Experimental Facilities
Requirements, Specifications and Interfaces for the Controls and Data Acquisition System

Version 2

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Identification and Signatures

This document, National Synchrotron Light Source II (NSLS-II) Experimental Facilities (XFD) Requirements, Specifications and Interfaces (RSI) for the Controls and Data Acquisition (DAQ) Systems, is a part of the documentation system and maps to the NSLS-II project Work Breakdown Structure (WBS) and Cost Estimate Database (CED).

It captures and summarizes all the general requirements and specifications for the WBS elements within 1.04.02, Standard Local controls and Data Acquisition Systems and describes all its technical interfaces with other WBS elements. Note that many individual pieces of equipment will carry their own controls or DAQ requirements that will be documented within individual RSI and/or statement of work (SOW) documents.

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Document Updates

The NSLS-II Experimental Facilities Requirements, Specifications and Interfaces for the Controls and DAQ Systems is a controlled document, revised under change control.

Revision Log

Version number	Date	Author	Changes made
1	May 13, 2011	Wayne Lewis Andy Broadbent Daron Chabot	First version ready for release
2	April 4, 2012	Wayne Lewis	Updates include: Encoder alarm indication and clock frequency specification. Digital camera manufacturer and model clarification. Analog camera interface requirement.

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1 Overview and General Control System Requirements

1.1 Acronyms

BOY	Best OPI Yet
BSA	Brookhaven Science Associates
CSS	Control System Studio
DAQ	Data Acquisition
dBA	deciBel (A weighted)
DHCP	Dynamic Host Configuration Protocol
EDM	Extensible Display Manager
EPICS	Experimental Physics and Industrial Control System
GUI	Graphical User Interface
IOC	Input/Output Controller
NSLS-II	National Synchrotron Light Source II
OPI	Operator Interface
PLC	Programmable Logic Controller
RSI	Requirements, Specification and Interfaces
TTL	Transistor-Transistor Logic
USB	Universal Serial Bus
VME	VERSA Module Eurocard
XFD	Experimental Facilities Division

1.2 References

Identification number or code	Title
LT-ENG-RSI-STD-002	NSLS-II Nomenclature Standard
LT-C-XF-SPC-CO-IIS-001	NSLS-II Beamline Systems Instrumentation Interfacing Standards

Table 1: References

1.3 Introduction

1.3.1 BSA has selected the EPICS control system tool kit for the distributed control system for the NSLS-II accelerators, beamlines and conventional facilities. The motor control system, vacuum control system and interface to the diagnostic components shall be based on this standard to enable cost effective and seamless integration with the rest of the facilities at NSLS-II.

1.3.2 Further information on EPICS can be found at http://www.aps.anl.gov/epics/

1.3.3 The EPICS clients shall be Debian Linux PCs.

1.3.4 EPICS servers in VME form factor shall run RTEMS version 4.10 (or other version as approved by BSA)

1.3.5 EPICS servers on PC hardware shall run Debian version 6.0 (or other version as approved by BSA)

1.4 EPICS software versions

1.4.1 All EPICS software submitted by the Contractors, Collaborators or any other third party shall be based on EPICS base version 3.14.12 (or later version as specified by BSA).

1.4.2 Where additional EPICS modules are used, the versions shall be according to Table 2. Later versions may be specified by BSA.

1.4.3 If a module is not explicitly specified in Table 2, the default version of this module used shall be the version provided in the synApps package version 5.6.

Module name	Version
areaDetector	1-6
asyn	4-16
autosave	4-7
busy	1-3
calc	2-8
modbus	2-1
motor	6-5
seq	2.0.12
std	2-8
stream	2-4-patch20100604

Table 2: EPICS Module Versions

1.5 EPICS support

Where the contract involves the development of an EPICS interface to the components, sections 1.5.1 to 1.5.6 shall apply.

IOC platform

1.5.1 The standard NSLS-II IOC hardware platform is the IBM x3550 M3.

1.5.2 All IOC hardware shall be installed into the standard 19-in. rack by the Contractor.

1.5.3 The IOC shall be included in the system performance tests at the Supplier's factory.

Database development

1.5.4 The Contractor shall provide EPICS databases with layout information compatible with the VDCT EPICS database development tool.

Device support

1.5.5 The Contractor shall supply EPICS device drivers and device support for any hardware delivered as part of this contract.

1.5.6 Where the Contractor provides a motion controller, the EPICS interface shall be the standard Motor record, or a set of records that provides equivalent functionality.

1.6 BSA Supplied Items

BSA will provide the following items to the Contractor:

1.6.1 Debian Linux version 6.0, upon request.

1.6.2 RTEMS version 4.10, upon request.

1.6.3 CSS (NSLS-II distribution), upon request.

1.6.4 19 inch equipment rack cabinets for mounting the control system components at NSLS-II

1.6.5 A GUI style guide, available on contract award.

1.6.6 A naming convention document for the instrumentation and control system, refer to Table 1.

1.6.7 A specification for the file structure to be used for software development, available upon Contract award.

1.7 Operator Interface (OPI)

Where the contract involves the development of an EPICS interface to the components, the following shall apply.

1.7.1 The Contractor shall supply graphical user interfaces (GUI) to perform the following functions:

a) Equipment control panel(s) showing the state of all signals associated with the equipment. These should enable users to monitor and control the equipment for routine operation. It shall be possible to call up the engineering control panels from the Equipment panel.

b) The engineering control panels should enable engineers to monitor and control all the available parameters of the equipment for commissioning and for troubleshooting.

1.7.2 The Operator Interface (OPI) shall be implemented in either Extensible Display Manager (EDM) or Control System Studio (CSS)/BOY.

1.7.3 The version of EDM used shall be 1.12.36, or later version as approved by BSA.

1.7.4 The version of CSS used shall be NSLS-II release 1.0.1, or later version as approved by BSA.

1.7.5 The version of BOY used shall be 1.2.0, or later version as approved by BSA.

1.7.6 The operator interface shall be implemented on a Linux PC. The version of Linux used shall be as defined in 1.3.5.

1.7.7 The operator interface shall be designed in accordance with the GUI style guide referred to in 1.6.5.

1.7.8 The OPI for all optical elements shall include information about the direction and sign of the coordinate system used, including linear and rotation axes.

1.8 Software development

1.8.1 The Contractor shall provide current versions of all source code developed by the Contractor when the relevant Equipment is delivered to the Purchaser.

1.8.2 The Contractor shall provide final versions of all source code developed by the Contractor at the completion of equipment commissioning.

1.8.3 The Contractor shall provide software design documentation including functional specifications, sequence diagrams, class diagrams etc. for the software developed to meet this contract.

1.8.4 A suitable level of commenting shall be adopted for all developed software. As an indication, comments should be provided, on average, for every subroutine and any complex code segment.

1.8.5 All software comments shall be in English.

1.8.6 The Contractor shall allow the source code developed to meet this contract to be open source, consistent with the GNU Lesser General Public Licence.

1.9 Other software

1.9.1 The Contractor shall provide EPICS device support source code for all devices supplied as part of this contract.

1.10 Naming

1.10.1 All devices and database records shall be named in accordance with the NSLS-II Nomenclature Standard, LT-ENG-RSI-STD-002.

1.10.2 Where the existing NSLS-II Nomenclature Standard does not provide the names required, the names shall be developed in consultation with BSA. The Contractor shall receive approval, in writing, from BSA for all names prior to final delivery of the devices and databases.

1.11 Computer and electronic hardware

1.11.1 Electrical energy consumption of rack-mounted hardware (e.g., PCs, IOCs and motor controllers) shall be minimized where reasonably possible.

1.11.2 Acoustical noise generation by rack-mounted equipment shall be minimized where reasonably possible. A suggested maximum SPL from each component, when operating, is 45 dBA, measured at 1 m taken with the equipment installed in the rack and the rack open.

1.11.3 Electrical energy consumption of desk mounted equipment (computers, monitors etc) shall minimize the heat dissipated to the air.

1.11.4 Acoustical noise generation by desk-mounted equipment shall be minimized. A suggested maximum SPL from each component, when operating, is 40 dBA, measured at 1 m.

1.11.5 All rack mounted equipment shall draw air from the front of the equipment and exhaust to the rear. The NSLS-II equipment racks are actively cooled, with cool air provided at the front of the rack and warm air removed from the back of the rack.

1.12 Equipment Protection

General

1.12.1 All equipment protection instrumentation and logic shall be designed to be fail safe. Circumstances to be considered include, but are not limited to, electrical power failure, compressed air failure, and cable breakage.

Motion control equipment protection

1.12.2 All components that have motion axes shall be protected by limit switches to prevent collision with other components or hard stops.

1.12.3 These limit switches shall be directly connected to the over-travel inputs of the motion controller.

1.12.4 Refer to the Wiring Standards document for details of limit switch configuration.

1.12.5 Where additional protection is required (e.g. for Health and Safety reasons, or due to the high value of the equipment), additional limit switches shall be provided which can be used to disable the amplifiers either by a signal to the amplifier or by actively removing the power supply to the amplifier.

1.12.6 Where collision between two moving components is possible, proximity switches shall be provided to prevent any collision.

1.12.7 These proximity switches shall be directly connected to the over-travel inputs of the motion controller.

1.12.8 Software-based equipment protection solutions may only be used in addition to a hardware solution, as described in 1.12.2 through 1.12.7.

Component equipment protection

1.12.9 All components, particularly those exposed to high heat loads, shall have sufficient instrumentation to allow monitoring the integrity of the equipment. This instrumentation will be interfaced to an interlock system which will take action to prevent any permanent damage to the component.

1.12.10 The Contractor shall define the safe operating range for each component based on the instrumentation provided for that component.

1.12.11 The Contractor shall define the required interlock actions when equipment is outside the safe operating range.

1.12.12 The Contractor shall define the length of time required for protective action to occur.

1.12.13 Where the Contractor implements the complete equipment protection system, it shall be PLC based. PLC hardware shall be as defined in 2.6, or equivalent.

Vacuum protection

1.12.14 Instrumentation to monitor the vacuum within the components will be provided using gauge heads on the equipment (supplied by the Contractor) and BSA-supplied vacuum controllers.

1.12.15 The Contractor shall supply sufficient isolation capability (e.g., vacuum gate valves) around each beamline component.

1.12.16 The Contractor shall define the required protection logic for vacuum protection.

1.12.17 Where the Contractor provides electrical or electronic in-vacuum devices that can only operate in certain pressure ranges, the Contractor shall define permitted operating ranges of these devices and shall provide a means of inhibiting these devices.

2 CONTROL SYSTEM INTERFACE DEFINITIONS

2.1 Motion control

This section defines the interfaces to the standard NSLS-II motion controller. In order to connect a motor to this motion controller, the components provided shall meet the following specifications.

The standard NSLS-II motion controller for stepper and servo motors is the Delta Tau GeoBrick-LV-NSLS-II.

2.1.1 Where the Contractor is supplying the motion controller, the Contractor should use the NSLS-II Standard Motion Controller. Use of alternative motion controllers shall be approved by BSA.

Motors

This section defines the motor types that can be driven by the NSLS-II Standard Motion Controller internal amplifiers. For motors that do not meet these specifications, refer to 2.1.35 to 2.1.37.

2.1.2 Stepper motors driven by the standard NSLS-II motion controller shall be two-phase bipolar.

2.1.3 Two-phase steppers should have the phases wired in parallel.

2.1.4 Two-phase steppers should have phase resistance of less than 2 ohms in the parallel wired configuration.

2.1.5 Two-phase steppers shall have either 200 or 400 full steps per revolution.

2.1.6 Stepper motors shall have a continuous current rating of 5 A maximum.

2.1.7 Stepper motors shall have a rated voltage of 48 V maximum.

2.1.8 Servo motors shall have a continuous current rating of 5 A maximum.

2.1.9 Servo motors shall have a rated voltage of 48 V maximum.

2.1.10 Servo motors may be brushed or three-phase brushless.

2.1.11 Three-phase brushless servos shall provide commutation information, either through an encoder or hall effect sensors, or equivalent.

2.1.12 The motor connector pinout shall follow the definitions in the Instrumentation Interfacing Standards document, LT-C-XFD-SPC-CO-IIS-001.

Encoders

2.1.13 Encoders shall provide incremental quadrature signals, unless an absolute encoder is specified or otherwise required.

2.1.14 Encoder signalling level shall be differential RS-422.

2.1.15 Encoders shall operate with a 5 V power supply.

2.1.16 Encoder pinout shall be provided as defined in LT-C-XF-SPC-CO-IIS-001, NSLS-II Beamline Systems Instrumentation Interfacing Standards.

2.1.17 Where the encoder provides an index position, the signal shall be differential RS-422.

2.1.18 Encoders shall indicate an alarm condition by setting the differential quadrature signals (A+, A-, B+, B-) to the same state. The Renishaw 3-state alarm format is an example of an alarm indication mode that meets this requirement.

2.1.19 Absolute encoders shall use the SSI or BiSS-C protocol. Final choice of absolute encoder protocol shall be approved by BSA.

2.1.20 Encoders shall have a maximum internal clock frequency of 10 MHz. Higher internal clock frequencies may only be used with BSA approval.

Limit switches

2.1.21 Limit switches shall be normally closed and shall open to indicate that the limit has been reached.

2.1.22 Limit switches shall provide a volt-free dry contact.

2.1.23 Limit switches shall be rated to 5 VDC or 24 VDC.

2.1.24 Where an optical, capacitance, inductance, proximity or similar limit switch is provided, suitable electronics shall be supplied to convert the signal to one that meets the criteria in 2.1.21 to 2.1.23.

2.1.25 Where an optical, capacitance, inductance, proximity or similar limit switch is provided, the switch must fail safe in the event of a power supply failure.

2.1.26 Where an optical, capacitance, inductance, proximity or similar limit switch is provided, the electronics shall be powered independently of the motion controller.

Reference/home/datum switches

2.1.27 These switches may be either normally open or normally closed.

2.1.28 These switches shall provide a volt-free dry contact.

2.1.29 These switches shall be rated to 5 VDC or 24 VDC.

2.1.30 Where an optical, capacitance, inductance, proximity or similar switch is provided, suitable electronics shall be supplied to convert the signal to one that meets the criteria in 2.1.28 to 2.1.29.

2.1.31 Where an optical, capacitance, inductance, proximity or similar switch is provided, the electronics shall be powered independently of the motion controller.

Motor brakes

2.1.32 Where a motor brake is provided, it shall operate with a 24 VDC signal provided by the motor controller. The current drawn by the brake, in either the activated or deactivated state, shall not exceed 500 mA.

2.1.33 If the motor brake requires higher voltage or current than those defined in 2.4.1, the Contractor shall provide all required components to allow the brake to be activated by a signal that meets the requirements defined in 2.4.1.

2.1.34 The use of motor brakes should be minimized as far as is practicable.

External motor drives

Where a motion axis has a motor that cannot be driven by the standard motion controller, as defined in 2.1.2 to 2.1.12, an external drive shall be provided for this axis. The motor drive shall meet the following interface specification for connection to the standard motor controller.

2.1.35 A stepper drive shall accept step and direction signals.

2.1.36 The step and direction signals shall be RS422 differential signal levels.

2.1.37 A servo drive shall accept either step and direction signals or a -10 V to +10 V analog signal.

2.2 Piezo actuators

2.2.1 The drive or controller for a piezo actuator shall accept either step and direction signals or a -10 V to +10 V analog signal.

2.2.2 Piezo actuators shall be supplied with a controller or drive system.

2.3 Controls network

2.3.1 Network-attached devices shall be compatible with a 1 Gb/s network.

2.3.2 Network-attached devices shall operate at a minimum network speed of 100 Mb/s.

2.3.3 Network-attached devices shall obtain their network address either through static address configuration or DHCP.

2.3.4 Network-attached devices shall include a standard RJ-45 Ethernet connection socket.

2.4 Serial devices

2.4.1 Any device that provides a serial communications interface to the control system shall be interfaced to the control system via a terminal server.

2.4.2 The serial connection from the device to the terminal server shall be RS232, 422 or 485.

2.4.3 The use of USB to connect a device to the control system shall be avoided, as far as is practicable.

2.4.4 Applications requiring high voltage isolation (e.g. vacuum gauge and pump controllers) shall use a Moxa CN2650I series terminal server, or equivalent.

2.4.5 Applications that do not require high voltage isolation shall use a Moxa NPort 6650 series or a Moxa CN2650I series terminal server, or equivalent.

2.5 Computing hardware

2.5.1 PCs running EPICS IOCs or other critical applications shall use the IBM x3550 M3 server or equivalent.

2.5.2 PCs running non-critical applications should use the IBM x3250 M3 server or equivalent.

2.6 PLC

2.6.1 The PLC family used at NSLS-II is the Allen Bradley CompactLogix and ControlLogix. Most applications will use the CompactLogix unless the specific application requires the additional capability of the ControlLogix.

2.6.2 The model numbers for the CompactLogix modules in use at NSLS-II are in Table 3.

Function	Part number
Digital input	1769-IQ32
Digital output	1769-OB32
Analog input	1769-IF8
Analog voltage input	1769-IF16V
Analog output	1769-OF8V
High speed analog IO	1769-IF4FXOF2F
Thermocouple and LVDC	1769-IT6
RTD and resistance	1769-IR6
High speed counter	1769-HSC
CPU	1769-L23E
Network connection	1769-L32E

Chassis	1769-A7
Power supply	1769-PA2

Table 3: Model Numbers for CompactLogix Modules

2.7 Digital IO

2.7.1 All digital inputs shall be dry, volt free contacts.

2.7.2 Where a digital input is part of a protection system, the polarity shall be designed to be fail-safe.

2.7.3 Any item that requires activation by a digital output (e.g., from a PLC) shall operate at 24 VDC, with a maximum current draw of 500 mA.

2.8 Analog IO

2.8.1 An analog signal from a device to the control system shall be in one of the following ranges: 0 to 10 VDC, -10 to 10 VDC, 0 to 5 VDC, 0 to 20 mA, 4 to 20 mA.

2.8.2 A device that accepts an analog signal from the control system shall accept at least one of the following ranges: 0 to 10 VDC, -10 to 10 VDC, 0 to 5 VDC, 0 to 20 mA, 4 to 20 mA.

2.9 Triggers

2.9.1 All generated triggers shall be TTL signal levels.

2.9.2 All trigger inputs shall accept TTL signal levels.

2.10 Cameras

2.10.1 The NSLS-II standard bus type for digital cameras is Gigabit Ethernet (GigE Vision).

2.10.2 The NSLS-II standard camera manufacturer is Prosilica. Specific camera model choice shall be approved by BSA.

2.10.3 The use of other digital camera buses shall be approved by BSA.

2.10.4 Analog cameras shall be supplied with a method for conversion to digital format. The preferred conversion method is an Axis video server.