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Revision History

Revision	Date	Description of Changes
A	4/10/2018	Initial release
B	11/1/2019	Clarify language and match updated design.
C	11/22/2022	Clarify language and add deliverables.
R0	12/12/2022	CDMS Initial Release

References

Document #	Document Title
SLAC-I-720-0A29Z-001-R023.5	ESH Manual Chapter 8: Electrical Safety

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Introduction and Purpose

This document outlines the different procurement grades for mechatronics systems for the LCLS Directorate. These grades define what a vendor is responsible for delivering, and at what point the SLAC Experimental Control Systems (ECS) group takes responsibility to finish integration. The grades are defined in order of increasing vendor effort, from level 1, which only delivers motors, encoders, and limit switches, to level 4, which delivers an operational control system fully integrated into the SLAC EPICS environment.

Definitions

BOM	Bill of Materials
ECS	LCLS Experimental Control Systems
EEIP	Electrical Equipment Inspection Program
EPICS	Experimental Physics and Industrial Controls System (distributed control system).
EPS	Equipment Protection System
FAT	Factory Acceptance Testing
I/O	Input/Output
IOC	Input/Output Controller, generally implemented in software for EPICS.
LCLS	Linac Coherent Light Source
PLC	Programmable Logic Controller
PMPS	Photon Machine Protection System
PV	Process Variable
SAT	Site Acceptance Testing
SCADA	Supervisory Control and Data Acquisition

Grades

Level 1 (Up to Bulkhead Termination)

- At this level, a mechatronic assembly will be delivered to SLAC with minimal to no drive or sensor electronics.
- Utilize generic 2-phase stepper motors.
  - < 50VDC
  - < 5A
- Servo motors may be supported, but proper justification must be provided.
  - <50VDC
  - <4.5A
- Utilize absolute (preferred) or relative encoders mounted to stage or actuator.
  - Absolute encoders with a BiSS-C or EnDat 2.0 or EtherCAT interface.
    - Among these, Renishaw is preferred.
  - Relative encoders with RS-422 quadrature signals and index.
    - Renishaw is the preferred encoder provider.
- Absolute encoders are required for devices that need protection from the X-ray beam through PMPS.
- Vendor will terminate motor, encoder, limit/home sensors, and any other sensors (as deemed necessary) to a strain-relief panel bulkhead connector specified by SLAC. (All devices and cables must be clearly labeled with their functional name, i.e., x motion, z motion, ry rotation, etc.).
  - Terminations are verified by functional checkout, e.g.:
    - Motor commutates.
    - Encoder value changes, absolute encoder interface is healthy.
- Home and limit sensors are functional.
- Any electrical component, if not NRTL certified, must comply with SLAC-provided EEIP standards and SLAC ESH Manual Ch 8: Electrical Safety.
- Final vendor design must be approved by SLAC review, including a review from ECS.
- FAT/SAT:
  - Executed by the vendor using their choice of driver and controller hardware.
  - All details of FAT and SAT methodology are provided to a level of thoroughness that would allow SLAC to understand and reproduce the results.
  - Results are provided as well-labeled plots and raw data.
- Deliverables:
  - High level system schematics, vacuum P&ID diagram etc.
  - Bulkhead connector(s) pinouts.
  - Datasheets and manuals for all parts.
  - A list of operational parameters for all motion components, including:
    - Motor specifications: maximum phase current, phase resistance, phase inductance.
    - Holding current.
    - Motor step angle.
    - Motor gearing, if any.
    - Velocity and acceleration limits.
    - Unit of motion traveled per step, e.g., mm/step for linear stages, deg/step for rotary stages, etc.
    - Encoder zero position.

  - Encoder parameters: resolution, bit depth, frequency.
  - Limit switch positions.

Level 2 (Up to and Including Drives)

- Level 1 requirements are satisfied, and further integration is accomplished to provide a fieldbus network interface to the mechatronics. This would leave the controller to be purchased and programmed by SLAC.
- The vendor shall provide a solution using LCLS preferred platforms (selection through consultation with SLAC point of contact) for drives, and controller:
  - If a Beckhoff EtherCAT solution exists that meets the device's functional requirements, it must be chosen.
  - An approved list of Beckhoff hardware and alternate hardware will be provided by SLAC.
  - Vendor will provide mechatronics integration to a fieldbus/ logical level.
  - Component mechatronics are interfaced to drives and sensor electronics.
    - With all of level 1 verification.
    - All drive configurations are set for functional operation and summarized in a document to be provided to SLAC.
- All actuator drives are tuned such that component functional specifications can be satisfied
- Power supply:
  - The vendor shall provide a bulkhead connector for the power interface as specified by ECS, interfacing to SLAC's 24V or 48V DC power system.
    - An exception may be made once consulting with a controls engineer.
    - In which case, the supply needs to be EEIP certified unless it is NRTL certified before being energized.
  - DIN-rail circuit breakers or electronic fuses (use SLAC-recommended components, unless explicitly agreed otherwise) shall be used. Conventional fuses are not permitted.
- Enclosures:
  - Control electronics shall be installed in rigid enclosures.
  - The enclosures shall accommodate feedthroughs/strain relief allowing for cable connections without opening the enclosure.
  - Control hardware inside the enclosure/rack shall be visible without having to remove a cover. The hardware shall still be protected; a transparent viewport or door panel is ideal.
  - Controls enclosures/rack hardware covers shall be removable without the use of tools (e.g., latches and other quick connection methods shall be provided).
  - All cables shall utilize cable management techniques including but not limited to devices such as: cable trays, cable sleeves, cable support systems, wraps, clips, strain relief and clamps.
  - For enclosures that exceed 5 degrees Celsius above ambient temperature, a cooling design must be created and reviewed by a ECS controls engineer.
  - Enclosures shall include ambient temperature readback.
- FAT/SAT:
  - Executed by the vendor using their controller and code.
  - Meets all requirements from level 1.
- Deliverables:
  - Level 1 deliverables.

- A package of schematics and drawings shall be delivered as a PDF and source file. A Complete schematics drawing should include the following:
  - Panel assembly drawings.
  - Pin-to-pin wiring for DC power from power terminals to I/O points.
  - PLC/Fieldbus topology diagram.
  - Pin-to-pin wiring information from every device to the fieldbus IO points/terminals.
  - System Reports: BOM and Cable/connectors Reports.

Level 3 (Up to and Including Controllers)

- Level 2 requirements are satisfied, and further integration is completed by the vendor to provide a SCADA-ready system.
- All functions specified by the component ESD are available via the following ECS-specific TwinCAT3 libraries:
  - lcls-twincat-general for logging.
  - lcls-twincat-motion for motion.
  - lcls-twincat-vacuum for vacuum.
  - Beckhoff-supplied TwinCAT3 built-ins for other functions.
- Non-Beckhoff systems must have interfaces approved in advance by ECS.
  - At a minimum, these must have available EPICS drivers compatible with R7.
- All software adheres to ECS requirements for documentation and style.
- FAT/SAT:
  - Motion control platform tools are utilized to record test results.
  - The vendor shall provide controller routines/function blocks to automatically execute all components of the acceptance tests.
  - Meets all requirements from level 1 and level 2.
  - Control system built for delivery is utilized for conducting the FAT/SAT and providing results.
- Deliverables:
  - Level 2 deliverables.
  - All relevant source code required to successfully build and run the project, along with test routines required to reproduce the results from the FAT/SAT.
  - TwinCAT solution includes a runtime which integrates all control components at the PLC structure variable level and applies generic device functionality with basic EPS as implemented in the SLAC-provided libraries to those PLC variables.
  - I/O linking and mapping for all inputs and outputs on PLC terminals to I/O function block variables on the PLC.
  - Device interlock logic documentation.
  - For non-Beckhoff solutions, enough documentation to enable the configuration of the available EPICS drivers compatible with R7.

Level 4 (EPICS Integrated)

- Level 3 requirements are satisfied, and further integration is completed by the vendor to provide an EPICS and beamline ready system.
- All functions as specified by the component ESD are available through an EPICS interface approved in advance by ECS.

- The vendor shall provide an IOC which is built and functional using the ECS EPICS environment.
    - ECS will provide a virtual environment for this process.
- FAT/SAT:
    - The vendor shall provide testing scripts for the component to automatically qualify functional specifications via the EPICS interface.
        - The scripts must be Python-based.
        - Python device integration must use the ophyd framework.
            - ECS engineers will advise and aid in the integration.
    - Meets all requirements from levels 1, 2, and 3.
- Deliverables:
    - Level 3 deliverables.
    - EPICS IOC source code, including all required databases and startup scripts.
    - Python source code for the device integration into the ophyd framework.
        - Linter (e.g., flake8) results indicating the code has no obvious errors.
        - Verification that the device implementation is correct and that all EPICS PV names are specified correctly.
    - Test scripts from the FAT/SAT and final test results.