MAX IV Control System

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Agenda

- Introduction
- Control System Overview
- Tango
- Architecture
- Workflow
- Conclusion

Introduction

3 accelerators:

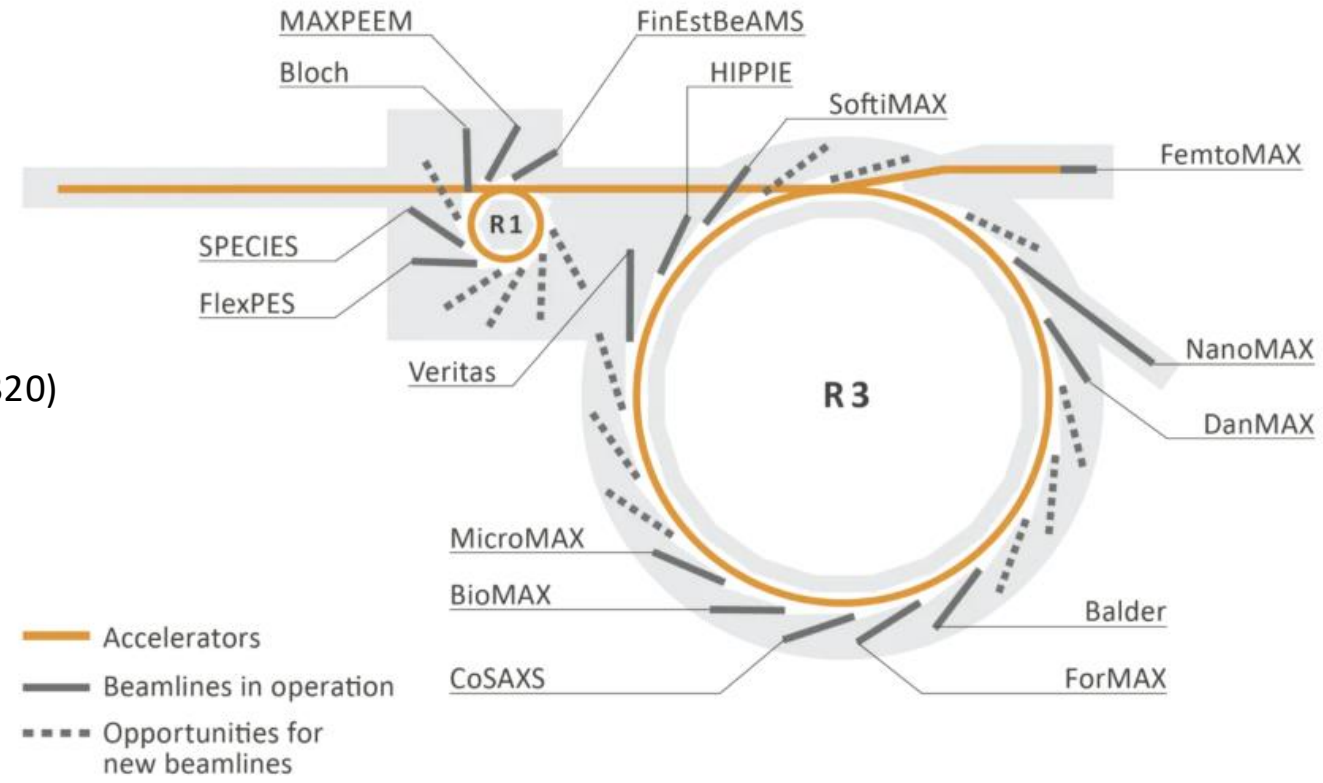
- Full energy injector Linac with SPF
- 1.5 GeV storage ring
- 3 GeV storage ring
- 4 Diagnostic beamlines (TDC, B105, B302 and B320)

16 beamlines in operation:

- 24 branches
- 1 in construction – SinCrys at DanMAX

1 beamline in construction:

- TomoWISE – founded by WISE
- Full-field tomography, 20 to 65 keV
- 10^{12} ph/s and and 45 mm x 4.5 mm beam



10 support labs/systems:

- KITSLAB, MagLab, LaserLab, Cryo, GunLaser, SEDSMAX, OpticsLab, SPM, NoMad and DummyMAX

Control System Overview

Tango toolkit for SCADA

98% of devices servers are written in Python

On accelerators we have:

- ~15,100 devices servers -> equivalent to EPICS IOC
- ~36,500 configuration properties -> similar parts of EPICS .db
- ~61,000 commands -> equivalent to EPICS PV
- ~105.300 attributes -> equivalent to EPICS PV

Sardana for scanning and data acquisition

See flyscan sessions for Sardana details.

Tango

🧬 Origins & Architecture

- Developed at **ESRF in 1999**
- Based on a **central configuration database**

🧱 Devices

- **Devices** act as microservices — software or hardware components
- Devices belong to a **Device Class** and have a **unique 3-part name**: Domain/Family/Member (D/F/M)
- Devices are **stateful** and accessed via a **standard API**
- Devices can be **composed** from other devices (hierarchical architecture)

📊 Attributes

- Represent **data fields** clients can **Read / Write / Subscribe to**
- Support **event-driven updates** (via **ZeroMQ**)
- Attributes can be **memorized** in the database

Tango

Commands

- Represent **actions**: e.g., On, Off, Move, Calibrate
- Support **typed arguments and results**
- Executed by clients to control device behaviour

Properties

- Stored in the database to **configure devices at startup**
- Can be set at **attribute**, **device**, **class**, or **global** level
- Accept **any Tango data type**

States & State Machine

- Every device has a **State** (14 predefined discrete values); Colour coded
- Each device class includes a **State Machine** to manage transitions
- Possible states: **ON**, **OFF**, **CLOSE**, **OPEN**, **INSERT**, **EXTRACT**, **MOVING**, **STANDBY**, **FAULT**, **INIT**, **RUNNING**, **ALARM**, **DISABLE** and **UNKNOWN**

Architecture - Network

Color-Coded Segmentation

Blue – Beamlines
- Each beamline is **isolated** from others

Green – Accelerator Systems
- Includes **PSS** (Personnel Safety System) and **MPS** (Machine Protection System)

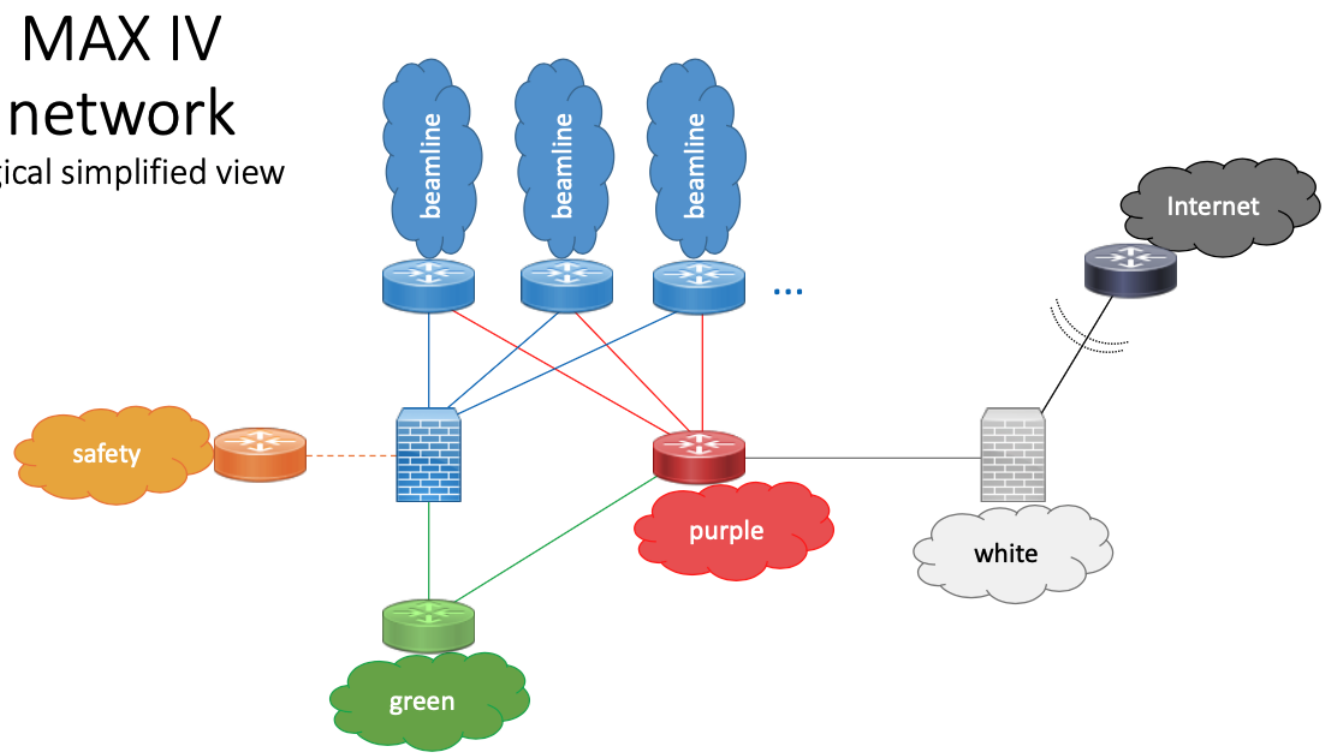
Purple – High Data Throughput Zone
- Covers **detectors, BPMs, storage, and compute** resources

White – Office Network
- General-purpose **servers, desktops, user services**

Safety – Dedicated to **Gas Systems**

Controlled Access & Security

- **Jump Hosts**, **VPN**, and **Firewalls** control traffic between segments
  - Example: **Beamline → Accelerator** access is strictly regulated



Architecture - Technologies

🛠️ **Control System Toolkit**
TANGO – one control system instance per system

💻 **Operating System**
Rocky Linux (Enterprise-grade Linux distribution)

🧱 **Virtualization Platform**
VMware for infrastructure and system isolation

🧑‍💻 **Programming Languages**
Python, **C++**, and **Java**

📦 **Device Configuration Database**
MariaDB for storing TANGO device and property definitions

📈 **Archiving System**
hdb++ on **TimescaleDB**
Custom-built data viewer: Archviewer

🚨 **Alarm System**
Achtung – in-house system, inspired by PANIC!

📪 **Alarm Notifications**
Notify – developed in collaboration with ESS

Architecture - Technologies

🖥️ **Graphical User Interfaces**
Taurus (based on PyQt)
Taranta (Web-based interface)

⏱️ **Timing System**
MRF – Micro-Research Finland timing hardware

🌐 **Communication Protocol**
Ethernet-based across systems

🛠️ **Configuration Management**
Ansible for system provisioning and automation

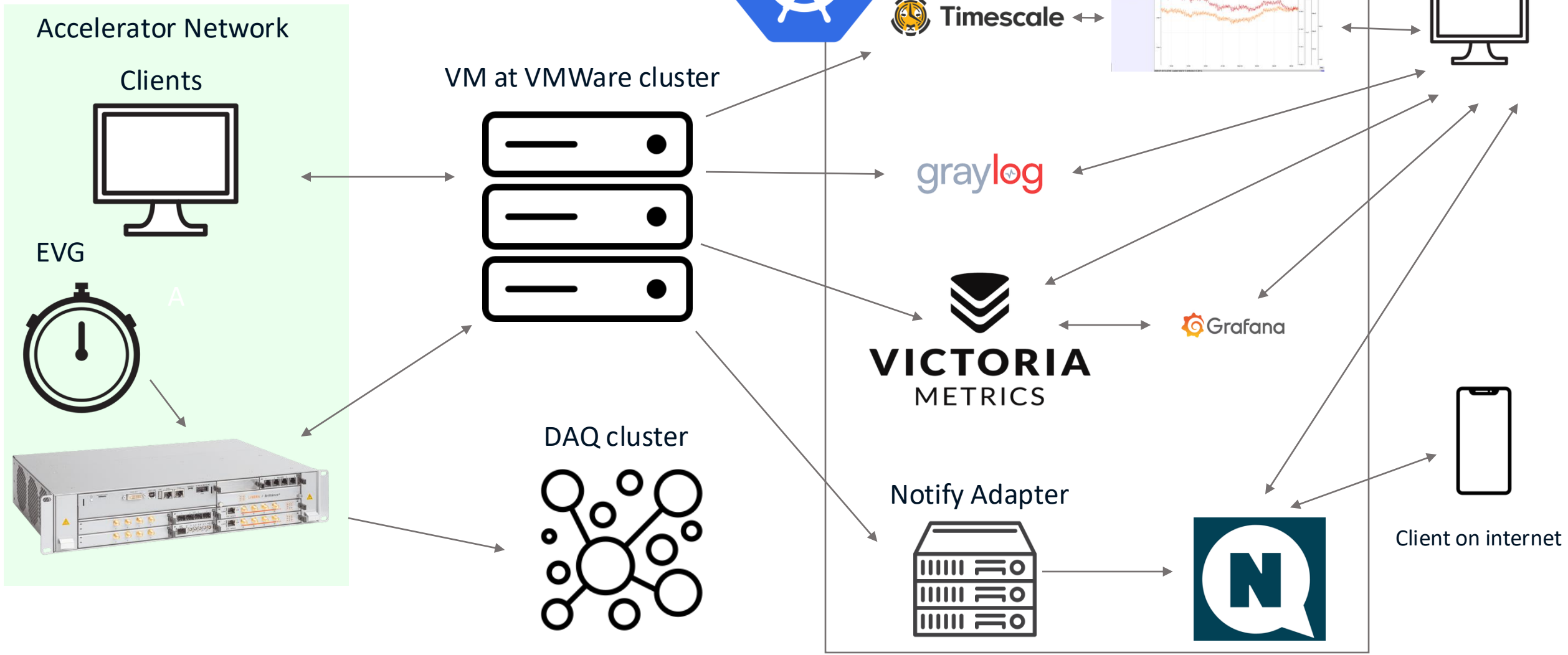
🔧 **Source Code Management**
Primarily **internal GitLab**
Gradual migration to public gitlab for selected projects

🚀 **CI/CD Pipeline**
GitLab CI integrated with **Ansible** for deployment

📊 **Monitoring & Alerts**
Grafana for metrics dashboards
Graylog for centralized logging and log analysis

🔬 **Scanning & Data Acquisition**
Sardana – flexible framework built on TANGO

Architecture



Archviewer

📈 Main Features

Attribute Search:

Locate attributes by full name or wildcard (e.g., */pressure).

Add attributes to left/right Y axes or create new ones.

Attribute Controls:

Customize colour, style, and aggregation function.

Download data in TSV or JSON format.

Y-Axis Management:

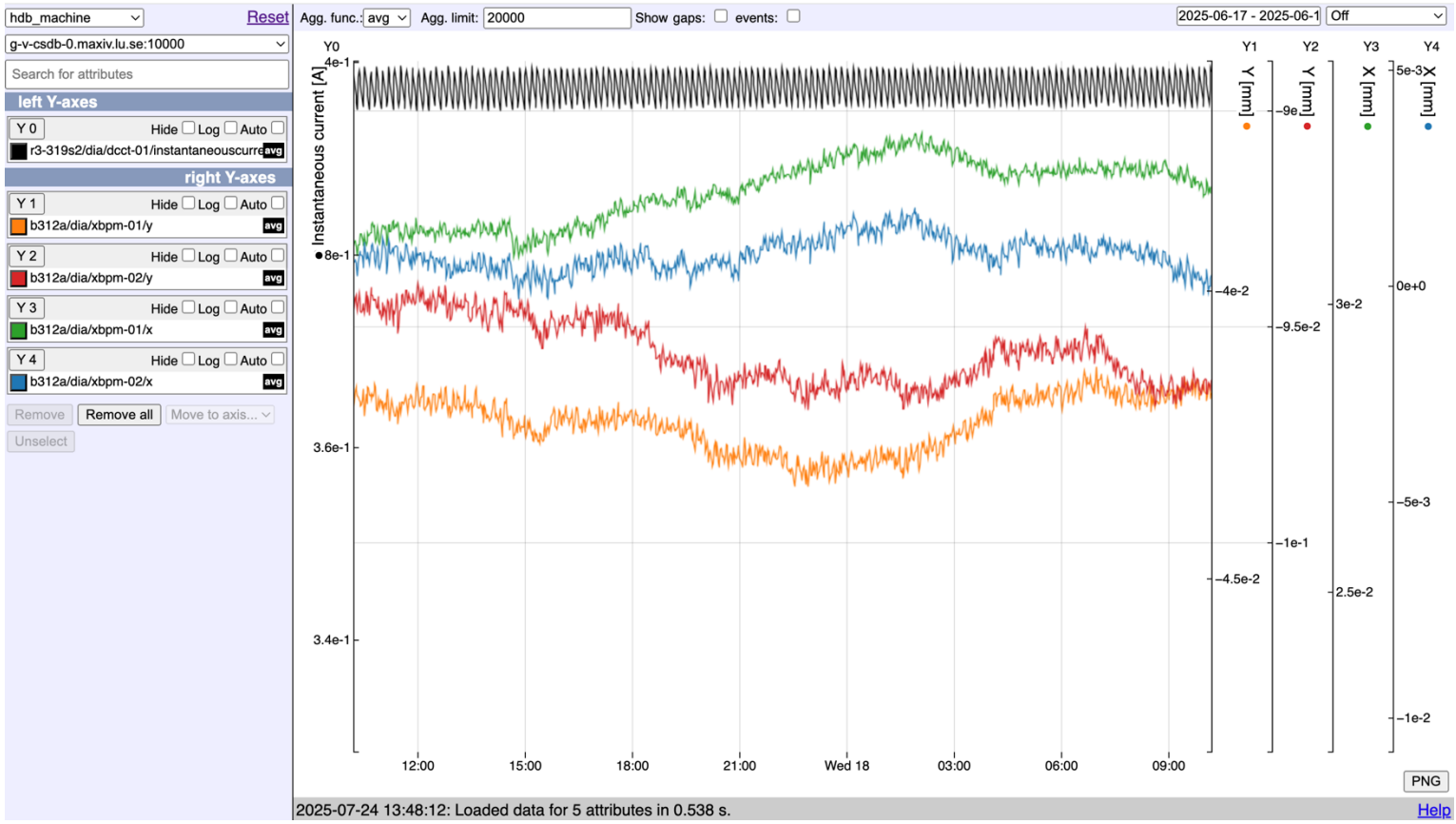
Each axis has individual settings: Log scale, Auto scale, visibility toggle, and manual limits.

Shared attributes on an axis use the same scale.

Time Range Control:

Adjustable via calendar, presets, or mouse interaction.

Supports **Live Mode** (auto-updating latest data view).



⚙ Advanced Functionality

Aggregation:

Reduces data volume by using functions like avg, min, max.

Automatically triggered for large datasets; customizable via aggregation limit.

Multiple Databases:

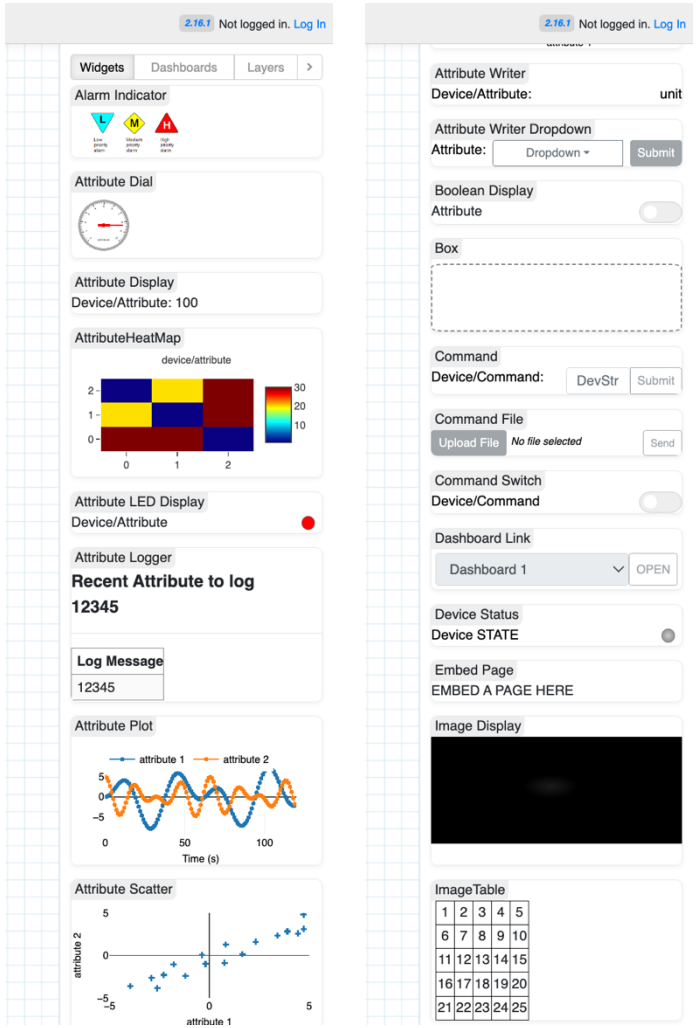
Attributes from different databases can be plotted together.

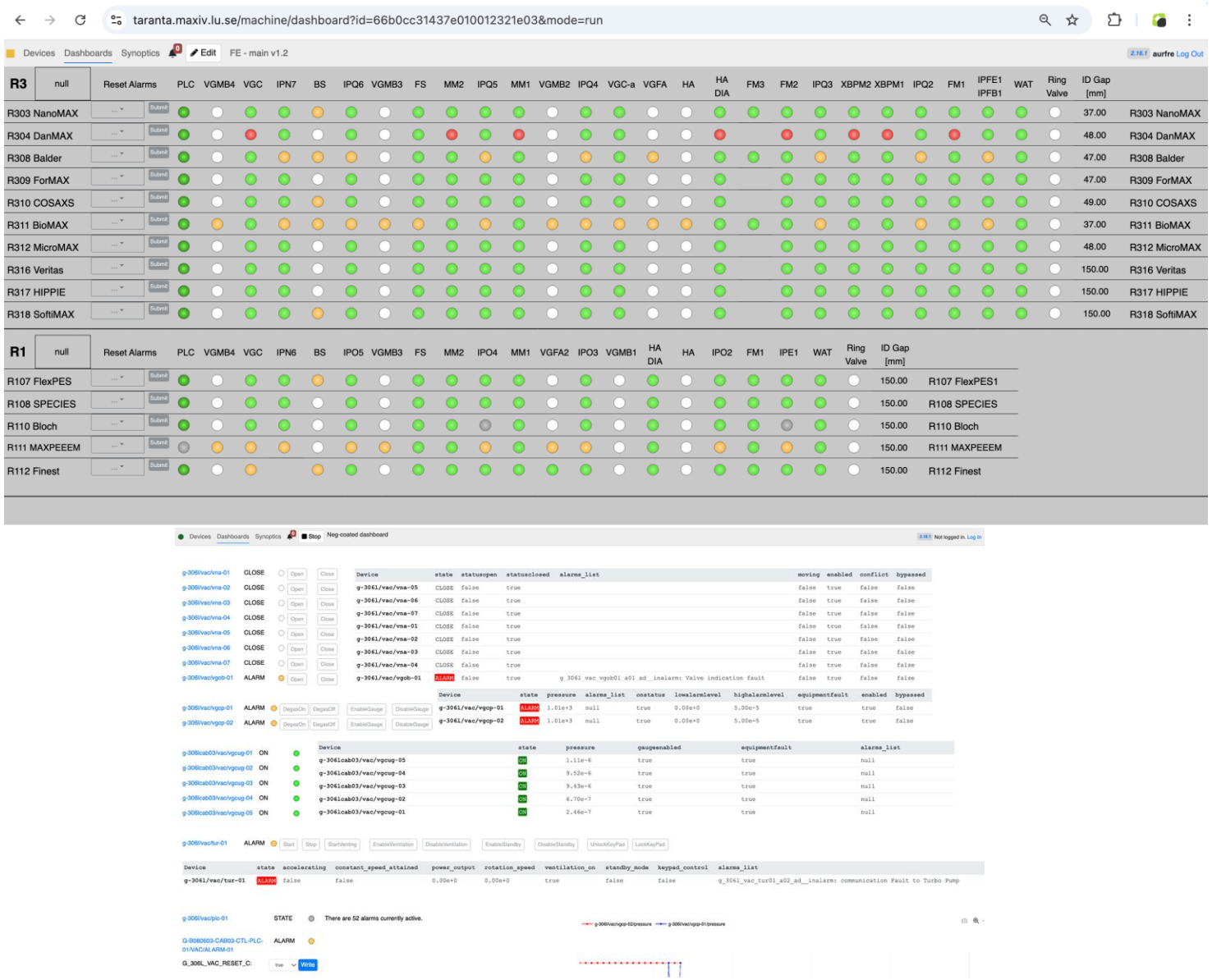
Data & Plot Export:

Download plot as PNG.

Use URL to save/share specific views

Taranta





MAX IV

PLC2Tango

plc2tango_auto_commit

Find file | Edit | Code

PLC2TANGO deployment by johgru on danmax-1
plc2tango-okd authored 4 days ago

c6edc848 | History

Name	Last commit	Last update
..		
.gitkeep	Add new directory	4 years ago
balder-1.csv	PLC2TANGO deployment by johgru on balder-1	3 months ago
biomax-1.csv	Big clean up update for most beamlines	1 year ago
bloch-1.csv	PLC2TANGO deployment by johgru on bloch-1	8 months ago
cosaxs-1.csv	PLC2TANGO deployment by jonlin on cosaxs-1	7 months ago
cryo-1.csv	PLC2TANGO deployment by mirlin on cryo-1	3 years ago
danmax-1.csv	PLC2TANGO deployment by johgru on danmax-1	4 days ago

Added

R3-A101311/WAT/FSW-01

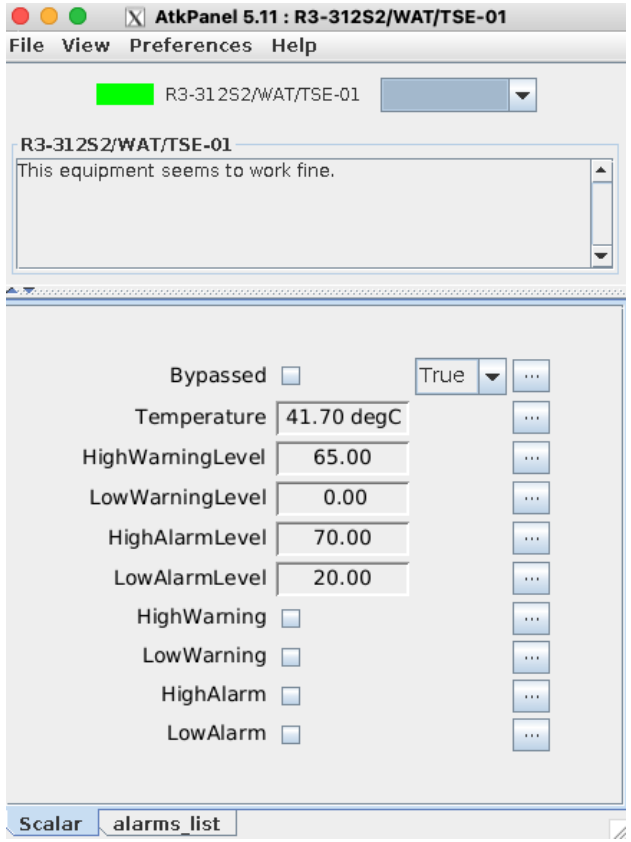
Server	FlowSwitch/R3-A111212-CAB02-WAT-PLC-02-WAT
Class	FlowSwitch

Property	Value
AlarmsDesc	R3_A101311_WAT_FSW01_A01_AD__InAlarm:CIRCULATOR
AlarmsList	R3-A111212-CAB02/WAT/PLC-02/R3_A101311_WAT_FSW01_A01_AD__InAlarm
AlarmsReset	False
ByPassedAttribute	R3-A111212-CAB02/WAT/PLC-02/R3_A101311_WAT_FSW01_BP
StatusClosedAttribute	False
StatusOpenAttribute	False

Updated

R3-A111212-CAB02-WAT-PLC-02/WAT/ALARM-01

Property	Value
AlarmD	R3_A101311_WAT_FSW01_A01_AD__InAlarm:CIRCULATOR



Workflow

🧩 Controls Team

- Responsible for the **software layer** of the Control System
- Collaborates closely with other technical groups

👥 Team Composition

- **10** permanent staff
- **4** consultants

📌 Distribution

- Each Controls team member acts as the **Contact Person** for **2–3 system** (↔ responsible for follow-up, coordination, and support)

🧭 Evolving Workflow

- Transitioning toward a **team-based structure**
- Exploring **Kanban** for planning and tracking work

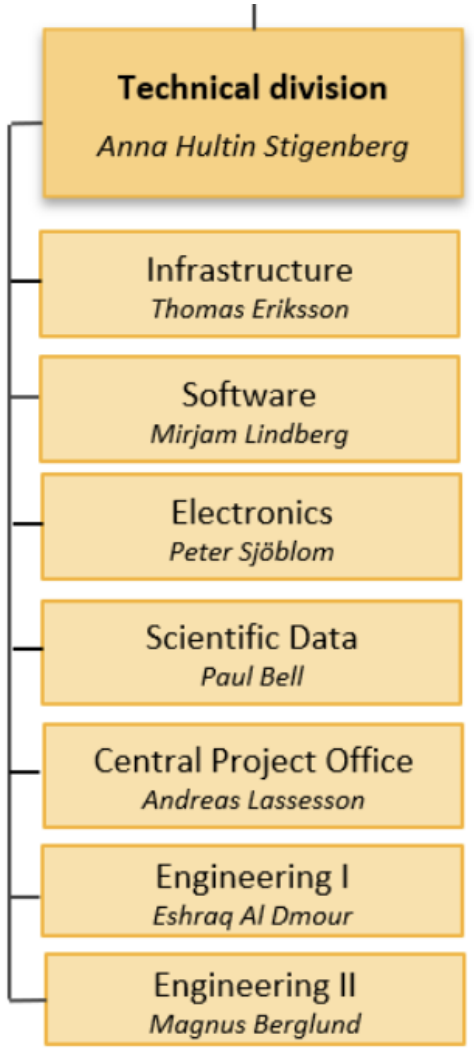
Software Group

MX	Controls	Applications
• Mirjam	• Áureo	• Carla
• Alberto 50%	• Benjamin	• Alberto 50%
• Elmir	• Anton	• Angshuman
• Fabien	• Ben	• Emil
• Matheus (July 2nd)	• Dmitry	• Martin
• Recruitment	• Henrique	• Moa
• Dominika	• Johan	• Recruitment
• Pawel	• Lin	• Recruitment (DUO)
	• Vanessa	• Jonatan
	• Yimeng	
	• Recruitment	
	• Recruitment	
	• Hanno	
	• Juanzi	
	• Lukas	
	• Wojtek	
	• Consultant	

Workflow

🤝 **Shared Responsibilities**

- **Infrastructure Group**
  - Manages clusters, storage, virtualization, and networking
- **Electronics Group**
  - Handles hardware installation, schematics, motion systems, and timing
- **Detectors & Scientific Data Group**
  - Manages detector interfaces, live view tools, and analysis pipelines
- **MX Team – Software Group**
  - Responsible for Crystallography beamlines: **BioMAX** & **MicroMAX**
- **Applications Team – Software Group**
  - Develops web-based user interfaces (e.g., **Taranta**), **data management systems** and **Digital User Office**



Workflow

Development Cycle: Operates on a **2-week sprint cycle**

Work Backlog Categories

Projects

- Long-term, externally or internally funded
- Managed by the **Central Project Office (CPO)**
- Sometimes grouped into **Programs**

Operation Projects

- Short-term tasks (~2–3 weeks)
- Managed by the **Beamline Office (BO)**

Operations

- Day-to-day tasks:
- Maintenance, issue resolution, user support, and small feature requests

Regular Meetings

Weekly Beamline Operations Meeting

Weekly Accelerator Operations Meeting

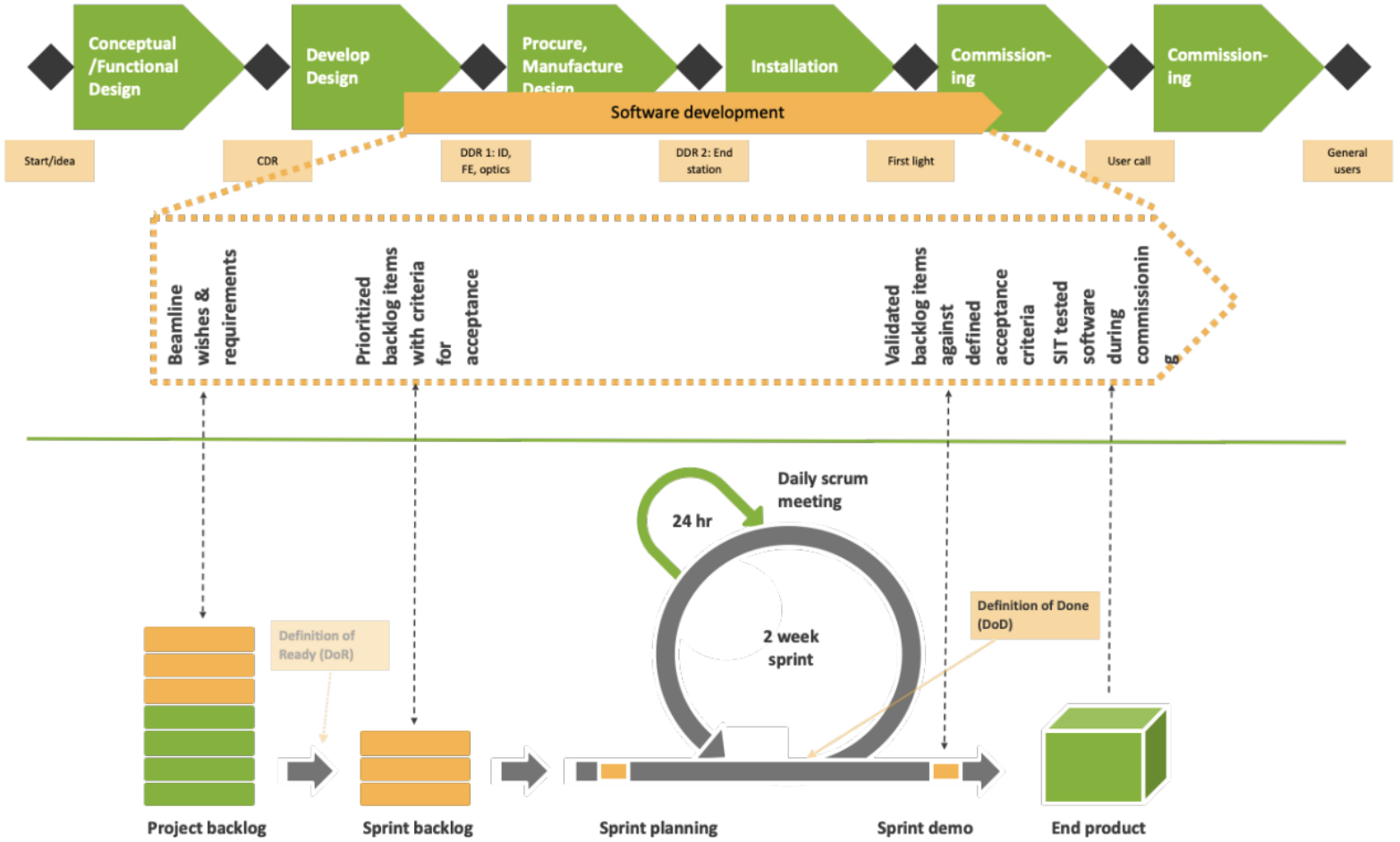
Prioritization

Not owned by the Controls team

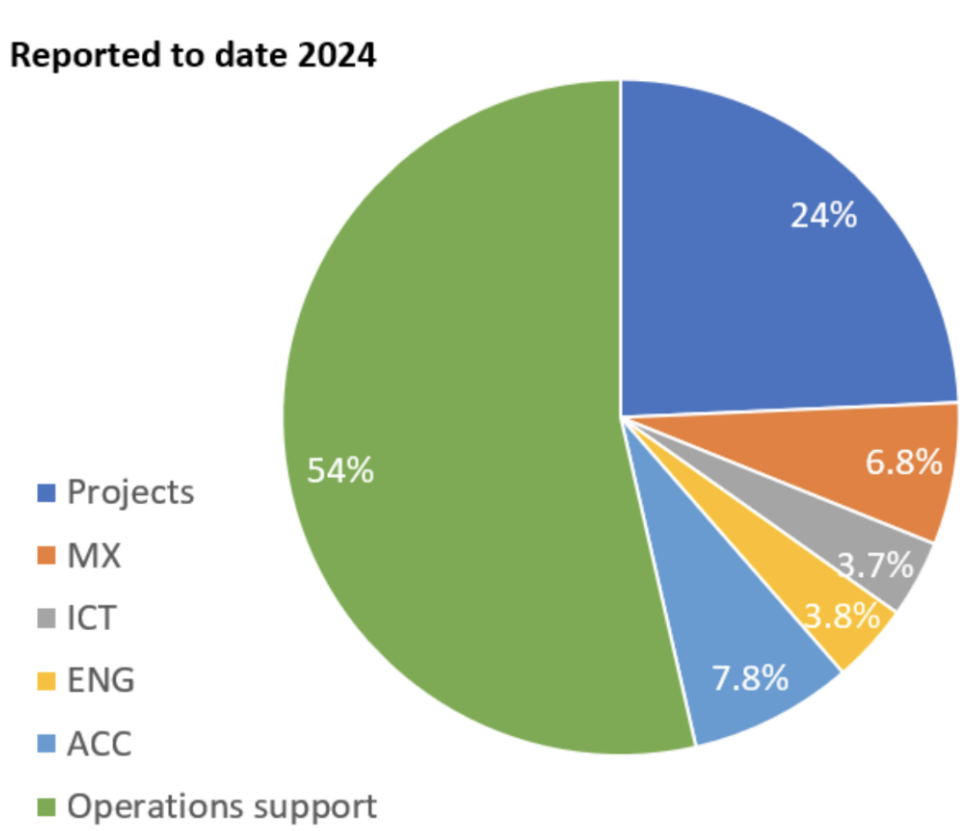
- Priorities are driven by external stakeholders and coordinating groups

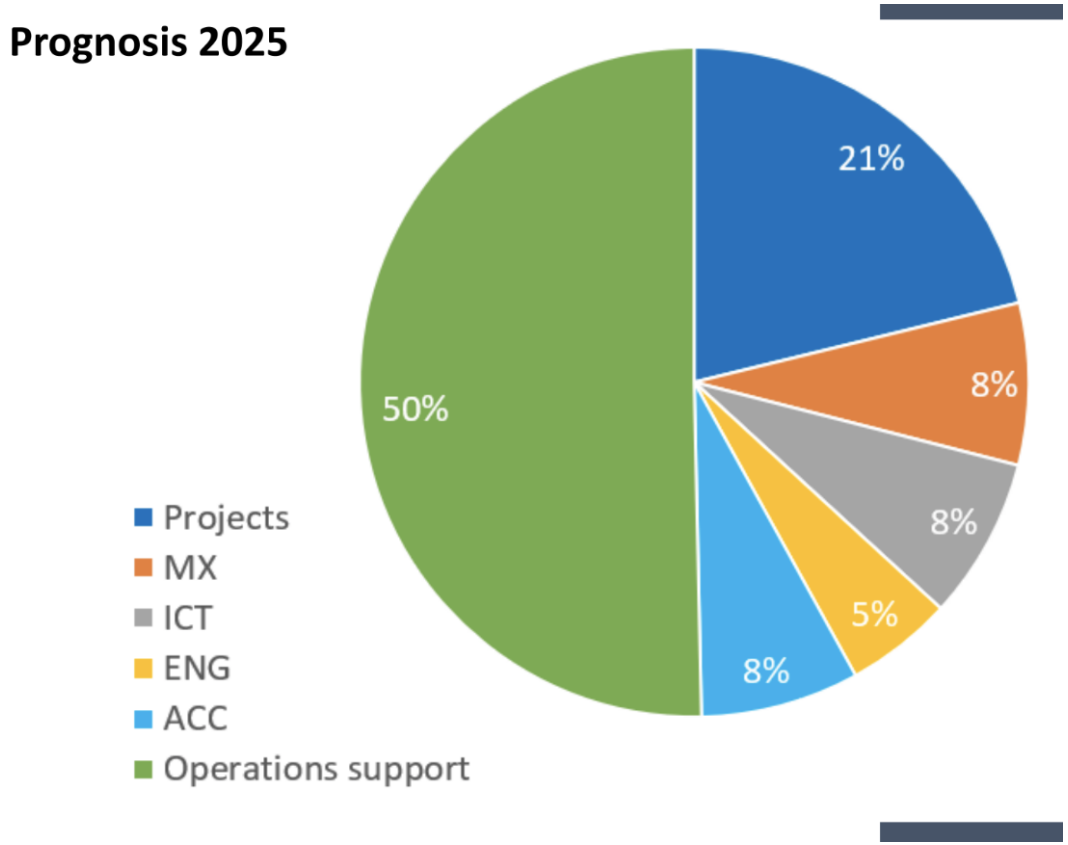
Tooling

Taiga – used for user story tracking and task management



Workflow - Ressource distribution





Workflow

📥 From Backlog to Plan

- **Beamline Contacts** and **Project Groups** propose items for the upcoming sprint
- Discussed during the **Planning Meeting**

📊 Estimation & Planning

- **Team Estimation Meeting**: effort and feasibility assessment
- **Group Manager (GM)** and **Team Leads (TLs)** review and clean up the sprint plan
- Priorities aligned with **CPO** and **BLOPS** (Beamline Operations)

🧑‍💻 Task Execution

- Team members **self-assign tasks**
- Task lifecycle:
  In Progress → In Review → In Validation → In Deployment → Done
- **Ad-hoc tasks** allowed for **urgent/emergency issues**

🚀 Deployment Routines:

Beamlines

- **Monday deployment** window
- Major deployments discussed in the **Beamline Operations Meeting**
- **Changelog** shared via mailing list (based on GitLab milestone)
- Deployed using **Ansible** with a **scheduled deployment crew**

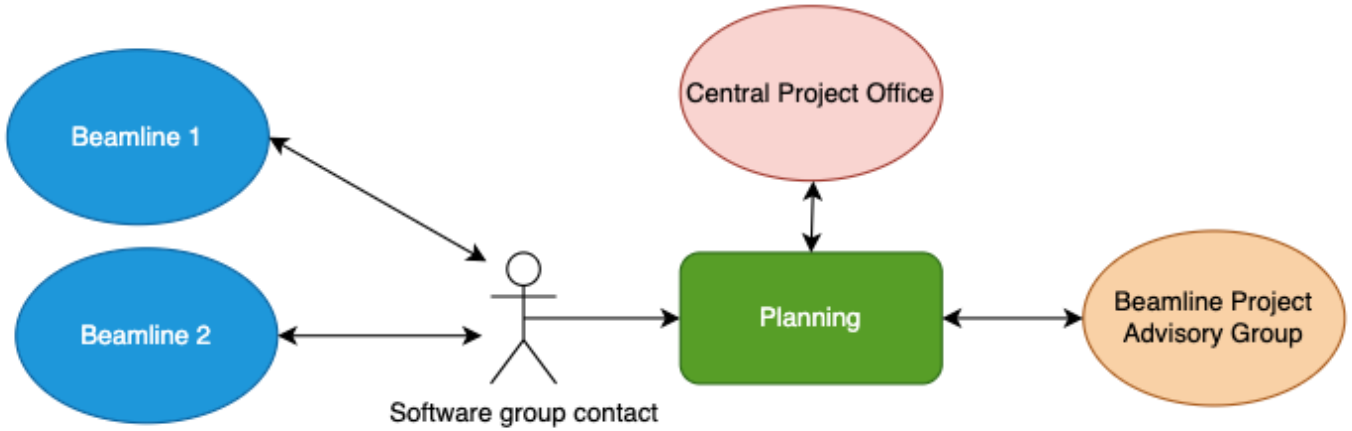
Accelerators

- Deployments planned during **Accelerator Operations Meeting**
- Evaluated in coordination with other activities
- Uses J5 stack for scheduling and tracking maintenance

ℹ️ More Info

See **Operational Support** session for further details

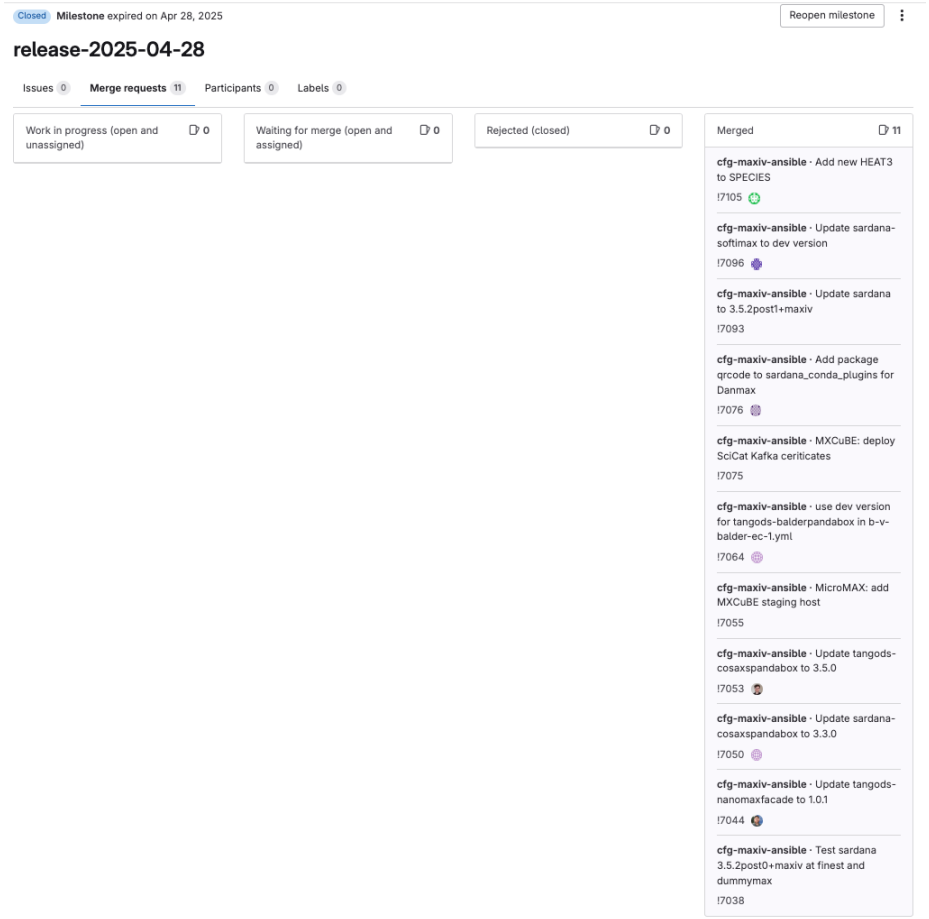
Planning workflow:



Technology Readiness Level TRL:

TRL Level	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Color code									
MAX IV definition		Basic simulation / calculation completed	Demonstrated in a laboratory / workshop that elements of the concept are feasible	Sub system test	System test	Technology fully implemented and fully verified	Technology validated with (experts, stakeholders)	Technology operational with intended users	Technology operationally in multiple environments or standard operation with bread and butter users
Test env.		Theoretical	Laboratory	Component test rig	Test rig with critical interfaces	Solution tested in operational environment	Operational environment	Operational environment	Operational environment
Involvement		Formulate project	Formulate Project	BL/ACC/Orderer- no end users	BL/ACC/Orderer- no end users	BL/ACC/Orderer- no external users	"Friendly/Expert users"	"End user/s"	"End users"
Support		Project team	Project team	Project team	Project team	Project team	Project team	KITOS & on call	KITOS & on call
TRL	**TRL 1->2**	**TRL 2->3**	**TRL 3->4**	**TRL 4->5**	**TRL 5->6**	**TRL 6->7**	**TRL 7->8**	**TRL 8->9**	
Level Criteria		Discuss with other subject matter expert if concept applies to real use case	core part of component developed and tested	component developed and tested	Verified by BL/ACC/Orderer	Validated with an expert or friendly end user	Acceptance after X beamtime with end-user	Proven Performance	
Operation	No Impact on operation				Removable from operation modes	Lower the overall level of operation mode			
Time Frame					Transition should be minimal in time e.g criteria evaluation have to be prepared in				
Feature			core feature	component implemented	System fully implemented				
Example			Software Library developed	Tango device with standard interface	Complete software and hardware suite				
Test			Unit tests	Integration tests	Verification			User feedback has been positive	

Milestone example:



Sprint example:

Sprint 265 2025-06-13 - 2025-06-27

My tasks

	ID	Title	Sprint	Points	Status	Assigned to
+	7940	[Issue] Finest: Timeout when changing EPU config	Sprint 265	2	Novo	
+	7937	Cont scans: study flexpes ID energy for trajectory preparation	Sprint 265	3	In validation	Lin Zhu
+	7936	Cont scans: make velocity restoration method more robust	Sprint 265	3	In validation	Wojciech Kitka
+	7932	Species GAS: mass flow regulator update for new OTD	Sprint 265	2	Terminado	Áureo Freitas
+	7945	PEAK: improvements from integration testing at HIPPIE - 35	Sprint 265	5	Terminado	Anton Joubert
+	7946	Eng Prog: VAC: continue VACCA updates	Sprint 265	2	In validation	Hanno Perrey
+	7869	Balder (DAQ 2): configure Eiger for either SPM or TotalTriggers	Sprint 265	5	Em andamento	Dmitry Egorov
+	7956	BioSAXS: Manager DS prototype	Sprint 265	5	Em andamento	Lukas Wittenbecher
+	7934	[DUO keep alive]:Matabase:Review all the reports and fix the broken ones [Part 7]	Sprint 265	3	Novo	Angshuman Chatterjee
+	7942	DUO: Move all the blob data to the filesystem from the EXPREPATT table	Sprint 265	5	Terminado	Alberto Nardella
+	7933	[MACH4] - fix trajectory motor ALARM state and add close traj point position function	Sprint 265	8	Terminado	Vanessa Silva
+	7935	[SOS] Tango 10 upgrade: tango-db and os upgrade (minor version)	Sprint 265	1	Terminado	Áureo Freitas
+	7938	[BPAG] Make wrapper for sequencer energy scan macro	Sprint 265	5	Terminado	Áureo Freitas
+	7943	DanMAX - Add rotary min value to pcap	Sprint 265	2	Terminado	ext-juashi
+	7944	Acc Ops: Investigate line positions not being stored in Basler camera	Sprint 265	3	In validation	Hanno Perrey
+	7947	Elogy: update elogy2	Sprint 265	1	Em andamento	Johan Forsberg
+	7948	Veritas: memory leak in sampletracker GUI	Sprint 265	2	In review	Johan Forsberg
+	7955	[scicat] update certificates	Sprint 265	1	Em andamento	Emil Gunnarsson
+	7959	[Unplanned] plc2tango: Unable to create facade devices for subsystem DIA on machine	Sprint 265	1	Terminado	Emil Gunnarsson
+	7960	[Unplanned]: MicroMAX: mono pid for optical hutch	Sprint 265	2	Terminado	Áureo Freitas
+	7961	Eng Prog: Neg-coating 2: update PLC stack and user interfaces	Sprint 265	3	Terminado	Áureo Freitas
				64		

Conclusion

🔄 Project Handover to Operations

- Formal **handover process still to be defined**
- Using **Technology Readiness Levels (TRL)** as a potential framework for transition

🛠️ Maintenance Process

- Opportunity for improvement in:
  - **Validation scheduling**
  - **Planning and resource coordination**
  - **Follow-up and accountability**

📊 Operations Classification & Tracking

Need to **categorize operational activities** to better understand resource usage

Important to distinguish between:

- **Unplanned work**
- **Work caused by poor planning**

🚧 Upcoming Project Challenges

SXL (Soft X-ray free electron laser)

MAX 4U – next major expansion at R3

TomoWise – Full-field tomography beamline

PLC on OPCUA – improve communication bandwith for timestamp resolution

MAX IV