

LCLS-II Undulator Motion Control

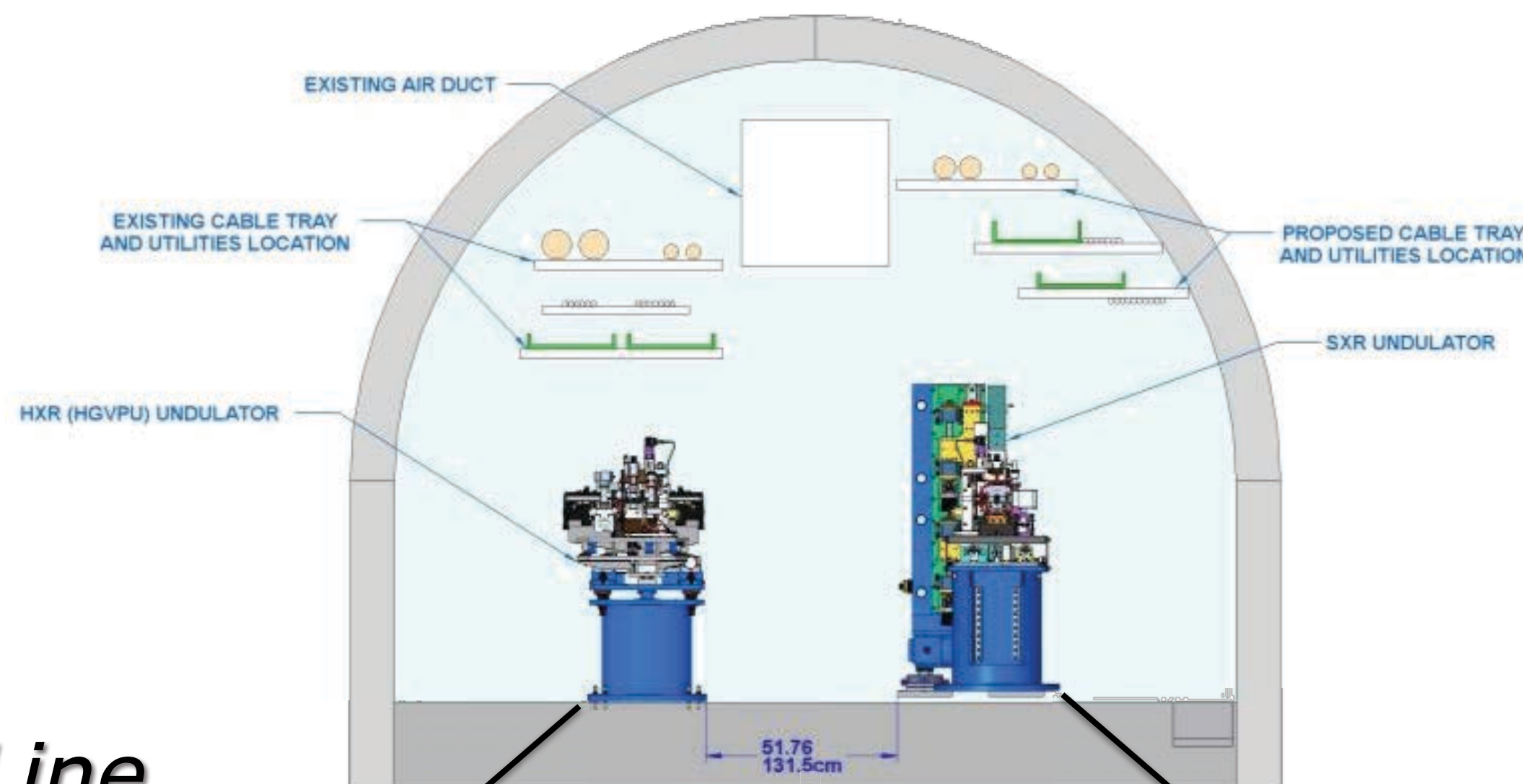


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Abstract

At the heart of the LCLS-II are two undulator lines: one for generating hard x-rays (HXR) and one for generating soft x-rays (SXR). The SXR line is comprised of 21 variable-gap undulator segments separated by an interspace stand with a cam positioning system capable of positioning with 5 degrees of freedom. The HXR line is comprised of 32 undulator segments, each including an integrated interspace assembly. The girder is placed on two stands with a similar cam-positioning system as in the SXR line allowing for movement in 5 DOF.

Undulator Hall

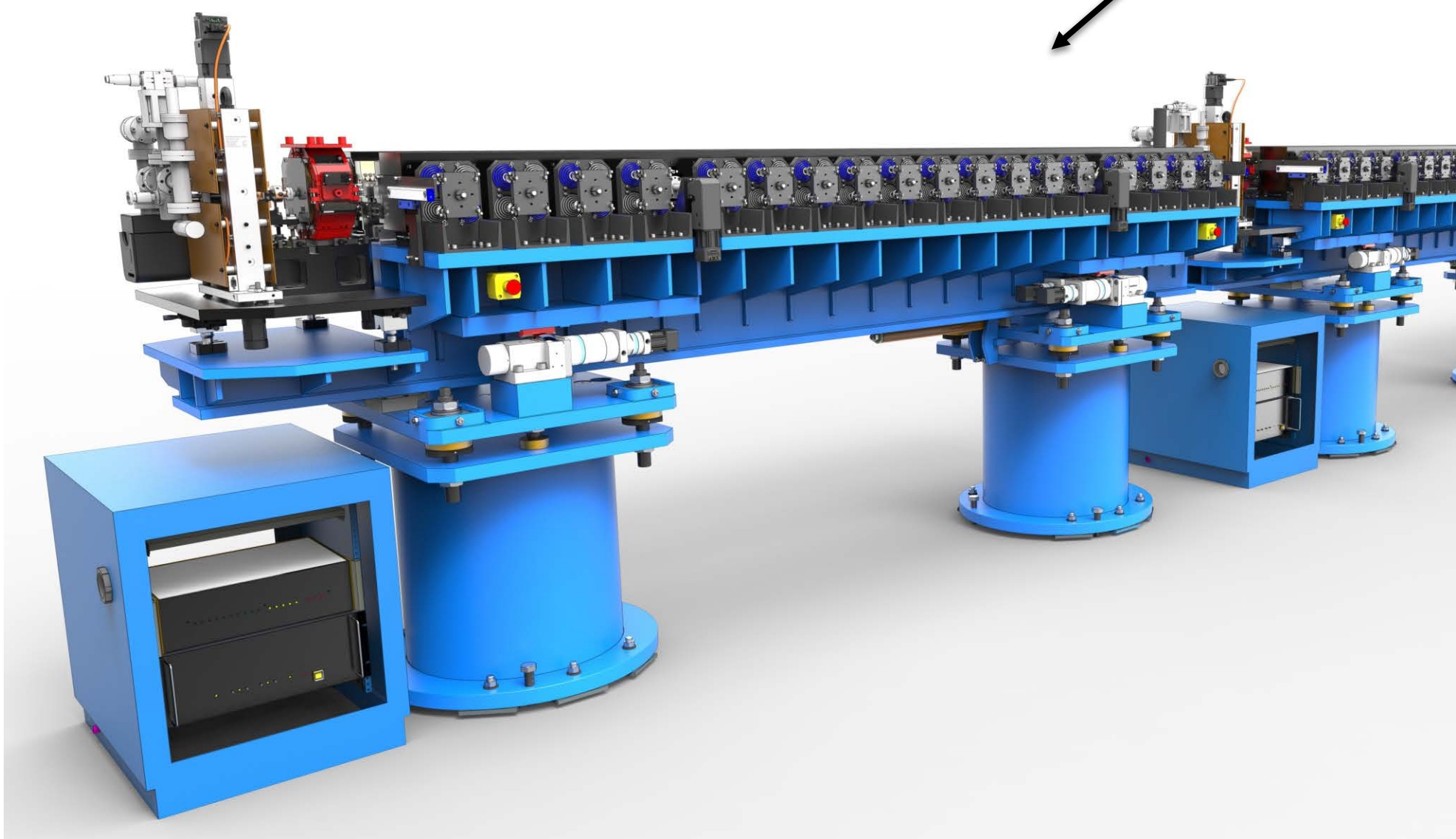


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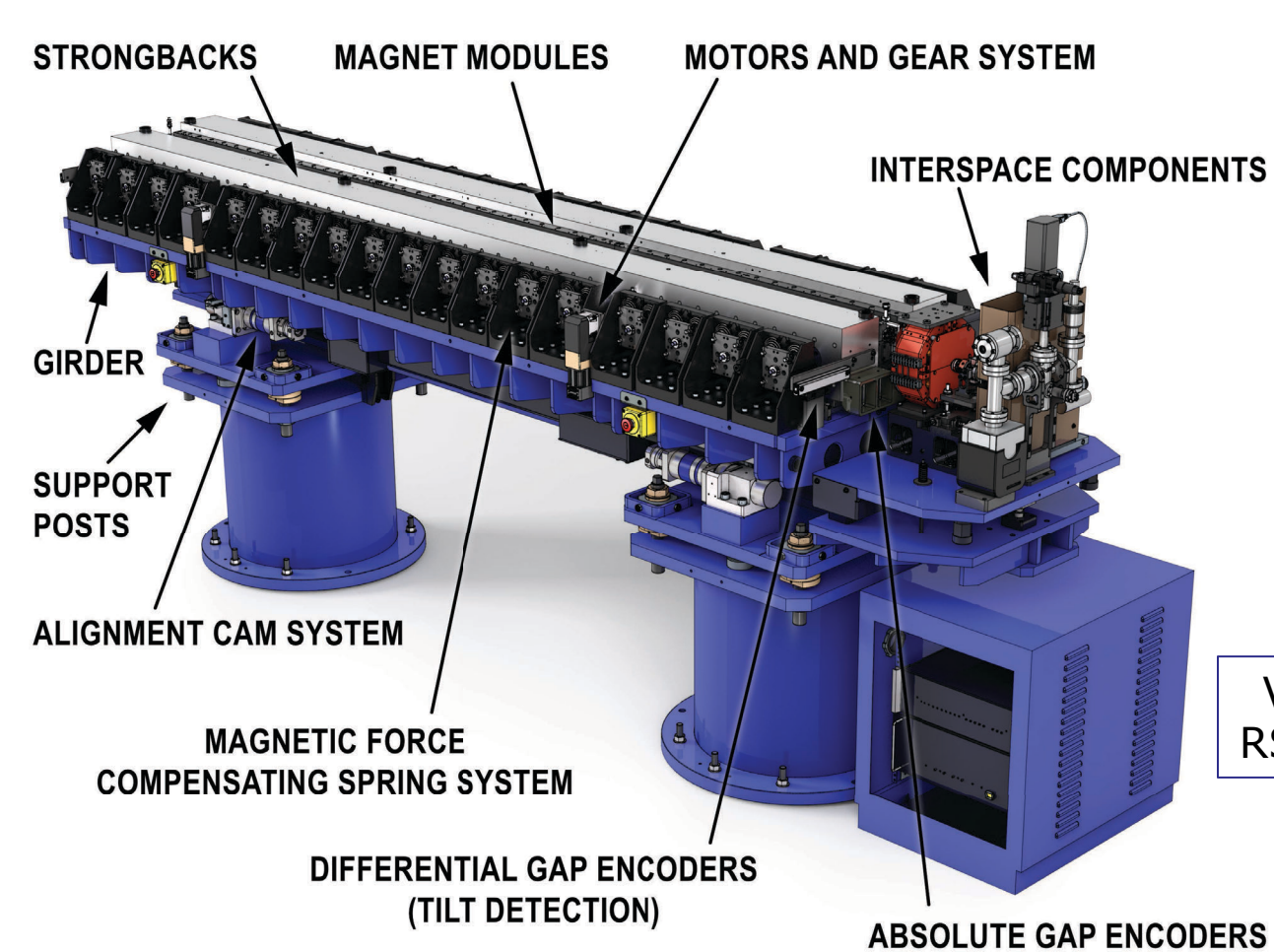
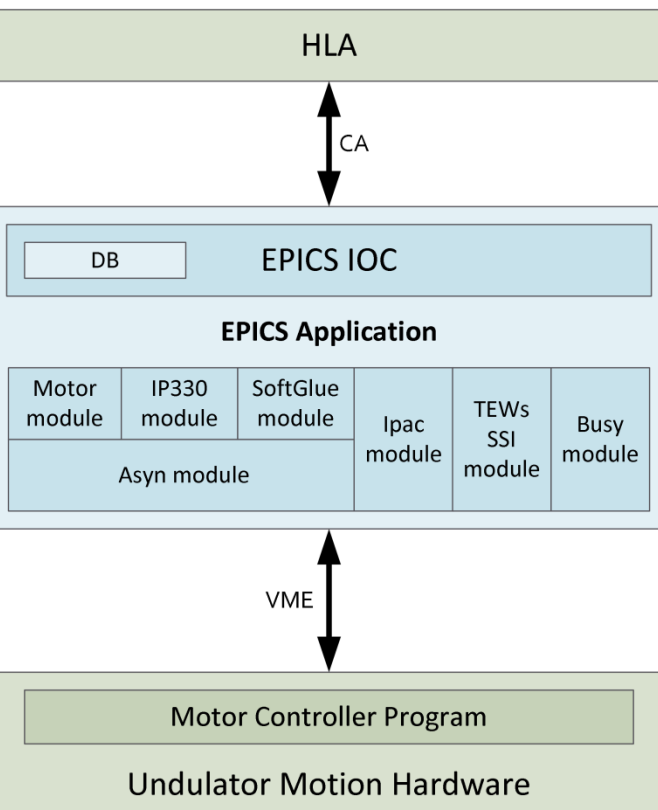
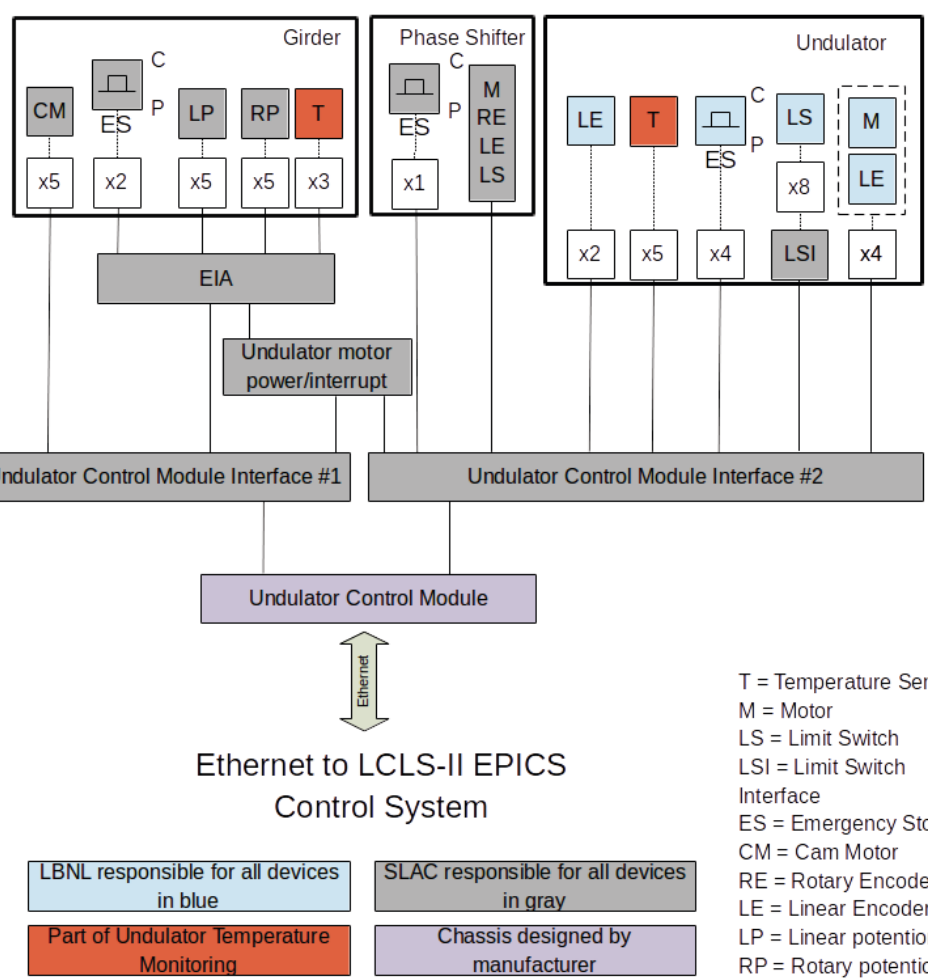
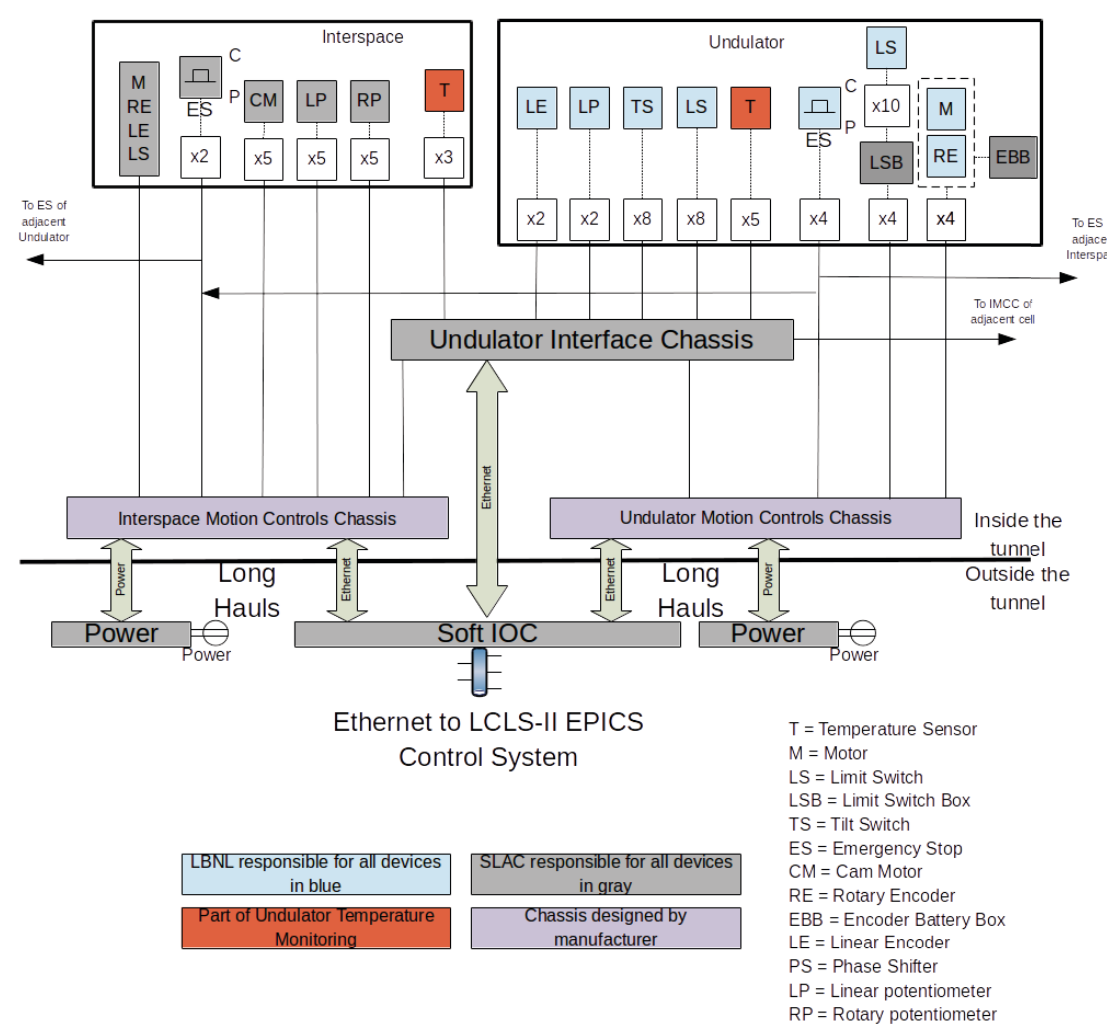
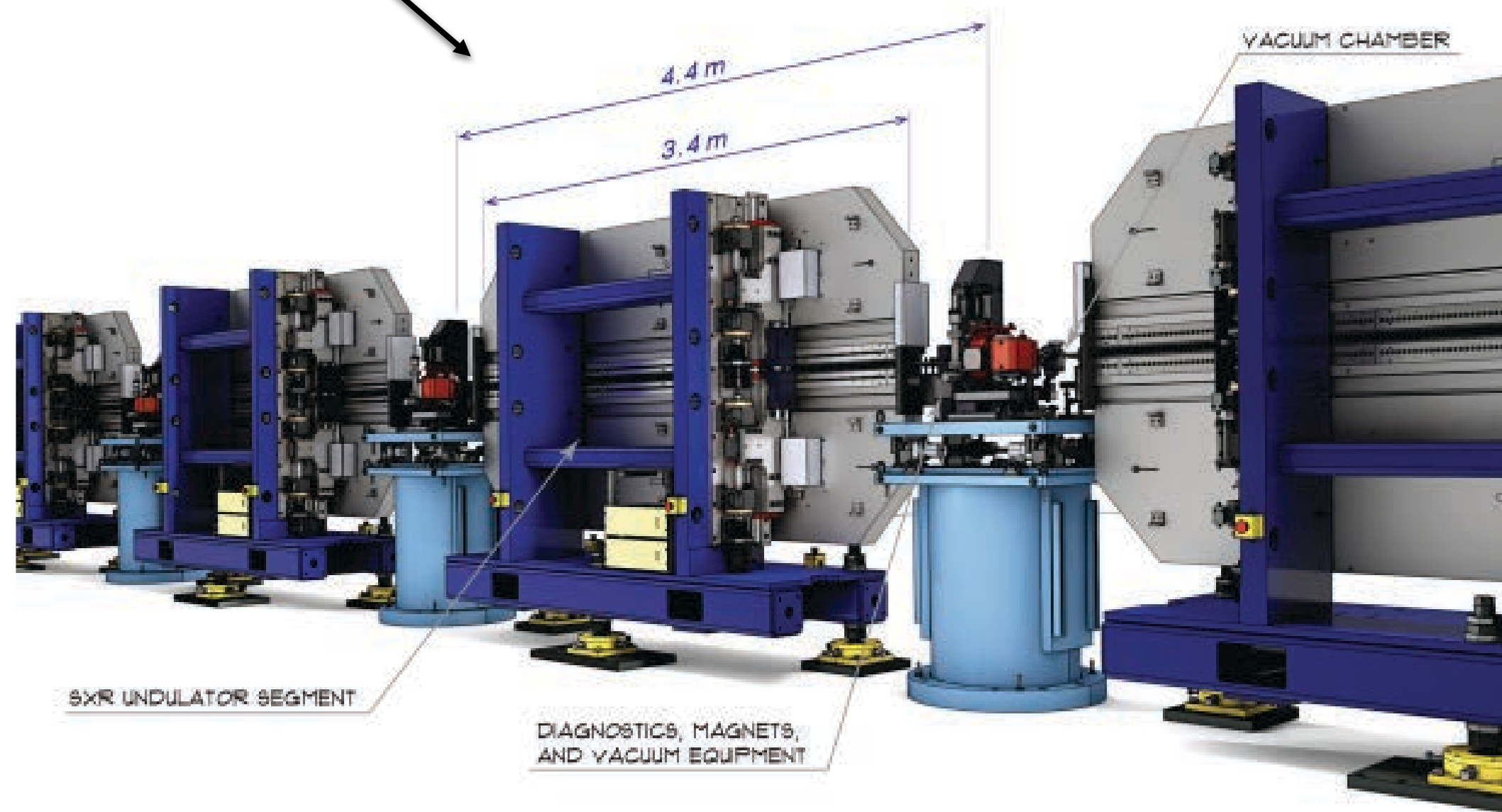
Michael Rowen, Daniel Bruch, Dennis Martinez-Galarce, Bobby McKee, Mitch D'Ewart, Mark Petree, Arturo Alarcon (PSI), Matthaeus Leitner (LBL), Erik Wallen (LBL), Daniel Sadlier (LBL), Kyle McCombs (LBL), Diego Arbelaez (LBL), Dawn Munson (LBL), Benjamin Bolyard (Keller Technology), James Wright (Keller Technology), Lonnie Daigler (Keller Technology)

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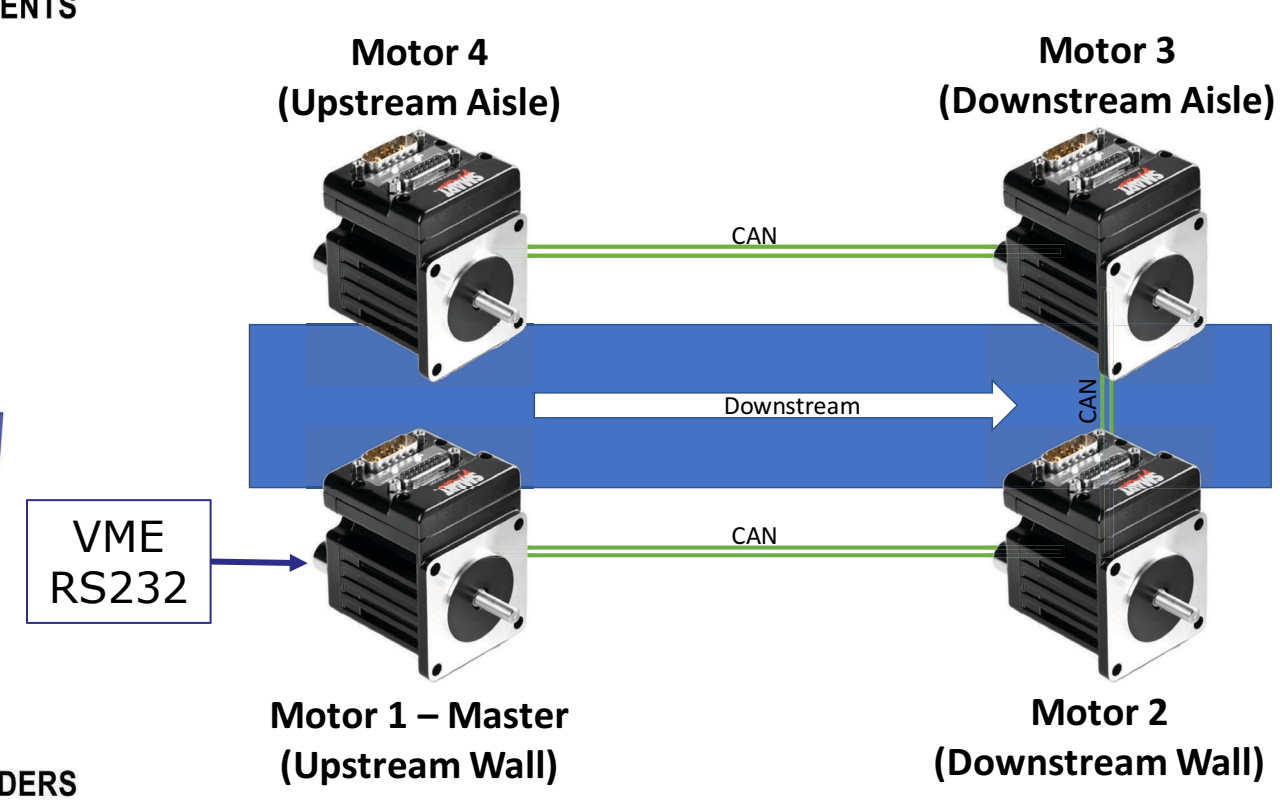
Hard X-ray Undulator Line



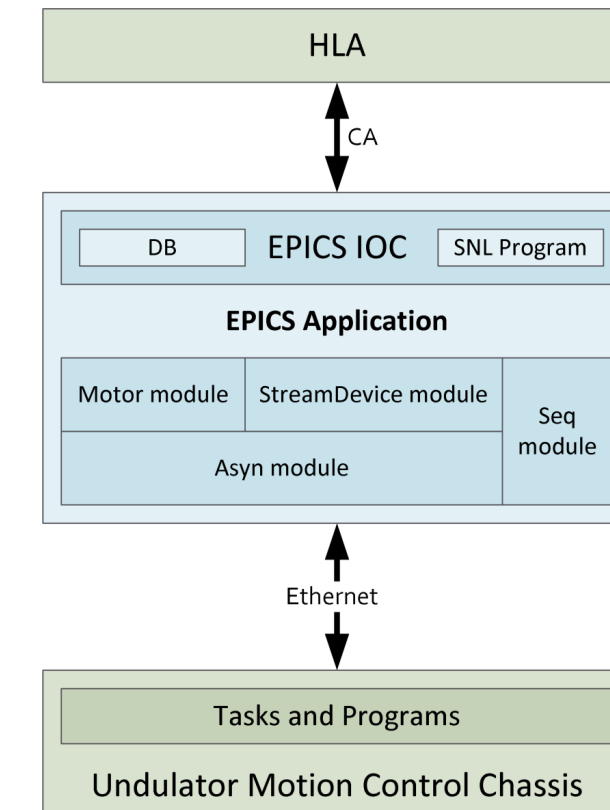
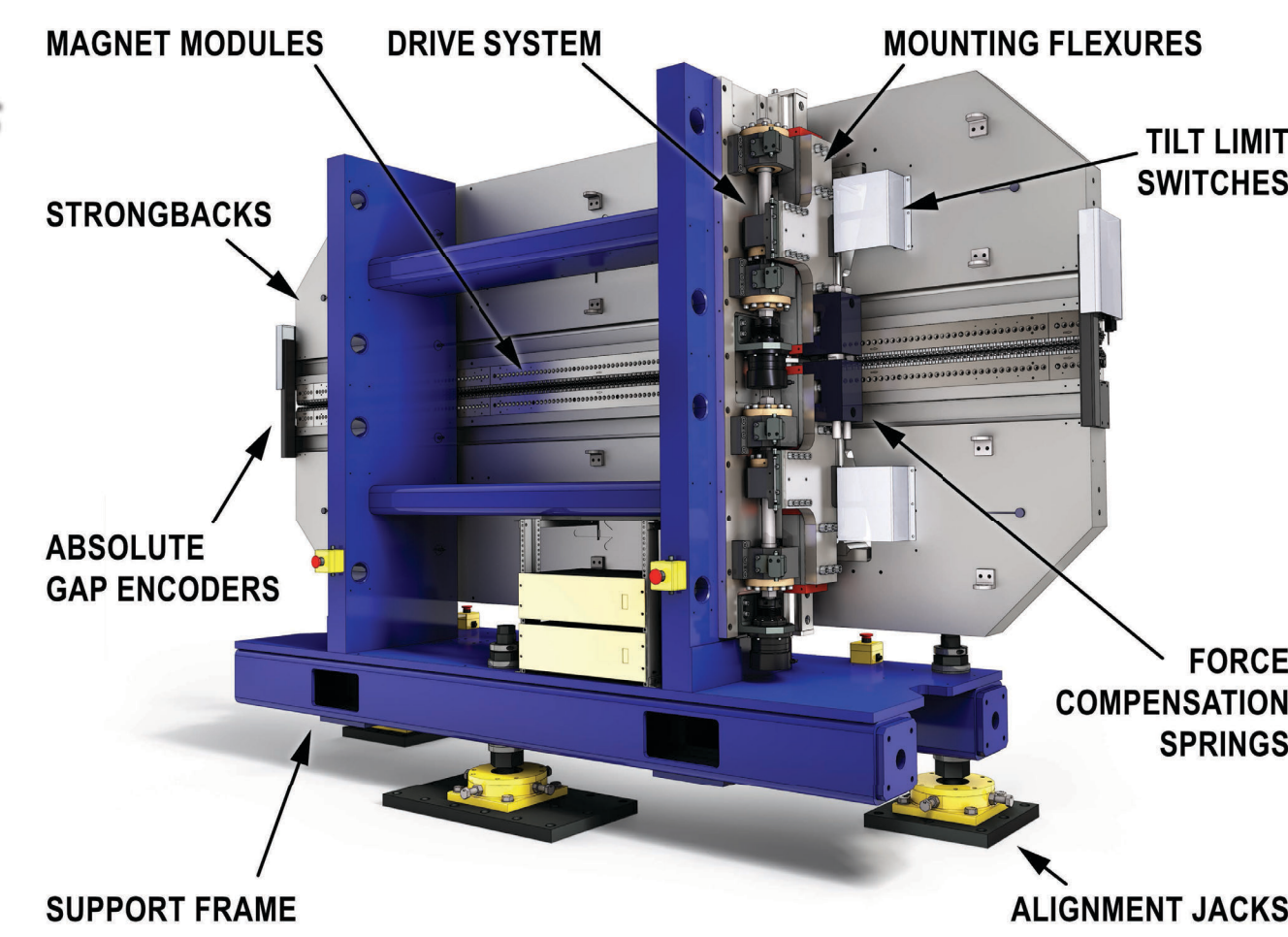
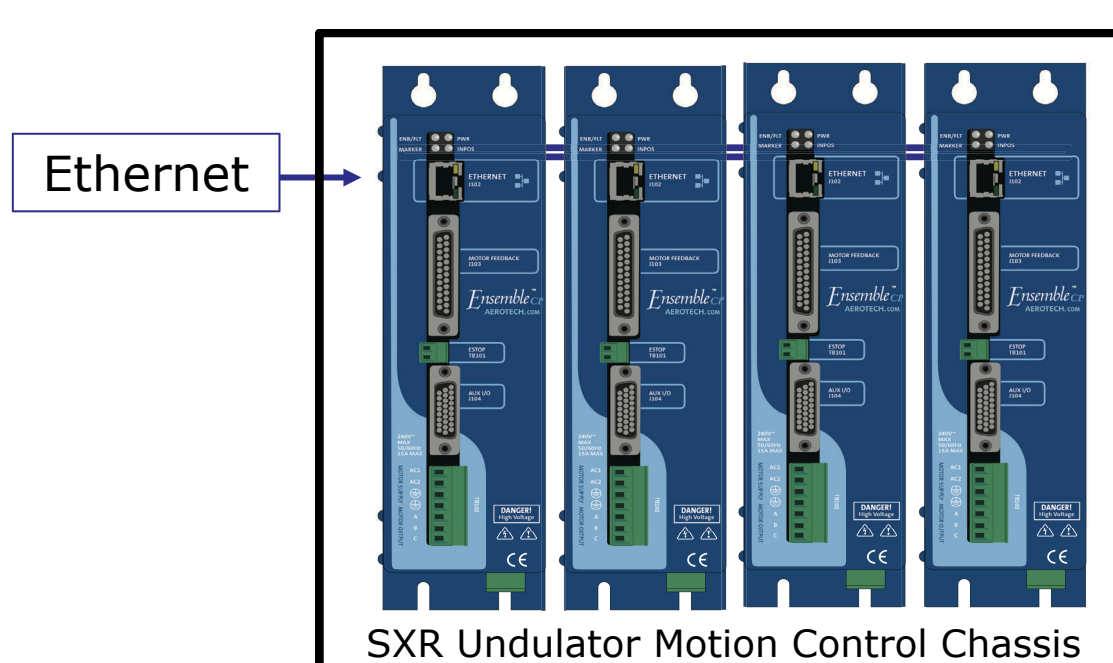
Soft X-ray Undulator Line



Custom coordinated motion through CAN Bus-connected SmartMotors



Native coordinated motion using 4-axis Aerotech Ensemble CP Chassis



Undulator Interface Rack (UIR)

- VME Crate**
 - EPICS IOC on RTEMS/MVME3100
 - FPGA on IP card for
 - Taper/asymmetry protection
 - Interlock/limit switch handling
 - Modules for RS232 and SSI encoders

- UCMI-2:** New LCLS-II Chassis
 - 4 gap motors control
 - Linear encoders, limit switches
 - Monitors voltage supply
 - E-stop chain monitor

- UCMI:** Undulator Control Module Interface
 - 5 cam motors
 - Temperature monitoring with RTDs
 - Rotary and linear potentiometers

- UMPI:** Undulator Motor Power Interlock
 - 24VDC logic power to UCMI, UCMI-2
 - 42VDC motor power for UCMI and UCMI-2
 - Receives faults from other chassis to kill power

Servo Motors: Animatics SM23165DT



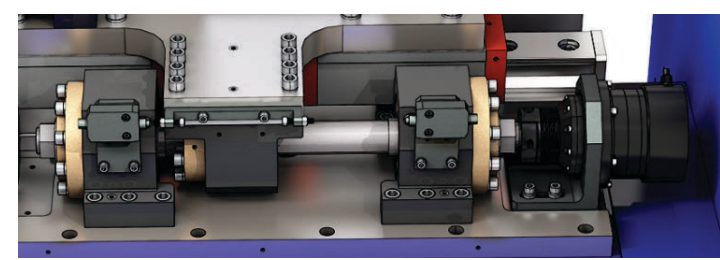
- Integrated:
 - Controller
 - Drive
 - Brake
 - Incremental encoder
- 100:1 gear reduction
- 5.08mm pitch lead screw
- Custom program supporting synchronized motion

Half- and full-gap encoders

- 4 FAGOR automation 0.1µm resolution **half-gap** linear SSI absolute encoders
 - Tilt comparison done on FPGA
- 2 AMO **full-gap** 0.25µm resolution linear SSI absolute encoders

Servo Motors: Harmonic Drive SHA-series

- Integrated encoder
- Integrated brake
- 51:1 gear reduction
- Strain wave gearing mechanism means zero-backlash and high torque
- 6.6 million encoder counts per revolution



Full-gap and rotary encoders

- 2 Renishaw Resolute RELA 50nm resolution **full-gap** absolute BiSS-C encoders (1µm absolute)
- 2 absolute **rotary** encoders (top jaw)
- 2 incremental **rotary** encoders (bottom jaw)

Support-frame rack-mounted components

- SXU Motion Controller**
 - Coordinated motion of all 4 Ensemble CP10 drives supported natively
 - 4 brushless DC servo motors with brakes
 - Support for up to 4 absolute encoders
 - Support for up to 4 incremental encoders
 - Dual-loop position/velocity feedback
 - Fully-featured programming language and development environment, with up to 5 simultaneously running tasks
 - One task used for end-of-travel limit switch logic
 - E-stop hardware circuit for overtravel or power limits



- UIC:** Undulator Interface Chassis
 - Aggregates and distributes limits (tilt, vacuum chamber proximity)
 - Potentiometers for vacuum chamber proximity
 - Beckhoff PLC for temperature monitoring
 - Minimum gap interlock between undulator and interspace

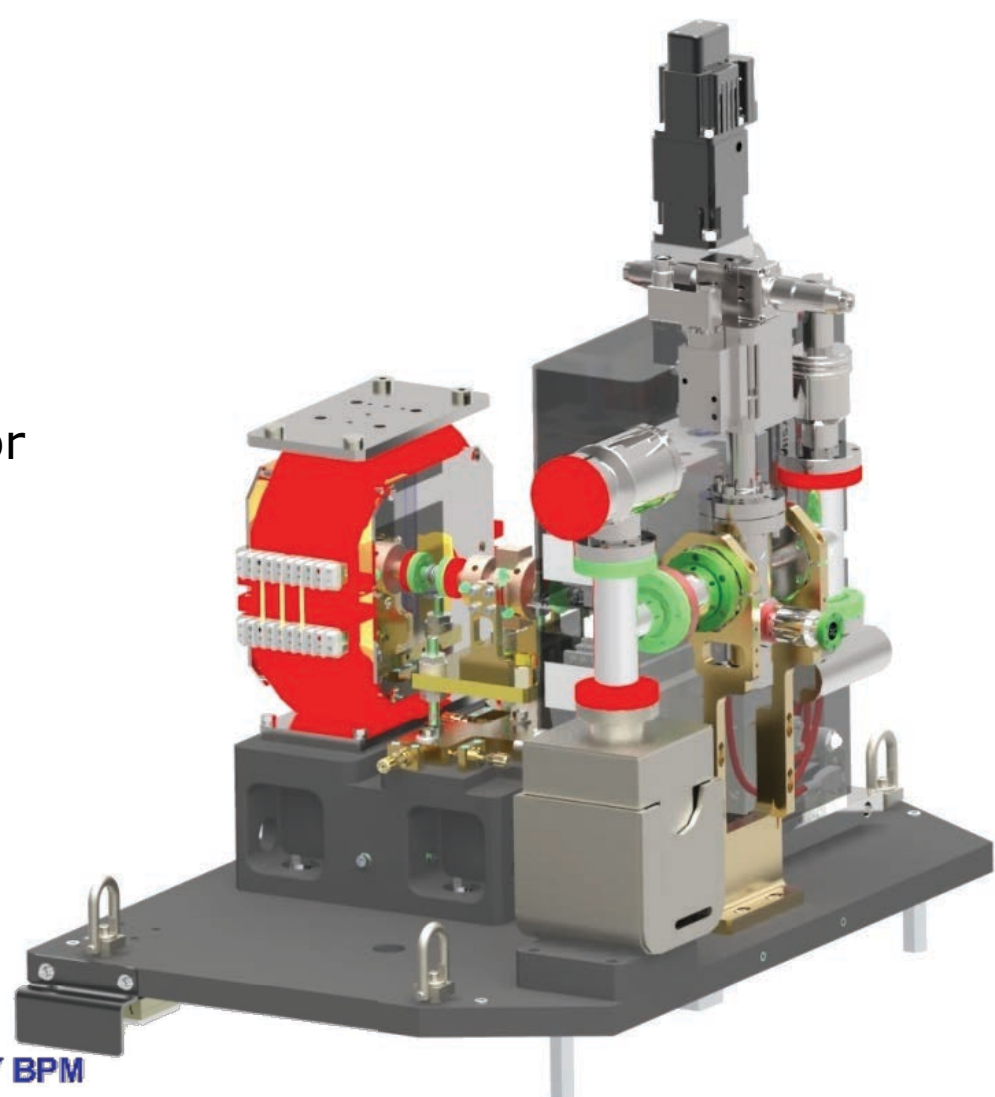


Girder Alignment Cam System and Interspace

As the HXR interspace is on the same girder as the HXR undulator, the alignment cam system is shared. Additional non-motion control components on the interspace are quad magnets, RF cavity BPMs, and vacuum valves.

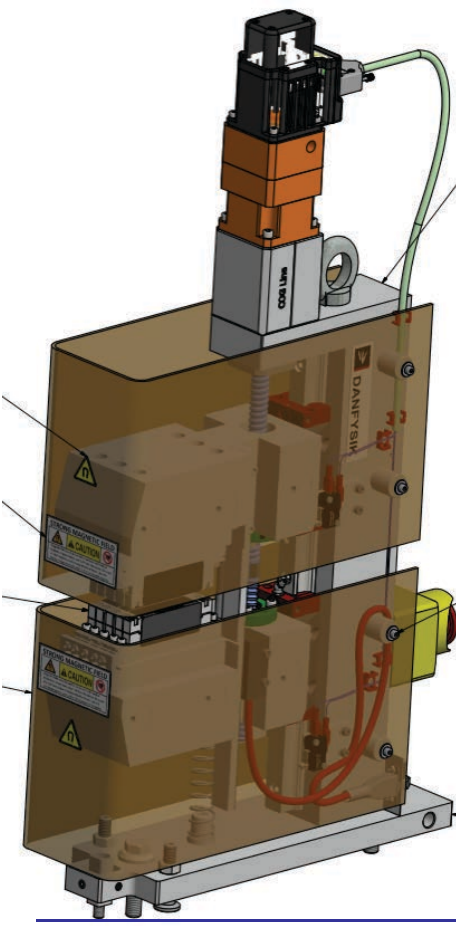
Cam system **hardware** is re-used from the LCLS-I undulator system:

- 5 Animatics SmartMotor SM2320D axes controlled by UCMI-1 in UIR
- Novotechnik rotary potentiometers
- Novotechnik linear potentiometers for calibration



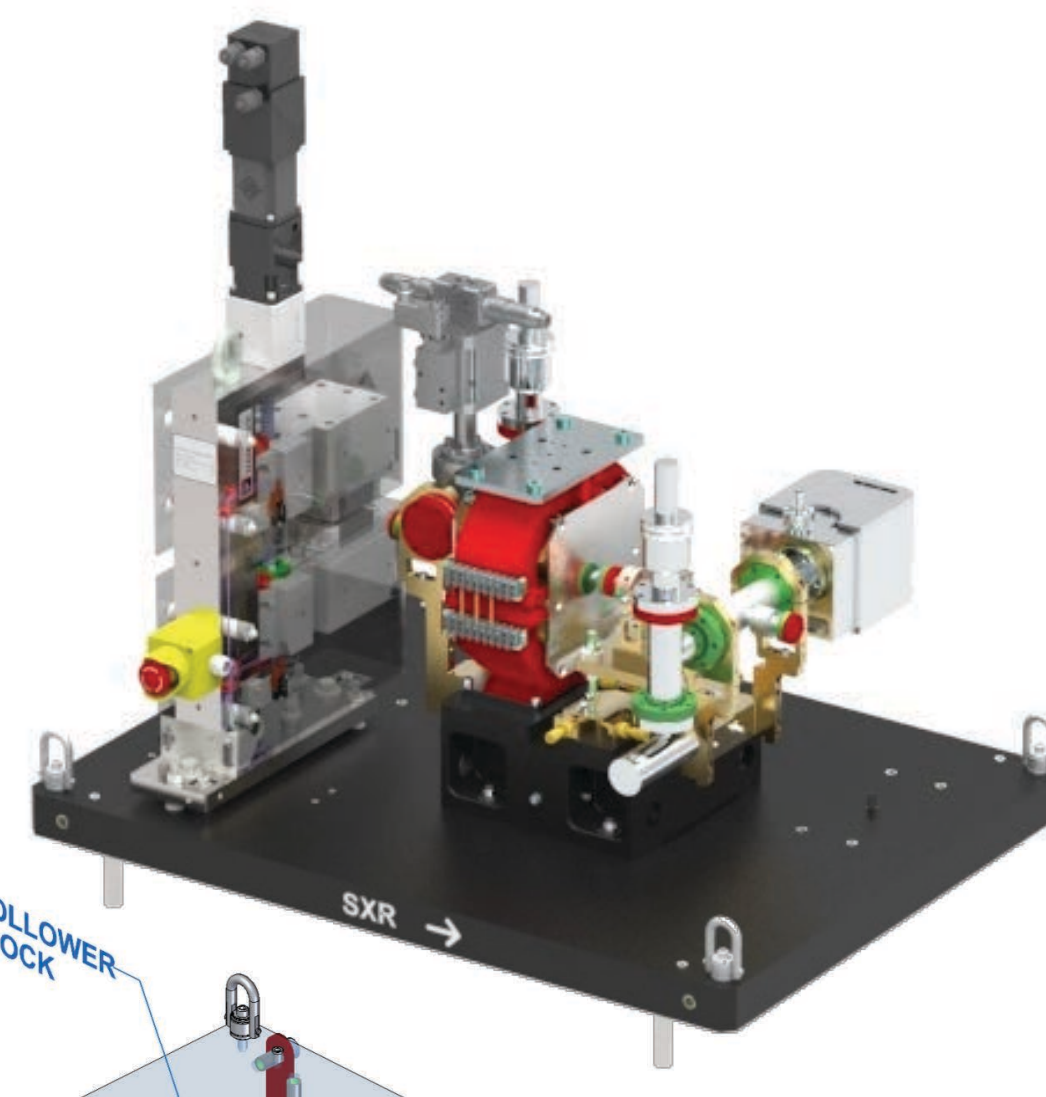
Hard X-ray Phase Shifter

- Single servo motor with integrated controller, drive, and brake (SM23165DT)
- AMO absolute full-gap SSI encoder
- End-of-travel and overtravel limit switches
- E-stop interface

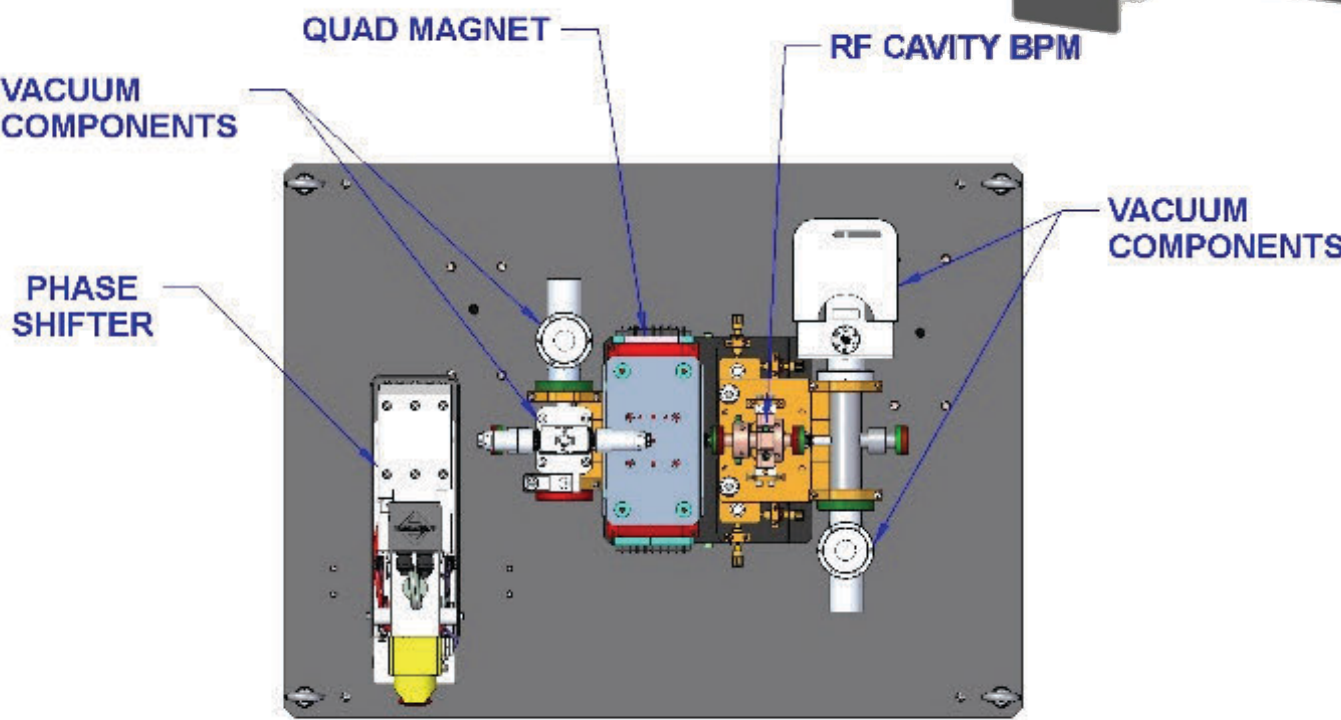
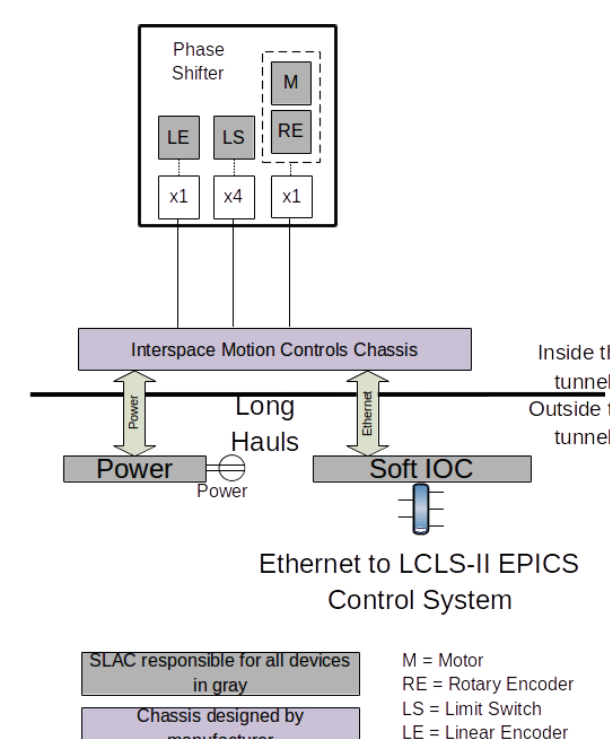


Soft X-ray Phase Shifter

- Single servo motor with brake
- Interspace motion controller
- Renishaw absolute full-gap encoder
- End-of-travel and overtravel limit switches
- E-stop interface



- Cam system **hardware**
 - 6 axis Aerotech motion controller for cam motors and phase shifter servo
 - 5 Applied Motion HT23-601DC stepper motors
 - Novotechnik rotary potentiometers
 - Novotechnik linear potentiometers for calibration



Requirement / Undulator	HXR	SXR	Unit
Minimum Undulator Gap	7.2	7.2	mm
Minimum Full Open Undulator Gap	120	200	mm
Taper Accuracy	±1.5	±2	µrad
Gap Repeatability	<1.5	<5	µm
Long term gap stability (24hr)	±1	±1	µm
Maximum available full gap speed	≥1.0	≥1.0	mm/s