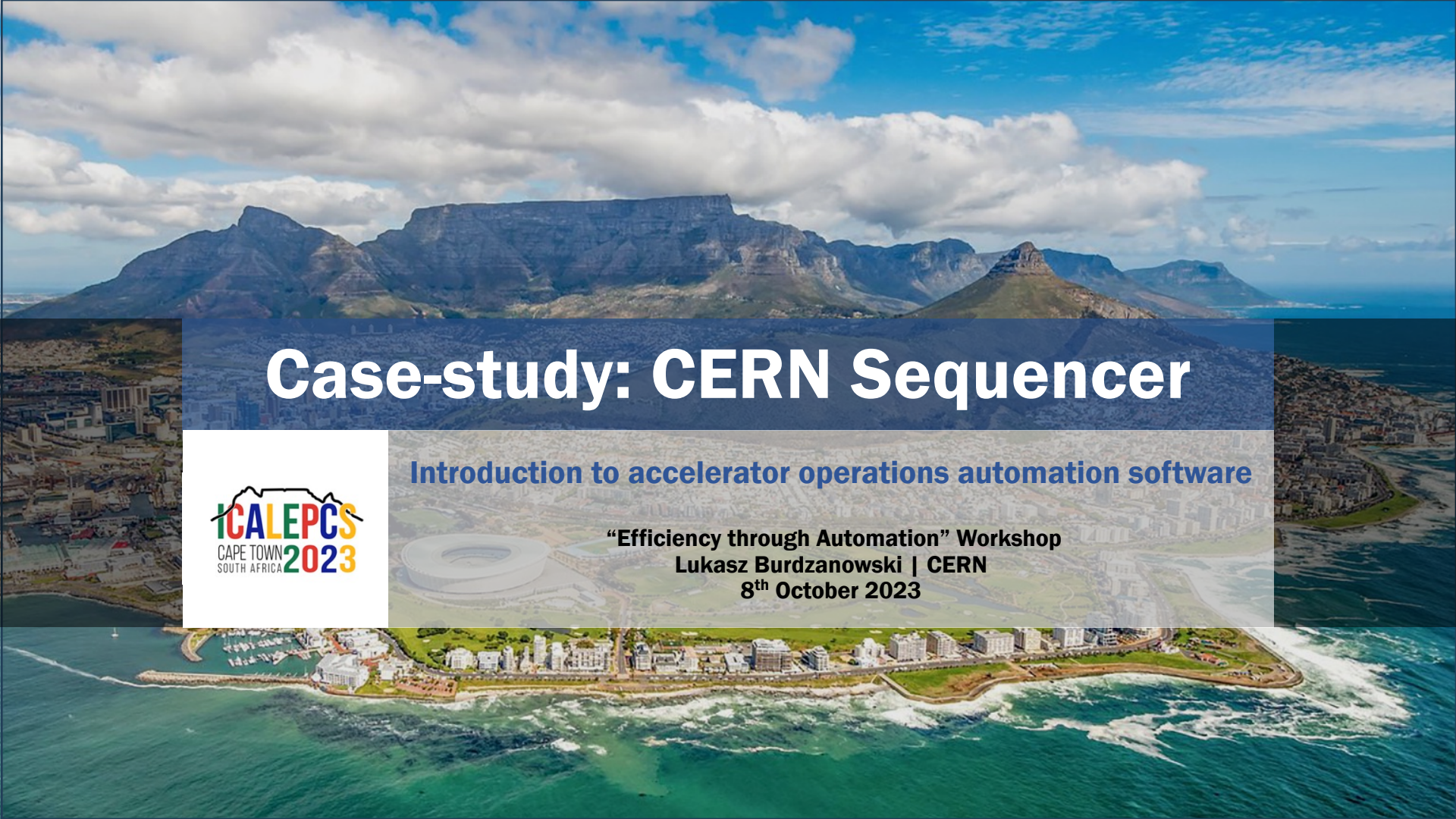


Case-study: CERN Sequencer

Introduction to accelerator operations automation software

“Efficiency through Automation” Workshop

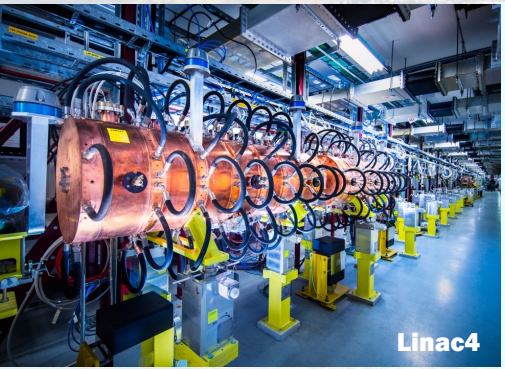
Lukasz Burdzanowski | CERN

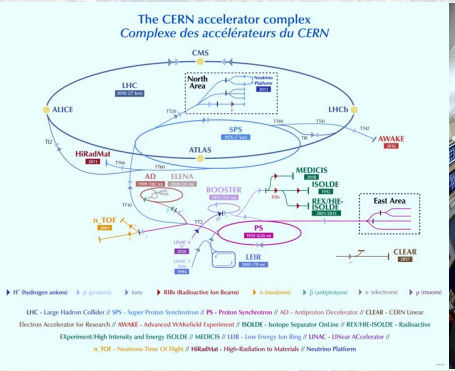
8th October 2023

Why Sequencer

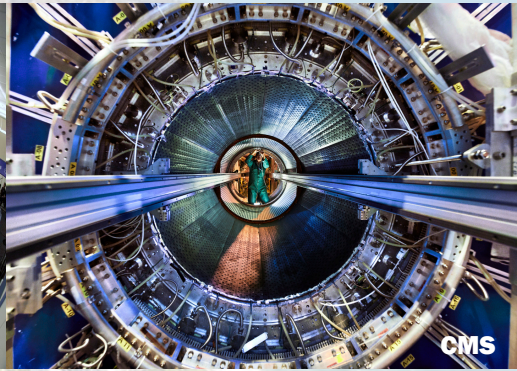
To reduce the number of manual actions needed to
to control the increasingly advancing machines and goals.

To shorten the turn-around times.


Linac4

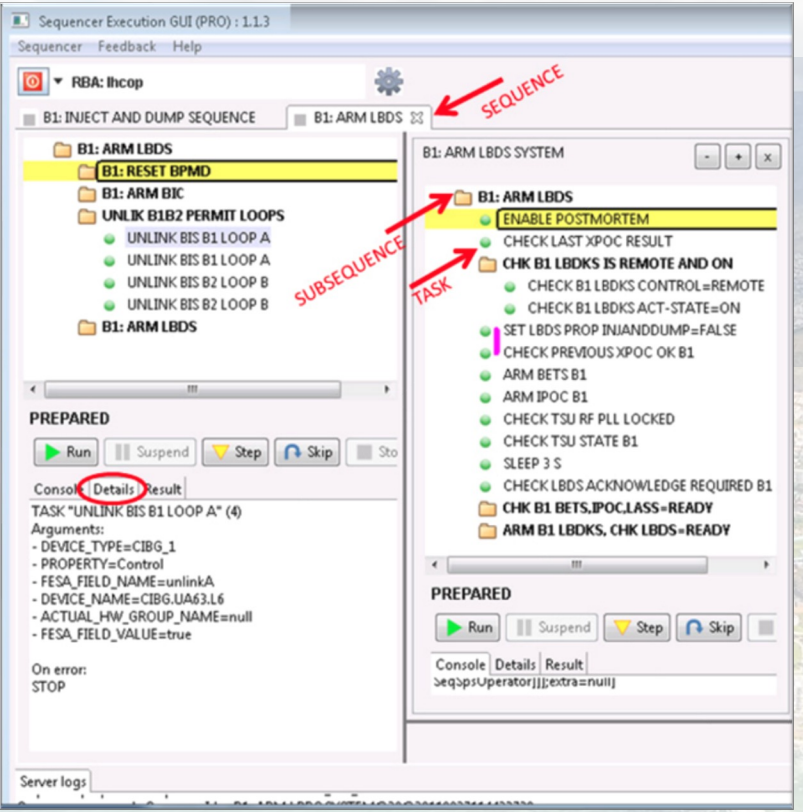



CERN Control Centre


CMS

The well-defined and deterministic problem to address:
efficiently execute n-steps to achieve the given state;
repeatedly and reproducibly.

Sequencer - automation of operations

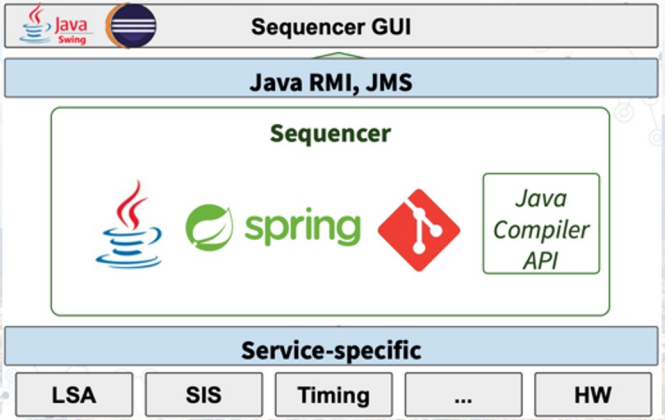


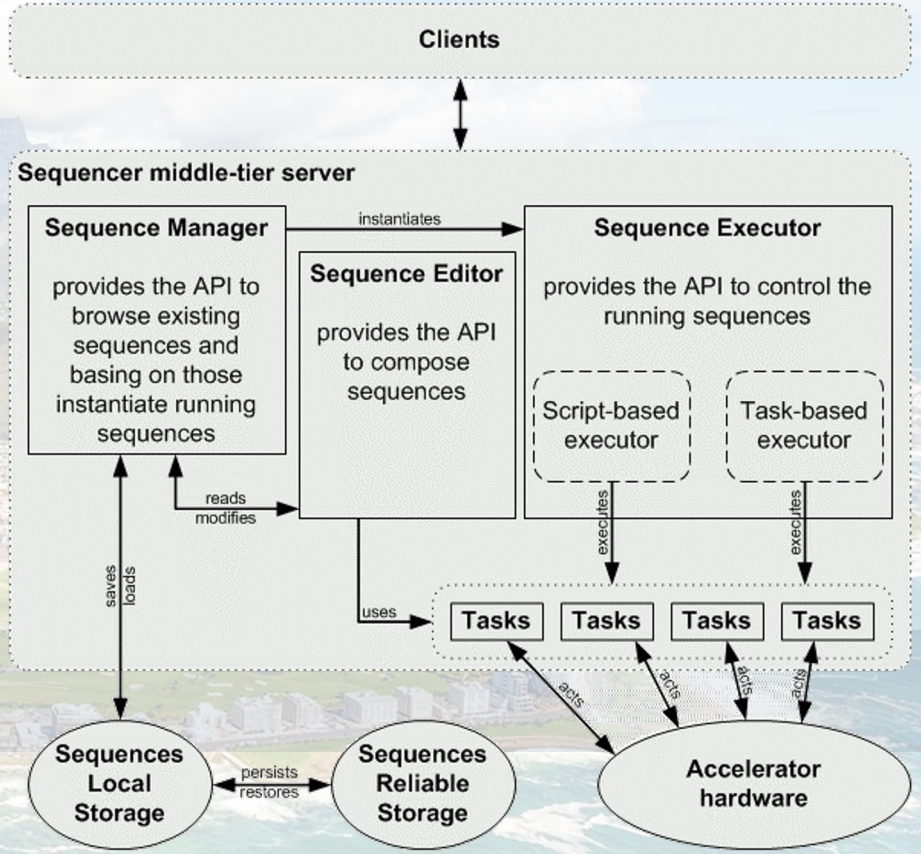
The Sequencer system:
framework and dedicated applications,
used to enable automation of operations and to help drive the accelerators through long sequence of tasks needed to produce the beam.

Provides full control over task execution, allowing:

- break-points,
- stepping, skipping, repeating, etc.
- executing the tasks in parallel.

System architecture





Technologies:

- Java (Spring, RMI), JMS for client-server (ActiveMQ),
- Eclipse SWT + JFace for GUI
- Sequences = Java classes in Git, *no RDBMS*

Except the authorisation (RBAC), Sequencer framework is not CERN specific

Sequencer in numbers
Framework: 1250 Java files, 105k LOC
Tasks utils & commons: 191 Java files, 14.5k LOC

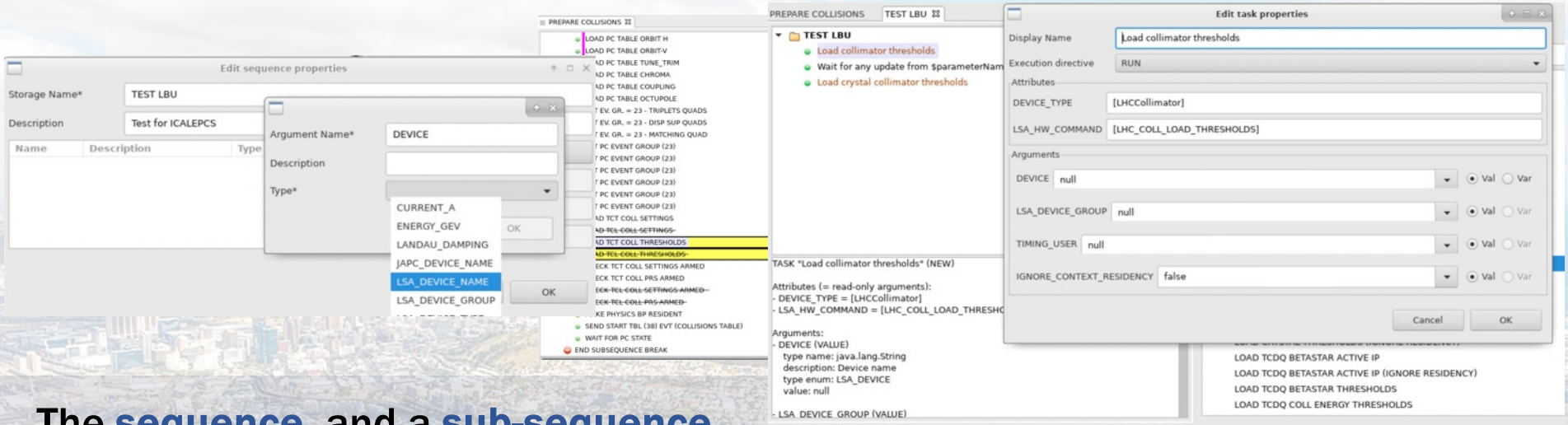
Sequencer - a task

```
@Attrib(name = DEVICE_TYPE, description = "LSA device type", typeEnum = TypeEnum.LSA_DEVICE_TYPE)
@Attrib(name = LSA_HW_COMMAND, description = "HW command", typeEnum = TypeEnum.LSA_HW_COMMAND, value = HWC_LHC_COLL_LOAD_THRESHOLDS)
@TaskMethod(name = "LOAD COLL THRESHOLDS", description = "Load collimator thresholds", displayName = "Load collimator thresholds")
public static ArrayResult<?> loadCollThresholds(
      @Param(name = DEVICE, description = "Device name", typeEnum = TypeEnum.LSA_DEVICE) String deviceName,
      @Param(name = LSA_DEVICE_GROUP, description = "Device group name", typeEnum = TypeEnum.LSA_DEVICE_GROUP) String deviceGroupName,
      @Param(name = TIMING_USER, description = "Timing user (context)", typeEnum = TypeEnum.JAPC_SELECTOR) String timingUser)
      throws Exception {
   return loadCollThresholdsIgnoringResidency(deviceName, deviceGroupName, timingUser, false);
}
```

Takeaways:

- tasks, from interacting with HW equipment, to running the algorithms, are procedures programmed in Java
- code-completion in IDE for developers, creating a task = writing code
- task meta-data (@Attrib) can be used to enable validation, and to limit generic tasks to specific scenarios (e.g. machines)
- like any code, tasks reside in VCS (version control system)

Sequencer – a sequence



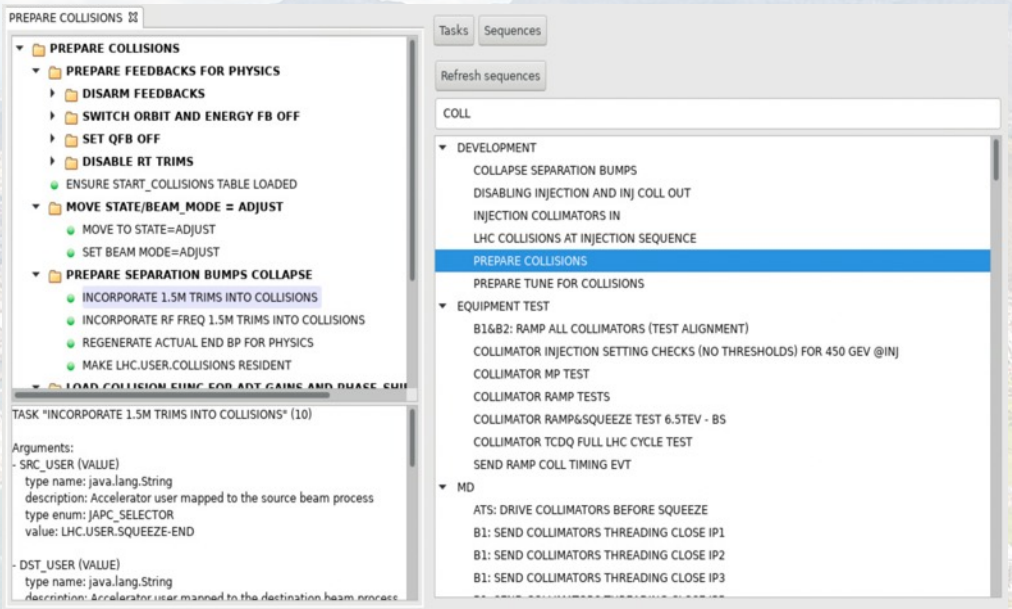
The sequence, and a sub-sequence, is a named list of tasks.

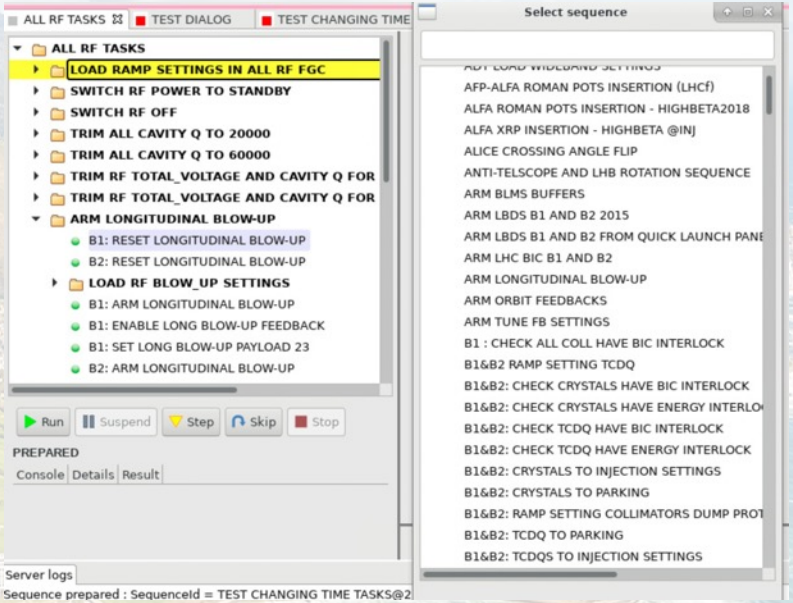
- Sequences are created with a dedicated editor
- Tasks & sub-sequences can be parameterised
- End-result, the sequence is generated Java code
- There are no limits on sequences length

```
@SequenceInfo(displayName="PREPARE COLLISIONS", description="PREPARE COLLISIONS FROM 3.5 M SQUEEZED OPTICS", categories="DEVELOPMENT")
public class PREPARE_20COLLISIONS {
  public void exec() throws Exception {
    _displayName("PREPARE FEEDBACKS FOR PHYSICS");new PREPARE_20FEEDBACKS_20FOR_20PHYSICS().exec();
    _displayName("ENSURE START_COLLISIONS TABLE LOADED");CBCM.ensureEventTableLoaded("Start_Collisions");
    _displayName("MOVE STATE/BEAM_MODE = ADJUST");new MOVE_20STATE_2fBEAM_5fMODE_20_3d_20ADJUST().exec();
    _displayName("PREPARE SEPARATION BUMPS COLLAPSE");new PREPARE_20SEPARATION_20BUMPS_20COLLAPSE().exec();
    _displayName("DRIVE COLLISIONS BP FOR PC's AND COLLIMATORS");new DRIVE_20COLLISIONS_20BP_20TO_20COLLIDE_20HW().exec();
    _displayName("END SUBSEQUENCE BREAK");_break();SEQ.sendLogMessage("End subsequence break", (java.lang.Boolean)null);
  }
}
```

Edit and execute

The Sequencer GUIs:
Editor of sequences and the Executor (to control and monitor the execution).



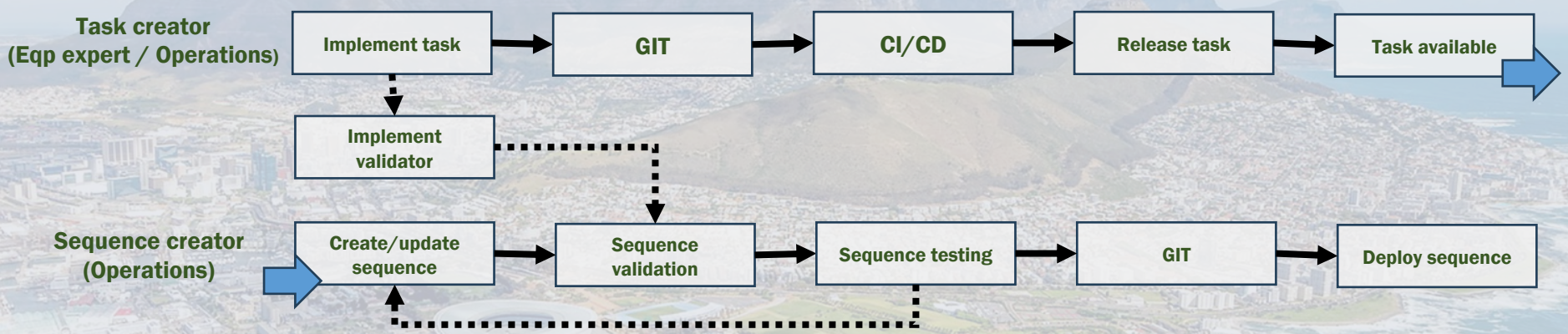


Sequencer Editor

Sequencer Executor

User workflow

Two distinct stages when using the system:
implementation of a task, and **assembly of the sequence.**



The tasks and sequences can be created by any user: equipment experts, operations, controls engineers, others. Once available in system repository, both entities can be used and require no detailed knowledge about the implementation details.

State of adoption

The Sequencer is used by several CERN machines, primarily in LHC, as well as across the injectors (SPS, PS, PSB, LEIR) and during HW Commissioning campaigns (HWC).

- For HWC fully programmatic approach is used (Sequencer via API access)
- The system is used in a variety of scenarios:
  - ✓ Hardware and machine commissioning
  - ✓ Machine Development specific procedures
  - ✓ Complete operational stages, e.g. RAMP, SQUEEZE in LHC
  - ✓ and more…
- The type of tasks usually falls into one of the categories: check/wait, set/ensure e.g.
  "check if all Power Converters are ready" → call HW status property
  "ensure Power Converters ready" → check if PCs are ON, if not, set ON and wait for confirmation

The portfolio of tasks and sequences is growing
close to 2000 (sub) sequences for LHC; over 350 task types; LHC nominal sequence → close to 2100 tasks

Lessons learned

What works well

- **Modular** approach with **configurable** entities such as: Task/Sub-Sequences/Sequences
  - Enable re-use of entities, limiting copy & paste proliferation of task and sequences
  - Sub-sequences simplify workflow de-composition, from small HW-oriented procedures to rich operational sequences
- Separation of Implementation (tasks), from Edition and Execution of sequences
- With hindsight – direct use of Java (**no DSL or scripting**)

and… what is missing to empower the users

- Sequences with loops, conditions, parallelism of sub-sequences
- Tasks to return results or depend on each-other → *a double-edge sword (rapid growth of complexity)*
- Complete API for programmatic interactions / embedding to other systems
- (possibly) Python task, and more…

The outlook

In the **context of efficiency,** and the objective to further automate and shorter the turn-around times of CERN machines, the Sequencer acts as a **building block**.

How to **automatically fill** LHC?
How to **automatically recover** from HW/SW issues?
... and many more specific questions to answer

In this context, we plan to:

Invest more into it, re-think GUI and modernize, addressing known technological risks, to consider opening it, when justified by the external interest, rearchitect.
The work to begin in 2024++ horizon, driven by the Efficiency working group@CERN.

How **other labs could benefit** from the Sequencer?

Summary

Sequencer is the **main automation software solution** for CERN accelerators operations.

It is a well-established system and the problems it addresses are **not CERN specific**.

Planned **evolution and extensions** aim to further increase the efficiency by helping to **shorten the turn-around times.**

We are embarking on making it more modular, extended, modernized. An **opportunity to collaborate** and let other labs profit.