Operation and Remote Collaboration Tools in view of the ITER Neutral Beam Test Facility Experimental Campaigns

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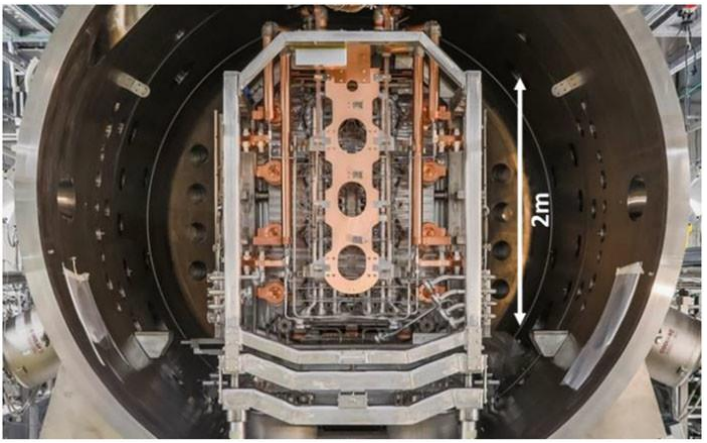
ITER Neutral Beam Test Facility

The ITER Neutral Beam Test Facility (NBTF) serves as a crucial testing ground for the development and validation of neutral beam injection systems essential for ITER's fusion power plant.



SPIDER (Source for Production of Ion of Deuterium Extracted from Rf Plasma)

- Focuses on the development and optimization of the ion source.
- Responsible for producing and accelerating the deuterium ions.
- Serves as a prototype for the ion source planned for use in ITER.

MITICA (Megavolt ITER Injector and Concept Advancement)

- Adds to the ion source technology by integrating high-energy beam acceleration.
- Aims to demonstrate the full-scale neutral beam injection system.
- Will be utilized in ITER for plasma heating, diagnostic, and control.

SPIDER and **MITICA** are relevant experiments towards ensuring the successful operation of neutral beam injection for heating and diagnosing ITER plasma.

Objectives

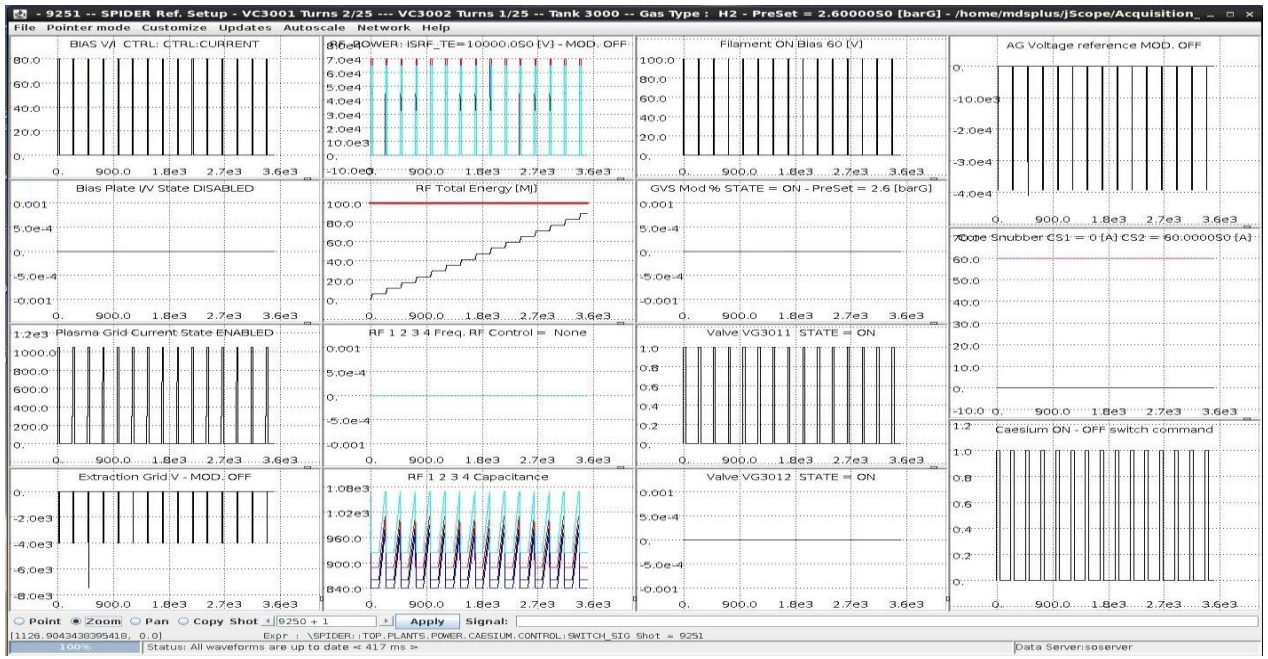
- Share the most relevant data trends, experiment parameter settings, experiment status in a live monitor (in quasi real-time);
- Share experimental data with ITER Organization, EUROfusion and other stakeholders.

Relevant issues to consider

- **Security** – Evaluate the best procedures to safely access and share scientific data between different premises;
- **Tools** – Evaluate and chose the relevant tools to use, considering fusion community and local knowledge/experience, preference for open source solutions, ITER requirements…
- **Infrastructure** – Evaluate the need of improving/increasing the computational infrastructure to accommodate the identified functions and requirements.

NBTF Experiments Remote Data Access

Requirements for live experimental data Remote Plant Monitoring



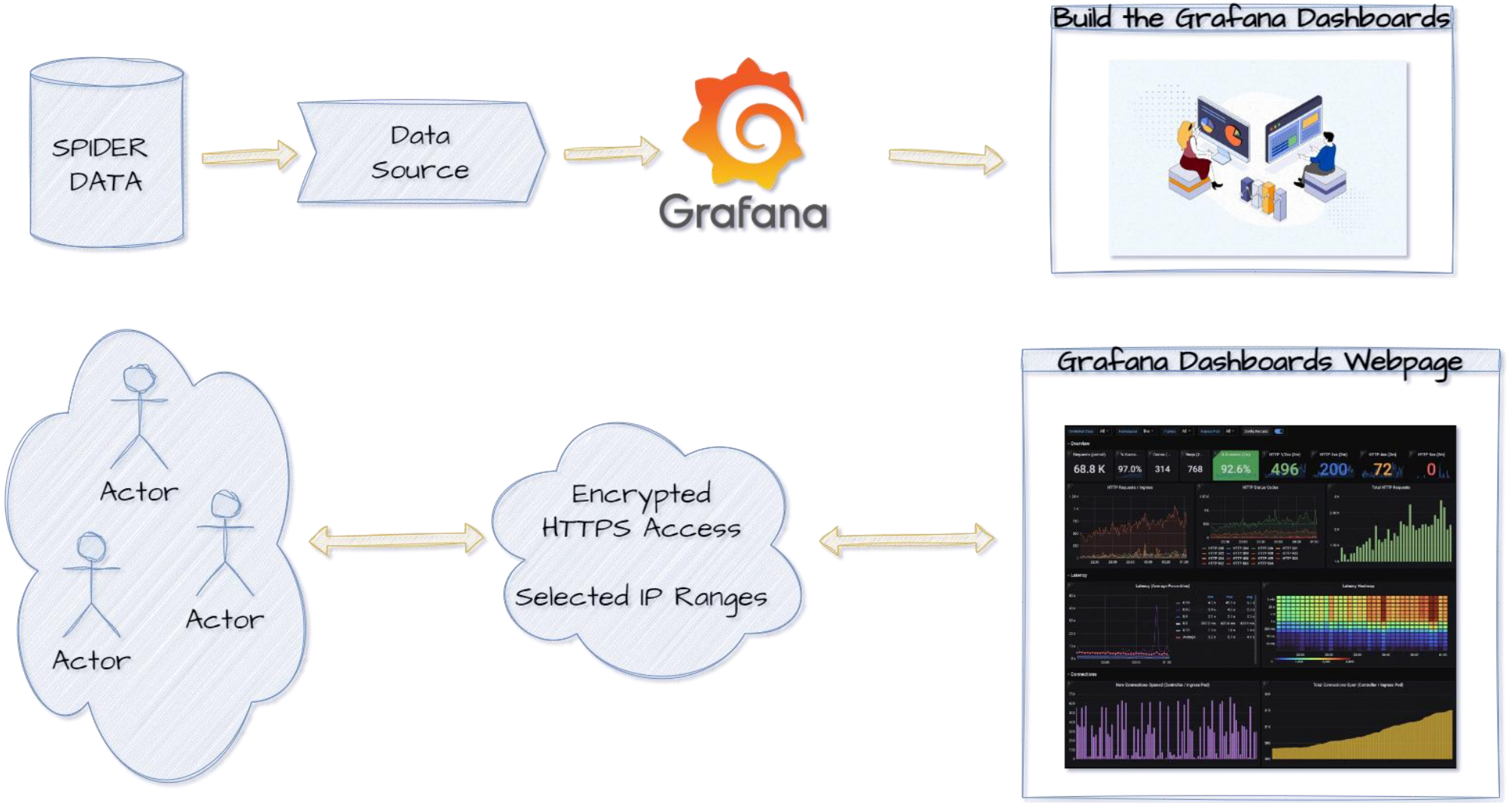
An example of the MDSplus Scopes in use in the Control Room, to be ported to Grafana.

- Replace local MDSplus scopes in SPIDER Control Room by remote access **Grafana Dashboards;**
- **Grafana** permits remote data access through a web browser; geographical independence; real-time monitoring; data security; user-friendly dashboards; data source integration; alerting and notification system.
- Grafana **SPIDER Dashboards** shall include all trends and parameters currently available through MDSplus Scopes and EPICS CSS OPIs in SPIDER Control Room

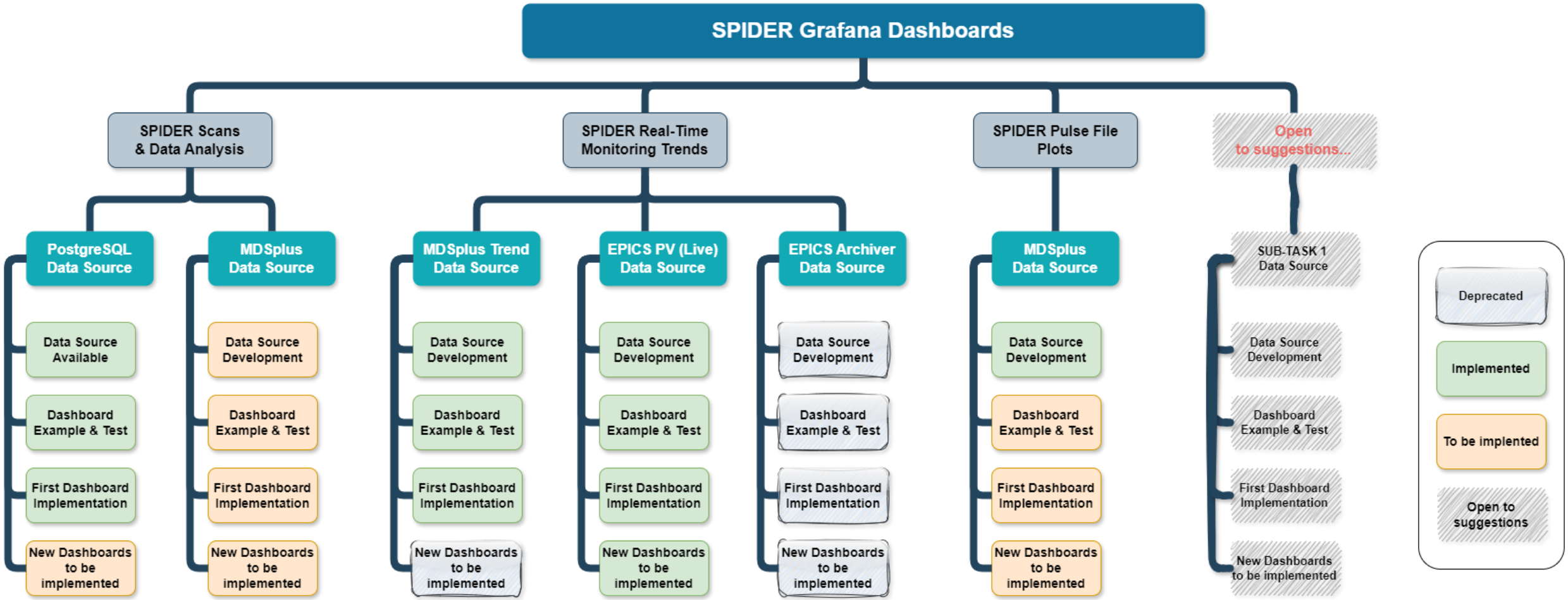
Security Issues – User Access Requirements

- Regarding Grafana web access - There shall be a set of internet addresses (IP Address or IP range) that can access the web site without user authentication. The list of IP addresses or IP range shall be made available by partners to open the access in the local firewall.
- Regarding the experiment remote data access a user-based authentication must be set:
  - Option 1 – Locally managed authentication is possible, but there is bureaucratic procedure that needs to be implemented considering authorization access protocol and handling of users private information.
  - Option 2 – Use of Federated Identity Managements to enable a set of authorized users from different institutions to access the experiment data.

NBTF Experiments Remote Data Access



Remote Data Visualisation Tools



Redis Time Series and Grafana for soft real-time data visualization

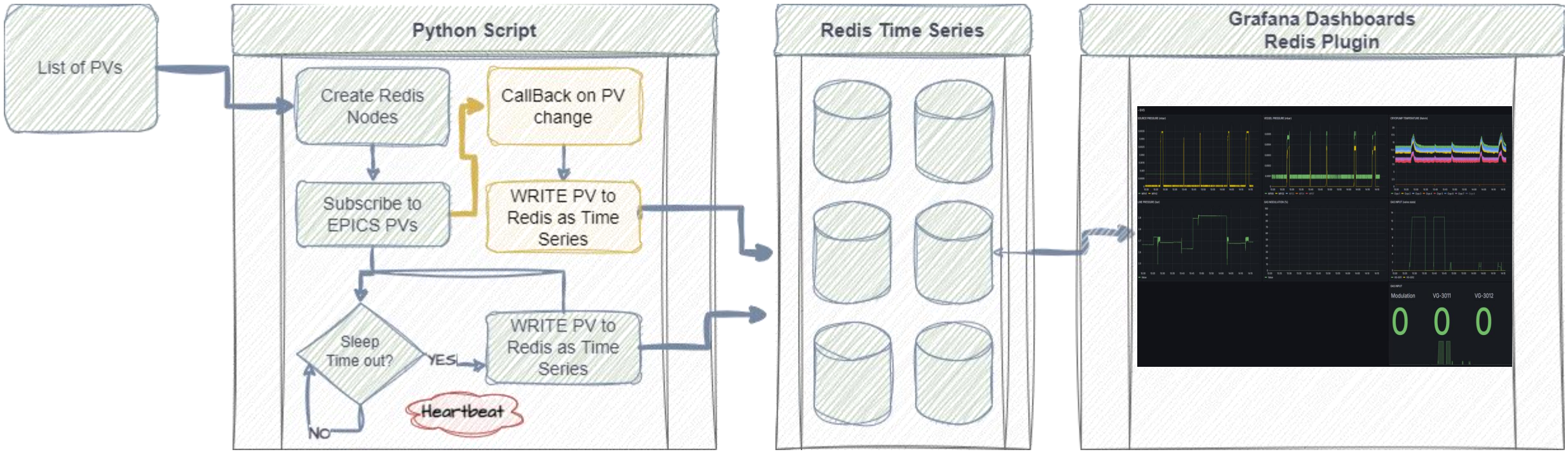
Author:
Ajeet Raina, Former Developer Growth Manager at Redis

The Redis Data Source for Grafana is a plug-in that allows users to connect to the Redis database and build dashboards in Grafana to easily monitor Redis and application data. It provides an out-of-the-box predefined dashboard, but also lets you build customized dashboards tuned to your specific needs.

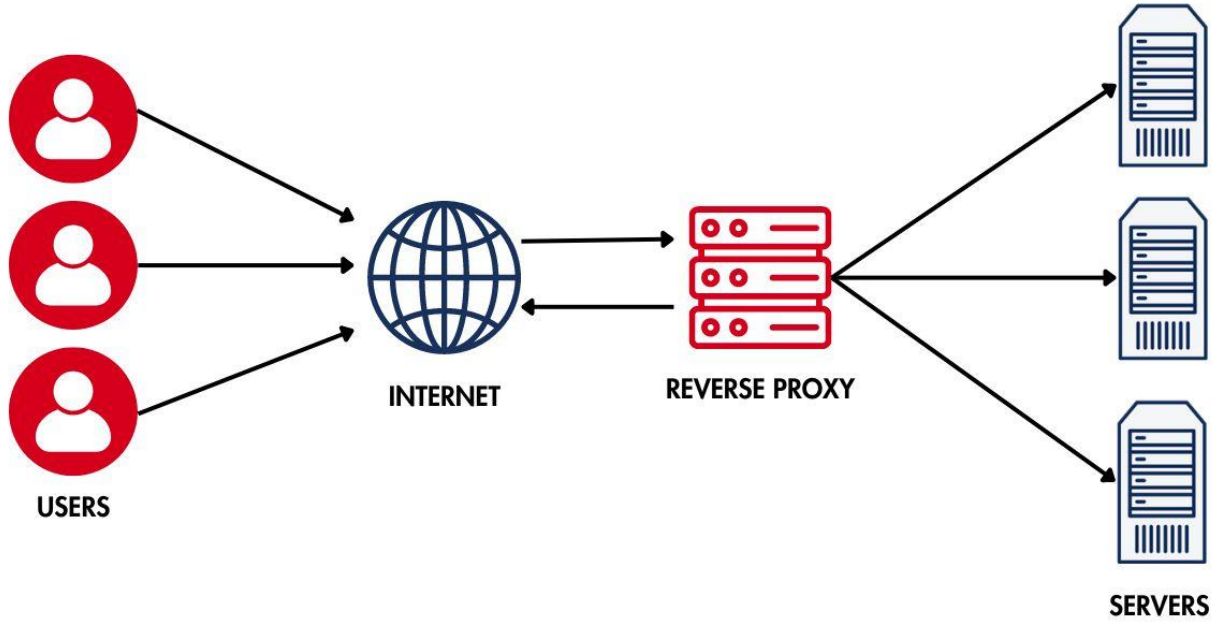
- https://redis.io/learn/explore/redisdatasource
- https://redisgrafana.github.io/

- RedisTimeSeries is designed to handle time-series data efficiently with scaling capabilities.
- Main features:
  - Fast data ingest: In-memory database, capable of over 500,000 records/second on standard node, 11.5 million records/second with a cluster of 16 Redis shards.
  - Resource efficiency: Allows data downsampling to compact data size, supports data retention policies and expiration by time.
  - Easy, fast queries: Supports aggregation functions (average, minimum, maximum, sum, count, range, first, last), can run over 100,000 aggregation queries/second with sub-millisecond latency, supports reverse lookups on labels within specific time ranges.

EPICS – REDIS – Grafana implementation



NGINX Reverse Proxy for Secure Access (pronounced "engine-x")



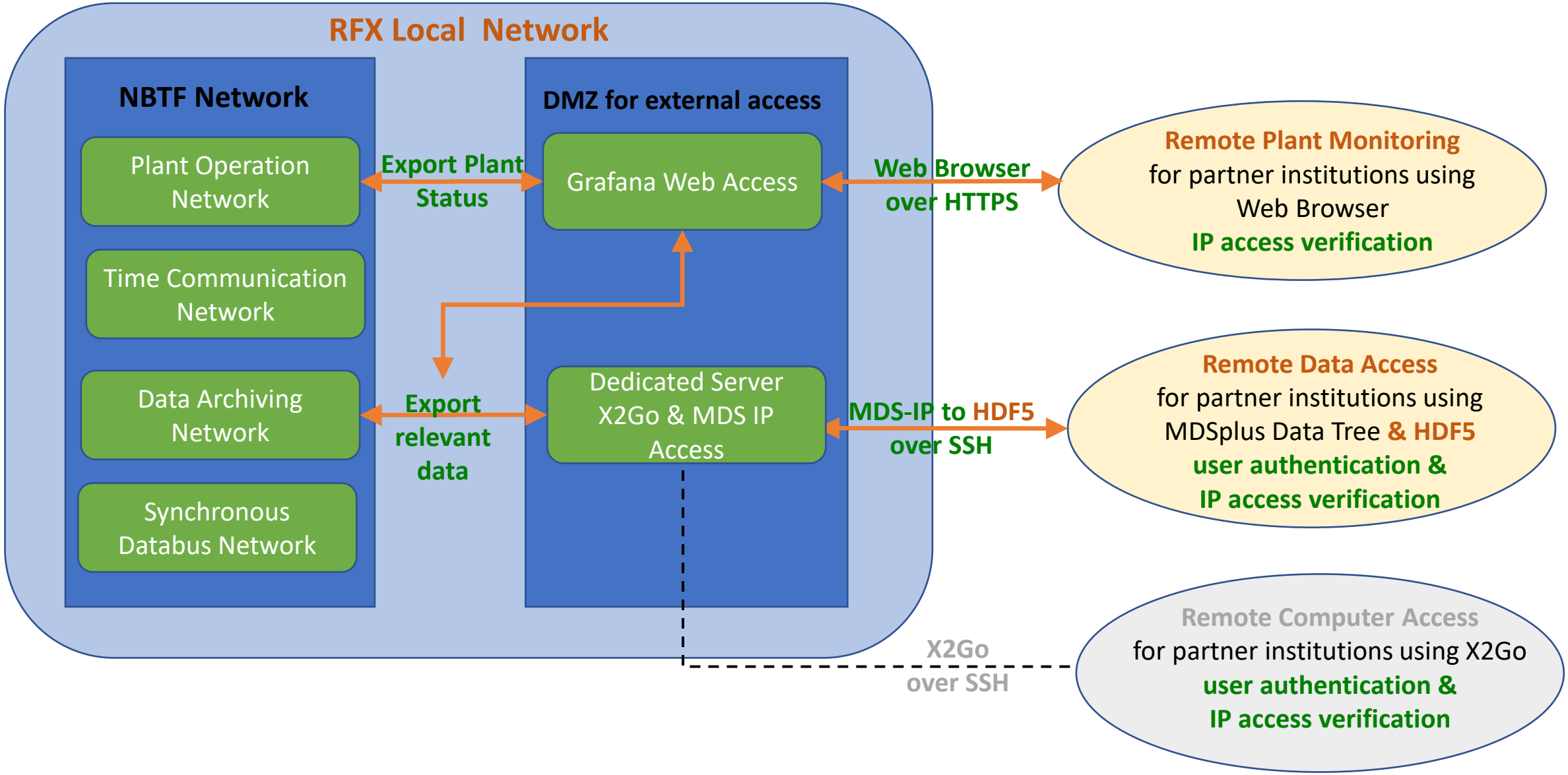
- NGINX gives Grafana HTTPS encrypted access
- NGINX gives IP or IP range based control access
- https://nginx.org/en/

Remote Data Visualisation Tools

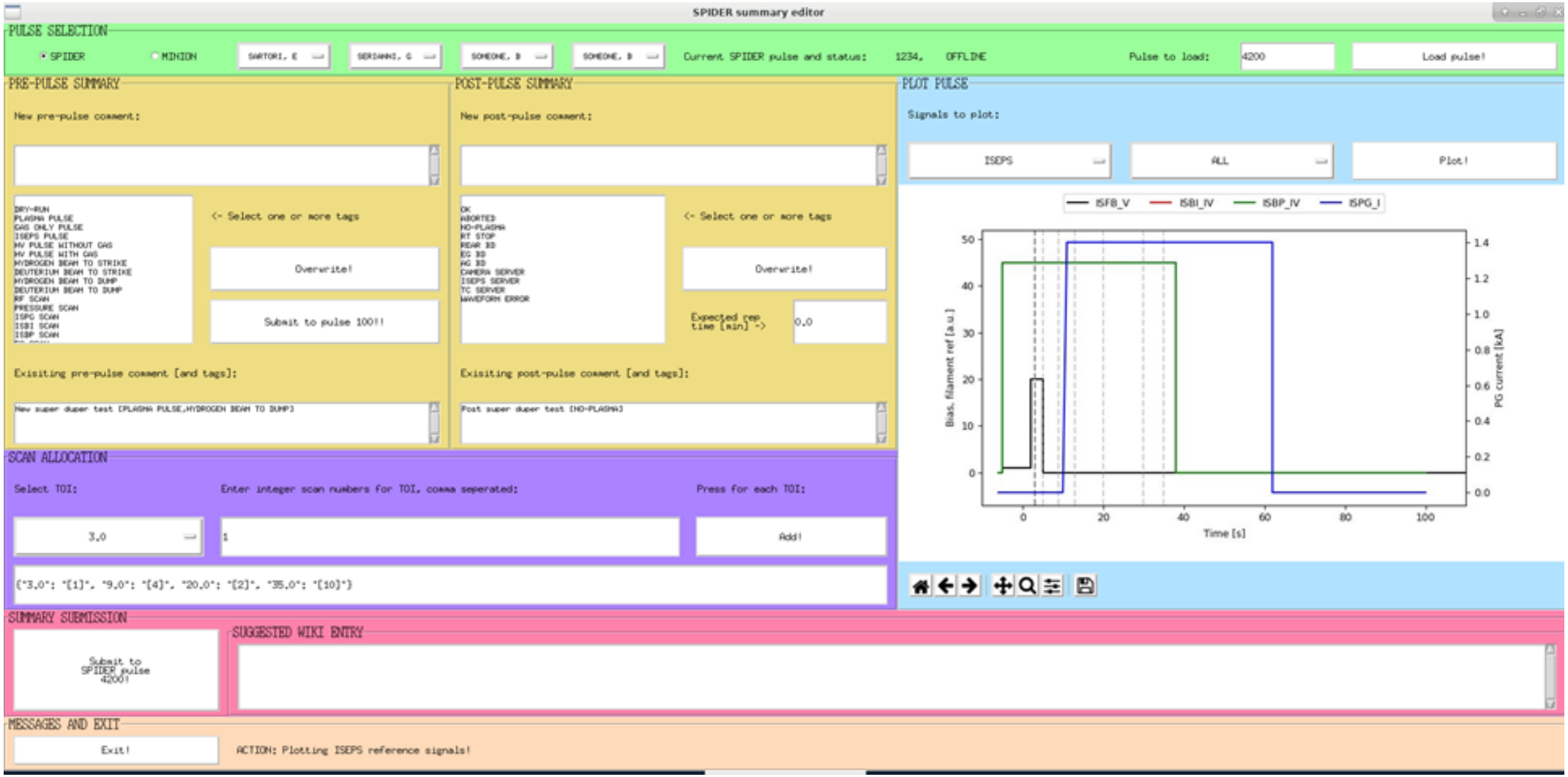
SPIDER Trends Dashboard using EPICS process variables data

SPIDER Scans Dashboard using PostgreSQL database

NBTF Remote Data Access Architecture



SPIDER Daily Summary Editor



SPIDER Daily Summary WEB visualization

SPIDER daily summary

Enter day (YYYYMMDD): 20231203 submit

03/12/2023

SL: SARTORI, E **RT:** SOMEONE, B

SC: SERIANNI, G **RT:** SOMEONE, B

Most recent pulse

Pulse number:	4200	**RF:**	60.0/70.0/70.0/70.0 kW	**BIASES:**	45.0/45.0 V	**PG:**	1.4 kA	**AG/EG:**	-2.0/0.0 kV	**GAS:**	H2, 4.30 bar
Start time:	none	**Set plasma time:**	nan	**Set beam time:**	nan			**Achieved plasma time:**	nan	**Achieved beam time:**	nan
Status:	finished	**Pre-pulse:**	New super duper test [PLASMA PULSE,HYDROGEN BEAM TO DUMP]					**Post-pulse:**	Post super duper test [NO-PLASMA]		

Next pulse

Pulse number:	100	RF, biases, PG, beam voltage, etc

Daily summary | Most recent pulse plots

Pulse number:	Start time:	Pre-pulse:	Post-pulse:
4200	none	New super duper test [PLASMA PULSE,HYDROGEN BEAM TO DUMP]	Post super duper test [NO-PLASMA]
4201	none	Another new comment. TEST [DRY-RUN]	Lots of stuff to write. [ABORTED]
4202	none	Macropulse, with an example of a really long input comment to check how much the tables etc move on the	Phew, worked! [OK]

Parameter Settings Tool – Introduction

- SPIDER parameters were configured using an MDSplus Human Machine Interface (HMI) using specific pulse number to temporarily store the setup configuration;
- Using a command line the Session Leader (SL – Scientific Coordinator) could load previous setup from an executed shot or reference shot;
- SL could check all the configuration using MDSplus jScope, with all the waveforms;
- An external tool could create the long pulse setup in IDL and store it in a reference shot;

However

- Responsible Technician (RT – Engineer in Charge) had limited verification/comparison tools (jScope);
- No digital tool for configuration approval and communication process;
- Approval process had to be made on a signed paper;
- Only limited consistency check of parameters is made when loading config;
- This was a time consuming and error prone operation without automatic verification, approval sequence or feedback to the SL;
- There was no possibility of having pre-approved pulses to setup a sequence of runs more efficiently;
- It was designed and developed a solution using ITER Interface Operator Tools and NBTF tools with the experience from operating RFX experiments.

Parameter Settings Tool - Requirements

SPIDER Configuration Tool Requirements

- It shall be a single tool to be used by Session Leader (SL) and Responsible Technician (RT), but with different viewer and permission settings;
- Human Machine Interface (HMI) shall be similar to the current SPIDER setup, reusing to the maximum extent the current design already developed;
- A new panel with the session operation limits for automatic verification of the setup validity;
- Include the functionality of loading configuration from a specific shot number or reference shot as a starting point for configuration changes;
- Add automatic verification if the loaded configuration is compatible with the present plant configuration;
- The application shall implement the synchronization between the setup tasks (both SL and RT) and the pulse sequence:
  - Shot number 100 shall be used to store the configuration in work (reference);
  - SL submits the parameter changes to RT before the pulse sequence is at CHECK STATE or READY STATE – These states shall inhibit the submission of a new configurations;
  - When SL submits a new configuration, the changes regarding the previous pulse shall be highlighted in the RT panel;
  - Submission of new configuration by RT to the model can only be made in PAS STATE;

SPIDER Configuration Tool Requirements

- The application shall be developed in Java or similar for Windows and Linux compatibility
- The definition of waveforms shall remain as an independent application, maintained by the SPIDER team (IDL tools)
- A new tab shall be created for definition of active diagnostics for the current pulse
- Regarding the diagnostics configuration:
  - A list of parameters for a specific diagnostic shall be integrated in the tool to be set by the SL
  - It shall be possible to load pre-defined tables of diagnostics for a certain type of pulse
  - It shall be also possible to change each diagnostic status in case of need by the SL
  - The SL shall be able to turn off certain diagnostics if they are not mandatory for the specific experimental program

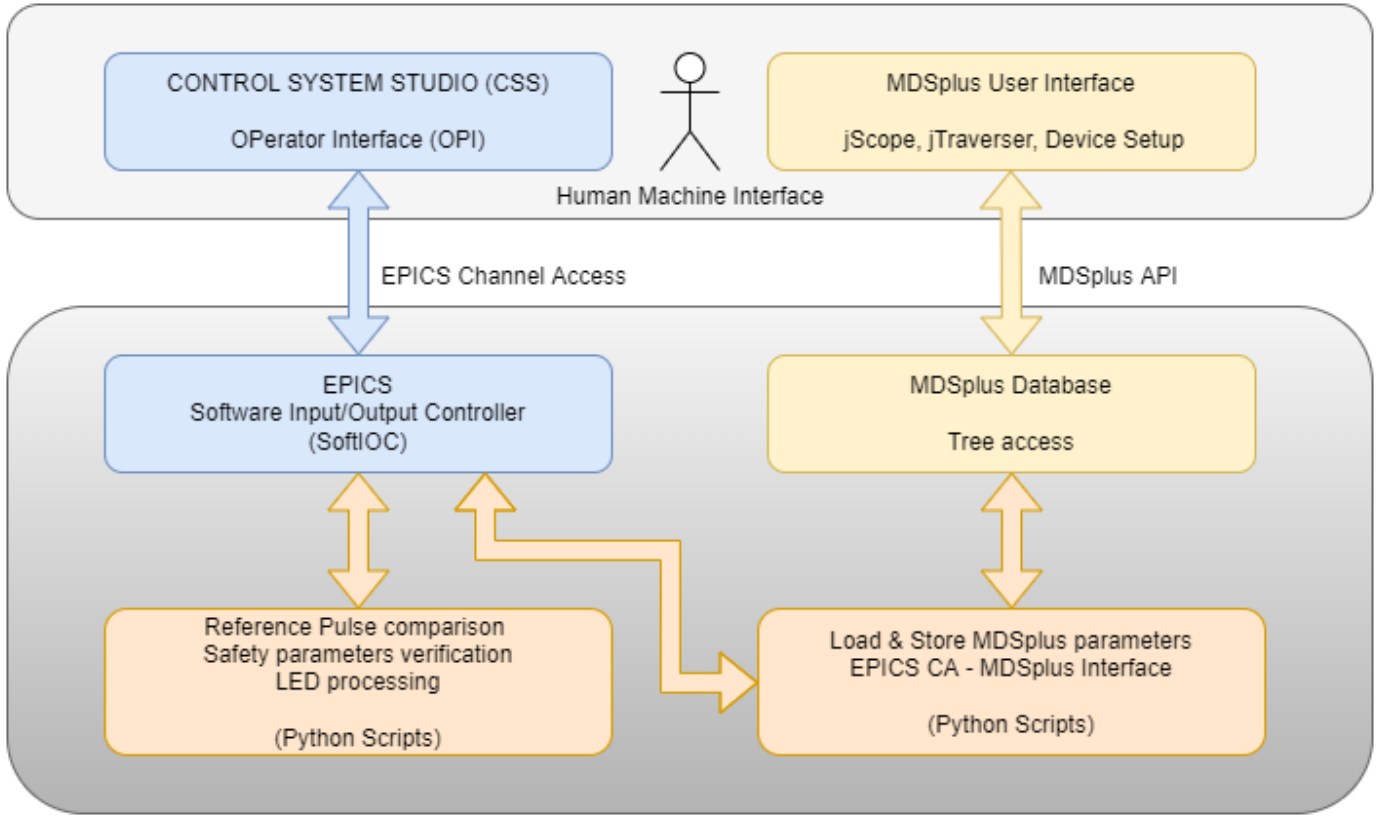
SPIDER Configuration Tool Requirements

- Regarding the communication between SL and RT:
  - The submission of a new configuration by SL to RT shall be clearly assigned using a SUBMIT button
  - This action shall highlight all parameter changes in RT panel to be accepted
  - The parameters highlighted shall be with reference to the previous pulse
  - Special attention shall be taken to avoid that a new submission of parameters by SL can cancel the previous highlight of a changed field
  - Each parameter change (or a small group according to a certain logic) shall have an action or accept button to turn highlight off
  - Each tab title shall remain red (highlighted) as long as any parameters inside that tab is still highlighted
  - The final configuration can only be validated (submitted to OT) when there are no highlighted parameters or tabs
  - The final configuration is submitted by means of a SUBMIT button
  - The session limits shall be modified only by RT. The SL can check what the parameters are, but he cannot change them.

A long and detailed list of requirements was prepared, that evolved in time...

- Functional requirements
- Development requirements
- Integration requirements

Parameter Settings Tool



Software Architecture

The Experimental Physics and Industrial Control System (**EPICS**) has been adopted for I&C in ITER operations:

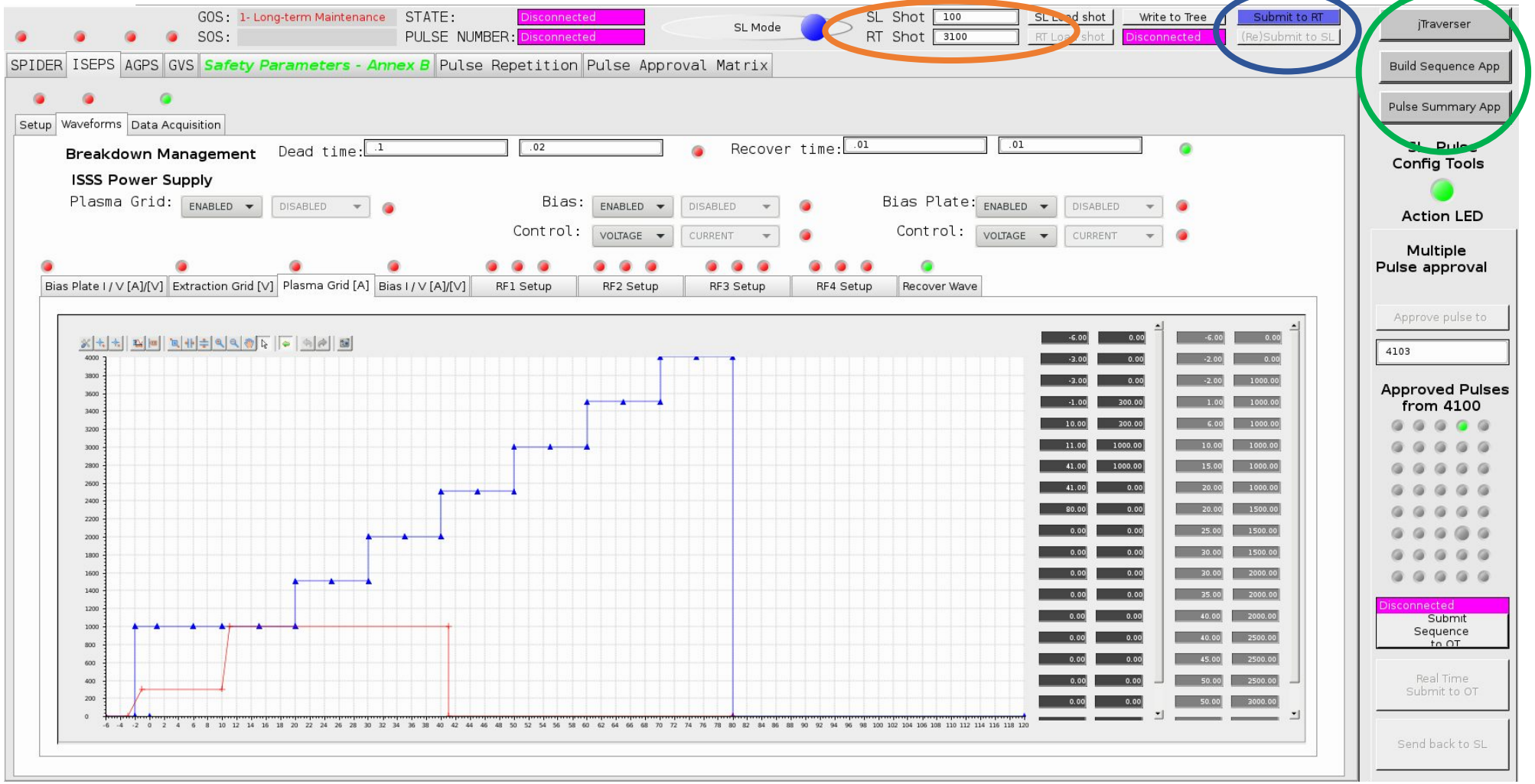
"EPICS is the software backbone of the CODAC control system." in ITER CODAC Team words

"Control System Studio (**CS-Studio**) will power ITER's dashboard, what we call the visualization layer—panels, graphs, sliders, symbols, metres and switches on the operator consoles in the ITER control room."

Parameter Settings Tool

Load a reference shot to make changes

Submit for approval

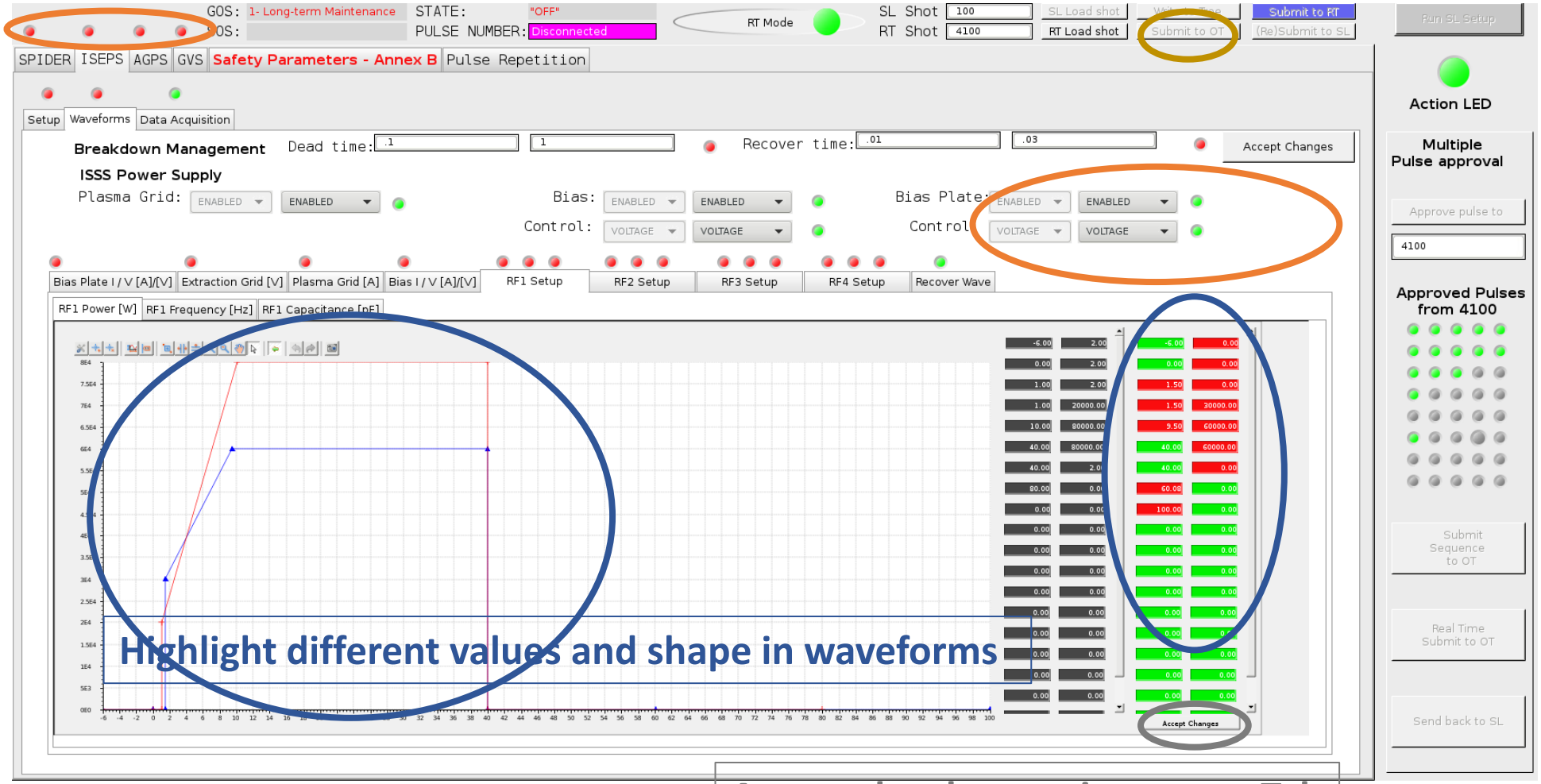


Open other relevant tools

Highlight and Approve Changes

Highlight Tabs with changes

Submit to OT button

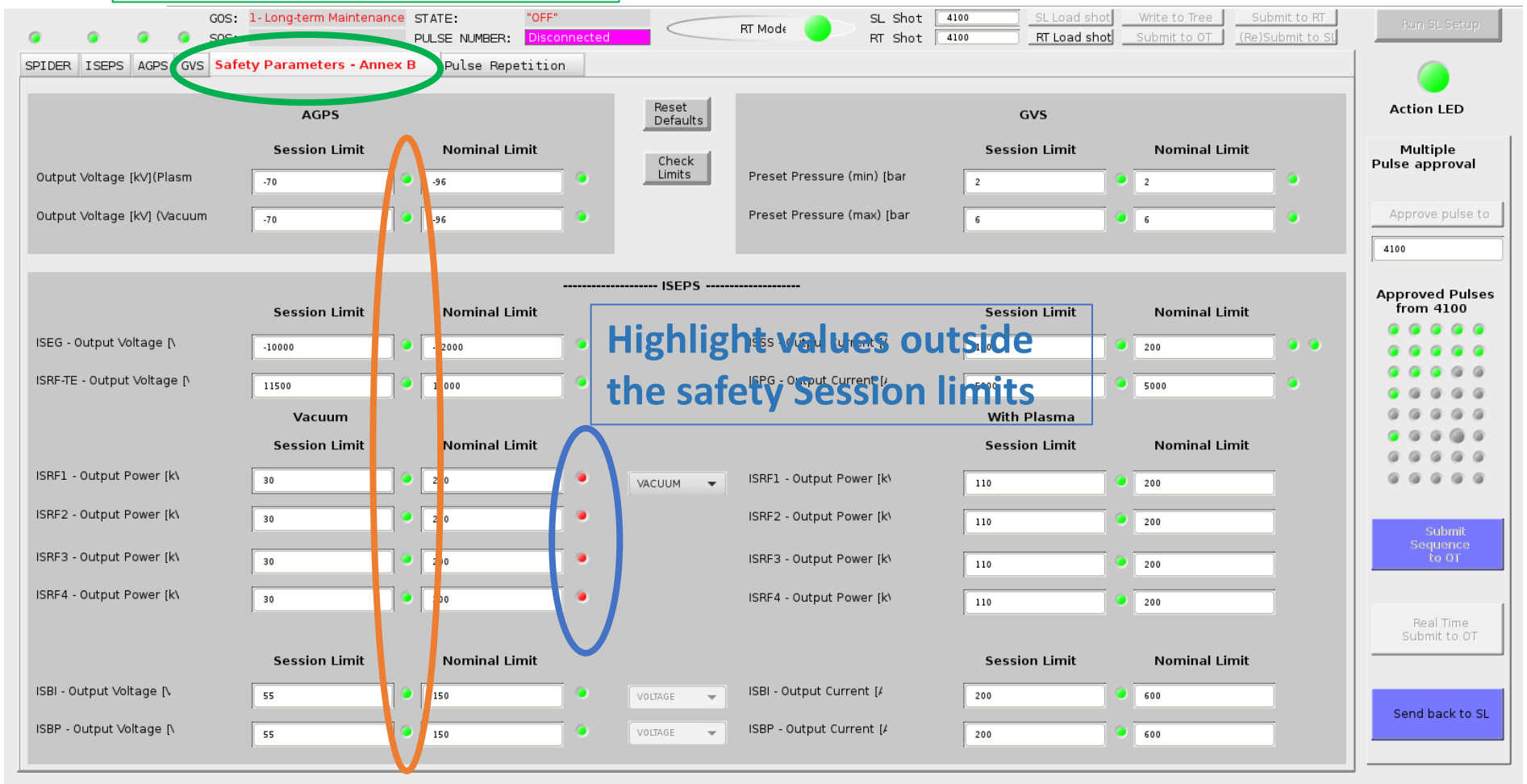


Highlight different values and shape in waveforms

Accept the changes in current Tab

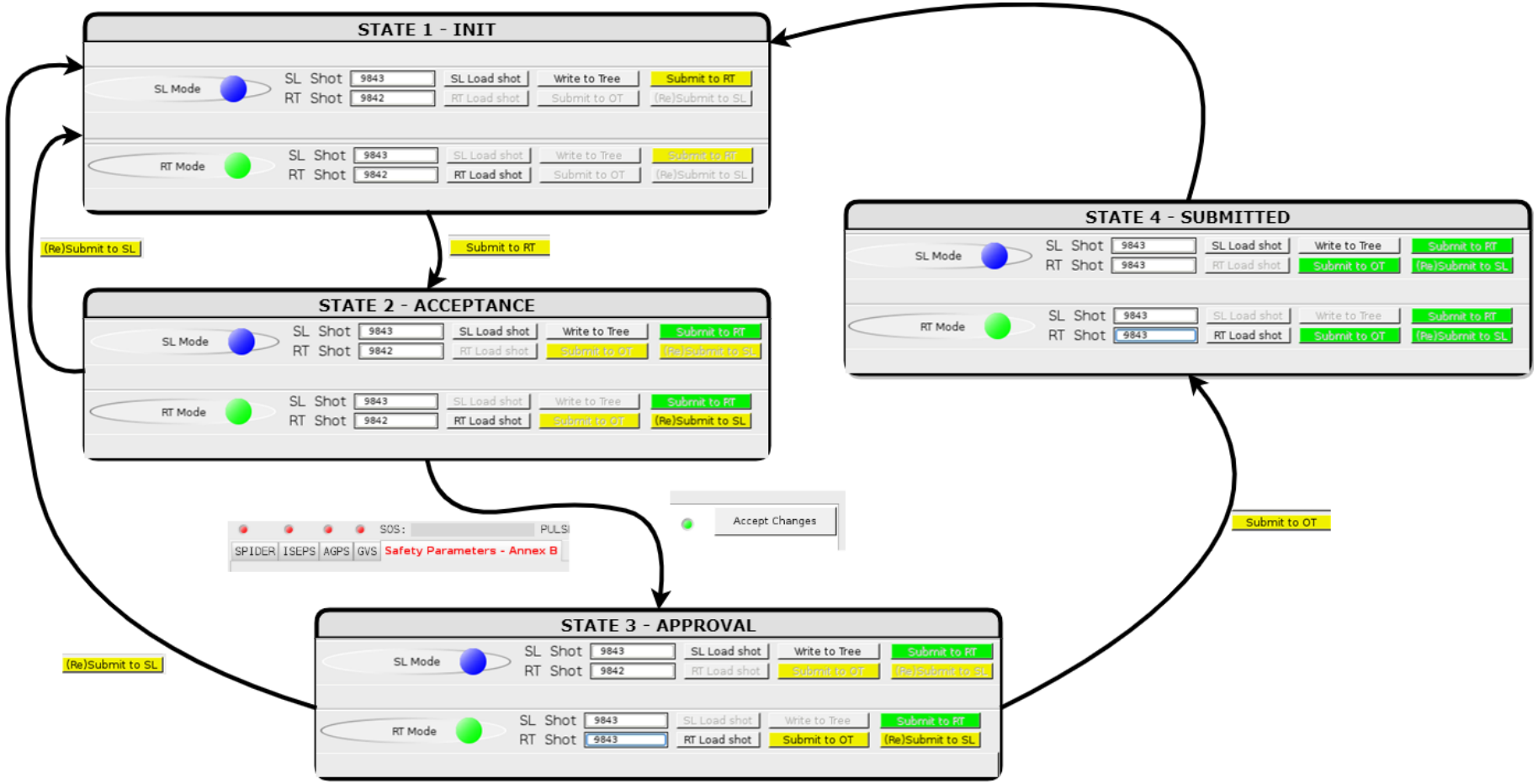
Verification of Operation Limits

Highlight Tab with errors

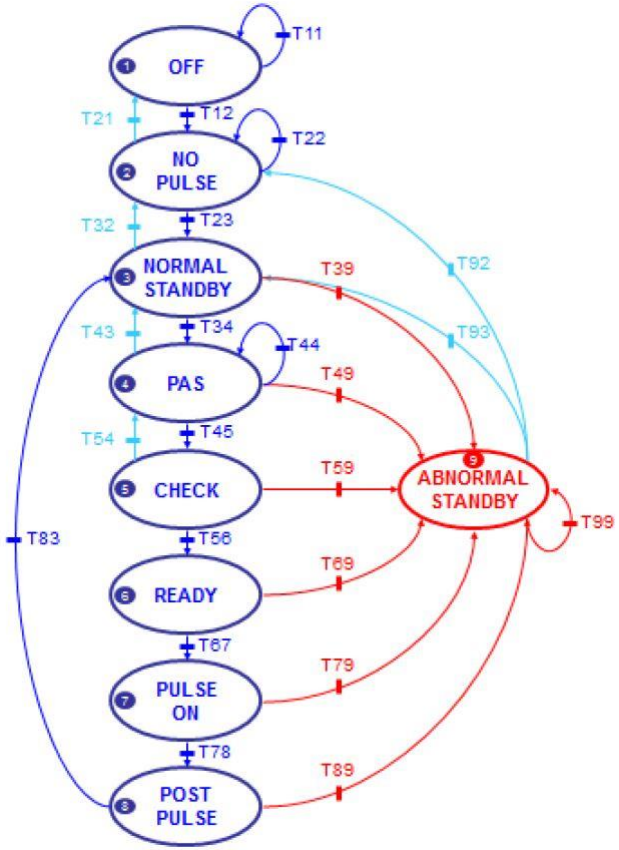


Highlight the Session Limits are inside the Nominal Limits

Single Pulse State Machine

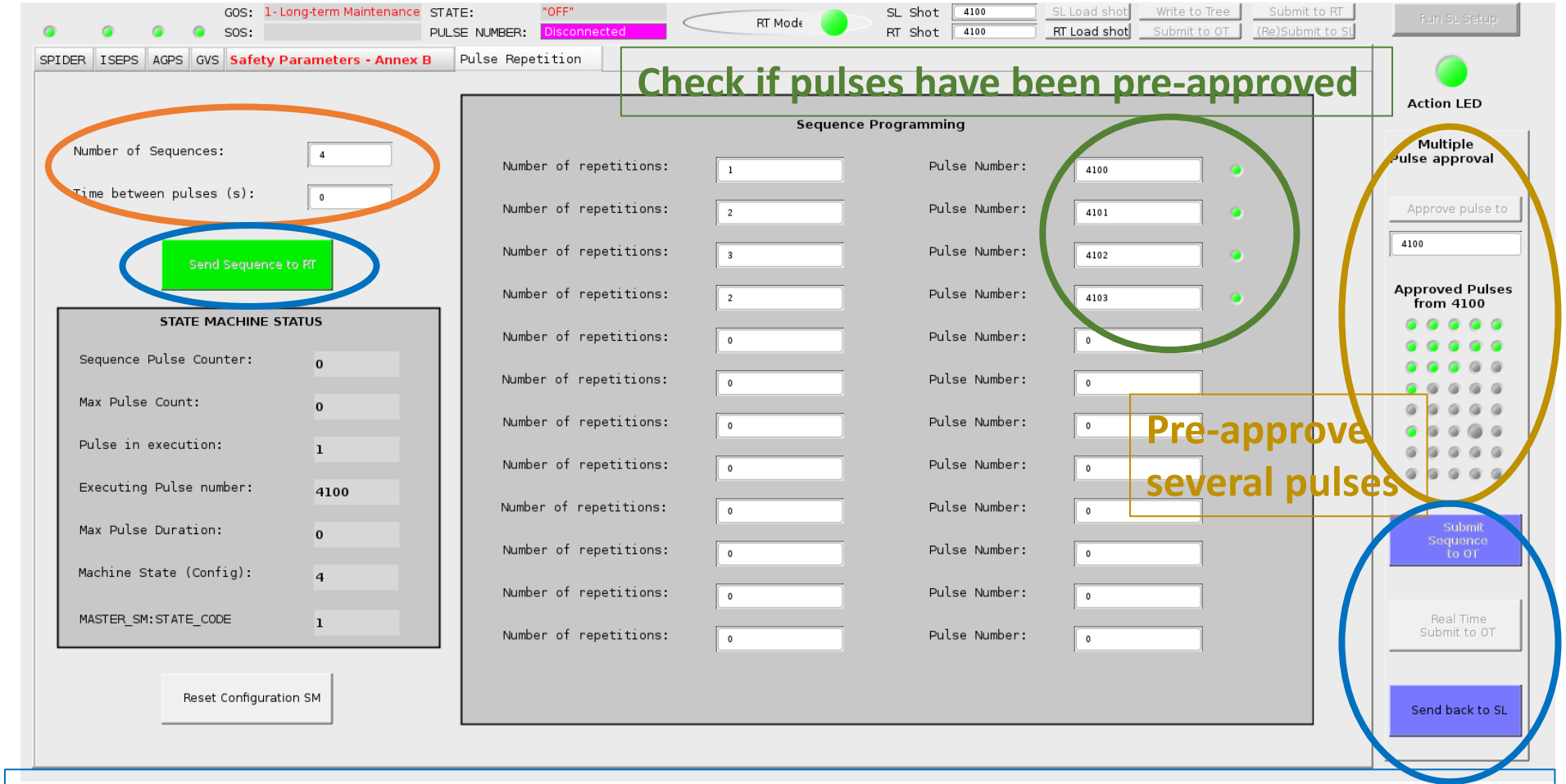


SPIDER Pulse Sequence



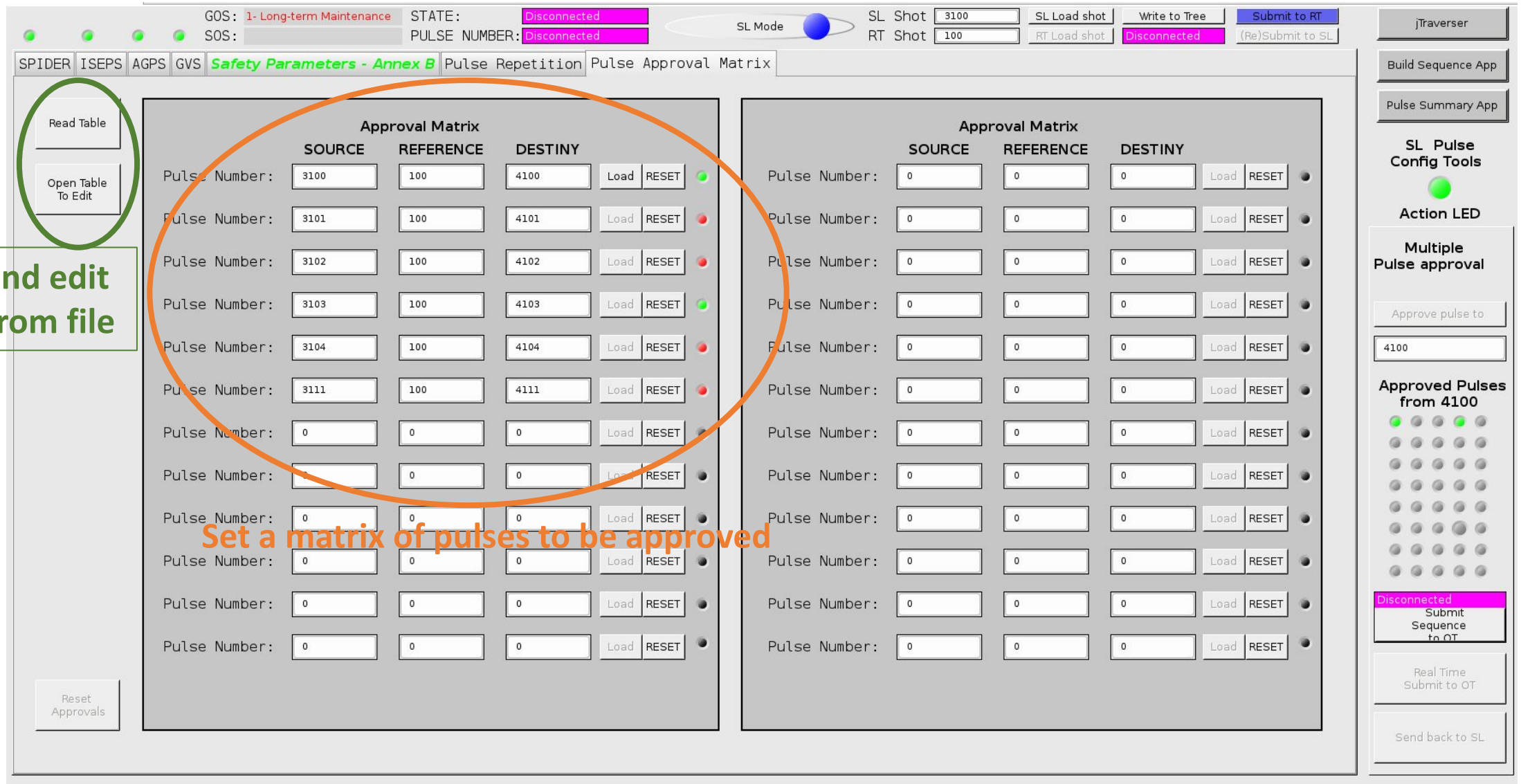
Building Sequences of Multiple Pulses

Program number of Sequences and time interval between discharges



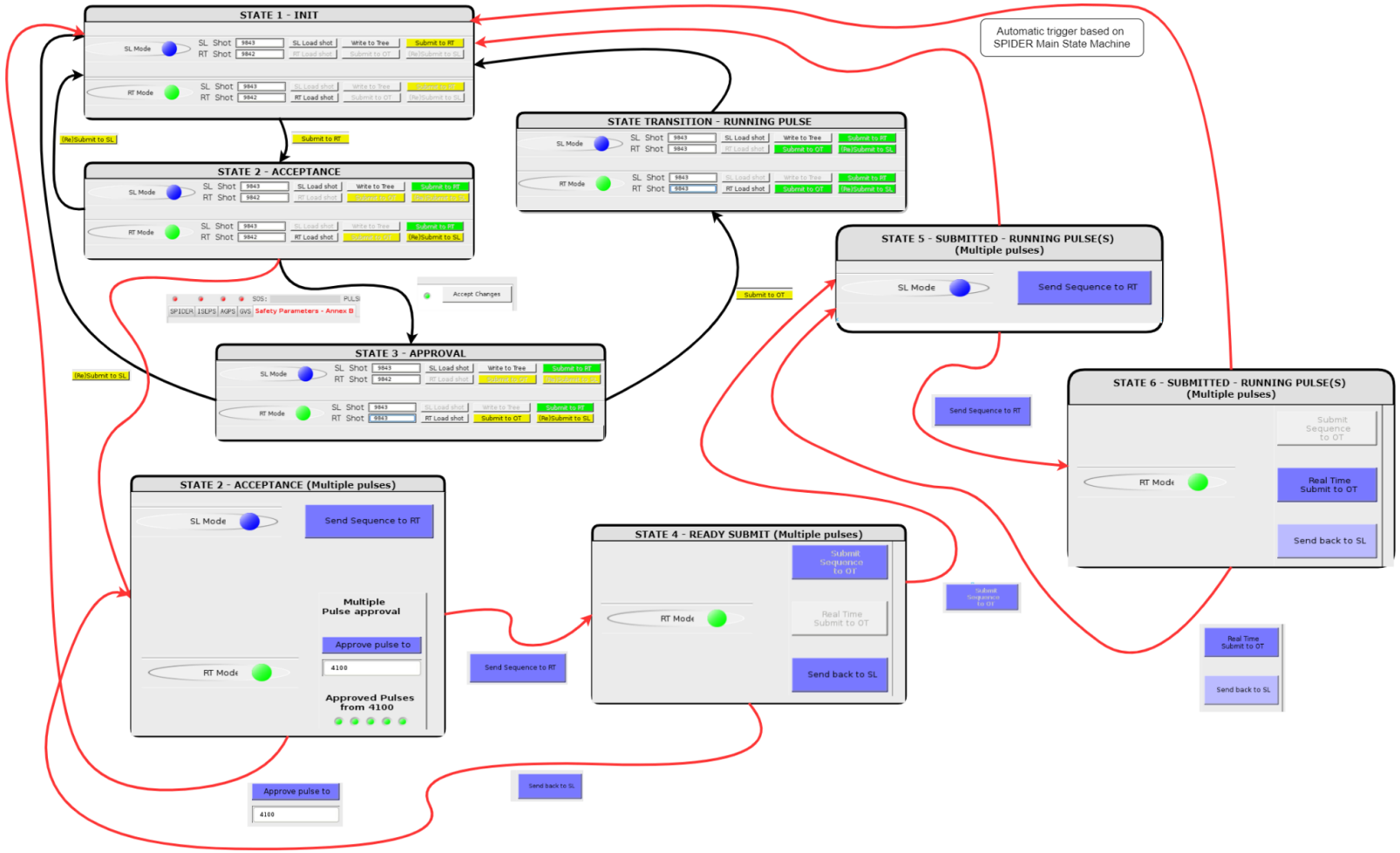
Actuate on the State-Machine by submitting and sending actions to other operators

Approval of several Pulses



Read and edit table from file

Multiple Pulses State Machine



Improved Pulse Repetition Rate

Sequences of pulses with 5 minutes repetition rate, obtained using the Parameter Settings Tool sequence of pre-approved pulses

Summary & Conclusions

- Requirements for improving SPIDER operations and remote collaborations were defined
- Open-Source Tools were chosen for new developments, in line with ITER CODAC Plant System I&C requirements
- Integration of different tools such as PostgreSQL, Redis, Grafana, MDSplus and EPICS, used in common developments for improving SPIDER operations and remote collaborations
- Tools have been commissioned and are being used in the current SPIDER Experimental Campaign
- Security and efficiency improvements in the operation include:
  - Remote access to real-time trends visualization tools
  - Automatic verification of operating session limits and nominal limits
  - Multiple pulse approval and automatic real-time reconfiguration of pulse sequence
  - Full integration with SPIDER pulse sequence
  - Improvement to the pulse repetition rate capabilities

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Thank you for your attention