

Introducing Karabo

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Control and Analysis Software group

Satellite Workshop on Data Analysis and Karabo

January 23rd, 2018

Afternoon Session: Karabo and Data Analysis at XFEL



Outline

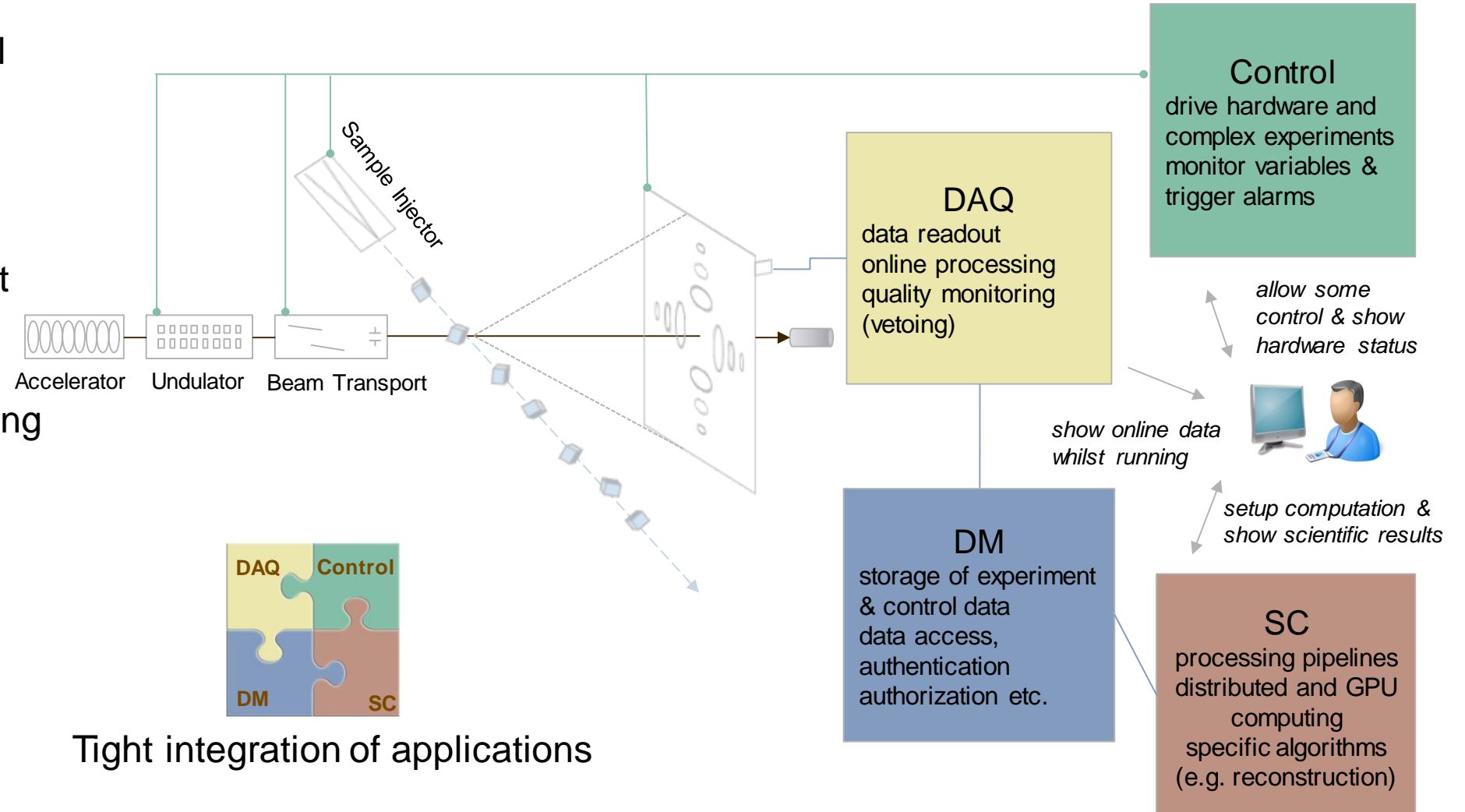
- Karabo Framework Overview
- Graphical User Interface
- Data Acquisition and Scanning

Introduction

- Karabo is custom made European XFEL's
 - **Control** System: controls a wide-range of light source instruments
 - **Data acquisition** system: GB/s scientific data collection
 - **Data processing** framework: Native support of distributed process chaining using pipelines.
- Under active development
- Drives European XFEL commissioning and, since September 2017, user experiments

Unified approach required for:

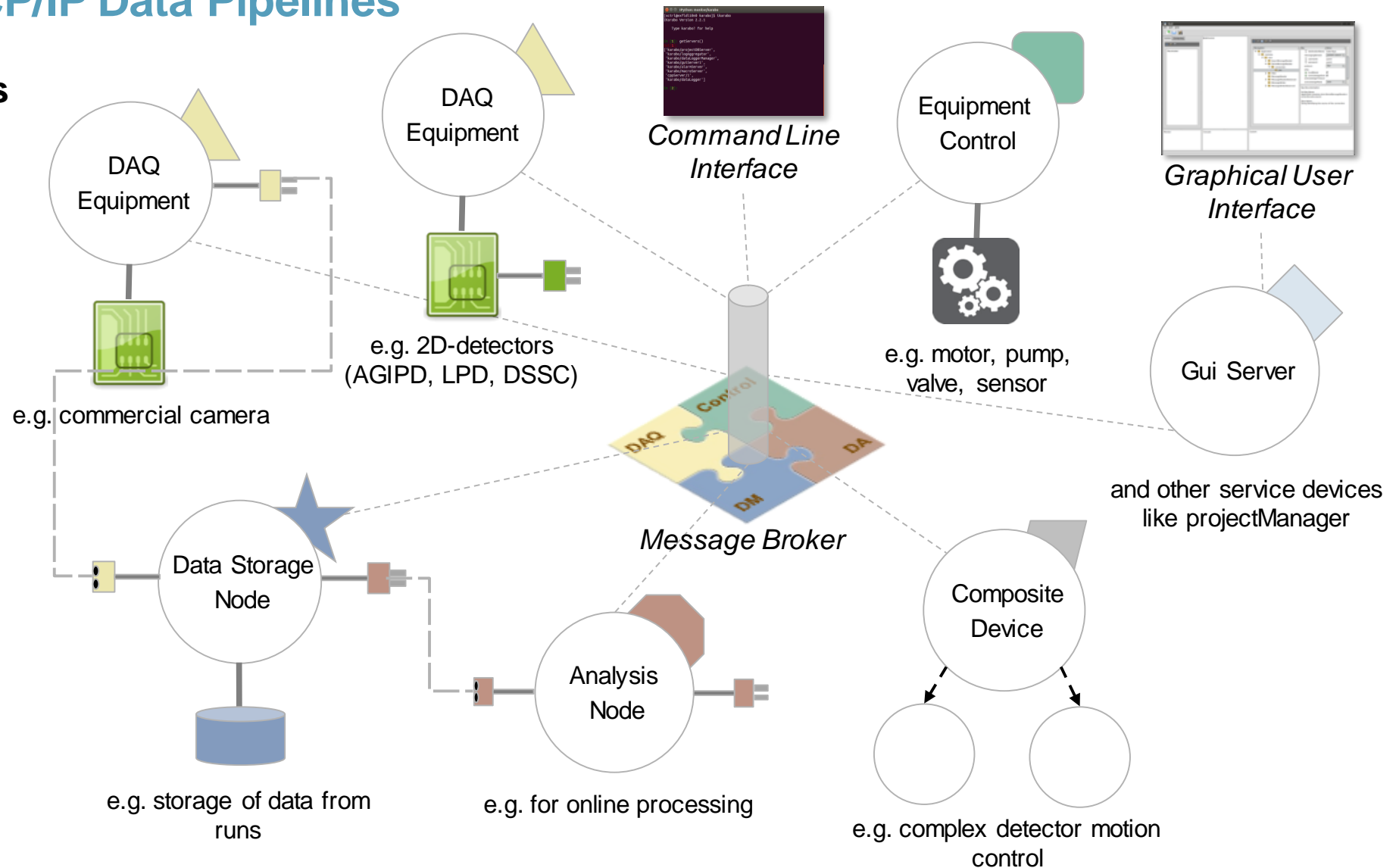
- Instrument Control
- Data Acquisition (DAQ)
- Data Management (DM)
- Scientific Computing (SC)



Karabo: Device Based Communication via a Message Broker and TCP/IP Data Pipelines

Individual Karabo Devices

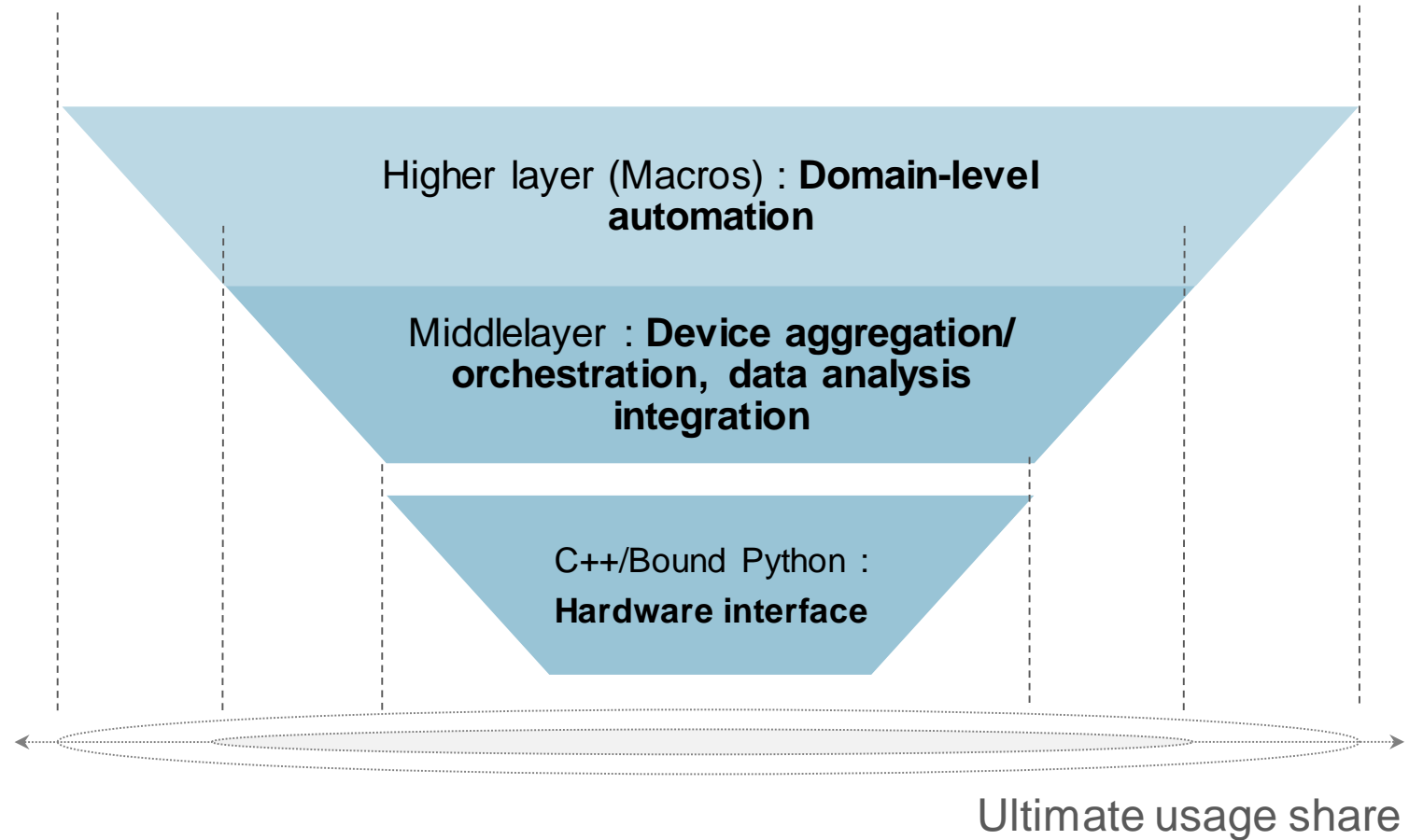
- Equipment control, e.g. motors, valves,...
- Detectors like
 - cameras,
 - big 2D detectors
- Data storage
- System services
- Online/offline data analysis, e.g. calibration



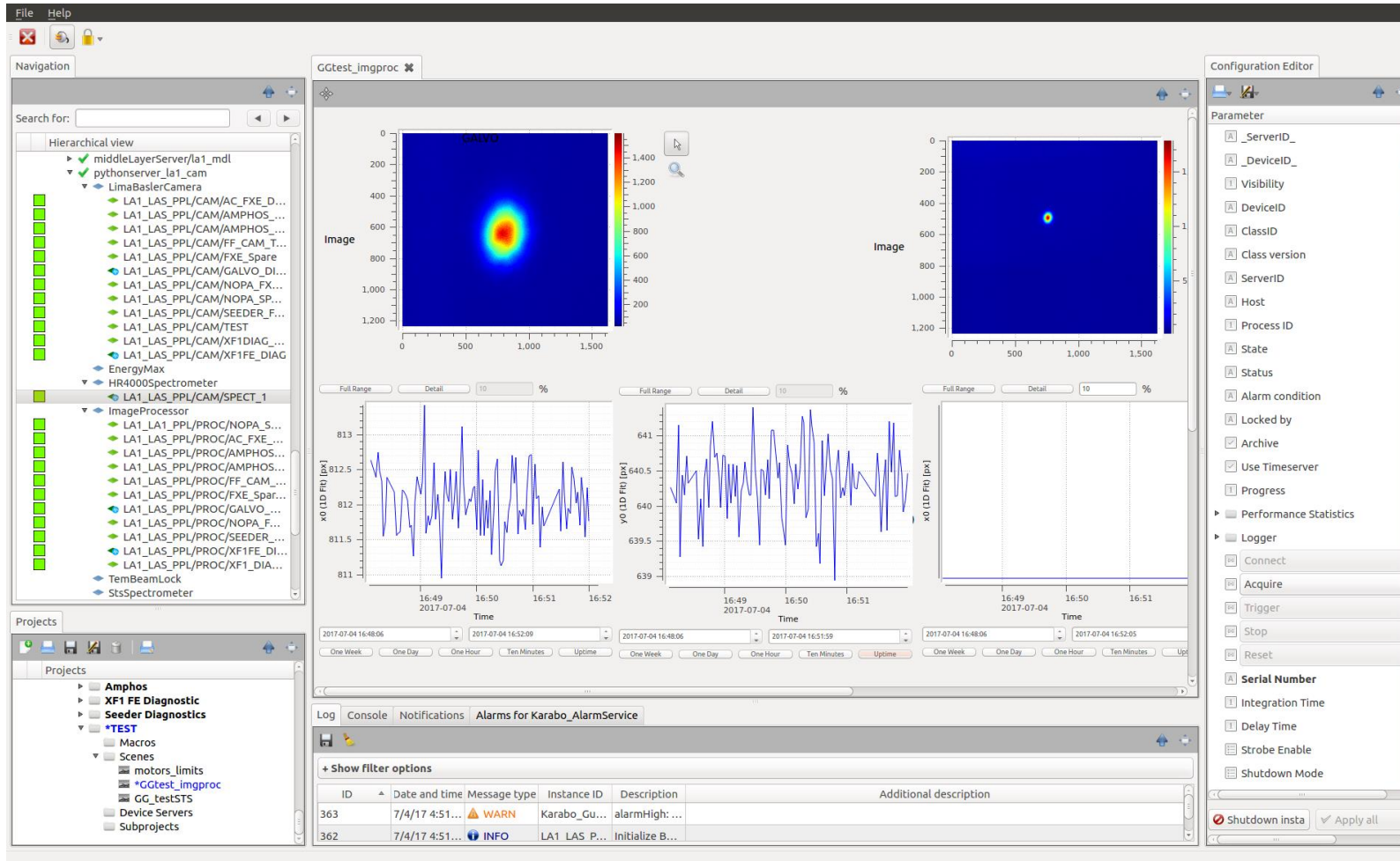
Four Application Programming Interfaces

...and whom they address:

- **Macros:**
instrument scientists,
possibly later users
- **Middlayer:**
Control experts with feedback
from instruments,
maybe instrument scientists
- **Hardware interface:**
Control experts with hardware
knowledge



Graphical User Interface: Integrated cockpit



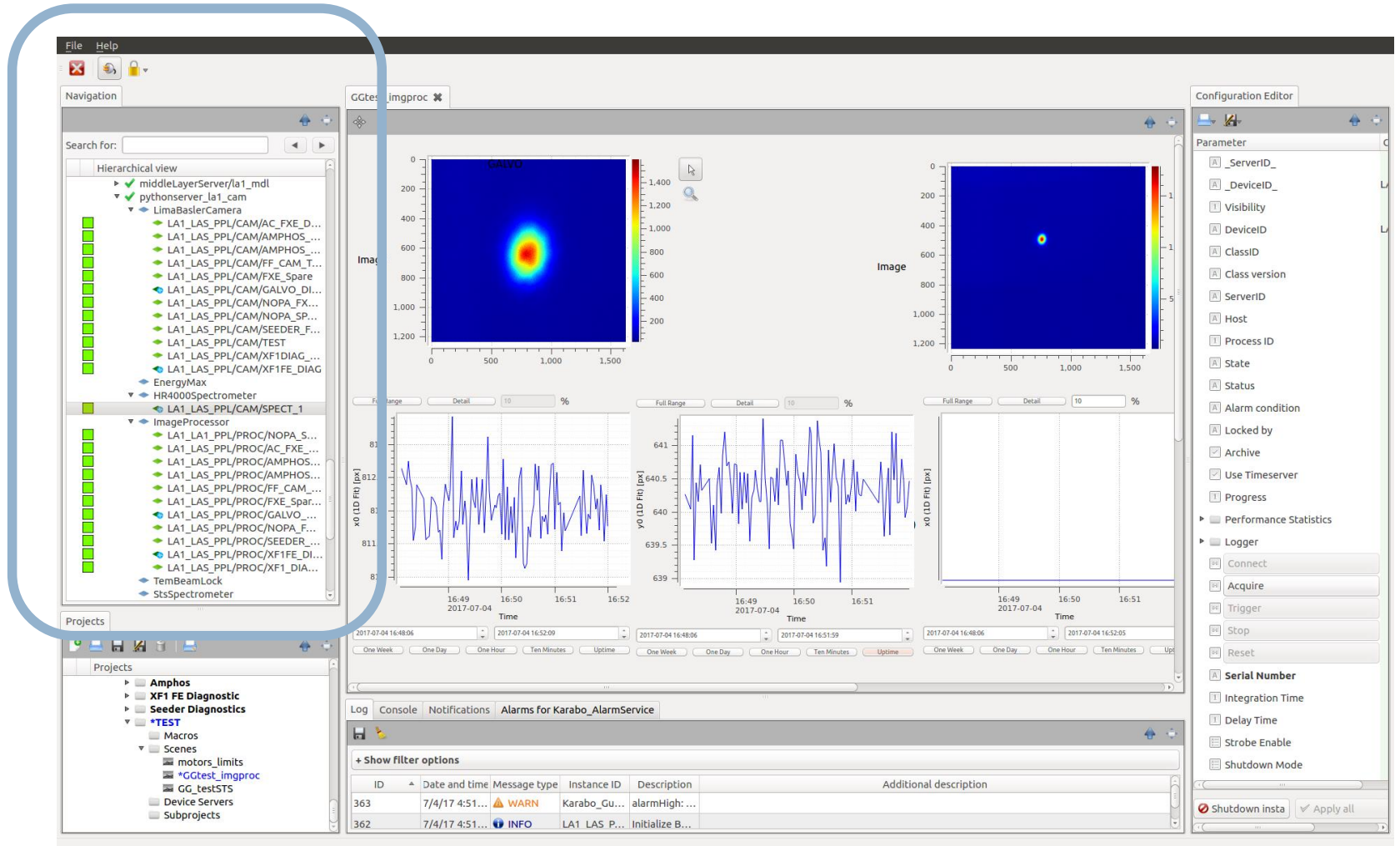
Unified tool:

- For experts:
 - Full system view.
 - Detailed access to configurations.
 - Integrated command line.
- For everybody:
 - Customizable “scenes” (no coding required).
 - Rich set of widgets.
 - Coherent handling, e.g. limits of settings.
 - Visualisation of
 - ▶ error state,
 - ▶ properties in alarm condition.
 - ...

Graphical User Interface

Navigation panel:

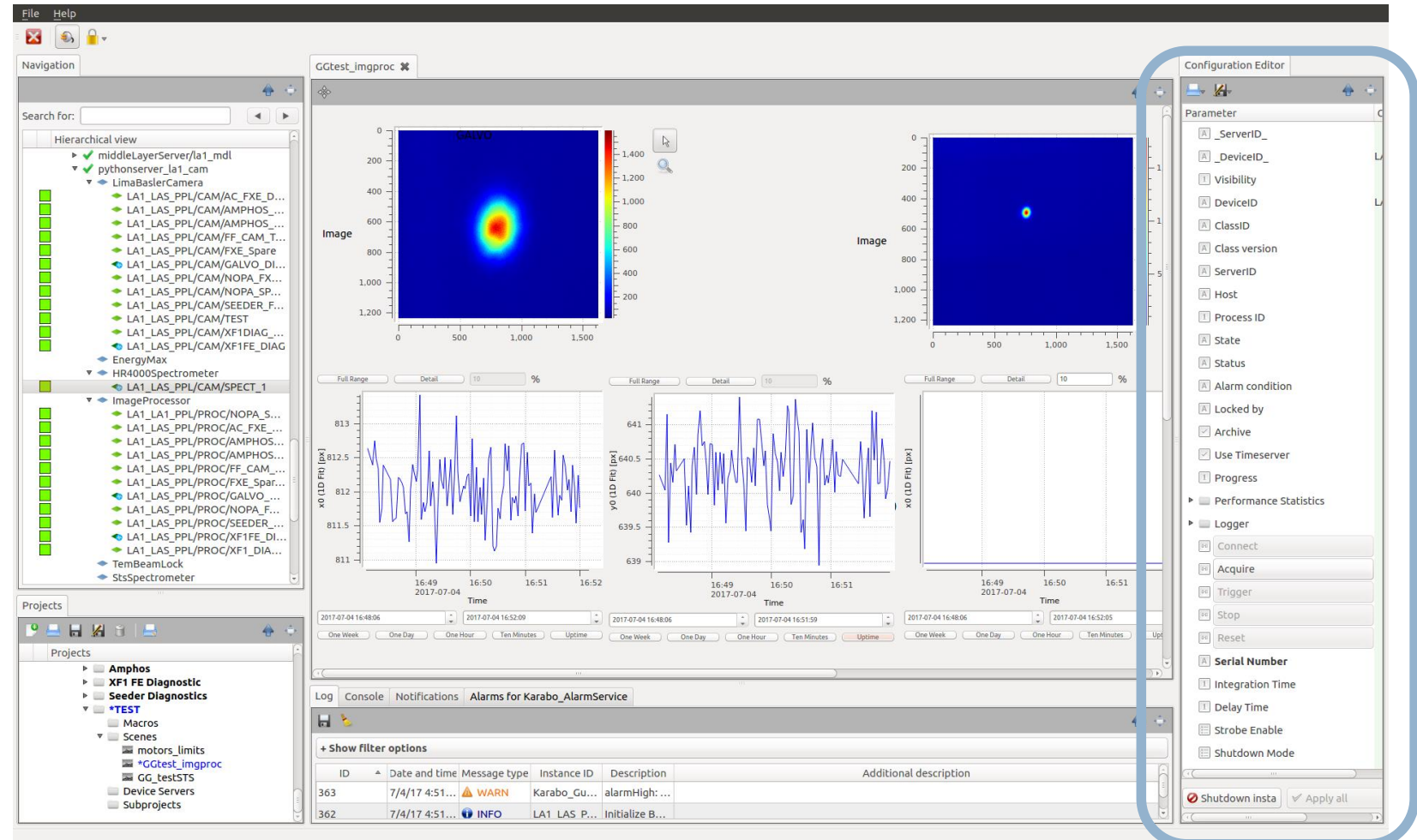
- Complete Karabo system topology
- Searchable
- Colour coded device state indicator



Graphical User Interface

Configuration panel

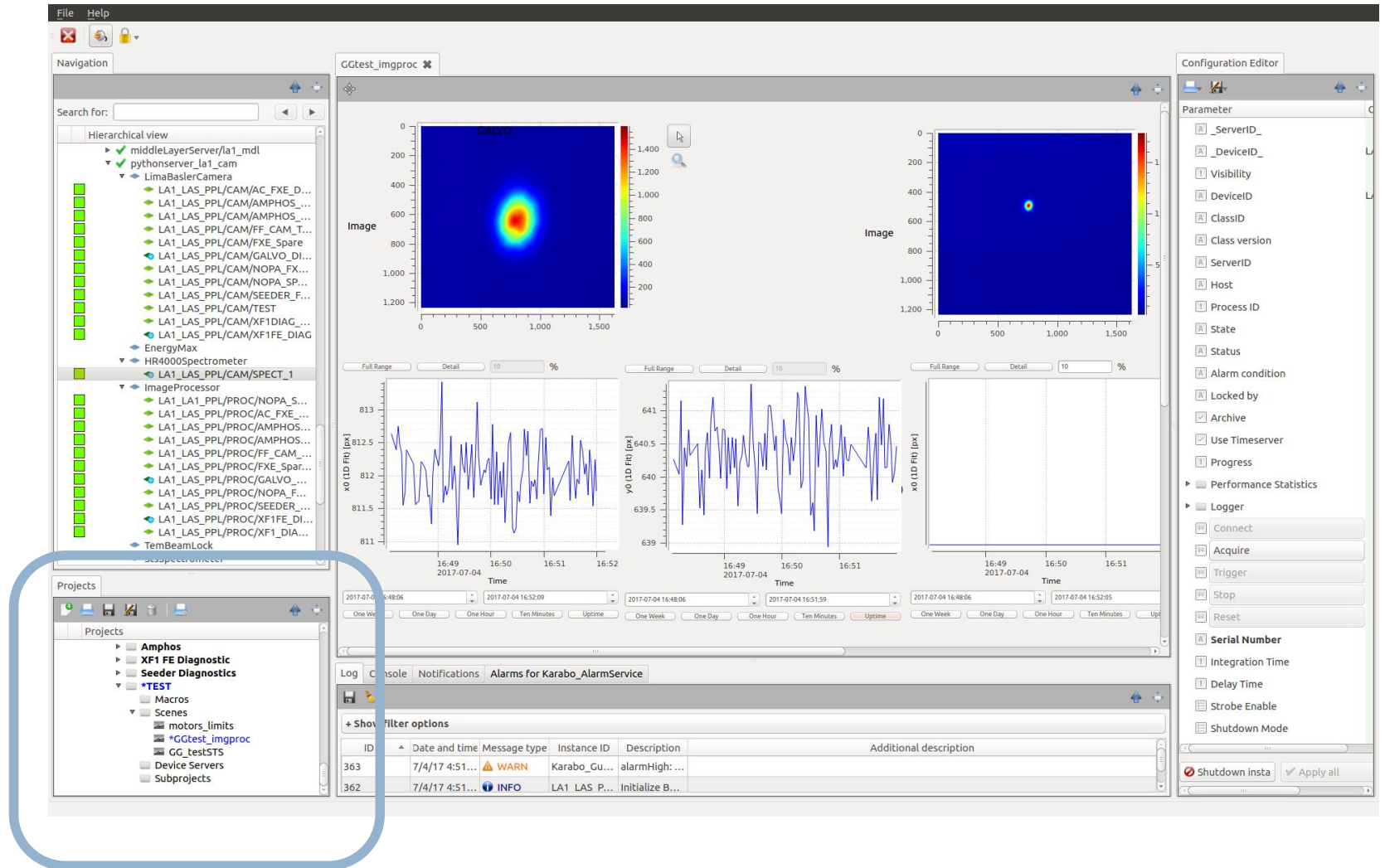
- Online and offline device configuration
- Send commands to devices



Graphical User Interface

Project panel

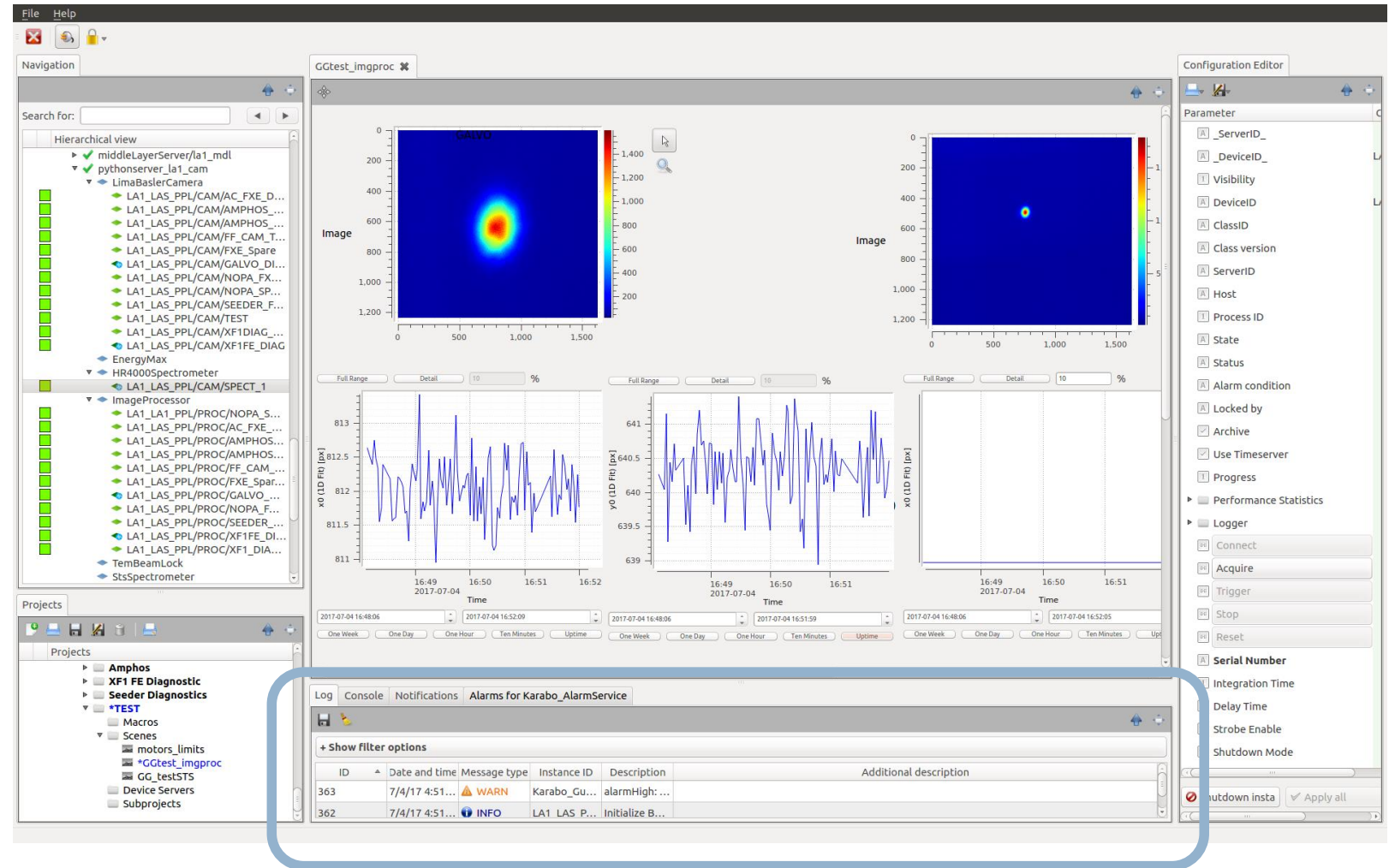
- Project data:
 - device configurations,
 - scenes (→),
 - macros.
- Projects stored in central data base.



Graphical User Interface

Panels for

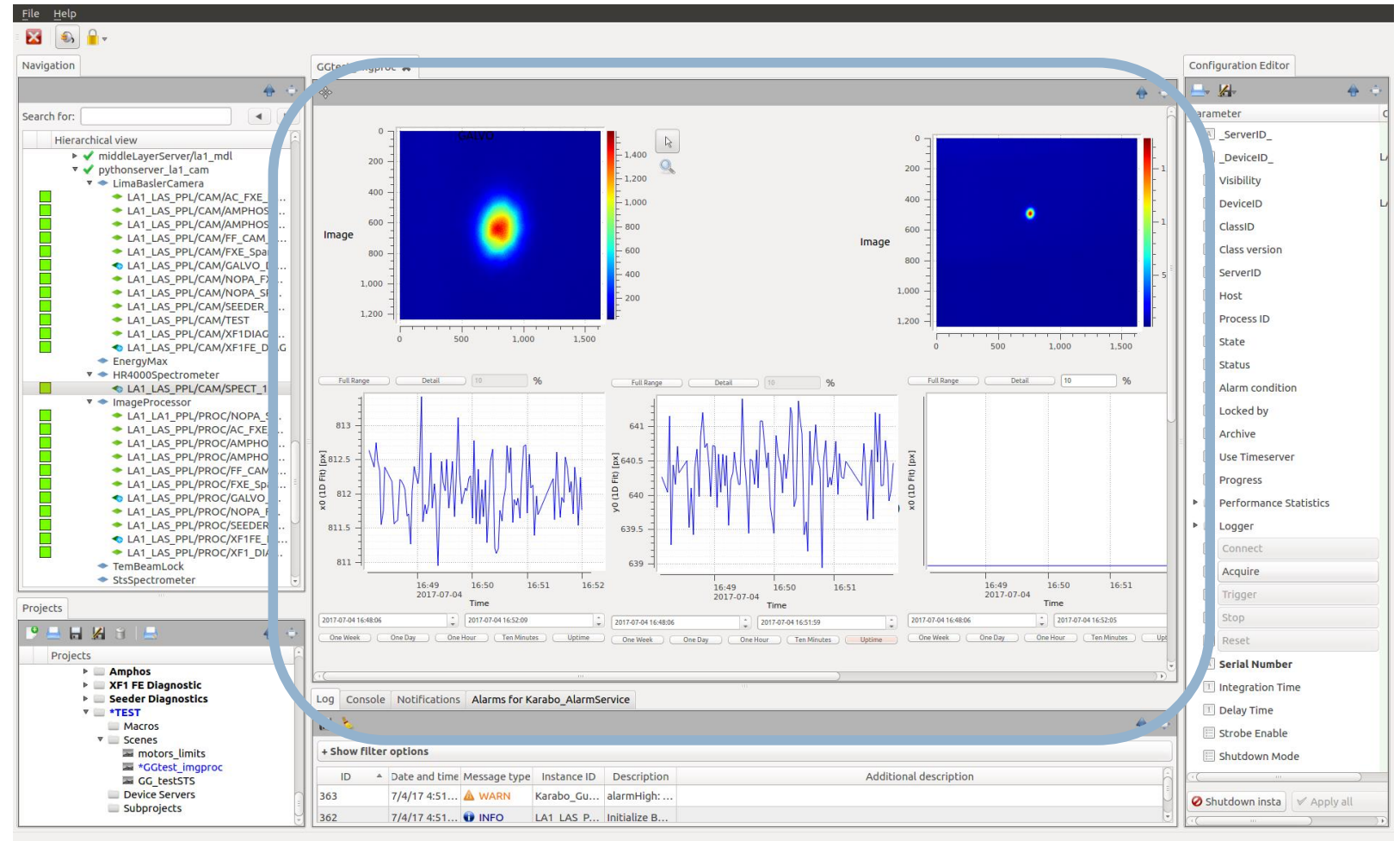
- Message logging
- Alarm handling
- Integrated command line



Graphical User Interface

Scenes

- Easily editable
 - using drag and drop
- Rich widget set
 - various image views,
 - trend lines,
 - commands,
 - device states,
 - standardized icons,
 - (some details in backup)
- Can un-dock from main window (as all panels)



Scene Example

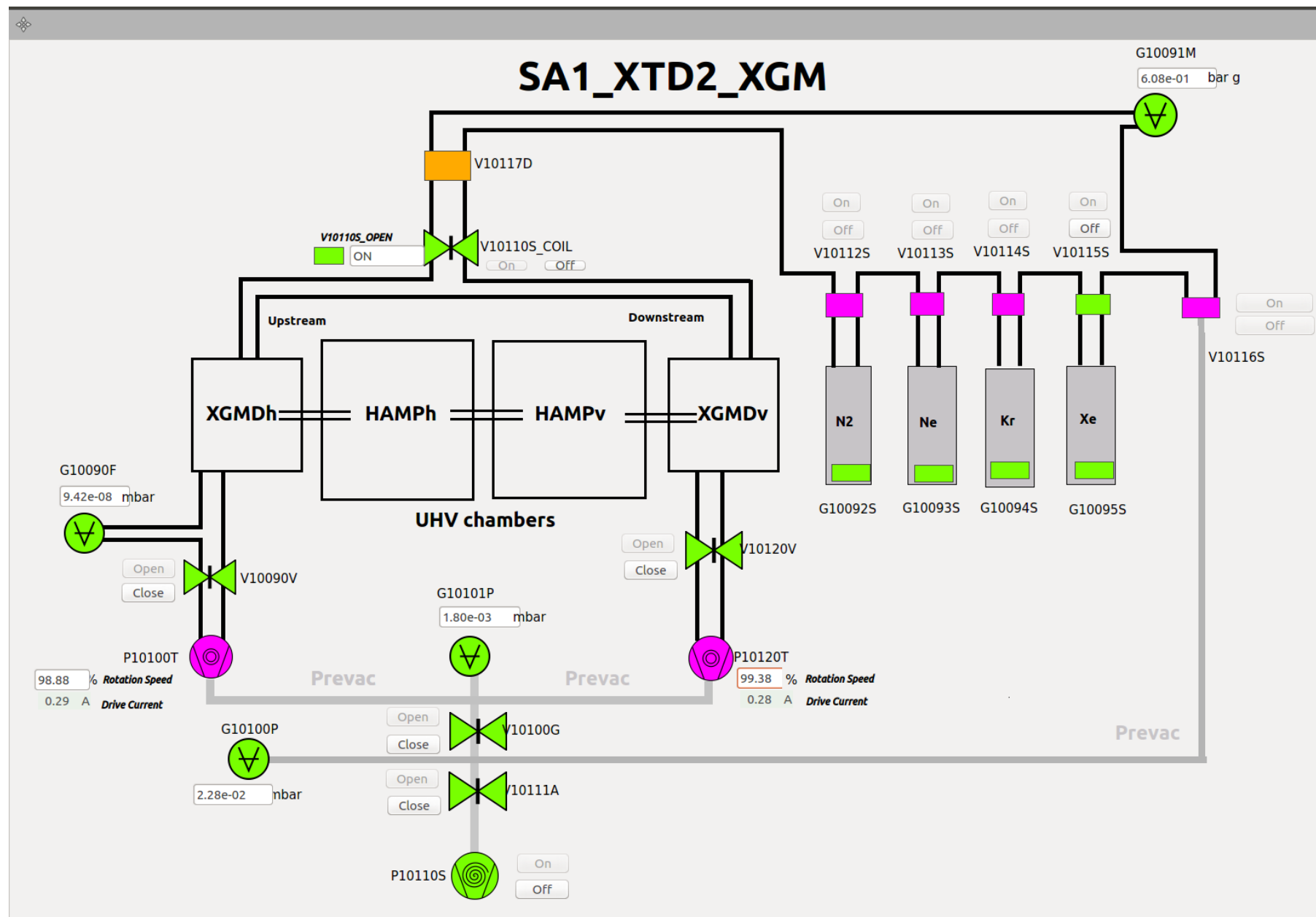
Beamline Control: SASE1

The screenshot displays the Karabo beamline control interface for SASE1, showing several interconnected panels:

- Navigation Panel (Top Left):** Displays a hierarchical view of the beamline structure, including components like `exfIcon07n0`, `cppServer/fxe_loop_1`, `AlarmService`, `BeckhoffAgilentPump`, `FXE_OGT1_VAC/ICTRL/PSLI...`, and `FXE_OGT1_VAC/IDUMP/AT`.
- Photon Beam Transport (Top Center):** A schematic diagram of the beam transport line, showing components such as `sm. ger Absorber V0`, `SRA`, `K-Mono`, `SR Imager`, `XGM`, `Solid Attenuator`, `CRL1`, `FEL Imager`, `M1`, `Beam loss monitor`, `M2`, `MCP`, `Pop-in monitor`, `Shutter XS3`, and `beam stop`. It also indicates `STOPPED` states for `SR Imager`, `FEL Imager`, and `Pop-in monitor`.
- SASE1 Vacuum Section VS12070 (Middle Left):** A diagram of the vacuum section, showing components like `V12080G`, `POP-IN`, `Front End` (with `Absorber` and `Shutter`), `V12090M`, and `INTERLOCK`. It displays pressure readings for `P12250I` (9.9e-09 mbar), `P12270I` (6.3e-09 mbar), and `P12280I` (3.9e-09 mbar).
- SASE1 M3 (Bottom Left):** A diagram of the SASE1 M3 section, showing a coordinate system with `Ry (pitch)`, `Ty`, `Rx`, `Rz`, and `Tx (moves into beam)`. It also includes a control panel for `SASE1 M3 RY (pitch)` with fields for `Hi limit`, `Position`, `TargetPos`, `StepDown`, and `Lo limit`.
- SASE1 Overview Vacuum (Bottom Center):** A detailed schematic of the vacuum section, showing components like `Linac`, `SRA`, `k-Mono`, `XGM`, `ATT`, `CRL1`, `Imag`, `M1`, `M2`, `MCP`, `Pop-in`, `Shutter Hirex`, and `M3`. It displays the status of various vacuum chambers (e.g., `V10000M`, `V10020G`, `V10030G`, `V10180G`, `V10190G`, `V10200G`, `V10210G`, `V10220G`, `V10230G`, `V10240G`, `V10250G`, `V10260G`, `V10270G`) and their associated valves (e.g., `V12010G`, `V12020G`, `V12040G`, `V12050G`, `V12060G`, `V12070G`, `V12080G`, `V12090M`).
- EPS to MPS interface (Top Right):** A panel showing the status of various interlocks and valves, including `Vacuum interlock XTD2`, `Shutter XS3`, `Vacuum XTD9 SPB`, `Vacuum XTD9 FXE`, and `Mode 1: Single pulse per train`.

Scene Example

Diagnostic:
XGM monitoring



Scene Example

Detector control: LPD Tile Control

The screenshot displays the Karabo 2 Tile Control interface, which is divided into several functional panels:

- 2 Tile Control:** This panel on the left contains controls for the system's state (STARTED), connection to the FEM (Connect/Disconnect), uploading FEM configuration, and starting/stopping the DAQ. It also includes status indicators for AsicPowerEnable0/1 and SensorBiasEnable0/1, and a FemAsicGain slider.
- DAQ and Run Configuration:** This central panel allows for configuring the data source list (currently showing DETLAB_LAB_DAQMINI/DET/0:x:tdf), setting the state to MONITORING, and configuring the data folder and mount point. It includes buttons for saving configuration, pushing to DAQ, ignoring data, applying configuration, monitoring data, starting/stopping the run, and a green restart button.
- Online Correction and Preview:** This panel at the bottom left shows the system state as ACTIVE and provides controls for enabling/disabling preview, setting pulse-to-preview, and performing initialization, reset, and commit operations. It also includes a second set of preview controls.
- Starting up system:** A text-based instruction panel on the right provides a step-by-step guide for hardware initialization, configuration, and starting the DAQ.
- Online Correction and Preview (Visuals):** Two heatmaps are displayed on the right. The top plot, labeled 'Raw', shows data with a color scale from 1.000 to 7.000. The bottom plot, labeled 'Offset corrected', shows the same data with a color scale from -250 to 50. Both plots include axes for time (0 to 250) and position (0 to 50).

Starting up system

Hardware

- (1) make sure all devices are initialized -> right click on device server, init all
- (2) Switch on 2tile if not running: plug 48V, assure ext. supply at 2.7V, enable both outputs
- (3) Connect FEMin 2 Tile Control
- (4) Verify settings, upload FEM config -> hardware ready for DAQ
 - * to change settings: prepare next config -> change -> update FEM config

DAQ

- (5) Assure run data source are configured in DAQ and Run Config
- (6) Apply configuration to PCLayer
- (7) Switch to monitoring or start run for recording (via monitoring)
- (8) Start DAQ in 2 Tile control -> after set # trains, FEM will switch to STOPPED state
- (9) Stop Run in DAQ and Run Configuration
 - * make sure to copy files out of /data to prevent overwrite after system restart

Online Correction and Preview

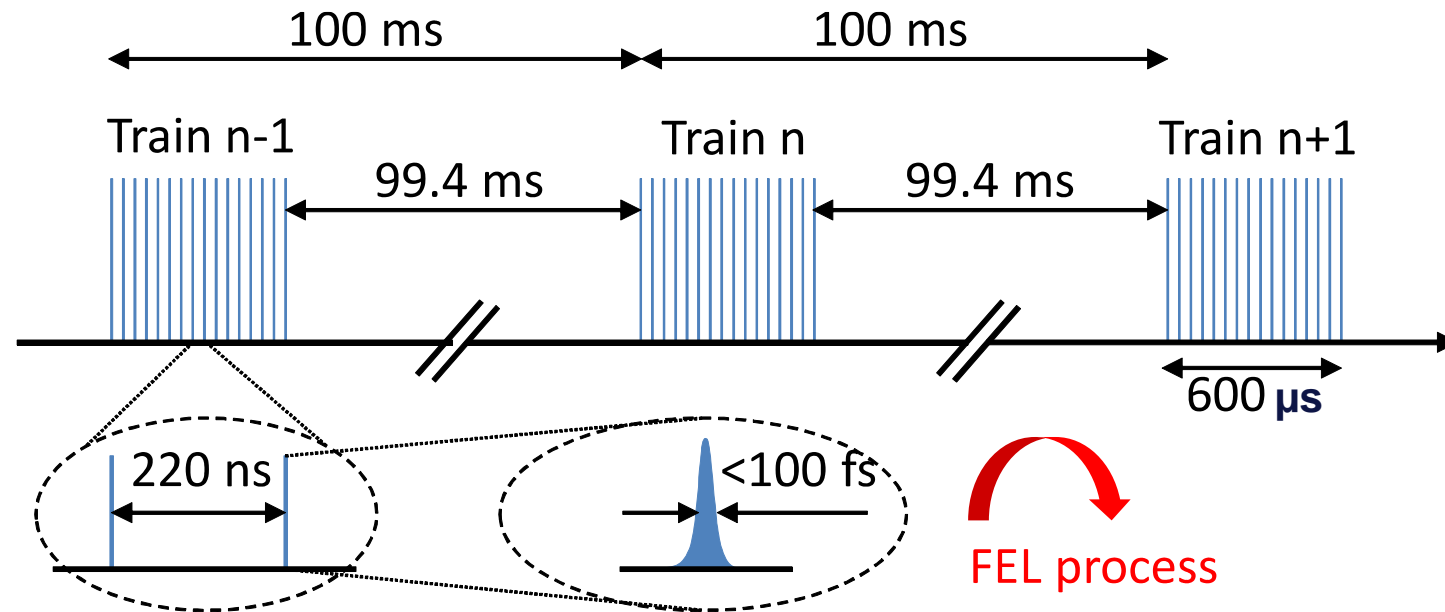
- (1) Init the calibration pipeline -> will load latest offset map
 - * to replace offset map: init -> acquire data (N times) -> end -> commit -> reset -> init this will also work in monitoring mode

Restarting DAQ

If the DAQ reports out of buffers, or does not pass data to online previews anymore

- (1) Open a console and source Karabo's activate script
- (2) execute: karabo-stop cppServer/daq
- (3) execute: ps aux | grep cppServer/daq
- (4) check if a karabo-cppserver process is still running, if so: kill -9 that pid
- (5) execute: karabo-start
- (6) from GUI init device again, follow DAQ instructions 5 and 6

European XFEL: Photons come in trains with short pulses



Pattern:

- **Trains** with 10 Hz
 - Relevant time unit for data storage
- Up to 2700 **pulses** per train
 - pulse duration < 100 fs
 - 220 ns spacing (4.5 MHz)
 - => train length 600 μs
 - next user operation period: up to 300 pulses
- On average:
up to 27 kHz of pulses

Karabo Data Acquisition (DAQ) Integration

Support for different types of data sources:

- Big 2D detectors as LPD, AGIPD (XFEL train data format)
→ **big & fast data**
- 2D or pulse resolved data: e.g. cameras, digitizers (Karabo pipeline)
→ **fast and/or medium sized data**
- Control data with train resolution: e.g. sensors, motors (Karabo)
→ **slow data**

Data acquisition organised via several Karabo devices

Data stored in HDF5 files

- available after run has finished,
- Karabo and data access tools provide data of all pulses of a train in one go.

Provide data stream for online display and online analysis,

- e.g. feeds calibration of big 2D detectors,
- can be replicated offline to tune online tools.

Karabo Data Acquisition (DAQ) Configuration

- Configure run-by-run which data to store:
- select sources (~devices) via run configuration scene

SA1_DAQ_DATA/DM/SA1_XTD2_IMGPII45_GROUP

Group name

SA1_XTD2_IMGPII45

Description

TOPIC : SA1
LOCATION : XTD2 TUNNEL

ALL THE DEVICES OF IMAGER

Update Group

User Sources

	Source	Type
0	SA1_XTD2_IMGPII45/SWITCH/SCREEN_OUT	control
1	SA1_XTD2_IMGPII45/DCTRL/CAM_POWER	control
2	SA1_XTD2_IMGPII45/DCTRL/LED_POWER	control

Expert Sources

	Source	Type	Behavior	Monitor out
0	SA1_XTD2_IMGPII45/DCTRL/CAM_POWER	control	record-all	<input checked="" type="checkbox"/> True
1	SA1_XTD2_IMGPII45/DCTRL/LED_POWER	control	record-all	<input checked="" type="checkbox"/> True

SA1_DAQ_DATA/DM/CONFIGURATOR

Run config. groups

source	type	behavior	monitor	access
<input checked="" type="checkbox"/> SPB_XTD9_XGM				
<input checked="" type="checkbox"/> SA1_XTD2_IMGPII45				
SA1_XTD2_IMGPII45/DCTRL/CAM_POWER	control	record-all	True	expert
SA1_XTD2_IMGPII45/DCTRL/LED_POWER	control	record-all	True	expert
SA1_XTD2_IMGPII45/SWITCH/SCREEN_OUT	control	record-all	True	expert
SA1_XTD2_IMGPII45/CAM/BEAMVIEW	control	record-all	True	expert
SA1_XTD2_IMGPII45/CAM/BEAMVIEW:daqOutput	control	record-all	True	expert
SA1_XTD2_IMGPII45/MOTOR/SCREEN	control	record-all	True	expert
<input checked="" type="checkbox"/> SA1_XTD2_IMGSR				
<input checked="" type="checkbox"/> SA1_XTD2_XGM				
<input type="checkbox"/> SA1_XTD2_KMONO				
<input type="checkbox"/> SA1_XTD2_IMGSEL				
<input type="checkbox"/> HIREX DATA				
<input type="checkbox"/> MCP_X2_DOWNSTREAM				
<input type="checkbox"/> SA1_WP74_KMONO_DOOCs				
<input type="checkbox"/> MCP_X1_UPSTREAM				
<input type="checkbox"/> SCANTOOL SA1				
<input type="checkbox"/> BEAM_COND				
<input type="checkbox"/> SA1_XTD2_IMGSEL_RED				
<input type="checkbox"/> SA1_MOTOR				
<input type="checkbox"/> SA1_XTD2_CRL				
<input type="checkbox"/> SA1_XTD9_IMGPII45				
<input type="checkbox"/> SPB_XTD9_IMGPI				

Send to DAQ

Run Control

SA1 Run Controller

Proposal number 900007 900007 Retrieve proposal

Update State MONITORING

White list SA1_DAQ_DATA/DA/1 SA1_DAQ_DATA/DA/1

Black list

Pipeline data handlers SA1_DAQ_DATA/DA/1

Slow data handlers SA1_DAQ_DATA/DA/1

Available SA1_DAQ_DATA/DA/1

Disabled

XTDF data handlers

Ignore data Assign data sources to aggregators

Data sources to data aggregators mapping

	Data source	Data aggregator
0	@SA1_XTD2_IMGPII45	SA1_DAQ_DATA/DA/1
1	@SPB_XTD9_XGM	SA1_DAQ_DATA/DA/1

Ignore data Apply configuration

Experiment

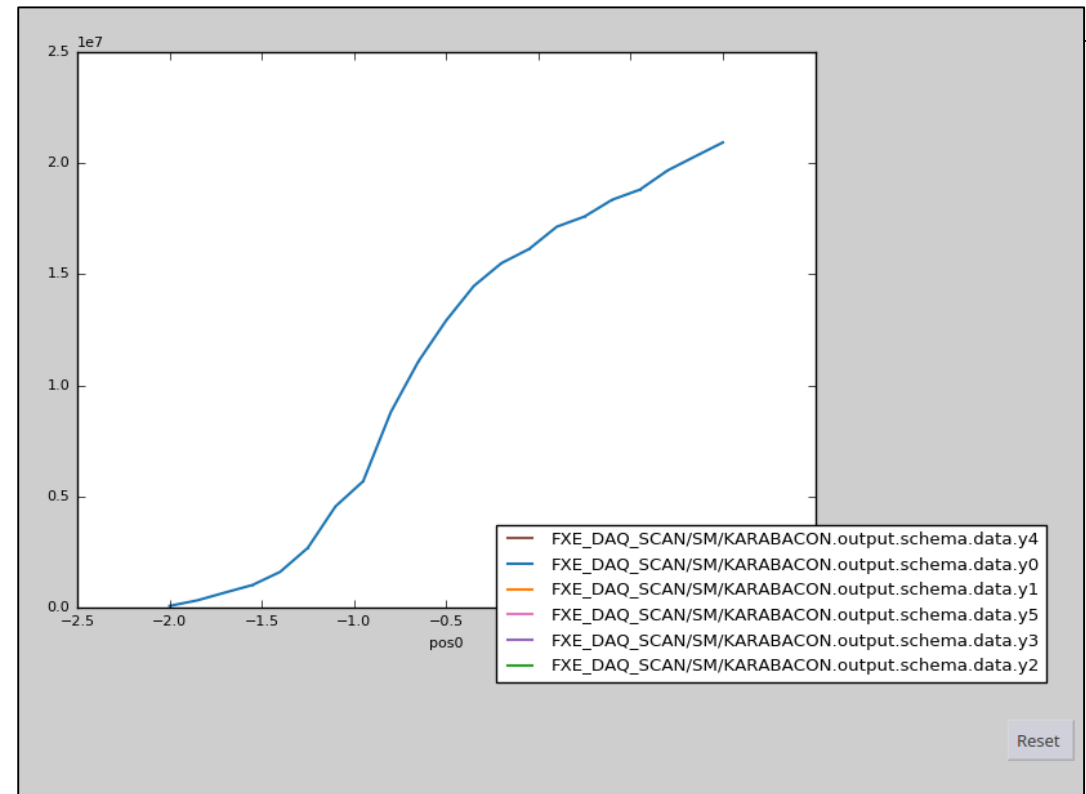
Sample

Train Id 18516999 Run number 0

Monitor data Start run Stop run

Scan Tool

- DAQ-integrated step scans:
 - one scan - one DAQ run.
- GUI and (spec like) command line.
- Configure devices:
 - abstract motor(s): steps to take,
 - passive and active (“triggers”) data sources.
- Scan types
 - absolute – 1-4 motors: ascan, a2scan,...
 - relative – 1-4 motors: dscan, d2scan,...
 - 2D grid – absolute and relative: mesh, dmesh
- Plotting being extended to non-scalar data



State
Progress 0 %

isConfigured ●

Start Scan

Start Scan

Stop Scan

Stop Scan

Toggle scan

Toggle scan

Configure

Configure

Scan Parameter

Scan Type

ascan

ascan

Start Positions

0.0

0.0

Stop Positions

10.0

10.0

Steps

10

10

Bidirectional

☐
☐

[19:18:33]: No sources selected!


[19:18:38]: Scan environment is configured!

----- Configuration -----

Motors: ['MOTOR1:default']

Data Sources: ['SENS1:default']

Triggers: []

 European XFEL

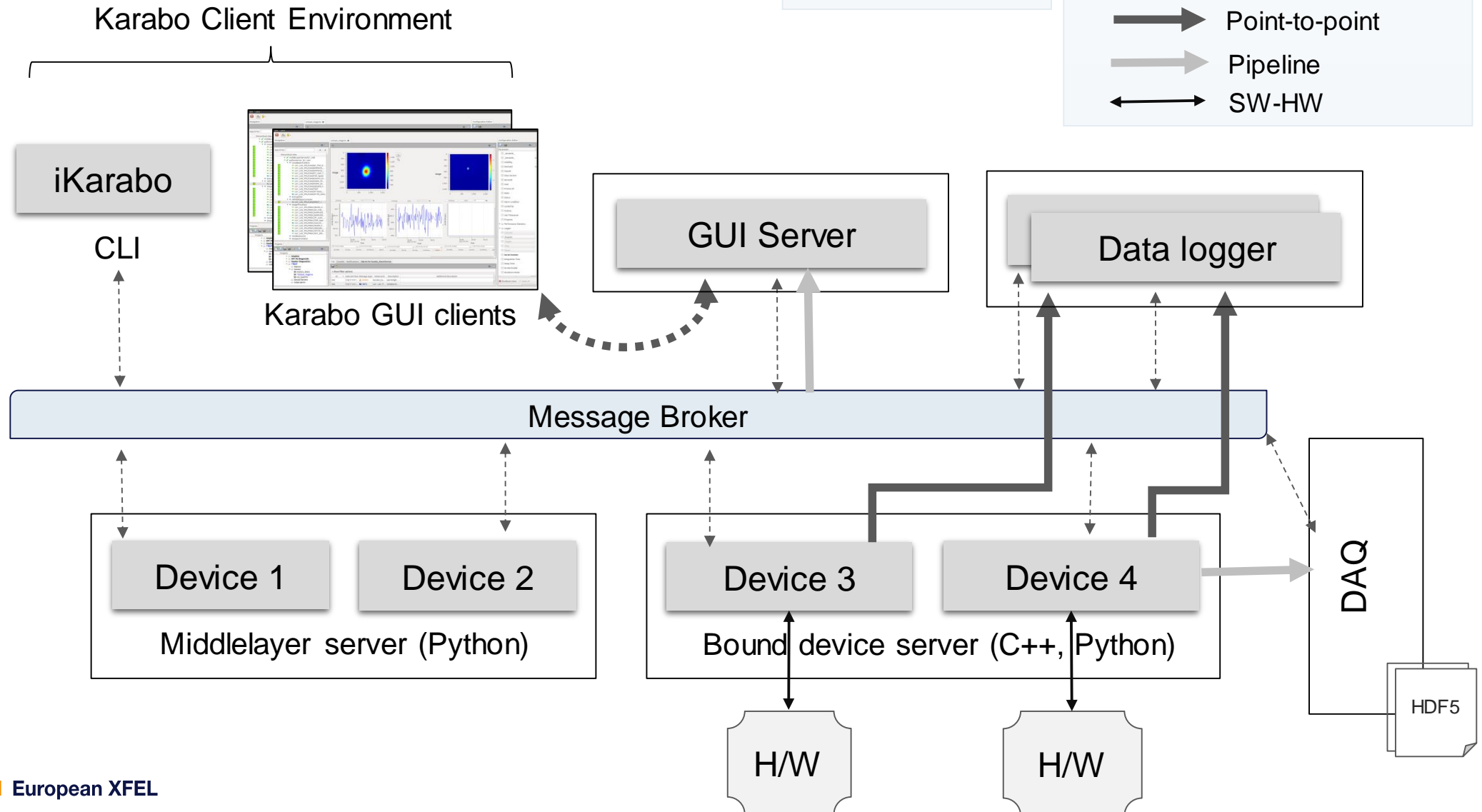
Karabo: Supervisory Control and Data Acquisition (SCADA) at work!

- Running several thousand Karabo devices at European XFEL
 - Instruments, beam lines, ...
- Data acquisition successfully stored “big data” in first user experiments:
 - FXE instrument: 57 TB
 - SPB instrument: 389 TB
- Pipeline processing:
 - LPD gain characterization "routinely" processes 3.5TB of data automatically within two days.

Summary

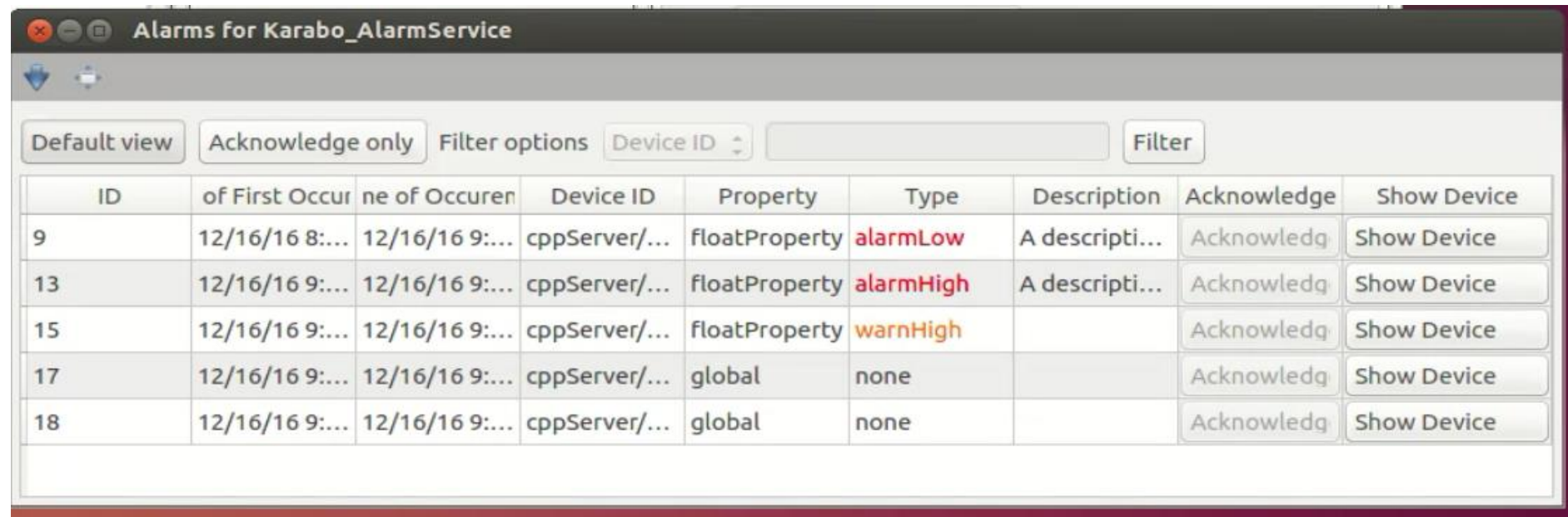
- Karabo, an integrated framework for
 - Instrument Control
 - Data Acquisition
 - Data Management
 - Scientific Computing
- Broker based communication
- Workflow support through data pipelines, e.g. for online monitoring
- Four APIs (C++, Python) for extensions
- GUI easily customizable via scenes
- Experiment automation using macros and scan tools
- [1] B. Heisen et al: "Karabo: An integrated software framework combining control, data management, and scientific computing tasks," in 14th ICALEPCS2013. San Francisco, CA, 2013.

Architecture



Alarms

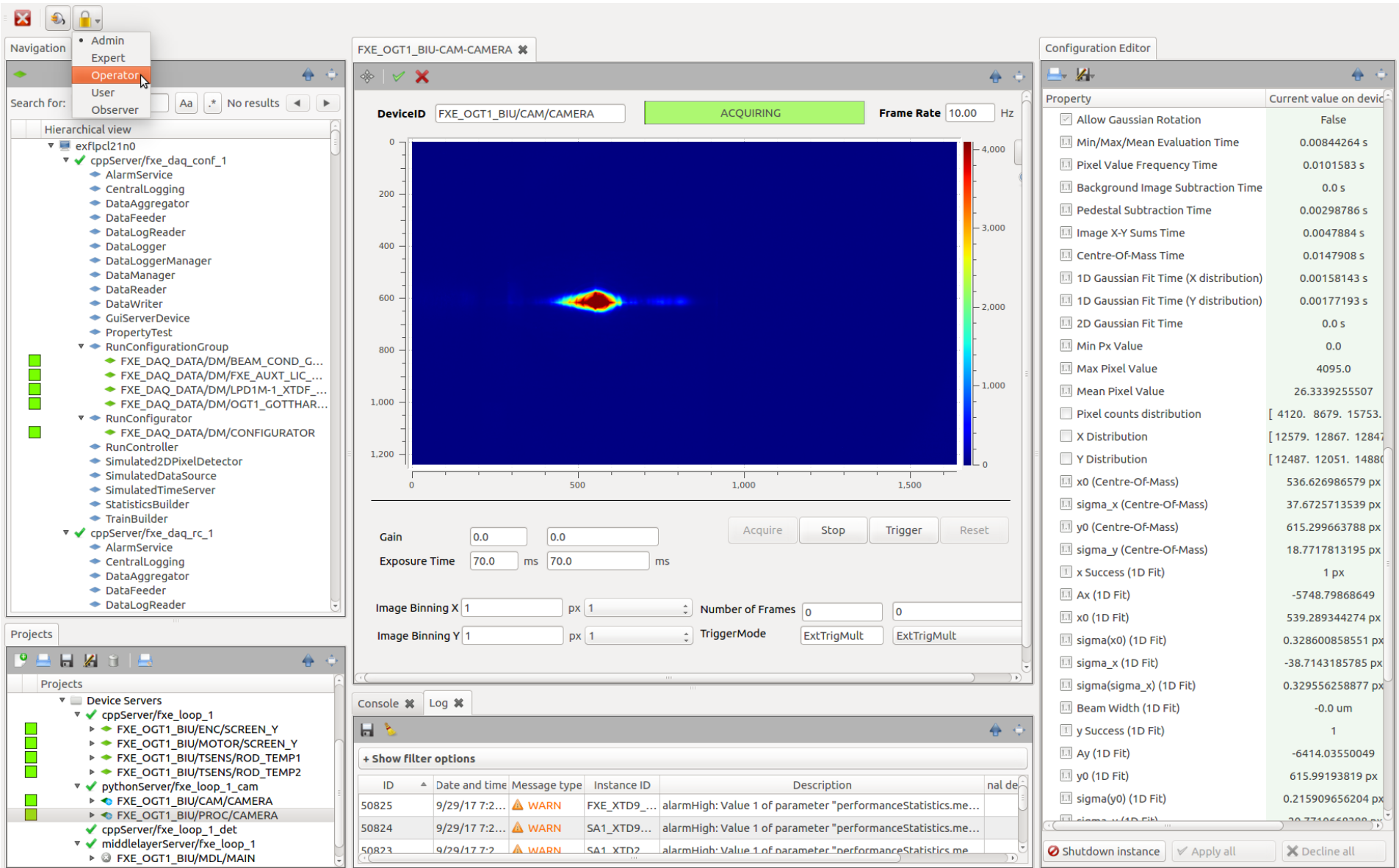
- Reports any trespassing of property-specific thresholds
- Can be investigated from the GUI and acknowledged as soon as the alarm condition has passed



ID	of First Occur	ne of Occuren	Device ID	Property	Type	Description	Acknowledge	Show Device
9	12/16/16 8:...	12/16/16 9:...	cppServer/...	floatProperty	alarmLow	A descripti...	Acknowledged	Show Device
13	12/16/16 9:...	12/16/16 9:...	cppServer/...	floatProperty	alarmHigh	A descripti...	Acknowledged	Show Device
15	12/16/16 9:...	12/16/16 9:...	cppServer/...	floatProperty	warnHigh		Acknowledged	Show Device
17	12/16/16 9:...	12/16/16 9:...	cppServer/...	global	none		Acknowledged	Show Device
18	12/16/16 9:...	12/16/16 9:...	cppServer/...	global	none		Acknowledged	Show Device

Scene Example

Experiment Control:
FXE's Beam Imaging Unit



Introduction to Value Displays

- Karabo comes with a set of standard visualization options for:
 - ▶ Scalars
 - ▶ Vectors
 - ▶ Images
 - ▶ Image stacks

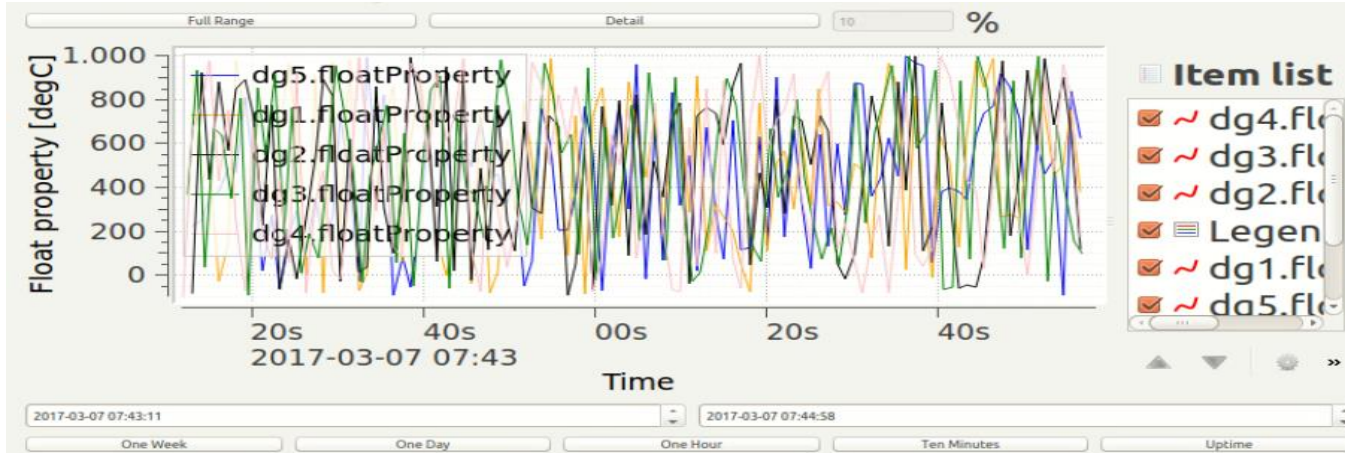
- For scalars: value field, expression evaluation, trendline, sparklines, x-y plots, bit fields, checkboxes

- For vectors: value fields, x-y plots, categorial plot

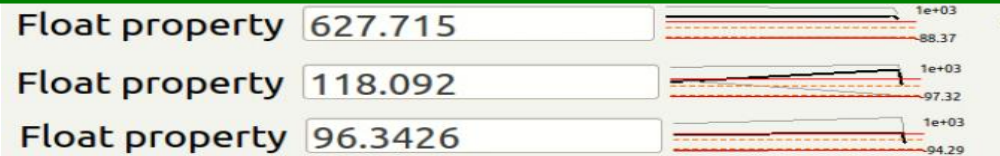
- For images: scientific, webcam, minimal, stacked

Introduction to Value Displays - Scalars

Trendline



Sparkline



Bool property ☐

Integer property 390

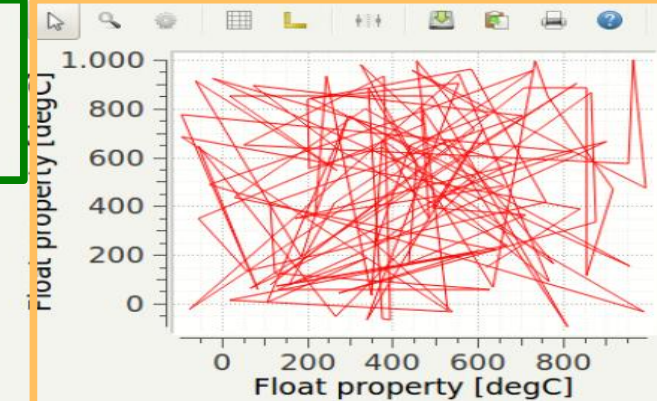
Integer property 186

Integer property

Integer property ☐

Integer property 390

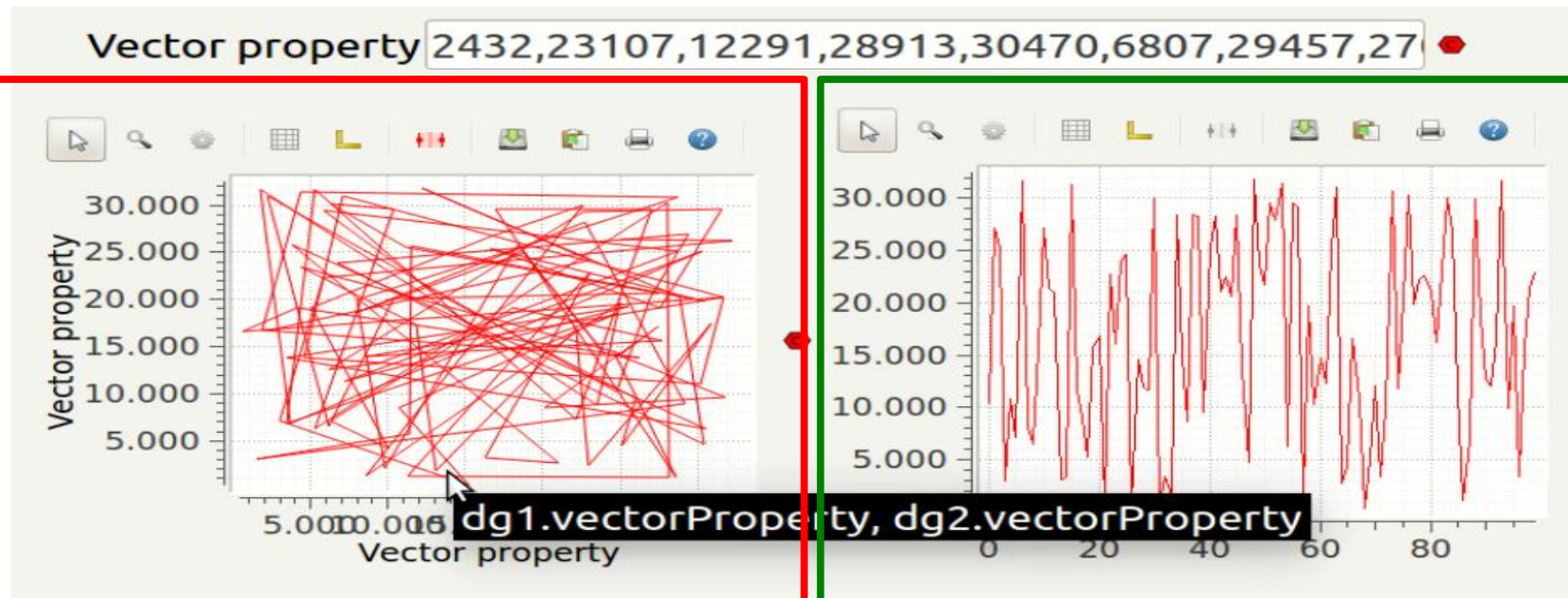
BitField



X-y plot

Introduction to Value Displays - Vectors

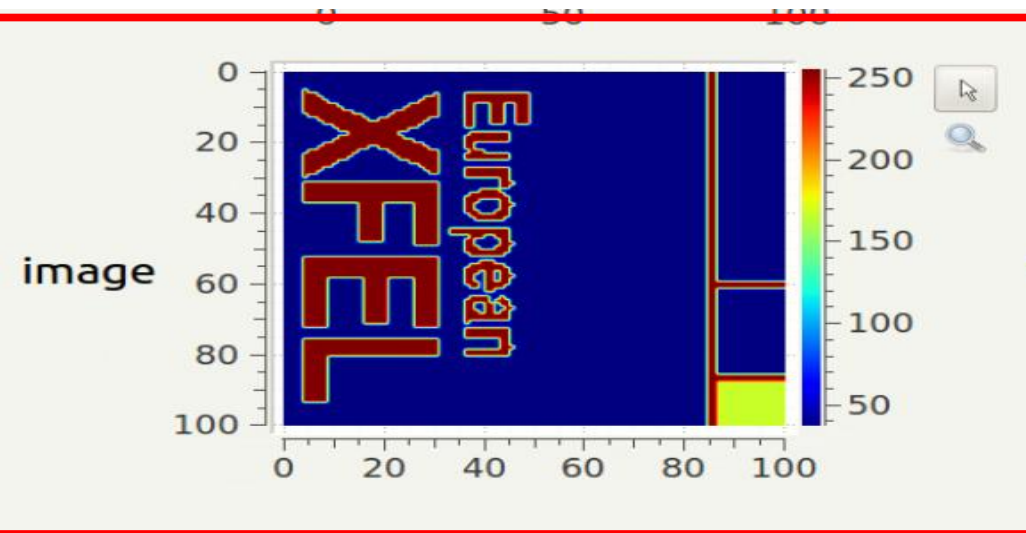
X-y plot



Categorical plot

Introduction to Value Displays - Images

Webcam



Scientific,
stacked

