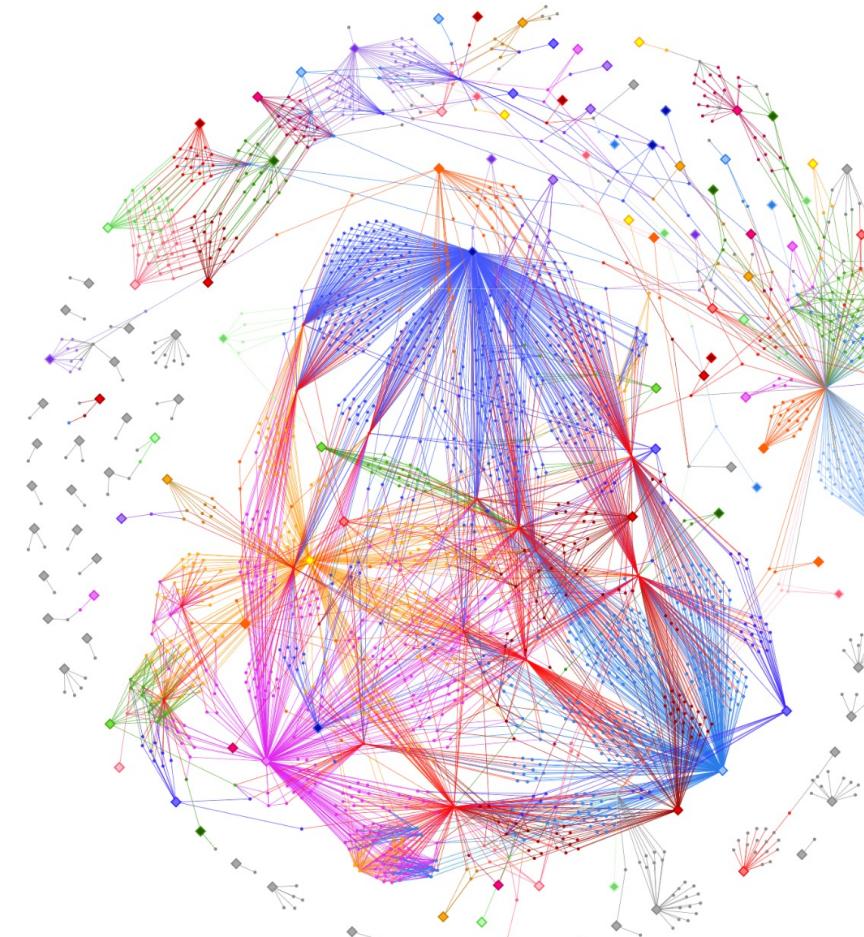
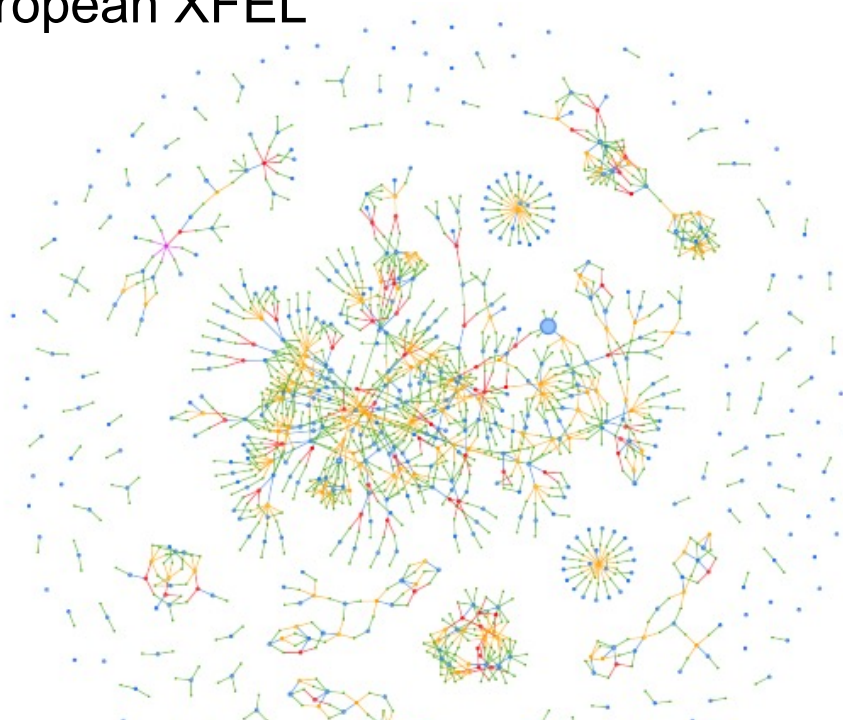
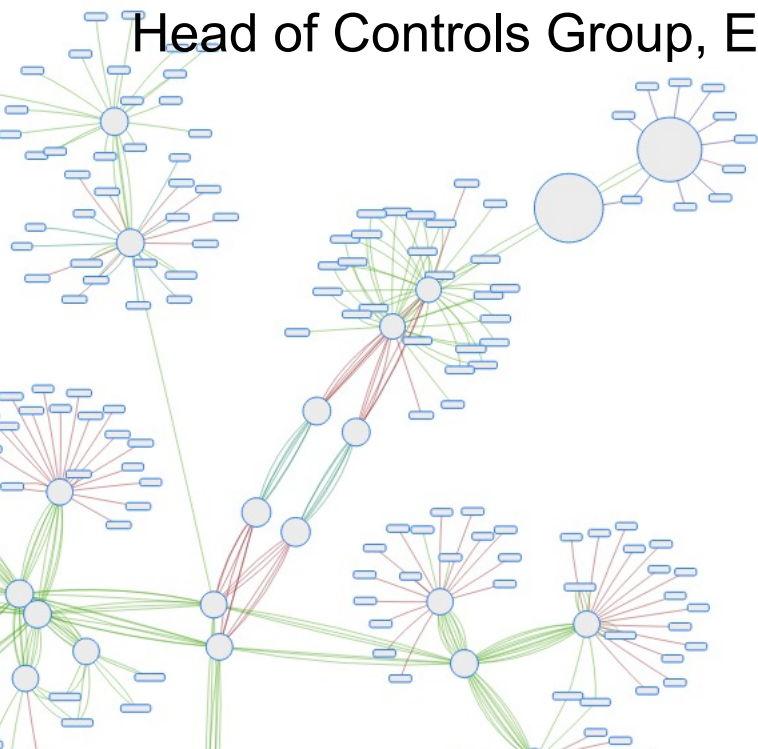


The Data Operation Center: supporting data challenges at the EU.XFEL



Steffen Hauf

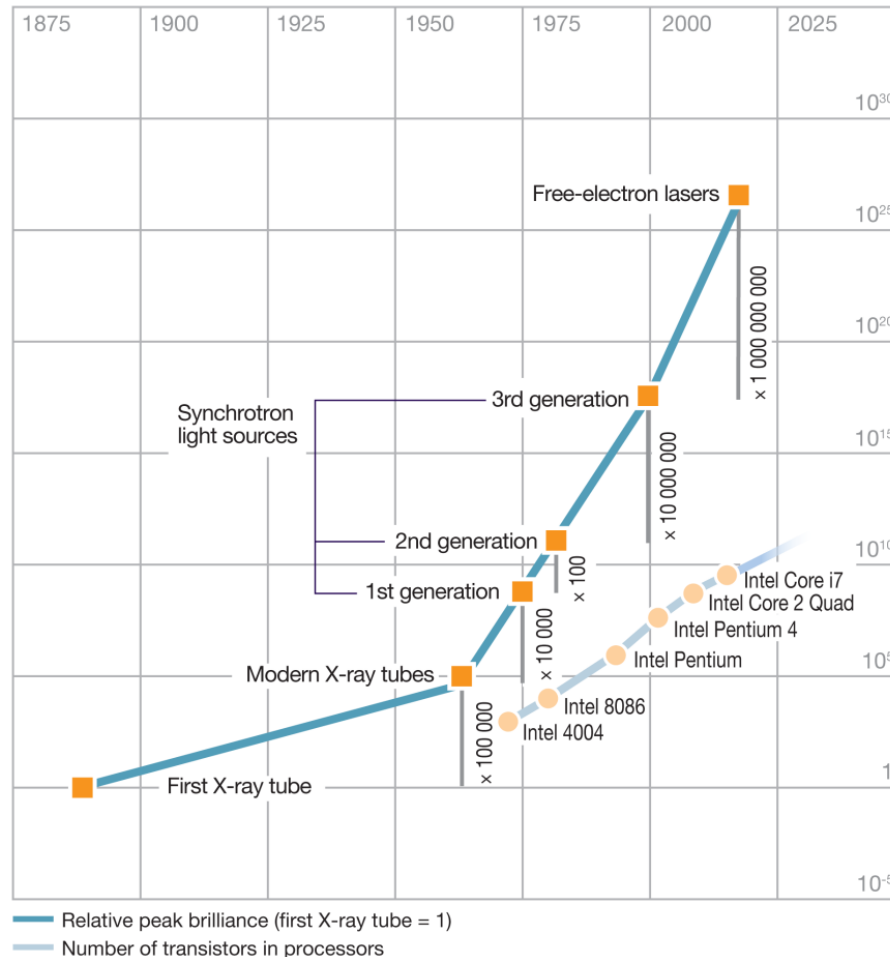
Head of Controls Group, European XFEL



Outline

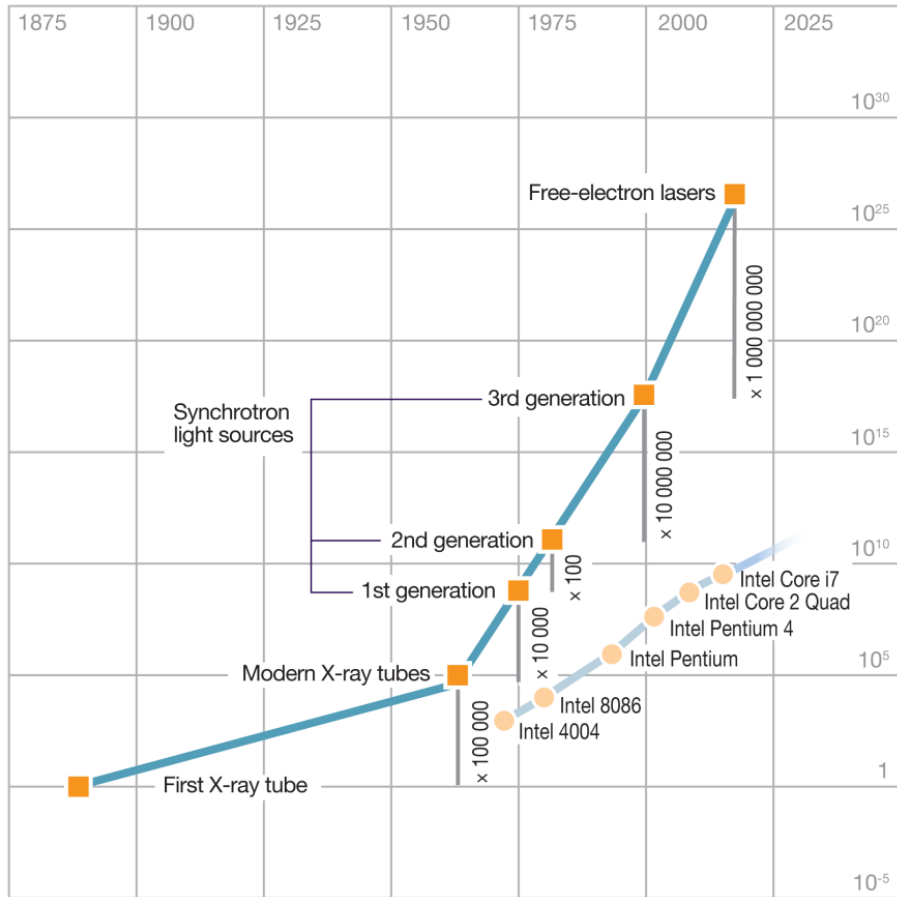
- * The European XFEL – a data perspective
- * The EU.XFEL Data Operation Center
- * Experiences from running the Data Operation Center

The European XFEL – a Data Perspective



* The development of light source facilities has been faster than the increase in computer processing capacity (i.e., Moore's Law)

The European XFEL – a Data Perspective



— Relative peak brilliance (first X-ray tube = 1)
 — Number of transistors in processors

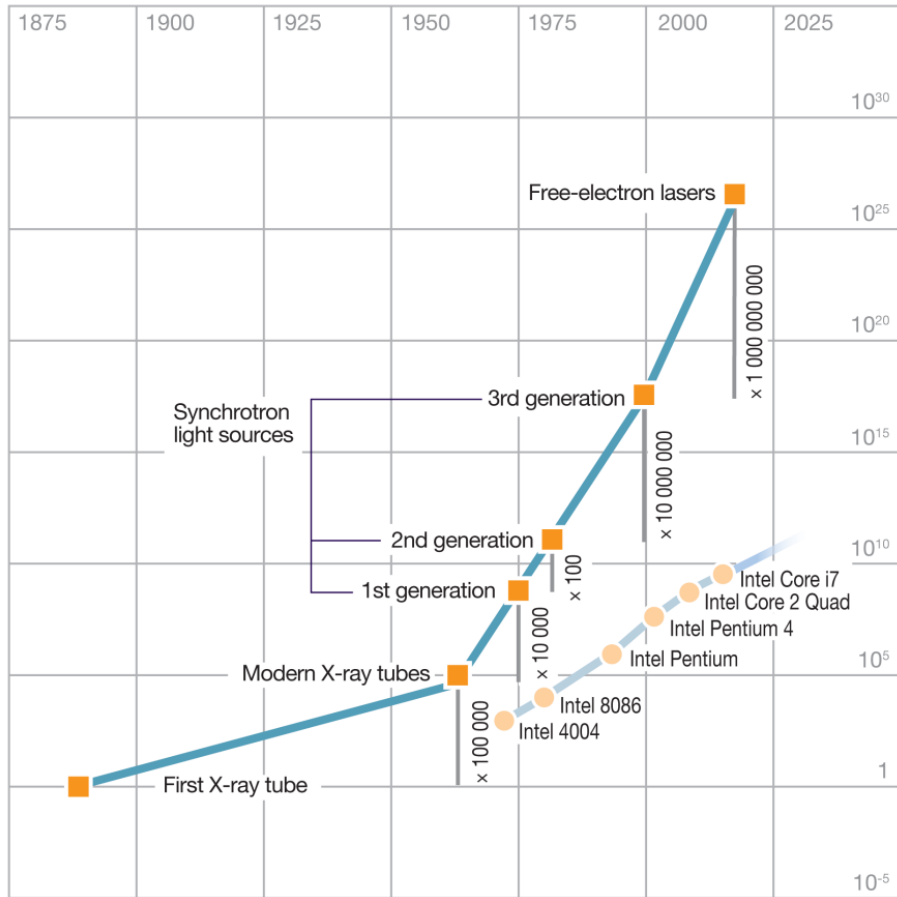
European XFEL

X-Ray Detectors at EU.XFEL Instruments

SASE I	Single Particles, Clusters and Biomolecules (SPB)	AGIPD	Gotthard V1/2	Jungfrau
SASE II Hard X-rays	Materials Imaging & Dynamics (MID)	AGIPD	Gotthard V1/2	ePix, Jungfrau
	Femtosecond X-ray Experiments (FXE)	LPD	Gotthard V1/2	Jungfrau
	High Energy Density Matter (HED)	Jungfrau	Gotthard V1/2	ePix, Jungfrau
SASE III Soft X-rays	Small Quantum Systems (SQS)	DSSC	pCCD	MCP
	Spectroscopy and Coherent Scattering (SCS)	DSSC	Fast CCD	

**100 MB/s - 10 GB/s
 10 Hz burst**

The European XFEL – a Data Perspective



— Relative peak brilliance (first X-ray tube = 1)
 — Number of transistors in processors

European XFEL

Custom FPGA-based Data Producers at EU.XFEL



MicroTCA Crates
 Large 12 slot 9U and small 6 slot 2U (including MCH, Power Supply and CPU)



X2Timer
 XFEL Timing System module for synchronization (clocks and triggers) and pulse parameters from NAT



DAMC2
 Required for Clock & Control system for fast 2D detectors, VETO System, Machine Protection System and photon beam loss monitors from DESY



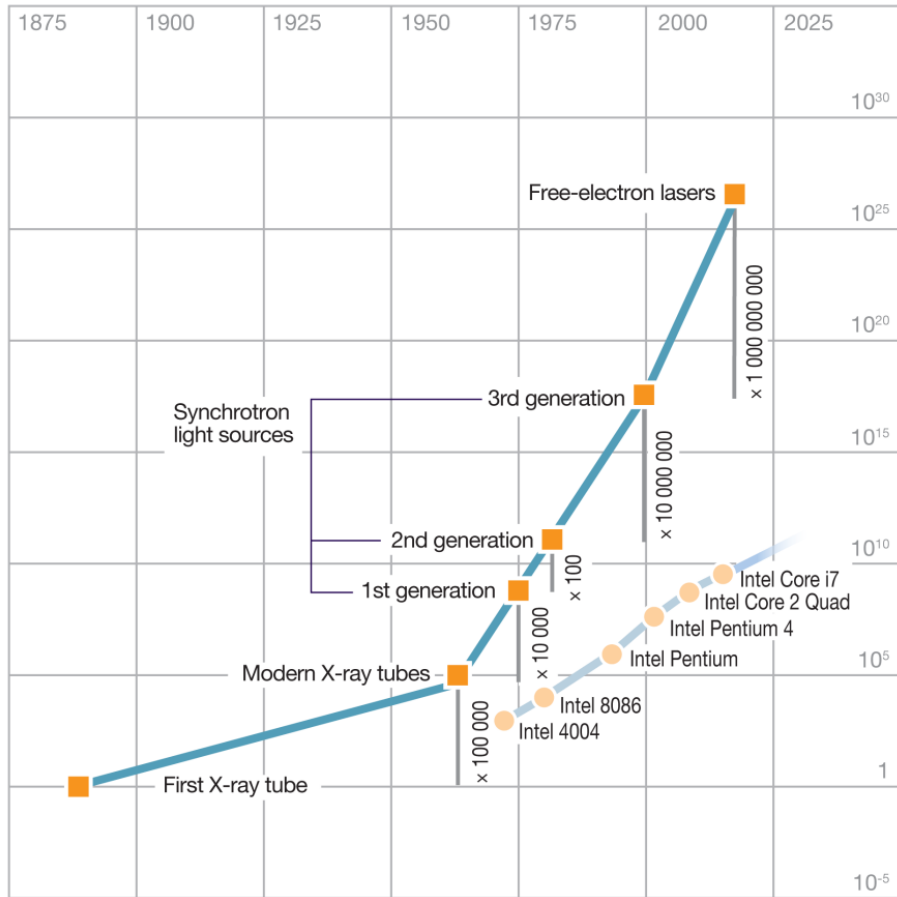
SIS8300
 Fast 125MSPS ADC with 10 channels and 16bit resolution for diagnostics and detectors from Struck Innovative Systems



ADQ412/ADQ14/ADQ7
 High-speed digitizers from 1.8GSPS to 10GSPS with 12 to 14 bit resolution from Tollyne SP Devices

**1 MB/s - 1 GB/s
 10 Hz burst**

The European XFEL – a Data Perspective



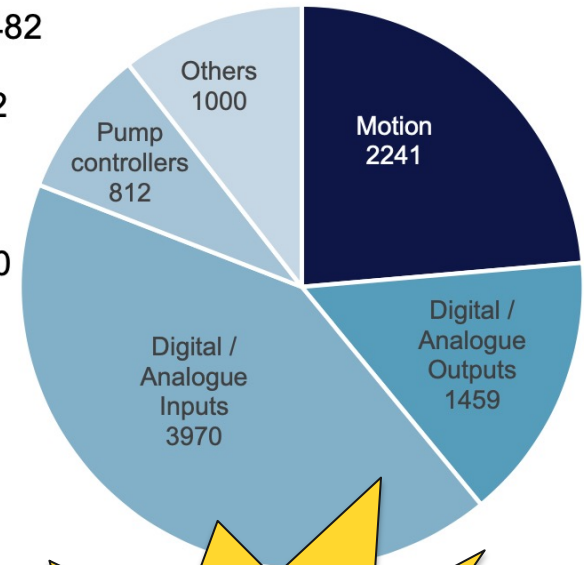
— Relative peak brilliance (first X-ray tube = 1)
 — Number of transistors in processors

European XFEL

PLC Systems at EU.XFEL

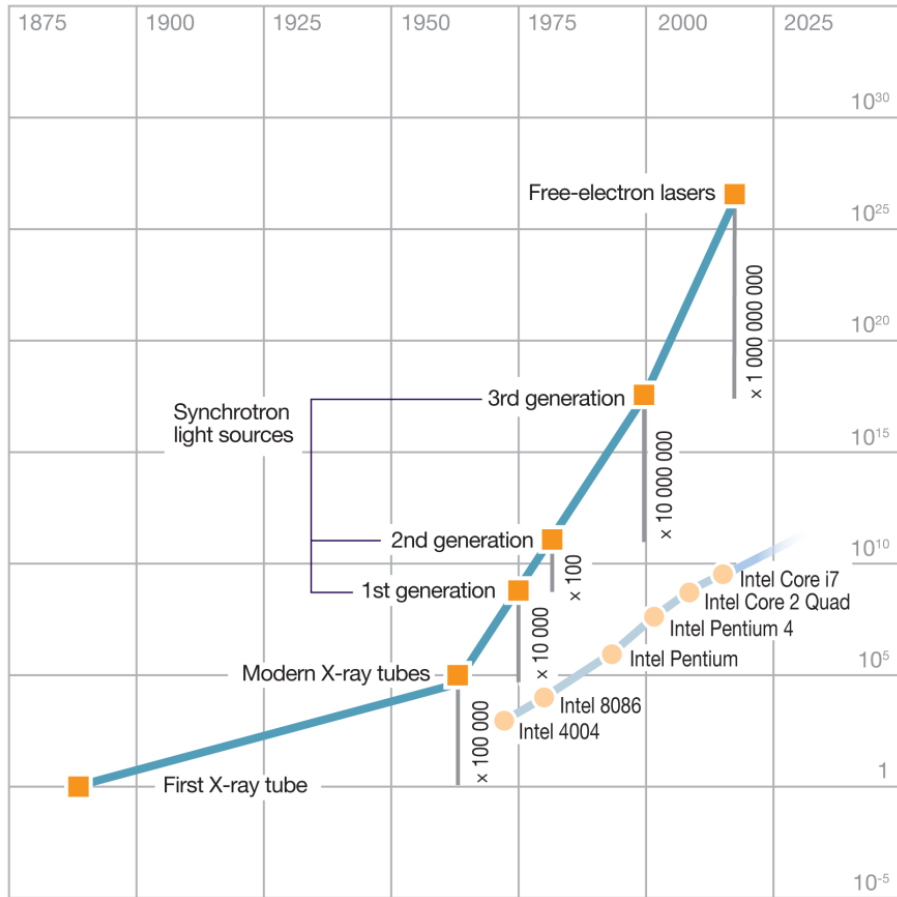
- Softdevices/Equipment: 9.482
- Number of Terminals: 8.452
- PLC Loops / CPUs: 120
- PLC Modules / crates: >500
- MicroTCA Systems: 35
- Digitizer channels: >280

Distribution of softdevices



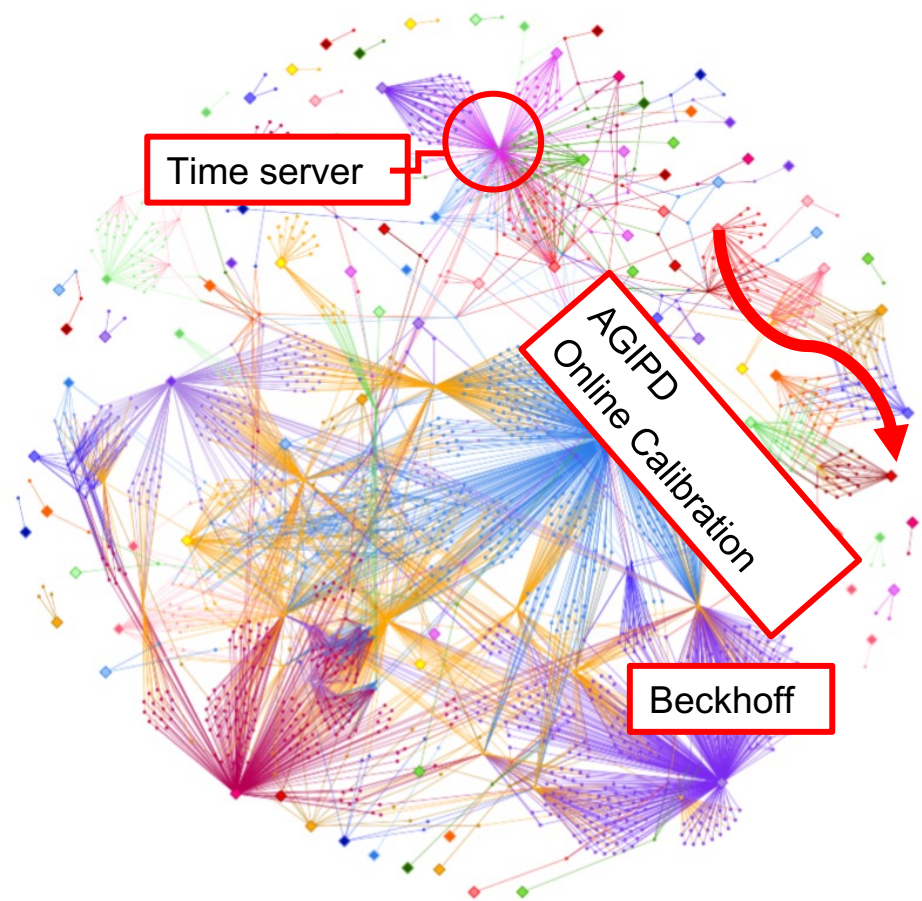
**1 B/s - 1 MB/s
 event driven**

The European XFEL – a Data Perspective



— Relative peak brilliance (first X-ray tube = 1)
 — Number of transistors in processors

The Karabo Control System for the MID instrument

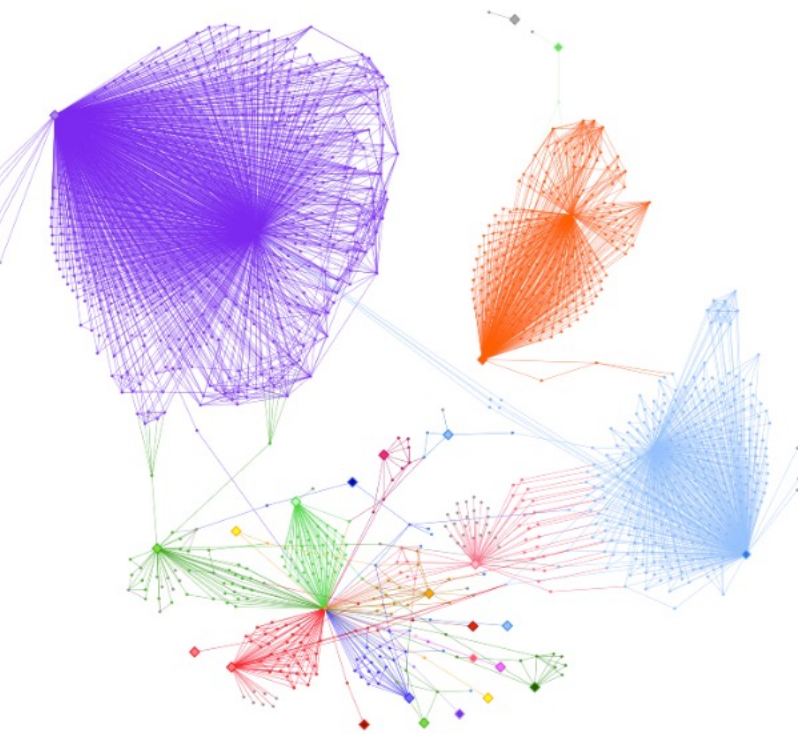


properties # devices

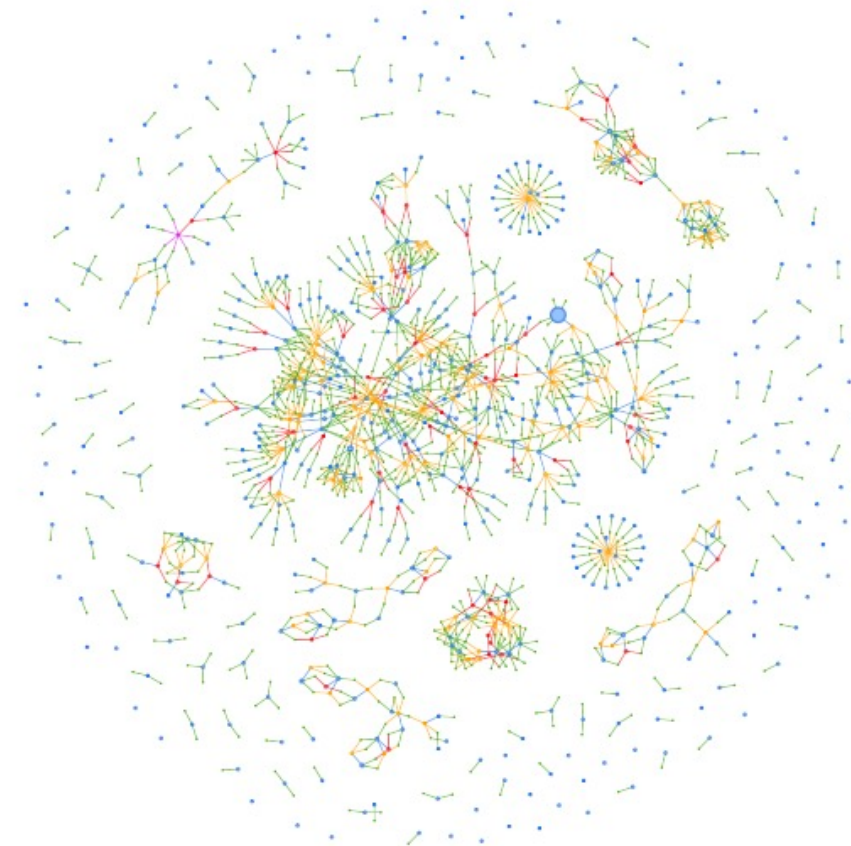
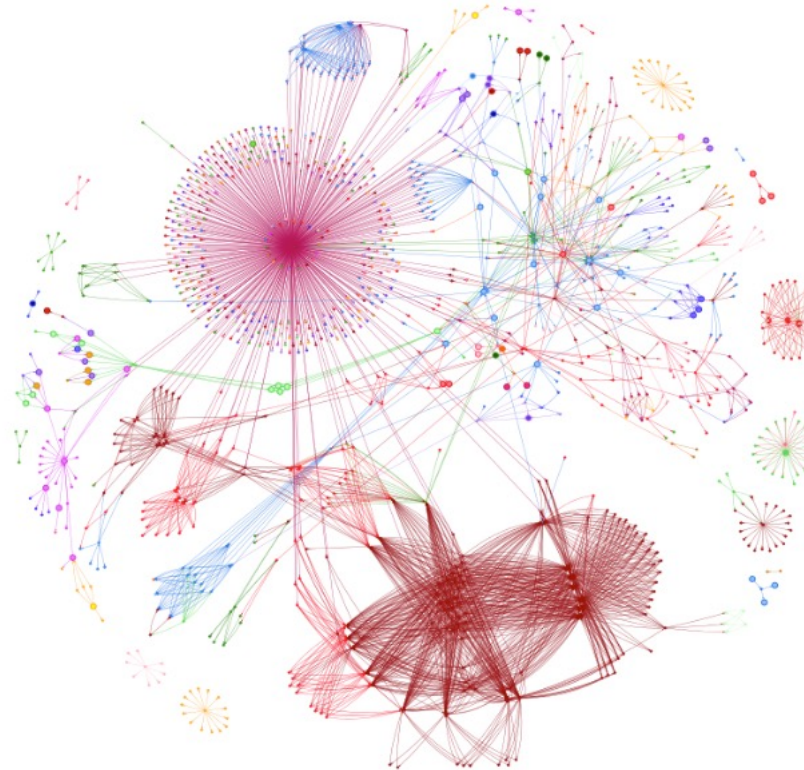
topic	# properties	# devices
LA1	26914.0	257.0
LA2	28103.0	250.0
LA3	32013.0	298.0
SA1	192656.0	1588.0
SA2	274426.0	2260.0
SA3	233216.0	1886.0
FXE	121905.0	905.0
HED	268688.0	1892.0
MID	258094.0	1789.0
SCS	205557.0	1444.0
SPB	267424.0	1872.0
SQS	306817.0	1954.0
Total	2215813.0	16395.0

The European XFEL – a Data Perspective

Karabo Host topology of SASE1



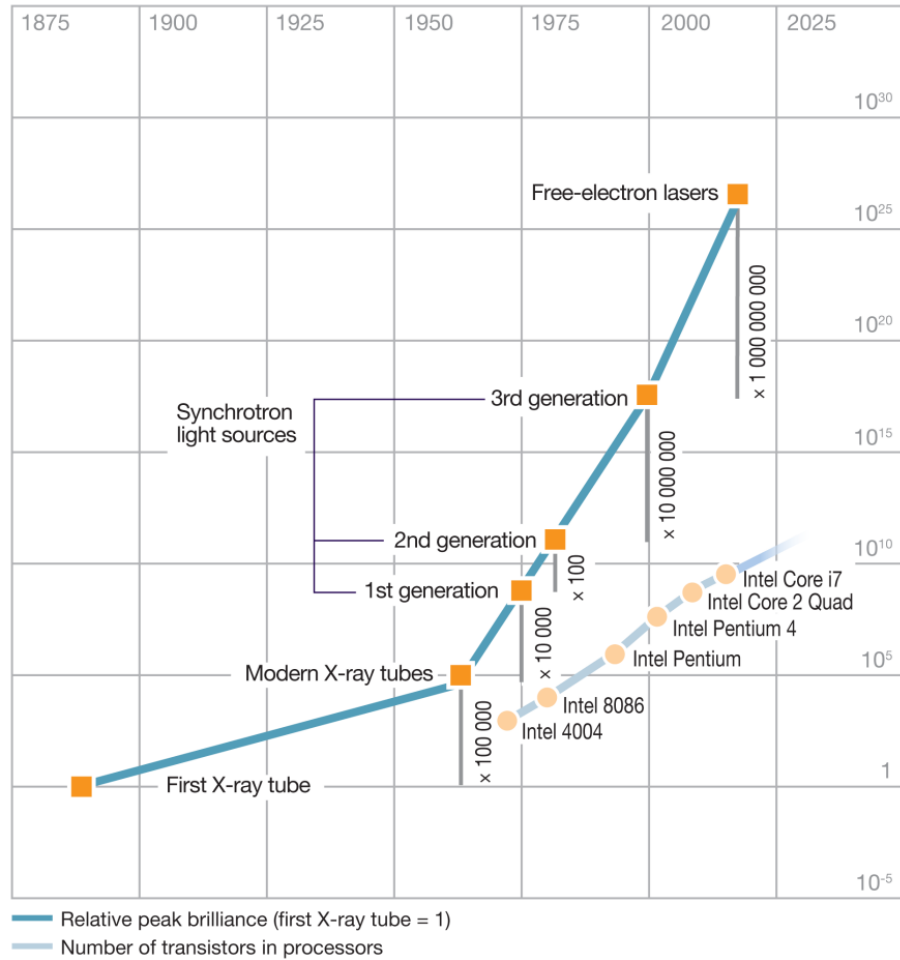
Interlock definitions and references in SASE1 PLCs



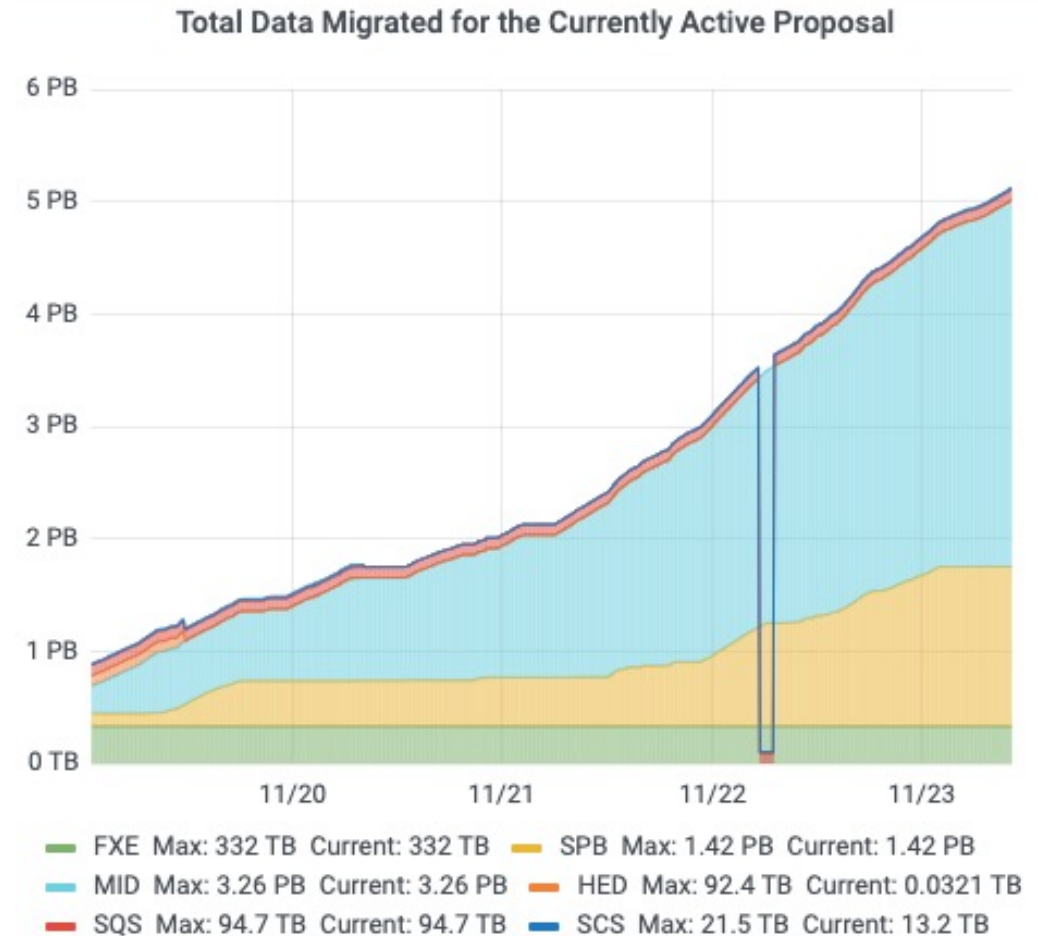
European XFEL

Links between synoptic panels of SASE1 in Karabo

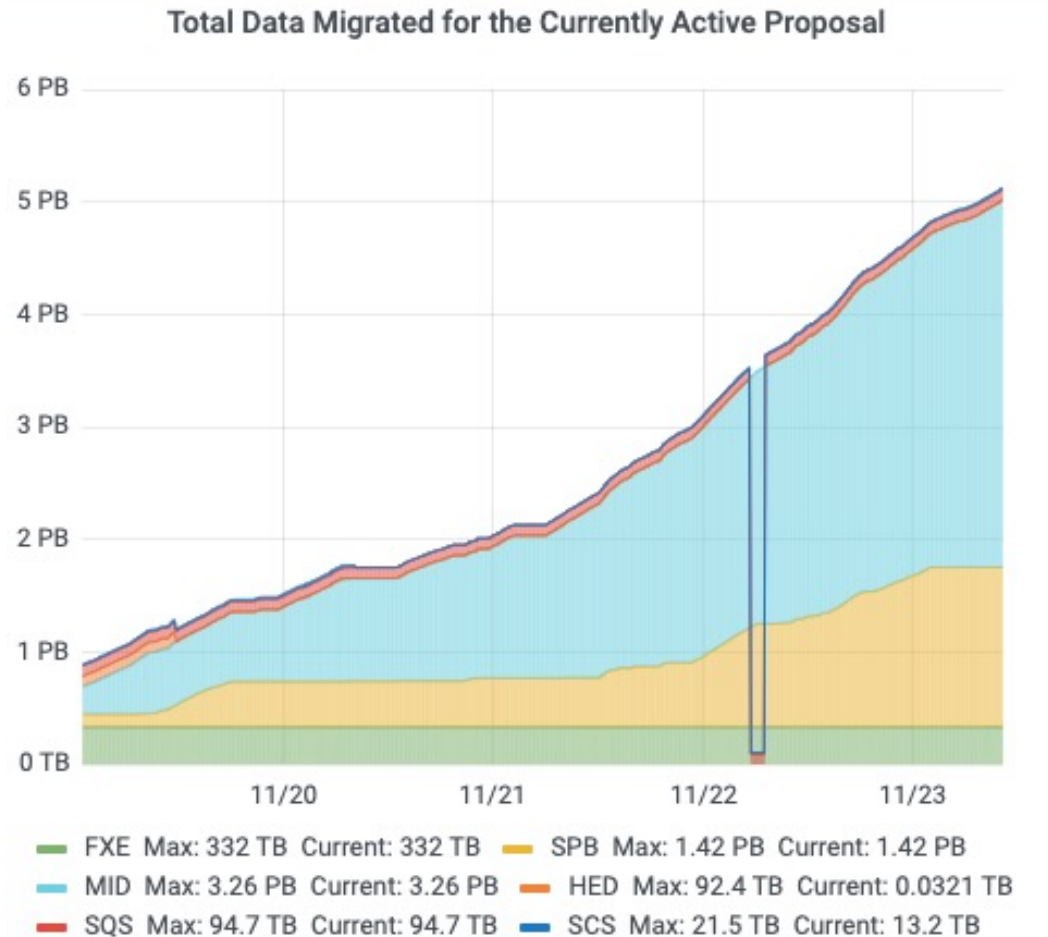
The European XFEL – a Data Perspective



Data Produced in CW46 2021 – All Data Systems Working



The European XFEL – a Data Perspective

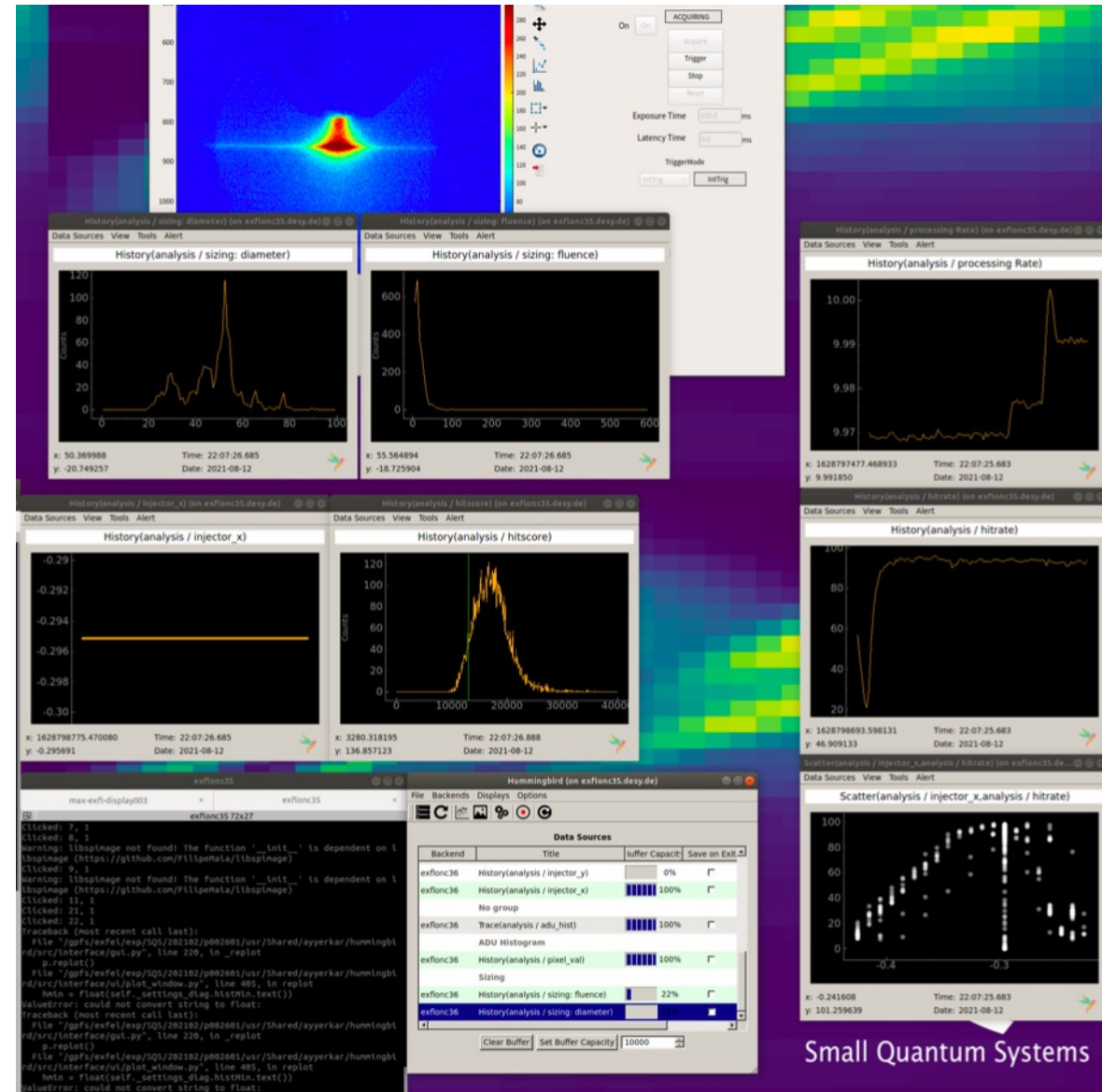


If data services are working, facilities like EU.XFEL easily produce scientific data in the Peta-Byte range in a few days

The European XFEL – a Data Perspective

Online Processing is equally “data-intensive“:

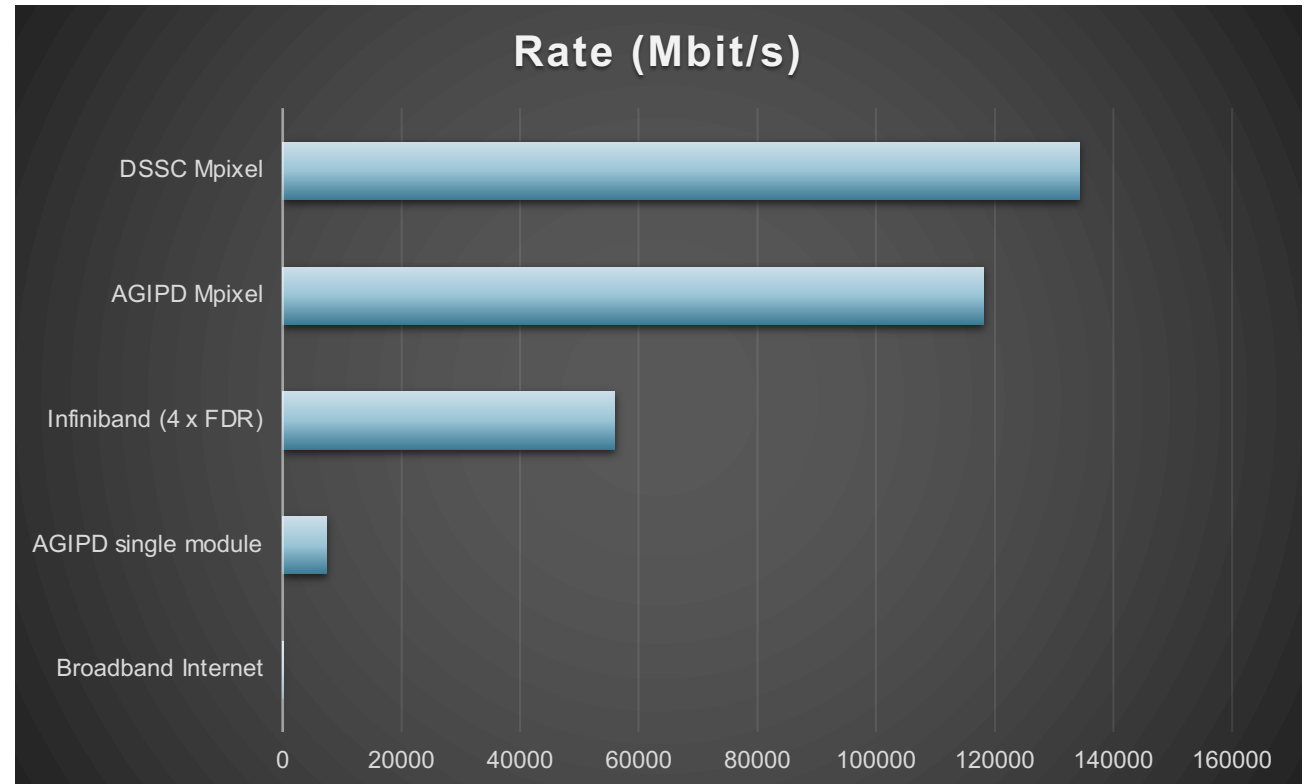
- Near-realtime streaming of up to 4KHz into „user space“
- Critical parameters:
 - Throughput: how may images per second can be calibrated, assembled and passed on to user-supplied code
 - Latency: with which delay does data arrive for user analysis



The European XFEL – a Data Perspective

Online Processing is equally “data-intensive“:

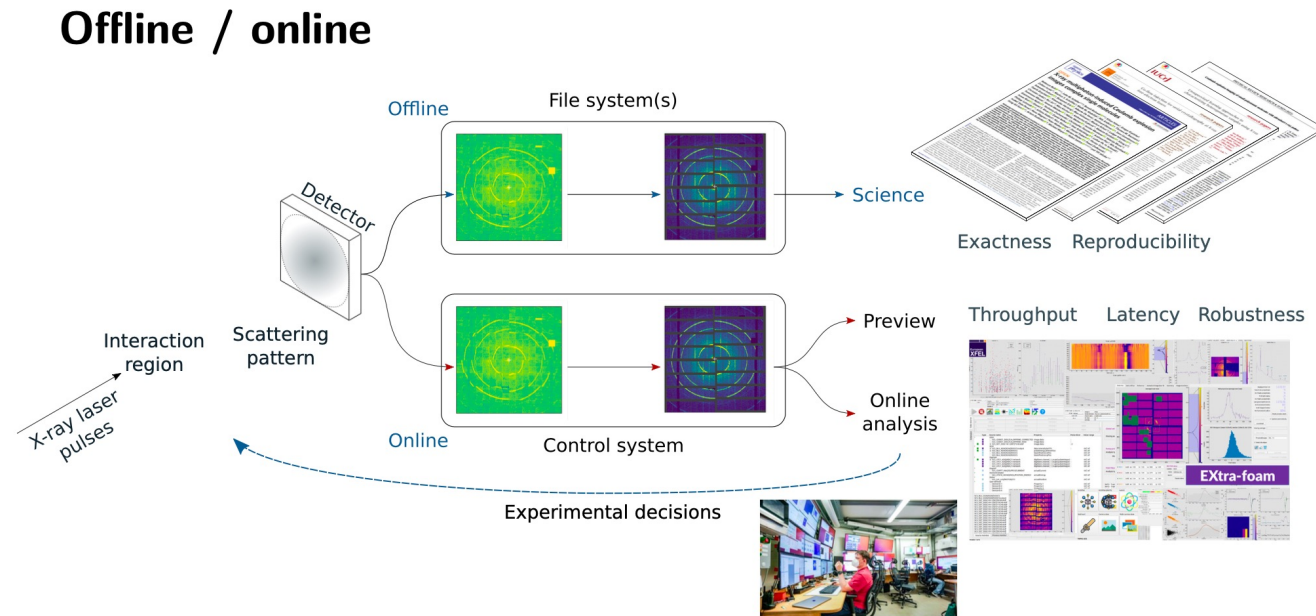
- Near-realtime streaming of up to 4KHz into „user space“
- Critical parameters:
 - Throughput: how many images per second can be calibrated, assembled and passed on to user-supplied code
 - Latency: with which delay does data arrive for user analysis
- **A full Mpix detector exceeds the Infiniband bandwidth of a single online calibration host**



The European XFEL – a Data Perspective

Additional data-related services that are critical to an experiment's success:

- Detector configurations optimized to the experimental needs
- Online and offline calibration
 - Processed data is calibrated and often the primary data product
 - Calibration constants are curated and selected by the facility
- Standardized data analysis tool-chains
 - Offline
 - Online
- Data access libraries
 - Abstract fragmented data originating from concurrent acquisition



The Mystery of the Broken Fiber - an example of Complexity

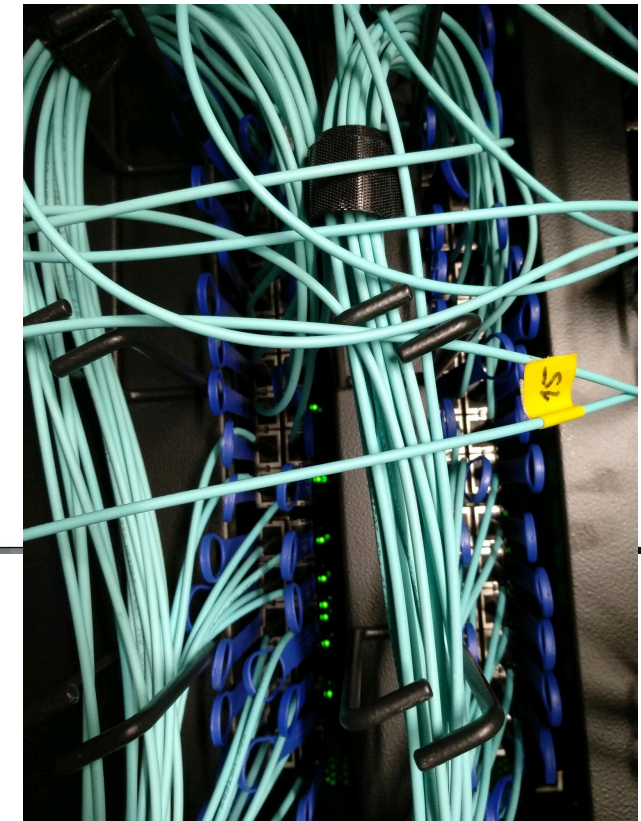
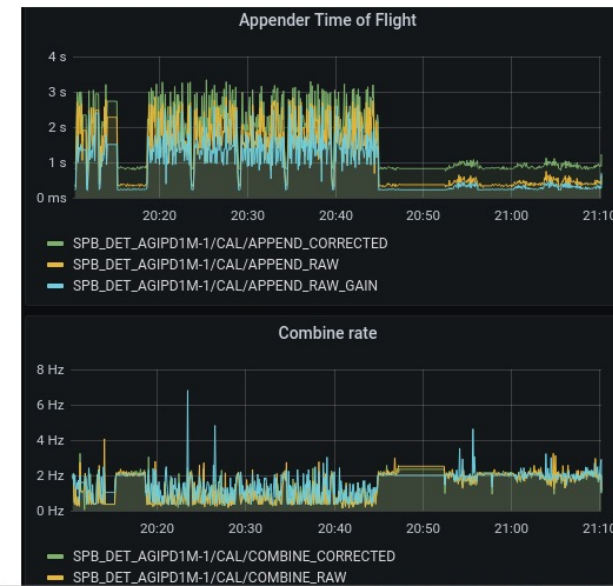
- * DOC observes strong jitter on AGIPD detector online preview, advises SPB instrument on issue (AGIPD is their main detector)
- * SPB and DOC iterate settings, no apparent misconfiguration
- * DOC observes correlation with DAQ - at some point DAQ and preview are mutually exclusive –if data is recorded SPB is blind
- * Experts from data dept. groups reduce problem set to link-layer
- * IT experts track possible bottleneck in network topology
- * Second-level IT support unplugs cable
- * **Example of a critical issue that could have stopped scientific data acquisition, and required expertise from multiple technical groups to locate and solve**



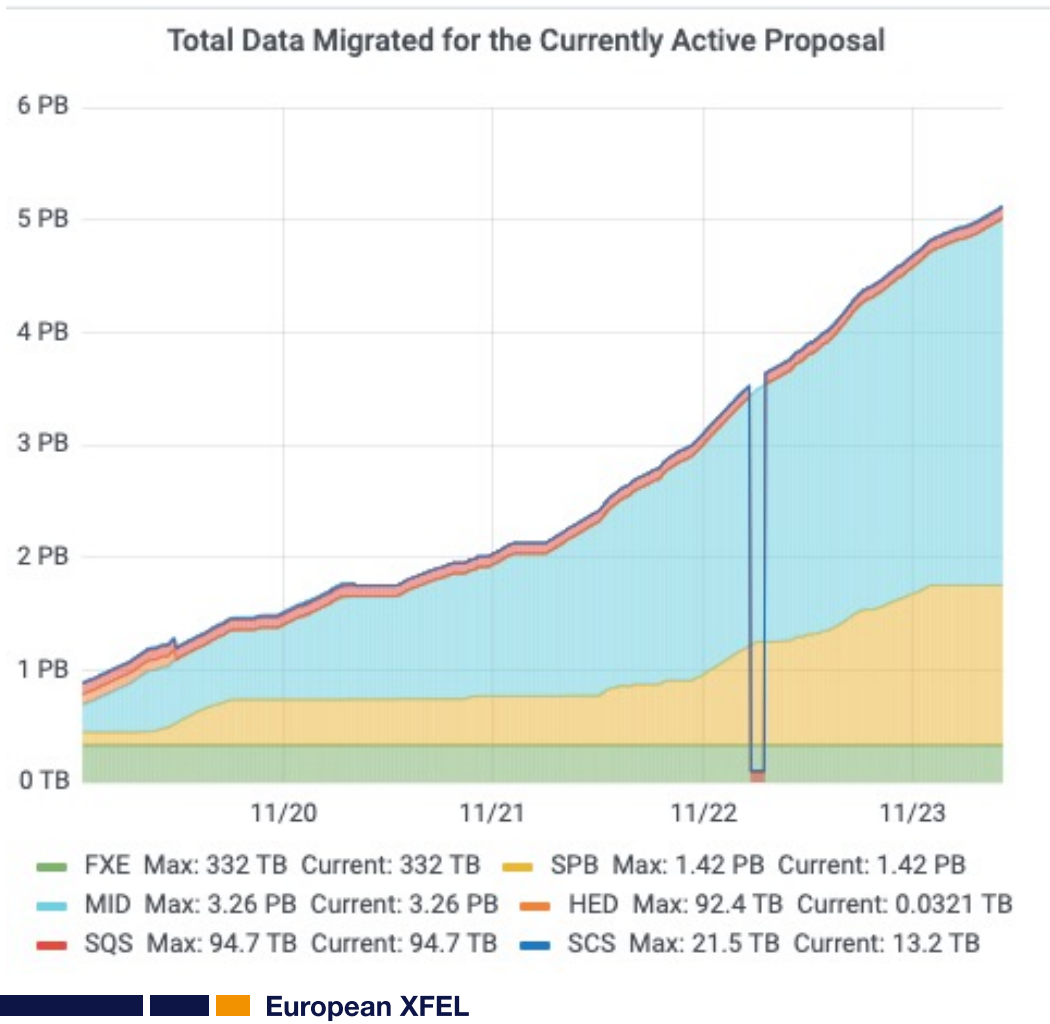
Steffen Hauf 14 Apr 2021 09:17 PM

The issue has been understood and fixed. The problem was a degraded link on the Infiniband Fabric. IT & DM helped identify this as the root cause, and provided a solution. The link was physically disconnected, forcing the fabric manager to route around it. With the degraded link in place, the throughput of the GPFS system is determined by the degraded link speed, which is why most DA's showed performance degradation. In short the link had reduced the available bandwidth, which impacted data traffic from the DAs to disk and to the online pipeline.

As far as we can tell the system has recovered to an the expected performance, and additional follow up will be done by ITDM during service time.



The European XFEL – a Data Perspective

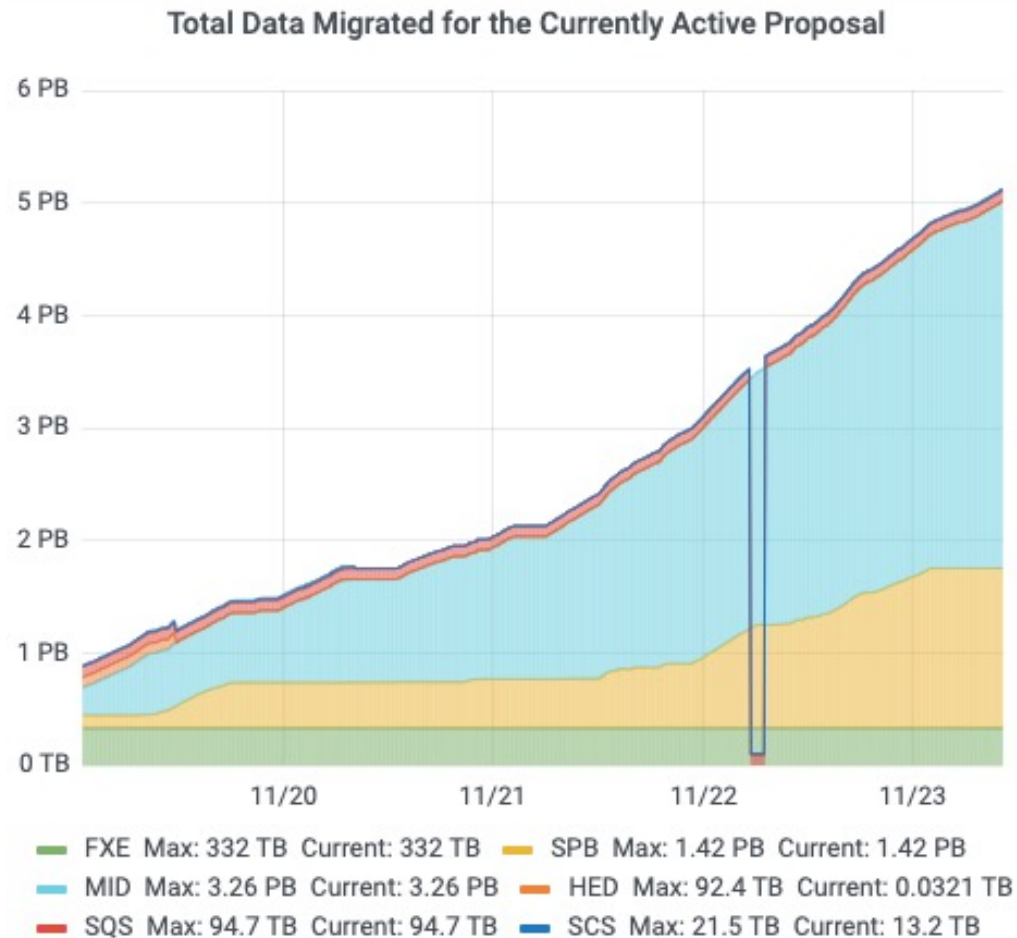


If data services are working, facilities like EU.XFEL easily produce scientific data in the Peta-Byte range in a few days

The complexity of the systems necessary for this significantly exceeds the knowledge and experience of any single person*

* At EU.XFEL data-related services e.g. are provided by the 5 groups of the DATA dept: Control, Electronic and Electrical Eng., IT & Data Management, Detectors, Data Analysis.

The European XFEL – a Data Perspective



If data services are working, facilities like EU.XFEL easily produce scientific data in the Peta-Byte range in a few days

The complexity of the systems necessary for this significantly exceeds the knowledge and experience of any single person

„Traditional“ support e.g. mainly through beamline staff and on-call/on-email experts reaches it's limits.

The Data Operation Center (DOC) – The Vision

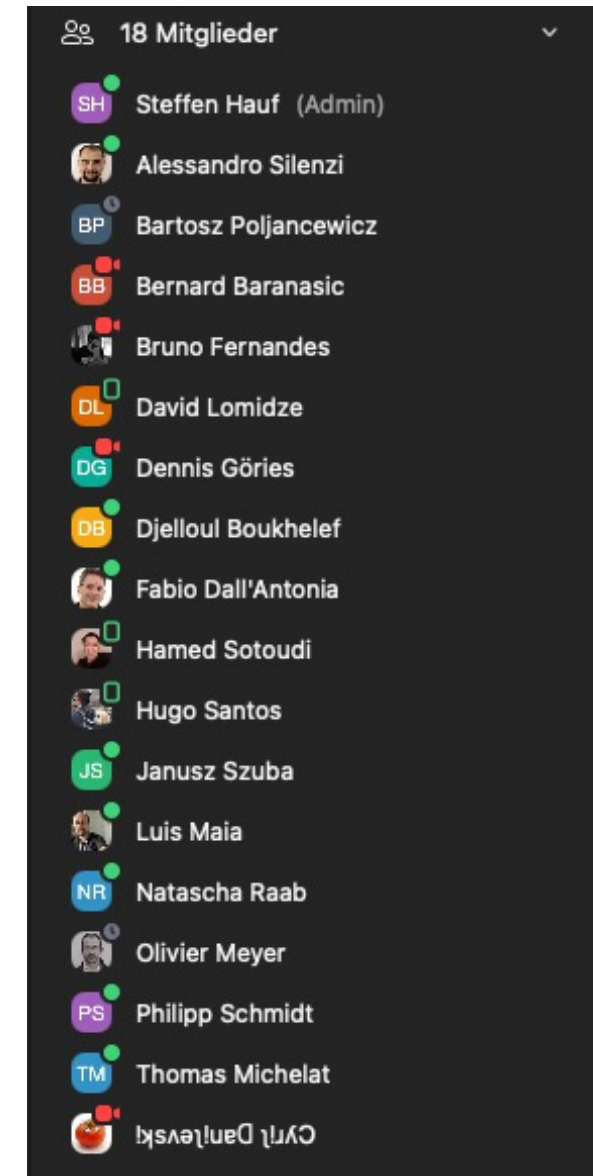
- * **Single point of entry** into DATA support during X-ray operation
- * **Proactive:** monitors DATA provided services essential during X-ray operation
- * **Cross-functional and inter-group**
- * **Not static:** will enhance its capabilities over time

**Apollo 11 had the computational power of a calculator,
Mission control that of a few iPhones**






Creating the DOC

- * A DOC Task Force was launched Dec 18th 2020
- * DOC to reach initial operational capability in early 2021
- * 18 TF members from across DATA dept., all groups represented
- * Emphasis on extensible but always usable capability set from day-1 on
→ an agile approach lends itself to this
 - * 3 Task force teams: hardware, documentation, monitoring tools
 - * 3 concurrent two week sprints
 - * TF members contributed between 20-40% of their time
 - * DATA management was stakeholder in the effort



Task Force Work Organization

- * SCRUM and task board
- * Product owner defines overall priority in coordination with stakeholders
- * Team defines effort for tasks
- * PO and team agree on *Definition of Done*
- * Anybody in the team can take on a task
- * A task may be further specified in a sprint but should not change in scope

Control and Monitoring Tools - Implementation III 01 Feb 2021 - 12 Feb 2021   

Goal for this sprint :

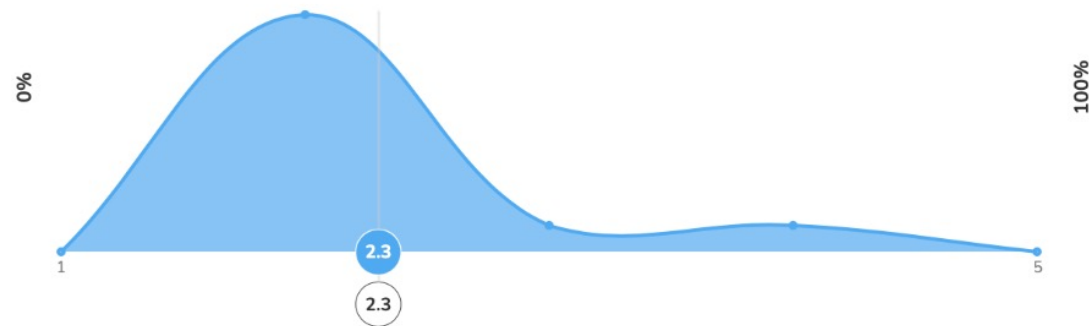
Identifying problems early on: motors, digitisers, cameras... COVID Research @ SPB

No swimlanes

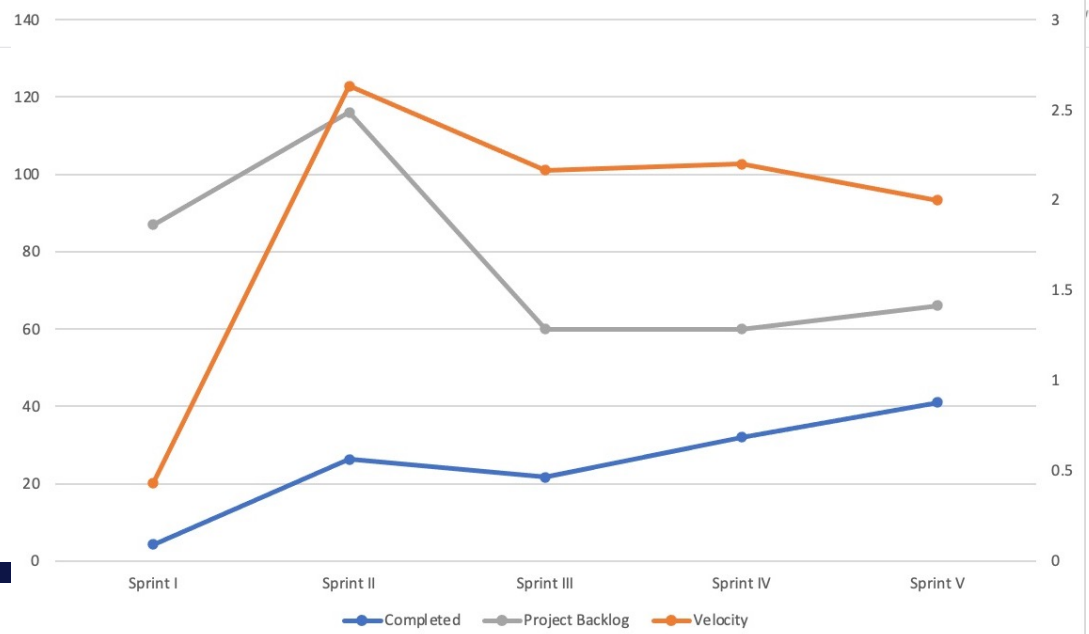
backlog (0/0)	New (0/0)	Realization (0/0)	To check (0/0)	Done (0/0)
<p>#82756 - Add online cluster nodes to DOC nagios 0.00 DOC Task Force</p>	<p>#80340 - monitor motors: identify motors with a velocity of zero - 2 0.00 DOC Task Force</p>	<p>#82349 - monitor detectors: overall system state (AGIPD) - 5 0.00 DOC Task Force</p> <p>#80334 - monitor digitisers: warn if a too large number of samples is chosen 0.00 DOC Task Force</p> <p>#80388 - monitor motors: define other critical parameters for motors - 2 0.00 DOC Task Force</p> <p>#80384 - Monitor if a camera is losing frames (acquiring state and less than 10Hz) - 5 0.00 DOC Task Force</p>	<p>#80332 - monitor uTCA crate health: identify a non-responsive crate - 2 0.00 DOC Task Force</p> <p>#80368 - monitor TrainMatcher status - identify what should be monitored - 2 0.00 DOC Task Force</p> <p>#80371 - installation: install Karabo and Karabo GUI on DOC clients - 2 0.00 DOC Task Force</p>	

DOC Taskforce – Measuring Progress

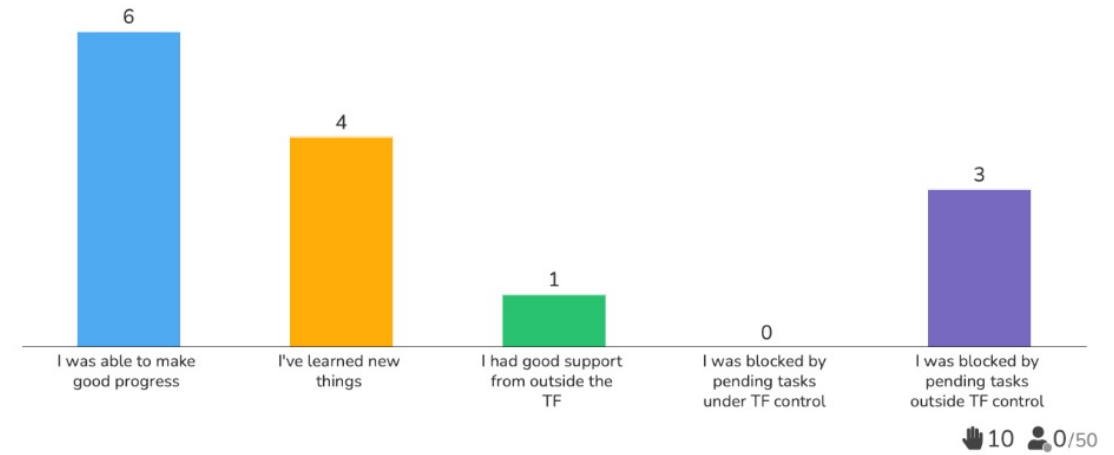
How much time can you contribute to the task force



Sprint Statistics



Select answers which apply

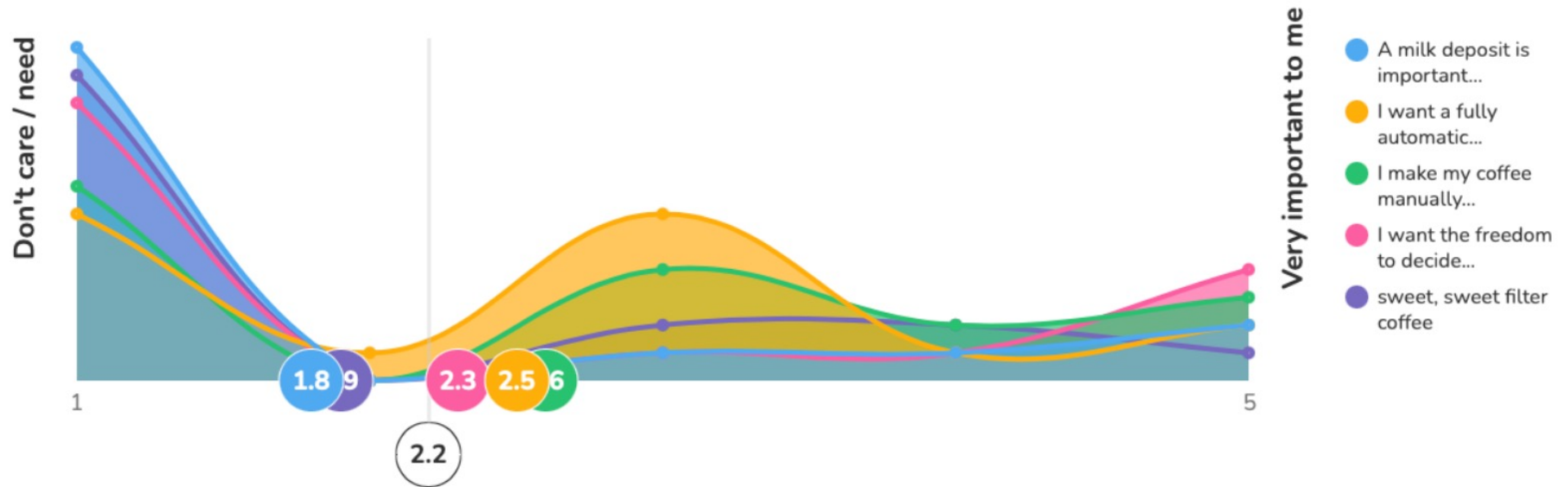


What impedes you most during X-ray operation

- Maybe it would've been better to have some people from the instruments involved from the start? (instrument)
- Detector calibration (FXE)
- DAQ failures (MID)
- Parameters lost after some upgrade (even worse: partially lost or changed). Karabo not connected to Beckhoff.
- Beckhoff devices down. Motors don't work. Triggers wrong on detectors because they are static. Missing data in DAQ. (HED)
- the lack of an infinite number of monkeys and typewriters :-)
- Problems with digitizers, Karabo failure or buggy (SA3 topic), problems with DAQ not recording data, data aggregators take too long, digitizer failure when changing parameters
- I have a problem with data analysis. (MB)
- Online calibration for area detectors (FXE)
- hot configuration of DAQ group / recorded data per run assignment (SPB/SFX)
- Slow data recording to DAQ (e.g. motors) is not working well. Too many parameters are recorded, which slows down / crashes DAQ.

DOC Taskforce – Other Interesting Surveys

The DOC Coffee Machine



🔒 Submission stopped [Open](#)

👤 16 🧑 0/50

The Data Operation Center (DOC) – The Vision

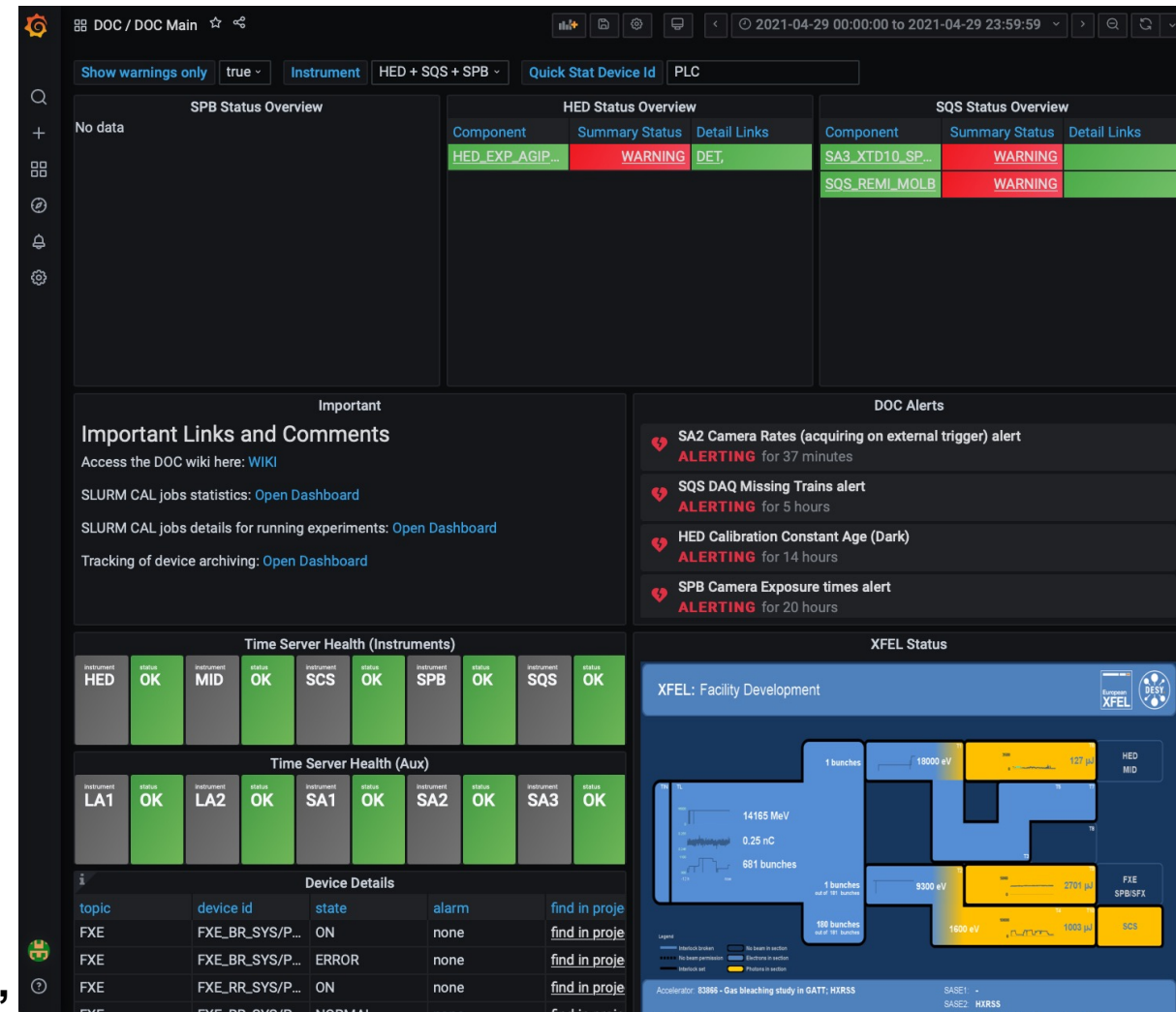
- * **Single point of entry** into DATA support during X-ray operation
- * **Proactive:** monitors DATA provided services essential during X-ray operation
- * **Cross-functional and inter-group**
- * Not static: will enhance its capabilities over time
- * Two people on shift and a Data Run Coordinator (DRC)
 - * DRC is the interface of the DOC to facility coordination
 - * DRC is an escalation path

XFEL DOC has access to a state-of-the-art timeseries DB, monitor 100+ servers, 10000+ devices and jobs on an HPC cluster. We do have less screens than NASA, but probably a similar amount of pixels available



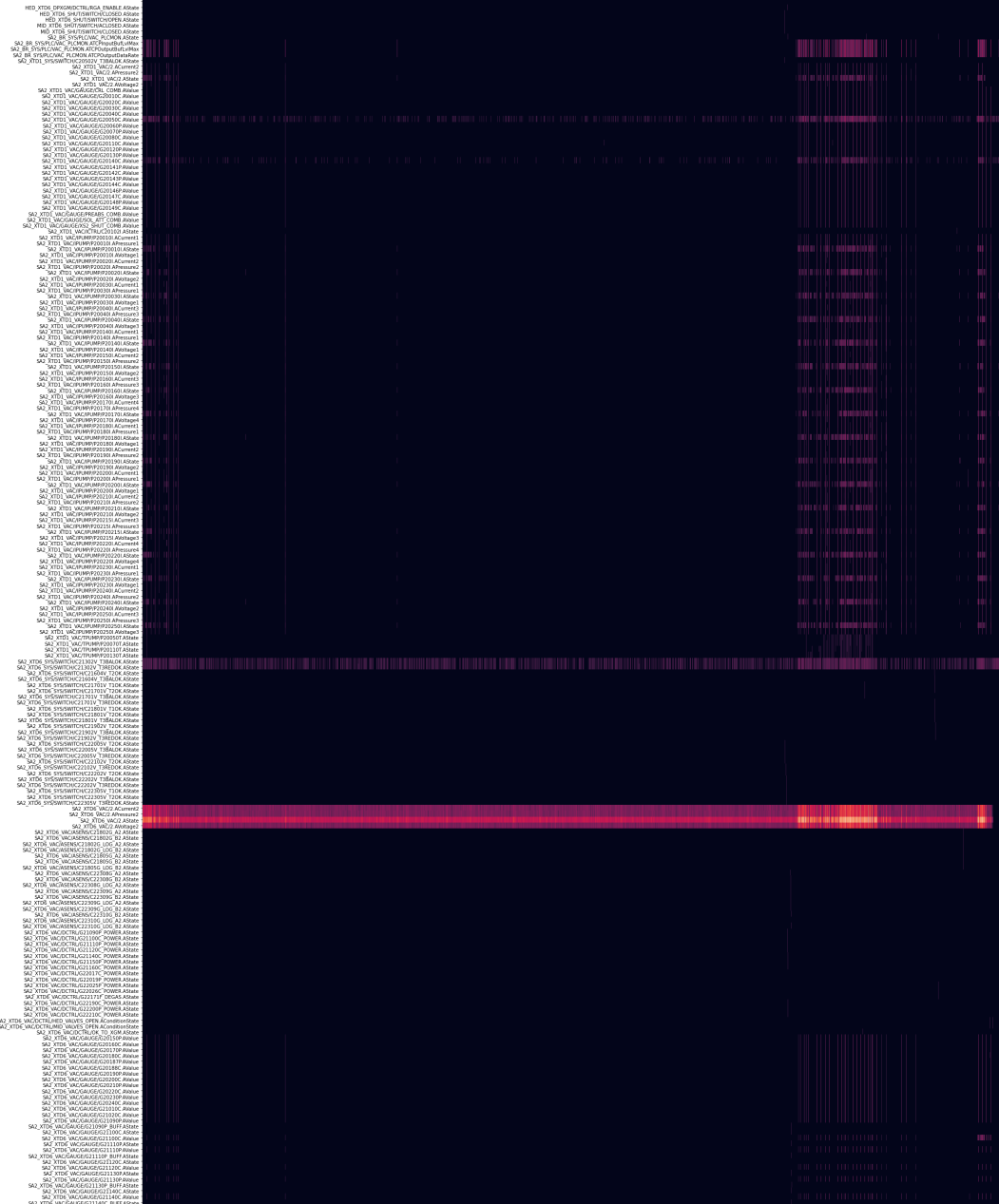
DOC Technology Choices

- * Three months to setup: early decision - do not reinvent the wheel
- * Identify existing systems to use
 - ▶ for communication (Zoom) - now testing Zulip
 - ▶ documentation (Redmine Wiki)
 - ▶ ticketing (Redmine)
 - ▶ logs (PSI elog)
- * But... for monitoring
 - * ~~Karabo~~: somewhat obvious, but large knowledge differences. Programming it, is an „expert“ skill
 - * **Grafana + Influx: was new to almost everyone, we learned together and supported each other**



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Data Operation Center Roles

Data Run Coordinator (DRC)



- RESPONSIBLE FOR DATA OPERATION DURING A GIVEN WEEK
- INFORMATION PATH
- ESCALATION PATH
- ON-SITE OR REMOTE

Shift Lead



- RESPONSIBLE FOR A GIVEN SHIFT
- EXPERIENCED ENOUGH TO CATEGORIZE MOST PROBLEMS
- PROACTIVE
- REACTIVE
- ON-SITE

Shift Deputy



- SUPPORTS DATA SERVICES AT THE FACILITY
- PROACTIVE
- REACTIVE
- ON-SITE

Data Operation Center Roles

from different groups

Data Run Coordinator (DRC)

Shift Lead

Shift Deputy

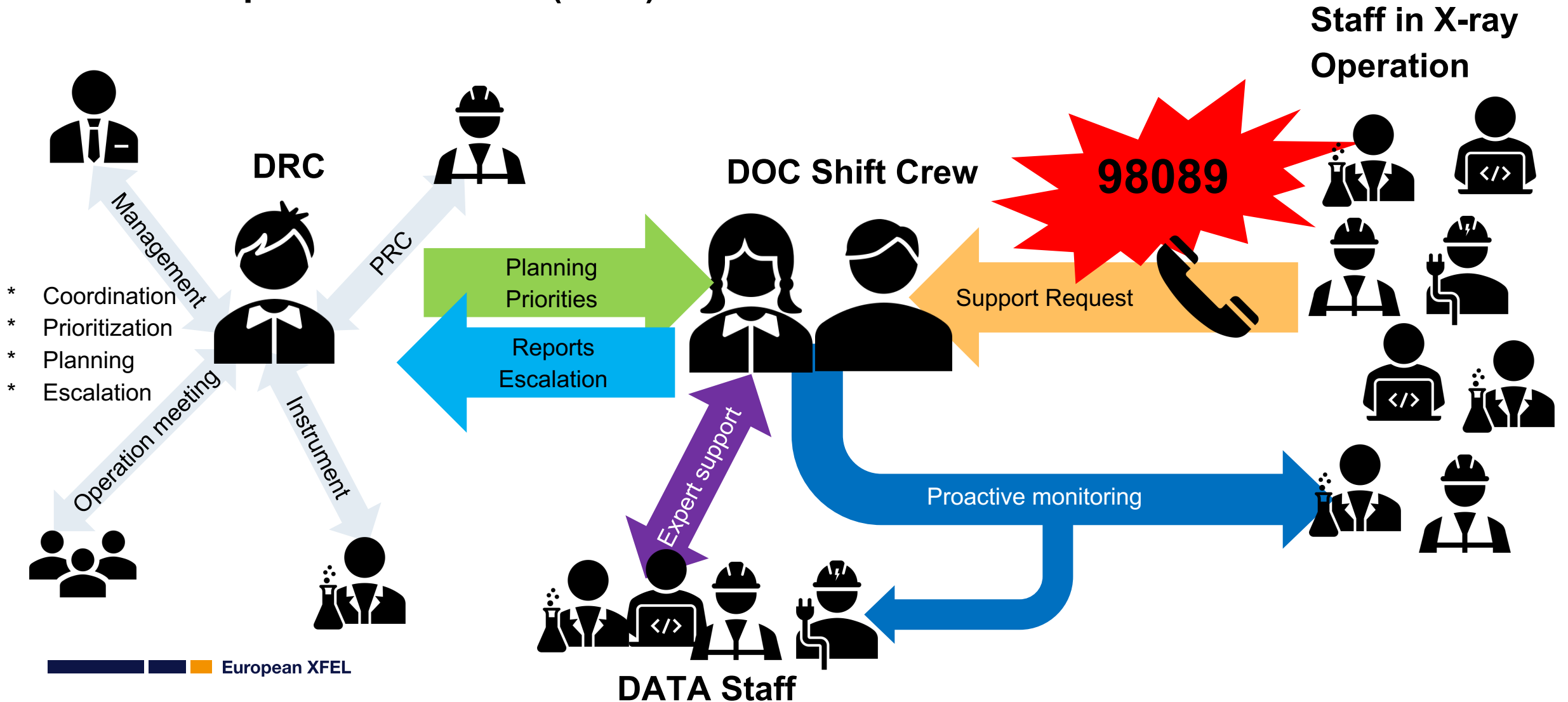


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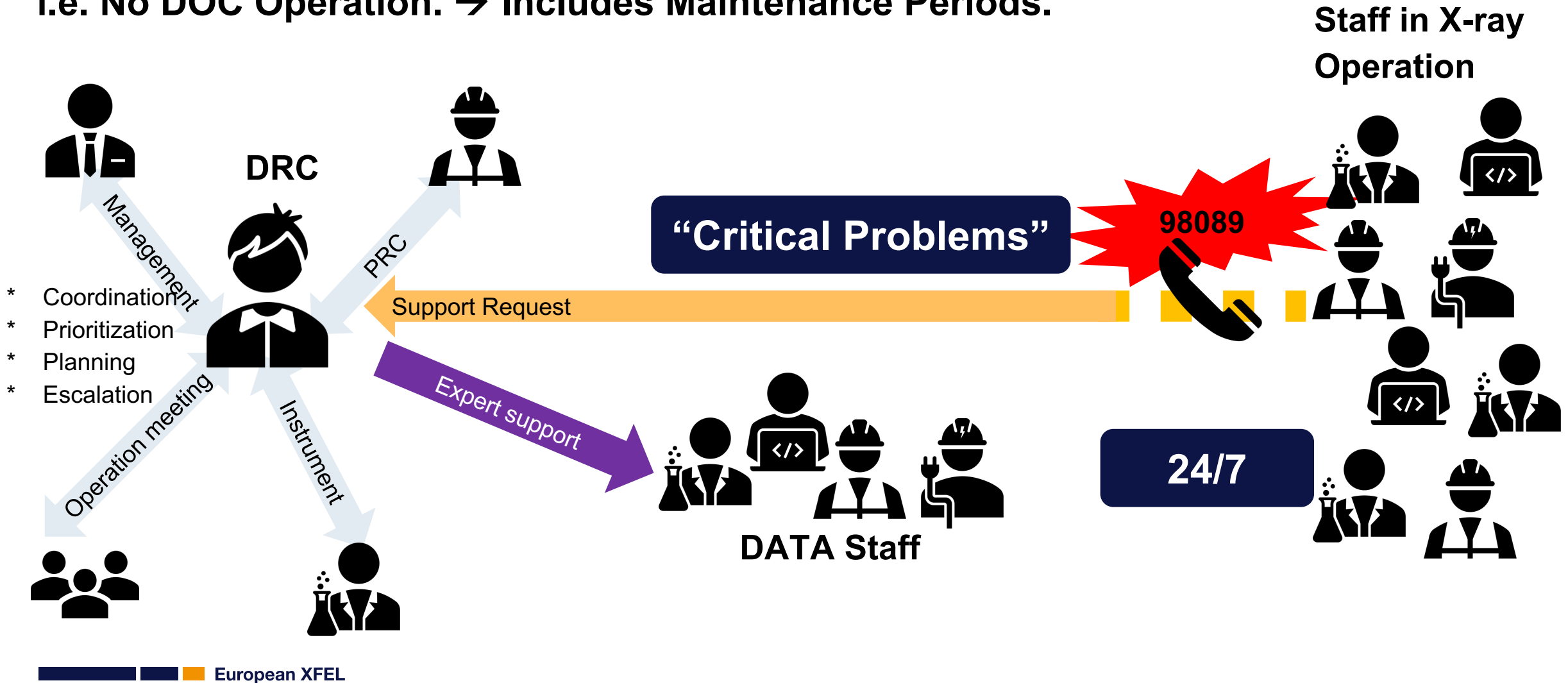
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The Data Operations Center (DOC) – 7/11 hours



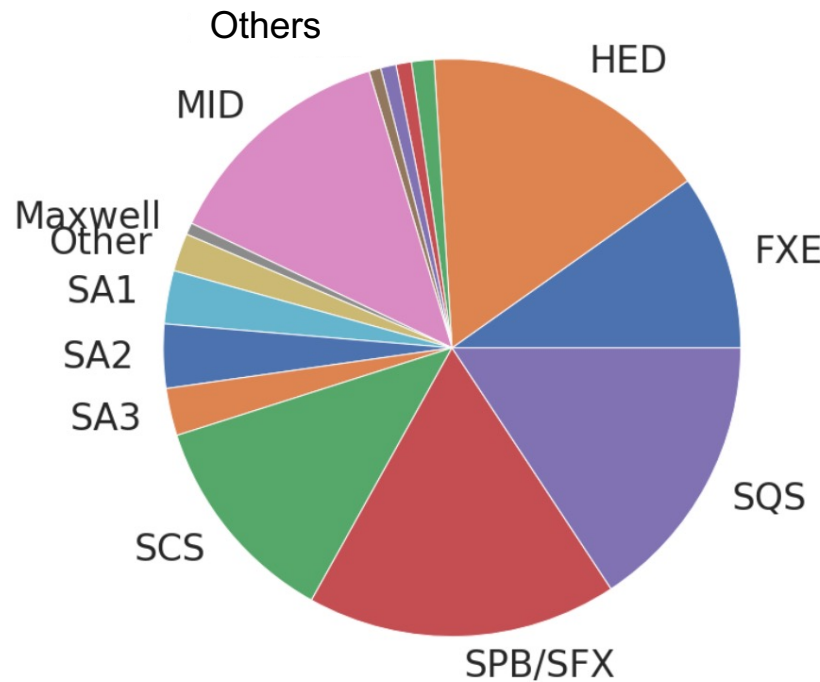
On-Call DATA support outside of priority X-Ray delivery i.e. No DOC Operation. → Includes Maintenance Periods.



Who the Data Operation Center Supports

- Number of support requests by different instruments are comparable
- Support needs vary significantly, depending on equipment and experimental methods used

Support by Installation



European XFEL

What the DOC supports (SPB/SFX, All Time)



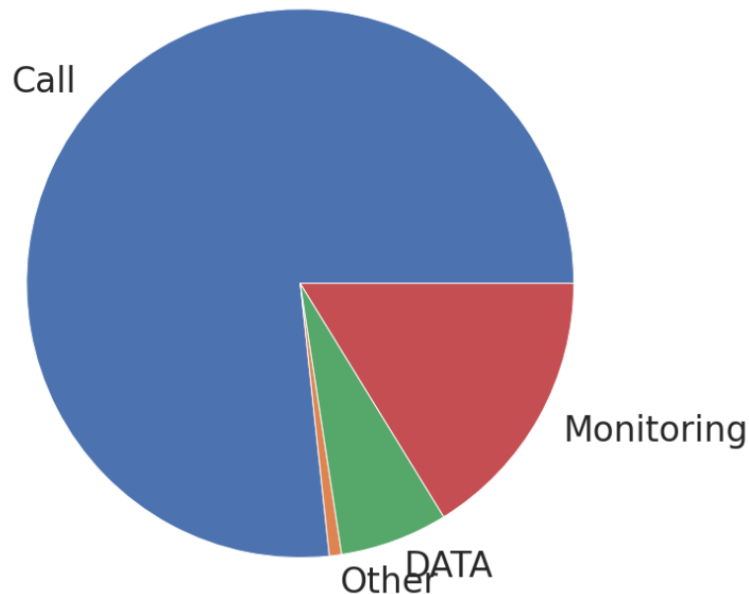
What the DOC supports (FXE, All Time)



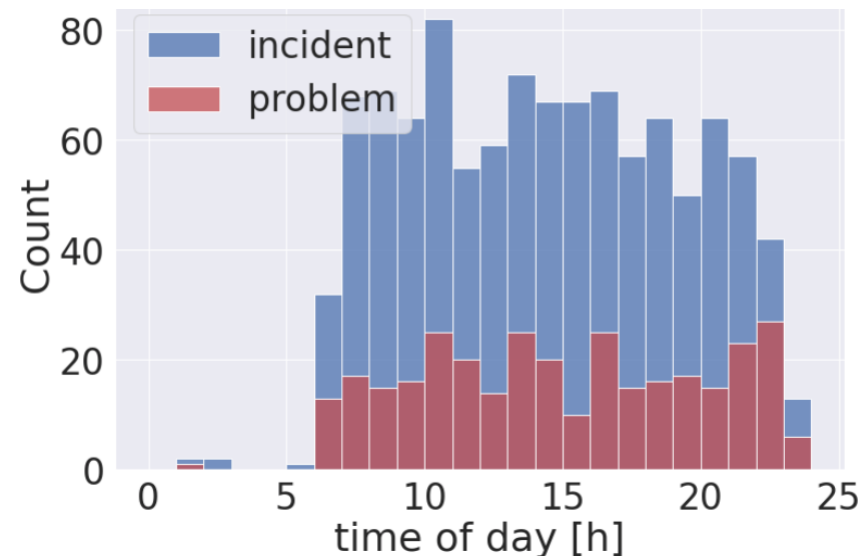
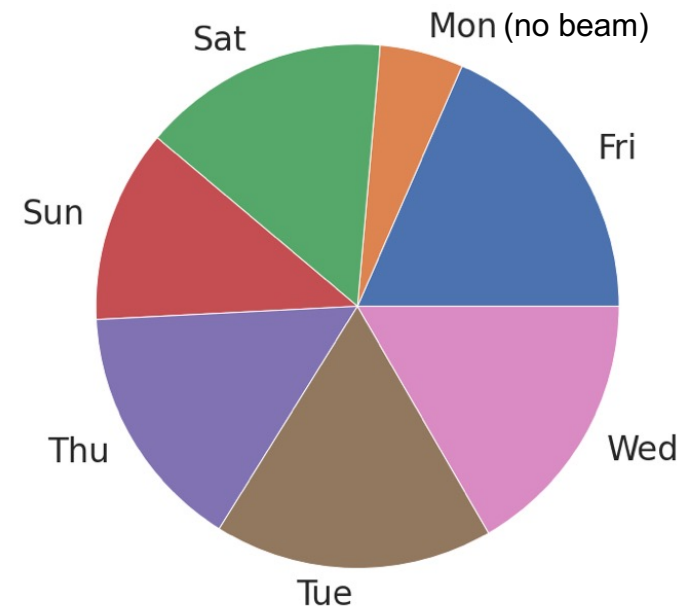
When the Data Operation Center Supports

- Support needs are roughly uniform in time
- ~25% of support is initiated through proactive monitoring of systems

How Support is triggered?



When is support given

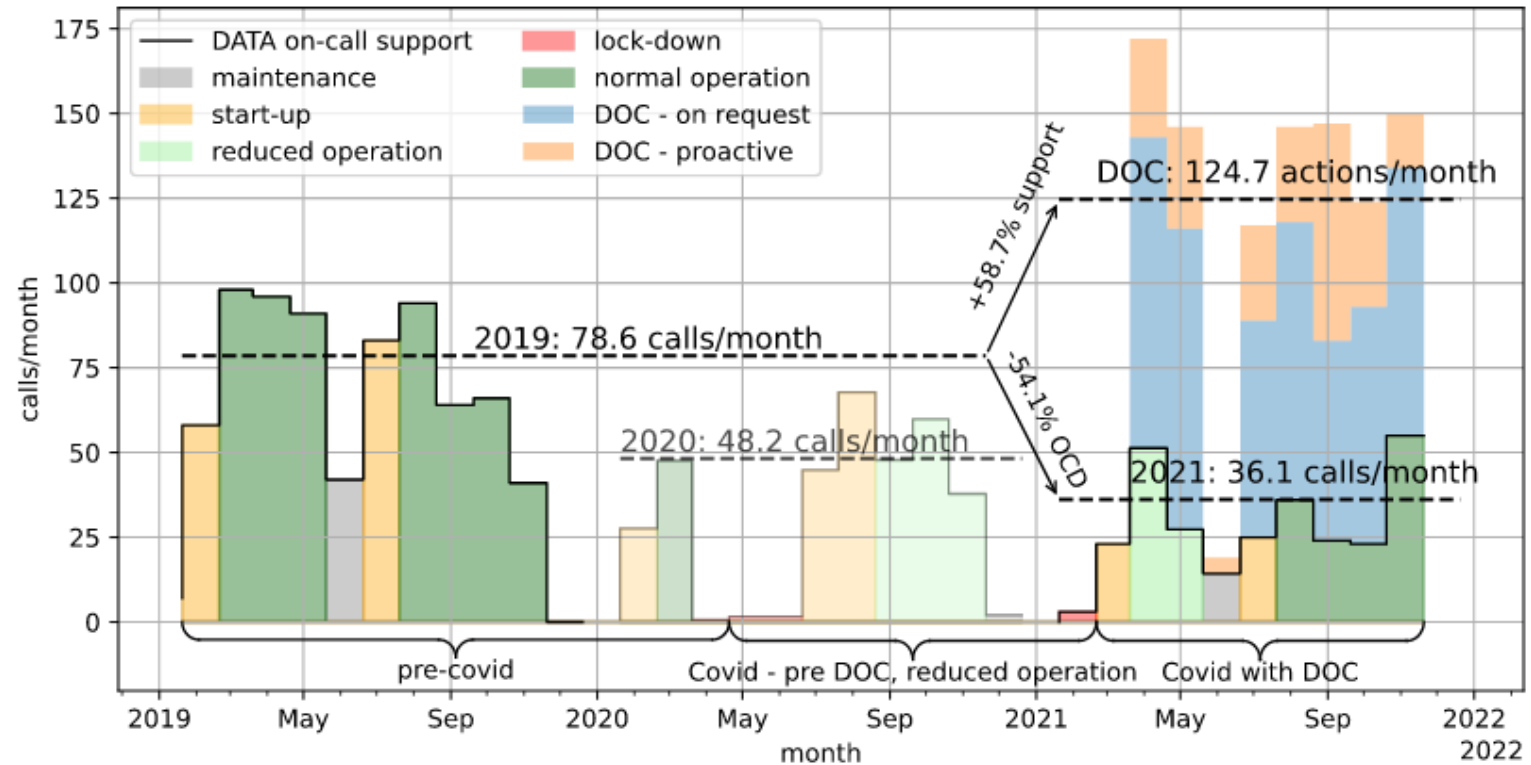


Overall DOC Impact on Support

- More support is given through the DOC than before
- Fewer ad-hoc, unplanned support activities, i.e. less disruption to routine activities of staff members
- Proactive support catches problems before they can impact user operation

→ Increase in scientific “efficiency“
(more, higher-quality beam time)

→ Increase in staff efficiency

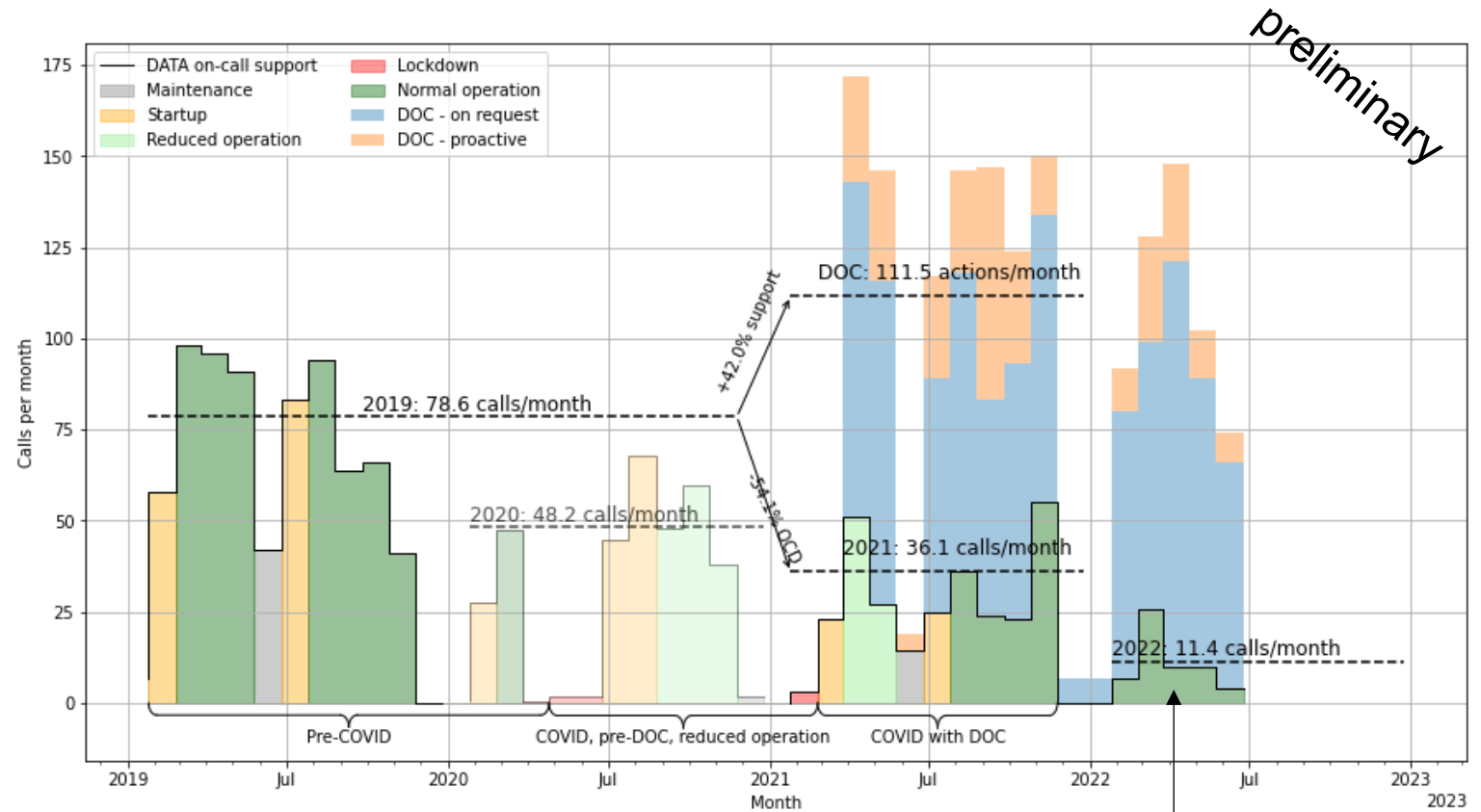


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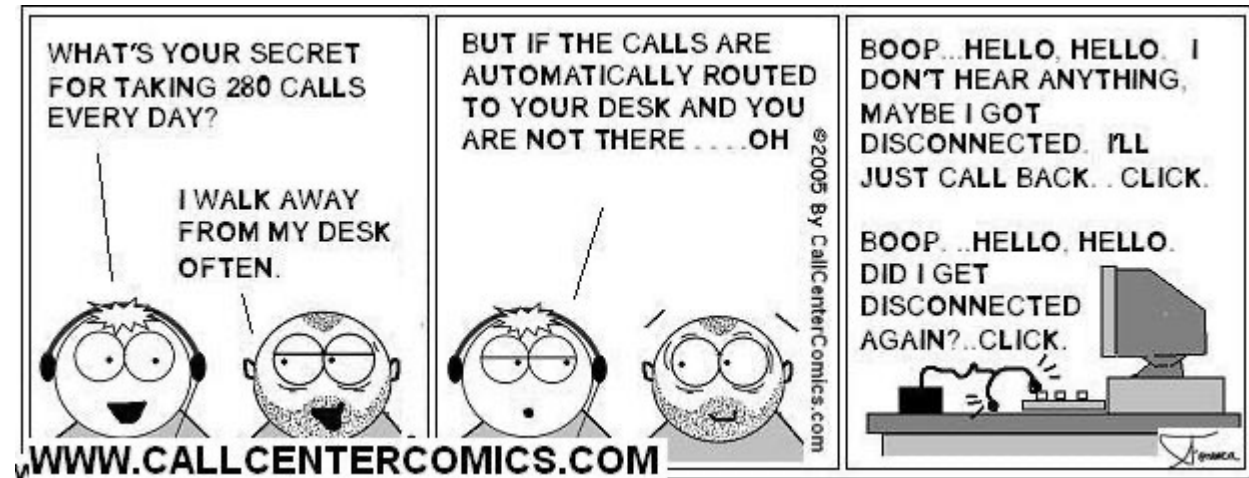
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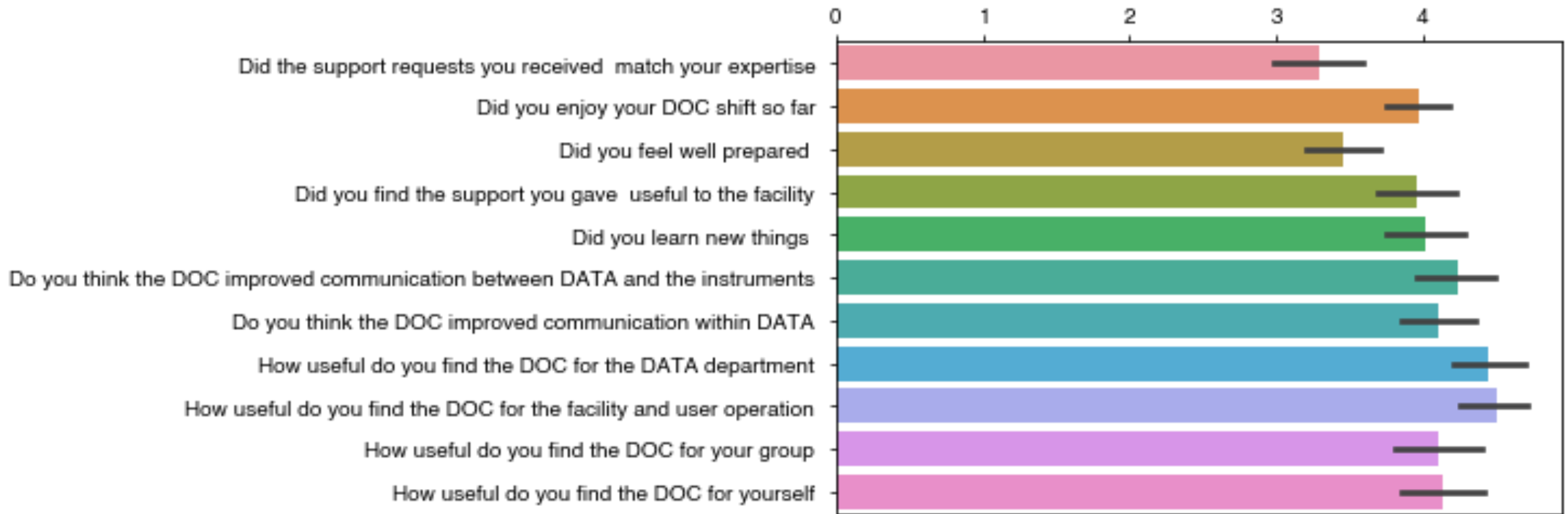


CTRL group only,
DATA likely at about same level as before

So it's a Call Center?



Staff Views on Data Operation Center



Selected results from the DOC shift crew survey. Answers were on a scale from 1 (very negative) to 5 (very positive). The average feedback was generally very positive, with a small spread in answers.

Staff Views on Data Operation Center



Staff Development

Selected results from the DOC shift crew survey. Answers were on a scale from 1 (very negative) to 5 (very positive). The average feedback was generally very positive, with a small spread in answers.

Addendum: The Bring Up Days

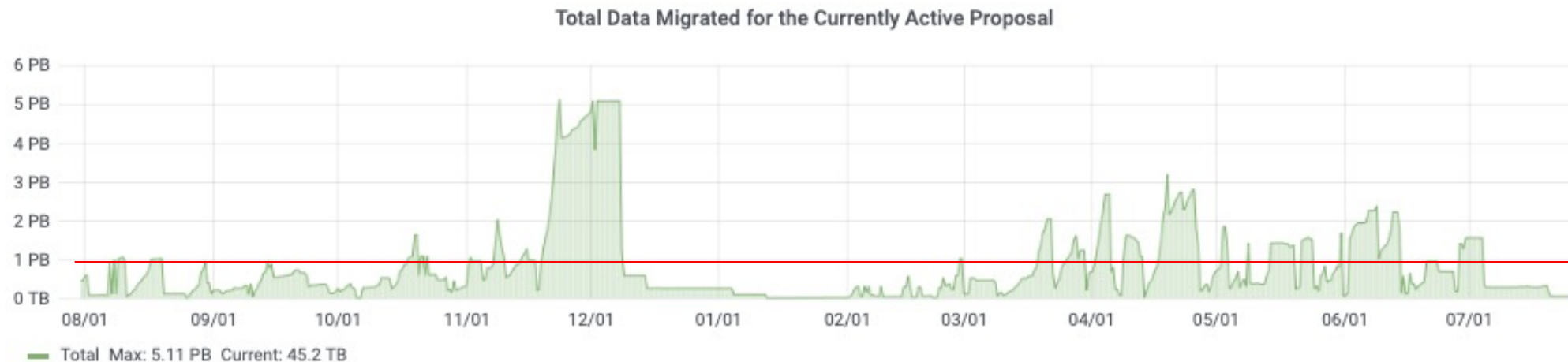
- * Since 2022 the DATA department conducts a structured hand-over of data services to instruments at the end of maintenance periods (2x annually).
 - * Check list of essential data services that are verified together with instrument staff over the course of two sessions:
 - ▶ Essential controls (PLCs, timing, Control System)
 - ▶ Data Acquisition and Processing (full stack, as much as is possible without beam)
- * Has lead to a noticeable decrease in number of support calls to the DOC coming out of maintenance periods.
 - * Especially, “small” issues like misconfigurations are caught early on and quickly resolved

Summary

- * The Data Operation Center is an innovative way to handle operational support for data services at the European XFEL
 - * traditional on-call/mail-in support reaches its limits at complex facilities like EU.XFEL
 - * bundles expertise and simplifies the interface for beamline staff
 - * proactive, with many issues identified before they impact operation
- significantly increases operational efficiency in a complex infrastructure and service environment

Summary

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- * The Data Operation Center fosters Staff Development
 - * Cross-training between shift crews
 - * Communication and awareness of achievements and problems outside staff's usual work portfolio
 - * 80+ members of the ~100 people in the DATA department have done shifts so far.

- * The Data Operation Center identifies avenues of improvement: we have the statistics and logs to see what's going wrong and why. These are used e.g. also in planning the bring up days.