

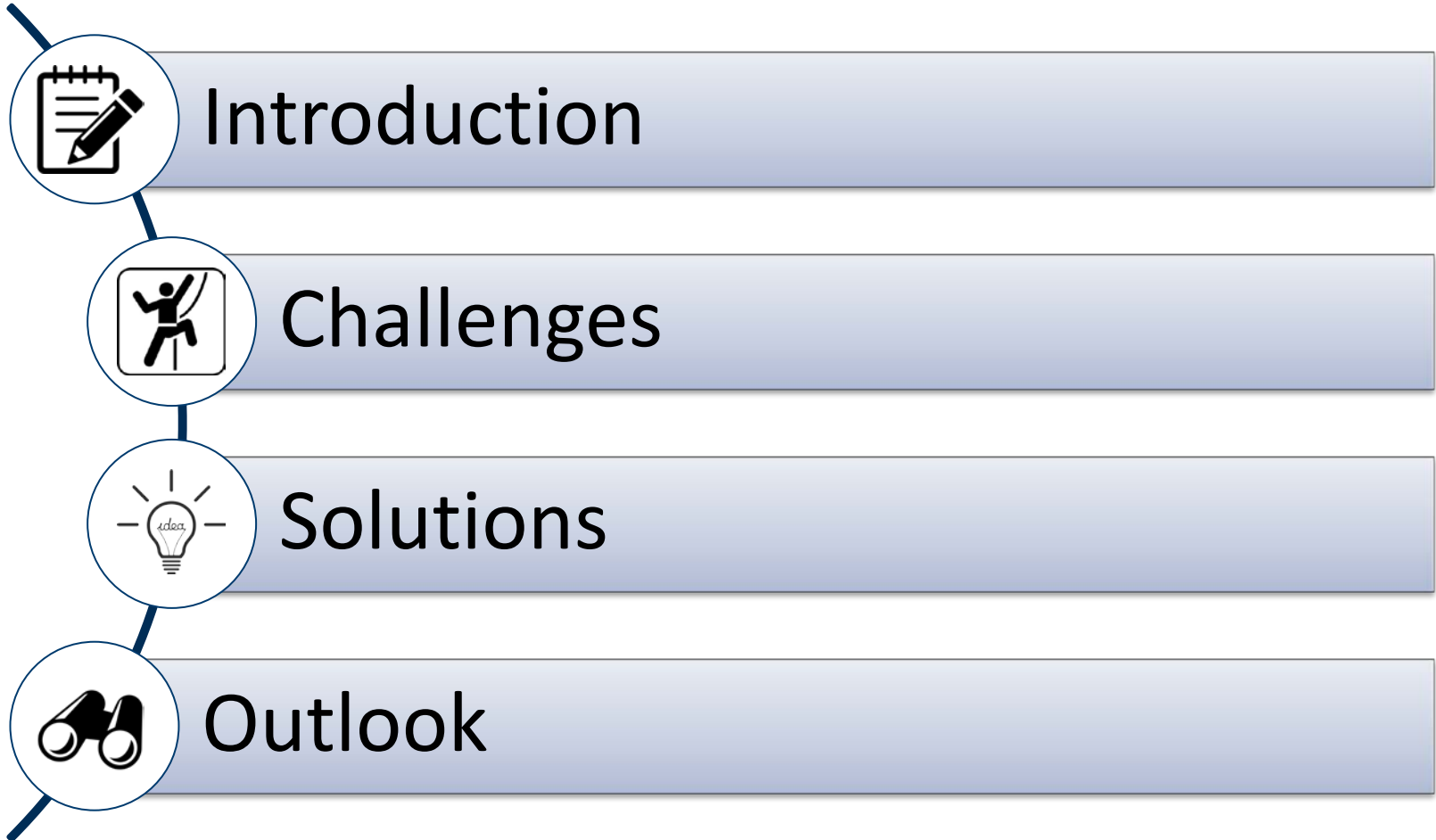
PAUL SCHERRER INSTITUT



Claude Pradervand :: Photonics Instrumentation :: Paul Scherrer Institut

Motion Control at Photon Sources

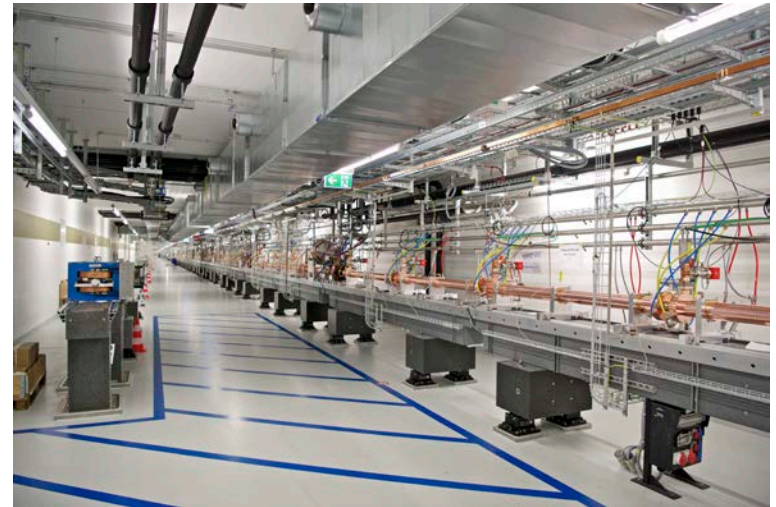
Knowledge sharing session, DENIM 2018, September 18th





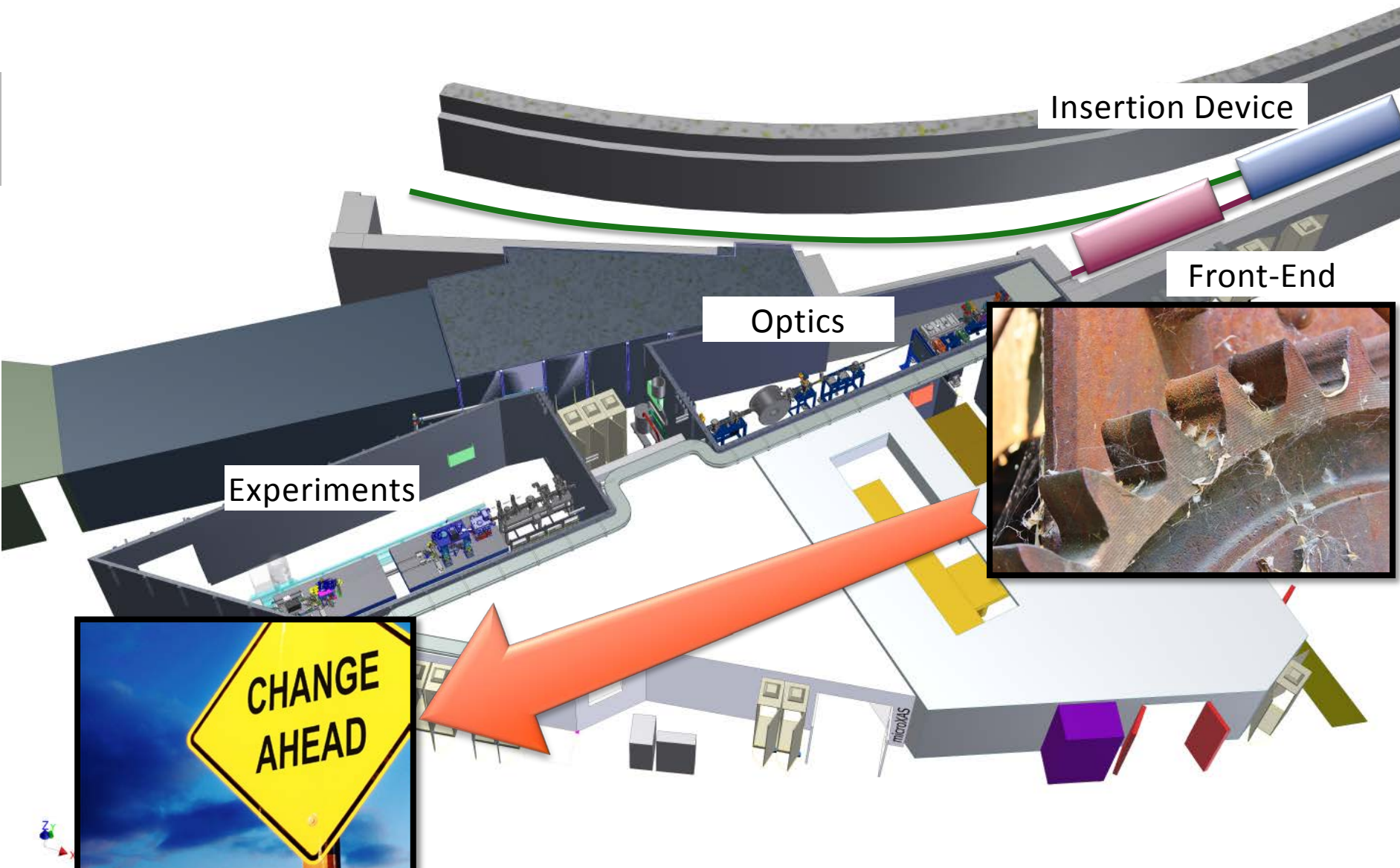
Swiss Light Source (SLS)

- In operation since 2001
- 2.4 GeV electron storage
- 400mA stored current
- 288 m circumference
- 18 beamlines
- Photon Energy: 10eV – 45keV
- Continuous Beam



SwissFEL

- In operation since 2017
- 5.8 GeV linear accelerator
- 10 μ J – 8mJ pulse energy
- 710m length
- 2 beamlines (4 in 2020)
- Photon Energy: 250eV – 12.4keV
- 100Hz pulse rate



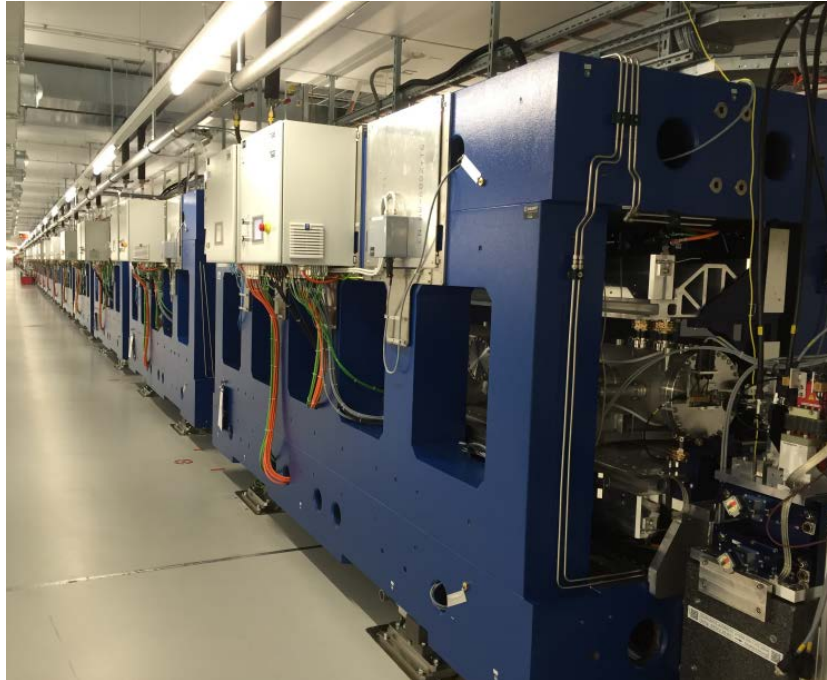
Challenges

Challenges for motion control



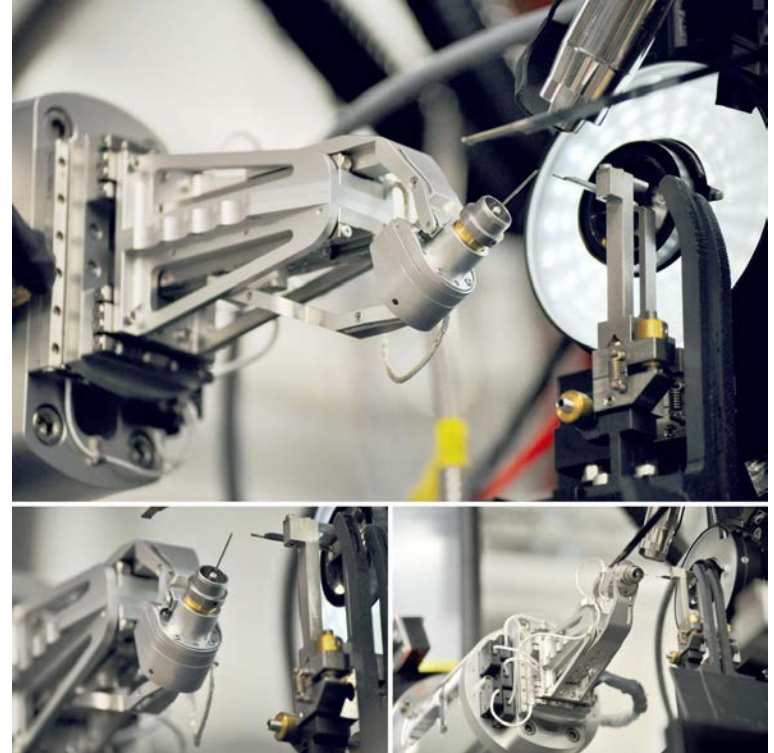
- Very big to very small loads → grams to tons
- High resolution for linear and rotary stages (down to nm or μdeg)
- High reproducibility required
- Large number of axis → requires standardization
- High reliability → many systems not (easily) accessible
- High radiation (x-rays, in accelerator also neutrons)
- Ultra High Vacuum (UHV $\sim 10^{-8}$ mbar)
- Flexible, changing setups, easy and fast configuration
- Pulse synchronous operation in SwissFEL
- Cost effective → SLS >2000 axis

Challenges - Extremes



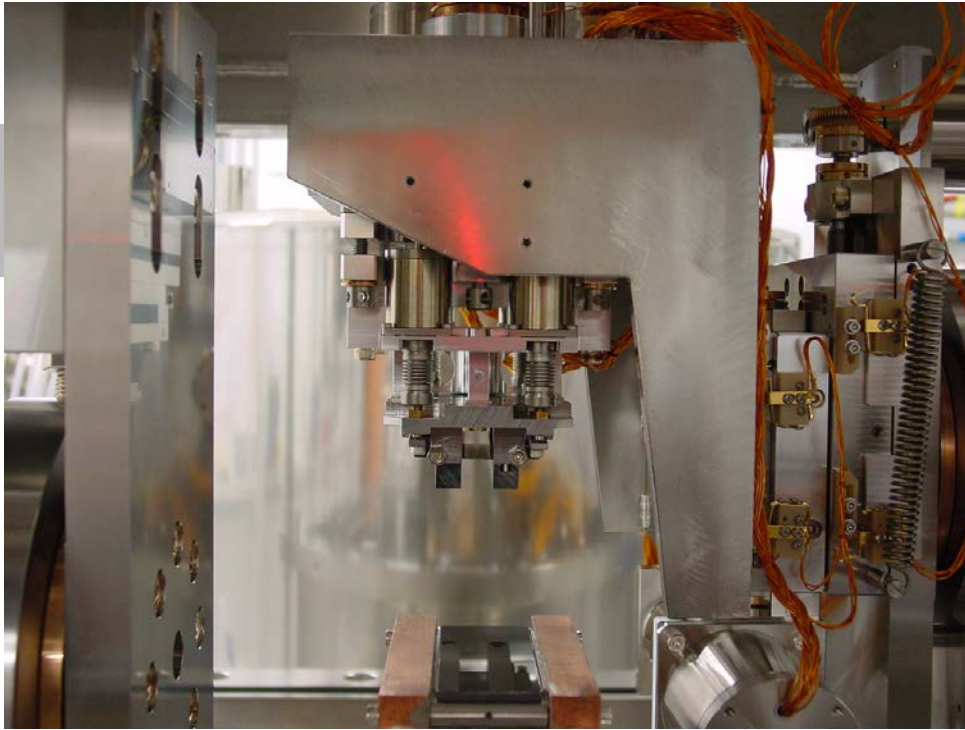
Undulator

- Load: several tons
- Several $1\mu\text{m}$ accuracy



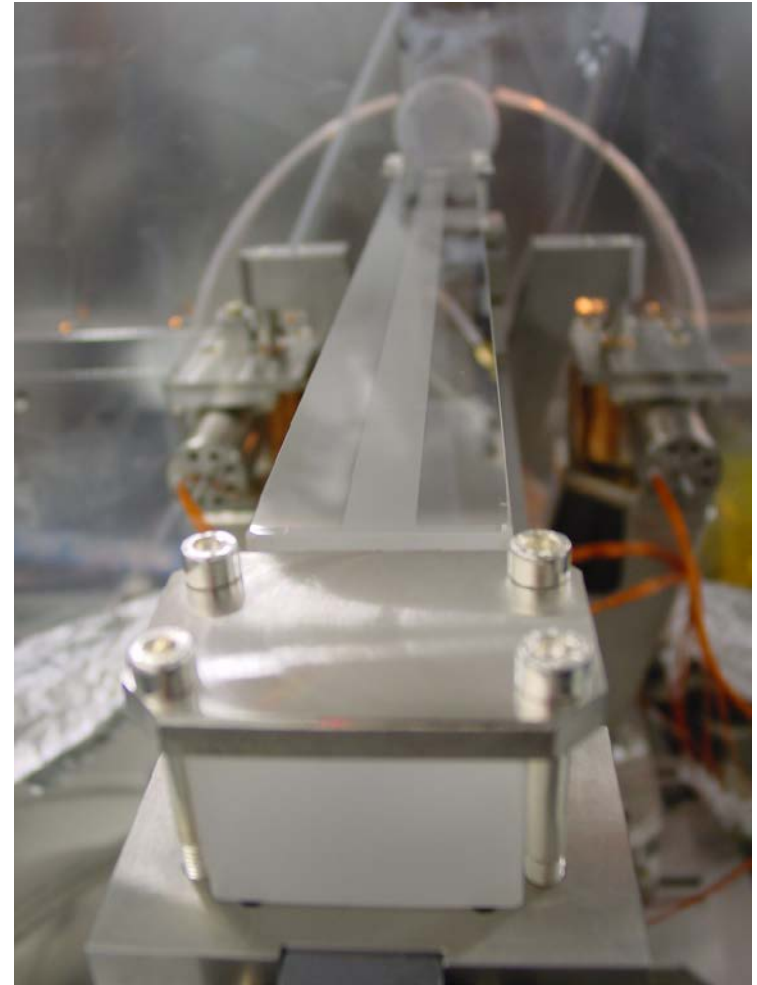
Sample Environment

- Load: several grams
- sub $1\mu\text{m}$ accuracy



Monochromator:

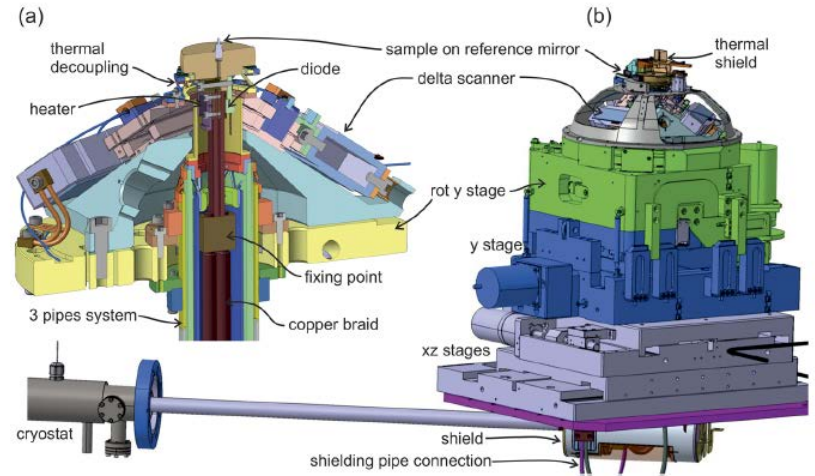
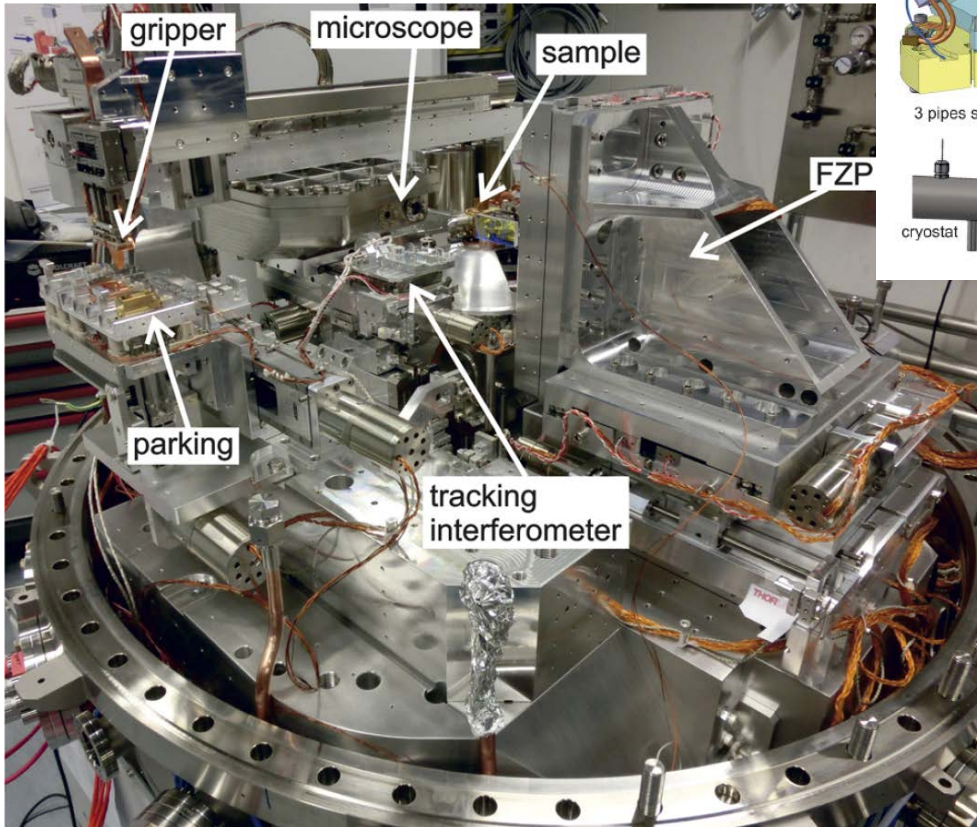
- UHV 11 Axis
- Rotation resolution: $\sim 30\mu\text{deg}$
- Bender resolution: 100nm



X-Ray Mirror:

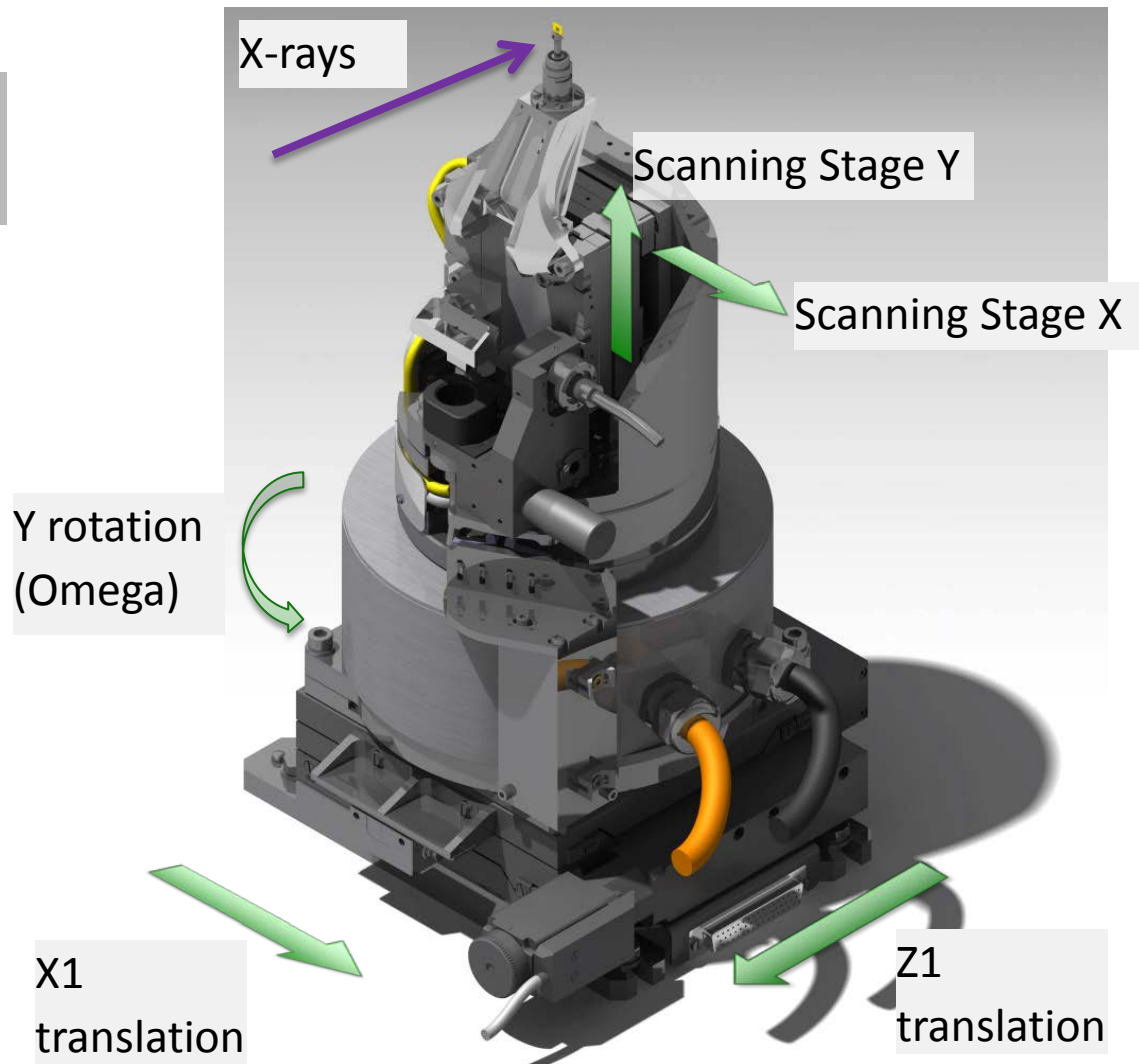
- UHV 6-8 Axis
- Position resolution: $\sim 25\text{nm}$

OMNY—A tOMography Nano crYo stage



- Several UHV stepper motors and piezo drives
- Sample stage: nm resolution over the entire travel range of 450 μ m
- Long term drift: few 100 nm/day

Vector Scanning Sample Diffractometer

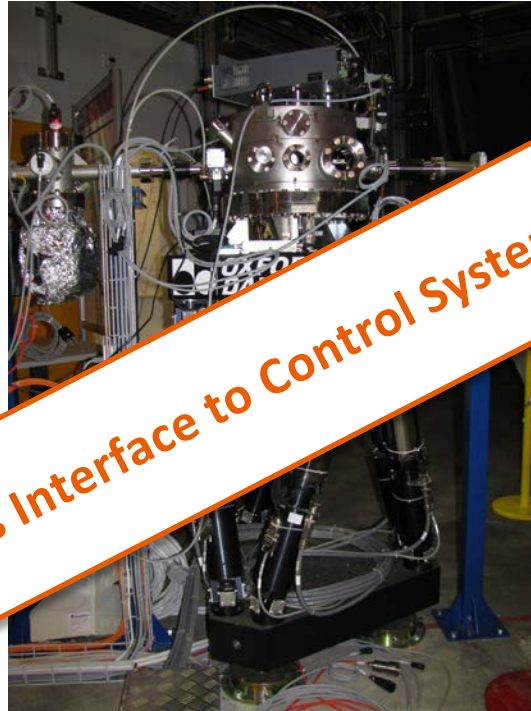


Dynamic motion for on-the-fly scanning of samples with 100Hz and position accuracy of a few μm

Optimized for:

- compact size
- highest accuracy
- minimal shadowing
- high Eigenfrequencies
- high dynamic stiffness

“Black Box” Solutions



Requires Interface to Control System



Hexapods

Multi-Axis Diffractometer

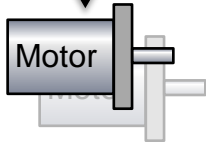
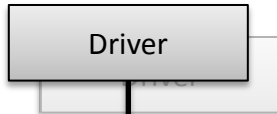
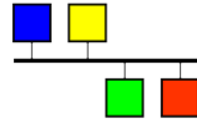
- Max. Load: 150kg
- Error sphere: ca 200 μ m

Sample Changers (Industrial Robots)

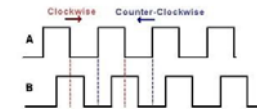
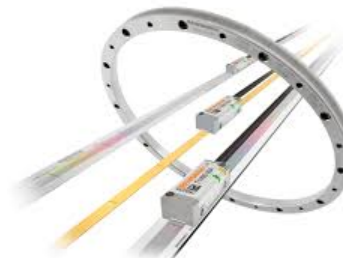
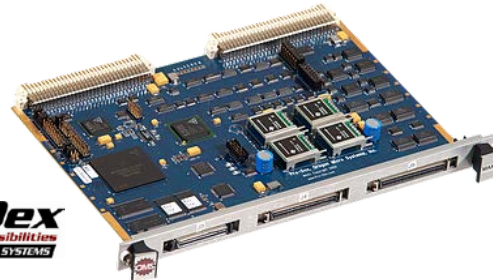
Solutions

Motion Control System

EPICS

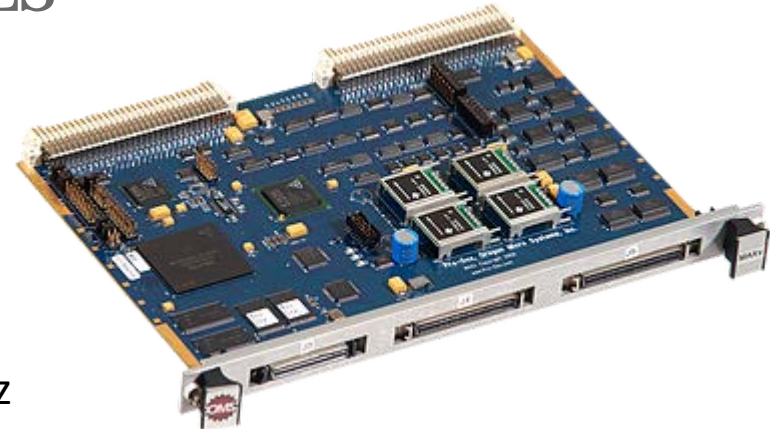


Encoder



Prodex MAXv motion controller

- 266-MHz, 32-bit Risc processor (PowerPC)
- 8 axes on a single card in VME64
- Quadrature Encoder Feed back up to 16 MHz
- Custom, parabolic, “S”-Curve & linear trajectory profiles.
- 16 “user definable” digital I/O.



PROS

- + Robust
- + Simple setup and programming

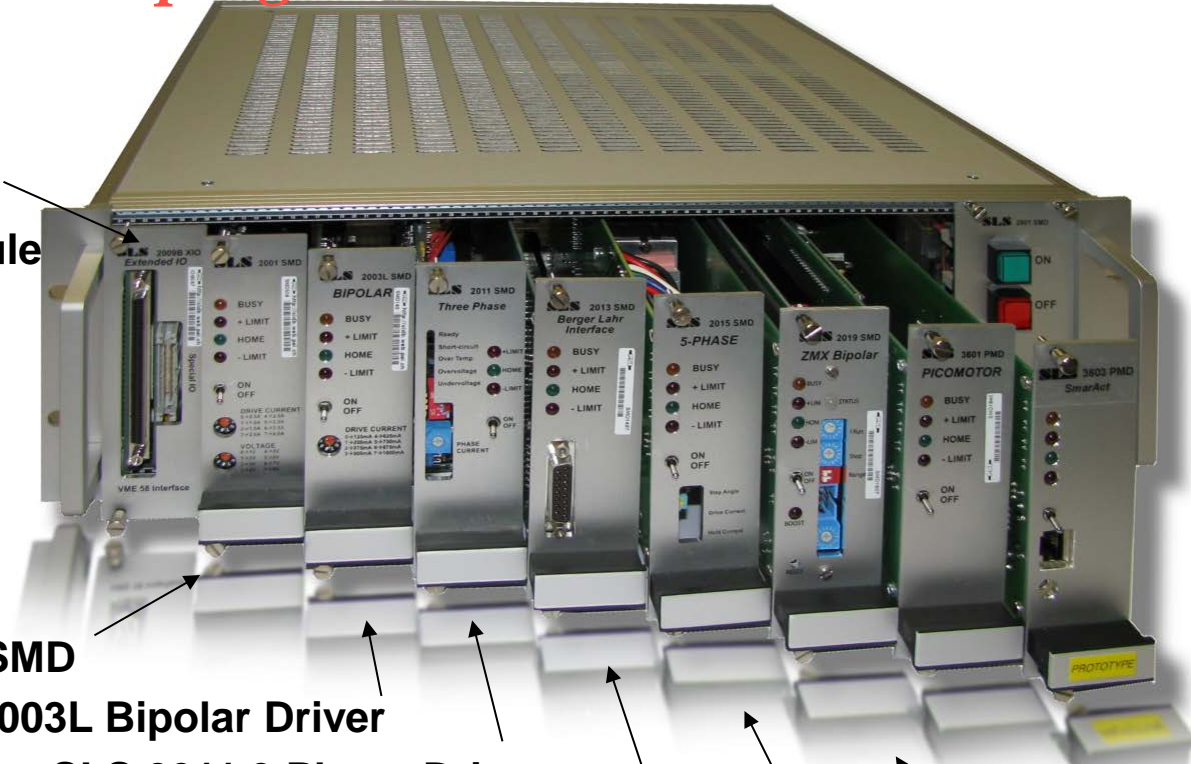
CONS

- Outdated
- Limited support through EPICS motor record

SLS Solution - SLS 2001 Motor Drive Unit

Keeping the beamline in motion.

SLS 2009
Extended IO Module



SLS 2001 SMD

SLS 2003L Bipolar Driver

SLS 2011 3 Phase Driver

SLS 2013 Berger Lahr Interface

SLS 2015 5-Phasen Driver

SLS 2019 ZMX Driver

SLS 3601 Picomotor Driver

SLS 3603 SmarAct Driver

One rack
One cable
One GUI

Any kind of motor

Motor Controller and Drivers @ SLS



- Drivers and Controllers for 48 axis



- Drivers for 64 axis

SLS 2001 Motor Drive Unit

PROS

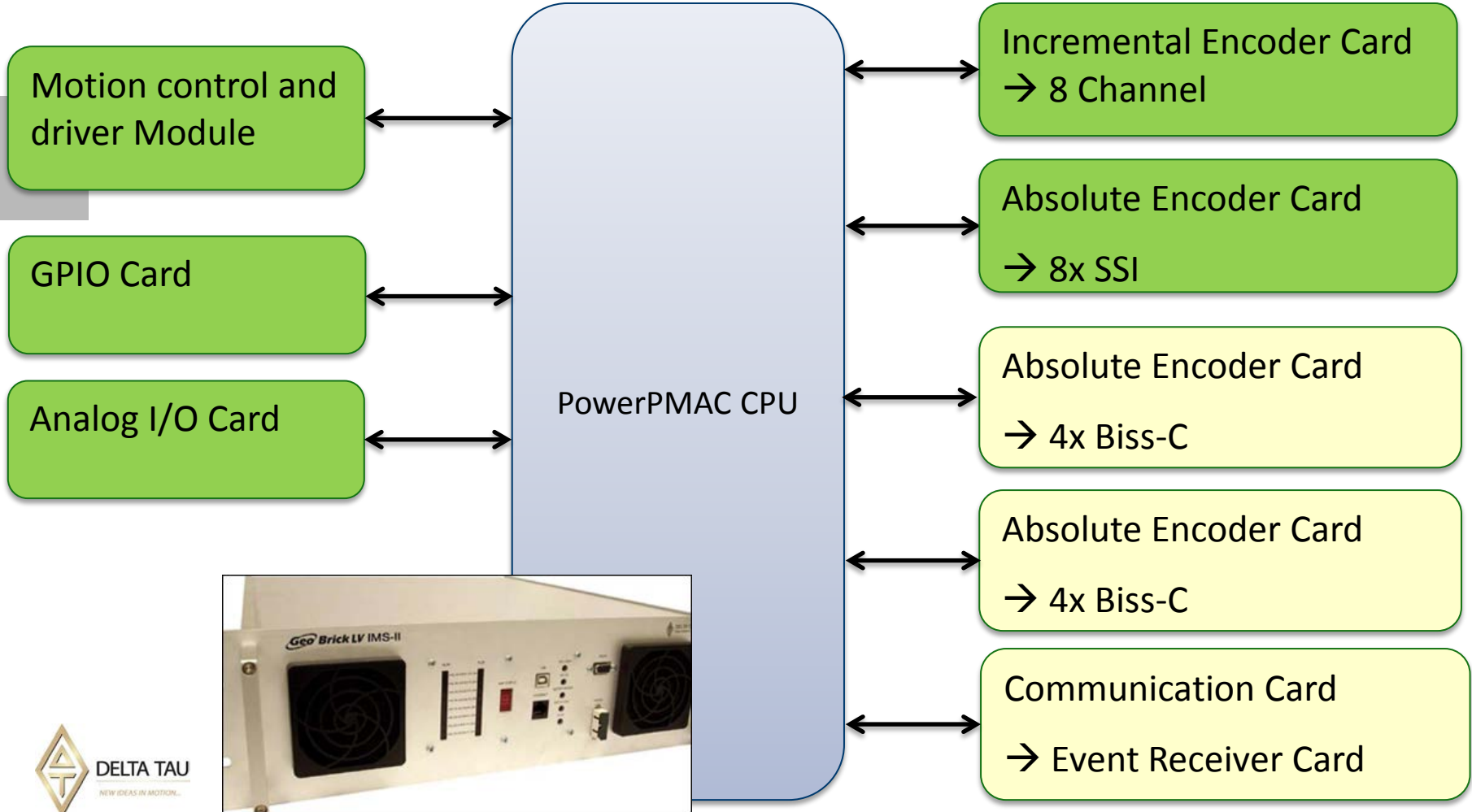
- + Support for many motor types (bipolar, unipolar, piezos etc)
- + Support for any type of stepping motor up to 5A per phase
- + Modular, can be configured to any setup
- + Simple configuration of driver
- + Robust system, very reliable
- + Build in power supply (600W)
- + Cost effective

CONS

- Driver only, requires VME Controller
- No encoder support, requires external encoder cards
- Outdated



DeltaTau PowerBrick LV IMS



Core

Default Extensions

Optional Extensions

PROS

- + Best overall performance
- + Support for bipolar stepping motor (<5A), 3-Phase motors and servos
- + Same programming over entire PowerPMAC family
- + Can be used for simple motions and also complex motions
- + EPICS IOC can run on PowerPMAC CPU
- + Event receiver can be interfaced to PowerPMAC CPU
- + New Product Family → long support (?)
- + Variety of encoders supported (SSI, BiSS-C)
- + Used by other facilities: NSLS II, Diamond, Soleil

CONS

- Cost
- Programming know-how need to be acquired
- Uncertain Future DeltaTau → Omron



Bipolar Stepping Motors with integrated driver

- Available in a different sizes
- EPICS support
- Used for conventional motions

PROS

- + Simple installation (Power and Ethernet)
- + Cost effective
- + EPICS support

CONS

- In case of drive failure, motor needs to be exchanged
- No in-vacuum motors
- Limited encoder support
- Radiation sensitive



SmarAct (Piezo) Positioner

Piezo Motors with integrated Encoder

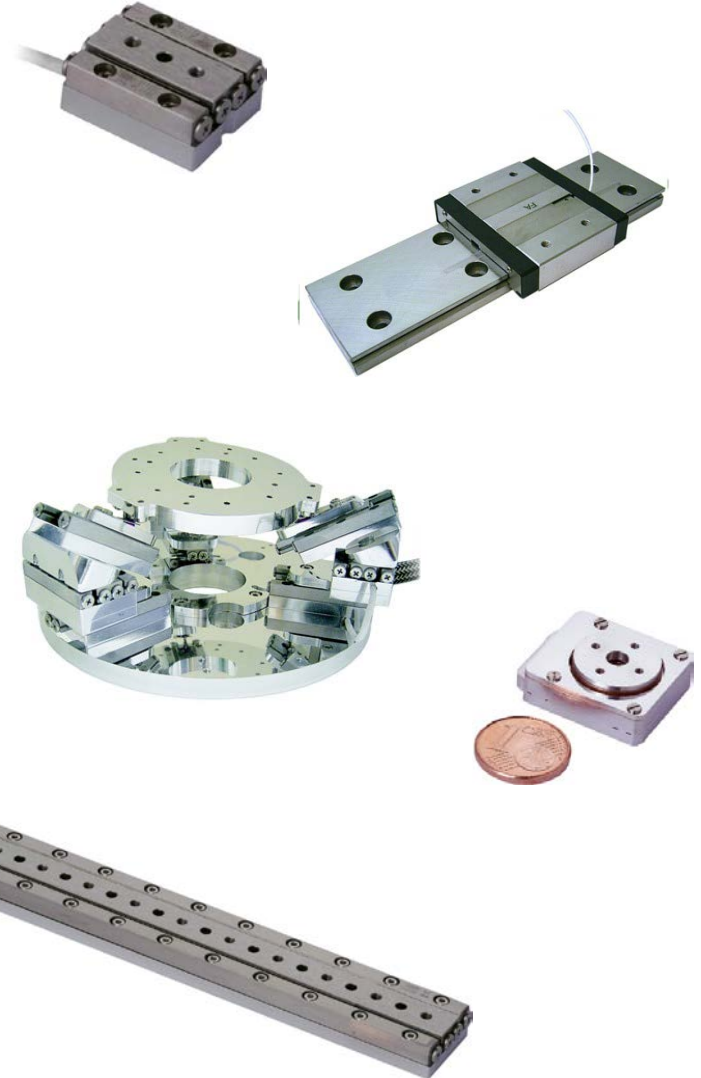
- Available in a different sizes
- Used for micro and nano positioning

PROS

- + Simple installation – all-in-one positioner
- + Very small size
- + Vacuum compatible devices available
- + EPICS support

CONS

- Limited load (lifting force $\sim 1\text{N}$)
- Limited speed ($< 10\text{mm/sec}$)
- Cost

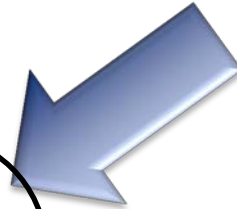


Outlook

SINQ



SLS2.0



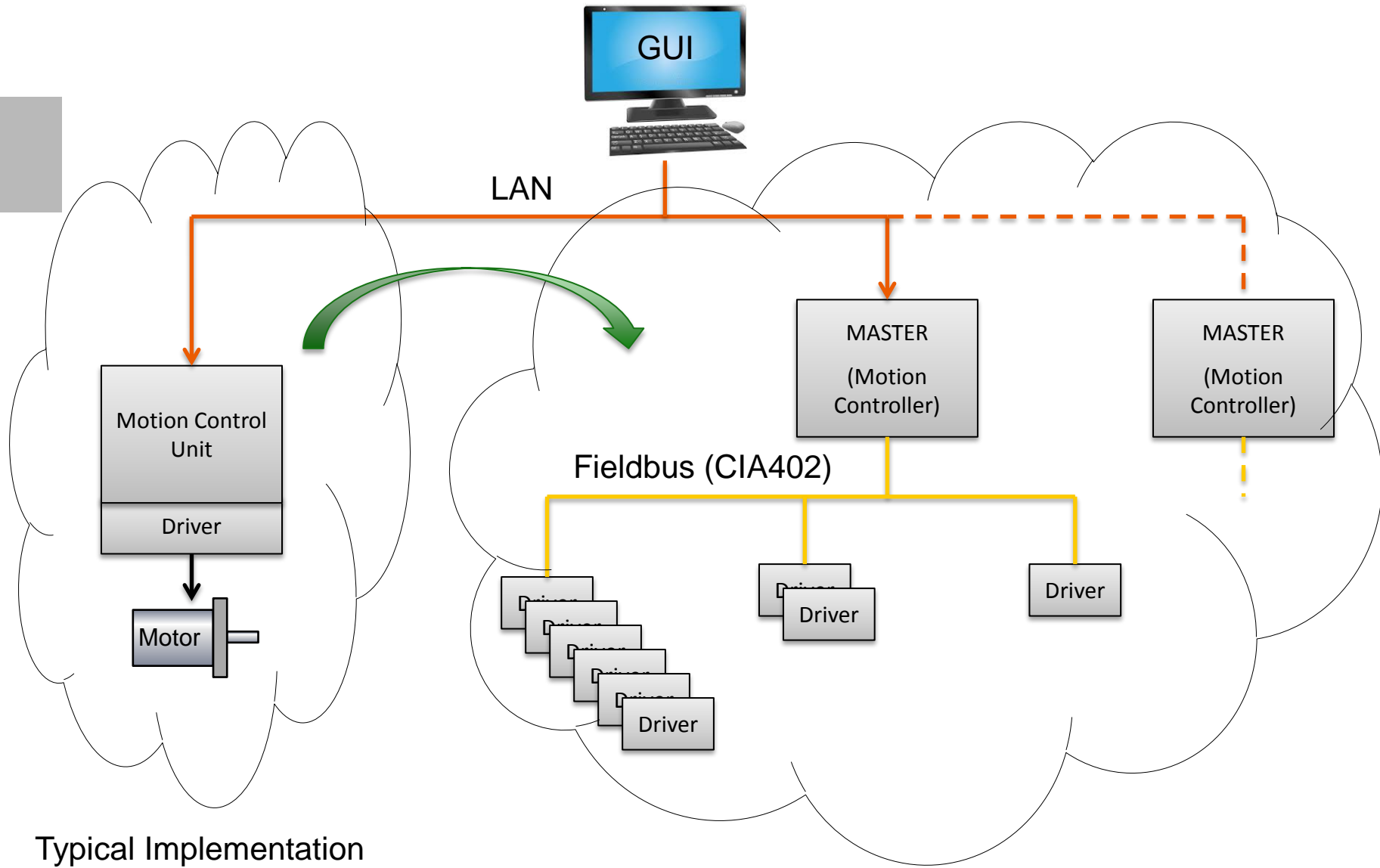
EtherCAT[®]
Motion Control



SwissFEL



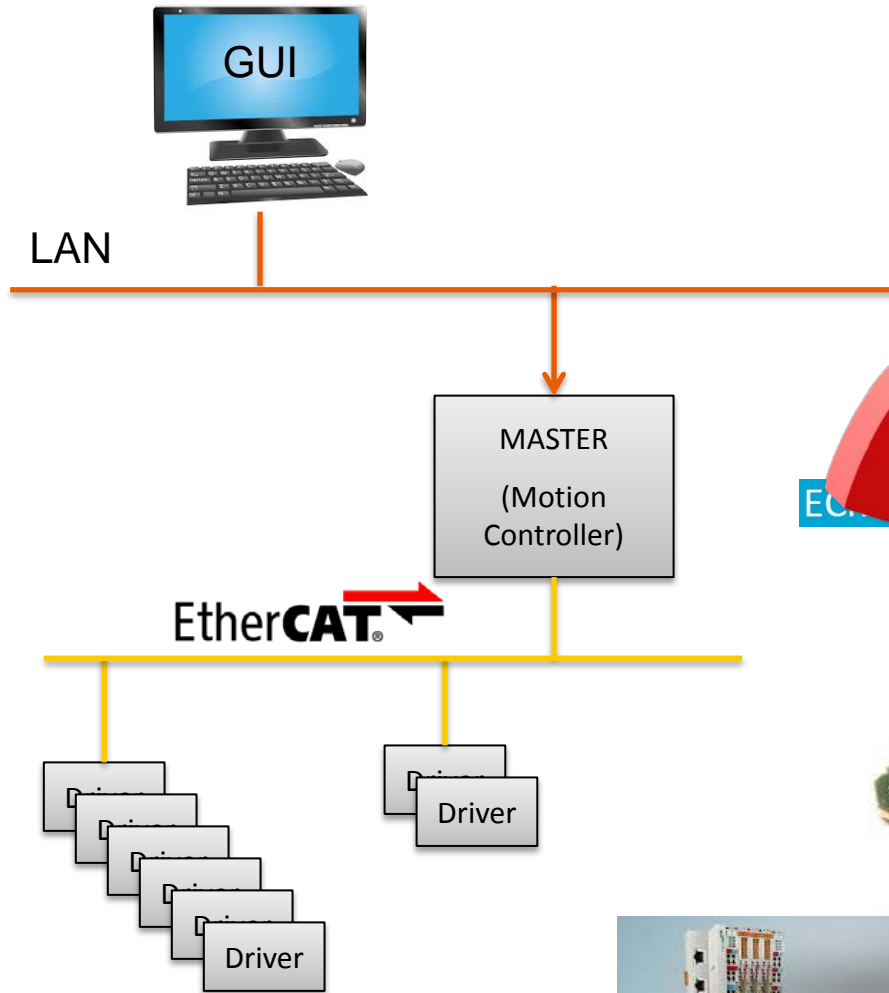
Motion Control Paradigm Shift



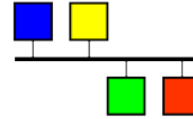
Typical Implementation
(SINQ, SLS, SwissFEL)

New Implementation

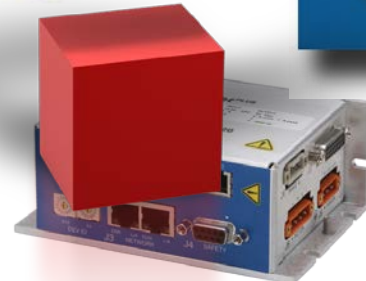
Possible Solutions



EPICS



ECAT Motion



**Questions?
Discussion**

