Automatic Machine
&
Control

Vincent Hardion on behalf of KITS Group, MAXIV
Automatic Machine Workshop

Agenda

Automation

KITS organisation

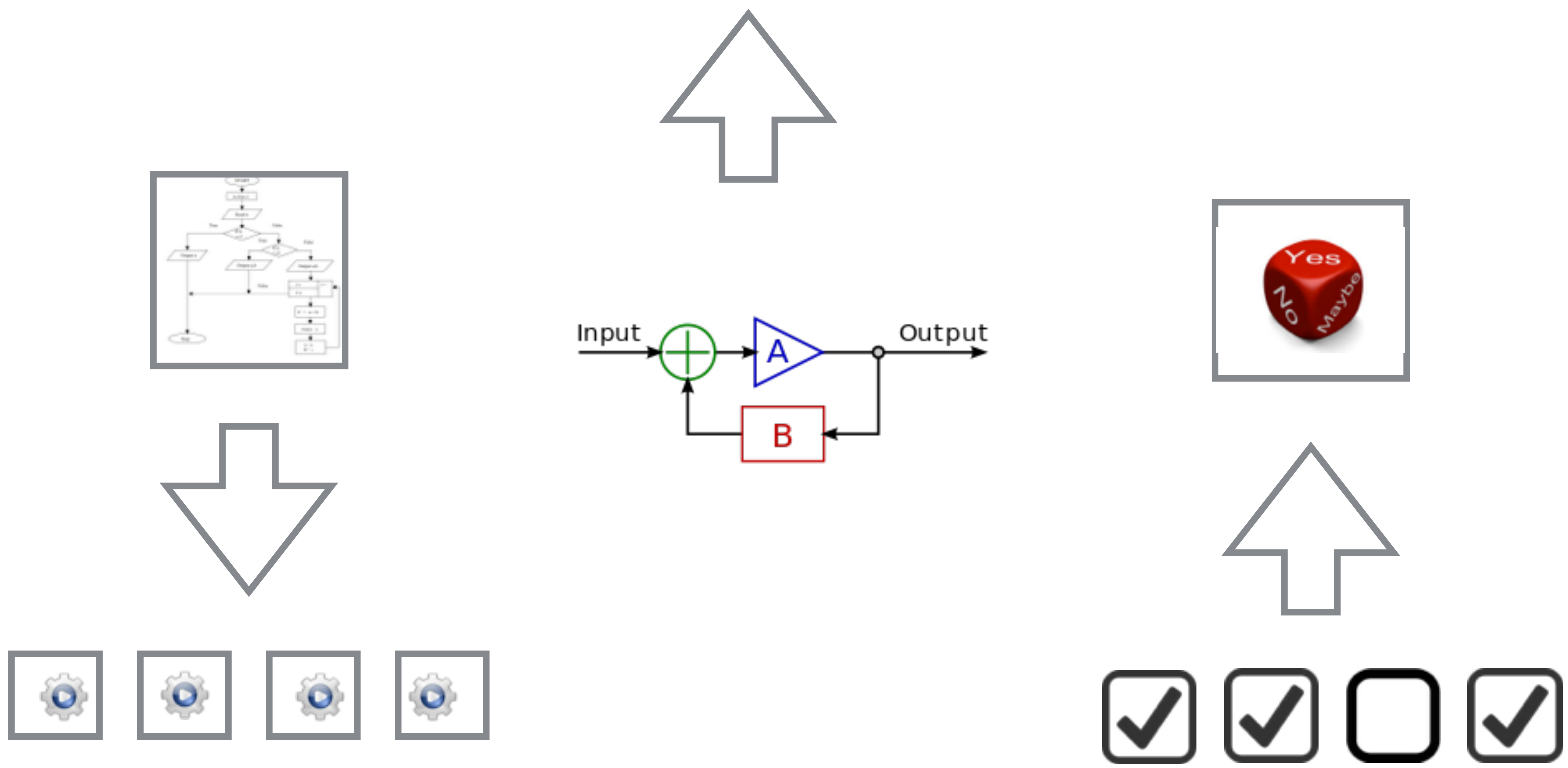
Robustness

Services

Examples

Automation in Control

Metrics

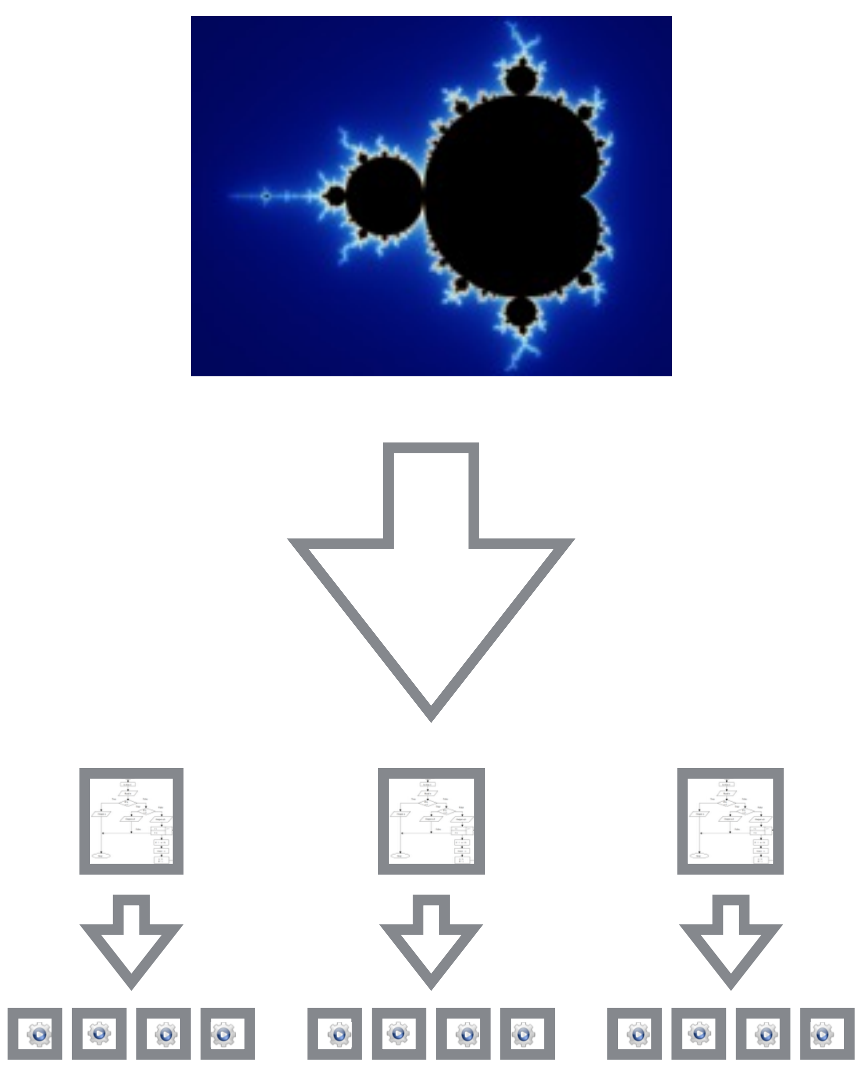


Reduce
repetitive operations
to sequence

Decision taken

Constraints of Automation?

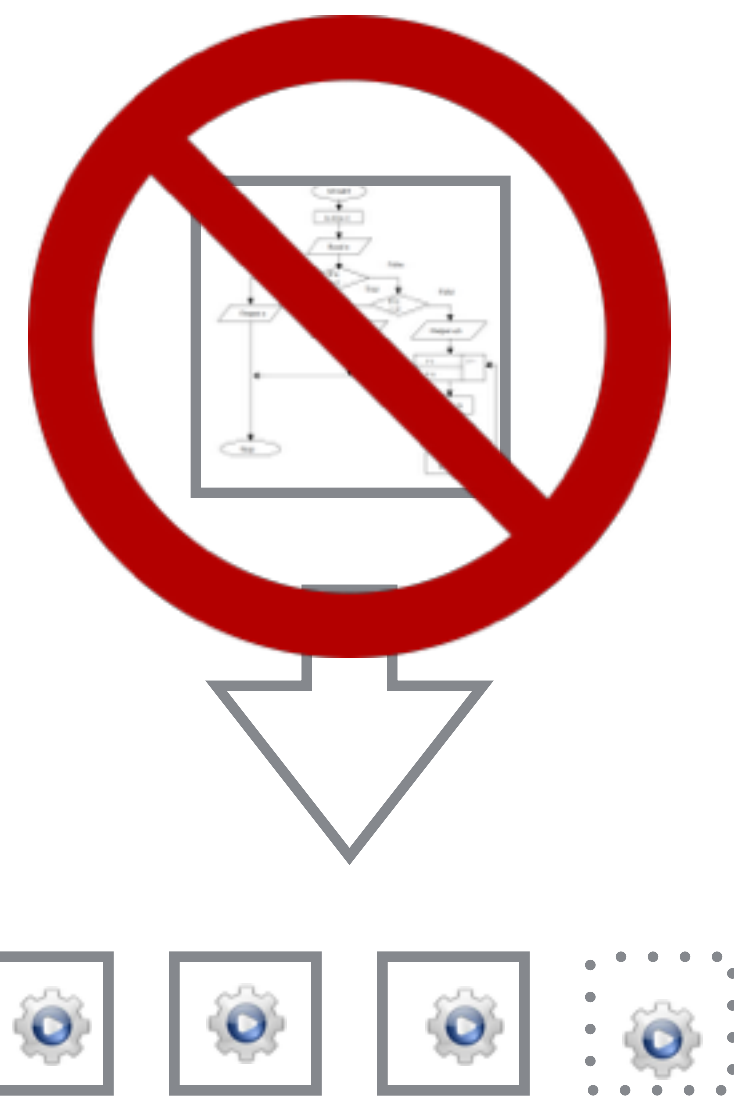
When to start and stop?



Virtually no limit

Based on pattern

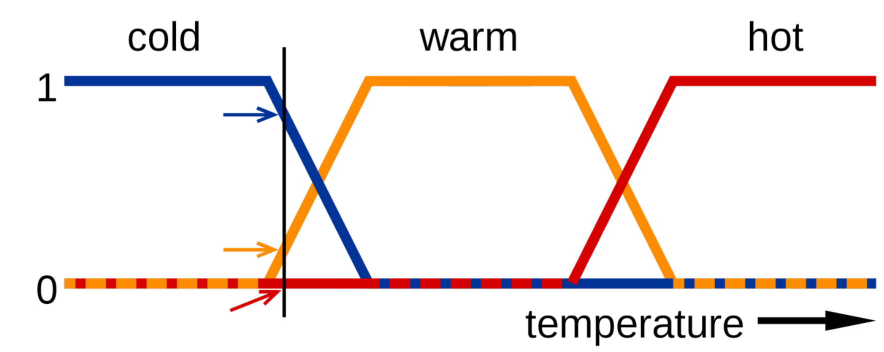
Stable

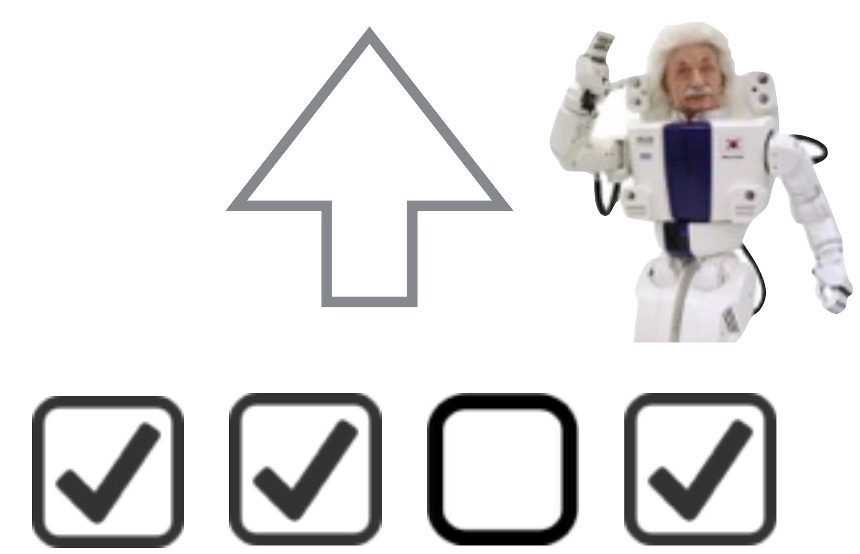


Operations

vs R&D

Analysis of feedback





Sometimes the more measurable drives out the most important.

--René Dubos

IT Organisation

Present Kontroll & IT Group

Group Head of Controls and IT
Darren Spruce

Control System Software
Vincent Hardion

Paul Bell
Mirjam Lindberg
Antonio Otero-Milan
Andreas Persson
Johan Forsberg
Vasileios Martos
(+1 recruitment)

Mikel Eguiraun (BioMAX)
Vincent Michel
Fredrik Bolmsten (BioMAX)

Antoine Dupres: consultant
Sebastien Gara: consultant

Control System Hardware
Julio Lidon-Simon

Jerzy Jamroz
Peter Sjöblom
Gabriela Todorescu

Scientific and Information Management
Krister Larsson

Jason Brudvik
Alberto Nardella
Sudha Padmanabhan

System Engineering and Administration

Daniel Liikamaa
Andreas Mattson

Scientific Software Coordination
(+1)

Servers and Network Architecture

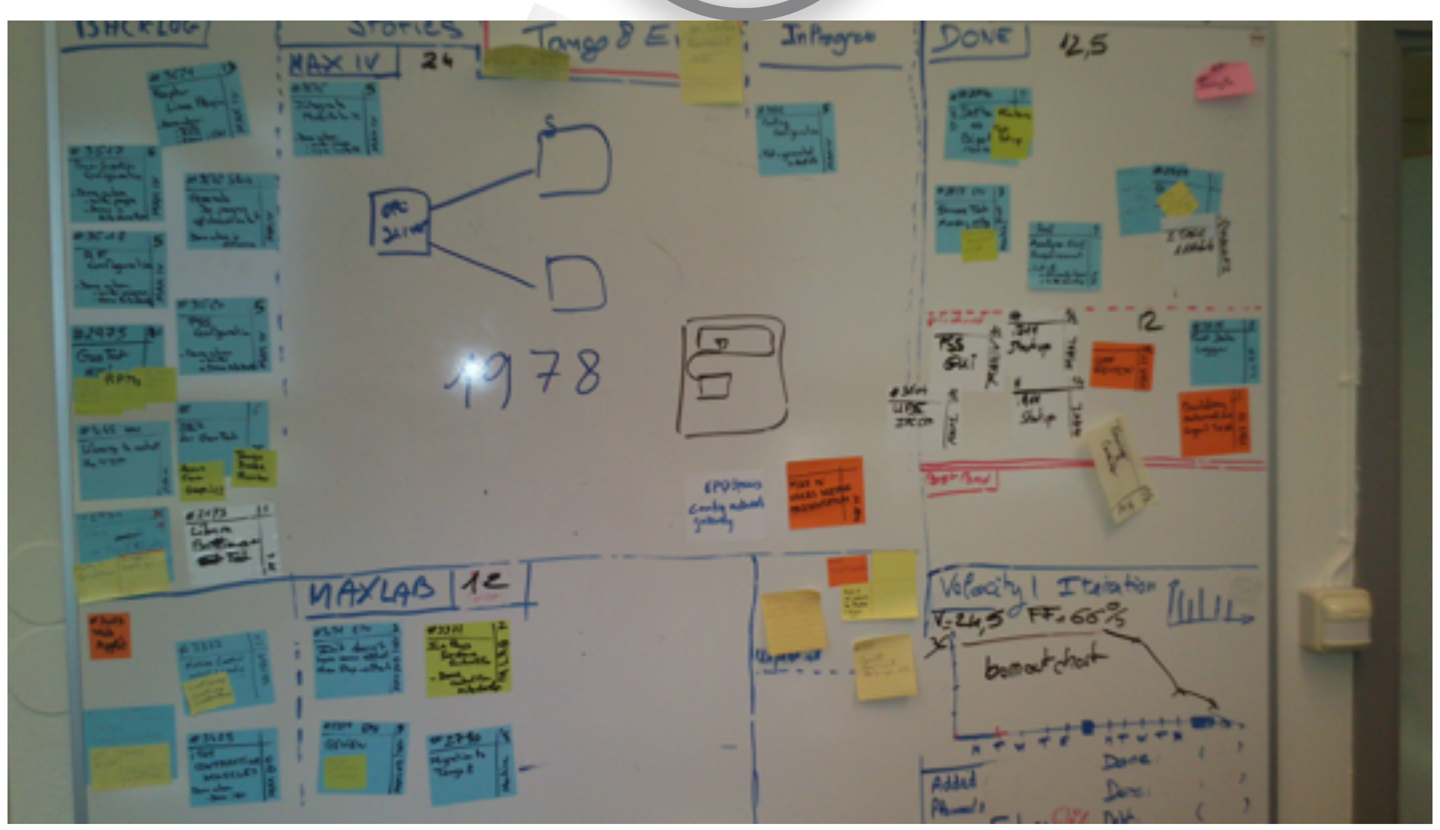
Maria Rosu*
Carl Cristian Arlock

IT Support

Anders Holmström
Henrik Jonsson

Lean and Agile (SCRUM)

Short Term — *Troubleshooting, unforeseen small tasks, informal meetings, brainstorming*



KITS biweekly planning

Accelerator biweekly controls planning

Issue Tracker

Other Project Meetings (3-6 Months)

MAC

SR

Long Term Planning (every 2 months)

LTP

Sub System Responsibles contact points

	KITS (10.5)	Linac	Storage Rings
Project Coordination	Julio + Vincent	Magnus S, Dieter	
		Sara, Erik	Pedro
Power Supplies	Mirjam	Claes, Pedro	
PLC + Vacuum	Mirjam	Johan T, Claes	
RF +LLRF	Antonio	Lars M	
Timing	Jerzy	Magnus S, Lars M, Pedro	
Magnets	Paul	Magnus S, Martin	
Motion Control	Julio	All	
PSS	Andreas	Magnus L	
Cooling	Andreas	Claes	
Control Room GUIs	Johan F.	Sara, Magnus, all	
Diagnostics	Paul	Erik M, Robert Nilsson, all	
High Level Physics	Jason Brudvik	Sara, Lennart	

Collaboration

Solaris: Budker pulse magnet, Danfysik PS, R&S RF Transmitter, Spectrum Analyser

Alba for all python software including Sardana and Taurus, Electrometer

ESRF Tango and Icepap

Soleil for the pulsed magnet, the nano probe, the wiggler and MxCube

ELI, ESS and others by sharing the experience (workshop)

Nexeya and **Cosylab**

Robustness

Robustness?

Statistics from Starters
Between 02 Dec 2009 01:00:35 and 26 Nov 2015 08:42:08 on:
95/106 Controlled hosts
1640 Controlled servers
Nb failures: 670
Availability: 99.0256 %

During 2185 days 7 h 41 mn 33 sec. 325 servers have failed

Server Name	Host Name	Failur...	Failure Duration	Availability	Last Failure
LiberaSinglePassE/I-KTR1-RFS...	i-ktr1-cab04...	1	-4229133.0 sec.	102.2431 %	19 Jan 2010 23:46:11
LiberaSinglePassE/I-K08-RFSPE3	i-kbc2-cab04...	3	-1294816.0 sec.	100.6911 %	02 Dec 2009 01:03:07
LiberaSinglePassE/I-KTR1-RFS...	i-ktr1-cab04...	2	-10011.0 sec.	100.0053 %	14 Apr 2015 14:34:52
AlarmPLC/2	g-v0-ec-0	1	8.0 sec.	100.0000 %	19 Dec 2013 11:13:42
SnapManager/01	g-v0-adb-2	1	6.0 sec.	100.0000 %	
RTMScope/I-K00-TEMP	g-v0-ec-10	1	4.0 sec.	100.0000 %	
LiberaSinglePassE/I-KBC2-RFS...	i-kbc2-cab04...	1	38 sec.	100.0000 %	
RTOScope/I-KBC2-CT	g-v0-ec-4	1	4.0 sec.	100.0000 %	
Eurotherm/I-K00	g-v0-ec-7	1	12 sec.	100.0000 %	
K2Modulator/I-K15	g-v0-ec-5	1	6.0 sec.	100.0000 %	
DeltaController/I.KBC1	g-v0-ec-1	1	16 sec.	100.0000 %	
OPCaccessDs/MAG	g-v0-ec-0	1	20 sec.	100.0000 %	
LiberaSinglePassE/I-KBC1-01	i-kbc1-cab04...	1	1 mn 08 sec.	100.0000 %	
RTOScope/I-KBC1-CT	g-v0-ec-4	1	8.0 sec.	100.0000 %	
loggerds/g-v0-ec-1	g-v0-ec-1	1	14 sec.	100.0000 %	
LiberaSinglePassE/I-KBC2-01-...	i-kbc2-cab04...	1	4.0 sec.	100.0000 %	
DeltaController/I-C080007	g-v0-ec-6	1	18 sec.	100.0000 %	
LiberaSinglePassE/I-KTR1	i-ktr1-cab04...	2	1 mn 24 sec.	100.0000 %	
LiberaSinglePassE/I-KBC2	i-kbc2-cab04...	1	1 mn 28 sec.	100.0000 %	
OPCaccessDs/VAC	g-v0-ec-0	1	33 sec.	99.9999 %	
LiberaBrilliancePlus/R3-301M...	r3-a110111-...	1	10 sec.	99.9999 %	
OPCAccessDs/PSS	g-v0-ec-2	1	42 sec.	99.9999 %	
DeltaController/I-C080008	g-v0-ec-6	1	32 sec.	99.9999 %	
LiberaSinglePassE/I-KBC2-RFS	i-kbc2-cab04	1	2 mn 28 sec	99.9999 %	

Statistics from Starters
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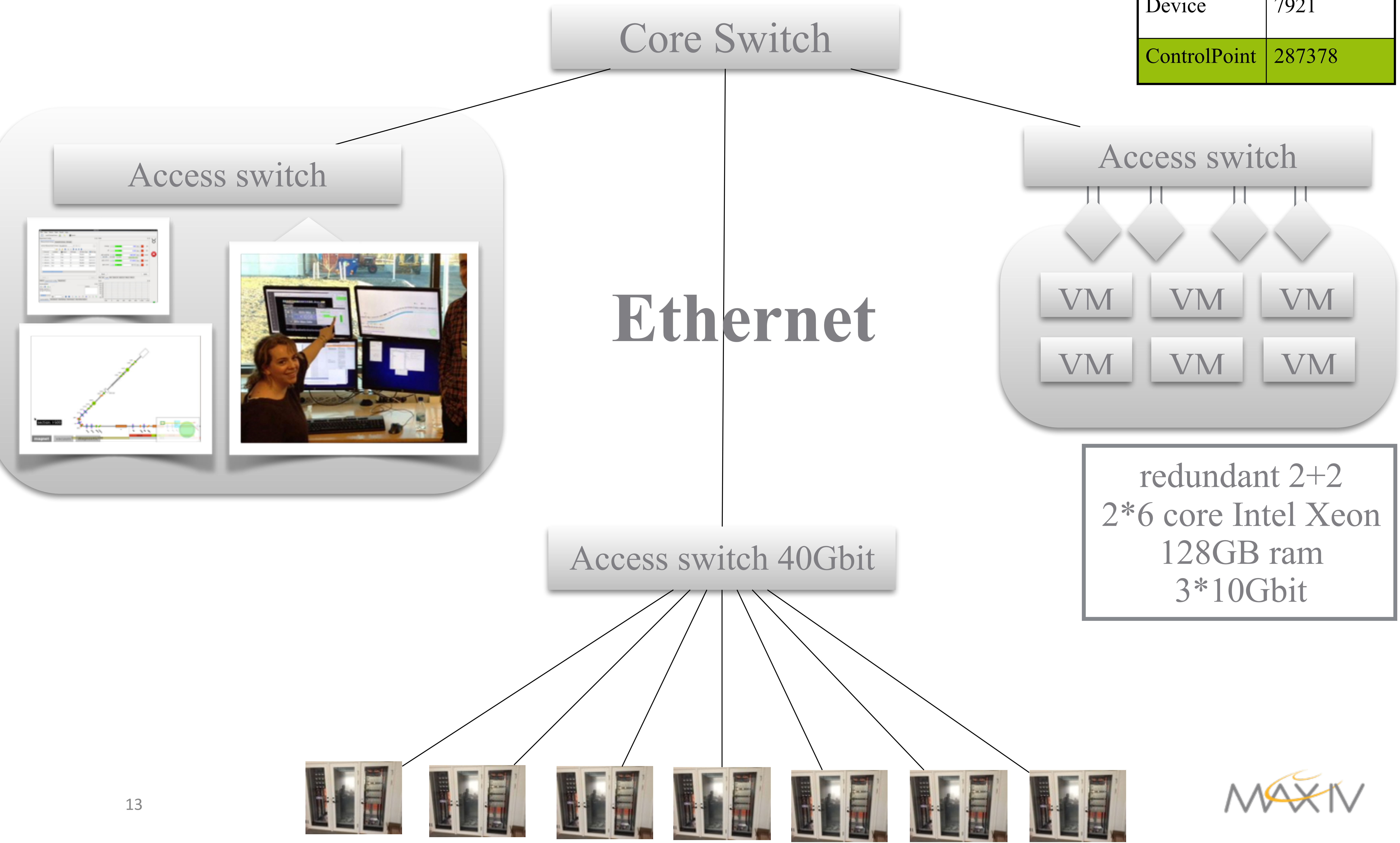
Server Name	Host Name	Failur...	Failure Duration	Availability	Last Failure
CTAveraging/I-CT-KBC1	g-v0-ec-4	3	17 days 19 h 00 mn ...	95.3624 %	18 Apr 2015 12:18
Fconc/R3-A111311-CAB04-C...	g-v0-ec-22	1	6 days 22 h 14 mn 5...	94.5205 %	07 Sep 2015 13:05
OPCaccessDs/I-PSS	g-v0-ec-2	17	38 days 7 h 58 mn 0...	93.2386 %	11 Nov 2015 08:21
OPCaccessDs/I-PSS-WATCHDOG	g-v0-ec-2	6	36 days 5 h 07 mn 4...	93.2163 %	08 May 2015 09:24
OPCAccessDS/I-WAT	g-v0-ec-0	5	52 days 21 h 29 mn ...	90.6825 %	08 May 2015 11:20
Fconc/R3-A110211-CAB04-C...	g-v0-ec-22	2	12 days 1 h 25 mn 1...	90.4608 %	23 Jul 2015 10:05:
ModulatorConditioner/I-K00	g-v0-ec-5	1	25 days 20 h 52 mn ...	89.6795 %	14 Oct 2015 16:06
Synchronizer/I-K00	g-v0-adb-1	4	48 days 14 h 14 mn ...	83.2257 %	16 Nov 2015 06:59
DelayGeneratorDG645/I-K00	g-v0-ec-5	2	47 days 19 h 57 mn ...	80.9199 %	13 Nov 2015 19:05
OPCaccessDS/I-VAC-SCRN	g-v0-ec-0	5	162 days 18 h 38 mn...	71.3268 %	17 Jun 2015 15:02
RohdeSchwarzRTM/I-K01	g-v0-ec-4	3	132 days 17 h 24 mn...	70.4166 %	03 Sep 2014 18:24
OPCaccessDs/I-MAG	g-v0-ec-0	9	182 days 6 h 48 mn ...	67.8906 %	31 Jul 2015 11:12:
PyAttributeProcessor/I-DIA	g-v0-ec-10	1	202 days 22 h 14 mn...	63.8701 %	13 May 2014 17:55
UnitedStates/I	g-v0-ec-10	3	138 days 2 h 27 mn ...	39.1050 %	04 Nov 2015 08:27
OPCaccessDs/PSS	g-v0-ec-0	2	721 days 13 h 29 mn...	6.4078 %	04 Dec 2013 19:15
FanoutConcentrator/R3-A110...	g-v0-ec-22	1	55 days 23 h 17 mn ...	5.1250 %	01 Oct 2015 10:24
FanoutConcentrator/R3-A111...	g-v0-ec-22	7	56 days 21 h 46 mn ...	3.5371 %	01 Oct 2015 10:24
AllenBradleyEIP/R3-315-VAC	g-v0-ec-9	1	250 days 15 h 43 mn...	1.6630 %	20 Mar 2015 16:58
OPCaccessDs/I-PSS-SEARCH	g-v0-ec-2	6	497 days 3 h 13 mn ...	0.3265 %	17 Jul 2014 06:38:
CTAveraging/I-CT	g-v0-ec-4	2	384 days 17 h 19 mn...	0.0122 %	06 Nov 2014 15:23
RohdeSchwarzRTO/I-K01	g-v0-ec-9	3	309 days 16 h 23 mn...	0.0012 %	20 Jan 2015 16:19
AllenBradleyEIP/R3-302	g-v0-ec-9	1	314 days 18 h 59 mn...	0.0000 %	15 Jan 2015 13:42
AllenBradleyEIP/R3-303	g-v0-ec-9	1	314 days 18 h 56 mn...	0.0000 %	15 Jan 2015 13:45
AllenBradleyEIP/R3-305	g-v0-ec-9	1	314 days 18 h 56 mn...	0.0000 %	15 Jan 2015 13:45

Robustness for the automation ISO 9126

Functionality	Usability	Reliability	Performance	Support.
~300 000 channels R/W @HW and Computation level **Need Feedback, Correction, Compensation and diagnostic**	Human factor: **Limited on general services**	Availability: MTTF in improvement (PSS Watchdog) but **Powersupply, Libera, Basler camera**… Known software issue (**Radiation Monitor**,…)	Speed: dependent on the hardware but enough for 100 Hz fast diagnostic	Testability: - Unit test on most of the Tango device, - Maintenance smoked test, - Incremental validation - **but less available time** - **obsolescence to manage**
Accurateness: functions tested and reviewed	Documentation: **Expert and Experienced People only**	Failure Extent: no metrics but day oncall support. VM fail over, monitoring of the servers	Efficiency: - **Time stamping in review**, - **Not enough for Archiving, snapshot and alarms**	Flexibility: - modularity of Tango - within scope > real time - management of the configuration **but Archiving, Snapshot …**
Reusability: - between accelerators - Tango binding and MML	Consistency: Standard Naming and behaviour (ALARM vs FAULT state)	Stability: overall the system is predictable	Resource consumption: 40 CPU & 80 GB, **Some HW bandwidth are consumed** (ITest)	Speed: - min 2 weeks iteration - real time for critical operation
Security: not required	Responsiveness to improve	Accuracy (Frequency/ Severity): No metrics but less urgent call; in continuous improvement	Throughput: Should handle camera at 50 Hz	Install-ability: - Accessible from dedicated local and remote computer
Compliance: not required			Capacity: **Scalability: yes but general service (mysql, polling system)**	Capacity: - possibility to increase the inventory

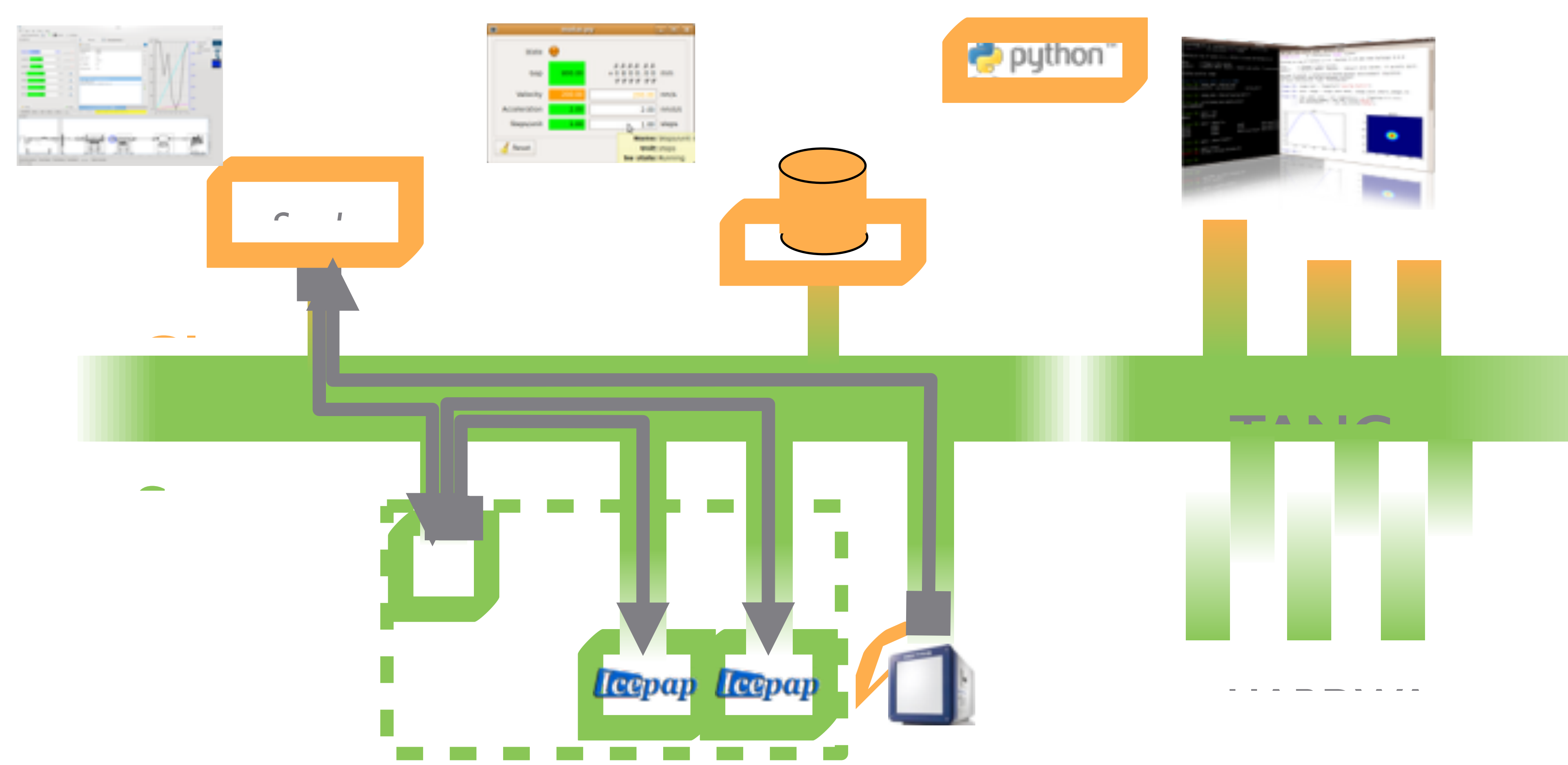
Network and System Architecture

Host	106
Process	1187
Device	7921
ControlPoint	287378



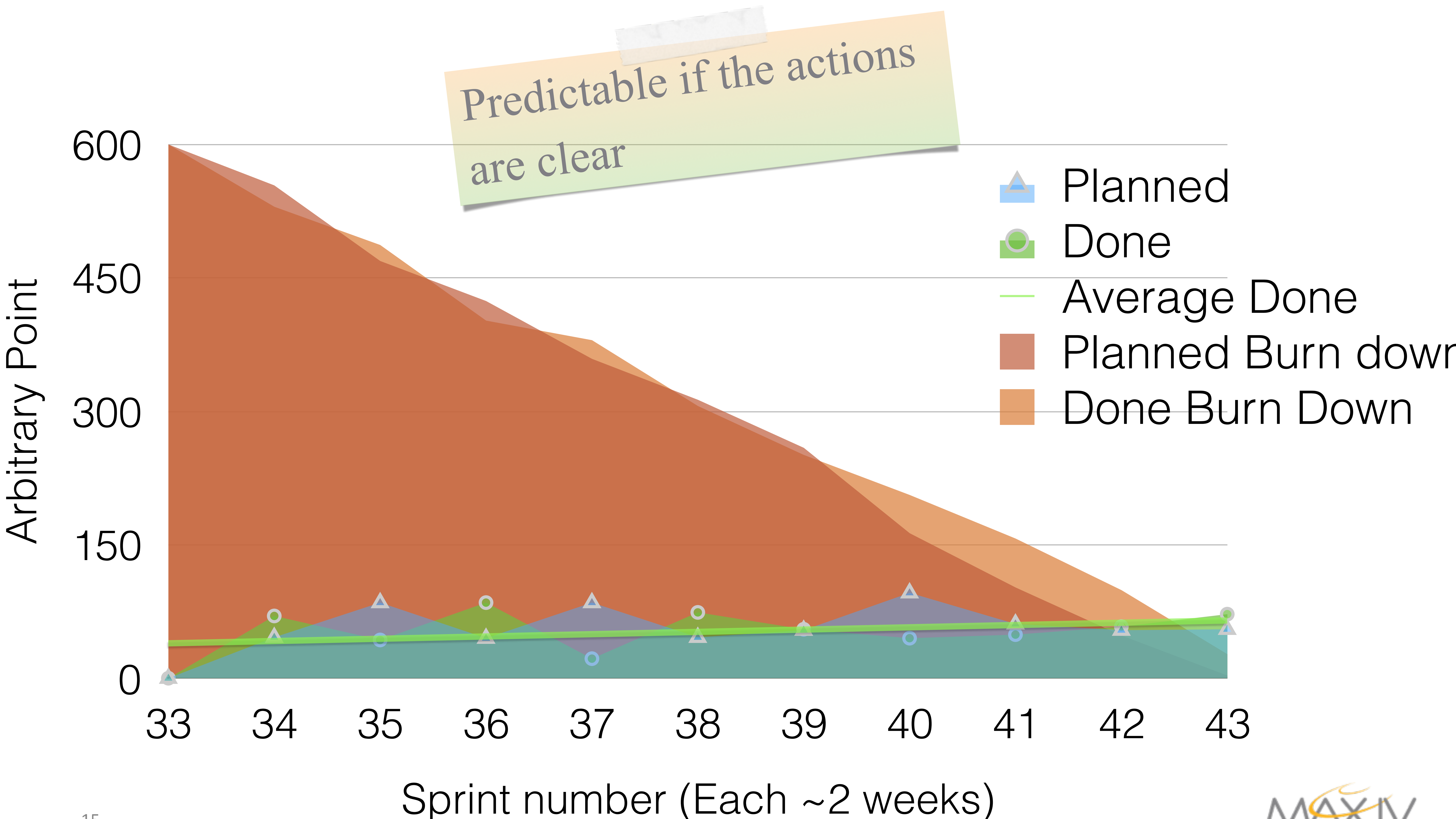
MAX IV CS Communication

- Good communication with the stakeholders
- Good participation of the stakeholders



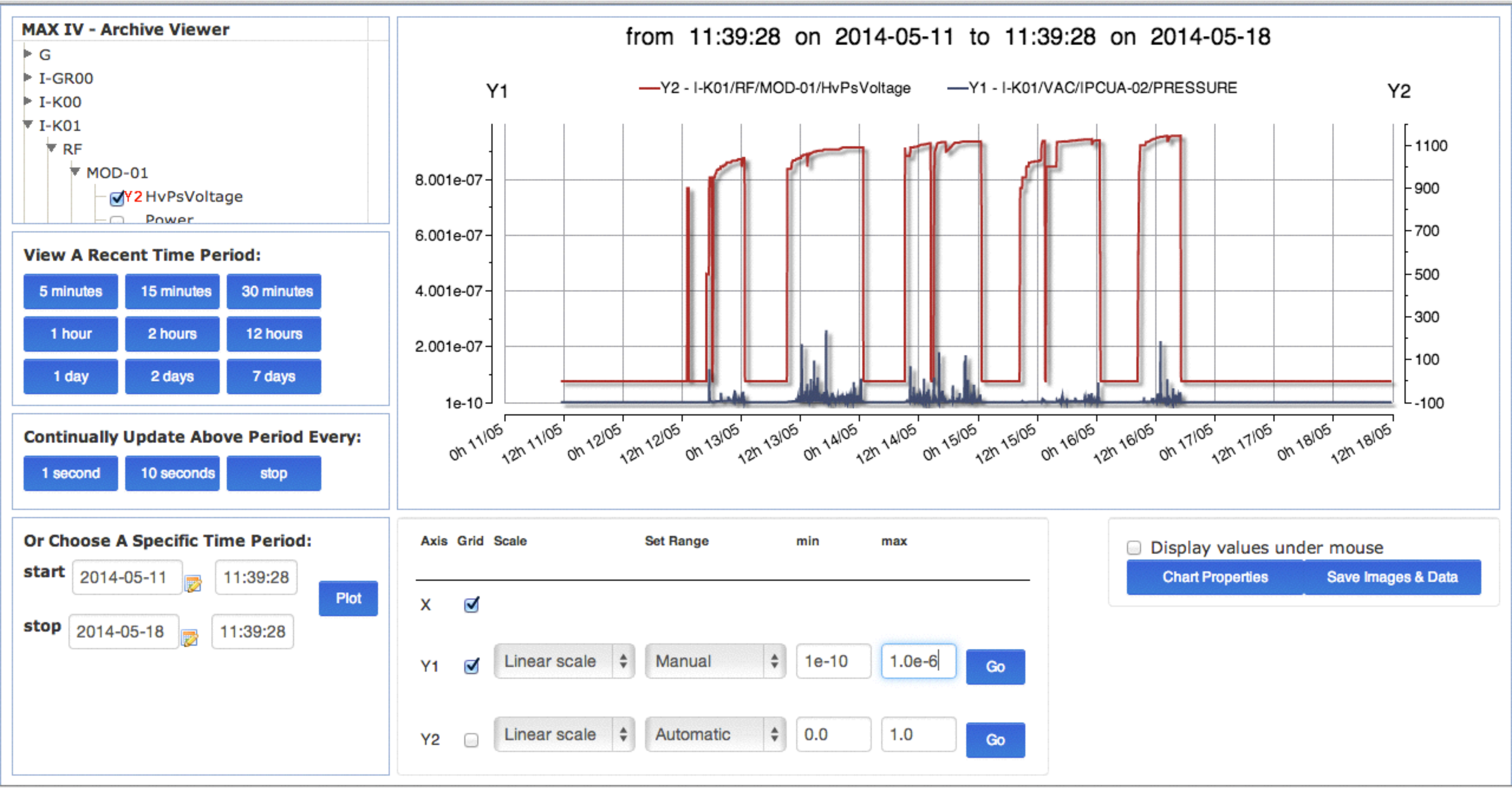
- Product Owner
- Unit Test
- Iterative validation
- Code review
- Sharing knowledge and standard

Agile 3 GeV Ring Installation and Test



CS Services

Services: Archiving



Services: Snapshot

Goal: System to restore the state of the Machine

Tango Snapshot (SOLEIL) allows to:

- reapply the set point
- reapply the read value
- select a subset of parameters
- compare to another snapshot

✖ but doesn’t reapply State in Tango definition

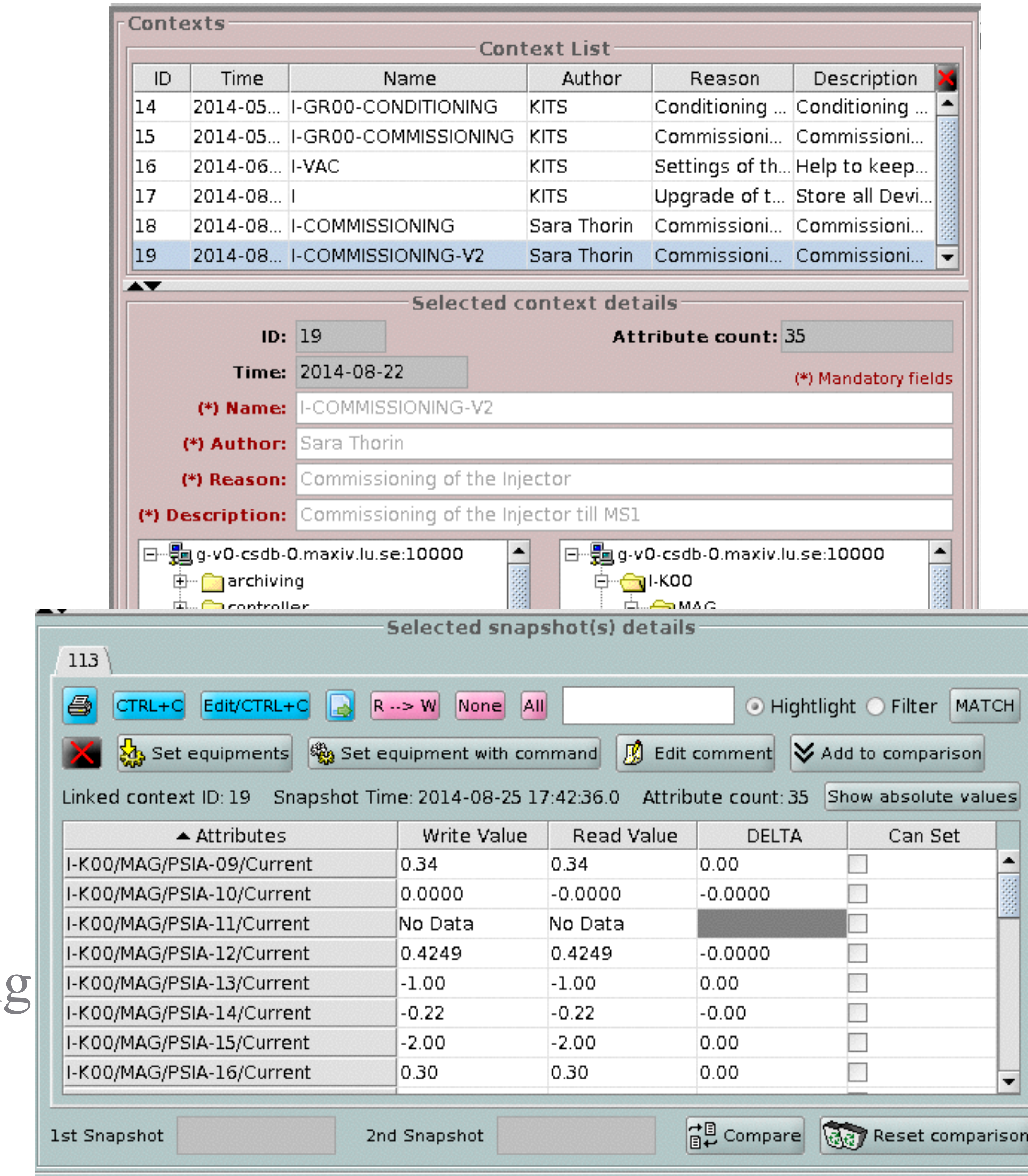
=> On/Off attribute

5 configurations:

- 1 general with 6313 settings

- 5 specific for conditioning, commissioning

=> to work in parallel



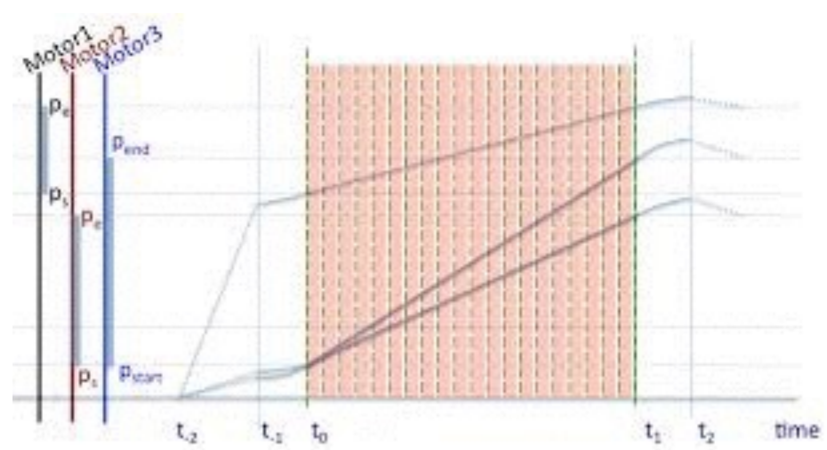
Services: Sequencing

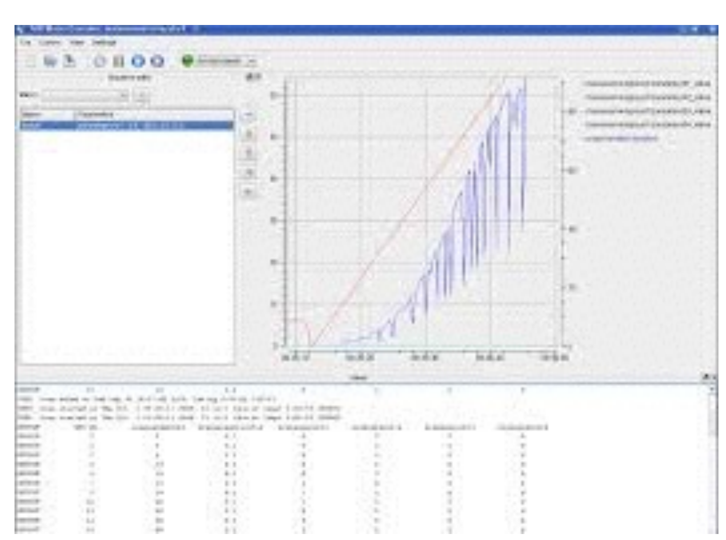
* Services

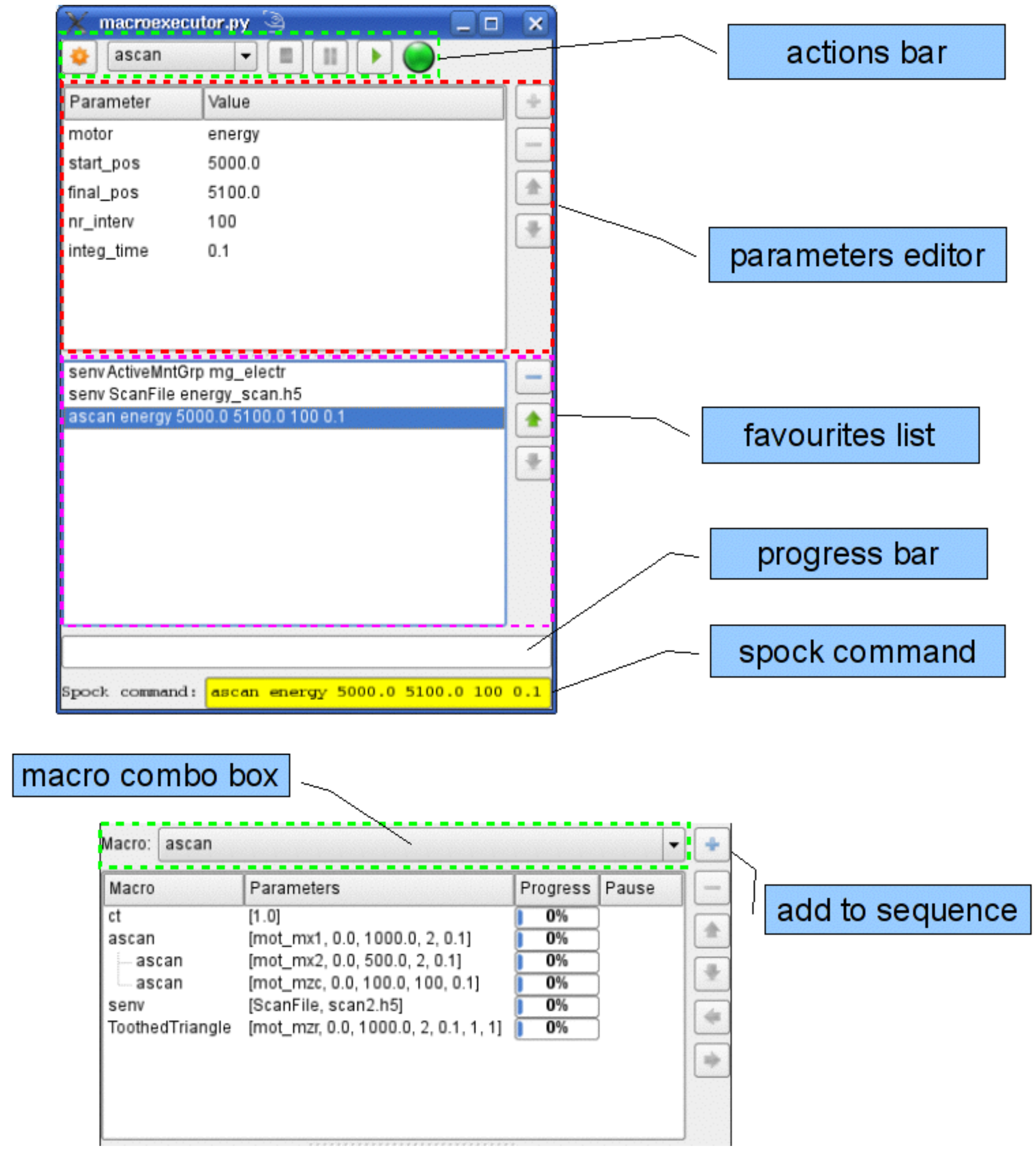
scan

macro

sequencing







Services: Status board

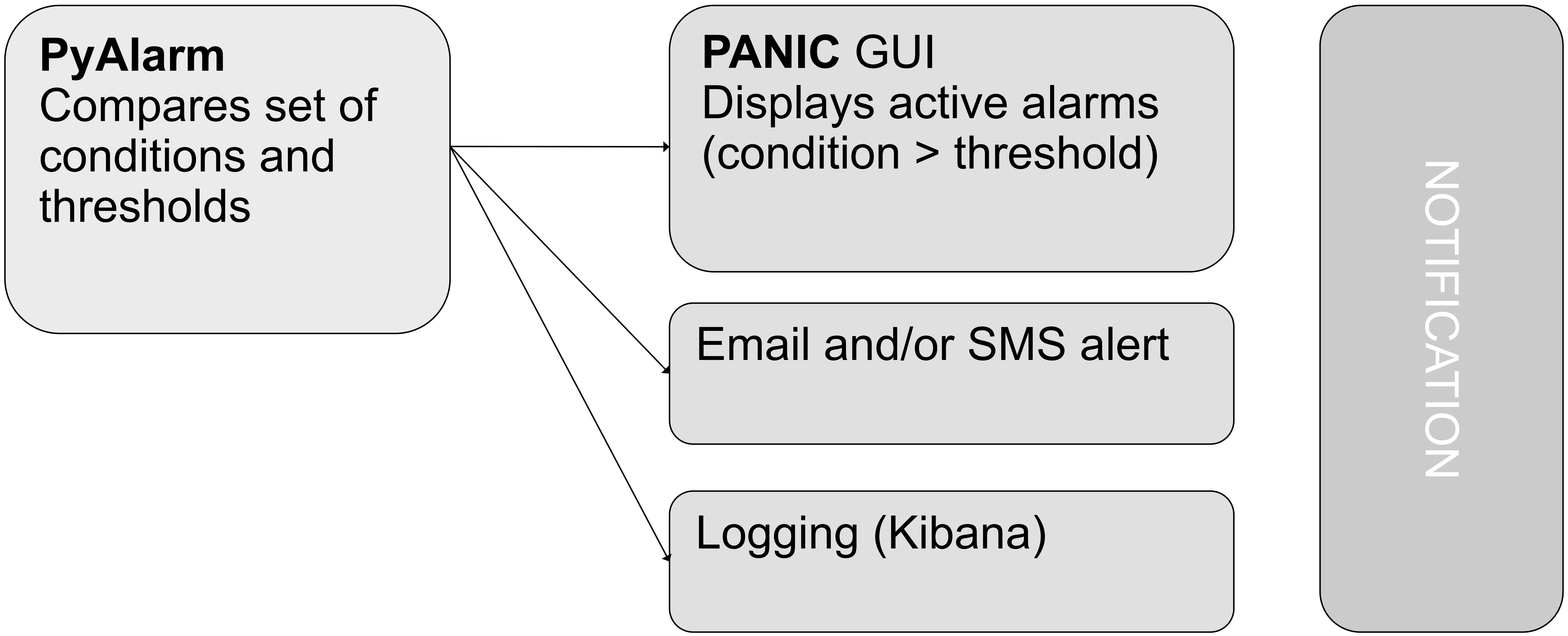
* Services

  Archiving, snapshot, sequencing (vincent)

  Status Board

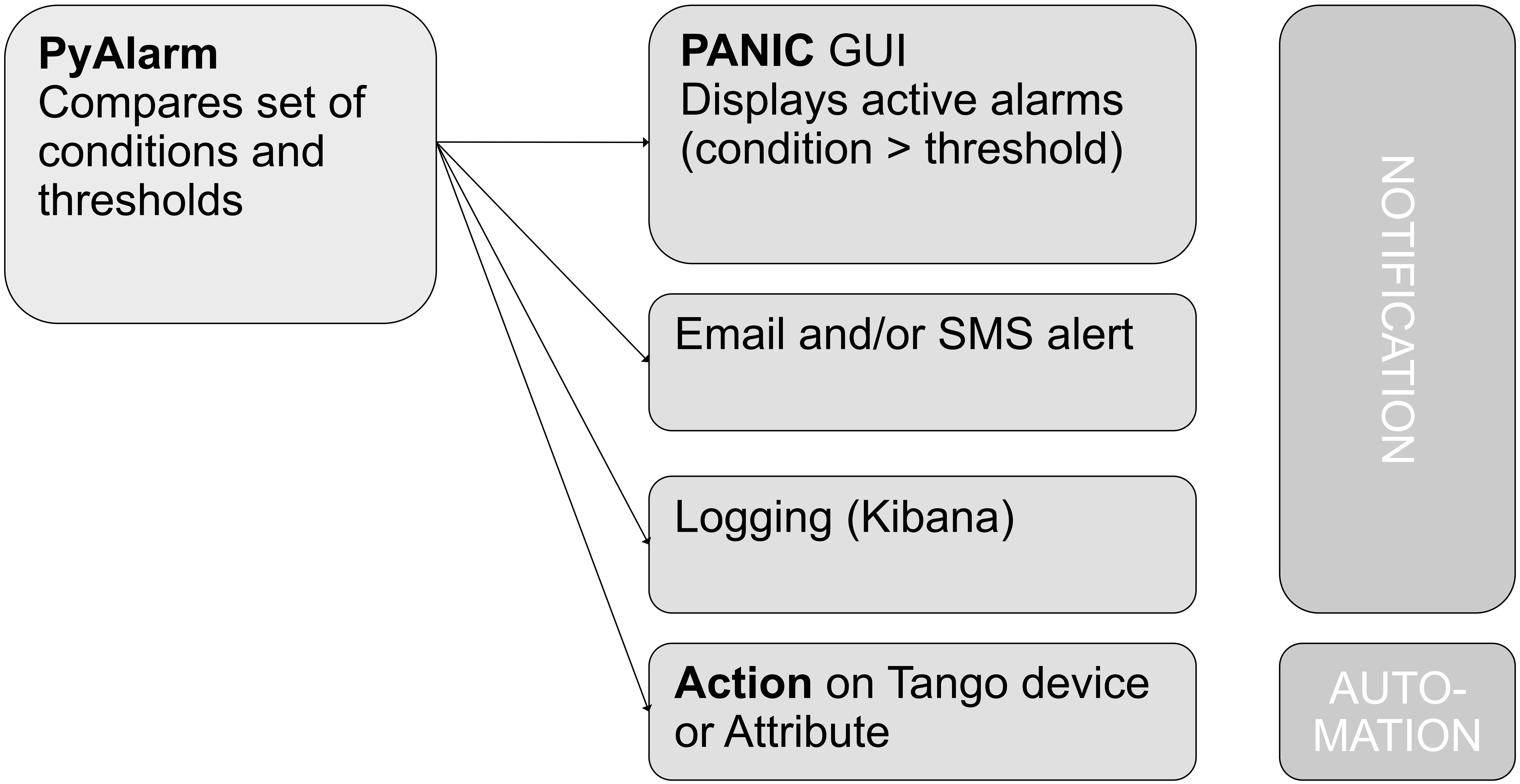
Alarms: from notification to automation?

Alarms in software



- We use "the" Python Tango Alarm handling tool, PyAlarm
  - Mainly configuration + some developments by MaxIV
- Does not handle critical actions, but used for notification and logging
- Conditions based on States and Attributes of any Tango devices in CS
- Typical alarms conditions are PLC interlock tags == True (for which the appropriate action is of course handled by the PLC)

Alarms in software: automation via actions



- PyAlarm allows actions to be defined on other Tango devices as a result of an Alarm condition becoming True
- **Example in use today:**
  - monitoring of magnet resistance as proxy for temperature.
  - If *resistance* (coil C) > *limit* (coil C) -> turn off power

Alarms in software: greater automation?

- PyAlarm is higher configurable so easy to imagine a greater role in automation
- Can provide a preventative layer of protection before PSS or MPS
  - If some WARNING threshold take some action
  - If some ALARM threshold take more severe action
  - Safety layer: If interlock condition -> handled by PLC

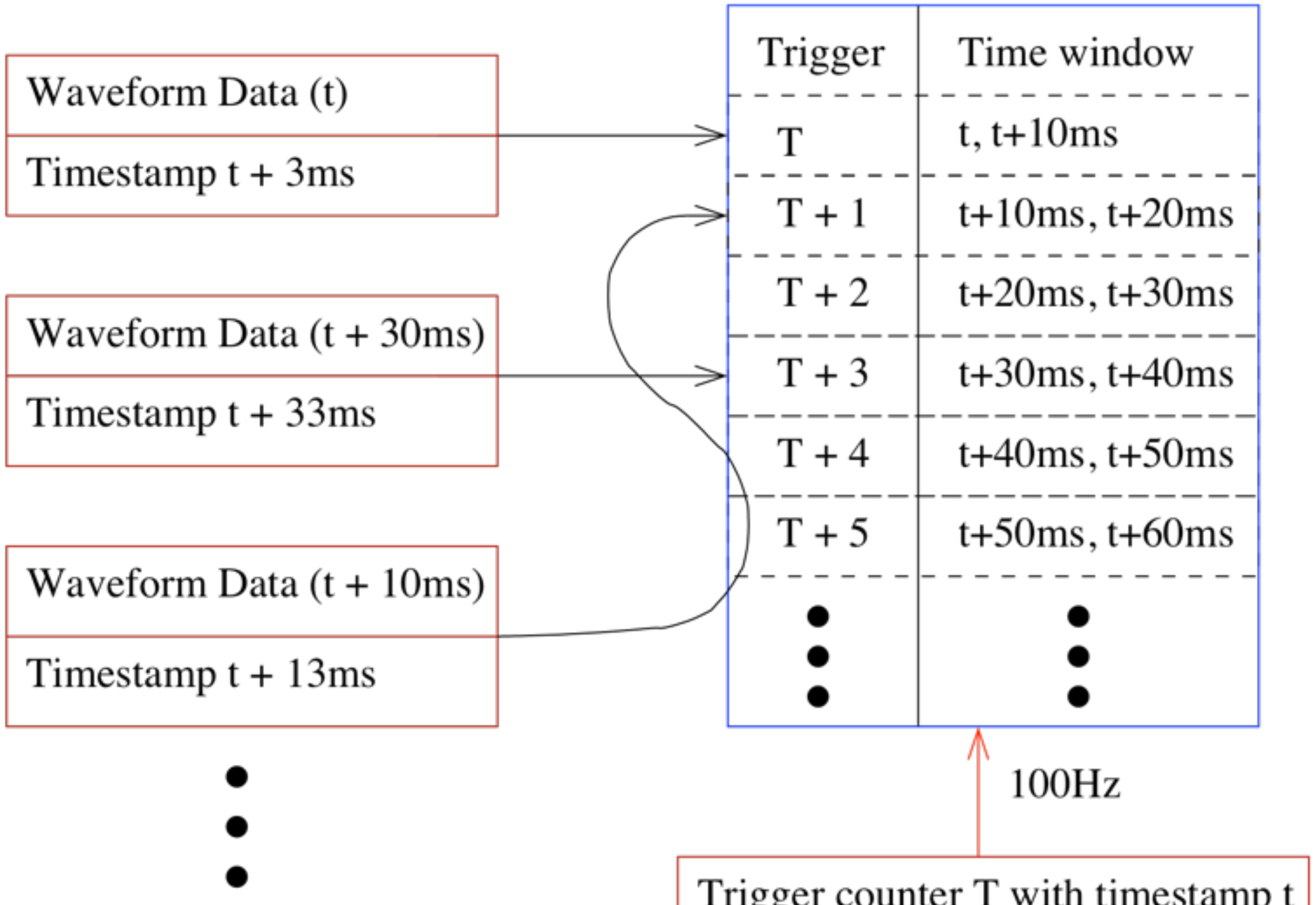
- Can also envisage other features to shorten procedures:
  - Greater use of PANIC GUI to issue resets when needed
  - Interface to elog to record actions taken?

- Keep in mind limitations:
  - Conditions limited to simple Python expressions

Role of diagnostics

Diagnostics: the basis for decisions

- Automation demands information on which to base decisions
- Can the required information be collected via Tango?
- **Performance example**: recording pulses from linac Charge Transformers (CTs)
  - Pulses from each CT device captured by oscilloscopes
  - Scope Tango devices send "Tango events" when new waveform captured
  - Synchroniser Tango device receives waveform data and timestamps, plus trigger counter and timestamps
  - Waveform data thus matched to correct trigger bunch number



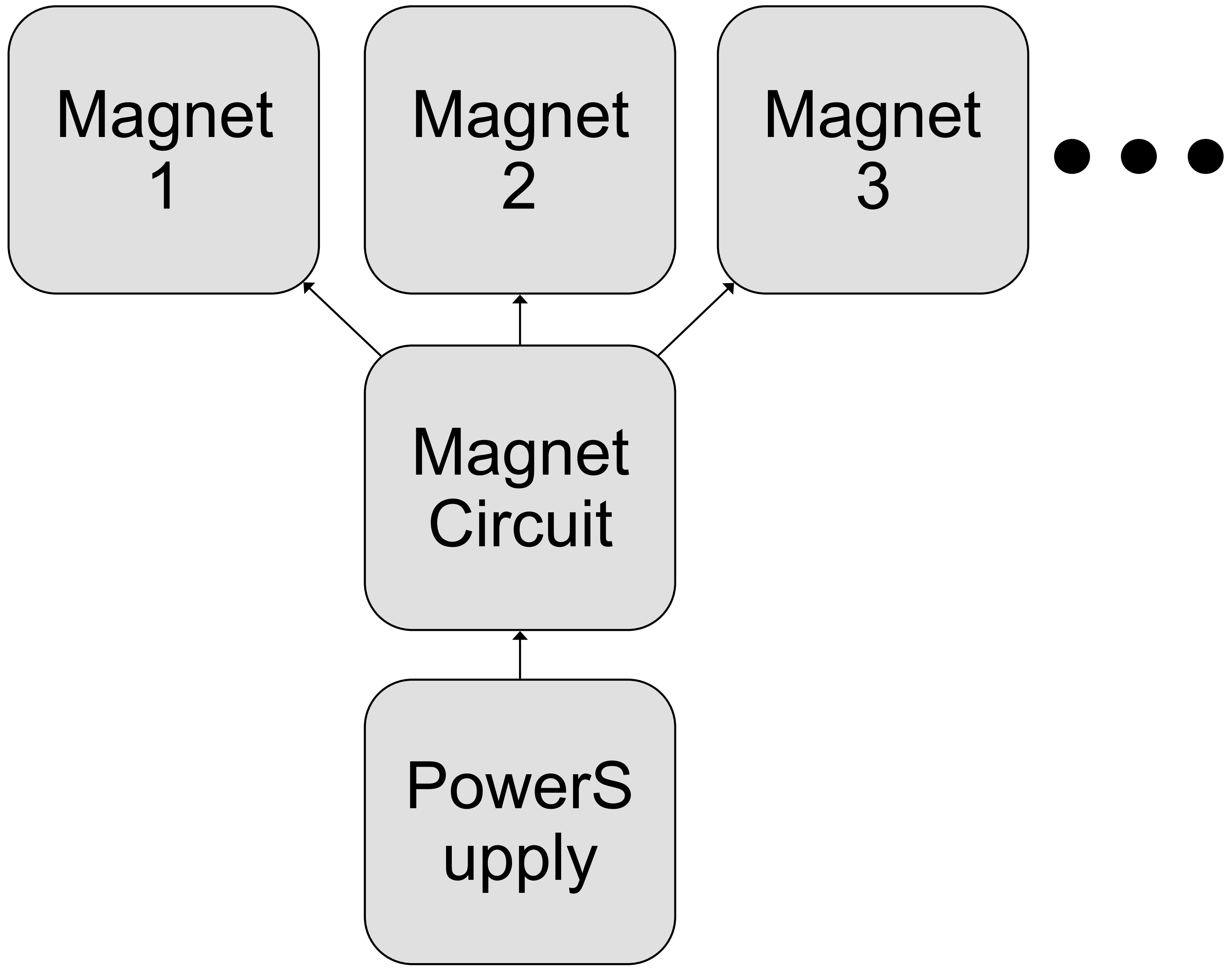
Diagnostics: the basis for decisions

- “Fast archiving” of data from Rohde & Schwarz oscilloscopes demonstrated at 100Hz in the lab
- Currently running at the 0.5Hz of the linac
  - Waveform data matched to trigger bunch number being written to hdf5 files at this rate
- Available for possible analysis running offline to feedback into control of linac?

Automation examples

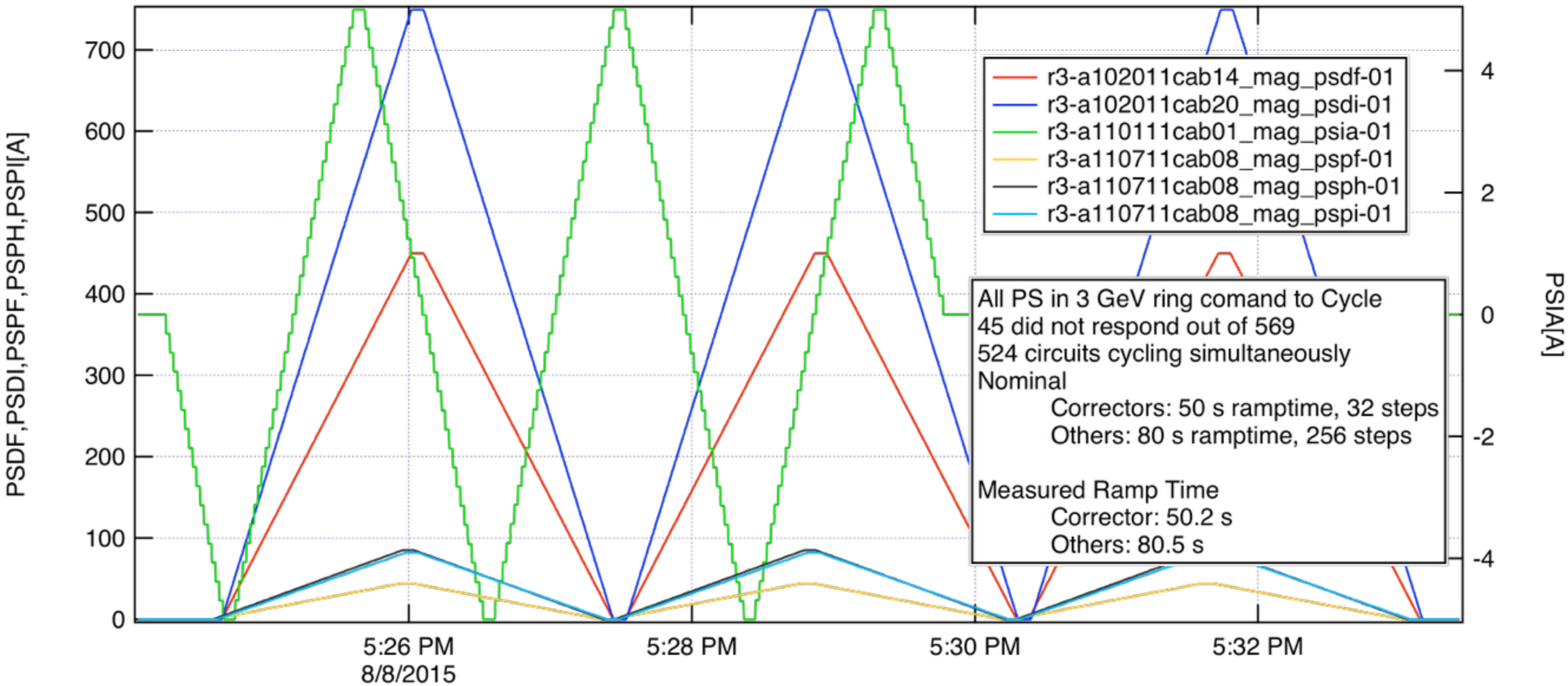
Example 1: Cycling script for magnets

- Magnet software is one step removed from the hardware layer (PS devices)
- Magnet circuit devices associate power supply devices with one or more magnets
- Magnet circuit devices read and write current on the power supply devices and use calibration data to convert between current and field, hence allow operator to steer by field



- Circuit device implements a Finite State Machine for magnet-PS cycling:
  - configure minimum and maximum range, number of cycles, steps…
- Tango's Matlab binding allows its ***automation through higher level scripts…***

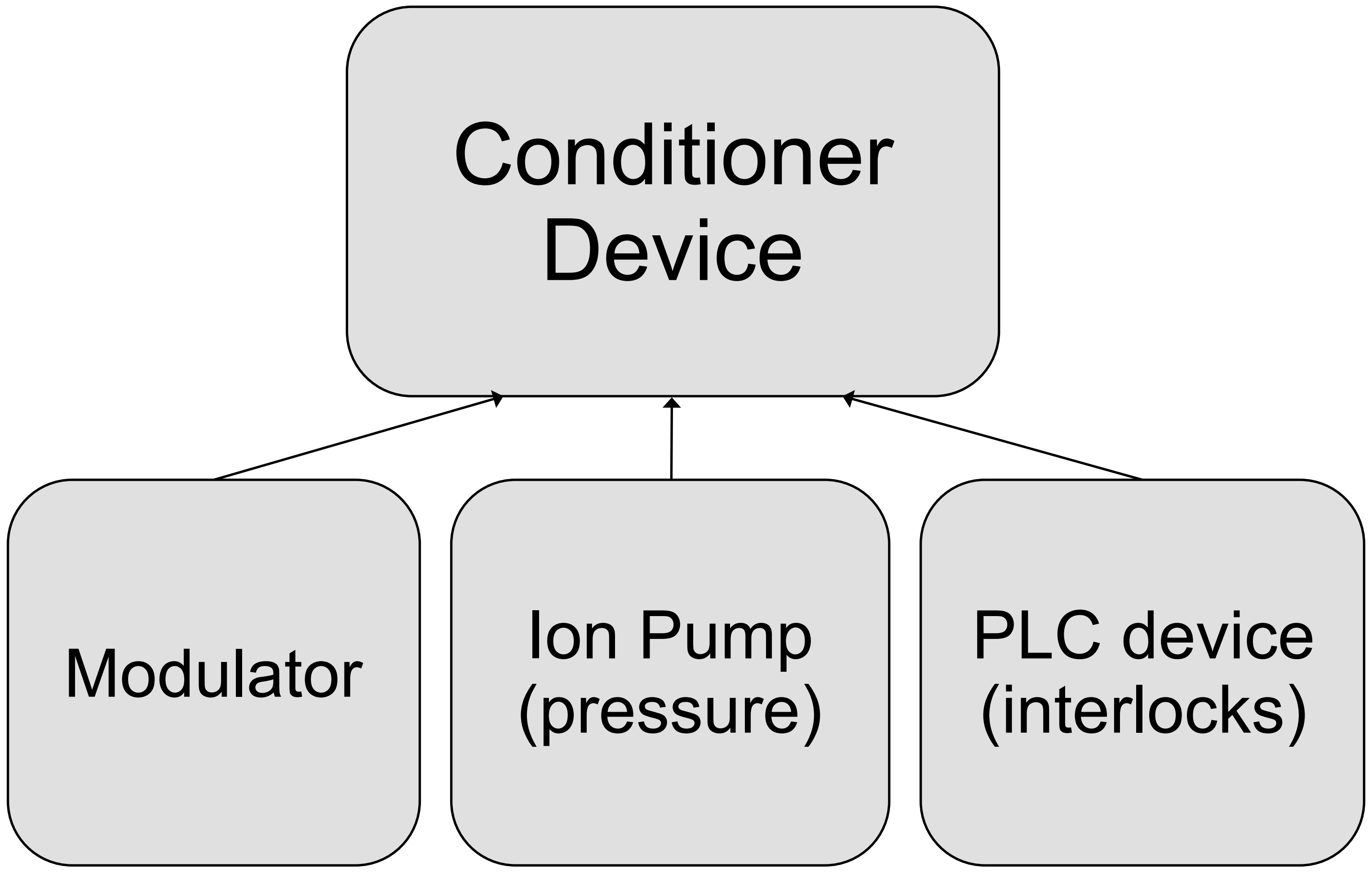
Example 1: Cycling script for magnets



- Design of script and Tango device is coupled
  - Tango device makes available the attributes needed by the script, such as the ramptime and step size
- NB: Tango “groups” feature makes addressing all or subsets of devices easy (here selecting all devices in 3GeV ring)

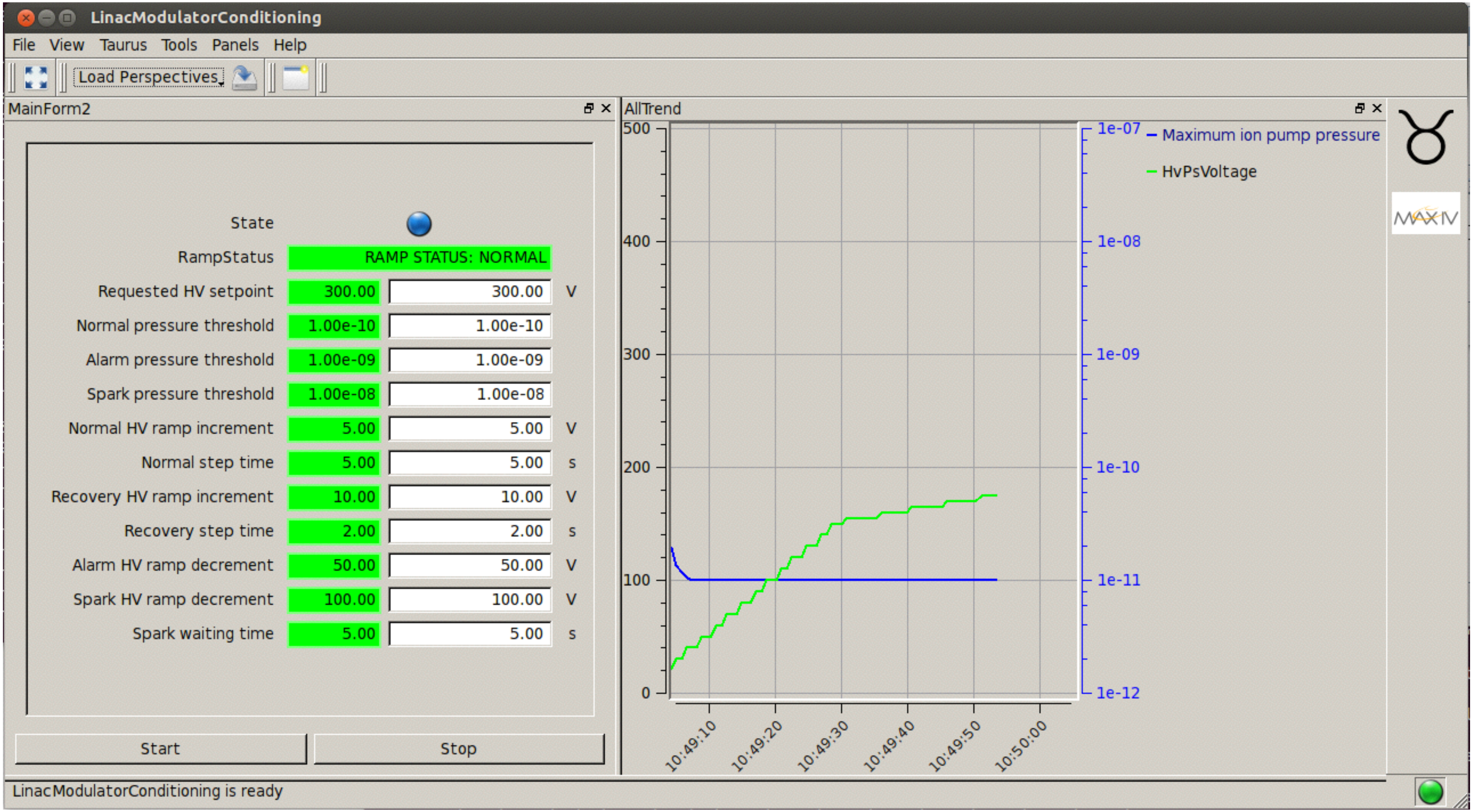
Example 2: Modulator conditioning

- Tango Modulator devices control Scandinova modulators in linac
- During commissioning, needed to slowly ramp voltage while monitoring pressure and interlocks
- This conditioning procedure was automated in a Tango “Conditioner” device



- ***Different approach to previous example***: here all intelligence is in the Tango device itself, not a client script. Just click “Start”…
- Uses similar underlying Finite State Machine code as in the magnet cycling, but with more complex conditions to handle: normal ramping, checking of pressures and interlocks, recovery phase, spark phase…
  - Takes input from several other Tango devices to make decisions.

Example 2:
Modulator conditioning



MAX IV