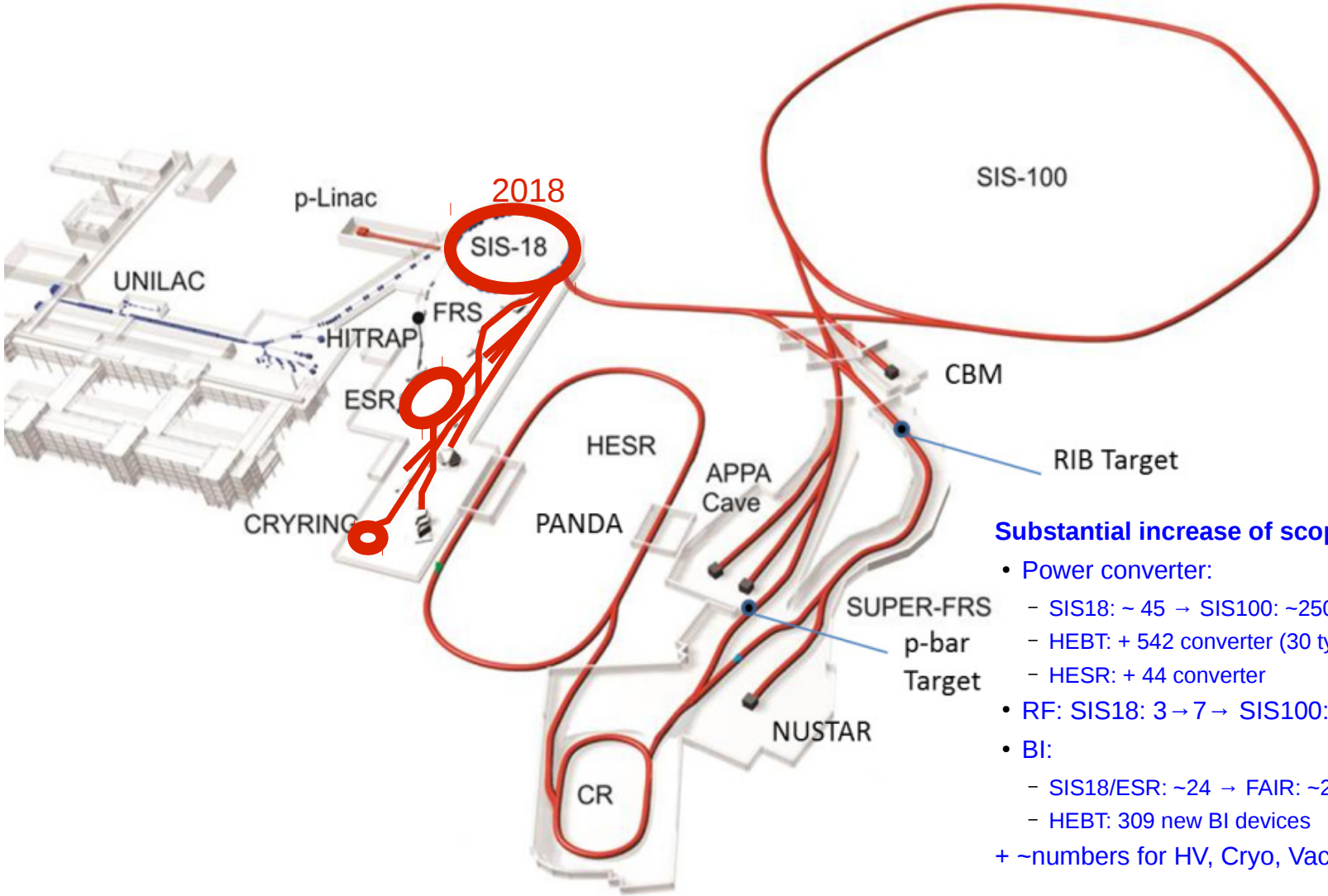
Dry-Run Procedures & 1st Sequencer Iteration

Ralph J. Steinhagen

* based on 2015/16 FC2WG presentations & meeting minutes

Accelerator Controls Retrofitting GSI → FAIR Transition in 2018



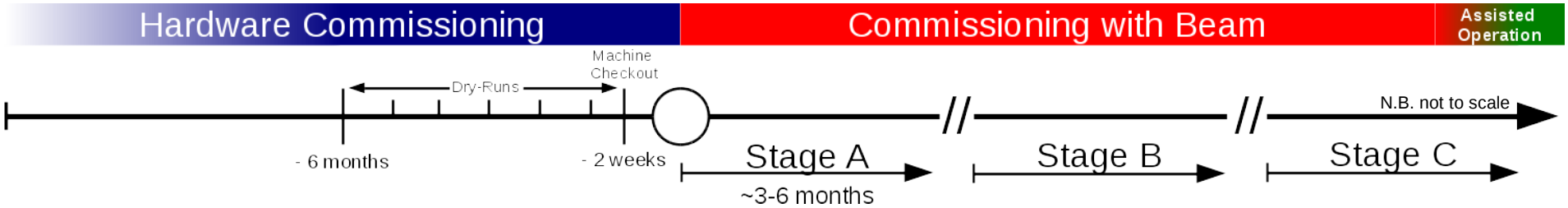
Substantial increase of scope w.r.t. GSI:

- Power converter:
  - SIS18: ~ 45 → SIS100: ~250 converter
  - HEBT: + 542 converter (30 types!)
  - HESR: + 44 converter
- RF: SIS18: 3→7→ SIS100: 38 RF sys.
- BI:
  - SIS18/ESR: ~24 → FAIR: ~250 BPMs
  - HEBT: 309 new BI devices

+ ~numbers for HV, Cryo, Vacuum, TI, ...

Commissioning without Beam

https://fair-wiki.gsi.de/FC2WG/HardwareCommissioning/



A) Hardware Commissioning (HWC → SAT A)

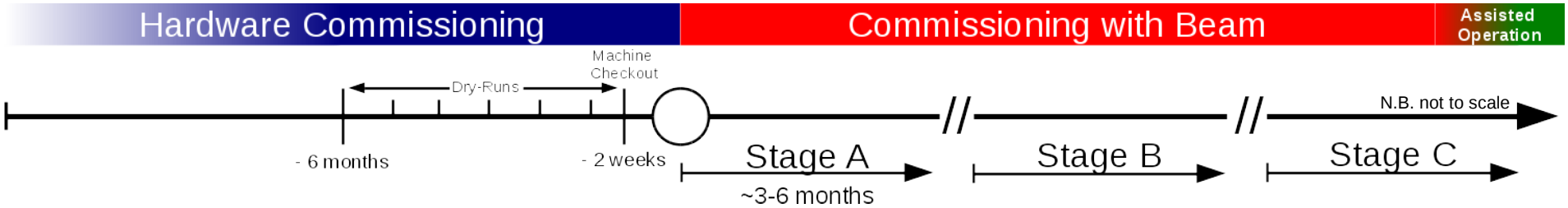
- conformity checks of the physical with contractual design targets,
- || commissioning of individual systems & tasks ↔ MPLs/equipment group responsibility

Terminology:

- **Dry-runs**: a rehearsal of the accelerator performance/function, starting typically six month before the targeted real BC
  - needs to (partially) repeated after shut-down or longer technical stop with substantial modifications
  - initial frequency: 1-2 days every month
  - frequency increased depending on the outcome of the initial dry-run tests
- **Machine-Checkout**: intense accelerator performance tests (e.g. machine patrols, magnet/PC heat-runs, etc.), typically two weeks before BC
  - needs to repeated after every shut-down or longer technical stop
  - repeated also on the long-term during routine operation of existing accelerators (already existing procedures/usus for existing machines)

Commissioning with Beam

https://fair-wiki.gsi.de/FC2WG/BeamCommissioning



- 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 → 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' → later: 'regular operation')

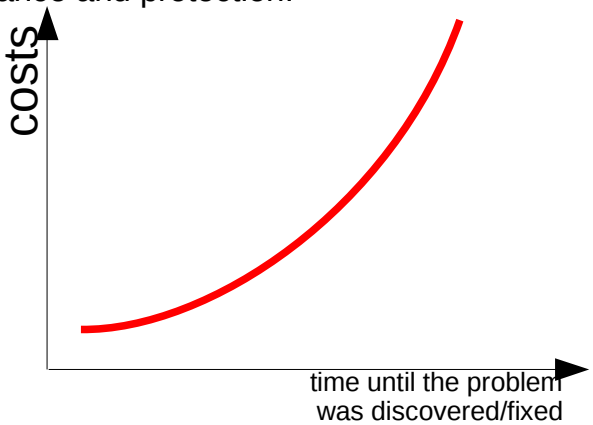
- push physics and beam parameter performance (emittance, momentum spread, ...)
- identify and improve upon bottlenecks impacting FAIR's 'figure-of-merit
- <u>make fast setup and switch-over between different beam production chains routine</u>

Poka-Yoke (ポカヨケ) – 'Mistake-Proofing'
Reaction-Time and Cost → “fix” errors early

… minimise common mistakes, procedural errors, etc. affecting machine performance and protection.

→ Fix problems early, when and where they occur:

- Minimises procrastination of errors
- “Safety starts with safe habits”!



- Benefits of early indicators of developing/not-yet-critical faults:
  - Identification/isolation of faults during HWC/DryRuns (e.g. via Sequencer)
    fixes “domino effect” problems at the source not its symptoms:
    - HWC: parallel testing possible → resource control by SPL/equipment group
    - BC: predominantly sequential testing → limited/no resource control ↔ “fire-fighting”
  - Preventative maintenance
    - early indication of drifting parameters (e.g. slow thermal runaway of IGBTs)
    - group common/similar maintenance tasks rather planning for having react (minimises “fire fighting”)
  - Post-Mortem analysis ('as good as new' SIL assurance)
    - insures safety-integrity-level, minimises risk at the source before they escalate
    - minimises human-intervention – OP/expert has to handle errors that have not/cannot be automatically analysed by the post-mortem system

FAIR Commissioning Procedures

- Procedures verify that functional and ‘Detailed Specification’ requirements have been fulfilled → FAT, SAT but also importantly for Beam Operation
  - checks MoU between various stake-holders (AP, BI, CO, RF, ...)
    - *define when, where and how the individual accelerator systems should fit in*
  - identify loop-holes/missing critical functionality
  - identification/isolation of errors & regression testing
    - *ie. minimises that errors fixed in the past are not being reintroduced*
  - ensures that HW is largely/fully commissioned prior to BC/operation
    - *N.B. HWC (testing in ||) vs. BC (testing predominantly sequentially)*
  - (semi-)automation: better to ‘act’ than to ‘react’ → triangle of *‘work to be done’ vs. ‘required project timeline’ vs. ‘available resources’*
  - traceability and documentation (for your peers, SPL/management, operation, …)
    - improve the quality of the project (QA)

- Test procedures describe the intention of what needs to be achieved
  - specifically not implementation or tool specific ie. implementation can be refactored without the need to change the intention of the test
  - terminology/hierarchy of: unit testing → integration testing → acceptance testing

Proposed Procedure Structure

- Description
  - test procedures describe the intention of what needs to be achieved
  - specifically not implementation or tool specific
- Entry Conditions
  - dependencies to other systems/conditions → reference to other test sequences
- Machine Setup
  - conditions to be checked beforehand
- Procedure – list of individual tasks
  - for each detailed testing step:
    - short-hand key for each step (e.g. ‘step A’, naming taken from DS document)
    - short description of what needs to be achieved (ie. a ‘one liner’)
    - acceptance criteria (either from DS or split into warning/error)
- Problems
  - be free to comment on (technical) concerns or potential issues
- Exit conditions
- Open Questions & Action Items
- References & Acronyms
  - where applicable, helps you with further QA documentation

Example: FAIR Commissioning Procedures

https://fair-wiki.gsi.de/FC2WG/BeamCommissioning

BeamCommissioning - BeamCommissioning - FC2WG - FAIR Wiki - Google Chrome

https://fair-wiki.gsi.de/foswiki/bin/view/FC2WG/BeamCommissioning/WebHome

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BC Overview

Stage A - Pilot Beams

Phase A.1 - Injection and First Turn

Phase A.2 - Circulating Pilot

Phase A.3 - Injection initial Commissioning

Phase A.4 - Ramp

Phase A.5 - Injection & Extraction Optics

Phase A.6 - Extraction

Phase A.7 - Final Focus/Target Steering

Phase A.8 - Preliminary Physics runs

Phase A.9 - Special aspects

Stage B - Intensity Ramp-up

Phase B.1

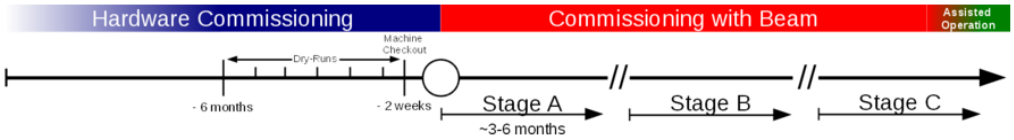
...

Stage C - Production Operation with nominal Intensities

Phase C.1

...

You are here: FC2WG » BeamCommissioning



The Commissioning with Beam (BC) for FAIR is grouped into the following three stages:

Stage A - Pilot Beams

Main focus for 2018
(re-commissioning, new CO)

- **main aim**:
  - drive the beam expeditiously through the BeamProductionChain (BPC): from the sources, through the synchrotrons, beam transfers, up to the experimental 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, ...
- always done with 'safe' resp. low-intensity/brightness beam
  - initially with 'easily available' ions (e.g. U28+, Ar -> simpler optics, beam dynamics, etc.), then protons (tests transition crossing, etc.)

Stage B - Intensity Ramp-up & Special Systems

- **main aim**:
  - achieving and maintaining nominal machine performance for a limited number of reference beam
  - 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.
- commissioning of e.g. e-cooler (if not needed earlier), slow extraction, transverse fast feedbacks
- commissioning and validation of machine protection & interlock systems
- possibly unsafe operations always preceded by checks with safe beam

Stage C - Production Operation with nominal Intensities

- **main aim**:
  - make fast setup and switch-over between different BeamProductionChains routine
  - push physics and beam parameter performance (intensity, brightness/emittance, momentum spread, ...)
  - identify and improve upon bottlenecks impacting FAIR's 'figure-of-merit'
  - improve the machine model using beam based techniques

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Example: FAIR Commissioning Procedures

https://fair-wiki.gsi.de/FC2WG/BeamCommissioning

BCStageA1 - BeamCommissioning - FC2WG - FAIR Wiki - Google Chrome

https://fair-wiki.gsi.de/foswiki/bin/view/FC2WG/BeamCommissioning/BCStageA1

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BC Overview
Stage A - Pilot Beams
Phase A.1 - Injection and First Turn
Phase A.2 - Circulating Pilot
Phase A.3 - Injection initial Commissioning
Phase A.4 - Ramp
Phase A.5 - Injection & Extraction Optics
Phase A.6 - Extraction
Phase A.7 - Final Focus/Target Steering
Phase A.8 - Preliminary Physics runs
Phase A.9 - Special aspects
Stage B - Intensity Ramp-up
Stage C - Production Operation with nominal Intensities

You are here: FC2WG » BeamCommissioning » BeamCommissioningStageA » BCStageA1

FAIR Commissioning Phase A.1) - Injection and First Turn

initial test in 2018

Last modified by WolfgangGeithner on 07 Mar 2016 - 09:29 - r11

- Description
- Entry Conditions
- Machine Setup
- Procedure
  - Details of activities
- Problems
- Exit conditions
- Open Questions & Action Items
- References
- Acronyms

Description

- Commissioning of the last section of the preceding transfer line (matching section + few metres before) and the injection region
- First commissioning of key beam instrumentation
- Commissioning of the trajectory acquisition and correction
- Threading the ring (first turn)
- Closing the orbit to be ready for phase A.2 Circulating Pilot Beam

Entry Conditions

Show...

Machine Setup

Show...

Procedure

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	X
.02	Setup injection elements with beam		1	
.03	Beam commissioning injection screens & grids		1	
.04	Detailed steering onto moved-in injection collimator (if available -> otherwise vacuum chamber)		1	
.05	Power injection kicker/bumper		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 waveform		2	
.08	Beam commissioning Software-Interlock-System (parasitic)		2	
.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		1	
.04	Threading around ring		1	
.05	First measurement of energy mismatch (correction if needed)		1	
.06	First BPM and corrector polarity checks and repairs		1	
.07	Beam commissioning of DCCTs & ICT		1	

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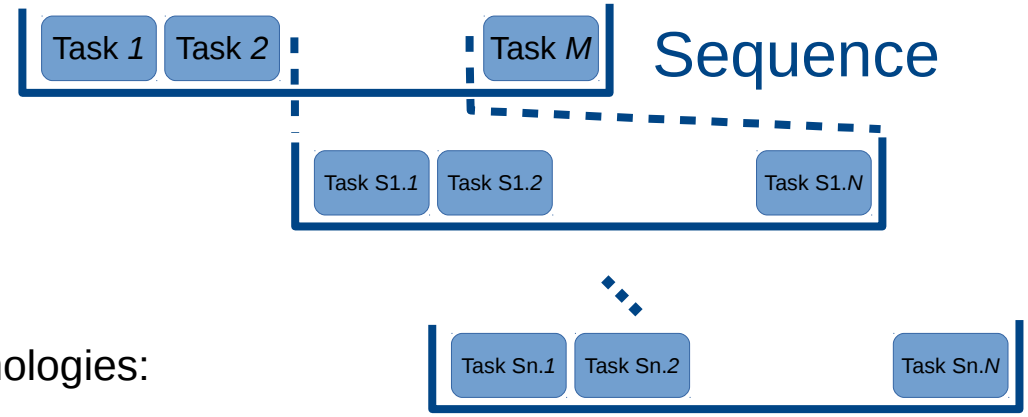
Sequences & Tasks I/III – Implementation

- ‘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

Sequences & Tasks II/III – Implementation

- What is provided by the sequencer frame-work:

```
abstract class AbstractSequenceImpl extends AbstractTaskImpl implements Sequence {
     void exec() {
          execPreUserCode(); // init communication to Archiving, LSA, Sequencer Service etc.
          execUserCode();
          execPostUserCode(); // reporting, etc.
     }
}
```

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

```
class FrontEndGenericConnectivityTest extends AbstractSequenceImpl implements Sequence {
     // [..]
     void execUserCode() {
          addTask(new Task("prepare", "init device status handler", this, () -> {
               deviceConnection = new GenericStatusTest(deviceName);
          }));

          addTask(new SkippableTask("step1", "check simple IP connectivity", this, () -> {
               if (deviceConnection.isHostReachable(CONNECTIVITY_TEST_IP) == false) {
                         throw new RawSequenceException("testCMW3get() - failed");
               }
          }));
          // [..]
     }
     // [..]
}
```

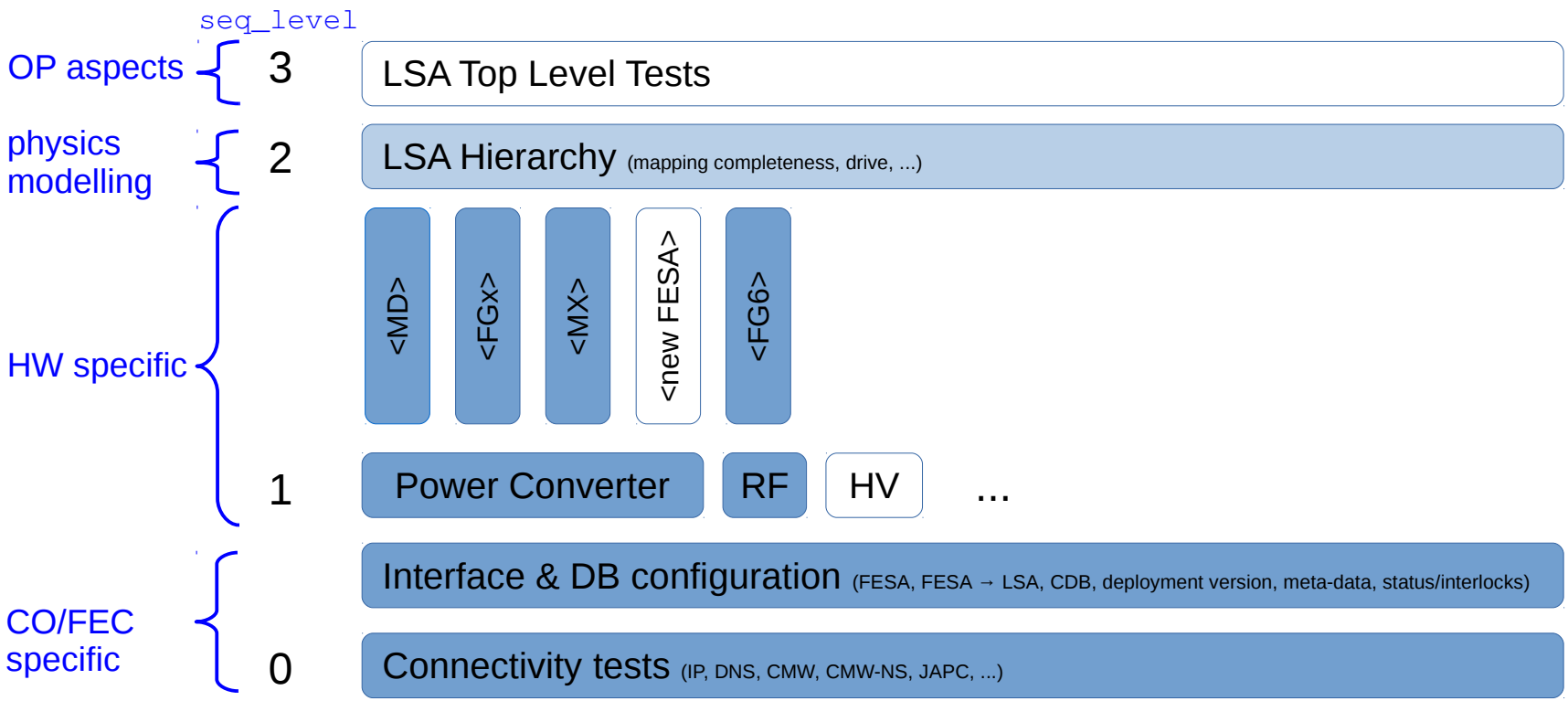
Sequences & Tasks III/III – Implementation

- what the user needs to implement

```
class HwcTest1 extends AbstractSequenceImpl implements Sequence {
      void execUserCode() {
           addTask(new FrontEndGenericConnectivityTest(getParameter()));

           addTask(new Task("step1", "description #1", seqReference, () -> {
                task1();  // user/device-specific non-skippable atomic test operation 1
           }));

           addTask(new SkippableTask("step2", "description #2", seqReference, () -> {
                task2();  // user/device-specific skippable atomic test operation 2
           }));
           [..]
      }

     void task1() {
           // test SAT-A sub-procedure x.1, see specification... item ...
           // [..], may throw Exception (or derivatives)
     }

     void task2() {
           // test SAT-A sub-procedure x.2, see specification... item ...
           // [..], may throw Exception (or derivatives)
     }
}
```

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

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 (↔ multi-user, parallelism)
  - seq_test_start: <time-stamp>

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

default - Discover - Kibana - Mozilla Firefox

https://logstash.acc.gsi.de/kibana/app/kibana#/discover/default?indexPattern=logstash-*&type=histogram&_a=(columns:!(logsource,level,Properties.seq_device,Properties.seq_task,message),filters:!(('$state':(store:appSt

kibana | Discover | Visualize | Dashboard | Settings | Last 15 minutes

user_name: "rstein" | Actions

logstash-*

Selected Fields
- t level
- t logsource
- t message
- ? Properties.seq_device
- ? Properties.seq_task

Available Fields

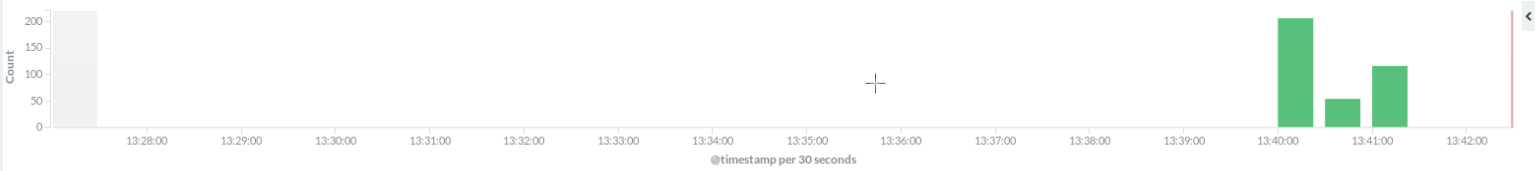
Analyzed: any
Indexed: any
Type:
Field name:
Hide Missing Fields

Reset Filters

Popular
- @timestamp
- t _index
- ? _source
- t _type

default 376 hits

18.Apr.2017, 13:27:27.815 - 18.Apr.2017, 13:42:27.815 — by 30 seconds



Time	logsource	level	Properties.seq_device	Properties.seq_task	message
18.Apr.2017, 13:41:06.356	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	device 'XYRT1QD62 ' available as deployed version '0.4.2', interlock = false, opReady = true
18.Apr.2017, 13:41:06.356	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	total of 104 devices available
18.Apr.2017, 13:41:06.356	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	total of 27 devices unavailable
18.Apr.2017, 13:41:06.355	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	device 'XYRT1IN1X ' available as deployed version '0.4.2', interlock = false, opReady = true
18.Apr.2017, 13:41:06.355	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	device 'XYR03KV7K ' available as deployed version '0.4.2', interlock = false, opReady = true
18.Apr.2017, 13:41:06.355	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	device 'XYR03MO3C ' available as deployed version '0.4.2', interlock = false, opReady = false
18.Apr.2017, 13:41:06.355	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	device 'XPLPSIZ1C1 ' available as deployed version '0.4.2', interlock = false, opReady = false
18.Apr.2017, 13:41:06.355	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	device 'XYR03KV6G ' available as deployed version '0.4.2', interlock = false, opReady = true
18.Apr.2017, 13:41:06.354	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	device 'XYRT1QD61 ' available as deployed version '0.4.2', interlock = false, opReady = true
18.Apr.2017, 13:41:06.354	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	device 'XYR03KV3G ' available as deployed version '0.4.2', interlock = false, opReady = true
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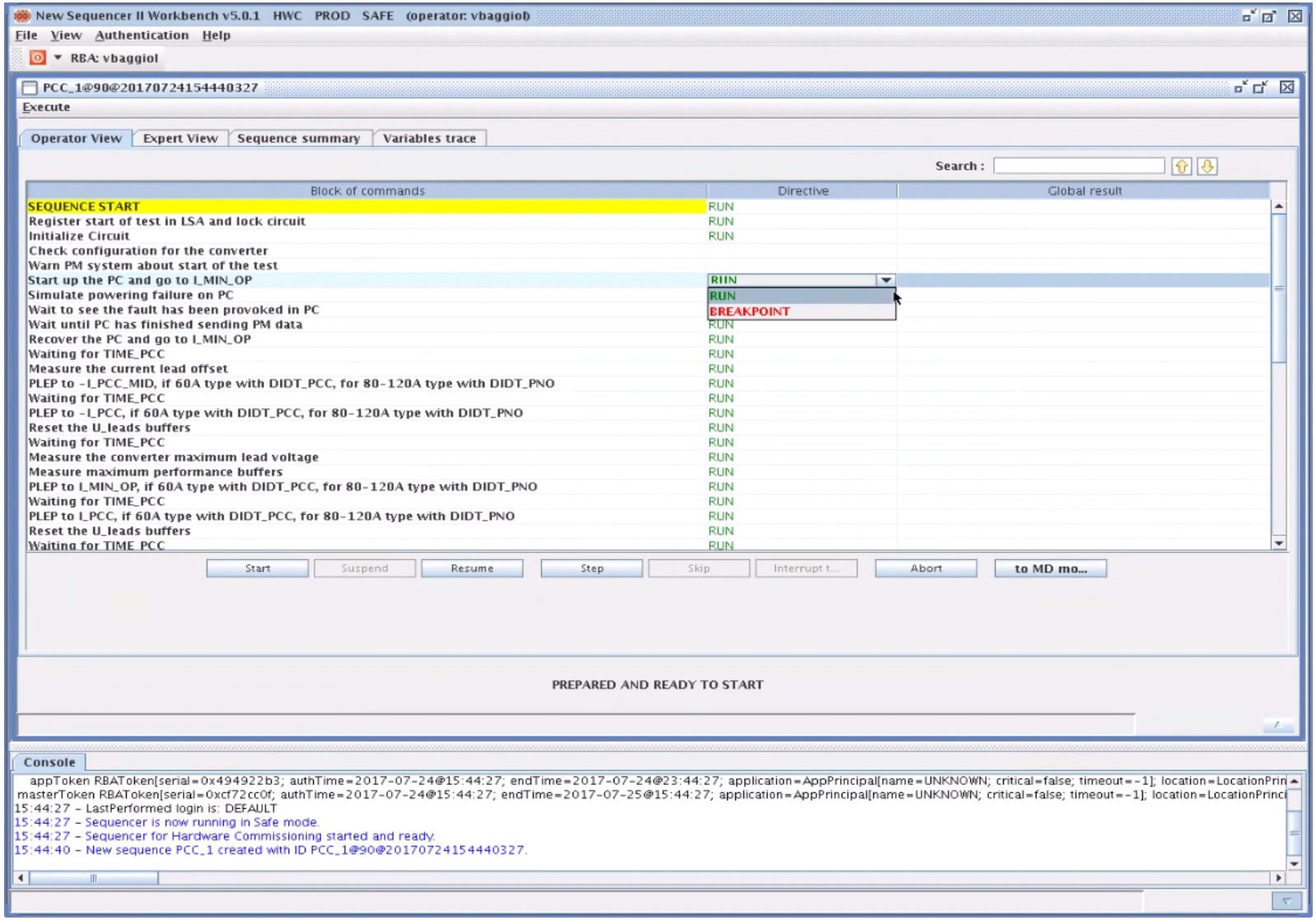
18.Apr.2017, 13:41:06.354	asl743.acc.gsi.de	INFO	Sequencer Summary	Sequencer Main Class	device 'XYR03KH3G ' available as deployed version '0.4.2', interlock = false, opReady = true

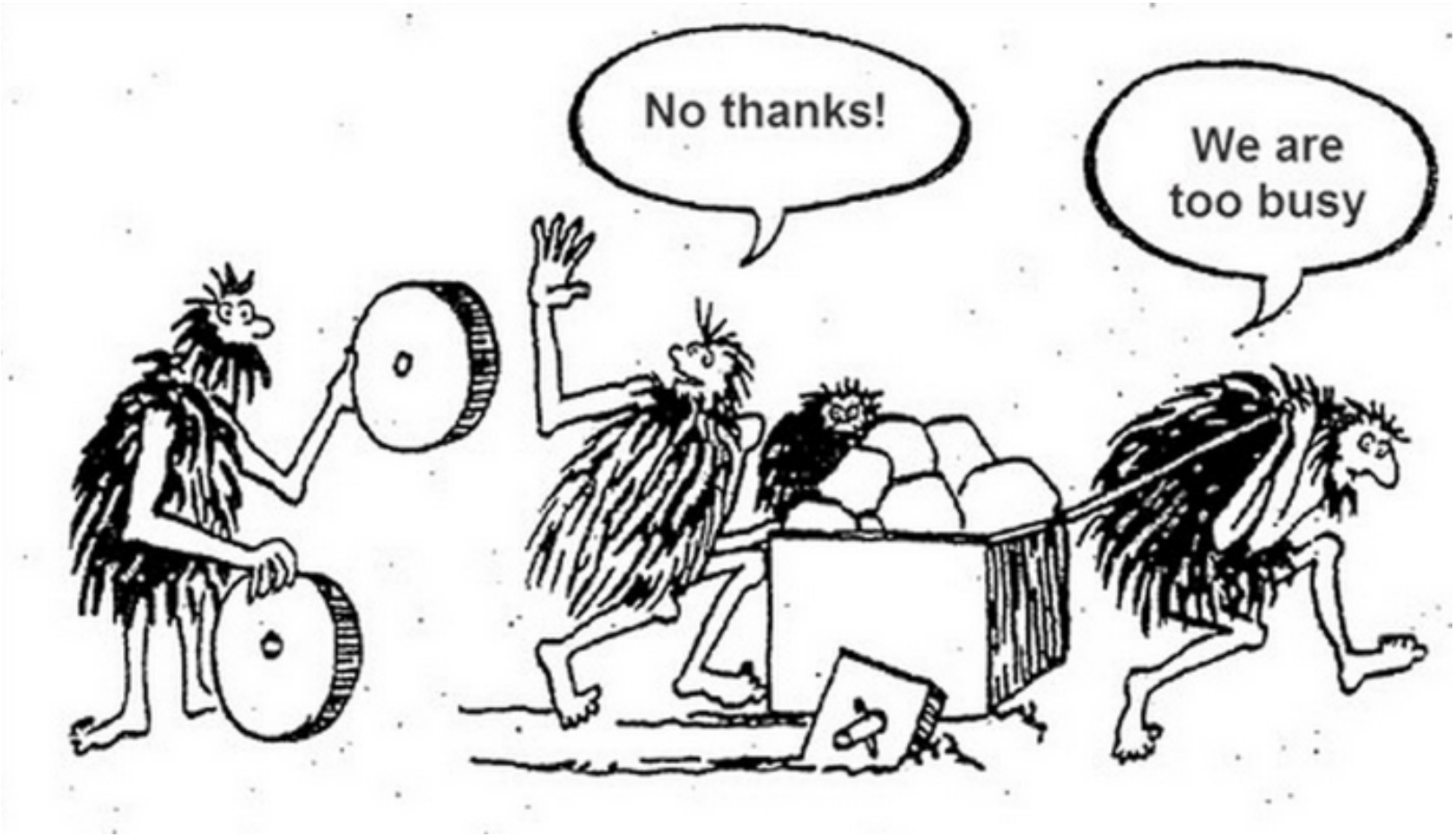
Sequencer | Highlight All | Match Case | Whole Words

Qualitative GUI Example



courtesy Vito Baggiolini

Reinventing the Wheel ...



SIS18 Power Converter Specification (incl. FAT & SAT, 1985, aka. *"AEG"*)

Aus: "Spezifikation für die Stromversorgung der Magnete des Schwerionensynchrotrons SIS 18",
GSI - SIS - SPEZ / 85 - 27, 06. August 1985 (EP)
https://edms.cern.ch/document/1225471/2
… 90 pages (don't have time during commissioning/dry-runs)

1/4th of main dipole PC:

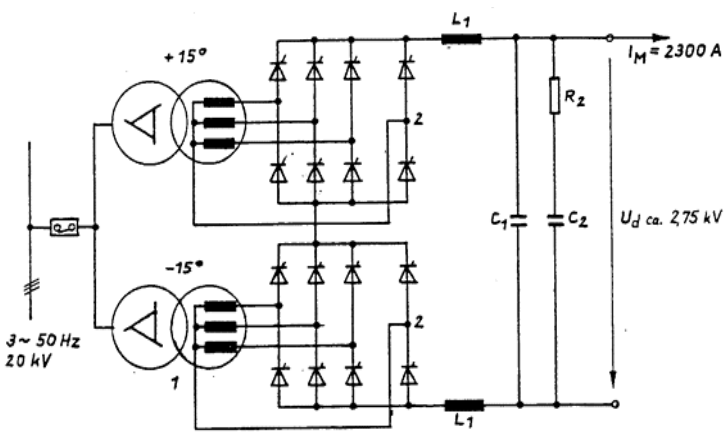


Bild I.6.3/1 Schaltung einer der vier Stromrichtergruppen zur Speisung der Dipolmagnete

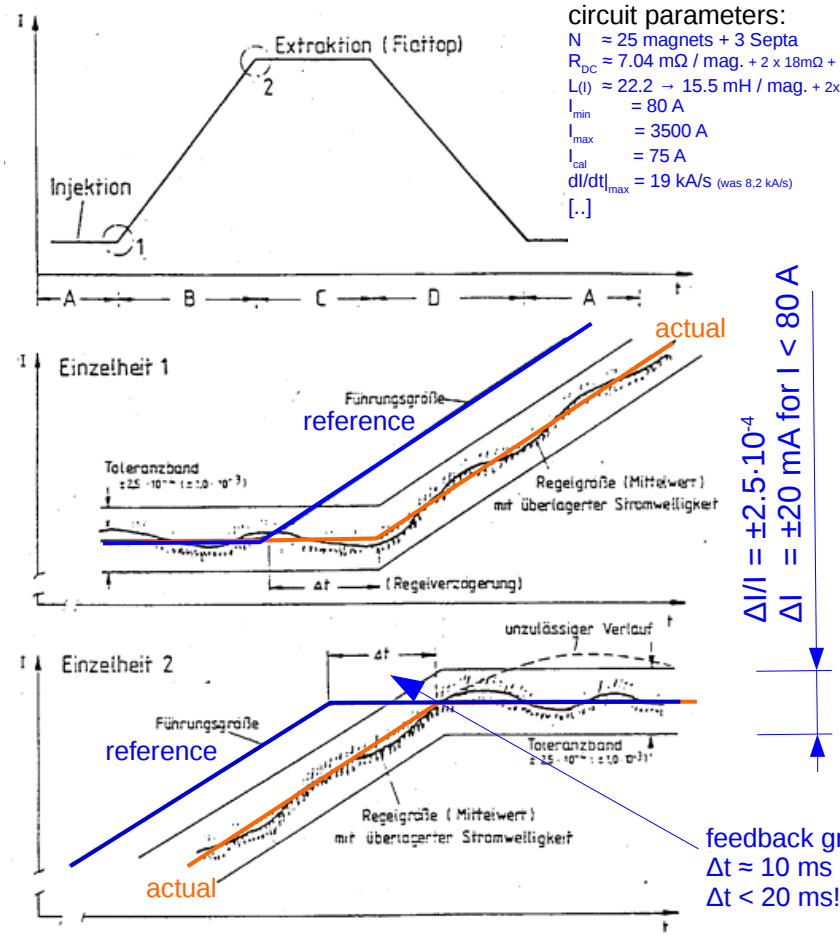
1 Transformator mit ± 15° Schwenkzipfeln
2 Drehstrombrücke mit Nullventilen
L_1C_1 Passivfilter, R_2C_2 Dämpfungsglied

x 4

[…]

- I.2.2 Magnetstromzyklen und technische Daten

circuit parameters:
N ≈ 25 magnets + 3 Septa
R_{DC} ≈ 7.04 mΩ / mag. + 2 x 18mΩ + 8.88 mΩ + R_{cable}
L(I) ≈ 22.2 → 15.5 mH / mag. + 2x 1.4 mH + 0.17 mH
I_{min} = 80 A
I_{max} = 3500 A
I_{cal} = 75 A
$dI/dt|_{max}$ = 19 kA/s (was 8,2 kA/s)
[..]



Example: “AEG” Documentation Power Converter Topology

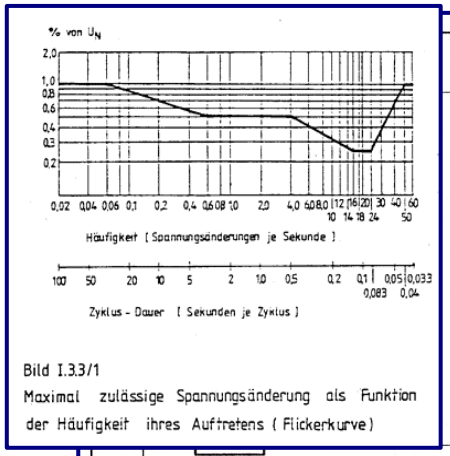
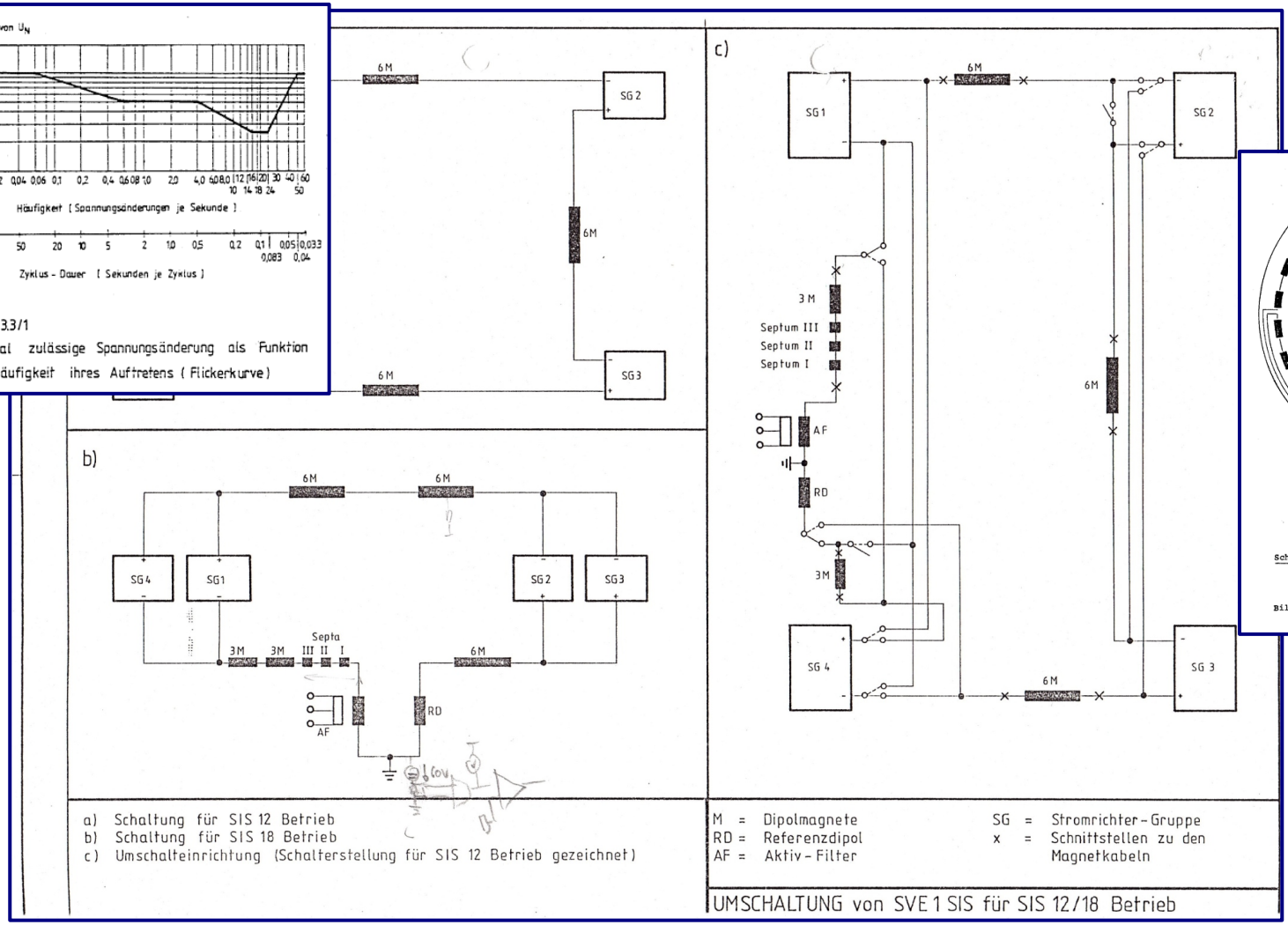


Bild I.3.3/1
Maximal zulässige Spannungsänderung als Funktion der Häufigkeit ihres Auftretens (Flickerkurve)



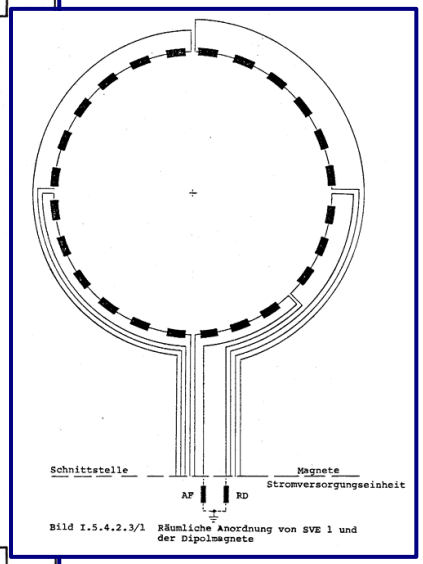


Bild I.5.4.2.3/1 Räumliche Anordnung von SVE 1 und der Dipolmagnete

Existing *"AEG"* SAT Description

https://edms.cern.ch/document/1225471/2

I.5.4.7.1 Nachweis der Forderungen der Magnetstromzyklen

Die Einhaltung folgender Forderungen ist durch Messung nachzuweisen (s. Bild I.2.2/2).

a) Stromgenauigkeit, bezogen auf Momentanwert, entsprechend Abschnitt 1.2.2: bei I_{max} & I_{min}

b) Langzeit-Genauigkeit: Messung der analogen Führungsgröße und der Regelgröße nach Erwärmung auf Endtemperatur über einen Zeitraum von 24 Stunden mit Differential-Voltmeter Siemens PM 4602 D oder Fluke Modell 887 AB

c) Welligkeit – Betrachtungszeiträume: 20 ms, 100 ms, 1 s

d) Übergang von I_{min} in den linearen Anstieg, Übergangszeit, Übergangsfunktion – bei maximalen dI/dt & bei 10% $dI/dt|_{max}$

e) Stromanstieg:

- Regelverzögerung Δt; überlagerte Welligkeit – bei maximalen dI/dt & bei 10% $dI/dt|_{max}$

f) Übergang Anstieg → Flattop: wie d)

g) Übergang Abstieg → I_{min}: Ausregelzeit – bei maximalen dI/dt & bei 10% $dI/dt|_{max}$

h) Meßanordnung für d-g)

- KO-Bild der Führungs- und Regelgröße Oszillograf mit Komparator-Einschub Tek. 7A13 bzw. Differenzverstärker-Einschub Tek. 7A22

maybe spec requires just a bit of checking/dusting
… otherwise a good basis as commissioning procedure!

I.5.4.7.2 Nachweis der Verluste [..]

I.5.4.7.3 Nachweis des Blindbedarfs [..]

I.5.4.7.4 Nachweis der Oberschwingungsströme [..]

I.5.4.7.5 Nachweis des Stromstoßes bei Einschalten des Transformatoren [..]

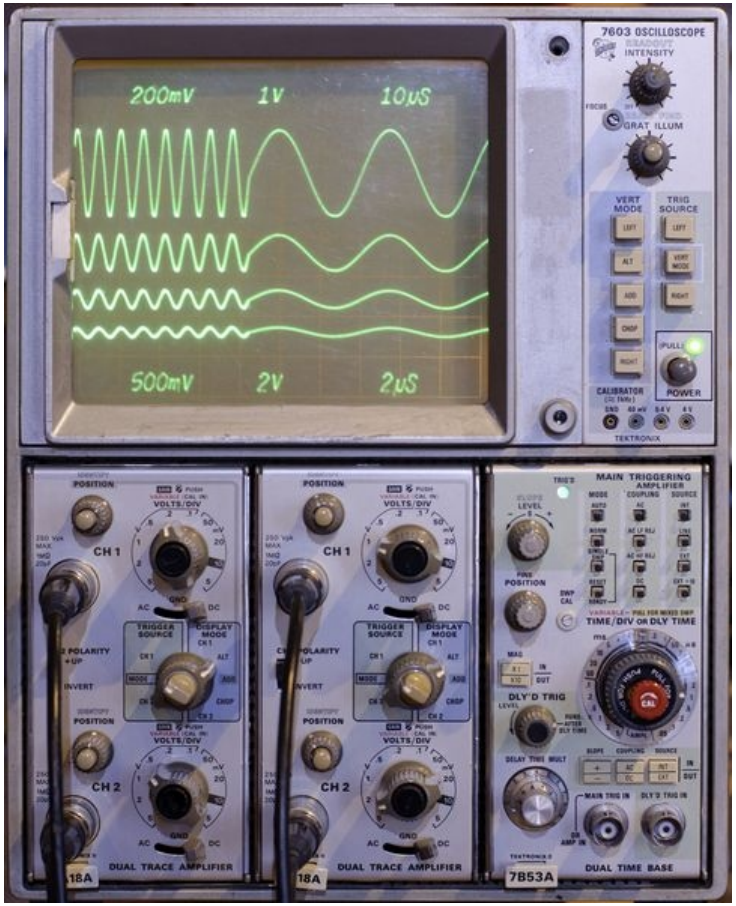
I.5.4.7.6 Nachweis der Rückwirkungen auf das 380 V-Netz von GSI [..]

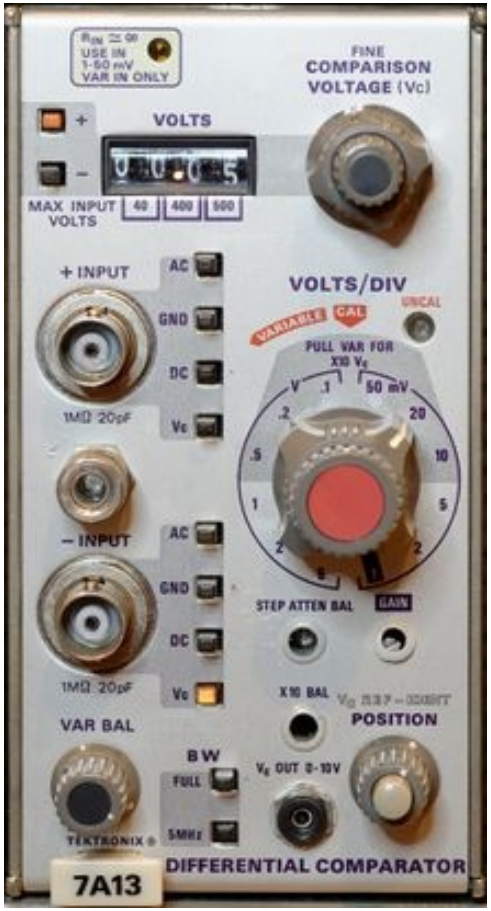
I.5.4.7.7 Nachweis der Erfassung des Isolationswiderstandes bzw. des Erdschlußstromes [..]

+ Controls Integration, Synchronisation with Timing System, Interlocks, ...

“Cathode Ray-Tube Picture”

TEK 7A13 & 7A22 (retired/not serviced by Tek since 1992)





Main Aims for FAIR
Prototyping at SIS18 Recommissioning in 2018

- Sequencer – range of functionality:
  a) logging and protocol of executed tests → aim at 100% test coverage
  b) (semi-)automated test sequences (‘unit-style HW testing)
  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)’ logging: inititally file-/logstash-based → 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)
    → prerequisite for any sustainable system integration and accelerator facility operation

Next Steps I/II

- responsibility of the HW commissioning (SAT) as well as follow-up of the integration lies ultimately (as always) with the equipment group experts & SPLs
  - covers: HWC → SW integration → functional integration/acceptance tests, up to handing it over to regular operation
  - still, that doesn't mean that one has to do everything alone→ other colleagues are there to support/help where necessary with the details – prerequisite: (SAT/Dry-Run) commissioning procedure specific to your system

- Commissioning Procedures – Next Steps:
  - register yourself and get a user account on the FAIR wiki: https://fair-wiki.gsi.de/System/UserRegistration
  - draft a tentative commissioning/Dry-Run procedure
    - can be based on existing documentation, previous documents, or best practice
    - KISS: focus on content & functional test procedure steps – this is not supposed to be a legal text but understood by your (external) colleagues/partners/reviewers – 'A good picture/diagram is worth a thousand words'
    - N.B. this would provide also a good basis of the functional/operational documentation
    - N.B. please keep non-german speakers in mind, use accepted common industry terminology, ISO, IEEE standards etc.
  - iterate with your immediate and affected peers (please keep R. Steinhagen and S. Reimann in the loop)
  - upload the procedure to the FC2WG Wiki don't worry too much about format etc. (will take care of the format editing/links etc.)

Next Steps cont.

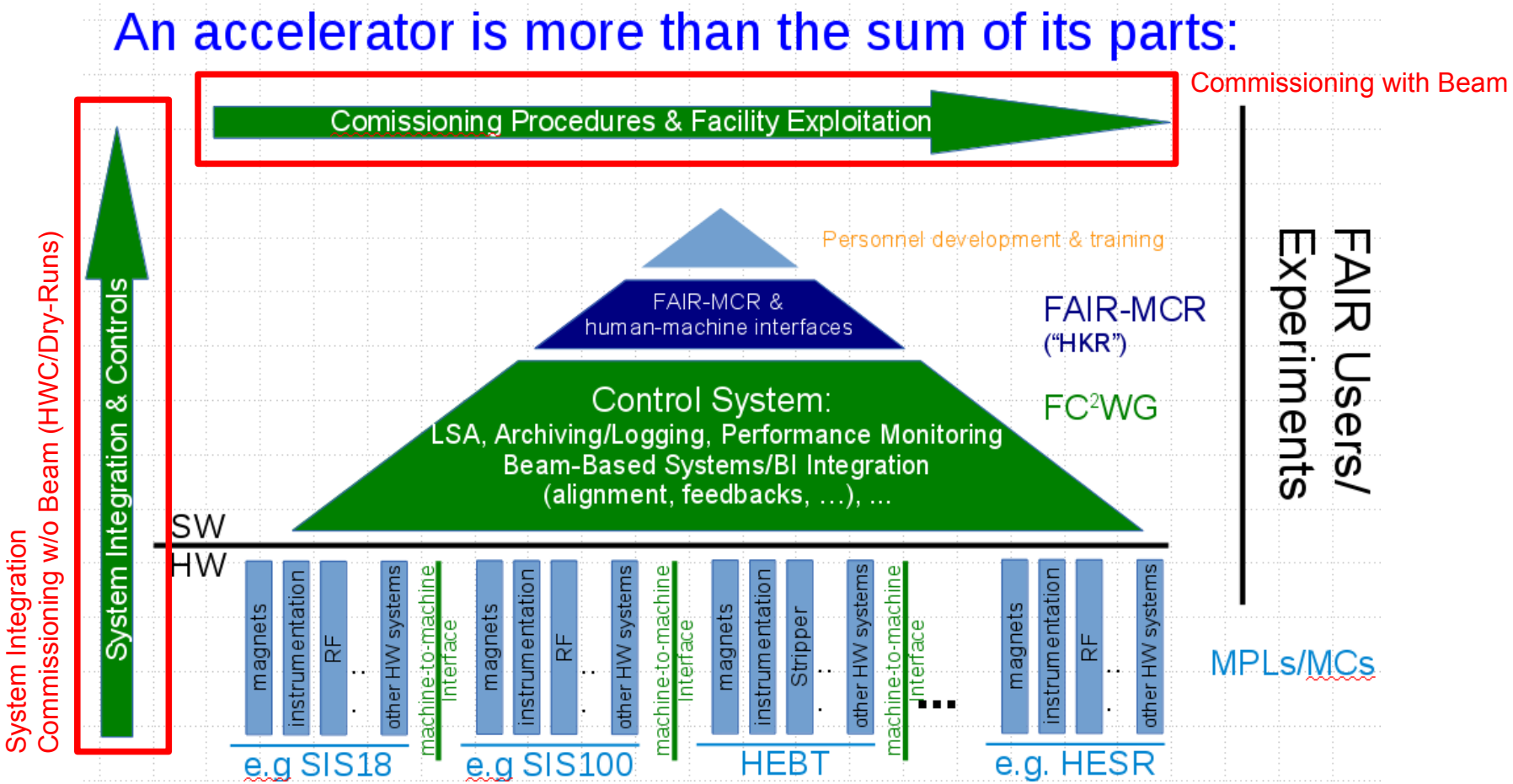
Semi-automated Test Sequences

- Prerequisite: arrange for an import of your to be tested devices into LSA (N.B. also a requirement for MASP and other CO applications)
  - notably missing: VAC, motor/compressed-air--drive controls, BI, …
- coding should start only after the commissioning procedure is in a good shape/has been established
  - (informal) agreement between key stakeholders (SPLs, SYS, CO, ...)
  - N.B. disclaimer: unless you code yourself and the sequence source code is the documentation by itself (OK for 2018 … only)
- Will organise a small mini-workshop on sequence-development for those who are willing to contribute/help with the procedures/test sequences → let yourself be known
- Tracking/documentation of the test execution will be done intrinsically by the Sequencer frame-work (via Archiving System), pending:
  - GUI for non-java-expert → best effort, … target ~Q1-2018
  - Analysis tools, graphical preparation of Dry-Run statuses and progress, … target for a rough first draft: Q1-2018

Appendix

FAIR Commissioning & Control WG

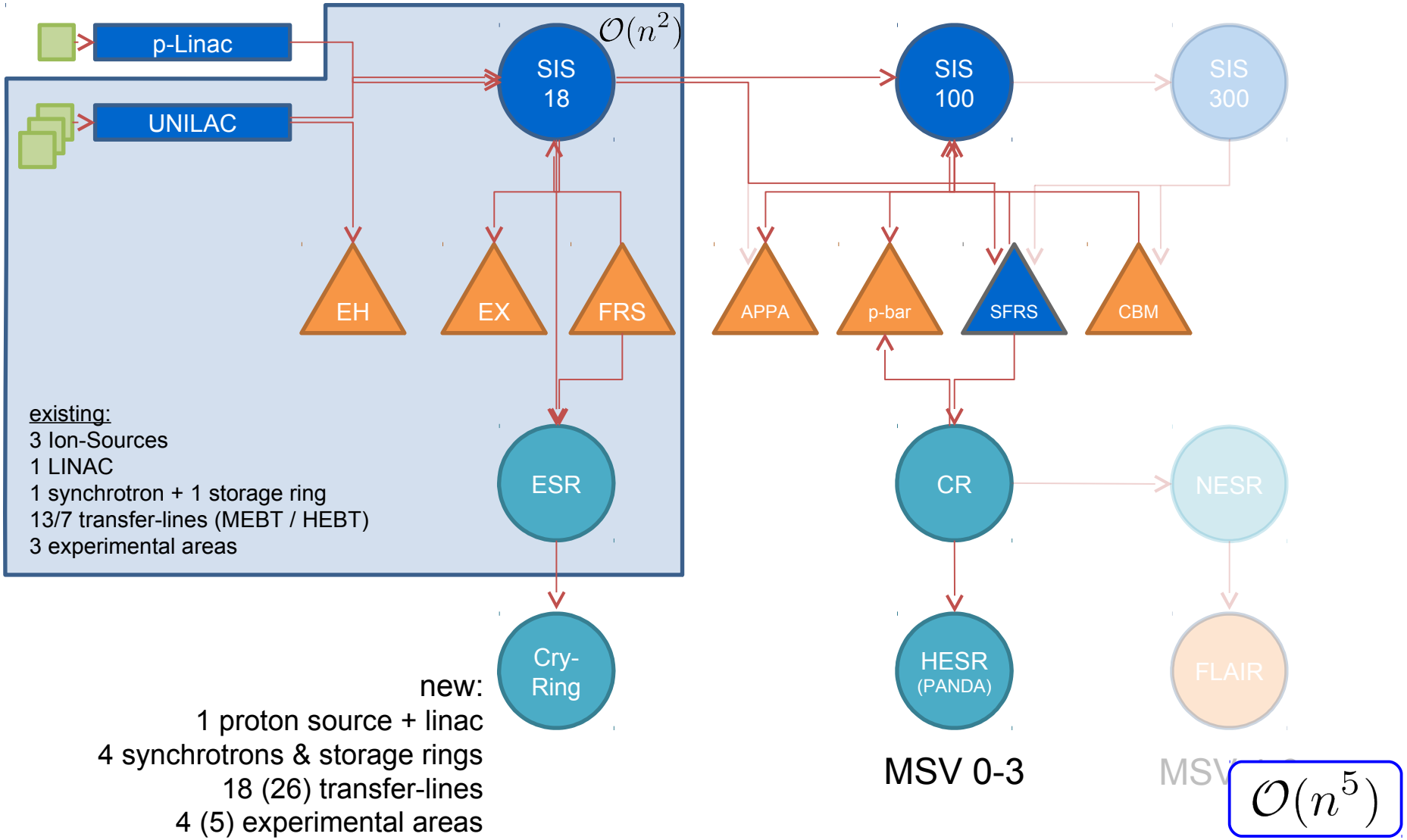
http://fair-wiki.gsi.de/FC2WG/



- FAIR Commissioning & Control Working Group
  - platform to discuss, coordinate and work-out FAIR commissioning and operation
  - open to all who can participate and contribute to this subject!

Migration Strategy

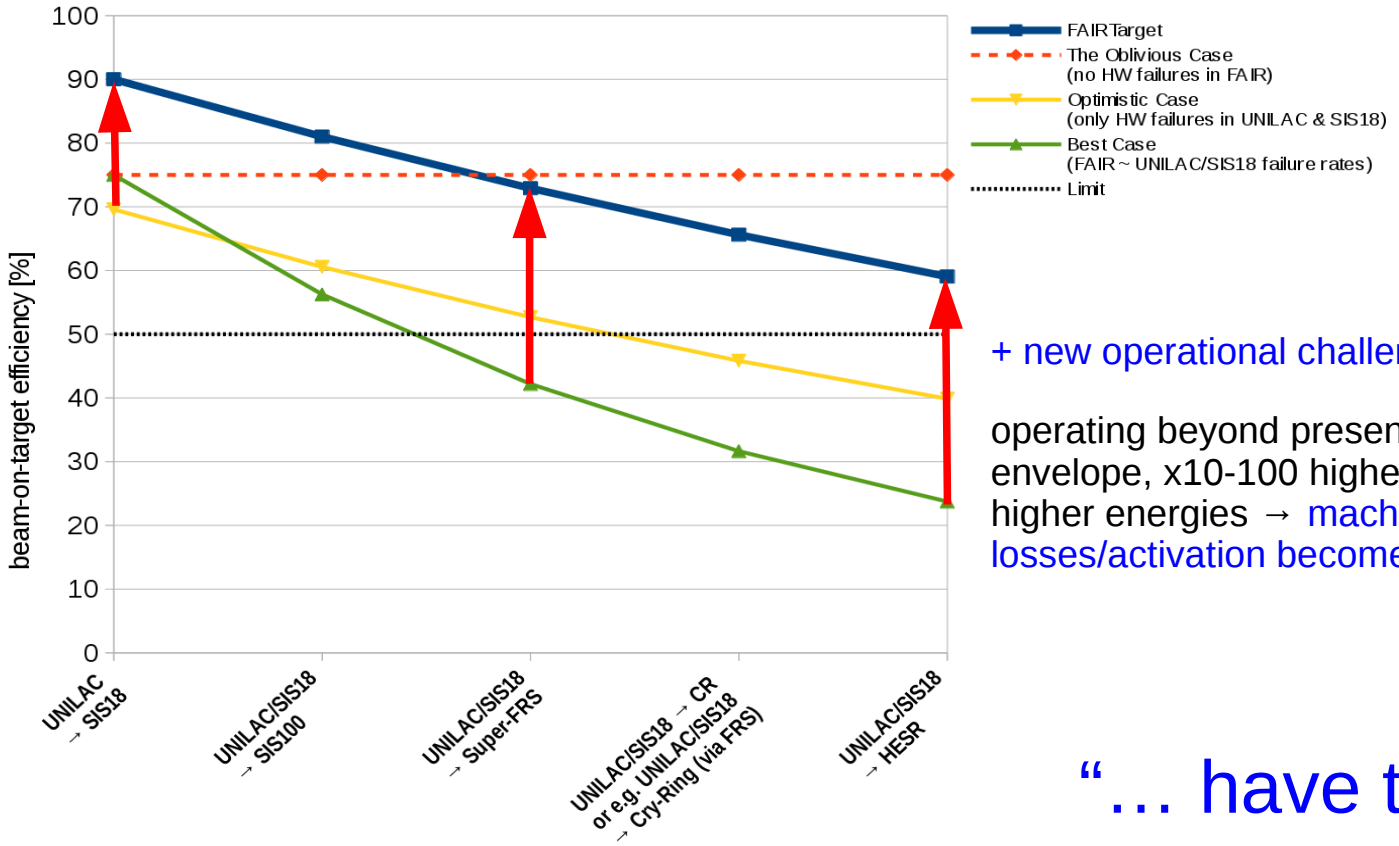
GSI 3 → FAIR 8½ (11+) accelerator(-like) machines



FAIR Challenges & Constraints
… SIS18 Operation Experience & Efficiency

- Beam-on-Target figure of merit (FoM) of ~75% → FAIR-BoT (efficiency ε_{FAIR}):

$$\varepsilon_{FAIR} := \prod_{i}^{n_{machines}} \varepsilon_i = \varepsilon_{UNILAC} \cdot \varepsilon_{SIS18} \cdot \varepsilon_{SIS100} \cdot \varepsilon_{SuperFRS} \cdot \varepsilon_{CR} \cdot \varepsilon_{HESR} \cdot \ldots$$

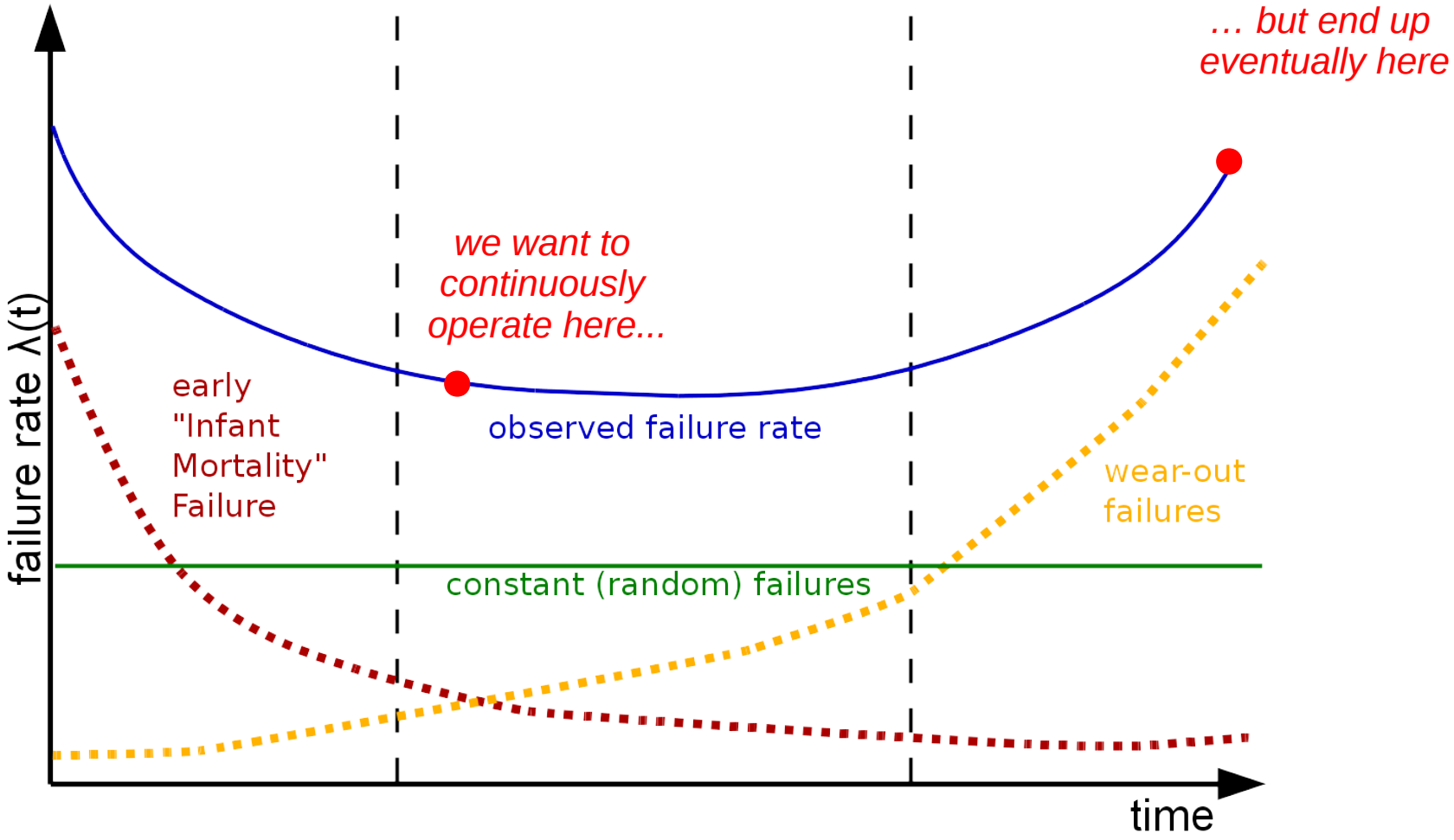


+ new operational challenges:

operating beyond present beam parameter envelope, x10-100 higher intensities, x10 higher energies → machine protection & losses/activation become an issue

"… have to improve!"

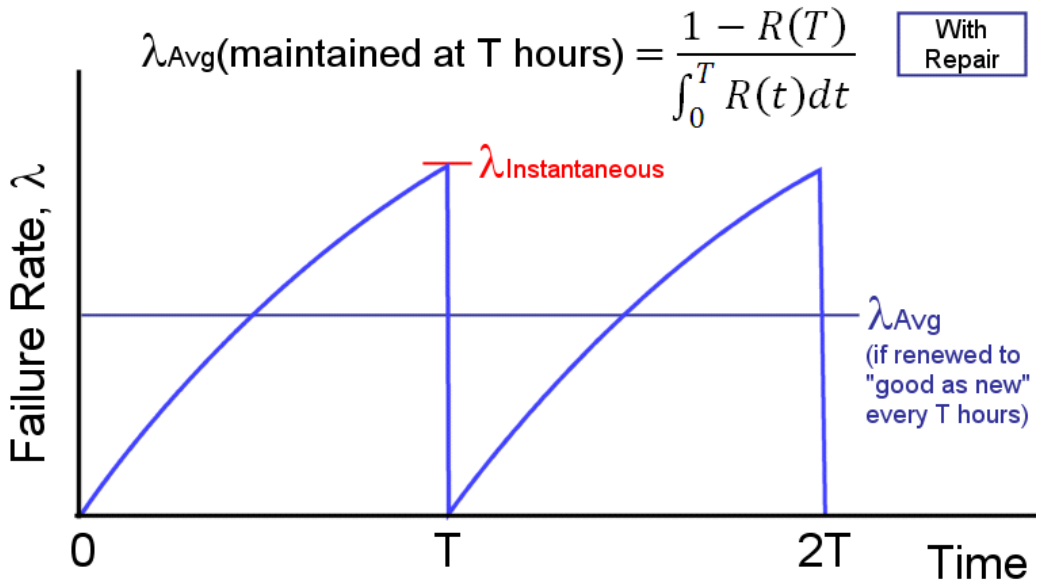
Problem definition: classical bath-tub curve – in an ideal/naïve world:



Reliability Engineering II/III

predictive maintenance or ‘as good as new’ checks

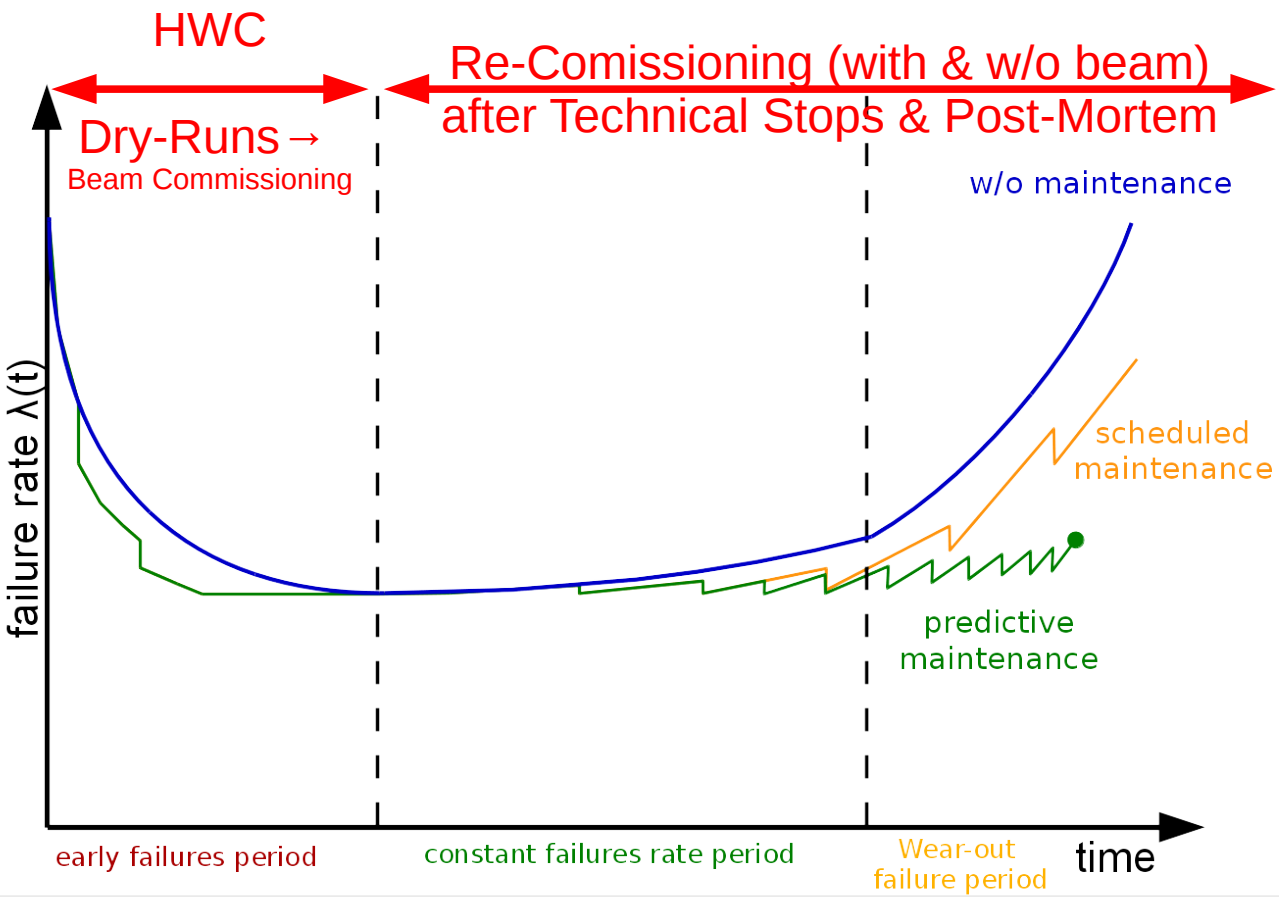
- Common improvement options: choice of materials, safety margin in material/parameter properties & adding redundancy
- However: redundancy provides only limited reliability gain
  → key to high reliability: performance surveillance + checks
  → ‘as good as new’ system validation
  - technical implementations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



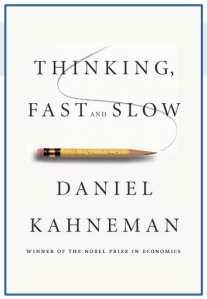
Reliability Engineering III/III

predictive maintenance or ‘as good as new’ checks

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



Facility Complexity & the Human Factor
Thinking Fast and Slow & “Human Multitasking”



- Kahneman studies[1] famously described the two different ways of our brain works and forms thoughts (N.B. → awarded 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
  - 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
→ unnecessary strain on operators, machine experts and operational risk

[1]Daniel Kahneman, “Thinking, Fast and Slow”, Farrar, Straus and Giroux, 2011