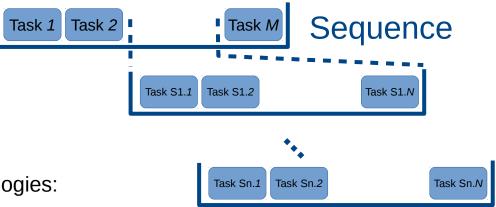
- Wikipedia: "... is the documented process of assuring that a computerized system does exactly what it is designed to do in a consistent and reproducible manner. The validation process begins with the system proposal/requirements definition and continues until system retirement and retention of the e-records based on regulatory rules"
 - or for FAIR equipment/machine experts: Java-based automatisation of the system integration, Site Acceptance Tests (SATs) and/or Beam Commissioning (BC) procedures
 - or for FAIR software developer: JUnit tests for hardware-based and other complex systems
- Main aspects:
 - test automation \rightarrow reproducibility, consistency, true parallelism and multi-tasking
 - identification & localisation of faults
 - follow-up/handling of tests that can last over several hours \rightarrow days
 - Machine protection (post-mortem): online validation of safety integrity level
 - Machine availability tracking and optimisation:
 - Continuous improvement of sequencer/commissioning procedures as evolving standard:
 - False-positive test procedure \rightarrow modify/fix test sequence
 - False-negative tests → add missing test procedure
 - Proper heuristics \rightarrow identify and provide a quantitative basis for facility upgrade decisisions



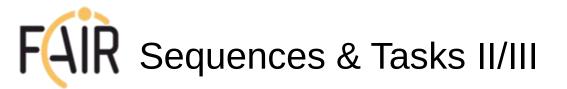


- 'Task' = device class specific atomic test, e.g.
 - connectivity test, power 'on', power 'off', ...
 - actual vs. reference comparison, ...
- 'Tasks' can be assembled to 'Sequences' ...

...which may also contain further sub-sequences:



- CO backbone technologies:
 - FAIR Archiving Systems → Documentation
 - LSA-based Settings Management → Reference & Data Supply
 - System- and Site-wide Digitisation of Analog Signals → 'actual vs. reference' process monitoring



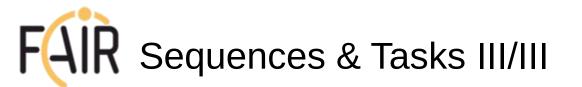


What is provided by the sequencer frame-work:

```
abstract class GenericHwcSequence {
    void exec() {
        initialize(); // communication to Archiving System, LSA, etc.
        specificPart();
        bookKeeping();
    }
}
```

• Level 1 & 2 tests (provided by the CO/equip. Group/machine experts):

```
class HwcSequence extends GenericHwcSequence {
     void initializeDeviceConnections();
     void specificPart() {
          super.specificPart();
          connectivityTest = initializeDeviceConnections(deviceName);
          if (connectivityTest.isHostReachable()) { // example: basic connectivity tests
               connectivityTest.testNameserver();
               connectivityTest.testCMW3get();
               connectivityTest.testJAPCget();
               connectivityTest.testCMW3Subscribe();
               connectivityTest.testJAPCSubscribe();
          } else {
               // error reporting, etc.
          }
     }
}
```





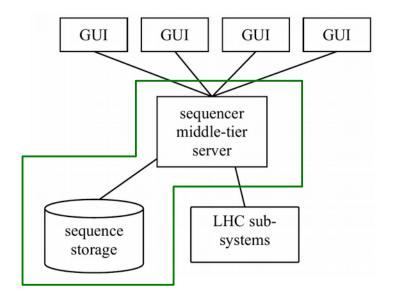
what the user needs to implement

```
class HwcTest1 extends HwcSequence {
      void specificPart() {
          super.specificPart()
          task1(); // user/device-specific atomic test operation 1
          task2(); // user/device-specific atomic test operation 2
          [..]
      }
     void task1() {
          // test SAT-A sub-procedure x.1, see specification... item ...
          // [..]
     }
     void task2() {
          // test SAT-A sub-procedure x.2, see specification... item ...
          // [..]
     }
}
```

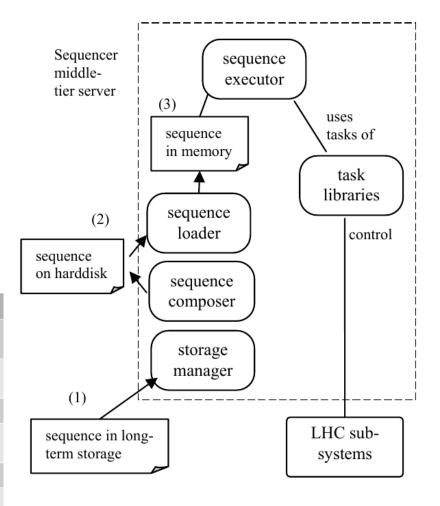
Some examples to get a flavour of the targeted code style and flavour: https://www-acc.gsi.de/svn/applications/app-codesnippets/

FAR LHC Sequencer Architecture re-use for FAIR/re-commissioning in 2018





	HWC	BC & OP
Execution	Run, stop, break, skip	Run, stop, break, skip, jump
Error Handling	Fail and stop on error	Ignore, stop, run recovery sequence
State	int. variables	No variables
Control Statements	Loops, if/else, try/catch	
Typical parallelism	Sequencences in	Tasks in
Typical mode	run-through automatically	"debug" and run- through

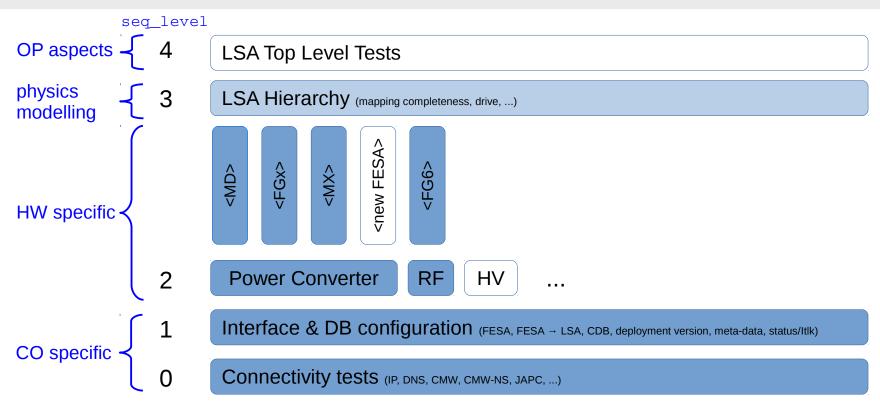


courtesy Vito Baggiolini

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FAR Some Preliminary Test Hierarchy





- Some logstash meta-data keys (see: https://logstash.acc.gsi.de/):
 - Existing tags: program: 'sequencer', user_name, pid, ...
 - seq_device: e.g. device name, LSA property name, global function
 - seq_level: <0 ... 4>, seq_task: <task/class name>, seq_sequence: <collection of tasks> (???)
 - seq_testID : unique identifier for given sequencer run (\leftrightarrow multi-user, parallelism)
 - seq_test_start: <time-stamp>

FAR Sequencer Protocolling Example https://logstash.acc.gsi.de/

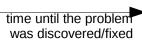


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FAIR Sequencer Key Aspects in a Nut-Shell

- 1. Test automation → reproducibility, consistency, true of parallelism and multi-tasking
- 2. Diagnostics: identification & localisation of faults
- 3.follow-up/handling of tests that can last over several hours \rightarrow days (\leftrightarrow SATs, UHV/RF/HV conditioning)
- 4. Machine protection (post-mortem): online validation of safety integrity level (SIL)
- 5. Machine availability tracking and optimisation:
 - -Continuous improvement of sequencer & commissioning procedures as evolving standard:
 - False-positive test procedure \rightarrow modify/fix test sequence
 - False-negative tests \rightarrow add missing test procedure
 - -Proper heuristics \rightarrow identify and provide a quantitative basis for facility upgrade decisisions

The sequence(r) is only as good as the procedures it implements → responsibility of every equipment group/owner and machine expert!







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FAR Main Aims for FAIR Prototyping at SIS18 Recommissioning in 2018

- Sequencer range of functionality:
 - a) protocolling of executed tests \rightarrow aim at 100% test coverage
 - b) (semi-)automated test sequences ('JUnit-style' HW Tests)
 - c) user-driven execution and configuration of test sequences (by non-Java equipment experts)
- next steps:
 - review/collect additional functional requirements
 - support test procedures together with equipment groups
 - main responsibility remains with equipment experts (EPC, CO, BI, ...)
 - priorities: 1. EPC, 2. HV (Septa & Kicker), 3. Ring-HF (rational: large quantity, (fairly) low complexity).
 - other equipment test-procedures (besides connectivity tests) require additional man-power (CO, vacuum, BI, ...).
 - support/drive Sequencer development
 - initial proof-of-concept for Dry-Run #1 covering:
 - 'a)' protocolling: inititally file-/logstash-based \rightarrow Archiving System
 - 'b)' using simple Java based sequences executed via Eclipse (Java-expert only)
 - extend to covering also 'c)' requirements by Q1-2017 (on a 'best effort' basis)
 - initial aim: simple non-configurable GUI that can execute pre-defined test-sequences by non-Java/Eclipse-affine equipment experts

- Follow-up of system- and machine commissioning procedures (with & w/o beams)

 \rightarrow prerequisite for any sustainable system integration and accelerator facility operation





"Ask not what FAIR can do for you, ask which Commissioning Procedure you can help prepare for FAIR!"



Yes, we/you can!





- M.Lamont et al., "Functional specification 'LHC Sequencer ...", LHC-CQ-ES-0001, EDMS #810407, 2006-12-21 https://edms.cern.ch/ui/file/810407/0.6/LHC-CQ-ES-0001-00-60.pdf
- V. Baggiolini et al., "A Sequencer for the LHC ERA", CERN-ATS-2009-114, ICALEPS'2009, Kobe, Japan, 2009 http://cds.cern.ch/record/1215886/files/CERN-ATS-2009-114.pdf
- R. Alemany-Fernandez et al., "The LHC Sequencer", ICALEPS'2011, Grenoble, France, 2011 http://accelconf.web.cern.ch/AccelConf/icalepcs2011/papers/mopmn027.pdf
- V. Baggiolini, R. Alemany-Fernandez et al., "LHC Sequencer", extended LTC Workshop, Chamonix, France, 2008 http://indico.cern.ch/event/28066/contributions/638169/attachments/.../LHC_Sequencer.pdf
- D. Anderson et al., "The AccTesting Framework: ... for Accelerator Commissioning and Systematic Testing", ICALEPCS2013, San Francisco, USA, 2013 http://accelconf.web.cern.ch/AccelConf/ICALEPCS2013/papers/thppc078.pdf

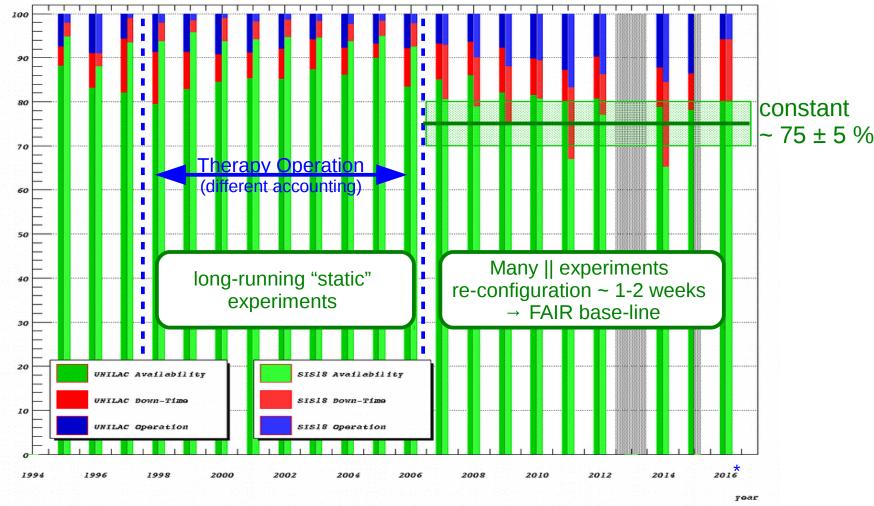






FAR Accelerator Experience & Efficiency 1995-2016: U. Scheeler, S. Reimann, P. Schütt et al.





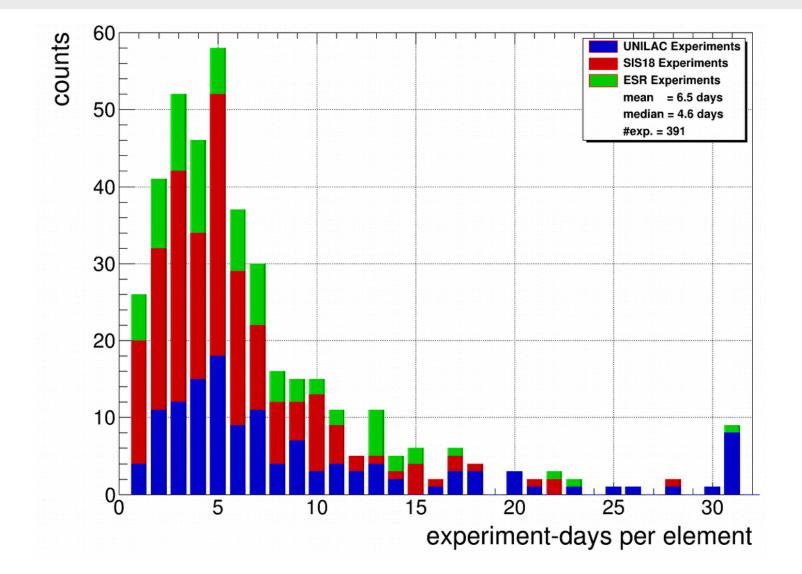
Based on: U. Scheeler, S. Reimann, P. Schütt et al., "Accelerator Operation Report", GSI Annual Scientific Reports 1992 – 2015 + 2016 (D. Severin) https://www.gsi.de/en/work/research/library_documentation/gsi_scientific_reports.htm N.B. ion source exchanges are factored out from UNILAC & SIS18 data (~ constant overhead) Availability: experiments + detector tests + machine development + beam to down-stream accelerators; Down-time: unscheduled down-time + standby; Operation: accelerator setup + re-tuning

* 2018 operation limitations:
• only ½ UNILAC (w/o A3 & A4)
• only 1 element in SIS18

GSI Helmholtzzentrum für Schwerionenforschung GmbH Ralph J. Steinhagen, r.steinhagen@gsi.de, 2017-05-31

FAR Accelerator Experience & Efficiency a closer look on Exp. Statistics 2006-2016









- HWC and BC sequencer are still different implementations? Specs?
- PNuts: still considered useful? Why not plain compiled java?
- Oracle database vs. svn. Pros/Cons?
- Sequence editing? How? Expert Level?
- Representation of sequences (high-level, low-level)? RMI usage?
- Result reporting: via DB? GUI interaction?
- Parallel execution of sequences (mutual blocking for same device, OK for different device). config of sequence/task by device?
- User level parameter & sequence modification (FAIR: e.g. user-level defined mini-ramp parameterisation, sequence(device name/group))
- Why sequence definition in oracle DB? SVN-stored sequences not sufficient?
- Who's editing the sequences routinely? Java-expertise needed as prerequisite?
- Commissioning reporting/error isolation functionality: How? How much? How much DB interaction? (see with Markus).

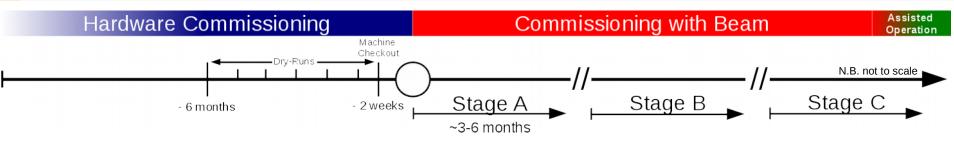
FAR FC2WG Control Topics – more than "Control System" & Data Supply



- Procedures: HWC, HWC-'Machine Check Out', BeamCommissioning, BC-Stage A (pilot beams), BC-Stage B (intensity ramp-up), BC-Stage C (nominal/production operation) Beam parameters, FAIR performance model, optimisation, Accelerator & Beam Modes
- Beam Instrumentation & Diagnostics System Integration
 - Intensity (DCCTs) & beam loss (BLMs) → Beam Transmission Monitoring System (BTM), trajectory & orbit (BPMs), Q/Q', optics (LOCO & phase-advance), longitudinal & transverse emittance (FCTs. WCM, screens, IPM, etc.), Δp/p, long. bunch shape (FCTs, Tomography), abort gap monitoring, ...
- Accelerator Hardware System Integration
 - Power converter, magnets, magnet model, RF, injection/extraction kicker, tune kicker/AC-dipole, beam dump, collimation/absorbers, cryogenics, vacuum, radiation monitoring, k-modulation, machine-experiment interfaces
- Control System
 - Archiving system, analog signal acquisition, test-beds, timing, bunch-to-bucket transfer, cyber security, rolebased-access, middleware, RT & Feedbacks, daemons
- Components
 - post-mortem, management of critical settings (safe-beam settings), machine protection, interlocks, beam quality checks, daemons, 'Page One', aperture model, ...
- Applications
 - Sequencer (semi-automated procedures), fixed-displays, ...
 - Beam-Based Applications, Cycle-to-Cycle Feedbacks & GUIs → second talk

FAR Commissioning with Beam





• Split Beam Commissioning into three stages:

A) Pilot beams/"easily available" ions (e.g. U28+, Ar)

- basic checks: threading, injection, capture, cool, convert, acceleration/decelerate, stripping & extraction
- always done with 'safe' ie. low-intensity/brightness beam
 - Ions: simpler optics, beam dynamics \rightarrow Protons: transition crossing

B) Intensity ramp-up & special systems

- · achieving and maintaining of nominal transmission and beam losses
- · 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

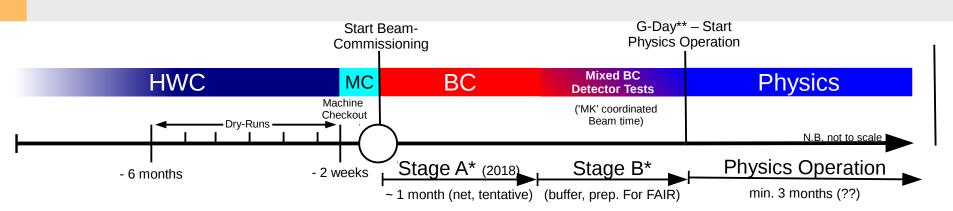
C)Production operation with nominal intensities

(N.B. first time counted as 'commissioning' or 'assisted operation' \rightarrow later: 'regular operation')

- push physics and beam parameter performance (emittance, momentum spread, ...)
- · identify and improve upon bottlenecks impacting FAIR's 'figure-of-merit
- make fast setup and switch-over between different beam production chains routine

Recommissioning & Operation in 2018 I/II https://fair-wiki.gsi.de/FC2WG/HardwareCommissioning/

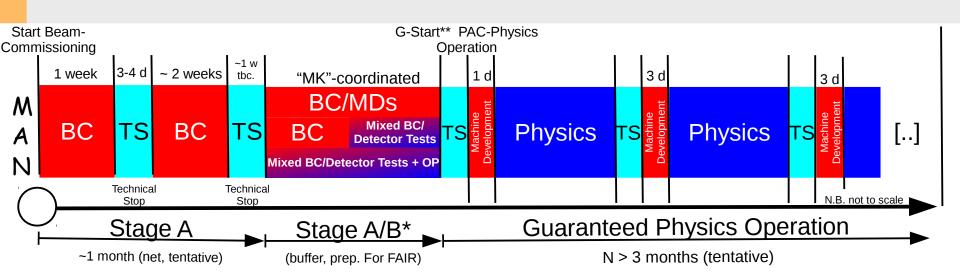




- Hardware Commissioning → coordinated by Sub-Project-Leaders & Machine Coordinators
 - link-existing facilities (GAF), upgrades, machine re-alignment, "SATs", HW systems (equip. groups),
- Dry-Runs for all machines post (possibly also UNILAC), each two days, fixed dates (↔ experts availability), starting:
 - Dry-Run #1 17.10.2017: CO-core: LSA, Timing System, Archiving System, SCUs, CO core application, ...
 - Dry-Run #2 14.11.2017: as before + tbd.
 - Dry-Run #3 12.12.2017: as before + tbd.
 - Dry-Run #4 09.01.2018: as before + BI + related applications
 - Dry-Run #5 06.02.2018: as before + Experiments (proposal) + Machine-Experiment Interfaces
 - Dry-Run #6 20.02.2018: as before + AEG + "last-minute" checks
 - Dry-Run #7 06.03.2018: buffer
- Machine-Checkout intensive "last minute checks" (N.B closed tunnel/machine):
 - UNILAC: -1 month \rightarrow BC- 'day 0'
 - patrols, heat runs: RF & power supply conditioning, ...
 - SIS, ESR, CRY: -3 weeks \rightarrow BC- 'day 0'
 - patrols, heat runs: RF & power supply/AEG conditioning, safety systems: personnel safety, access system, legal ZKS & RP checks (§66 Abs. 2 StrlSchV), "very lastminute" checks/bug fixes: vacuum, power, BI, CO, ...
- * in 2018: light-version w.r.t. commissioning of new machines
- ** "guaranteed" start physics operation (Plan A), no hick-ups, sacrificial buffer being activities related to 'Stage B'

FAR Recommissioning & Operation in 2018 II/II https://fair-wiki.gsi.de/FC2WG/BeamCommissioning





- Stage-A: Initial Beam Commissioning (BC): 2 dedicated 3 week@24h/7 BC blocks, main aim:
 - drive beam expeditiously through the Beam Production Chain: sources \rightarrow synchrotrons & beam transfers \rightarrow exp. targets & storage rings
 - check basic 'accelerator mechanics': threading, injection, capture, cool, convert, acceleration/decelerate, stripping & extraction
 - identify beam-related limitations: polarities, RF, beam instrumentation, machine alignment, effective physical machine aperture, ...
- Immediately followed by dedicated, scheduled Technical Stop (TS)
 - needed for follow-up of HW (tunnel) and SW issues (CO, $\ldots)$
- Stage-A/B*: Mixed-BC, Machine-Development, Detector Tests (aka. "splash events" for experiments) & Operator Training
 - N.B. "old machine" but completely new CO, substantial modifications
- Physics operation: as promised/targeted nett 3 months (to be confirmed), grouped into 2-3 blocks interleaved with
 - TS: routine maintenance → increases overall availability, follow-up of OP/CO/equipment issues + major ion species/source changes
 - MDs: follow-up of beam physics issues, CO improvements (e.g. beam-based FBs), improve facility to reach nominal FAIR parameters
 - N.B. also better for guaranteeing smooth restart/picking-up of physics operation after technical stops (experts availability)