LCLS WBS DICTIONARY
1.1 PROJECT MANAGEMENT

1 LCLS PROJECT — PED & CONSTRUCTION

This summary WBS covers the Total Estimated Cost (TEC) Estimate for the LCLS Project being constructed at SLAC. The LCLS TEC is supported through Project Engineering and Design (PED) and Construction funds by the U.S. Department of Energy.

1.1 Project Management, Planning & Administration (TEC)

This summary WBS covers the project management, planning and organization function of the PED and construction phases (TEC) of the LCLS Project.

1.1.1 Environment, Safety & Health

This summary WBS describes the ES&H support for the LCLS project at SLAC.

1.1.1.1 Radiation Physics

This WBS supports radiation physics experts/consultants responsible for specifying permissible radiation levels for the LCLS enclosures, interfacing with conventional facilities personnel on the details of labyrinths, shielding walls, permissible materials, etc., and for conducting periodic radiation safety reviews on the LCLS project.

1.1.1.2 ES&H Management & Coordination

This WBS supports ES&H experts/consultants responsible for specifying permissible work areas for the LCLS enclosures, interfacing with conventional facilities personnel on the details of labyrinths, shielding walls, permissible materials, etc., and for conducting periodic general safety reviews on the LCLS project.

1.1.1.3 Seismic & Engineering Support

This WBS supports seismic and engineering experts/consultants responsible for determining the permissible seismic and/or engineering specifications for enclosures and for conducting periodic general seismic and engineering reviews on the LCLS project.

1.1.2 Project Management

This summary WBS describes the project management function for the LCLS project at SLAC.

1.1.2.1 SLAC Project Management Office

This summary WBS describes the LCLS Project Office at SLAC.

1.1.2.1.1 SLAC Project Office – General

This WBS provides for the management function of the LCLS Project Office, which includes:

- The LCLS Project Director who is responsible for directing the overall LCLS project through design, fabrication, installation of the LCLS Project. The scope of the Project Director also includes organizing and selecting staff for the LCLS project at SLAC, ANL and LLNL, ensuring that all ES&H responsibilities and requirements are integrated into the project organization, and representing the LCLS project in interactions with the DOE and Laboratory management.
- The LCLS Chief Engineer who has oversight responsibility for the management and engineering activities of the LCLS project at SLAC, ANL and LLNL. The Chief Engineer also is responsible for determining the technical, cost and schedule dimensions of the project, and establishing systems to coordinate and report construction costs, schedules manpower and technical issues to the LCLS Project Director and DOE.
- The LCLS Budget Officer who is responsible for providing monthly summaries of budgets, costs and obligations in a usable format to LCLS management. The LCLS Budget Officer also represents the LCLS project as the point for contact to SLAC, ANL, LLNL and DOE for all financial and/or auditable information.
- The LCLS Cost & Schedule Manager who is responsible for analysis of progress performance of the LCLS Project using a resource-loaded Work Breakdown Structure (WBS) linked to a network schedule. The C&S Manager heads the Project Cost and Schedule Group, whose collective duties include maintaining the Work Breakdown Structure (WBS) and the Project Management Cost and Schedule (PMCS) System and tracking and maintaining the cost and schedule baseline and documenting the Baseline Change Proposal (BCP) System.
- The LCLS Administrative Support to the scientists, engineers, and technical staff supporting the LCLS project. The LCLS Administrative Support also provides support for financial and budgetary forecasting, procurement, and also organizes meetings, reviews, conferences, and travel.

1.1.2.1.2 SLAC Project Support

This WBS provides for the support function of the LCLS Project Office, which includes:

- The LCLS Project Management Control System (PMCS) supported by a team of professional cost/schedule analysts that will establish and maintain a PMCS to track the planning, performance and resource allocation during the LCLS construction project. This requires collecting monthly the earned-value reporting progress and actual costs for the LCLS, and the actual costs from the three partner laboratories (ANL, LLNL and SLAC). Primavera is used as the primary scheduling tool and COBRA is used for cost analysis.
- Website support for the LCLS project which includes maintaining the LCLS website as the primary repository of project information. The LCLS website will include a general area of information about LCLS (education, outreach, LCLS applications and future directions), technical areas for LCLS groups to disseminate information, and sensitive LCLS management information on costs, budgets, PMCS data (earned-value, change control). The website will be functional ~100% of the time, backed up regularly, and virus-protected.
- Database support for the LCLS project will include maintaining the LCLS documentation database as the primary repository of database project information. The LCLS Database

will collect and organize in a relational database such items as purchase req's, drawings, design specifications and control parameters. The database will be accessible via the LCLS website, functional ~100% of the time and backed up regularly.

- Procurement support for the LCLS project will include maintaining LCLS requisitions, purchase orders and P-card transactions.
- Quality assurance and quality control support for the LCLS project will include maintaining LCLS performance specifications, as-built/as-tested documentation, "travelers" and change control.
- Specialty software licenses necessary to support the global LCLS project.
- Computing support for the LCLS project staff. This includes PC and network support including troubleshooting and computer security.
- Recruiting/relocation support for newly hired staff to the LCLS project.

1.1.2.1.3 SLAC Project Office M&S

This WBS provides for the Materials & Supplies (M&S) for the LCLS Project Office, which includes:

- Miscellaneous M&S to operate the LCLS project on a day-to-day basis which includes all office supplies, binders, etc. to support the LCLS team. All M&S costs necessary to support the LCLS project during reviews (Management, Physics, Safety, Engineering, etc.) is included in this WBS.
- Tele/videoconferencing equipment (polycoms, monitors, phones, modems) and projector costs for the LCLS project, including setup labor.
- All PC + software costs for the LCLS group.
- Miscellaneous shipping or storage of general LCLS items at SLAC. This is not assumed to cover large shipping/storage costs associated with large LCLS deliverables (i.e., undulators, etc.).
- Project-related travel costs for the SLAC Project Office. Also includes travel funds for technical experts to travel at the request of the project office for project-related consultations.
- Building refurbishments, relocations or minor remodeling to existing SLAC buildings to meet the needs of the LCLS project staff.
- Project-related travel costs for technical experts to travel at the request of the project office for reviews or project-related studies or workshops.

1.1.2.1.4 Unused

1.1.2.1.5 Unused

1.1.2.2 Unused

1.1.2.3 Unused

1.1.3 Technical Integration

This summary WBS describes the technical integration effort for the LCLS Project. These integration tasks are technical activities or tasks that support the global effort for the LCLS and integrate specific LCLS systems into a fully functional LCLS.

1.1.3.1 Global Controls

This WBS describes the technical integration effort to support the LCLS global control system, which includes:

- Software programming support to provide a common software interface to hardware used across the LCLS systems. This will also support programming effort to write drivers and test hardware and support the integration of LCLS hardware with the SLAC SLC control system.
- Controls management and consulting effort at the global LCLS level which include a controls manager and expert consultant to produce an integrated control system for the LCLS. This requires merging a new EPIC-based control system with the existing SLAC SLC control system.
- Refurbishments to the existing SLAC Main Control Room to support the LCLS Project.
- Global controls system administrator to manage all aspects of the control system software including the operating system, version control of LCLS applications and EPIC's programs.
- High level application programming to support the physics application and software programs for the LCLS, such as the LCLS testing, fast feedback and integration programs.
- LCLS beam instrumentation, controls and test equipment to support the global LCLS controls effort, which includes such items as prototype IOC's, development hardware, instrumentation, oscilloscopes, power supplies and function generators.

1.1.3.2 Surface Network Components

The surface network determines the global geometry of the machine. It is represented by monuments which are the physical representation of the coordinate system.

1.1.3.3 Global Installation Coordination

This is to cover the global installation effort for the LCLS activities that are not related to specific LCLS systems. This will support a global LCLS Installation Manager necessary to coordinate activities related to installing technical equipment in the new LCLS conventional facilities. The global installation manager will facilitate and coordinate each system installation managers and their specific activities to ensure a safe and organized installation effort for the LCLS.

1.1.4 Education Support

This summary WBS describes the education and outreach support for the LCLS project and LCLS scientific program.

1.1.4.1 Education/Outreach Travel

This WBS provides education/outreach travel to support the LCLS project such as presenting lectures on the scientific merits of the LCLS and promoting Free Electrons Lasers (FEL's) as scientific instruments.

1.1.4.2 Education/Outreach M&S

This WBS provides education/outreach M&S (brochures, posters, CD's, etc.) to support the LCLS project and the scientific merits of the LCLS.

1.1.5 Unused

2 LCLS PROJECT — R&D, SPARES, COMMISSIONING

This summary WBS covers the Other Project Cost (OPC) Estimate for the LCLS Project being constructed at SLAC. The LCLS OPC is supported through Research & Development (R&D), Spares and Commissioning funds by the U.S. Department of Energy.

2.1 Project Management, Planning & Administration (OPC)

This summary WBS covers the project management, planning and organization function of the R&D, Spares and Commissioning (OPC) phases of the LCLS Project.

2.1.1 Physics Support (OPC)

This summary WBS provides for physics support through the LCLS R&D and commissioning phases of the project.

2.1.1.1 SAC-MAC Physics

This WBS provides for global physics support through the LCLS R&D and commissioning phases of the project. This will provide support for the LCLS Physics Group Leader who is responsible for directing the overall physics effort for the LCLS project, and provides direction and guidance to the LCLS System Physicists to ensure that LCLS System Requirements meet the needs of the LCLS.

2.1.1.2 Injector Physics

This WBS provides support for the LCLS Injector System Physicist through the R&D and commissioning phases of the LCLS Injector System. The Injector System Physicist is responsible for directing the overall physics effort for the LCLS Injector system and for providing system requirements that satisfy the global requirements of the LCLS project.

2.1.1.3 Linac Physics

This WBS provides support for the LCLS Linac System Physicist through the R&D and commissioning phases of the LCLS Injector System. The Linac System Physicist is responsible for directing the overall physics effort for the LCLS Linac system and for providing system requirements that satisfy the global requirements of the LCLS project.

2.1.1.4 Undulator Physics

This WBS provides support for the LCLS Undulator System Physicist through the R&D and commissioning phases of the LCLS Injector System. The Undulator System Physicist is responsible for directing the overall physics effort for the LCLS Undulator system and for providing system requirements that satisfy the global requirements of the LCLS project.

2.1.1.5 X-Ray Transport Physics

This WBS provides support for the LCLS X-Ray Transport System Physicist through the R&D and commissioning phases of the LCLS X-Ray Transport System. The X-Ray Transport System Physicist is responsible for directing the overall physics effort for the LCLS X-Ray Transport system and for providing system requirements that satisfy the global requirements of the LCLS project.

2.1.1.6 X-Ray Endstations Physics

This WBS provides support for the LCLS X-Ray Endstations System Physicist through the R&D and commissioning phases of the LCLS X-Ray Endstations System. The X-Ray Endstations System Physicist is responsible for directing the overall physics effort for the LCLS X-Ray Endstations system and for providing system requirements that satisfy the global requirements of the LCLS project.

2.1.1.7 Conventional Facilities Physics

This WBS provides support for the LCLS Conventional Facilities System Physicist through the R&D and commissioning phases of the LCLS Conventional Facilities System. The Linac Conventional Facilities Physicist is responsible for directing the overall physics effort for the LCLS Conventional Facilities system and for providing system requirements that satisfy the global requirements of the LCLS project.

2.1.1.8 Consulting Physics (Collaboration)

This WBS provides for physicist support and consultation through the R&D and commissioning phases of the LCLS, such as analytic and numerical computations of the SASE process in the LCLS, optimization of the LCLS design, modeling predictions of FEL performance to support modifications for self-seeding operation of the FEL. Also, ad hoc computer modeling programs in support of the LCLS commission effort are included.

2.1.1.9 Consulting Physics (SLAC)

This WBS provides for physicist support and consultation through the R&D and commissioning phases of the LCLS, such as analytic and numerical computations of the electron beam emittance, bunch length, bunch charge, and full-length LCLS (electron to photon) simulation studies to optimize the commissioning of the LCLS are included.

2.1.1.10 Global Controls Physics Liaison

This WBS provides support for the LCLS Global Controls Physicist through the R&D and commissioning phases of the LCLS. The LCLS Global Controls Physicist is responsible for directing the overall physics controls effort for the LCLS and for providing control system requirements that satisfy the global requirements of the LCLS project.

2.1.1.11 Global Controls OPC

This WBS provides support for the commissioning effort to test and verify the functionality of each successive LCLS control system. Typical activities included are; verification of RF performance, fast feedback, interaction of the LCLS Personnel Protection System (PPS), Beam Containment System (BCS), and the Machine Protection System (MPS), and verification and testing of local S20 controls and remote control at the SLAC Main Control Center.

2.1.2 R&D Studies and Prototyping

This WBS provides support for building new timing and RF boards. Both the timing boards and the RF boards require VME architecture to interface with the existing SLAC timing system and the existing SLAC klystron infrastructure.

2.1.3 Project Management, Planning and Administration – M&S (OPC)

This WBS provides funds to support the global OPC effort for the LCLS, and includes programmatic travel for the LCLS Collaboration, Scientific Advisory Committee, and Machine Advisory Committee through the R&S and pre-operations phases of the LCLS. Also included are funds to support the LCLS pre-operations power usage in FY2007 and FY2008.

LCLS WBS DICTIONARY
1.2 INJECTOR

1.2 INJECTOR SYSTEM

The injector generates the electron beam and accelerates it to 135 MeV. This system includes the laser, optical transport, the electron gun, the accelerator sections, the solenoids and other magnets, the diagnostics including a diagnostic section at the end of the injector, the LCLS timing system, and the laser room. The interface to the Linac is at the downstream end of Dog Leg 1 (DL1), ending at the valve at the entrance to linac section L1.

1.2.1 Injector System Management & Integration

At level 3 of the WBS the Injector System is divided into 17 discrete systems. Each of these systems can have multiple functional requirements that range from local and sub system, to Linac, LCLS project, and then SLAC. This section of WBS identifies these interdependencies, supports the establishment of consistent and hierarchical requirements, and supports systems that manage and integrate these efforts. Requirements and planning for Injector installation is covered in this section.

1.2.1.1 Injector System Integration Effort / M&S

This element covers the costs over the entire Injector for materials and supplies through the PED and Construction phase of the project. Specific categories are identified; Travel, Computers, Cost Account Management, as well as general Management.

1.2.2 Injector Controls Subsystem

The injector controls system is to be an EPICS – Experimental Physics and Industrial Control System. The Injector control system must interface with the existing linear accelerator (LINAC) timing system. Local system control, at Sector 20, will be used for development through the commissioning phase of the project. Operational control will reside in the LCLS Main Control Center (MCC).

1.2.2.1 Unused

1.2.2.2 LLRF Controls

1.2.2.2.1 Readback & Controls – LLRF Gun & Temperature

The section covers costs associated with phase, amplitude, and temperature read backs into the control system in support the RF Gun.

1.2.2.2.2 Readback & Controls – LLRF L0

The section covers costs associated with phase, amplitude, and temperature read backs into the control system in support the L0.

1.2.2.2.3 Readback & Controls – LLRF Transverse Cavity

The section covers costs associated with phase, amplitude, and temperature read backs into the control system in support the Transverse Cavity.

1.2.2.2.4 S-Band Cavity Controls

The section covers costs associated with phase, amplitude, and temperature read backs into the control system in support the phasing cavity.

1.2.2.3 E-Beam Diagnostics Controls

1.2.2.3.1 Unused

1.2.2.3.2 Controls – Toroids

Toroid[1] (current monitor) controls include the cables from the hardware to the control modules in the VME crates, the VME control modules and the software to communicate with the toroids. The crate, controller and license are included in section 1.2.2.8.

1.2.2.3.3 Controls – Faraday Cups

There are four Faraday Cups[2] in the LCLS injector. Each contains its own OTR or YAG profile monitor. Where the energy is low, a YAG is used; where the energy is high, an OTR is used. Where the Faraday Cup is used to momentarily intercept the electron beam, a pneumatic actuator is used to insert the FC/PM assembly.

1.2.2.3.4 Controls – Tune-Up Dump

Tune up dump[3] controls include the cables from the hardware to the control modules in the VME crates, the VME control modules and the software to communicate with the toroids. The crate, controller and license are included in section 1.2.2.8.

1.2.2.3.5 Controls – Profile Monitors

There are two types of profile monitors: YAGs (where energy is low) and Optical Thermal Radiators (OTR) (where energy is higher). Controls include the camera and accompanying PC (ratio of cameras: PC may > 1), the Cables between each and the Ethernet cable to get data to MCC, along with software for interpreting the image data.

1.2.2.3.6 Controls – E/O Diagnostics

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[1] TOROid. A beam current monitor which uses transformer action to measure the intensity of a beam pulse. Usually placed around a ceramic gap in the beam pipe.

[3] A FARaday Cup is a device designed to stop an accelerated beam and measure the integrated charge. Some are also used to park beams at low rep rates for short periods. FARCs are usually connected to ground through a current measuring device so that the integrated current in the beam may be measured.

[3] A Tune up dump is a safe place to absorb beam energy during tuning and adjustment.

The electro-optic phase diagnostic consists of an analog signal of pulse length measurements which will be input into an ADC VME module in the diagnostics crate or via a digitizer. Software in the IOC will calculate the centroid of the array of pulse lengths, and from that, due to the linear relationship between the chirped pulses' length and time, determine the relative time between the electron and the laser beam. The result will be converted to an analog signal via a DAC VME module which will be used to vary the drive laser signal such that the relative time goes to zero. This same result will also be used to vary the gun phase such that the relative time goes to zero.

1.2.2.3.7 Controls – BPM

The BPM (Beam Position Monitor) controls for the injector consist of the cables from the BPM hardware to the local VME crate, along with the controller, license and software to communicate with the BPM.

1.2.2.4 Laser Controls

1.2.2.4.1 Unused

1.2.2.4.2 Controls – Gun Laser

This element includes costs for the design and documentation of local control and the interface of the Gun Laser to the main control system.

1.2.2.5 Laser Heater Controls

The laser heater controls system consists of control modules, cables and software to:

- Do on/off control of two laser shutters one in beam conditioning optics, one at launch table.
- Steer the IR beam by controlling two motorized mirror stages on the launch table.
- Modifying the OTR control, if necessary, for the laser heater.
- Transmit the IR joulemeter signal from IR diagnostics to MCC. There are 4 analog signals which need to get to PEP via an ADC. There might be 0.5 months software work here, too.
- Transmit the IR timing diode signal to an oscilloscope near diagnostics port.
- Transmit the Spiricon camera image on the diagnostic table to MCC and receive controls from MCC.
- Transmit the electron beam energy spread data from OTR and to MCC. A PC might be needed here for the spectrometer.
- Reduce the data for the laser and the e-beam (the previous two items).
- Control the Undulator by stepping the motor and reading the position from LVDT sensors and the limit switches.

1.2.2.6 Timing Controls

One master timing controller is needed for the injector. This controller interfaces to the LINAC's Main Drive Line (MDL) and passes on the timing signals to a maximum of 8 outputs.

The fiducial output (FIDO) module divides the 476 MHz signal by 4 to become a 119 MHz signal (8.4 nsec ticks). The FIDO sends its signal to the PDU II module in the VME crate of the receiving system. It uses Heliax cable between the FIDO and the PDU II.

1.2.2.7 Vacuum Controls

The vacuum design for the waveguide is based on the vacuum design at LINAC sector 2. Controllers, power supplies, gauges, valves, and cables are identified in this system. The pumps are small ion pumps, equally spaced along the waveguide. The pump power supplies are controlled via set points sent via VME IDIM signals. Two kinds of gauge controllers will be used. The Pirani and the Cold Cathode gauges are controlled by a HPS 937 gauge controller; the hot filament gauges are controlled by a GP307 Ion gauge controller. During the design phase, the number of each type of gauge used will be determined. There are 4 valves. All 4 valves can be controlled by a single programmable multi valve controller, PMVC6, module. Faston relays are also used to control the valves.

1.2.2.8 Software & Controls Infrastructure

1.2.2.8.1 Unused

1.2.2.8.2 Unused

1.2.2.8.3 Data Communications

Controls workstations will have access to MCC from the control room and from the RF hut. The network will be configured to get images to MCC without compromising control commands. Laptops will have wireless access to the visitor network. Access points will be at both the ground and subground levels.

1.2.2.8.4 Computers & Crates

The VME crates with Power PC IOC controller and VxWorks.

1.2.2.9 Power Supply Controls

There are two main types of power supplies to control for the injector. The controls for these power supplies are expected to be simple ON/OFF, with reporting back, which could be a VSAM module. The second type of power supply is the MCOR system. There are 4 instances of these and each one uses both a SAM and a DAC module to interface to the IOC.

1.2.2.10 PPS, BCS, MPS, Controls

This section covers the cost of designing and writing software to integrate the new EPICS Control system with the existing accelerator control system.

1.2.3 Injector Lasers

The drive laser system provides ultraviolet (UV) irradiation to the cathode of the LCLS RF photoinjector. The drive laser utilizes a standard chirped pulse amplification (CPA) design beginning with a mode-locked infrared (ir) oscillator. Oscillator pulses are temporally shaped and stretched before entering the IR amplifier chain. This chain amplifies the single pulse energy in two sections (i) the preamplifier and (ii) the final amplifier. Ir pulse energies of order 10's of millijoules are obtained during the final amplification where the repetition rate is also reduced to 120 Hz, the RF photoinjector design repetition rate. Following amplification and repetition rate reduction, a portion of the IR pulse energy is converted to UV irradiation via third harmonic generation in nonlinear media. UV pulse energies of a few millijoules are generated, conditioned, and transported to the photocathode.

1.2.3.1 Unused

1.2.3.2 Drive Laser Oscillator

The drive laser oscillator is the ultimate source of optical irradiation for driving the LCLS RF photoinjector. It is a mode-locked source operating at a 119 MHz repetition rate. It also includes a cw diode pump laser. Samples of the oscillator pulse energy can be used for diagnostics and diagnostic probe beams. Oscillator timing is referenced (and locked) to an external (SLAC) RF source. It establishes the maximum single pulse infrared (ir) bandwidth available to the drive laser system.

1.2.3.3 Oscillator Diagnostics and Isolator

The oscillator diagnostic cluster is intended to monitor the intrinsic oscillator output as well as the results of temporal pulse shaping and stretching. The diagnostic cluster includes a spatial profile imaging system, a fast photodiode, an average power sensor, a time-integrated spectrometer for monitoring bandwidth as well as mode-locked operation, and broadband time-resolved diagnostics for monitoring temporal pulse-width and shape (using techniques such as scanning autocorrelation and frequency-resolved optical-gating (FROG) detection). Where possible, diagnostics require only a sample of the oscillator pulse energy. In the main beamline isolation via optical Faraday rotation is included to protect the oscillator from pulse energy that can reach the oscillator from downstream origins (such as spurious reflections and the preamplifier).

1.2.3.4 Stretcher /Shaper

The temporal ir pulse shaper is intended to alter the temporal shape of the pulse exiting the oscillator from a nominally Gaussian temporal envelope to a nominally flattop (rectangular) envelope with specified steepness for rise and fall edges. Given the nominal rectangular envelope requirement, this device then establishes the duration (FWHM) and shape of the final high energy ir pulse to be used for UV conversion.

The stretcher is an optical assembly intended to temporally stretch ir (infrared) pulses exiting the shaper by at least two orders of magnitude to nanosecond durations. It is comprised of ir transmission optics and a pair of optical gratings. Pulses exiting the stretcher are therefore of extended duration and are input to the preamplifier section.

1.2.3.5 Unused

1.2.3.6 Oscillator Beam Transport and Enclosure

Transport of the oscillator beam concerns beam properties and the beam path from the oscillator section to the preamplifier section. Physical beam enclosures are also included.

1.2.3.7 Preamplifier

The preamplifier follows the stretcher/shaper in the system and amplifies these stretched and shaped ir pulses to the millijoule level. It includes a diode pump laser. Seed pulses come from the oscillator but at a reduced repetition rate. Electro-optic input pulse selection steps the repetition rate down to the KHz level. Timing stability as referenced to the external SLAC RF source is determined by the oscillator timing stability. In addition, repetition rate samples (pulse sharing) of the preamplifier output can also be used for diagnostics and diagnostic probe beams.

1.2.3.8 Preamplifier Diagnostics and Isolator

The preamplifier diagnostic cluster is intended to monitor the preamplifier output. It includes fast photodiode detection, a pulse energy/power meter, spatial profile imaging, and broadband single pulse detection (as would be provided, for example, by polarization-gated frequency-resolved optical-gating detection (PG-FROG)). This single pulse broadband time-resolved detection monitors the temporal pulse shape (envelope) that is established between the preamplifier and the oscillator. The isolator is included to protect the preamplifier from pulse energy that can reach it from downstream origins (such as spurious reflections and the amplifier).

1.2.3.9 Preamplifier Temporal Pulse Shaping and Low Power Compressor

The low power compressor recompresses the pre-amplified, stretched and shaped ir pulses back to the shaped level (i.e. without the stretching). It consists of a pair of optical gratings and a mirror prism that returns the beam at a different elevation. The compressed result facilitates monitoring temporal pulse shape, as programmed between the oscillator and preamplifier, to include preamplifier effects. It is monitored at the preamplifier exit using the broadband single pulse diagnostic with adequate temporal resolution (such as the PG-FROG). Using the repetition rate sample of the preamplifier output the low power diagnostic compressor can be used in this way without sampling part of the pulse energy that seeds the final amplifier. Provision can also made for potentially shaping ir pulses at the preamplifier energy level.

1.2.3.10 KHz Pulse Selection and 120 Hz Splitter

The electro-optic pulse selection occurs between the stretcher/shaper and the preamplifier. It reduces the preamplifier seed repetition rate to 1 KHz. The 120 Hz pulse splitter is also electro-optic and is located at the preamplifier exit . It reduces the seed repetition rate (for the final amplifier) to 120 Hz. It then subsequently splits the 120 Hz output to four 30 Hz pulse trains. The remaining 880 Hz pulse train (i.e. those pulses not seeding the final amplifier) is directed to the low power compressor for diagnostics.

1.2.3.11 Preamplifier Spatial Filter

The 120 Hz preamplifier output pulse train seeds the final amplifier and is therefore spatially filtered between the 120 Hz splitter and the final amplifier. It consists of a positive lens pair with an on-axis pinhole place between them.

1.2.3.12 Preamplifier-Based Measurements

Component-based measurements include items that are not identified as separate drive laser components yet are essential to the drive laser development. In the preamplifier case this includes measurements of timing stability (relative to the external SLAC RF source to which the oscillator output is locked), pulse energy stability, and beam pointing or steering stability. These stabilities refer to shot-to-shot variations of the 120 Hz seed beam. Shot-to-shot measurements of pulse energy and steering stability serve also to assess utilized stabilization schemes. The preamplifier diagnostic cluster is used.

1.2.3.13 Preamplifier Beam Transport and Enclosure

Transport of the preamplifier beam concerns beam properties and the beam path from the preamplifier exit to the final amplifier section. Physical beam enclosures are also included.

1.2.3.14 Final Amplifier

The final amplifier section amplifies seed pulse energies to the 10's of millijoules level. These pulses remain stretched and shaped as set at the oscillator level. It is located between the 120 Hz pulse splitter and a 120 Hz combiner. Final amplifier operation at this repetition rate is accomplished through the use of four parallel amplifier arms, each operating at 30 Hz. Each amplifier arm is a multipass design (with respect to the seed pulse) pumped at 30 Hz by the second harmonic of a flashlamp-pumped, 'Q'-switched Nd:YAG laser. Pulse trains from the four arms of the final amplifier are combined downstream to obtain the required 120 Hz. As with the preamplifier, timing stability, relative to the external SLAC RF source, is set by the oscillator.

1.2.3.15 Final Amplifier Diagnostics

At the final amplifier exit, this diagnostic cluster is used to monitor the final amplifier output prior to UV conversion. It is located in regions before and after the 120 Hz combiner and high power compressor. It includes fast diode detection, a time-integrating spectrometer, spatial profile imaging, energy/power sensors, and broadband time-resolved single pulse diagnostics, with potential to add a single-pass oscillator probe beam. As with the preamplifier, single pulse broadband detection is used to monitor the established temporal pulse shape (envelope) with all amplifier effects included.

1.2.3.16 120 Hz Combiner

The 120 Hz combiner electro-optically combines the output of the four 30 Hz pulse trains from the final amplifier. It is located at the final amplifier exit and combines pulse train pairs at two stages. Two 60 Hz pulse trains are obtained in the first stages and a single 120 Hz pulse train results after the second one. The high power compressor is located between these two stages.

1.2.3.17 High Power Compressor

Energetic ir pulses emerging from the final amplifier remain shaped and stretched. The high power compressor performs a final compression of these pulses to durations at the originally shaped level as set at the oscillator exit. The compressed result therefore includes effects of the entire amplifier chain. It also affords additional flexibility in setting the final pulse duration and shape prior to UV conversion. A portion of the pulse energy exiting the compressor is used for some final amplifier diagnostics.

1.2.3.18 High Power Vacuum Spatial Filters and Relay

The final compressed energetic ir pulses must be spatially filtered prior to UV conversion. The spatial filter is then located between the final stage of the 120 Hz combiner (i.e. downstream of the high power compressor) and the harmonic generation unit (which is the site of UV conversion). It is comprised of a positive lens pair with a filtering pinhole aperture between them. Due to the high pulse energy the space between lenses must be evacuated. The relay portion refers to the optical relay of pulse energy along the beam path to the harmonic generation unit.

1.2.3.19 Final Amplifier-Based Measurements

Component-based measurements include items that are not identified as separate drive laser components yet are essential to the drive laser development. In the final amplifier case this includes measurements of timing stability, pulse energy stability, beam pointing or steering stability, and high power spatial profile shaping. Stabilities refer to shot-to-shot variations of the 120 Hz seed beam. Shot-to-shot measurements of pulse energy and steering stability serve also to assess utilized stabilization schemes. Pulse energy stabilization includes the input seed levels and pump levels for the final amplifier. The final amplifier diagnostic cluster is used.

1.2.3.20 Final Amplifier Beam Transport and Enclosure

Transport of the final amplifier beams concerns beam properties and the optically relayed beam paths from the exit of each arm of the final amplifier to the harmonic generation unit. This then incorporates the 120 Hz combiner and high power compressor. Physical beam enclosures with evacuation capability are also included.

1.2.3.21 UV Conversion Harmonic Generation Unit

The harmonic generation unit is located after the high power compressor and final stage of the 120 Hz combiner. The required UV irradiation for the photocathode is generated in this unit via third harmonic generation. A pair of nonlinear crystal is required because it must be accomplished in two stages; (i) first, a second harmonic generation stage (SHG) and (ii) second, a third harmonic generation stage (THG). The unit also includes dichroic optics for wavelength separation. The crystal pair with dichroic optics is shrouded in a purged environment with temperature control.

1.2.3.22 UV Diagnostics

Located at the harmonic generation unit the UV diagnostic cluster monitors the UV pulse features prior to transport to the photocathode in the tunnel. It includes a fast photodiode, a pulse energy/power monitor, a time-integrated spectrometer, spatial profile imaging, and single pulse broadband time-resolved UV pulse detection (which will include a streak camera).

1.2.3.23 UV Measurements

Component-based measurements include items that are not identified as separate drive laser components yet are essential to the drive laser development. In the case of UV generation these measurements include pulse energy stability, pulse timing stability, and verification of crystal damage fluence thresholds. Stabilities refer to shot-to-shot variations of the 120 Hz seed beam. In addition, other important UV pulse measurements are included in the UV pulse conditioning section.

1.2.3.24 UV Optical Transport and Transport Diagnostics

Transport of UV pulses concerns the beam properties and the optically relayed beam paths distance for UV light over an extended distance from the exit of the harmonic generation unit to the gun photocathode which is housed in the tunnel. This then incorporates the launch optics associated with final UV pulse conditioning near the photocathode as well as the long vertical transport tube that extends from the laser bay to the tunnel. Physical beam enclosures with evacuation capability are also included. The potential for final UV beam steering stabilization also exists here.

Transport diagnostics refer to the cluster located at the gun site near the photocathode in the tunnel. This cluster is to provide a final characterization of the UV pulse before irradiating the photocathode and incorporates the virtual cathode concept. It includes a fast photodiode, spatial profile imaging (incident and specular reflection from the photocathode), UV energy/power detection (incident and potentially specular reflection from the photocathode), and single pulse broadband time-resolved detection as needed.

1.2.3.25 Visible Optical Transport and Transport Diagnostics

Visible light transport refers to the transport of second harmonic light from the harmonic generation unit to a diagnostic site along the gun electron beamline. For example, the visible beam can be used for electro-optic electron beam diagnostics. This includes beam properties, relayed beam paths and enclosures. As such, the long vertical transport tube extending from the laser bay down to the tunnel is part of this section.

Visible transport diagnostics include fast photodiode and pulse energy detection both at the harmonic generation unit end and at the diagnostic site end in the tunnel along the electron beamline. Spatial profile imaging and broadband time-resolved detection can be incorporated on a need basis.

1.2.3.26 IR Optical Transport and Transport Diagnostics

Transport of IR light refers to transport from the harmonic generation unit to the start of the pulse conditioning section for the IR LASER HEATER. This concerns ir beam properties, beam path and enclosures. Transport diagnostic include a fast photodiode and a pulse energy monitor.

1.2.3.27 UV Conditioning Summary

Important UV pulse conditioning issues (for photocathode irradiation) that finally bring the UV pulse parameters into compliance with the LCLS injector specifications are included here. These include final adjustments to temporal profile shaping at the IR oscillator level, spatial profile shaping and spatial filtering, the performance of UV launch optics near the gun photocathode, and electron beam-based UV pulse energy control. Spatial profile filtering and shaping are accomplished together by combining a UV 'flattener' with an input spot size selection using positive lenses. Grating-based launch optics set the required time slew and spatial anamorphic compression. The electron beam-based UV pulse energy control unit is a polarized optics assembly with a waveplate that can be tuned (via rotation) according to the electron bunch charge level.

The spatial profile and filtering as well as UV launch optics are set up along side the gun photocathode at the end of the UV transport section. The additional temporal shape control is implemented between the oscillator and preamplifier. The UV pulse energy control is located in the laser bay within the UV transport section and near the harmonic generation unit.

1.2.3.28 Laser Bay Infrastructure and Laser Bay System-Wide Items

Drive laser system-wide components are included here. This includes, optical tables (in the laser bay and in the injector tunnel), 3D layouts of the full laser system (with diagnostics and beampaths), and important laser-related reviews.

1.2.3.29 Alignment Laser

The alignment laser is a visible CW diode source located along side the gun photocathode near the end of the UV transport section. Its purpose is to establish and to verify electron beam alignment down the evacuated electron beamline of the injector. This section includes the required steering and collimating optics (and required mounting hardware) that are located outside the vacuum beamline.

1.2.3.30 Light Path to Streak Camera

This broad-band, visible optical path takes light from a prompt Cherenkov view screen in the gun-to-linac region and images it onto the slit of a streak camera in the laser bay. Its purpose is to measure the electron beam bunch shape. The path optics should be imaging in order to measure transverse-longitudinal correlations between the bunch shape and time. The system includes lenses and mirrors and optical mounts, an alignment laser, mechanical supports and enclosures.

1.2.4 RF Gun, Load Lock & Supports

1.2.4.1 RF Gun (Copper Brazement Only)

The RF Gun is at the north end of the Sector 20 alcove. This section includes the copper brazed gun with a cathode, laser windows, and motorized tuners. It is similar to the GTF gun with an added second RF feed, see drawing SA-290-330-04-REV-1. This device will require cooling water (special), temperature sensors, tuner controls, vacuum, clean nitrogen gas, RF power, and laser light.

1.2.4.2 RF Gun Supports

The RF Gun Support is at the north end of the Sector 20 Alcove. This section includes the small support between the gun and a larger table under the GTL area.

1.2.4.3 Gun Load Lock

The Gun Load Lock is just upstream of the RF gun in the Sector 20 alcove. This section includes the cathode clamping hardware, the load lock chamber, the cathode transfer mechanism, the external alignment rail system, and the load lock transportation cart. This device will require cooling water (special), vacuum, and clean nitrogen gas.

1.2.4.4 Gun Load Lock Supports

The Gun Load Lock Support is at the north end of the Sector 20 Alcove. This section includes the small support between the load lock assembly and a larger table under the GTL area.

1.2.4.5 Gun Solenoid

The Gun Solenoid is just downstream of the RF gun in the Sector 20 alcove. This section includes the solenoid magnet similar to the one in GTF, see drawing SA-290-330-64-REV-1, with a skew quad added to the inner bore. This device will require cooling water (LCW), temperature sensors, and electrical power.

1.2.4.6 Gun Solenoid Supports

The Gun Solenoid Support is at the north end of the Sector 20 Alcove. This section includes the small support between the solenoid and a larger table under the GTL area.

1.2.4.7 Gun RF Feed

The Gun RF Feed is just above the RF gun in the Sector 20 alcove. This section includes a circulator, like a Titan TBC284D007 filled with SF6, two RF windows, and a RF splitter, similar to SA-700-870-66. This device will require SF6 and vacuum.

1.2.4.8 Gun RF Feed Supports

The Gun RF Feed Support is at the north end of the Sector 20 Alcove. This section includes the small support between the RF feed and a larger table under the GTL area.

1.2.5 Gun to Linac Section (GTL)

1.2.5.1 GTL BPMs (3)

The GTL BPM's are just after the gun solenoid in the Sector 20 alcove. This section includes 4 BPM's, similar to SA-906-205-75-REV3 - one of which may be special to fit into the gun solenoid, and their supports. These devices will require read-out electronics. They measure the X-Y position of the beam.

1.2.5.2 GTL Faraday Cup/YAG1

The Faraday Cup/YAG1 chamber is just after the gun solenoid in the Sector 20 alcove. This section includes a vacuum chamber with a moveable part that has a Faraday cup, a YAG screen, and a wake field mitigating plug and the chamber support. These devices will require read-out electronics for the Faraday cup, a camera for the YAG screen, an external mover, and possibly a vacuum pumping port. The Faraday cup measures the beam current and the YAG screen shows the beam shape. It may become necessary to add a laser alignment mirror to this device.

1.2.5.3 GTL Current Monitor (CM1)

The GTL Current Monitor is just after the gun solenoid in the Sector 20 alcove. This section includes a ceramic break and a transformer coil, and their supports. This device will require read-out electronics. It measures the current of the beam.

1.2.5.4 Unused

1.2.5.5 Unused

1.2.5.6 GTL Steering Coils, (2) (SC1)

The GTL Steering Coils are just after the gun solenoid in the Sector 20 alcove. This section includes X-Y dipole coils and their supports. This device will require 2 power supplies. It will deflect the beam as necessary. These may become part of a quad magnet to save Z space.

1.2.5.7 GTL Vacuum Components

The GTL Vacuum Components are just after the gun solenoid in the Sector 20 alcove. This section includes an isolation valve (which may require wake field mitigating fingers) and a special chamber to mitigate the wake field when the beam is directed either to the straight ahead or the side spectrometer and their supports. The valve will require air pressure and position readout and the chamber will require an external mover.

1.2.5.8 GTL Supports

The GTL Supports are at the north end of the Sector 20 Alcove. This section includes the large support table under the load lock and extending to just before the first accelerator section. The support may require water and read-out for temperature stabilization.

1.2.5.9 Gun Spectrometer (GS) Assembly

1.2.5.9.1 GS Dipole

The GS Dipole is just downstream of the RF gun in the Sector 20 alcove. This section includes a dipole magnet and its support. This device will require cooling water (LCW), temperature sensors, and electrical power. It will be used to bend the beam about 90 degrees to measure the beam energy. It needs to have zero residual field when turned off - this may require special trim coils.

1.2.5.9.2 GS Current Monitor (CM2)

The GS Current Monitor is just to the side of the spectrometer dipole in the Sector 20 alcove. This section includes a ceramic break and a transformer coil, and their supports. This device will require read-out electronics. It measures the current of the beam.

1.2.5.9.3 GS BPM (1)

The GS BPM is just to the side of the spectrometer dipole in the Sector 20 alcove. This section includes a BPM, similar to SA-906-205-75-REV3, and its supports. This device will require read-out electronics. It measures the X-Y position of the beam.

1.2.5.9.4 GS Faraday Cup/YAG2

The GS Faraday Cup/YAG2 chamber is just to the side of the spectrometer dipole in the Sector 20 alcove. This section includes a vacuum chamber with a moveable part that has a Faraday cup, a YAG screen, and a wake field mitigating plug and the chamber support. These devices will require read-out electronics for the Faraday cup, a camera for the YAG screen, and an external mover. The Faraday cup measures the beam current and the YAG screen shows the beam shape. It may become possible to build simpler separate devices.

1.2.5.9.5 Unused

1.2.5.9.6 GS Quadrupoles (3)

The GS quad magnets are just downstream of the RF gun in the Sector 20 alcove. Two are just before the spectrometer dipole and one is just to the side of the spectrometer dipole. This section includes 3 quad magnets and their supports. These devices will require cooling water (LCW), temperature sensors, and electrical power.

1.2.5.9.7 GS Supports

The GS Supports are at the north end of the Sector 20 Alcove. This section includes any special supports under the spectrometer that extend past the side of the large GTL support table. The support may require water and read-out for temperature stabilization.

1.2.5.10 GTL Pumping & Optic Chamber

The COMBINATION PUMPING & OPTIC CHAMBER is just downstream of the RF Gun and Solenoid in the Sector 20 alcove. This chamber serves multiple uses as a foundation for multiple devices. Included in the chamber is the main vacuum pumping for the gun along with a YAG, EO and alignment laser feed mirror. This device will require an air feed, cooling water (LCW), temperature sensors, and electrical power. It will also need precision alignment adjustment. The chamber gives a in vacuum environment for the varies components that are integral in its assembly.

1.2.5.11 GTL YAG (1 ea)

1.2.6 Injector Linac Structures

1.2.6.1 L0-1 Structure Assembly

The LO-1 LINAC section is mounted on the major tube support directly after the gun spectrometer in the sector 20 alcove. This is the first booster section after the gun and is surrounded by a solenoid magnet. This device will require controlled temperature water, temperature sensors, electronics and RF waveguide power from a klystron. It also has a load attached to it and RF couplers for feedback. There is a set of flexures and a strong back support attached to the section. This is the first stage for boosting the beam energy in the injector area.

1.2.6.2 L0-2 Structure Assembly

The LO-2 LINAC section is mounted on the major tube support directly after the LO-1 LINAC section and associated focusing quads in the sector 20 alcove. This is the second booster section after the gun. This device will require controlled temperature water, temperature sensors, electronics and RF waveguide power from a klystron. It also has a load attached to it and RF couplers for feedback. There is a set of flexures and a strong back support attached to the section. This is the second stage for boosting the beam energy in the injector area. It raises the beam energy to the 135mev range.

1.2.6.3 Major Linac Support

The MAJOR LINAC tube support is located under the accelerator sections after the gun area and before the first shield wall in the sector 20 alcove. This device gives the major support for the LINAC boost section of the injector. It also acts to stabilize the boost system with respect to vibration and thermal variation.

1.2.6.4 Linac Solenoid and Supports

The LINAC Solenoid is mounted over the input end of LO-1. This solenoid magnet is similar in function to the one located in the CID area of the main linac. This device will require cooling water (LCW), temperature sensors, and electrical power. The solenoid acts to focus and collect the beam.

1.2.7 L0-1 to L0-2 Section (L0-1TL0-2)

1.2.7.1 L0-1TL0-2 Quadrupoles (2)

The LO-1TLO-2 quad magnets are located between the two accelerator sections in the Sector 20 alcove. This section includes 2 quad magnets and their supports. These devices will require cooling water (LCW), temperature sensors, and electrical power. The quadrupoles act as part of the electron beam optics.

1.2.7.2 L0-1TL0-2 BPMs (2)

The LO-1TLO-2 BPMs are located inside the two quadrupoles that are between the injector accelerators. This BPMs will require read-out electronics. They measure the X-Y position of the beam.

1.2.7.3 Unused

1.2.7.4 L0-1TL0-2 OTR/YAG (1)

The LO-1TLO-2 OTR/YAG is located between the two injector accelerator sections. This area includes two quadrupoles, BPMs, RF cavity and associated supports. This device includes a vacuum chamber with a moveable part that has, a YAG screen, a wake field mitigating plug and the mover support. This device will require a camera for the YAG screen, and an external powered mover. The YAG screen shows the beam shape.

1.2.7.5 L0-1TL0-2Linac Steering Coils (4)

The LO-1TLO-2 Steering Coils are located on each end of the injector accelerators. These coils will require mutipole power supplies. They will deflect the beam as necessary to meet necessary precision steering demands. One set of coils is located within the linac solenoid.

1.2.7.6 L0-1TL0-2Vacuum Components

This element covers all costs associated with the design, integration, evaluation, and purchase of vacuum components and supports for this area.

1.2.7.7 L0-1TL0-2 RF Phase Cavity (Major tube support structure)

The element cover the cost to engineer, design, procure, and evaluate the RF Phase Cavity Support Tube.

1.2.8 Linac to DL1 (LTDL1)

1.2.8.1 LTDL1 Current Monitors (CM3)

The LTDL1 Current Monitor is located after the two injector accelerator sections between the two quadrupole magnets. This section includes two quadrupoles, BPMs, a OTR/YAG, steering coils and associated supports. This device will require read-out electronics. It measures the current of the beam.

1.2.8.2 LTDL1 BPMs (6)

The LTDL1 BPMs are located within the quadrupoles and after one of the wire scanners in this area. This section includes the shield walls, three wire scanners, the laser heater, RF kicker, beam stopper, current monitor, steering magnets, dipoles and quadrupoles. The BPMs are similar to SA-906-205-75-REV3. This device will require read-out electronics. They measure the X-Y position of the beam.

1.2.8.3 LTDL1 OTR (5)/YAG (1)

The LTDL1 OTR/YAGs are located right after the LO-2 accelerator and along side each wire scanner. This device includes a vacuum chamber with a moveable part that has a OTR/YAG screen, a wake field mitigating plug and the chamber support. These devices will require control electronics for the mover, a camera for the screen, and an external air powered mover system. The camera/screen system gives the beam shape and size.

1.2.8.4 LTDL1 Quadrupoles (6)

The LTDL1 quad magnets are located as three sets of two magnets each in the Sector 20 alcove. Two or the sets are located on either side of the LASER heater and one set is located next to the DL1 dipole in the LINAC housing. These devices will require cooling water (LCW), temperature sensors, and electrical power. They act as electron beam optical devices with each set of two magnets a doublet.

1.2.8.5 Unused

1.2.8.6 LTDL1 RF Kicker

The LTDL1 RF KICKER is located just after the LASER heater and before the first shield wall in the Sector 20 alcove. This device will require supports, a RF waveguide feed and feedback coupler along with the necessary electronics. It will momentarily deflect the beam to measure the longitudinal phase space parameters.

1.2.8.7 LTDL1 Steering Coils (2 ea) X-Y

The LTDL1 Steering Coils are located on either side of the shield walls in the Sector 20 alcove. These coils will require multiple power supplies. They will deflect the beam as necessary to meet necessary precision steering demands.

1.2.8.8 LTDL1 PPS Stopper

The LTDL1 PPS STOPPER is located between the two shield walls. This area also contains a wire scanner and OTR/YAG. The stopper protects people in the sector 20 alcove during normal LINAC operation when they service injector components in the gun and booster linac area behind the shield wall. This device will require air and actuation control electronics.

1.2.8.9 LTDL1 E/O EO2

The LTDL1 E/O is located between the quads just after the transverse kicker in the Sector 20 alcove. This section includes a vacuum chamber with a moveable platform that holds a crystal in the electron beam, a wake field mitigating plug and the chamber support. This device will require a laser with diagnostic electronics and an external air actuated mover. It is a beam diagnostic device that measures electron bunch shape and timing.

1.2.8.10 LTDL1 Minor Tube Supports

The LTDL1 MINOR TUBE SUPPORT is located between the laser heater and the first shield wall. It supports the beam line components in this region including the RF kicker, two quads, EO, OTR and wire scanner. It will require screw jack support actuators for location and height adjustment.

1.2.9 Dog Leg 1 Bend (DL1)

1.2.9.1 DL1 B01 & B02 Dipoles

The DL1 B01 & B02 DIPOLES are located in the LINAC housing at the point where the injector beam turns to match the main LINAC beam line. This section includes the two dipole magnets and location adjustment supports. These magnets will require cooling water (LCW), temperature sensors, and electrical power supplies. They will bend the beam 35 degrees to match the main LINAC beam trajectory. The magnets require zero residual field when switched off - this will be accomplished using the trim coils.

1.2.9.2 DL1 QB Quadrupole

1.2.9.3 DL1 Wire Scanner

The WIRE SCANNER is located between the two DL1 dipoles in the main LINAC housing. This device will require supports, along with the necessary electronics and lead shielding for the sensor. It measures beam position parameters.

1.2.9.4 DL1 OTR

The DL1 OTR/YAG is located between the two DL1 dipoles. This area includes one quadrupole, a BPM, steering magnet, a wire scanner and associated supports. This device includes a vacuum chamber with a moveable part that has, a YAG screen, a wake field mitigating plug and the mover support. This device will require a camera for the YAG screen, and an external powered mover. The YAG screen shows the beam shape.

1.2.9.5 DL1 Supports

The DL1 SUPPORT is located over the main LINAC laser support tube. It is the base support structure for the beam line components in this region including the two dipoles, a quad, steering magnet, OTR, wire scanner and vacuum chamber. It is a stand alone frame that rests on the main LINAC housing floor.

1.2.9.6 DL1 Vacuum Chamber

The DL1 vacuum chamber is located between the two DL1 dipoles and along the main LINAC in the LINAC housing. It also extends through the main LINAC line to the straight ahead spectrometer. This device will require adjustable supports for vacuum loading and positioning.

1.2.10 DL1 to Linac (DL1TL)

1.2.10.1 DL1TL BPMs (2)

The DL1TL BPMs are located inside the two injector quadrupoles that are positioned on the main LINAC beam line. These BPMs will require read-out electronics and are similar to the SLAC SA-906-205-75-REV3 model. They measure the X-Y position of the beam.

1.2.10.2 DL1TL Steering Coils (3 ea X-Y Assys)

The DL1TL Steering Coils are located along side the two injector quadrupoles that are positioned on the main LINAC beam line. This section includes X-Y dipole coils and their supports. This device will require 2 power supplies. It will deflect the beam as necessary.

1.2.10.3 DL1TL Quadrupoles (2)

The two DL1TL injector quadrupoles are positioned on the main LINAC beam line after the DL2 bend magnet and before the first LCLS main LINAC accelerator section. This section includes X-Y steering dipoles, BPMs, CM, EO, OTR and their supports. These devices will require cooling water (LCW), temperature sensors, and electrical power supplies. They act as electron beam optical devices.

1.2.10.4 DL1TL Vacuum Components

The DL1TL Current Monitor is positioned on the main LINAC beam line after the DL2 bend magnet and before the first LCLS main LINAC accelerator section. This device will require read-out electronics. It measures the current of the beam.

The DL1TL OTR/ YAG is positioned on the main LINAC beam line after the DL2 bend magnet, after the second Quad magnet and before the first LCLS main LINAC accelerator section. This device includes a vacuum chamber with a moveable part that has, a YAG screen, a wake field mitigating plug and the mover support. This device will require a camera for the YAG screen, and an external powered mover. The YAG screen shows the beam shape.

1.2.10.5 DL1TL Current Monitor (CM4)

1.2.10.6 DL1TL OTR

An OTR profile monitors is a beam emittance and energy spread diagnostic devices. They characterize beam shape, size, and position. Profile monitor designs consist of a fluorescent screen or metal foil that interacts with the electron beam and produces secondary radiation that is monitored by detectors and/ or cameras OTR designates a specific foil or screen type. This section covers the design and procurement of the device and its supports.

1.2.10.7 Unused

1.2.11 Straight Ahead Beamline (SAB)

1.2.11.1 SAB Spectrometer Dipole

The SAB Dipole is located at the end of the straight section of the injector in the main LINAC housing. This section includes a dipole magnet and its support. This device will require cooling water (LCW), temperature sensors, and an electrical power supply. It will be used to bend the beam about 35 degrees to measure the beam energy. It acts as a beam diagnostic device.

1.2.11.2 SAB Quadrupoles (3)

The three SAB SPECTROMETER quadrupoles are positioned parallel to the main LINAC beam line after the SAB spectrometer dipole bend magnet and before the final beam dump. This section includes X-Y steering dipoles, BPMs, an OTR and their supports. These devices will require cooling water (LCW), temperature sensors, and electrical power supplies. They act as electron beam optical devices.

1.2.11.3 SAB Current Monitor (CM5)

The SAB SPECTROMETER Current Monitor is positioned parallel to the main LINAC beam line after the SAB spectrometer dipole bend magnet and before the final beam dump in the main LINAC housing. This device will require read-out electronics. It measures the current of the beam.

1.2.11.4 SAB BPM (4 ea)

The three SAB SPECTROMETER BPMs are positioned in the SAB quadrupoles. These BPMs will require read-out electronics and are similar to the SLAC SA-906-205-75-REV3 model. They measure the X-Y position of the beam.

1.2.11.5 SAB YAG

The SAB SPECTROMETER SAB OTR/ YAG is positioned parallel to the main LINAC beam line after the SAB spectrometer dipole bend magnet and before the final beam dump in the main LINAC housing. This area includes three quadrupoles, BPMs, steering magnets, current monitor and associated supports. This device includes a vacuum chamber with a moveable part that has, a YAG screen, a wake field mitigating plug and the mover support. This device will require a camera for the YAG screen, and an external powered mover. The screen shows the beam shape.

1.2.11.6 SAB Vacuum Chamber and Components

The SAB SPECTROMETER SAB OTR/ YAG is positioned parallel to the main LINAC beam line after the SAB spectrometer dipole bend magnet and before the final beam dump in the main LINAC housing. This area includes three quadrupoles, BPMs, steering magnets, current monitor and associated supports. This device includes a vacuum chamber with a moveable part that has, a YAG screen, a wake field mitigating plug and the mover support. This device will require a camera for the YAG screen, and an external powered mover. The screen shows the beam shape.

1.2.11.7 SAB Beam Dump and Shielding

The SAB BEAM DUMP & SHIELDING is positioned parallel to the main LINAC beam line at the end of the SAB spectrometer system in the main LINAC housing. This area includes a dipole, three quadrupoles, BPMs, steering magnet, current monitor and vacuum chambers. This device includes a vacuum chamber with a Faraday cup, a YAG screen. It will require read-out electronics for the Faraday cup and a camera for the YAG screen. It will also require water cooling, temperature sensors and the shielding will be primarily lead. The Faraday cup measures the beam current and the YAG screen shows the beam shape. It may become possible to build simpler separate devices.

1.2.11.8 SAB Supports

The SAB SUPPORT is located over the main LINAC laser support tube and is connected to the DL1 supports. It is the base support structure for the beam line components in this region including the dipole, three quadrupoles, BPMs, steering magnet, OTR, CM and vacuum chambers. It is a stand alone frame that rests on the main LINAC housing floor.

1.2.11.9 SAB Steering Coils (2)

The SAB SPECTROMETER Steering Coils are located near the quadrupoles positioned in the tune up dump line. This device will require an electrical power supply. It will deflect the beam as necessary for efficient spectrometer use.

1.2.12 Injector RF Waveguide Subsystem

1.2.12.1 RF Waveguides

The INJECTOR RF WAVEGUIDE is located and extends through three different areas: the sector 20 injector alcove, the main LINAC housing, and the klystron gallery. It is split into four systems each fed from a separate klystron. The systems feed the GUN, each of two injector accelerator sections and one transverse kicker section. Three of the systems travel down the ceiling of the klystron gallery, down through a LINAC housing penetration into the main LINAC housing and through the shield wall into the sector 20 injector alcove. The fourth system travels down the LINAC housing and through the shield wall into the sector 20 injector alcove. The systems require vacuum pumping, temperature controlled water and controls feedback. The RF waveguide transports microwave energy from the klystrons to injector beam line components.

1.2.13 Injector RF Sub-System

1.2.13.1 S-Band Low Level System

The LLRF system consists of the RF components, less than 10kW in peak power, required to maintain 70fS stability for the injector electronics. The scope of work includes the following:

- Modifications to the front end RF and timing system of the SLAC main linac, to achieve 70fS stability.

- A low phase noise LCLS frequency source and distribution system located at the LCLS injector.
- RF phase and amplitude monitors including the heliax cables connected to the high power WR284 waveguide adapters. RF phase and amplitude control and drive amplifiers up to the 1kW input of the 5045 klystrons.
- Beam phase monitor system to include beamline device, all electronics and cables.
- User interface software and algorithm development for feedback loops.

1.2.13.1.1 Controls Interface & Timing

The existing timing and RF distribution system for the two mile linac starts in sector 0 of the linac. The 476MHz Master Oscillator gets a timing pulse superimposed on it and drives the 2 mile Main Drive Line, MDL. Modifications to the RF system start with a lower phase noise master oscillator. The timing system will also be upgraded to meet the LCLS requirements. The output of this system will drive the 2 mile MDL with 30 watts at 476MHz.

1.2.13.1.2 LLRF Phase Reference System

The phase reference system will include locking of a low noise oscillator to the linac RF reference. The 476 MHz reference will be multiplied to 2856MHz and distributed to the laser, RF gun, L0-1, L0-2, transverse accelerator, L1-X and L1-S drive and monitoring systems. Electronics for interfacing to the LASER phase lock. The electronics will be housed in a temperature controlled room enclosing penetration 20-17, which all the phase critical heliax cables will be run down.

1.2.13.1.3 LLRF Monitor & Control System

Design and development of an RF phase and amplitude detector to measure the RF at the output of several high power waveguide couplers. Heliax cables are included here to connect to the high power waveguide couplers. Design and development of a solid state 1kW S-band amplifier to drive a 5045. Design and development of the RF control system used to adjust phase and amplitude of the high power RF components. Control cables to connect to modules in a control create are also included here.

1.2.13.1.4 Beam Phase Monitor Cavity

Development of a beam phase monitoring system. The desired sensitivity of this system is about 50fS on a single pulse. Includes the beam line component, RF detectors, and interfaces to the control system. All electronics and cables up to the control create modules are included here.

1.2.13.1.5 RF System S/W Development / Docs

Development of software tools and user interfaces required to run the LCLS RF system. This will include development of algorithms for feedback loops.
Documentation will be complete enough to enable the system to be maintained by the AMRF group.

Requires system to be operational-signed BAS. Need to be able to run beam through the injector and measure beam parameters.

1.2.14 Cathode Processing (CP) Station

1.2.14.1 CP Cathode Assembly and Supports

The CP Cathode Assembly & Supports are in the load lock room of the of the Sector 20 LCLS facilities. This section includes a chamber or method of storing cathodes and their supports. This device will require vacuum and clean nitrogen gas.

1.2.14.2 CP Load Lock

The GP Load Lock is in the load lock room of the of the Sector 20 LCLS facilities. This section includes the load lock hardware. This device will require vacuum and clean nitrogen gas. The load lock should be compatibly with the RF gun load lock.

1.2.14.3 CP Load Lock Supports

The GP Load Lock Support is in the load lock room of the of the Sector 20 LCLS facilities. This section includes the load lock support hardware and transportation cart. The GP load lock support should be compatibly with the RF gun load lock.

1.2.14.4 CP Station

The GP Cathode Processing Chamber is in the load lock room of the of the Sector 20 LCLS facilities. This section includes the chamber to dock the load lock and process the cathode. This device will require laser light, diagnostic electronics, vacuum monitoring, vacuum and clean nitrogen gas.

1.2.14.5 Cathode Lab Infrastructure

The GP Lab Infrastructure is in the load lock room of the of the Sector 20 LCLS facilities. This section includes the tools necessary to work on and process a cathode before insertion into the RF gun.

1.2.15 Injector Laser Heater Sub-System

This is a system designed to add uncorrelated energy to the LCLS beam in the injector, at 150 MeV, by crossing an IR laser beam with the electron beam in an undulator. The system starts just past from a dichroic beam splitter that is downstream from the drive laser doubling crystals. The IR beam that is not absorbed by the doubling crystals passes through an optics system on the drive laser table, down to the linac tunnel, into the electron beamline, along the electron beam in a chicane, and out into a diagnostic system at the end.

1.2.15.1 System Design & Optimization

System Design and Optimization consists of developing the physical models for the laser beam / electron beam interaction. This category also includes an overall system design review and reviews by safety committees at SLAC.

Definition of the overall parameters, (e.g. undulator length and period, laser beam power and wavelength, beam size and shape) needed to obtain the desired energy modulation. The desired energy modulation is determined beam dynamics models for the FEL as a whole.

Refinement of the parameters, and integration of the laser heater into the rest of the injector.

A design review of the laser heater subsystem of the injector; with some participation outside of SLAC. This review is in addition to a separate review for the undulator proper.

Safety reviews for electrical, earthquake, laser optics, radiation, and mechanical hazards. These reviews will be done by internal SLAC committees.

1.2.15.2 Beam Conditioning Optics (Laser Bay)

This system includes the optics downstream from the dichroic beam separator to the first mirror in the optics transport system down to the linac tunnel. These optics will be on the drive laser table. The subsystems include a grating pair pulse compressor, a collimating telescope, a path length adjustor, and a shutter.

Establishment of the optical principles required to prepare the IR beam from the drive laser and deliver it to the transport system. Establishment of all the optical parameters and requirements, and performance of modeling calculations (Zemax).

Preparation of a schematic layout with optical components.

Identification of commercial optics to be used for beam conditioning, and placement of purchase orders for them. Also, expediting, receipt, and checking of items on receipt.

The arrangement of the beam conditioning optics on the drive laser optics bench, their alignment and verification of operation to the point of departure into the transport system.

1.2.15.3 Transport Optics (Bay to Tunnel)

The transport optics starts at the deflecting mirror that guides the beam from the laser bay into transport tubes to the launch table. The system will include:

- HeNe laser on beam conditioning table for alignment with dichroic mirror.
- Input mirror, mount and enclosure.
- Three transport tubes, with windows and valves for pumpout.
- Two deflecting mirrors between each tube with mount, adjusting stage, and enclosure, with flip in crosshairs for alignment.
- An optics table to mount the launch optics with isolation legs and dust enclosure.
- A reducing telescope on the launch table and half-wave plate.
- A window into the e-beam pipe and mirror on manual adjustor to deflect beam into the undulator. This mirror may be focusing.
- Establishment of optical principles and strategy for beam transport, including model calculations. (Zemax)
- Dimensioned drawing of entire transport system.

Identification of commercial optics to be used for transport system and placement of purchase orders for them. Also, expediting, receipt, and checking of items on receipt.

The arrangement of the beam transport optics, their alignment and verification of operation to the point of departure into the undulator chicane. This should be done using the beam that is delivered from the beam conditioning system.

Design of enclosures and tubes so that the transported beam travels mostly in low vacuum piping. Where it exits the piping to be redirected by mirrors, the mirrors will be provided with dust and air current protections.

Purchase or fabrication of an enclosure for the beam where it enters and exits each tube, and a set of evacuable transport tubes. These tubes can be evacuated to low vacuum, valved off, and the vacuum pumps detached.

Assembly of the tubes and enclosures, and installation into the injector area.

1.2.15.4 Chicane

The chicane is a four magnet bump that displaces the electron beam parallel to its axis sufficiently so that the IR laser beam may be superposed onto it coaxially, using a launch mirror upstream from the undulator that is inserted between the pairs of chicane magnets.

The physics, thermal, electrical, and mechanical layout parameters for the four chicane magnets, modeling, and beam dynamics.

A drawing set suitable for manufacturing these four identical electromagnets.

Choice of SLAC or outside vendor for magnet fabrication, and placement of purchase orders for them. Also, expediting, receipt, and checking of items on receipt.

Verification of design parameters in the SLAC magnetic measurements lab.

Design of supports for the four chicane magnets that will integrate with the undulator mechanism and the optical tables for launch and diagnostics optics.

Choice of SLAC or outside vendor for support fabrication, and placement of purchase orders for them. Also, expediting, receipt, and checking of items on receipt.

Determination of voltage, current, and ripple specs for the magnet power supplies. Takes into account coil connection topology (series, parallel, etc.).

Identification of vendors for commercial power supplies and placement of purchase orders for them. Also, expediting, receipt, and checking of items on receipt.

Placement of the magnet power supplies in racks in the space next to the laser bay, and provision of AC power lines to these supplies.

Design of the beampipe through the chicane and the undulator, with bellows, RF transistions, vacuum ports, ports for the entrance of the laser beam and for YAG crystal inserters and optics to observe the electron beam spot.

Design and drawing of the beampipe, suitable for provision to vendor for manufacturing.

Choice of SLAC or vendor fabrication of beampipe, placement of purchase or work order, expediting of process and check on completion, including vacuum integrity check.

Design YAG crystal inserters and the TV or CCD camera mounts to observe e-beam. This design may be already done for another purpose by Lynn Bentson.

Fabrication at SLAC or by outside vendor of the YAG monitor hardware, including cameras and software if necessary.

Installation, alignment, and testing of YAG monitor system with live electron beam.

Installation of the beampipe through the chicane. The chicane magnets are of an H design, and will need to be split to be installed over the beampipe; the undulator is of a C design, and will slip over the beampipe.

The date by which the chicane is complete, tested with live electron beam and YAG monitors, and available for testing with the undulator.

1.2.15.5 Undulator

A variable gap hybrid undulator 1 meter or shorter in length, with 50 mm period and 28 mm gap that is intended to give the injector beam transverse motion to allow it to couple to a co-propagating IR laser beam.

Establishment of the physical, mechanical, magnetic, and beam dynamic parameters of the undulator, and generation of a technical description suitable for presentation to vendors for RFQ.

A design review of the undulator that will consider its physics, mechanical and magnet engineering, and the modeling from which the various parameters were developed. This review should include some participation from outside SLAC.

An assembly level drawing of the undulator; more refined designs will come from the vendor if the undulator is built outside, or from further SLAC designs if we build it here.

Choice of internal or external construction. If internal construction is chosen, selection of personnel to do the work, and supervision of the work. If external construction is chosen, sending of bid packages, choice of vendor, possible vendor design review, supervision of contract, expediting and checking of item on receipt.

If the undulator is awkward or difficult to install, rigging must be designed to put it into place. This requirement is much reduced as of placement of the undulator upstream from the shielding walls.

Fabrication of any rigging required for emplacement of undulator

Measurements by the SLAC magnetic measurements group of the magnetic fields of the undulator, to verify that the device meets its specifications. This work will also include calibration of trim coils provided to cancel the earth's field and any residual dipole errors.

1.2.15.6 Photon Beam Diagnostics

Overall engineering design of the system that includes a power meter, a profile camera, and a timing diode, with appropriate optics on a small table downstream from the IR beam - e-beam interaction region. The system will include:

- spiricon camera for beam profile monitoring
- molectron power meter for beam power monitoring
- timing diode for local timing measurements
- Optics, table and enclosure at end of beamline, including shielding from e-beam radiation

Identification of commercial optics to be used for diagnostics and placement of purchase orders for them. Also, expediting, receipt, and checking of items on receipt.

An imaging system that will provide transverse beam profiles to be transmitted to MCC.

A joule meter capable of transmitting power information to MCC.

A fast photodiode and an oscilloscope (10 GHz) to monitor temporal characteristics of the IR laser pulse. The oscilloscope will have to be placed near the diode in use, and removed during accelerator operations.

A support table for the diagnostics breadboard. Spare equipment for any diagnostics optics which, if it failed, would prevent the operation of the laser heater. No items identified at present.

Installation of the photon diagnostics, and testing of the optics with live beam from the beam conditioning, and transport systems.

1.2.16 Injector Protection and Power Conversion Subsystem

The Injector Power Conversion Subsystems has two sections, Protection Systems and Power Conversion Systems.

1.2.16.1 Personnel Protection System (PPS)

The Injector PPS systems will create the physical barriers, which will be monitored by electronic, electrical and electro mechanical devices, for the purpose of restricting access to individuals from exposure to ionizing and non-ionizing radiation. These sections, described below, will provide for the Design, Procurement, and Fabrication of these protection systems, as well as any SLC database support.

This system, for protection from ionizing radiation, will restrict access to the accelerator housing, off-axis tunnel at Sector 20. This section will provide for the gates, doors, fencing, interlocks and control chassis for the system. Also, all system logic and control will be provided for by a Programmable Logic Control system. All modifications or additions to the PPS system for the LCLS in Sectors 20, 21, 22 and the LCLS Injector will be the responsibility of this WBS. The Beam Shut-off Ion Chamber or BSOIC's, to be installed in the Injector, will also be the responsibility of this WBS element which includes the following:

- The Beam Shut-off Ion Chamber is the responsibility of this section
- All electronic hardware will be provided
- SLC database support will also be the responsibility of this section

Protection from non-ionizing radiation will focus on the Laser and Load lock room. The hazard for this area is Non-ionizing radiation. This system will restrict access to the Laser and Load-Lock rooms, access will only allowed when individuals have donned the required "PPE", Personal Protective Equipment. The construction of the clean room is not the responsibility of this section. This section will provide for the hardware and software that will monitor the status of the doors, gates and other interlocks. The system logic and control will be provided for by the use of a Programmable Logic Control "PLC" system.

1.2.16.2 Unused

1.2.16.3 Machine Protection System (MPS)

A good description of the MPS system can also be found in the CDR for the LCLS, Chapter 11, and Section 11.7. "A Machine Protection System (MPS) is designed to protect the LCLS components from damage by the beam. The three primary functions of the MPS are to protect: (1) the integrity of the vacuum system; (2) the proper cooling of the water-cooled components; and (3) the LCLS components from damage resulting from errant steering of the electron beam." This WBS section contains only one machine protection sub-system and will be interlocked with the SLAC or LCLS machine protection system. The system will be monitoring temperatures on Drive LASER and various beam line devices. All the Design, Procurement, and Fabrication of the electronic hardware, cable and chassis will be provided.

Any SLC database support is also included in this section. All computer interface cards will be provided as well as the cable that connects the interface cards to the Interlock Chassis. CAMAC and VME crates are not part of this system.

1.2.16.4 Injector Power Conversion

The power supplies for the LCLS injector will be a standard design, which is used through the SLAC accelerator system. The injector system will require nine power supply systems. There will be five large power systems and four multi-channel small magnet driver systems. This WBS unit includes the power supplies and all the supporting electronics that will be required to make it operational.

1.2.16.4.1 Beamline Power Conversion (Dipole Type)

1.2.16.4.1.1 10kw Power Supply – (Solenoid 1)

This unit provides DC power to the first magnetic element in the LCLS system. The Solenoid requires about 250 amperes at 22Volts. The stability is specified to be at the 0.05% level.

1.2.16.4.1.2 30kw Power Supply – (Solenoid 2)

This unit provides DC power to Solenoid 2 in the LCLS injector system. This Solenoid requires about 250 amperes at 22Volts. The stability is specified to be at the 0.05% level.

1.2.16.4.1.3 Unused

1.2.16.4.1.4 15kw Power Supply – (B1-2)

This unit provides DC power to the first large bend system in the LCLS system. This system requires, during standardizing about 350 amperes at 18Volts. The stability is specified to be at the .05% level.

1.2.16.4.1.5 15kw Power Supply – (B3 Spect)

This unit provides DC power to the last magnetic element in the LCLS Injector system. This bend system requires, about 350 amperes at 18Volts during standardization. The stability is specified to be at the .05% level.

1.2.16.4.1.6 10kw Power Supply – (New)

This unit provides DC power to the “Heater” in the Injector LCLS system. The system will require 250 Amperes at 20Volts. The stability is specified to be at the .01% level.

1.2.16.4.2 Beamline Power Conversion (Trim Type)

These systems provide DC power to a number of magnetic elements in the Injector LCLS system which requires less than 12 to 30 amps.

1.2.16.4.2.1 12Amp Power Supply – (MCOR_1)

1.2.16.4.2.2 30Amp Power Supply – (MCOR_2)

1.2.16.4.2.3 30Amp Power Supply – (MCOR_3)

1.2.16.4.2.4 30Amp Power Supply – (MCOR_4)

1.2.16.4.3 ***Controls & Power Supply –Misc Hardware***

This section covers the costs associated with the packaging (integration of systems equipment) and testing of electrical equipment racks for the Power Conversion and Control Systems. Rack infrastructure i.e. AC power distribution, plugstrips, utility outlets, cooling fans and mounting brackets are integrated prior to the integration of previously procured rack and crate mounted equipment from the various sections.

Cableplant installation design of Trays and Long-Haul cables (Using CAPTAR database) to be installed into the various areas, resulting in an award of contract, takes place here.

1.2.16.4.4 Magnet Interlock Protection System

1.2.17 INJECTOR INSTALLATION SUMMARY

1.2.17.1 Injector Infrastructure Installation

This section accounts for the general installation activities for the Injector tunnel at Sector 20. The activities are wide ranging and vary from, to alignment network and device footprints, to the installation completion of cable tray and other utilities. Post delivery operations like component alignment, pump down and leak check as well as all other operations that are necessary to bring the injector to 'commissioning' are included in this section for injector infrastructure.

1.2.17.2 Unused

1.2.17.3 Injector Lasers Install & Align

This section accounts for the general installation activities for the Injector Laser at Sector 20. The activities are wide ranging and vary from, to alignment network and device footprints, to the installation completion of cable tray and other utilities. Post delivery operations like component alignment, pump down and leak check as well as all other operation that are necessary to bring the injector to 'commissioning' are included in this section for injector laser.

1.2.17.4 RF Gun & Load Lock Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.5 Gun to Linac Section (GTL) Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.6 Injector LINAC Structures Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.7 L0-1 to L0-2 Section (L0-1TL0-2) Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.8 Linac to Dog Leg 1 (LTDL1) Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.9 Dog Leg 1 Bend (Dl1) Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.10 DL1 to Linac (DL1TL) Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.11 Straight Ahead Beamline (SAB) Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.12 Injector RF Waveguide Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.13 Unused

1.2.17.14 Cathode and Load Lock Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.15 Injector Laser Heater Subsystem Install & Align

This section accounts for the specific tasks associated with the field installation of the specific Injector section.

1.2.17.16 Unused

1.2.17.17 Power Conversion Subsystem Installation

The element covers the cost of installation for the following power conversion systems:

- Injector Drive Laser Safety System
- Injector portion of the ionizing Radiation Safety System (PPS)
- Injector portion of the Machine Protection System (MPS)
- Injector Dipole Magnet power supply system
- Injector Trim Magnet power supply system

2. LCLS PROJECT – R&D, SPARES AND COMMISSIONING

2.2 INJECTOR SYSTEM (OPC)

Other Project Costs (OPC) Summary for the Injector System. It includes effort and costs associated with R&D, Spares, and Commissioning.

2.2.1 Unused

2.2.2 Injector Controls Subsystem (OPC Summary)

2.2.2.1 EPICS VXI Control Modules

This element covers special processing spares required for this section.

2.2.2.2 LLRF Controls

This element covers special processing spares required for this section.

2.2.2.3 E-Beam Diagnostics Controls

This element covers special processing spares required for this section.

2.2.2.3.1 Unused

2.2.2.3.2 Controls – Toroids

This element covers special processing spares required for this section.

2.2.2.3.3 Controls – Faraday Cup

This element covers special processing spares required for this section.

2.2.2.3.4 Controls – Tune-Up Dump

This element covers special processing spares required for this section.

2.2.2.3.5 Controls – Profile Monitors

This element covers special processing spares required for this section.

2.2.2.3.6 Control –EO Diagnostic

This element covers special processing spares required for this section.

2.2.2.3.7 Controls – BPM Processor Module

This element covers special processing spares required for this section.

2.2.3 Injector Lasers (OPC Summary)

2.2.3.1 Drive Laser Prototyping

This element covers special processing spares required for this section.

2.2.3.2 Drive Laser Oscillator

This element covers special processing spares required for this section.

2.2.4 RF Gun & Load Lock (OPC Summary)

2.2.4.1 RF Gun

This element covers special processing spares required for this section.

2.2.4.2 RF Gun Supports

This element covers special processing spares required for this section.

2.2.4.3 Gun Load Lock

This element covers special processing spares required for this section.

2.2.5 Gun to Linac Section (GTL) (OPC Summary)

2.2.5.1 Unused

2.2.5.2 GTL Faraday Cup/YAG1

This element covers special processing spares required for this section.

2.2.6 Injector Linac Structures (OPC Summary)

2.2.6.1 Unused

2.2.6.2 L0-2 Structure Assembly

This element covers special processing spares required for this section.

2.2.6.3 Unused

2.2.6.4 Unused

2.2.7 L0-1 to L0-2 Section (L0-1TL0-2) (OPC Summary)

2.2.7.1 Unused

2.2.7.2 L0-1TL0-2 BPMs ( )

This element covers special processing spares required for this section.

2.2.8 Linac to DL1 (LTDL1) (OPC Summary)

2.2.8.1 Unused

2.2.8.2 LTDL1 BPMs ( )

This element covers special processing spares required for this section.

2.2.9 Dog Leg 1 Bend (DL1) (OPC Summary)

2.2.9.1 Unused

2.2.9.2 DL1 QB Quadrupole

This element covers special processing spares required for this section.

2.2.10 DL1 to Linac (DL1TL) OPC Summary

2.2.10.1 Unused

2.2.10.2 DL1TL Steering Coils (X-Y Assys)

This element covers special processing spares required for this section.

2.2.11 Straight Ahead Beamline (SAB) OPC Summary

2.2.11.1 Unused

2.2.11.2 SAB Quadrupoles ( )

This element covers special processing spares required for this section.

2.2.12 Injector RF Waveguide Subsystem OPC Summary

2.2.12.1 Unused

2.2.12.2 RF Waveguide Supports

This element covers special processing spares required for this section.

2.2.13 Injector RF Subsystem

2.2.14 Cathode Processing (CP) Station

This element covers special processing spares required for this section.

2.2.14.1 Unused

2.2.14.2 CP Load Lock

2.2.15 Injector Laser Heater Subsystem (OPC Summary)

2.2.15.1 Unused

2.2.15.2 Beam Conditioning Optics (Laser Bay)

This element covers the effort associated commissioning with the specific Linac functional area.

2.2.16 Injector Power Conversion Subsystem (OPC Summary)

2.2.16.1 Personnel Protection System (PPS) R&D

2.2.16.2 Unused

2.2.16.3 Unused

2.2.16.4 Power Conv (beamline pwr supp) Spares

This element covers special processing spares required for this section.

2.2.17 Injector System Commissioning (OPC Summary)

2.2.17.1 Unused

2.2.17.2 Drive Laser Commissioning

This element covers the effort associated commissioning with the specific Injector functional area.

2.2.17.3 RF Conditioning

This element covers the effort associated commissioning with the specific Injector functional area.

2.2.17.4 RF Gun Operation with Beam

This element covers the effort associated commissioning with the specific Injector functional area.

2.2.17.5 L0-1&L0-2 Commissioning

This element covers the effort associated commissioning with the specific Injector functional area.

2.2.17.6 L0&SAB Commissioning

This element covers the effort associated commissioning with the specific Injector functional area.

2.2.17.7 DL1 Commissioning

This element covers the effort associated commissioning with the specific Injector functional area.

2.2.17.8 Injector Optimization

This element covers the effort associated commissioning with the specific Injector functional area.

LCLS WBS DICTIONARY
1.3 LINAC SYSTEM

1.3 LINAC SYSTEM

The Linac accelerates the electron beam while preserving the transverse emittance and compressing the longitudinal size. This element includes modifications to the last third of the existing SLAC linac, Bunch Compressor 1 (BC1), Bunch Compressor 2 (BC2), beam transport to the Undulator (LTU), beam transport after the undulator, bend magnets and beam dump, the bypass system for transporting test beams to end station A, and diagnostics including characterizing both the electron and x-ray beams as they pass through the undulator. The interface with the undulator is a vacuum flange at each end of the undulator. This element includes the common beam line beyond the undulator for the electrons and x-rays until the electrons are deflected enough for an interface to the x-ray beam line.

1.3.1 System Management & Integration

The Linac is made up of a number of individual devices and systems. These devices and systems must be integrated into functional blocks. In consecutive order with respect to the electron beam the functional blocks or areas are: Linac 1 (L01), Bunch Compressor Chicane 1 (BC1), Linac 2 (L02), Bunch Compressor Chicane 2 (BC2), Linac 3 (L03), Linac-to-Undulator Transport Line (LTU), and Main Electron Dump (E-Dump).

1.3.1.1 Linac Mechanical Integration

Linac Mechanical Integration defines a physical envelope for the LCLS modifications in the Accelerator Housing and Klystron Gallery. Mechanical Integration also ensures that existing Linac systems are, once modified by LCLS, returned to an acceptable level of function along with complete documentation.

1.3.1.1.1 L01 System Integration

L01 accelerates and ‘chirps’ the electron beam in preparation for first stage BC1 compression. Representing an LCLS Linac functional block, it is here where the functional requirements for systems and components are presented, reviewed, and documented. The mechanical top assembly of this functional area is completed here.

1.3.1.1.2 BC1 System Integration

BC1 applies first stage bunch compression to the electron beam. Representing an LCLS Linac functional block, it is here where the functional requirements for systems and components are presented, reviewed, and documented. The mechanical top assembly of this functional area is completed here.

1.3.1.1.3 L02 System Integration

L02 accelerates and ‘chirps’ the electron beam in preparation for first stage BC1 compression. Representing an LCLS Linac functional block, it is here where the functional requirements for systems and components are presented, reviewed, and documented. The mechanical top assembly of this functional area is completed here.

1.3.1.1.4 BC2 System Integration

BC2 applies second stage bunch compression to the electron beam. Representing an LCLS Linac functional block, it is here where the functional requirements for systems and components are presented, reviewed, and documented. The mechanical top assembly of this functional area is completed here.

1.3.1.1.5 L03 System Integration

L3 accelerates the electron beam to a final energy of 14 Gev. Representing an LCLS Linac functional block, it is here where the functional requirements for systems and components are presented, reviewed, and documented. The mechanical top assembly of this functional area is completed here.

1.3.1.1.6 LTU System Integration

LTU transports the electron beam to the FEL Undulator. The system includes bend magnets that support energy and emittance diagnostics. Representing an LCLS Linac functional block, it is here where the functional requirements for systems and components are presented, reviewed, and documented. The mechanical top assembly of this functional area is completed here

1.3.1.1.7 E-Dump System Integration

The Electron Dump receives the electron beam from the FEL Undulator and terminates the electron stream. It is a high radiation area with possibly some beam diagnostic capabilities. Representing an LCLS Linac functional block, it is here where the functional requirements for systems and components are presented, reviewed, and documented. The mechanical top assembly of this functional area is completed here

1.3.1.2 Unused

1.3.1.3 Travel

Linac group project-related travel expenditures.

1.3.1.4 Linac Management

Linac group costs related to management; administration, personal computers, productivity software, as well as simulation and modeling software.

1.3.2 Linac Controls & Power Conversion Subsystem

1.3.2.1 Personnel Protection System (PPS)

This system creates a physical barrier that subtends the LCLS for the purpose of personnel protection from radiation, electrical, and other present or imagined hazards. An LCLS area may use or combine with other SLAC control areas. The PPS system will include monitoring of radiation shielding integrity, barriers, area status annunciators, and multiple interlocked control gates for access to a safe machine space.

1.3.2.2 Beam Containment System (BCS)

The BCS includes components like stoppers and dumps that along with shielding provide a safe way to contain radiation that is generated under all LCLS operating conditions. This system also includes active instruments (beam shut off ion chambers - BSOIC's) that will disable operations if elevated levels of radiation (Neutron & Gamma) are detected outside of the PPS control area.

1.3.2.3 Machine Protection System (MPS)

This is a system of sensors (i.e. water flow switches, thermocouples) supplied as Digital and/or Analog signals which are interlocked, that will in turn shut off the beam if conditions exist/persist that will cause damage to machine hardware or other protection systems.

1.3.2.4 Linac Power Conversion Subsystem

The power supplies for the LCLS Linac will, for the most part, be a standard design and are used throughout the SLAC accelerator. This Linac WBS Power Supply subsystem has been divided into three types, Dipole, Quadruple and Trim and are described below.

The WBS unit will not provide for Fabrication or Installation activities. In addition, the design of the magnet power supply systems assumes that all magnets will have their magnet electrical connections covered such that the powered systems comply with SLAC, National Electric Code and OSHA regulations. There is no provision for interlocking the magnet power supplies for magnet safety.

1.3.2.4.1 Beamline Power Conversion (Dipole Type)

The Dipole Power Supplies provide power to dipole magnets. These units cover the LINAC, BSY and the LTU. There are 7 units, which are: BXH11-14, BXH 21-26, BXH 31-34, BY1, KICKER (BYBKIK), BYW, and the Dump Bend.

1.3.2.4.1.1 Beamline Power Supplies (Dipole Type)

The first section, WBS 01.03.02.04.01 is named the Dipole type. These Dipole Power Supplies provide power to dipole (bend) magnets. There are 8 units, which are: BXH11-14, BXH 21-26, BXH 31-34, BY1, KICKER (BYBKIK), BYW, Dump Bend and The Wiggler.

1.3.2.4.1.2 Power Supply (B21-26)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.1.3 78kw Pwr Supply – (B31-34)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.1.4 Unused

1.3.2.4.1.5 Power Supply (BY1)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.1.6 Kicker (BYBKIK)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.1.7 Unused

1.3.2.4.1.8 78kw Pwr Supply – (Dump Bend)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.1.9 Unused

1.3.2.4.2 Beamline Power Conversion (Quadruple Type)

The Quadruple Section power supplies power quadruple magnets which provide power to the focusing elements in the transport system. This section have the largest number of units and there will be 31 units which are: SEC-23 (2KW), SEC-24(2KW), SEC-25 (2KW), SEC-26 (2KW), SEC-27 (2KW), SEC-28 (2KW), SEC-29 (2KW), Q24701, QM21, Q24901, QM22, QVM1, QVM2, QVM3, QVM4, QVB1, QDL1, QE31, QEM1, QEM2, QEM3, QEM4, Qtm1, Qtm2, QUM1, QUM2, QUM3, QUM4, QDMP, QUE1 and QUE2.

1.3.2.4.2.1 2kw PS – (Sec 23)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.2 2kw PS – (Sec 24)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.3 2kw PS – (Sec 25)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.4 2kw PS – (Sec 26)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.5 2kw PS – (Sec 27)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.6 2kw PS – (Sec 28)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.7 2kw PS – (Sec 29)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.8 10kw PS – (Q24701)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.9 10kw PS – (QM21)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.10 Unused

1.3.2.4.2.11 10kw PS – (Q24901)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.12 10kw PS – (QM22)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.13 Power Supply (QVM1)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.14 Power Supply (QVM2)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.15 Power Supply (QVM3)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.16 Power Supply (QVM4)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.17 Power Supply (QVB1)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.18 Power Supply (QDL1)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.19 Power Supply (QE31)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.20 Power Supply (QEM1)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.21 Power Supply (QEM2)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.22 Power Supply (QEM3)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.23 Power Supply (QEM4)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.24 Power Supply (QTM1)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.25 Power Supply (QTM2)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.26 Power Supply (QUM1)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.27 Power Supply (QUM2)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.28 Power Supply (QUM3)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.2.29 Power Supply (QUM4)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.3 Beamline Power Conversion (Trim Type)

The last type is the Trim Type and these power supplies power magnets that operate at low currents and make minor orbit corrections to the beam. There will be 10 new units, which are: MCOR_1, MCOR_2, MCOR_3, MCOR_4, MCOR_LTU1, MCOR_LTU2, MCOR_LTU3, MCOR_LTU4, MCOR_LTU5, MCOR_LTU6.

1.3.2.4.3.1 MCOR_1 (12Amp)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.3.2 MCOR_2 (30Amp)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.3.3 MCOR_3 (30Amp)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.3.4 MCOR_4 (30Amp)

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.3.5 Unused

1.3.2.4.3.6 Unused

1.3.2.4.3.7 Unused

1.3.2.4.3.8 Unused

1.3.2.4.3.9 Unused

1.3.2.4.3.10 MCOR_LTU1

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.3.11 MCOR_LTU2

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.3.12 MCOR_LTU3

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.3.13 MCOR_LTU4

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.3.14 MCOR_LTU5

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.3.15 MCOR_LTU6

This number identifies the resources and cost associated with the above specific power supply.

1.3.2.4.4 Controls and Power Supply – Miscellaneous Hardware

This section covers the costs associated with the packaging (integration of systems equipment) and testing of electrical equipment racks for the Power Conversion and Control Systems. Rack infrastructure i.e. AC power distribution, plugstrips, utility outlets, cooling fans and mounting brackets are integrated prior to the integration of previously procured rack and crate mounted equipment from the various sections.

Cableplant installation design of Trays and Long-Haul cables (Using CAPTAR database) to be installed into the various areas, resulting in an award of contract, takes place here.

1.3.2.5 Controls – LLRF

LLRF is a system for the amplitude and phase control of the electron beam. It includes a new master oscillator and the distribution of the 2856 MHz RF and the machine timing signals. It also includes the RF control system around individual klystrons for stabilizing (low noise, low drift) and monitoring of their operation. A preponderance of design and procurement resides within the RF Section budget leaving controls with a engineering supporting role. This equipment also provides the means of avoiding Main Drive Line phase jumps when operating PEPII.

1.3.2.6 Controls – E-Beam Diagnostics

Diagnostic devices measure salient beam parameters such as beam size, position, phase, bunch length, beam current etc. for the purposes of setting and tuning the various machine parameters such as the strength of magnets and the amplitude and phase of klystrons. The diagnostic signals provide a monitoring function and in some case a direct feedback for closed-loop control of the accelerator hardware.

1.3.2.6.1 Controls – Wire Scanners

Wire scanners are beam profile monitors used to provide accurate measurements of beam size and position in all three planes (vertical, horizontal and 45 degrees) for beam measurement systems and beam tuning procedures. Components include wires capable of being moved precisely through the path of a beam, and a detector which can accurately measure the amount of charge striking a wire. When in use, a wire is scanned across the path of a beam using stepper motors, and a plot of wire position versus beam intensity is generated that represents the beam profile.

1.3.2.6.2 Controls – BPMs

Beam Position Monitor. A device including four electrodes located inside the beam pipe, and the associated electronics necessary to locate the position of the centroid of the beam. The electrodes are usually located about 90 degrees apart inside the vacuum chamber, far enough away from the beam's path not to interfere with it, but close enough to feel the electric charge of the beam's passing. A device called an RF cavity BPM uses resonant cavities in place of electrodes to detect the electric charge of the beam.

1.3.2.6.3 Controls – Toroids

The Toroid is an average beam current (charge) monitor (CM) which uses transformer action to measure the intensity of a beam pulse. A lead shielded pre-amplifier is usually placed near and connected to the wire wound ferrites. The amplified signal is then cabled to an electronic module external to the shielded housing. Comparisons can be made between Toroid installations as a way of determining beam losses between two points.

1.3.2.6.4 Controls – Stoppers

A Personnel Protection System device used to stop the beam, usually by allowing a heavy metal slug to pivot into the beam's path. The de-energized default is in the beam path as a fail-safe. This is removed from the path by means of air solenoids. This device, as all PPS devices rely on redundant parallel limit switches to supply status prior to allowing entry into beamline areas.

1.3.2.6.5 Controls – Profile Monitors

A screen inserted is inserted into a beam transport line to view the beam cross section via a remote camera focused through a glass viewing port. The screen can be made from a variety of materials suited to the beam energy at that location. The visible emission picture is captured on a digital video camera, triggered to look a specific beam pulse. Profile monitor screens can be inserted and removed remotely by the machine operators. Position status is determined by limit switches. Cameras can be remotely triggered, iris controlled, zoom activated, lamp intensity varied via electronic modules connected to a two channel Profile Monitor chassis.

1.3.2.6.6 Controls – E/O Diagnostics

The electro optic, EO, bunch length monitor is a laser-based measurement for measuring the absolute bunch with subpicosecond resolution. An instrumented class 3 laser is table-mounted and can be remotely operated and parameters changed via electronic stepper motor modules and interface with positional information read-back via an analog input module. Control and monitoring are transmitted by cable to modules located in a non-hazardous area.

1.3.2.6.7 Controls – Bunch Length Monitors

The bunch length monitor, BLM, is used to measure the length of the bunch after each longitudinal compression stage in the accelerator. The measurement is done on a pulse-by-pulse basis so that the information can be transmitted to a feedback loop for control and stabilization of the bunch length. The BLM device senses the coherent radiation from the bunch, where the spectral power is proportional to the peak current in the bunch and so is able to detect relative changes in bunch length. For calibration purposes this measurement is compared to measurements made with the RF transverse deflecting cavities.

1.3.2.6.8 Controls – Beam Loss Monitors

Beam loss monitors, BLM's, are placed on the beamline immediately adjacent to the beam pipe wherever there is a potential for beam loss or beam scraping to occur, such as locations where the beamline bends, or there is a fixed aperture protection collimator, or a moveable collimator to scrape the beam. The signal from the loss monitor is compared to a preset threshold by the Machine Protection System, MPS, which will respond by limiting the rate of the beam pulses according to the severity of the beam loss. The BLM can measure local losses at a point on the beamline using a Protection Ion Chamber, PIC, or can measure global losses along the length of the beamline by using a distributed Panofsky Long Ion Chamber, PLIC, device. Different beam loss sensing detectors can be used according to the type of radiation expected and the sensitivity required.

1.3.2.6.9 Controls – Single Beam Dump

The single bunch beam dumper, SBBD, consists of a fast-acting pulsed magnet that is able to selectively deflect a bunch toward a beam stopper on a pulse-by-pulse basis. The purpose of this is to control the rate at which beam is sent to the downstream undulator beam line which contains sensitive equipment. If a fault condition occurs such as a beam loss in the undulator then the SBBD is able to prevent the next beam pulse from being sent down the beam line and potentially causing damage. The fault conditions are passed to the SBBD from the Machine Protection System, MPS. The SBBD is able to stop the full-rate 120 Hz beam from the linac upstream and selectively allow single shots, 1 Hz, 10 Hz or an arbitrary rate to be sent downstream, thereby facilitating tune up of the beam without risking damage to the beam line.

1.3.2.6.10 Controls – E Beam Dump

The main electron beam dump is used to safely stop the spent electrons after the undulator. The design of the dump addresses issues of cooling the maximum possible heat load from the electron beam with regard to thermal stress and corrosion problems to ensure that the radiation in the dump is fully contained. The control system monitors temperatures and coolant systems for long-term reliability.

1.3.2.6.11 Controls – Protection Collimators

These fixed mask devices are a principal initial means of scraping errant beams thereby preventing damage to beamline components and/or beampipe if not outright venting of the vacuum envelope. Water flow and temperatures are monitored using distributed digital and analog input modular devices via signal interfaces.

1.3.2.6.12 Controls – Movable Collimator

This system provides control and monitoring of two-axis beam intercepting blades which can be used as a diagnostic in the LTU front end and further downstream for beam clean-up. Stepper-motors are used for movement which is read back with transducers (LVDT's) for positional information.

1.3.2.6.13 Controls – X-Band Structure

1.3.2.7 Unused

1.3.2.8 Controls – Timing

This system includes the synchronization of pulsed accelerator devices with generating the beam and the acquisition of beam measurements for use in feedback and timing.

1.3.2.9 Controls – Vacuum System

This system includes the monitoring and control of gages, pumps, and valves. This system includes interlocks for the protection of the machine during maintenance and against a catastrophic change in pressure.

1.3.2.9.1 Controls – Vacuum Instrumentation & Interlocks

This system collects and displays the operating state of vacuum system in discrete areas of the accelerator. It uses this information to control beam operation as well as the state of isolation valves and vacuum pump power supplies.

1.3.2.9.2 Controls – Vacuum Pump Power Supplies

These are High Voltage power supplies, controlled current, to pump down and maintain design operating pressure in the accelerator.

1.3.2.10 Software and Controls Infrastructure

The controls infrastructure provides the interconnection between various parts of the control system. It performs supervisory function for the control network. It includes the software tolls and applications for the real time programming of the control modules as well as the tools for supporting the database structure.

1.3.2.10.1 Unused

1.3.2.10.2 Unused

1.3.2.10.3 Unused

1.3.2.10.4 Data Communications

Gigabit networking has been costed to connect 5 locations to MCC. The locations are: Bldg 406, sector 24, sector 30, support bldg at near end and the end of the LTU. One gigabit switch has been allocated per location except at the end station, where two have been allocated because of the high quantity of cameras at this location. Wireless network access points (to the visitor network) are also included.

1.3.2.10.5 Computers

This is actually "Computers and crates". VME crates with Power PC controllers and VxWorks run-time licenses have been costed for all systems. The cables and the modules that go in the crates are distributed across the systems (in the rest of the controls WBS) that use/need them.

No workstations have been costed for the Linac controls. We need to add 2 per location still (Linux PCs at $1.2K each).

1.3.3 Linac Magnets & Supports

This system may include permanent and electromagnetic elements (dipoles, quadrupoles, sextupoles, and correctors) for the manipulation and direction of charged beams. The structure and systems to locate and accurately position these elements are included in the system.

1.3.3.1 Bend Magnet (BX1_BC1)

This is a new bend magnet design for use in BC1. It is direct current string of four magnets powered to bend the electron beam into and out of the BC1 chicane. The final alignment stage for each magnet and support stand for the entire BC1 system have been cost with these components.

1.3.3.2 Bend Magnet (BX3_LTU)

This is an existing bend magnet design for use in the LTU. Five existing bend magnets will be recycled from SLAC / FFTB. One of the five will become the first bend in the dump line in front of the BYD bend magnets.

1.3.3.3 Bend Magnet (BX2_BC2)

This is a new bend magnet design for use in BC1. It is direct current string of four magnets powered to bend the electron beam into and out of the BC2 chicane. The final alignment stage for each magnet and support stand for the entire BC2 system have been cost with these components.

1.3.3.4 Bend Magnet (BY_LTU)

This is a new bend magnet design for use in the LTU. It is a direct current powered to bend the electron beam in a vertical plane in the LTU.

1.3.3.5 Quadrupole Magnet (0.91Q17.2_LTU)

These magnets are an existing design. Fifteen additional units will have to be fabricated to augment the lot of existing refurbished units that will be removed from FFTB.

1.3.3.6 Unused

1.3.3.7 Quadrupole Magnet (QE)

This is and existing linac design(s) of a laminated steel quadrupole. It is used to focus or defocus the electron beam. They are usually found at linac intergirder and or drift locations. The majority of these magnetic elements already exists in the current linac and will assume new position and control for LCLS.

1.3.3.8 Corrector Magnet (Linac Type 4)

This is an existing linac design for a weak (iron core) bend magnet. Its large appeture allows for installation over the accelerating structure. They provide bend correction for the electron beam. A single design can be installed in either a vertical or horizontal orientation. The majority of these magnetic elements exists in the current linac and will assume new position and control for LCLS.

1.3.3.9 Bend Magnet (BYD_LTU)

This is a new direct current electromagnetic dipole that bends the bends the spent electron beam after the Undulator and directs it to the main dump. Along with other magnetic elements, this magnet is part of a spectrometer that analyzes the energy distribution of the discarded electrons that reach the dump.

1.3.3.10 Quadrupole Magnet (QA)

This is an existing linac Quadrupole magnet for focusing or defocusing of the electron beam. They are usually found at linac intergirder and or drift locations. The majority of these magnetic elements already exists in the current linac and will assume new position and control for LCLS.

1.3.3.11 Bend Magnet (BYPM_LTU)

This is a new system of permanent dipole magnets located immediately after the dump bend magnet that directs the electron beam into a safe shielding zone in the event of a failure of the Dump Bend Magnet.

1.3.3.12 Bend Magnet (BYKIK_LTU)

This is a new pulsed magnet in the LTU that limits the rate of beam bunches into the Undulator by deflecting unwanted bunches out of the forward Beamline into the Single Beam Dump.

1.3.3.13 Bend Magnet (BYW_LTU)

This magnet system is a diagnostic device rather than a beam transport element. The magnet for this application will be a refurbished item from SSRL.

1.3.4 Linac Beamline Vacuum Subsystem

1.3.4.1 Unused

1.3.4.2 Linac Beamline Vacuum System

This section represents all of the interconnecting vacuum parts between accelerating, magnetic, or diagnostic components for the identified LCLS system. It includes, but is not limited too, drifts, tees, pumps, gauges, pumps, and manifolds. Gauge controllers and ion pump controllers are not included in this section. They are estimated under WBS 1.3.2.9. Cutting and re-assembly of accelerator structures are not covered under this WBS number. Those activities are covered under WBS 1.3.6.2.

1.3.4.3 BC1 Vacuum System

This section represents all of the interconnecting vacuum parts between accelerating, magnetic, and diagnostic components for the identified LCLS system. It includes, but is not limited to, drifts, tees, pumps, gauges, pumps, and manifolds. Gauge controllers and ion pump controllers are not included in this section. They are covered under WBS 1.3.2.9. Since the vacuum supports are an integral part of the BC1 magnet support system those items are covered under WBS 1.3.3.1.

1.3.4.4 BC2 Vacuum System

This section represents all of the interconnecting vacuum parts between accelerating, magnetic, or diagnostic components for the identified LCLS system. It includes, but is not limited to, drifts, tees, pumps, gauges, pumps, and manifolds. Gauge controllers and ion pump controllers are not included in this section. They are estimated under WBS 1.3.2.9. Since the vacuum supports are an integral part of the BC2 magnet support system those items are covered under WBS 1.3.3.3.

1.3.4.5 Linac to Undulator (LTU) Vacuum System

This section represents all of the interconnecting vacuum parts between accelerating, magnetic, or diagnostic components for the identified LCLS system. It includes, but is not limited to, drifts, tees, pumps, gauges, pumps, vacuum supports and manifolds. Gauge controllers and ion pump controllers are not included in this section. They are estimated under WBS 1.3.2.9

1.3.4.6 Dumpline Vacuum Systems

This section represents all of the interconnecting vacuum parts between accelerating, magnetic, or diagnostic components for the identified LCLS system. It includes, but is not limited to, drifts, tees, pumps, gauges, pumps, vacuum supports and manifolds. Gauge controllers and ion pump controllers are not included in this section. They are estimated under WBS 1.3.2.9

1.3.5 Linac Electron Diagnostics

1.3.5.1 Wire Scanners (15)

Wire Scanners are used to measure beam size in order to determine Beam Emittance and Energy Spread. They consist of at least one set of wires orthogonal to the beam Z-axis that are moved through the electron beam. The resulting radiation is measured by a photon detector.

1.3.5.2 Beam Position Monitor

Beam Position Monitors (BPM) identify the local position of the electron beam relative to a known mechanical and magnetic reference (quadrupole magnet magnetic center relative to physical references). The LCLS linac has two BPM design types; electrode and RF. The stripline electrode BPM generates a signal proportional to the dimensional offset between the electron bunch center and the BPM center. The RF BPM is an RF resonant cavity that measures the bunch position based on the amplitude and phase shift of the RF pulse proportional to the electron bunch. BPM and magnet data can be used to automatically tune the electron beam position.

1.3.5.2.1 BPM – Standard Linac

This device is a strip line electrode type BPM of proven design. Many examples of this design are installed in SLAC Linac Quadrupole magnets.

1.3.5.2.2 BPM – RF

The RF BPMs are positioned in the LTU upbeam of the Undulator. They are used to verify and tune beam position prior to entry into the Undulator. The LTU RF BPMs will utilize the undulator RF BPM design and new control electronics designed at SLAC.

1.3.5.2.3 BPM – FFTB

This electrode type FFTB BPM is an established design. Existing units in the SLAC FFTB will be refurbished and used in the LTU. The balance of the required FFTB type BPMs (~30%) will be a revised design modeled on the historical design.

1.3.5.2.4 BPM – High Resolution BC1 (3 ea)

These are variants of the standard Linac BPM required for use in the BC1 and BC2 chicanes. The large aperture BPM is equivalent in resolution to a standard linac BPM with an increased internal aperture to accommodate a larger electron beam.

1.3.5.3 Toroid Beam Current Monitor

Toroids measure both discrete local and integrated system level electron beam current. As a local device, a Toroid measures beam current by producing a signal proportional to the electron bunch current. Measurements by two or more Toroids in a system can be made to indicate average current per bunch. A system of Toroids can also be used to indicate beam losses by comparing bunch current at multiple locations.

1.3.5.4 Stoppers TU Dump (2ea)

Beam stoppers are water cooled diagnostic/protection devices that are inserted into the electron path to stop the beam. They are designed to absorb the electron beam power. Beam stoppers may be designed for a reduced electron bunch rate to minimize heat load and radiation effects. Stoppers are placed in the beam path to tune the upbeam electron beam path while the stopper is protecting personnel and downbeam radiation sensitive devices.

1.3.5.5 Profile Monitors

Profile monitors are beam emittance and energy spread diagnostic devices. They characterize beam shape, size, and position. Profile monitor designs consist of a fluorescent screen or metal foil that interacts with the electron beam and produces secondary radiation that is monitored by detectors and/ or cameras.

1.3.5.6 E/O Bunch Length Monitor

The electro-optical bunch length monitor measures longitudinal bunch length profile and beam energy distribution. The E/O has the capability to measure a single electron bunch arrival time and duration with picosecond accuracy.

1.3.5.7 Bunch Length Monitors (4 ea)

This device generates a signal proportional to the bunch length by measuring terahertz and synchrotron radiation produced as the electron beam passes through a thin foil.

1.3.5.8 Beam Loss Monitors

These devices measure ionizing radiation that is produced when the electron beam deviates from the design trajectory and impinges on a component of the system or vacuum envelope. The beam loss monitors consist of two types, protection ion chambers (PIC) and Panofsky long ion chambers (PLIC)..

1.3.5.8.1 PIC Beam Loss Monitors

The PIC is designed to be placed locally downbeam from devices that are candidates for beam divergence during system failure modes.

1.3.5.8.2 PLIC Beam Loss Monitors

The PLIC is a distributed region device that averages over a long region of the system to identify beam loss.

1.3.5.9 Single Beam Electron Dump

The single beam dump is an electron beam stopper designed to absorb the full beam energy. This dump is designed for system tuning and to provide protection for the undulator system in concert with a pulsed bend magnet.

1.3.5.10 Electron Beam Dump

The electron beam dump is the endpoint for the electron beam in the LCLS system after the beam passes through the undulator system.

1.3.5.11 Protection Collimator

Protection collimators are designed to limit the beam cross sectional dimensions in X and Y to prevent damage to devices downbeam from the collimator.

1.3.5.12 Movable Collimator

Movable collimators are designed to tune the electron beam characteristics by limiting the beam dimension in either the X or Y axes.

1.3.5.13 Safety Dump

The safety electron dump is a redundant system designed to remove the electron beam in the event of a system failure mode.

1.3.6 Linac RF Subsystem

1.3.6.1 Unused

1.3.6.2 S-Band High Power System

All of the new and modified RF power transmission parts necessary to upgrade the Linac to the LCLS standard are included in this section. Layout for these components is charged to system integration for the particular LCLS functional area where the modification takes place. Parts found here are typically, S-

Band waveguide straights and bends, pump outs, waveguide supports, and low energy couplers. Parts necessary to protect the linac during installation and/or store removed assemblies are included in this section.

1.3.6.3 S-Band Structures

For LCLS, two existing 10 ft DLWG structures will be removed and be replaced by shortened sections (9.5 ft) to make room for LCLS optics or additional diagnostic devices. This section includes the cost to replace the 10 ft sections with existing 9.5 ft sections from current linac spares.

1.3.6.4 X-Band Low Level System

The X-band RF system will be operated from the existing modulator and modified control system, which can adjust the phase and amplitude to within 10 picoseconds in phase and 2% in amplitude. A new feedback system will measure phase and amplitude of the beam, via BPMs and Bunch Length Monitors, process the information, and more precisely correct the phase and amplitude to meet LCLS specifications.

1.3.6.5 X-Band High Power System

1.3.6.5.1 X-Band High Power Klystron

A conventional XL-4, X-Band klystron will be employed for LCLS operation. This klystron model has shown it is capable of delivering 50 MW at 60 Hz and 1.6 us pulse lengths and it is not anticipated that running at 120 Hz and 0.1 us pulse lengths at a power of 25 MW for LCLS should be a problem for this tube.

1.3.6.5.2 X-Band High Power Modulator

The X-band modulator will comprise of an existing S-Band modulator, modified to to achieve as short a rise time as possible, to limit the average power from the klystron. A 19:1 turn ratio pulse transformer will enable the required 450 kV to be achieved from the standard 23.5 kV/6.7 kA modulator.

1.3.6.5.3 X-Band High Power Waveguide System

The system will use WR90 waveguide out of the klystron to a WR293 mode converter section, which will run from the gallery above straight down to the tunnel below. Once in the tunnel a mode converter will change back to WR90 and fed to the RF structure. There will be three high power Bethe hole couplers in the system, one at the klystron output, one at the accelerator input, and one at the accelerator output. The coupler at the klystron output will be used to feed into the existing control system for the 21-2 klystron. The accelerator input and output couplers will be routed to the new RF feedback system.

1.3.6.6 X-Band Structures

The structure that will be used will be a NLCTA type 60cm long traveling wave structure, whose shunt impedance is of the order of 30 MOhms/m. The 7.2mm diameter aperture of this structure will be the limiting aperture in the main linac and interception of high power End Station beams could be damaging. Therefore, removal of the structure, either automatic or manual, during high power End Station running is foreseen.

1.3.6.7 RF Distribution System

1.3.6.7.1 Modulator Refurbishment

Not all modulators in the linac are stable enough to enable the RF output of a 5045 klystron to meet LCLS specifications. The critical stations used in feedback and for L1 will require the stability of the best linac modulators. Most of the voltage jitter is believed to be coming from the thyratron. The modulators will be refurbished and have new thyratrons installed.

1.3.6.7.2 Solid State Sub Booster

The Solid State Sub-Booster (SSSB) is a pulsed amplifier with 600W out and is used to drive a 5045 klystron. With 50dB of gain the unit can be driven from the LLRF system with 10mW input power levels. Klystrons with SSSBs can be controlled independent of other klystrons in the sector on a pulse to pulse basis. PED for this unit is done in the injector budget.

1.3.6.7.3 IPA Modifications

The IPA chassis is used on existing stations to control phase and amplitude on the 5045 klystrons. The chassis takes about 2kW of input RF power and has about 3dB of loss. On stations with SSSBs the IPA chassis is reconfigured to place the high power phase shifter before the SSSB to reduce the losses at the 1kW power level.

1.3.6.7.4 Klystron Controls Interface

Standard CAMAC modules and signals will be used to run the feedback stations in sectors 24 and 30. Bunch length monitors and beam phase monitors also require interfacing to the control system. Information from these may also need to be routed to the injector micro for feedback. Cables need to be defined and installed from the CAMAC modules to the RF units.

1.3.6.7.5 Bunch Length Electronics

The bunch length and electronics will require interfaces to the control units. These interfaces will be developed under the injector PED and are expected to consist of a single chassis and cables.

1.3.6.7.6 RF Phase Measurements

Modifications to the S-band Phase and Amplitude Detector (PAD) are required to run the X-band system with the existing control system. This task will include modifications internal to an existing PAD or development of a new PAD with compatible IO.

1.3.6.7.7 RF Distribution L2 & L3

The existing RF distribution system is not accurate to LCLS specifications. A new reference line running the last kilometer of the accelerator in the temperature stabilized tunnel will improve stability an order of magnitude, relaxing the requirements of the feedback systems.

1.3.6.7.8 RF Fiber Optics Electronics System

A fiber optic line will run from the LCLS injector to the research yard to give the experimenters an RF reference to sync to.

1.3.6.7.9 RF Stability

RF stability measurements, algorithm development, software for feedback, and user interfaces will need to be done to control the phase/timing of the RF reference to the x-ray pulse at the experimenters' facility. This will include measurements of the stability of the experimenters' lasers.

1.3.7 Linac Installation & Alignment

This WBS section covers the reception of parts, components, and sub assemblies from either a Post Processing & Testing or a Rack Integration activity. Installation begins at beneficial occupancy or at a planned SLAC Linac downtime and completes all necessary activities prior to the start of commissioning. These activities are, but not limited to, mechanical installation of beam line components, installation of vacuum components, alignment, vacuum pump down, vacuum leak checking and functional testing of components and all of their respective control systems. Management of project installation activities are not covered in this section. Those activities are covered under WBS 1.3.1, System Management & Integration. This WBS section also covers the removal and/or relocation of existing SLAC Linac beam line components to make room for new LCLS Linac components such as magnets, vacuum components, RF components and diagnostic instruments.

1.3.7.1 Linac L01 System Installation & Alignment

This WBS section identifies and collects the resources and costs associated with the removal and/or relocation of SLAC Linac beam line components and the installation and relocation of all LCLS Linac beam line components in accordance with the activity description above. This section also accounts for the shortening of the existing SLAC Linac accelerator structures in SLAC Linac Sector 21.

1.3.7.2 Linac BC1 System Installation & Alignment

This WBS section identifies and collects the resources and costs associated with the removal of SLAC Linac beam line components and the installation of all BC1 components in accordance with the activity description above.

1.3.7.3 Linac L02 System Installation & Alignment

This WBS section identifies and collects the resources and costs associated with the removal and/or relocation of SLAC Linac beam line components and the installation of all LCLS Linac beam line components in accordance with the activity description above.

1.3.7.4 Linac BC2 System Installation & Alignment

This WBS section identifies and collects the resources and costs associated with the removal of SLAC Linac beam line components and the installation of all BC2 components in accordance with the activity description above.

1.3.7.5 Linac L03 System Installation & Alignment

This WBS section identifies and collects the resources and costs associated with the removal and/or relocation of SLAC Linac beam line components and the installation of all LCLS Linac beam line components in accordance with the activity description above.

1.3.7.6 Linac LTU System Installation & Alignment

This WBS section identifies and collects the resources and costs associated with the removal and/or relocation of SLAC FFTB beam line components and the installation of all LCLS Linac beam line components in accordance with the activity description above.

1.3.7.7 Linac E-Dump System Installation & Alignment

This WBS section identifies and collects the resources and costs associated with the removal and/or relocation of SLAC FFTB beam line components and the installation of all LCLS Linac beam line components in accordance with the activity description above.

2. PROJECT – R&D, SPARES, COMMISSIONING

2.3 LINAC SYSTEM (OPC)

OPC Summary for the Linac System. It includes effort and costs associated with R&D, Spares, and Commissioning.

2.3.1 System Management & Integration

2.3.2 Linac Controls & Power Conversion Subsystem (OPC)

2.3.2.1 Unused

2.3.2.2 Unused

2.3.2.3 Unused

2.3.2.4 Power Conversion

This element covers special processing spares required for this section.

2.3.2.4.1 Spare Power Supply (Dipole Type)

This element covers special processing spares required for this section.

2.3.2.4.2 Spare Power Supply (Quad Type)

This element covers special processing spares required for this section.

2.3.2.4.3 Spare Power Supply (Trim Type)

This element covers special processing spares required for this section.

2.3.2.4.4 Unused

2.3.3 Linac Magnets & Supports (OPC)

2.3.3.1 Bend Magnet (BX1_BC1)

This element covers special processing spares required for this section.

2.3.3.2 Bend Magnet (BX3_LTU)

This element covers special processing spares required for this section.

2.3.3.3 Bend Magnet (BX2_BC2)

This element covers special processing spares required for this section.

2.3.3.4 Bend Magnet (BY_LTU)

This element covers special processing spares required for this section.

2.3.3.5 Quad Magnet (Quad_LTU)

This element covers special processing spares required for this section.

2.3.3.6 Unused

2.3.3.7 Unused

2.3.3.8 Unused

2.3.3.9 Bend Magnet (BYD_LTU)

This element covers special processing spares required for this section.

2.3.3.10 Unused

2.3.3.11 Bend Magnet (BYPM_LTU)

This element covers special processing spares required for this section.

2.3.3.12 Bend Magnet (BYKIK_LTU)

This element covers special processing spares required for this section.

2.3.3.13 Bend Magnet (BYW_LTU)

This element covers special processing spares required for this section.

2.3.4 Linac Vacuum Subsystem (OPC Summary)

2.3.4.1 Linac Vacuum Subsystem Operations Equip

This element covers special processing spares required for this section.

2.3.4.2 Linac Beamline Vacuum System

This element covers special processing spares required for this section.

2.3.4.3 BC1 Vacuum System

This element covers special processing spares required for this section.

2.3.4.4 BC2 Vacuum System

This element covers special processing spares required for this section.

2.3.4.5 Linac to Undulator (LTU) Vacuum System

This element covers special processing spares required for this section.

2.3.4.6 Dumpline Vacuum System

This element covers special processing spares required for this section.

2.3.5 Linac Electron Diagnostics (OPC Summary)

2.3.5.1 Wire Scanners

This element covers special processing spares required for this section.

2.3.5.2 Beam Position Monitors

This element covers special processing spares required for this section.

2.3.5.3 Toroids Beam Charge

This element covers special processing spares required for this section.

2.3.5.4 Stoppers Tune Up Dump

This element covers special processing spares required for this section.

2.3.5.5 Profile Monitors

This element covers special processing spares required for this section.

2.3.5.6 Unused

2.3.5.7 Bunch Length Monitors

This element covers special processing spares required for this section.

2.3.5.8 Beam Loss Monitors

This element covers special processing spares required for this section.

2.3.5.9 Unused

2.3.5.10 Electron Safety Beam Dump

2.3.5.11 Protection Collimators

This element covers special processing spares required for this section.

2.3.5.12 Movable Collimators

This element covers special processing spares required for this section.

2.3.5.13 Safety Dump

This element covers special processing spares required for this section.

2.3.6 Linac RF Subsystem (OPC Summary)

2.3.6.1 Unused

2.3.6.2 Unused

2.3.6.3 Unused

2.3.6.4 Unused

2.3.6.5 X-Band High Power System

This element covers special processing spares required for this section.

2.3.6.6 Unused

2.3.6.7 RF Distribution System

This element is a summary of RF Distribution Spares.

2.3.6.7.1 Modulator

This element covers special processing spares required for this section.

2.3.6.7.2 Solid State Sub Booster

This element covers special processing spares required for this section.

2.3.6.7.5 Bunch Length Electronics

This element covers special processing spares required for this section.

2.3.6.7.7 RF Distribution L2 & L3

This element covers special processing spares required for this section.

2.3.6.7.8 RF Fiber Optics Electronics

This element covers special processing spares required for this section.

2.3.7 Linac System Commissioning (OPC Summary)

2.3.7.1 Linac L01 System Commissioning

This element covers the effort associated commissioning with the specific Linac functional area.

2.3.7.2 Linac BC1 System Commissioning

This element covers the effort associated commissioning with the specific Linac functional area.

2.3.7.3 Linac L02 System Commissioning

This element covers the effort associated commissioning with the specific Linac functional area.

2.3.7.4 Linac BC2 System Commissioning

This element covers the effort associated commissioning with the specific Linac functional area.

2.3.7.5 Linac L03 System Commissioning

This element covers the effort associated commissioning with the specific Linac functional area.

2.3.7.6 Linac LTU System Commissioning

This element covers the effort associated commissioning with the specific Linac functional area.

2.3.7.7 Linac E-Dump System Commissioning

This element covers the effort associated commissioning with the specific Linac functional area.

LCLS WBS DICTIONARY
1.4 UNDULATOR

1.4 UNDULATOR SYSTEM

The LCLS Undulator System Project Costs, including undulator magnets and supports, undulator diagnostics, vacuum systems, and controls for the undulator equipment are included herein. Integration and installation are also included within this area. Total cost for the LCLS undulator system planning, project management, design, construction, and installation are summed at this level.

1.4.1 Undulator System Management & Integration

All project management and engineering integration oversight is covered by this element. Total cost of all project management and project integration tasks required to design, construct, test and install an operationally complete undulator system for the LCLS: Undulator System Management; ANL Project Support; Undulator System M&S – General; Undulator System Reviews and Workshops.

1.4.1.1 Undulator System Management

Oversee project management details and delivery of a completely operational undulator system for the LCLS. This section includes all project management and project integration tasks required to design, construct, test and install an operationally complete undulator system for the LCLS: Undulator System Management-Technical; ANL Project Support-General.

1.4.1.1.1 Undulator System Management – Technical

Oversee the technical project management details and delivery of a completely operational undulator system for the LCLS. Technical management and oversight cost of all project management and project integration tasks required to design, construct, test and install an operationally complete undulator system for the LCLS.

1.4.1.1.2 ANL Project Support

Provide all necessary administrative, PMCS, budget, schedule, and contract monitoring, website and other basic sundry support required for the delivery of a completely operational undulator system for the LCLS. This section includes direct and indirect ANL LCLS project support costs required to design, construct, test, and install an operationally complete undulator system for the LCLS.

1.4.1.2 Undulator System Materials and Supplies

This section covers the total M&S cost of the ANL LCLS project office required during the design, construction, testing and installation of an operationally complete undulator system for the LCLS.

1.4.1.2.1 Undulator System M&S – General

Basic M&S cost excluding travel of the ANL LCLS project office required during the design, construction, testing and installation of an operationally complete undulator system for the

LCLS: Office supplies and miscellaneous materials; Tele/video conferencing; CPUs and Software; Shipping and Storage.

1.4.1.2.2 Undulator System Travel

Basic M&S cost of travel for the ANL LCLS project required during the design, construction, testing and installation of an operationally complete undulator system for the LCLS.

1.4.1.3 Undulator System Reviews and Workshops

This section provides the necessary support for all reviews of the undulator system or required workshops. It includes all costs required to cover all semiannual reviews and occasional workshops focused on the needs of the LCLS undulator system: Organization and management of all LCLS undulator system reviews and related workshops; Travel for reviewers or necessary workshop attendees; Miscellaneous items required during the reviews and workshops.

1.4.2 Controls

Overall undulator controls task covers all controls issues involved with the LCLS undulator. This includes the costs involved with the entire controls section of the LCLS undulator. It also consists of the specification, design, procurement, assembly and testing of all controls components of the LCLS undulator.

1.4.2.1 Controls Management and Integration

Cost tracking for management issues within the undulator controls section, including controls management and integration with SLAC. Specifically the subsystems which must communicate with the SLAC control system.

1.4.2.1.1 Unused

1.4.2.1.2 Unused

1.4.2.1.3 Software Interface with SLAC

This is the Cost Center for the software design effort required for high-level control applications which will interface with the SLAC control system. Includes commercial software required for design and implementation of these applications. The high level software is that which the operators and scientists in charge of the LCLS use to interact with the undulators. By necessity, this software must function in a dual control system environment (LCLS and SLAC).

1.4.2.2 Motion

This element tracks any controls effort and materials for motion within the LCLS undulator hall. This consists of all controls effort and materials required to control motion based component within the LCLS undulator.

1.4.2.2.1 Fine Motion

This element covers effort and materials for the multiple motion platforms that require accurate (with feedback) positioning.

1.4.2.2.1.1 Motor Interface

Motor interface for fine motion requirements covering the specification, testing and procurement of the motor interface used in fine (accurate) motion applications within the Undulator Control System (UCS). Fine motion axis in the LCLS undulator includes the strongback cradle motion and scanning wire probes.

1.4.2.2.1.2 Encoder Interface

Encoder interface for fine motion requirements including the specification, testing and procurement of the encoder interface used in fine (accurate) motion applications within the UCS. Fine motion axis in the LCLS undulator includes the strongback cradle motion and scanning wire probes.

1.4.2.2.1.3 Motor Driver

Motor driver for fine motion requirements including the specification, testing and procurement of the motor driver used in fine (accurate) motion applications within the UCS. Fine motion axis in the LCLS undulator includes the strongback cradle motion and scanning wire probes.

1.4.2.2.1.4 Cabling

Cables required for fine motion requirements. This includes the design, specification, assembly, testing and procurement of the motor and encoder cables used in fine (accurate) motion applications within the UCS. Fine motion axis in the LCLS undulator includes the strongback cradle motion and scanning wire probes.

1.4.2.2.1.5 Integrate Components

Integration of motor, encoder, drivers and cables along with software for a complete motion control subsystem for the strongback cradle. This includes the integration of all motion components used in strongback motion. This includes the motor and encoder interfaces, the motor drivers and the cables. Also included are the control software design and implementation as well as system testing.

1.4.2.2.2 Phase Corrector Motion

The phase corrector motion is done with piezoelectric drivers and as such requires unique motion control. The actuators to be used for the phase correctors are unique in that they utilize piezoelectric motors for motion requirements. The control of these actuators is typically done with off-the-shelf controllers, but they are very different from the other motion platforms within the undulator.

1.4.2.2.2.1 Motor Interface

Motor interface for phase corrector requirements, including the specification, testing and procurement of the motor interface used in the phase corrector within the UCS. The phase correctors will be controlled via piezo drivers.

1.4.2.2.2.2 Unused

1.4.2.2.2.3 Unused

1.4.2.2.2.4 Cabling

Cables required for phase corrector requirements, including the design, specification, assembly, testing and procurement of the motor and encoder cables used in phase corrector motion applications within the UCS.

1.4.2.2.2.5 Integrate Components

Integration of motor and cables along with software for a complete phase corrector subsystem, including the integration of all motion components used in phase corrector motion applications within the UCS. This includes the motor, cables, control software design and implementation as well as system testing.

1.4.2.2.3 Unused

1.4.2.2.4 Unused

1.4.2.2.5 Unused

1.4.2.2.6 Scanning Wire Motion

The motion of the scanning wire element is contained within this element. This covers the controls effort and costs involved in the motion of the scanning wire transducer.

1.4.2.2.6.1 Motor Interface

Motor interface for scanning wire requirements covers the specification, testing and procurement of the motor interface used in the motion of the scanning wire.

1.4.2.2.6.2 Unused

1.4.2.2.6.3 Unused

1.4.2.2.6.4 Unused

1.4.2.2.6.5 Integrate Components

Integration of motor, encoder, drivers and cables along with software for a complete motion control subsystem for the scanning wire diagnostic. This covers the integration of all motion components used in the scanning wire motion. This includes the motor and encoder interfaces, the motor drivers and the cables. Also included are the control software design and implementation as well as system testing.

1.4.2.2.7 Macroscopic Motion

This section is the total center for macroscopic motion controls effort and equipment. Macroscopic motion is defined as any motion requirement that does not need positional feedback for operation. Currently it includes the diagnostic "elevator" and OTR camera controls.

1.4.2.2.7.1 Motor Interface

Motor interface for macroscopic motion requirements, including the specification, testing and procurement of the motor interface used in macroscopic motion applications within the UCS.

1.4.2.2.7.2 Unused

1.4.2.2.7.3 Motor Driver

Motor driver for macroscopic motion requirements, including the specification, testing and procurement of the motor driver used in macroscopic motion applications within the UCS.

1.4.2.2.7.4 Cabling

Cables required for macroscopic motion requirements, including the design, specification, assembly, testing and procurement of the motor and encoder cables used in macroscopic motion requirements. Macroscopic motion within the UCS consists of EBD stage motion and camera controls

1.4.2.2.7.5 Integrate Components

Integration of motor, encoder, drivers and cables along with software for a complete motion control subsystem for the EBD station and camera controls, including the integration of all motion components used in the EBD station and camera controls. This includes the motor and encoder interfaces, the motor drivers and the cables. Also included are the control software design and implementation as well as system testing.

1.4.2.3 Signal Analysis

This element includes all signal analysis done for data acquisition and beam analysis within the LCLS undulator. All signal acquisition hardware and software for signal analysis is included in this element. Effort for data analysis and control is also included.

1.4.2.3.1 RFBPM

This element consists of the hardware and software required to interface the RFBPM units to the control system. All hardware and software required for interfacing the RFBPM units to the control system is included within this element. This includes the timing interface, signal acquisition and control software.

1.4.2.3.1.1 Unused

1.4.2.3.1.2 Signal Acquisition

Analog to digital conversion for acquiring RFBPM signals. This covers the specification, testing and procurement of the ADC interface used to acquire RFBPM data.

1.4.2.3.1.3 Timing Interface

This section designates the Timing board to interface with SLAC timing system and trigger acquisition of RFBPM signals. It covers the design of the timing electronics needed for the RFBPM trigger circuitry.

1.4.2.3.1.4 Cabling

These are Low level signal cables. This section covers the specification and procurement of the low level RFBPM signal cables to connect the BPM signal conditioning electronics to the ADC modules.

1.4.2.3.1.5 Integrate Components

Integration of RFBPM front-end electronics to ADC hardware via cables; includes software design to perform data analysis. This section covers the integration of all RFPBM signals into the control system. It includes the development of the BPM software and integration with the SLAC control system.

1.4.2.3.2 Charge Monitor

This element consists of effort involved in interfacing the charge monitors into the undulator control system. All effort involved in the interfacing of the charge monitor into the undulator control system will be tracked in this element.

1.4.2.3.2.1 Unused

1.4.2.3.2.2 Unused

1.4.2.3.2.3 Integrate Components

Integration of charge monitor with the undulator control system. The element includes software design to perform data analysis.

1.4.2.3.3 Scanning Wire

This covers the integration of the scanning wire transducer into the undulator control system. All effort involved in interfacing the scanning wire transducer into the undulator control system will be tracked in this element.

1.4.2.3.3.1 Unused

1.4.2.3.3.2 Unused

1.4.2.3.3.3 Unused

1.4.2.3.3.4 Unused

1.4.2.3.3.5 Unused

1.4.2.3.3.6 Integrate Components

Integration of motor, encoder, drivers and cables along with software for a complete motion control subsystem for the scanning wire transducer. Costs in this element cover the integration of all motion components used in the scanning wire motion. This includes the motor and encoder interfaces, the motor drivers and the cables. Also included are the control software design and implementation as well as system testing.

1.4.2.4 Video

All video requirements for the undulator control system. Any effort or materials required for video signal acquisition, routing and analysis are tracked within this element.

1.4.2.4.1 OTR Monitor

All video requirements needed for the OTR Monitor. Any video requirements for use of the OTR diagnostic within the LCLS undulator will be tracked in this element. The OTR diagnostic uses image capture (via video cameras) and data analysis to characterize the beam (size, position, shape) in real time.

1.4.2.4.1.1 Camera

Specification and procurement of the OTR camera, including costs to cover the specification, testing and procurement of the CCD cameras to be used in the OTR diagnostic stages. A high-resolution CCD camera to be used for image capture of the OTR diagnostics. This camera must be capable of capturing images up to 30Hz.

1.4.2.4.1.2 Camera Trigger Interface

This element tasks the Camera interface for connection to the image capturing system. It includes the costs to cover the specification, testing and procurement of the camerlink interface from the CCD camera to the video digitizing system. A camerlink camera requires dedicated hardware for interfacing to commercial digitizing hardware.

1.4.2.4.1.3 Digitizer

Video digitizer used to export OTR data to the control system. The costs cover the specification, testing and procurement of the video digitizing subsystem. A PCI-based digitizing system will be used based on standard COTS PC platform.

1.4.2.4.1.4 Timing Interface

This element designates the Timing board to interface with SLAC timing system and trigger acquisition of OTC video capture. It covers the design costs of the timing electronics needed for the video capture trigger circuitry. Design of the video capture timing requirements will be used to drive the SLAC/EPICS timing modules.

1.4.2.4.1.5 Cabling

Cables required for OTR video monitor. The costs cover the specification, testing and procurement of the video cables to be used with OTR applications within the UCS.

1.4.2.4.1.6 Integrate Components

This section covers the Integration of the OTR video capture and analysis subsystem. The costs include the integration of the video capture, analysis and multiplexing of the OTR video signal.

1.4.2.4.2 Unused

1.4.2.4.3 Observation Station Video

This element consists of all controls responsibilities for the observation stations. All control effort for the observation video stations will be tracked in this element. Also, the video multiplexing system will be tracked here.

1.4.2.4.3.1 Camera

This element covers the specification and procurement of the observation camera. The covered costs are the specification, testing and procurement of the CCD cameras to be used to monitor certain areas of the undulator hall and components. A color video camera with pan/tilt and zoom capabilities.

1.4.2.4.3.2 Camera Trigger Interface

This section tasks the trigger interface for the observation video camera. Costs include the labor involved in testing and integrating the observation video camera with the multiplexer.

1.4.2.4.3.3 Multiplexer

This section tasks the video multiplexer specification and procurement. The costs cover the specification, procurement, testing and integration of the undulator video multiplexing system.

1.4.2.4.3.4 Cabling

This section describes cables required for observation video system. The costs cover the specification, testing and procurement of the video cables to be used with observation applications within the UCS.

1.4.2.4.3.5 Integrate Components

This element covers the integration of the observation video subsystem. The costs cover the integration of the video multiplexing of the observation video signal. Control of the video multiplexer via the UCS will allow control of video source and destinations to and from a variety of locations within the LCLS.

1.4.2.5 Data Acquisition and Control

This element covers the various I/O that is not covered in previous elements but is a part of the control system. In general the costs underneath this section are effort only. If hardware is required, it is typically for reading of discrete signals. This consists of the specification and integration of general signals into the control system.

1.4.2.5.1 Strongback Temperature Monitoring

Consists of the software required to communicate to the strongback temperature probes. The costs cover the effort involved in interfacing the strongback temperature monitoring equipment to the undulator control system. This consists mainly of effort involved in creating software to talk to the temperature equipment.

1.4.2.5.1.1 Integrate Components

Integration of the temperature transducers on the undulator strongback into the UCS. The costs cover the software design and effort for integrating two channels of temperature information per strongback into the control system. Data acquisition of the temperature monitoring system attached to the undulator strongbacks.

1.4.2.6 Vacuum

This is the overall element covering any controls tasks involved in interfacing the vacuum equipment. This is a parent to the other (specific) vacuum controls tasks. It consists of software effort to interface commercial vacuum components.

1.4.2.6.1 Ion Pump Controller

Integration of the ion pump controllers into the undulator control system (UCS). The costs cover the software design and effort for integrating the ion pump controllers to be used within the undulator hall. Readback and control of the ion pump controllers via dedicated communications cables.

1.4.2.6.1.1 Integrate Components

Integration of the ion pump controllers into the UCS. The costs cover the software design and effort for integrating the ion pump controllers to be used within the undulator hall. Readback and control of the ion pump controllers via dedicated communications cables.

1.4.2.6.2 Unused

1.4.2.6.3 Unused

1.4.2.6.4 RGA

Integration of the residual gas analyzer controllers into the undulator control system. The costs cover the software design and effort for integrating the residual gas analyzers to be used within the undulator hall.

1.4.2.6.4.1 Integrate Components

Integration of the RGA controllers into the UCS. The costs cover the software design and effort for integrating the residual gas analyzers to be used within the undulator hall. Readback and control of the RGAs via dedicated communications cables.

1.4.2.7 Machine Protection

All MPS components and effort will fall under this category. The MPS system is responsible for protecting the undulator hall from equipment damage. It must interface to the SLAC injector to cause a beam abort in event of a failure.

1.4.2.7.1 Undulator Global MPS

This element covers the design of necessary components and the interface effort for commercial products into the machine protection system. This includes any custom hardware required and the interface effort for equipment.

1.4.2.7.1.1 Hardware Design

The costs cover the design, testing, assembly and procurement of the hardware necessary to protect the undulator. Any device which participates in the undulator machine protection system will have an input via this hardware.

1.4.2.7.1.2 Interface Components

This section covers the design, testing, assembly and procurement of the hardware necessary to interface the undulator protection system to the SLAC MPS. All signals required by the SLAC machine protection system will be provided by this hardware.

1.4.2.7.2 Cerenkov Detector

All effort and materials devoted to the MPS portion of the Cerenkov detector will be tracked within this element. The Cerenkov detector generates a signal which must be processed to interface to the machine protection system.

1.4.2.7.2.1 Signal Interface

This includes the design, testing, assembly and procurement of the hardware necessary to interface the Cerenkov detectors to the undulator machine protection system.

1.4.2.7.3 Gamma-Ray Detector

All effort and materials devoted to the MPS portion of the gamma-ray detector will be tracked within this element. The gamma-ray detector generates a signal which must be processed to interface to the machine protection system.

1.4.2.7.3.1 Signal Interface

This includes the design, testing, assembly and procurement of the hardware necessary to interface the gamma ray detectors to the undulator machine protection system.

1.4.2.7.4 Chamber Temperature

All effort and materials used to interface the temperature monitoring equipment to the machine protection system will be tracked in this element.

1.4.2.7.4.1 Signal Interface

This includes the design, testing, assembly and procurement of the hardware necessary to interface the temperature detectors to the undulator machine protection system.

1.4.3 Undulator Magnet and Support

The LCLS undulator magnets and supports, including integration and installation are included within this area.

1.4.3.1 Undulator Magnet & Support – Management and Integration

Management and integration of the undulator design, construction, installation, and commissioning efforts.

1.4.3.2 First Prototype Undulator and Mfg. Plan

This section covers the design, construction, testing, and modification of a full-scale prototype undulator magnetic structure. Reviews and reporting efforts are included within this area. A plan for acquiring the LCLS production undulators is to be developed.

1.4.3.3 1st Article Undulators and Long Lead Procurements

Procurement of the long lead items, Titanium Strongbacks, Magnet Blocks, and Magnet Poles is in this area. The first articles from each vendor of the production undulators are also contained herein.

1.4.3.3.1 Titanium Strongback [LLP]

Procurement of Long Lead Items: Titanium Strongbacks. This covers the labor and materials for 33 production devices. Additionally, there are 7 operational spares, located in WBS 2.4.3.3.1. This cost includes effort for design, procurement, testing and receiving of these units.

1.4.3.3.2 Magnet Blocks [LLP]

Magnet blocks for the 33 installed undulators, plus 5% extra construction/assembly spares. Blocks for the 7 operational spare undulators are located in WBS 2.4.3.3.2. This covers the labor and materials for enough magnet blocks to fabricate 33 production undulators, and includes 5% spares to cover those that are likely to be broken during assembly. Additionally, there are enough blocks for 7 operational spare undulators, without the 5% spare count, located in WBS 2.4.3.3.2. This cost includes effort for design, procurement, testing and receiving of these units.

1.4.3.3.3 Magnet Poles [LLP]

Magnet poles for the 33 installed undulators, plus 5% extra construction/assembly spares. Poles for the 7 operational spare undulators are located in WBS 2.4.3.3.3

1.4.3.3.4 Magnet Assembly and Supports – 1st Articles

Assembly of the first article undulators from each vendor is included within this WBS area.

1.4.3.3.5 Magnetic Measurement (ANL or SLAC)

Magnetic measurement and tuning of the 1st article production undulators is included within this WBS area.

1.4.3.4 Production Undulator

Procurement, magnetic measurement, and tuning are included in this area.

1.4.3.4.1 Magnet Assembly and Supports

Magnet Assembly and Supports – Assembly of 31 Production Undulators and Supports (Assembly of the 7 operational Spare Units is listed under WBS 2.4.3.4.1).

1.4.3.4.2 Unused

1.4.3.5 Focusing Magnets

Focusing Magnets – 34 quadrupole magnets and supports; 4 spares are in 2.4.3.5.

1.4.3.5.1 Quadrupoles

Focusing magnets – 34 quadrupole magnets and supports; 4 spares are in 2.4.3.5.1

1.4.3.5.2 Unused

1.4.3.6 Undulator Magnetic Measurement Facility (SLAC)

1.4.3.6.1 Undulator MMF Setup

1.4.3.6.1.1 Undulator Test Stand Prototype

The undulator test stand prototype is the development bed for the new full length test stand. It serves mainly for testing hardware and the process control and analysis software. (For definition of "Undulator Test Stand" see 1.4.3.6.1.4.

1.4.3.6.1.2 Unused

1.4.3.6.1.3 Unused

1.4.3.6.1.4 Undulator Test Stand

The undulator test stand is a setup which facilitates the measurements of magnetic properties of a permanent magnet based undulator to very high accuracy. The key component is the ability to position the sensor in the 3-D space of the entire magnet gap volume to within few µm deviations. The test stand is used to tune the undulator segments to the required specifications.

1.4.3.6.1.5 Undulator Fiducialization

In the fiducialization process, the magnetic axis of an undulator segment is determined and subsequently referenced onto physical fiducials. A combination of magnetic measurements and mechanical measurements on a Coordinate Measurement Machine are used.

1.4.3.6.1.6 Quad Strength and Field Quality

This set-up uses a vibrating wire method to determine the quadrupole field strength and quality.

1.4.3.6.1.7 Quad Fiducialization System

In the fiducialization process, the magnetic axis of a quadrupole is determined and subsequently referenced onto physical fiducials. A combination of magnetic measurements and mechanical measurements on a Coordinate Measurement Machine are used.

1.4.3.6.1.8 Hall Probe Calibration System

The undulator field measurements are carried out using Hall Probe sensors. These sensors are calibrated to absolute standards by comparing their read-out against NMR probes. The NMR probes have a 10 fold higher intrinsic accuracy and have a traceable calibration record.

1.4.3.6.1.9 Undulator Handling

Rigging systems are setup to facilitate the receiving, storage and set-up of undulator segments in the Magnetic Measurements Facility.

1.4.3.6.2 Fiducialization and Magnetic Measurements

The magnetic properties of all beam-steering components are measured using the LCLS Magnetic Measurements Facility. Additionally, the magnetic axes of these components are referenced to mechanical fiducials used for alignment.

1.4.3.6.2.1 F/MM Undulator Magnet Sections

The undulator sections as received from fabrication need to be magnetically qualified and subsequently tuned to meet the undulator magnet specifications. Secondly, the magnetic axis of each segment is determined and referenced to mechanical fiducials.

1.4.3.6.2.2 F/MM Quadrupoles

The quadrupoles as received from fabrication are magnetically qualified and subsequently the magnetic axis of each magnet is determined and referenced to mechanical fiducials.

1.4.3.6.2.3 F/MM BPMs

The electrical axis of each BPM is determined and referenced to mechanical fiducials.

1.4.3.6.2.4 F/MM Correctors

The corrector magnets as received from fabrication are magnetically qualified and subsequently the magnetic axis of each magnet is determined and referenced to mechanical fiducials.

1.4.3.6.2.5 F/MM Vacuum Chambers

The mechanical axis of each Vacuum Chamber is determined and referenced to mechanical fiducials.

1.4.3.6.2.6 F/MM Photon Diagnostics Components

1.4.3.6.3 Undulator Monitoring

1.4.3.6.3.1 Stretched Wire System

A stretched wire system is installed to monitor the horizontal motion of individual undulator segments.

1.4.3.6.3.2 Hydrostatic Level System

A hydrostatic level system is employed to monitor the vertical motion of undulator segments and their support tables.

1.4.3.7 Unused

1.4.3.8 Fixed Supports

This system provides an ultra-stable non-adjustable support platform for the majority of the undulator system components.

1.4.3.8.1 Fixed Support Management and Integration

This section covers the effort to organize the design, fabrication/procurement and installation and test of the system, and report to the undulator system manager.

1.4.3.8.2 Fixed Support Design

All design work for this system is put in this WBS category.

1.4.3.8.3 Stabilized Girder Assemblies

Long insulated granite beams, joined together in the tunnel. This is the primary piece of fixed support system.

1.4.3.8.4 Thermal Intercept System

This section covers the costs of the system that surrounds the girder insulation and intercepts heat from the environment and sends it to chilled water.

1.4.3.8.5 Thermometry

This category refers to thermometry monitoring the temperature of parts of the girder. It does not cover the costs for the system used for the control of the thermal intercept water.

1.4.3.8.6 Kinematic Girder Support

This element covers the cost of a rolling support for the girder that is kinematic and low friction.

1.4.3.8.7 Earthquake Bracing

Welded assemblies bolted or built into the floor that limit the motion of the girder in the event of an earthquake, but do not touch the girder otherwise.

1.4.3.8.8 Controls and Software

The cost of controls to read the temperature, and valve position data and present the data to the SLC control system. This software calculates the changes in girder positions and implied changes in bpm, quad, and undulator positions, by taking data from the HLS and WAS systems.

1.4.4 Vacuum System

This is the Total Center for Vacuum System in the Undulator System to deliver a functional vacuum system for the Undulator System within LCLS. The Vacuum System and related equipment includes the effort required for procuring the technical equipment, including specification review, oversight of the bid process, issue of purchase requests, and billing. This center includes all vacuum components from the upstream treaty valve to the downstream treaty valve.

1.4.4.1 Unused

1.4.4.2 Undulator Vacuum Chamber Assembly

Total Center for Undulator Chamber Assembly in the Vacuum System in the Undulator System. The Undulator Vacuum Chamber is an assembly that resides within the Undulator Magnet. It is designed to contain the electron beam and the produced x-ray beam under vacuum within its walls with little interaction to the beam. Undulator Vacuum Chamber Assembly and related equipment includes the effort required for procuring the technical equipment, including specification review, design, oversight of the bid process, issue of purchase requests, and billing.

1.4.4.2.1 Prototype Chamber Weldment

Total cost of (2) Prototype Undulator Vacuum Chambers that includes: design, procurement, quality assurance, and testing. This element includes material and labor charges. Prototype Chamber Weldment and related equipment includes the effort required for procuring the technical equipment, including specification review, oversight of the bid process, issue of purchase requests, and billing. The (2) prototypes will be used to qualify both the design and the materials selection for the Production Vacuum Chamber.

1.4.4.2.2 Production Chamber Weldment

Total cost of (34) Production Undulator Vacuum Chambers including: design, procurement, quality assurance, and testing. This element includes material and labor charges. Production Chamber Weldment and related equipment includes the effort required for procuring the technical equipment, including specification review, design, oversight of the bid process, issue of purchase requests, and billing. The chambers will be in a state ready for installation when they are shipped from ANL to SLAC.

1.4.4.3 Beam-line Bellows Module Assembly

Total Center for Bellows Assembly in the Vacuum System in the Undulator System. The Beam-line Bellows are placed in the spaces between the undulators. The Bellows assembly contains both a barrier for vacuum and a liner (channel) for the beam to follow. Beam-line Bellows Module Assembly and related equipment includes the effort required for procuring the technical equipment, including specification review, oversight of the bid process, issue of purchase requests, and billing.

1.4.4.3.1 Prototype Bellows Module

Total cost of (3) Prototype Bellows Modules including: design, procurement, quality assurance, and testing. This element includes material and labor charges. The (3) prototypes will be used to qualify both the design and the materials selection for the Production Bellows Module.

1.4.4.3.2 Production Bellows Module

Total cost of (47) Production Bellows Modules including: design, procurement, quality assurance, and testing. This element includes material and labor charges. The (47) Production Bellows Modules will be used in the Short and Long Diagnostics Breaks along with the Entrance and Exit Sections.

1.4.4.4 Unused

1.4.4.5 Short Diagnostic Break (SDB) Assembly

Total Center for (23) Short Diagnostic Break Assembly in the Vacuum System in the Undulator System. This center includes: design, procurement, quality assurance, and testing. This element includes material and labor charges. The Short Diagnostics Break is that set of vacuum components that reside within the smaller breaks between the undulator magnets. This is also the assembly that includes both diagnostics devices and vacuum components, although the costing of these items will be found in other places in the WBS.

1.4.4.6 Long Diagnostic Break (LDB) Assembly

Total Center for (11) Long Diagnostic Break Assembly in the Vacuum System in the Undulator System. The Long Diagnostics Break is that set of vacuum components that reside within the larger breaks between the undulator magnets.

1.4.4.7 Entrance Section Assembly

Total Center for (1) Entrance Section Assembly in the Vacuum System in the Undulator System. The Entrance Section Assembly is composed of diagnostic devices and vacuum components that reside in the area that starts at the upstream treaty valve and ends at the first undulator.

1.4.4.8 Exit Section Assembly

Total Center for (1) Exit Section Assembly in the Vacuum System in the Undulator System. The Exit Section Assembly is composed of diagnostic devices and vacuum components that reside in the area that starts at the end of the undulator to the downstream treaty valve.

1.4.4. 9 Baking System

Total Center for Baking System in the Vacuum System in the Undulator System. This element covers the labor and materials for the baking system for vacuum components going into the undulator vacuum system. This includes effort for design, procurement, and receiving of these units. Baking System and related equipment includes the effort required for procuring the technical equipment, including specification review, oversight of the bid process, issue of purchase requests, and billing.

1.4.5 Diagnostics

Deliver a functional Diagnostics for the Undulator System within LCLS. This center includes all diagnostics devices from the upstream treaty valve to the downstream treaty valve.

1.4.5.1 Unused

1.4.5.2 E-Beam and X-Ray Profile Diagnostics

Total Center for the E-Beam and X-Ray Diagnostics for the Undulator System. This element covers the labor and materials for this center. This includes effort for design, procurement, testing and receiving of the units. This center contains the intra-undulator diagnostics that reside within the diagnostics station that are placed in the (11) Long Diagnostics Breaks.

1.4.5.2.1 EBXPD Test Station

This element covers the labor and materials for making the (1) EBXPD Test Station. This includes effort for design, procurement, testing and receiving of this unit. The Test Station will be used along with the prototypes of the scanning wire, OTR, x-ray imaging, x-ray intensity, and monochromator to test the sub-systems in a beam line.

1.4.5.2.2 EBXPD Vacuum Chamber

This element covers the labor and materials for the group of (11) production vacuum chambers. This includes effort for design, procurement, testing and receiving of the units. The EBXPD Vacuum Chamber is the housing where the production type EBXPD Diagnostics are contained.

1.4.5.2.3 Positioning Mechanism

The Positioning Mechanism is a device for moving from one diagnostic device to another within the EBXPD Diagnostics Station. This cost element covers the labor and materials for prototype related work and the group of (11) production devices. This includes effort for design, procurement, testing and receiving of the units.

1.4.5.2.4 Scanning Wire Assembly (EBXPD-SWA)

The Scanning Wire, also called wire scanner, will be used to measure the overlap of the electron beam and the x-ray beam.

1.4.5.2.5 Optical Transition Radiation (OTR) Imaging Assembly

The OTR is used to produce an image of the electron beam to characterize its size and shape, this is needed for beam tuning purposes. This element covers the labor and materials for prototype related work and the group of (11) production devices. This includes effort for design, procurement, testing and receiving of the units.

1.4.5.2.6 Unused

1.4.5.2.7 Unused

1.4.5.2.8 Unused

1.4.5.2.9 EBXPD Design & Integration

This element represents the integration of the subsystems, like OTR and scanning wire, into the EBXPD station. There will be (11) EBXPD Stations produced for the LCLS Undulator System and this unit cover the integration of the sub-systems into the station. The element includes design, procurement, quality assurance, lab testing, and shipment to SLAC.

1.4.5.3 Unused

1.4.5.4 End-of-Undulator (EOU) Diagnostics & Profile Diagnostics

The End of Undulator Diagnostics is an important area where studies and simulations are being conducted to best utilize the area. Total Center for the End-of-Undulator Diagnostics for the Undulator System. There will be just a single suite of EOU diagnostics.

1.4.5.4.1 Prototype Construction and Testing

This element covers the labor and materials for the fixtures related to testing the (1) EOU prototype. This includes effort for design, procurement, testing and receiving of the fixtures and test pieces for the EOU prototype test.

1.4.5.4.2 Bunch Length Monitor-Streak Camera

The Bunch Length Monitor will take the form of a streak camera that will measure the length of the generated x-ray pulse. This element covers the labor and materials for prototype related work and a single (1) production device. This includes effort for design, procurement, testing and receiving of the units.

1.4.5.4.3 Upstream Corrector / Separator

These are magnets used to separate the electron beam from the x-ray beam by a small magnetic bump. This element covers the labor and materials for prototype related work and a single (1) production device. This includes effort for design, procurement, testing and receiving of the units.

1.4.5.4.4 Optical Diffraction Radiation Imaging Assembly

Similar to OTR, ODR is used to produce an image the electron beam to understand its size and shape, this is needed for beam tuning purposes. ODR is different from OTR in that ODR produces an image from the fringe of the beam rather than a direct beam strike onto a screen. ODR is used in higher power application than OTR. This element covers the labor and materials for prototype related work and a single (1) production device. This includes effort for design, procurement, testing and receiving of the units.

1.4.5.4.5 X-Ray High Resolution Monochromator Assembly

The monochromator will be used to measure the x-ray strength over a narrow range of wavelengths. This element covers the labor and materials for prototype related work and a single (1) production device. This includes effort for design, procurement, testing and receiving of the units.

1.4.5.4.6 X-Ray Imaging High Resolution Detector Assembly

This device will be used to form an image of the generated x-ray beam to understand if there are shape changes occurring down the undulator beam line. This element covers the labor and materials for prototype related work and a single (1) production device. This includes effort for design, procurement, testing and receiving of the units.

1.4.5.4.7 EOU Design and Integration

This element represents the integration of the subsystems, like ODR and bunch length monitor, into the EOU station. There will be (1) unit produced for the LCLS Undulator System. The element includes design, procurement, quality assurance, lab testing, and shipment to SLAC.

1.4.5.5 RFBPM

The RFBPM will be used to precisely measure the position of the electron beam in all the breaks between the undulators. Total Center for RFBPM Diagnostics for the Undulator System. This element covers the labor and materials for (3) prototypes and a group of (35) production devices. This includes effort for design, procurement, testing and receiving of the units.

1.4.5.6 Unused

1.4.5.7 Charge Monitor (CM)

The charge monitor that is located at the end of the undulator system is used to measure the amount of charge that is in each electron beam bunch. Total Center for Charge Monitor Diagnostics for the Undulator System. This element covers the labor and materials for a group of (2) production devices. This includes effort for design, procurement, testing and receiving of the units.

1.4.5.8 Cerenkov Detector

The Cerenkov Detector is used to measure Cerenkov radiation that is generated when the electron beam unintentionally strikes something. This is part of the machine protection system. Total Center for Cerenkov Detector Diagnostics for the Undulator System. This element covers the labor and materials for a group of (35) production devices. This includes effort for design, procurement, testing and receiving of the units.

1.4.5.9 Radiation Detection Monitor (RDM)

Radiation Detection Monitor is a gamma ray detector and is part of the machine protection system. RDM and related equipment includes the effort required for procuring the technical equipment, including specification review, oversight of the bid process, issue of purchase requests, and billing. This element covers the labor and materials for a single (1) production device. This includes effort for design, procurement, testing and receiving of this unit.

1.4.5.10 Unused

1.4.5.11 Supplemental Shielding

Total Center for the Diagnostics Supplemental Shielding for the Undulator System. This element covers the labor and materials for a group of supplemental shielding for diagnostics devices and electronics stationed in the undulator tunnel. This includes effort for design, procurement, and receiving of these units.

1.4.6 Undulator System Installation and Alignment

Following beneficial occupancy of the LCLS undulator hall all technical equipment, fixed supports, undulators and quadrupole magnets, diagnostics, vacuum systems, and controls system, will be moved into the undulator hall, installed, basic checkout performed, and if required aligned to the stated position and accuracy. Total cost center for all M&S and effort, management oversight, technical and other labor, required for the LCLS undulator system installation, basic checkout, and alignment tasks.

1.4.6.1 Undulator System Installation and Alignment Integrat

This WBS element covers all installation and alignment oversight and integration tasks along with their required M&S needed to support the overall installation and alignment of the LCLS undulator system at SLAC. Total cost center covering the oversight and integration oversight of all installation and alignment tasks of the LCLS undulator system; in particular, the entrance section, the exit section, and ancillary needs of the various other components are covered by this cost center.

1.4.6.1.1 Undulator System

To oversee the installation and integration of the LCLS undulator beam line system and related equipment. This includes the effort for all integration and oversight of the installation for the system from the end of the LCLS undulator entrance section to the entrance of the

LCLS undulator exit section. Total cost center for the integration and installation oversight of the LCLS undulator system at SLAC. This element covers the labor for installation oversight and system integration of components in the undulator beam-line system. This includes effort from both ANL and SLAC.

1.4.6.1.2 Entrance Section

The Entrance Section is situated between the Treaty Valve and the first undulator magnet and it includes a collection of vacuum components, diagnostic devices and their supports. Total cost center for the installation of the Entrance Section of the Undulator System at SLAC. This element covers the labor for installing components in the Entrance Section going into the undulator beam-line system. This includes effort from both ANL and SLAC.

1.4.6.1.3 Exit Section

Exit Section and related equipment includes the effort required for installing it into the LCLS beam-line. The Exit Section is situated between the last undulator magnet and the Treaty Valve and it includes a collection of vacuum components and diagnostic devices. Total cost center for the installation of the Exit Section of the Undulator System at SLAC. This element covers the labor for installing components in the Exit Section going into the undulator beam-line system. This includes effort from both ANL and SLAC.

1.4.6.2 Control System Installation and Alignment

The control system installation will be done as the pieces to be controlled are installed - in a phased approach. Checkout will be done when specific modules are in place and testing will be productive. All costs involved in the installation and checkout of the undulator control system will be tracked within this element.

1.4.6.3 Magnet and Supports Installation and Alignment

This area covers all additional interface issues between the undulators, quadrupoles, and their associated fixture to the fixed support system as well as installation and alignment of the various items to one another. Total cost center for the installation and alignment of the LCLS undulator system magnets and fixed supports. This element covers the labor for this installation process.

1.4.6.3.1 Magnets Installation and Alignment

Installation and Alignment of the undulator magnets and quadrupoles. This cost center covers all costs associated with the installation and alignment of all magnet elements onto the fixed support system.

1.4.6.3.2 Fixed Supports Installation and Alignment

Fixed Supports Installation and Alignment. This cost center covers all costs associated with the installation and alignment of all magnet elements onto the fixed support system.

1.4.6.4 Vacuum System Installation and Alignment

This element contains the individual effort for transporting the vacuum system into the LCLS undulator tunnel and installing the different vacuum components in the Undulator System. Installation, integration, and checkout of bellows, pumps, vacuum gauges, residual gas analyzers, pump-out valves, and gate valves will be worked on in this element. Total Center for the installation of the Vacuum System in the Undulator System at SLAC. This element covers the labor for vacuum components going into the undulator vacuum system.

1.4.6.5 Diagnostics System Installation and Alignment

This element contains the individual effort for transporting to the LCLS undulator hall installing and doing the operational checkout of the different diagnostics devices in the Undulator System. Installation, integration, and checkout of Charge Monitors, RF BPM's, EBXPD stations, Radiation Detectors, and Cerenkov Detectors will be worked on in this element. Total Center for the installation of the Undulator System Diagnostics at SLAC. This element covers the labor for the System Diagnostics for the different devices, like EBXPD station and RFBPB, going into the undulator system. This includes effort from both ANL and SLAC.

2. LCLS PROJECT: R&D, SPARES & COMMISSIONING

2.4 Undulator System (OPC)

The LCLS Undulator System OPC area for spares plus any R&D and commissioning for all elements including undulator magnets and supports, undulator diagnostics, vacuum systems, and controls for the undulator equipment are included herein. Total cost for the LCLS undulator system Other Project Costs (OPC) including R&D, spares, and commissioning.

2.4.1 Undulator System Management and Integration

All LCLS Undulator Systems project management and commissioning oversight for Other Project Costs (OPC) items is covered by this element. Total cost of all project management and commissioning oversight tasks required to perform R&D, commissioning or oversight of the acquisition of spares is included in this element.

2.4.2 Controls [OPC]

All controls related spares and OPC. Any spares purchased for controls are tracked underneath this element.

2.4.2.1 Controls Management and Integration [OPC]

Management and integration tasks associated with spares and OPC. Any management effort associated with control spares and OPC will be tracked within this element.

2.4.2.2 Motion [OPC]

Controls spares to support the motion platforms. Any spares required for the motion platforms within the undulator will be tracked in this element. This consists of 10% spares for all motion components.

2.4.2.3 Signal Analysis [OPC]

Controls spares to support signal analysis platforms. Any spares required for the signal analysis applications within the undulator will be tracked in this element. This consists of 10% spares for all signal analysis components.

2.4.2.4 Video [OPC]

Controls spares for the video components of the undulator. Any spares required for the video subsystems within the undulator will be tracked in this element. This consists of 10% spares for all motion components.

2.4.2.5 Data Acquisition and Control [OPC]

Controls spares to support the data acquisition requirements. Any spares required for data acquisition applications within the undulator will be tracked in this element. This consists of 10% spares for all components.

2.4.2.6 Vacuum [OPC]

Controls spares to support vacuum controls. Any spares required for the control of the vacuum equipment within the undulator will be tracked in this element. This consists of 10% spares for all components.

2.4.2.7 Machine Protection [OPC]

Controls spares to support the machine protection system of the LCLS undulator. Any spares required for the machine protection system of the undulator will be tracked in this element. This consists of 10% spares for all components.

2.4.3 Undulator Magnet and Support

Other Project Costs [OPC] are collected in this WBS area. This WBS area includes some management, integration, as well as the construction and assembly of spare undulators.

2.4.3.1 UND Magnet Support – Management and Integration

Other Project Costs [OPC] related to the undulators are collected in this WBS area. This WBS area includes some management, integration.

2.4.3.2 First Prototype Undulator and Manufacturing Plan

Other Project Costs [OPC] related to the undulators are collected in this WBS. Specifically, this area contains elements related to construction of the first prototype undulator and development of a manufacturing plan. Specifically, this area contains elements related to construction of the first prototype undulator and development of a manufacturing plan.

2.4.3.3 First Article Undulators and Long Lead Procurements

Other Project Costs [OPC] related to the undulators are collected in this WBS. Specifically, this area contains elements related to construction of the first article undulators and long lead procurements. Specifically, this area contains elements related to construction of the first article undulators and long lead procurements.

2.4.3.3.1 Titanium Strongback [LLP] – Operational Spares

This element covers the labor and materials for 7 operational spare units. Additionally, there are 33 production devices, located in WBS 1.4.3.3.1. This cost includes effort for design, procurement, testing and receiving of these units. There are 33 active undulators in the LCLS, with an additional seven operational spares, making a total of 40 devices.

2.4.3.3.2 Magnet Blocks [LLP] – Operational Spare Undulators

This element covers the labor and vendor cost for 5% of the number of magnet blocks required to fabricate 33 production undulators, covering those that are likely to be broken during undulator assembly. Additionally, there are enough blocks for 7 operational spare undulators, without the 5% spare count, located in WBS 2.4.3.3.2. This cost includes effort for design, procurement, testing and receiving of these units.

2.4.3.3.3 Magnet Poles [LLP] - Operational Spare Undulators

2.4.3.3.4

2.4.3.3.5 Focusing Magnets - Quadrupoles - Spares

4 spare permanent magnet quadrupoles with precision movers.

2.4.3.4 Production Undulator

This area contains elements related to construction of the Production Undulators.

2.4.3.5 Focusing Magnets

This area contains elements related to construction of the 4 spare Focusing Magnets with precision movers.

2.4.3.6 Undulator Magnetic Measurement Facility [SLAC]

This area contains elements related to construction of the Undulator Magnetic Measurement Facility [SLAC].

2.4.3.7 Unused

2.4.3.8 Fixed Supports

This area contains elements related to construction of the Fixed Supports.

2.4.4 Vacuum System [OPC]

Total Center for the OPC Spares of the Undulator Vacuum System. This center includes all vacuum components from the upstream treaty valve to the downstream treaty valve.

2.4.4.1 Unused

2.4.4.2 Undulator Vacuum Chamber Assembly [OPC]

Total Center for the spare Undulator Vacuum Chamber and supports for the Undulator System. This element covers the labor and materials for (7) spare chambers and (4) spare supports. This includes effort for procurement and receiving of the unit.

2.4.4.3 Beam-Line Bellows Module Assembly [OPC]

This element covers the labor and materials for (7) spares. This includes effort for procurement and receiving of the unit. The (7) spare Bellows Modules will be used in the Short and Long Diagnostics Breaks along with the Entrance and Exit Sections.

2.4.4.4 Unused

2.4.4.5 Short Diagnostics Break (SDB) Assembly [OPC]

The SDB Assembly is composed of diagnostic devices and vacuum components that reside in the area of the short breaks between the undulators. SDB Assembly and related equipment includes the effort required for procuring the technical equipment including issuing of purchase requests and billing.

2.4.4.6 Long Diagnostics Break (LDB) Assembly [OPC]

The LDB Assembly is composed of diagnostic devices and vacuum components that reside in the area of the long breaks between the undulators. LDB Assembly and related equipment includes the effort required for procuring the technical equipment including issuing of purchase requests and billing.

2.4.4.7 Entrance Section Assembly [OPC]

The Entrance Section Assembly is composed of diagnostic devices and vacuum components that reside in the area that starts at the upstream treaty valve and ends at the first undulator. Entrance Section Assembly and related equipment includes the effort required for procuring the technical equipment including issuing of purchase requests and billing.

2.4.4.8 Exit Section Assembly [OPC]

The Exit Section Assembly is composed of diagnostic devices and vacuum components that reside in the area that starts at the end of the undulator to the downstream treaty valve. Exit Section Assembly and related equipment includes the effort required for procuring the technical equipment, including issuing of purchase requests and billing.

2.4.4. 9 Unused

2.4.5 Undulator System Diagnostics [OPC]

Total Center for the OPC Spares of the Undulator System

2.4.5.1 Unused

2.4.5.2 E-Beam and X-Ray Profile Diagnostics [OPC]

Total Center for spares and R&D effort in the E-Beam and X-Ray Diagnostics for the Undulator System. This center contains the intra-undulator diagnostics that reside within the diagnostics station that are placed in the Long Diagnostics Breaks.

2.4.5.3 High Power X-Ray and Profile Diagnostics [R&D]

This contains the prototype assemblies for optical diffraction radiation diagnostics and a laser wire device for measurement of high power x-ray properties. The HPPD consist of elements that will be determined after a group study is completed in mid 2005. The HPPD at this time is made up of a number of projected types of x-ray diagnostics. The laser wire and the optical diffraction radiation are two very promising types of x-ray instrumentation. These tasks will be performed as an R&D task. Total Center for High Power Diagnostics for the Undulator System. This collection of diagnostics devices will be worked on as an R&D activity. This area provides for one prototype of each type to be built and tested.

2.4.5.4 End-of-Undulator (EOU) X-Ray Profile Diagnostics

This effort contains the study and a workshop to help decide what will be the best course of action to pursue for the design of x-ray instrumentation. Total Center for the R&D effort in the End-of-Undulator Diagnostics for the Undulator System. This element covers the labor for this center. This includes effort for design, procurement, testing and receiving of the units.

2.4.5.5 RFBPM [OPC]

The RFBPM will be used to precisely measure the position of the electron beam in all the breaks between the undulators. Total Center for RFBPM Spares for the Undulator System. This element covers the labor and materials for (4) spares of the production devices. This includes effort for procurement and receiving of the units.

2.4.5.6 Unused

2.4.5.7 Charge Monitor [OPC]

The charge monitor that is located at the end of the undulator system is used to measure the amount of charge that is in each electron beam bunch. Total Center for the spare Charge Monitor for the Undulator System. This element covers the labor and materials for (1) spare. This includes effort for procurement and receiving of the unit.

2.4.5.8 Cerenkov Detector [OPC]

The Cerenkov Detector is used to measure Cerenkov radiation that is generated when the electron beam unintentionally strikes something. This is part of the machine protection system. Total Center for Cerenkov Detector Spares for the Undulator System. This element covers the labor and materials for (4) spares of the production devices. This includes effort for procurement and receiving of the units.

2.4.5. 9 Radiation Detection Monitor (RDM) [OPC]

This element covers the labor and materials for (1) spare. This includes effort for procurement and receiving of the unit. Total Center for the spare Radiation Detection Monitor for the Undulator System.

2.4.6 Undulator System Commissioning

Effort support for the commissioning of the LCLS undulator system. This includes support from commissioning of the controls system, the mechanical systems, and basic beam physics support during the initial turn on and commissioning of the overall LCLS system.

2.4.6.1 Undulator System Commissioning

Effort support for the commissioning of the LCLS undulator system. This includes support from commissioning of the controls system, the mechanical systems, and basic beam physics support during the initial turn on and commissioning of the overall LCLS system.

LCLS WBS DICTIONARY
1.5 X-RAY TRANSPORT OPTICS & DIAGNOSTICS SYSTEM (XTOD)

1.5 X-RAY TRANSPORT OPTICS & DIAGNOSTICS SYSTEM

XTOD includes mechanical and vacuum systems for the x-ray beam path, attenuators, x-ray optics and x-ray diagnostics required for manipulation and characterization of the x-ray beam downstream of the undulator. “Manipulation” includes collimation, attenuation, focusing, splitting/delaying, turning, and monochromatizing. “Characterization” includes measurement of x-ray beam properties as necessary for commissioning and operation of the LCLS.

1.5.1 System Management and Integration

This element provides overall management for XTOD.

1.5.1.1 Management

This element provides overall management for XTOD safety, conceptualization, R&D, design, construction, testing, installation, integration, and commissioning.

1.5.1.1.1 XTOD Management (Technical)

This covers a full time manager.

1.5.1.1.2 LLNL Project Support

This covers a half time administrator, and funding for programmatic travel to attend weekly staff meetings, recruit project staff prepare monthly reports, prepare reviews, and other required project documentation.

1.5.2 Controls

Controls captures upper-level work required to interface and integrate the LCLS system-wide control systems to the XTOD primitive controls and to provide remote access to the instrumentation in the Front End Enclosure (FEE), the Near Experimental Hall (NEH), the Tunnel, and the Far is one Hall (FEH).

1.5.2.1 Unused

1.5.2.2 Slow Controls

This element covers the development and delivery of an overlying control system for remote access to the slower instrumentation. The slower instrumentation includes valve positions, motor positions, and gas flows and pressures. The planned system will have two servers in the NEH, and one in the FEH and 3 VME crates for interface electronics.

1.5.2.3 Fast Controls

This element covers the development and delivery of an overlying control system for remote access to the faster instrumentation. This is mostly data acquisition and storage of imagery data from the sensors. Resources for this element cover the programming tasks required to select data streams from specific cameras and store them on user accessible disks.

1.5.2.4 Femto Controls

This element covers labor Engineering and parts for interfacing the very fast timing signals from the FEL to the streak camera and pulse length sensors in the commissioning Diagnostics Tank.

1.5.3 Mechanical & Vacuum Subsystem

Design pumps, pipes and stands for interconnecting the experimental tanks in the FEE, Near Hall, Tunnel and Far Hall.

1.5.3.1 Unused

1.5.3.2 Mech/Vac Front End

This covers the mechanical and vacuum specification, design, and procurement for the FEE.

1.5.3.3 Mech/Vac Near Hall

This covers the mechanical and vacuum specification, design, and procurement for the Near Hall.

1.5.3.3.1 NEH Hutch 1

This covers the mechanical and vacuum specification, design, and procurement for the NEH Hutch 1

1.5.3.3.2 NEH Hutch 2

This covers the mechanical and vacuum specification, design, and procurement for the NEH Hutch 2

1.5.3.3.3 NEH Hutch 3

This covers the mechanical and vacuum specification, design, and procurement for the NEH Hutch 3

1.5.3.4 Mech/Vac Tunnel

This covers the mechanical and vacuum specification, design, and procurement for the Tunnel.

1.5.3.5 Mech/Vac Far Hall

This covers the mechanical and vacuum specification, design, and procurement for the Far Hall.

1.5.3.5.1 FEH Hutch 1

This covers the mechanical and vacuum specification, design, and procurement for the FEH Hutch 1

1.5.3.5.2 FEH Hutch 2

This covers the mechanical and vacuum specification, design, and procurement for the FEH Hutch 2

1.5.3.5.3 FEH Hutch 3

This covers the mechanical and vacuum specification, design, and procurement for the FEH Hutch 3

1.5.4 Optical Subsystem

All elements used to manipulate the X-Ray beam.

1.5.4.1 Unused

1.5.4.2 Facility Optics

This WBS element will provide specification, design, procurement, install and testing for the fixed masks, the slits and collimators, the flipper mirror, the gas attenuator, and the solid attenuator.

1.5.4.2.1 Unused

1.5.4.2.2 Fixed Mask

The 3 Fixed Masks insure that all radiation allowed downstream is confined to within a very small angular region. The masks are cm thick blocks of hi-z material with a TBD (~4 mm) clear aperture in the center.

1.5.4.2.3 Slits and Collimators

Slit A consists of a two movable jaws defining an adjustable horizontal aperture, and two movable jaws defining an adjustable vertical aperture. The purpose of the slit is to allow the users to remove the halo of spontaneous radiation surrounding the FEL. The jaws are x-ray mirrors designed to reflect the FEL beam. This prevents the jaws from being damaged when inadvertently struck by the FEL. Slit B is similar in design and purpose to Slit A.

1.5.4.2.4 Flipper Mirror

The flipper mirrors are a set of two or more mirrors, located in a differentially pumped tank at the beginning of the tunnel. The mirrors can be set to allow the x-ray beam to be introduced into one of the 3 x-ray paths leading to the FEH.

1.5.4.2.5 Gas Attenuator

The gas attenuator is a 10 m long section of pipe filled with gas whose purpose is to attenuate the FEL beam especially at low photon energies. The gases under consideration are N2, Ar and Xe at pressures up to 150 Torr. The gas attenuator must be windowless because of damage and absorption issues with the FEL beam. This means that gas will leak into the beam pipe and must be differentially pumped.

1.5.4.2.6 Unused

1.5.4.2.7 Unused

he Al, which further attenuates the beam enough to prevent damage to the Ta.

1.5.4.2.8 Solid Attenuator

The solid attenuators reside in a vacuum tank directly downstream of the gas attenuator. The attenuators are mounted on a series of wheels inside the tank allowing various combinations of attenuators to be selected. The attenuators will be made of low-Z materials such as Be, Li, and/or

B4C in thicknesses raging from 100 microns to 5 cm. Their use is limited to photon energies above TBD (3-4 KeV) to prevent dangerous vaporization of the solids.

1.5.4.2.9 Unused

1.5.4.3 End Station Optics

This WBS element will provide specification, design, procurement, install and testing for: Optic Tanks for Near Hall.

1.5.4.3.1 Unused

1.5.4.3.2 Optic Tanks for Near Hall

This is a 1 x 2 m turbo-pumped vacuum tank to house optical elements in the NEH.

1.5.4.3.3 Unused

1.5.4.3.4 Unused

1.5.4.3.5 Unused

1.5.4.4 Crystals & Gratings

This WBS element will provide specification, design, procurement, install and testing for the System Monochrometer and the Pules Split and Delay System.

1.5.4.4.1 Unused

1.5.4.4.2 System Monochrometer

Some experiments in the FEH will require a bandwidth narrower than the intrinsic bandwidth of the FEL. The system monochrometer is a standard monochromator using Si and diamond crystals and should not suffer any damage due to the peak power.

1.5.4.4.3 Pulse Split & Delay

This system, located in the end of the tunnel, will use crystal diffraction to split the FEL pulse, direct the two x-ray pulses around unequal path lengths, and bring them back onto the primary beam path with a time delay between them. The beam splitting is accomplished by a very thin (10 µm) silicon crystal.

1.5.5 Diagnostics Subsystem

Provide diagnostics to characterize and measure beam performance for the users and the facility.

1.5.5.1 Unused

1.5.5.1.1 Unused

1.5.5.2 Modeling & Simulation

Develop Monte Carlo and Wave based numerical models of the LCLS FEL and spontaneous radiation for use in specifying diagnostics.

1.5.5.2.1 Wave Model

This element covers the development and execution of programs modeling the wave properties of the diagnostics and optical elements.

1.5.5.2.2 Monte Carlo Model

This element covers the development and execution of Monte Carlo simulations of the x-ray interactions within the diagnostics and optical elements.

1.5.5.3 Facility Diagnostics

This WBS element will provide specification, design, procurement, prototype, install and testing for the Direct Imager, Indirect Imager, Pulsed Ion Chamber, Gas Mixing System, FEE Diagnostic Tanks, Ion Pump Diagnostic Tanks.

1.5.5.3.1 Direct Imager

The Direct Imager is an insertable, high-resolution scintillator viewed by a CCD camera for measuring spatial distributions and for alignment and focusing of optical elements. The imager utilizes a thin crystal of LSO or YAG to convert x-rays into visible photons and will be damaged by the full FEL.

1.5.5.3.2 Indirect Imager

The Indirect Imager overcomes the FEL damage problems of the Direct Imager by utilizing a thin foil of a low-Z material such as Be to act as a beam splitter to partially reflect a portion of the beam onto the YAG imaging camera which remains out of the beam. The reflected intensity can be adjusted by changing the angle of incidence. The Be mirror will be damaged by the FEL if it is not at the correct angle and/or possibly at low photon energies.

1.5.5.3.3 Pulsed Ion Chamber

The windowless ion chamber is a short version of the gas attenuator operating at lower pressures and with additional electronic to measure the ionization of the gas to infer x-ray intensity.

1.5.5.3.4 Gas Mixing System

This system provides a mixture of gases to the ion chamber.

1.5.5.3.5 FEE Diagnostic Tanks

This tank is a 2 m x 1 m ss tank and vacuum system housing the imaging diagnostics and associated rails and stages for positioning them.

1.5.5.3.6 Ion Pump Diagnostic Tanks

These are smaller tanks, which are ion pumped to hold diagnostics in the FEE.

1.5.5.4 Commissioning Diagnostics

This WBS element will provide specification, design, procurement, prototype, install and testing for the Commissioning Diagnostic Tank, Total Energy Measurement, Spectral Measurement, Spatial Coherence, Spatial Shape & Centroid Measurement, and the Divergence Measurement.

1.5.5.4.1 Commissioning Diagnostic Tank

This tank is a 2 m x 1 m stainless steel tank and vacuum system housing the commissioning diagnostics and associated rails and stages for positioning them.

1.5.5.4.2 Total Energy Measurement

This calorimeter is a small volume x-ray absorber (probably Be), which absorbs all of the x-ray energy resulting in a rapid temperature rise that may be used to infer the intensity of the FEL pulse. The heat capacity and mass of the absorber determine the temperature rise.

1.5.5.4.3 Unused

1.5.5.4.4 Spectral Measurement

The commissioning diagnostic tank is converted into a spectrometer by adding a crystal at 8 keV or a grating at 0.8 keV. In either case the optic disperses the radiation onto an x-ray sensitive region of a fast readout position-sensitive detector.

1.5.5.4.5 Spatial Coherence

The transverse coherence will be measured in the commissioning diagnostics tank using the setup shown in the figure that employs an array of double slits with constant slit width but different slit spacing. The slits sample the beam in two places and the resulting diffracted beams interfere with each other at the position of the detector.

1.5.5.4.6 Spatial Shape & Centroid Measurement

The spatial shape and centroid location of the FEL beam will be measured on a pulse-by-pulse basis by the imagers located in the facility diagnostics tanks distributed along the beam lines.

1.5.5.4.7 Divergence Measurement

This measurement is performed at 8 keV using the imaging detectors located along the beam line. The measurement is performed at 0.8 keV using the Windowless Ion Chambers located along the beam line.

1.5.6 Installation and Alignment

1.5.6.1 Front-End-Enclosure Install

This covers the mechanical and vacuum installation for the FEE.

1.5.6.2 Near Hall Install

This covers the mechanical and vacuum installation for the NEH.

1.5.6.3 Tunnel Install

This covers the mechanical and vacuum installation for the Tunnel.

1.5.6.4 Far Hall Install

This covers the mechanical and vacuum installation for the FEH.

2. LCLS PROJECT: R&D, SPARES & COMMISSIONING

2.5 X-RAY TRANSPORT & DIAGNOSTICS SYSTEMS (OPC)

OPC Summary for the S-Ray Transport, Optics and Diagnostics System. It includes effort and costs associated with R&D, Spares, and Commissioning.

2.5.1 System Management & Integration

2.5.1.1 Management

This WBS element covers the management of R&D issues associated with component design and layout at the conceptual level. It also covers the commissioning team that brings up the Diagnostics systems.

2.5.2 Controls

2.5.2.1 Unused

2.5.2.2 Unused

2.5.2.3 Fast Controls

This covers the commissioning of the fast controls.

2.5.2.4 Femto Controls

This covers the commissioning of the Femto controls.

2.5.3 Mechanical & Vacuum Subsystem

2.5.3.1 Unused

2.5.3.2 Mech/Vac Front End

This WBS element covers the commissioning of the mechanical and vacuum systems in the Front End Enclosure.

2.5.3.3 Mech/Vac Near Hall

This WBS element covers the commissioning of the mechanical and vacuum systems in the near Hall.

2.5.3.4 Mech/Vac Tunnel

This WBS element covers the commissioning of the mechanical and vacuum systems in the x-ray transport tunnel.

2.5.3.5 Mech/Vac Far Hall

This WBS element covers the commissioning of the mechanical and vacuum systems in the Far Hall.

2.5.4 Optical Subsystem

2.5.4.1 Optical Systems Engineering

This WBS element covers R&D into FEL induced damage of the optical and Diagnostics systems.

2.5.4.2 Facility Optics

This WBS element covers the commissioning of the slits, solid attenuator, fixed masks, flipper mirror, and the gas attenuator.

2.5.4.3 Unused

2.5.4.4 Crystals & Gratings

This WBS element covers the commissioning of the pulse split delay system, and the monochromator.

2.5.5 Diagnostics Subsystem

2.5.5.1 Unused

2.5.5.2 Modeling & Simulation

This WBS element covers R&D aimed at the development of practical simulations of the LCLS beam for use in developing Diagnostics and optics.

2.5.5.3 Facility Diagnostics

This WBS element covers R&D aimed at the development of practical simulations of the LCLS beam for use in developing Diagnostics and optics. It also has spare parts for diagnostic equipment likely to be damaged by the FEL.

2.5.5.4 Commissioning Diagnostics

This WBS element covers R&D aimed at the development of the commissioning Diagnostics.

2.5.6 Unused

LCLS WBS DICTIONARY
1.6 X-RAY ENDSTATION SYSTEM

1.6 X-RAY ENDSTATION SYSTEMS

This element includes the infrastructure required to integrate x-ray experiments with the LCLS source and conventional facilities. Specifically, this includes safety systems, computer and network systems, experimental chambers, synchronized laser systems, and prototype detectors that will be used by most of the foreseeable LCLS experiments. It also includes additional sample handling equipment needed for the first studies of FEL-atom interactions (Atomic Physics experiments).

1.6.1 System Management and Integration

This element provides management and integration for all design engineering and construction phases of the Project.

1.6.1.1 Management

Attend meetings, arrange for staffing for the project, prepare reports, formulate conceptual design, and travel as required.

1.6.2 Controls

Create protocols, networks, and systems needed for controlling experimental equipment and handling experimental data, and design and create safety interlock systems.

1.6.2.1 Cabling

Design, procure, and test the cabling required for the control systems.

1.6.2.1.1 Front End Enclosure Cable

1.6.2.1.2 Near Hall Cable

1.6.2.1.3 Tunnel Cable

1.6.2.1.4 Far Hall Cable

1.6.2.2 Network

Design, procure, and test the hardware and software required for computer network support for LCLS experiments.

1.6.2.3 PC Support

Design, procure, and test the hardware and software needed for experimental station computer systems and associated computer systems used by experimenters at LCLS.

1.6.2.4 Beamline controls

Design, procure, and test the hardware and software needed to control equipment installed at the experimental stations, including precision motion equipment, sample manipulation and monitoring equipment, and detectors.

1.6.2.5 X-Ray PPS

Design, procure, and test the hardware and software needed for the personnel protection system that will ensure radiological safety for the experimental stations and x-ray beam transport areas (front end enclosure, Near Experimental Hall, x-ray transport Tunnel, and Far Experimental Hall).

1.6.2.5.1 FEE X-Ray PPS

1.6.2.5.2 Near Hall X-Ray PPS

1.6.2.5.3 Tunnel X-Ray PPS

1.6.2.5.4 Far Hall X-Ray PPS

1.6.2.6 X-Ray MPS

Design, procure, and test the hardware and software needed for the machine protection system that will minimize the possibility of significant damage to the LCLS source due to accidents in the experimental stations and x-ray beam transport areas (front end enclosure, Near Experimental Hall, x-ray transport Tunnel, and Far Experimental Hall).

1.6.2.6.1 FEE X-Ray MPS

1.6.2.6.2 Near Hall X-Ray MPS

1.6.2.6.3 Tunnel X-Ray MPS

1.6.2.6.4 Far Hall X-Ray MPS

1.6.2.7 Laser PPS

Design, procure, and test the hardware and software needed for the personnel protection system that will ensure laser safety in the Near Experimental Hall and Far Experimental Hall.

1.6.2.7.1 Near Hall Laser PPS

1.6.2.7.2 Far Hall Laser PPS

1.6.2.8 User Safeguards

Design, procure, and test the hardware and software needed for the personnel protection system that will guard against experiment-specific hazards in the experimental stations in the Near Experimental Hall and Far Experimental Hall (i.e., special chemical hazards, oxygen deficiency hazards, etc).

1.6.2.8.1 Near Hall User Safeguards

1.6.2.8.2 Far Hall User Safeguards

1.6.3 Mechanical/Vacuum

Design, procure, and test the mechanical supports and vacuum components associated with experimental chambers in the Near Experimental Hall and Far Experimental Hall.

1.6.3.1 Chamber Support Tables

Design, procure, and test the mechanical supports (which may involve motorized degrees of motion) for experimental chambers in the Near Experimental Hall and Far Experimental Hall.

1.6.3.2 Vacuum Components

Design, procure, and test the valves, pumps, gauges, and other vacuum components associated with experimental chambers in the Near Experimental Hall and Far Experimental Hall.

1.6.3.2.1 Valves - Vacuum

1.6.3.2.2 Hardware - Vacuum

1.6.3.2.3 Ion Pump - Vacuum

1.6.3.2.4 Turbo Pump - Vacuum

1.6.3.2.5 Gauges - Vacuum

1.6.3.3 Experimental Chambers

Design, procure, and test an experimental chamber to be used in the Near Experimental Hall, and a chamber to be used in the Far Experimental Hall. The chambers will accommodate initial LCLS experiments of the types described in the LCLS First Experiments document.

1.6.3.3.1 Near Hall Experimental Chamber

1.6.3.3.2 Far Hall Experimental Chamber

1.6.4 Laser Systems

Design, procure, and test the ultrafast laser systems that will be installed in the Near Experimental Hall and Far Experimental Hall, and the timing system that will synchronize these lasers to the LCLS x-ray pulses.

1.6.4.1 Oscillator Laser and Pump

Specify, procure, and test the pump laser and Ti:sapphire ultrafast laser oscillator that will be installed in the Front Experimental Hall, and the similar laser system that will be installed in the Far Experimental Hall.

1.6.4.1.1 Near Hall Oscillator Laser & Pump

1.6.4.1.2 Far Hall Oscillator Laser & Pump

1.6.4.2 Laser Diagnostics

Design, procure, and test the hardware and software that will be used to monitor the operation of the ultrafast laser systems in the Near Experimental Hall and Far Experimental Hall.

1.6.4.3 Laser Supplies and Optical Transport

Specify and procure the optical tables, mirrors, lenses, etc. required for operation of the ultrafast laser systems in the NEH and FEH, and design, procure, and test the optical transport system for transporting the ultrashort laser pulses to each of the experimental hutches.

1.6.4.4 Laser Timing

Design, procure, and test the hardware and software required to synchronize the ultrafast laser systems in the NEH and FEH to the LCLS x-ray pulses. Synchronization with the linac master oscillator to better than 100 fs is required. In addition, trigger signals from the linac and correlation detectors in the experimental hutches will be used to identify the precise arrival time of the x-ray pulses, to which the laser pulses will be synchronized. The timing system must be able to record information from x-ray/laser correlation detectors on a shot-by-shot basis, to be used for experimental data analysis.

1.6.4.5 Laser Amplifiers

Specify, procure, and test the pump lasers and Ti:sapphire laser amplifiers required to boost the intensity of the laser oscillator pulses, for the laser systems in the NEH and FEH. An output pulse rate of about 1 kHz is required, with pulse energy of about 1 mJ.

1.6.4.5.1 Near Hall Laser Amplifier

1.6.4.5.2 Far Hall Laser Amplifier

1.6.5 X-Ray Detectors

Specify, procure, and test prototype detectors that will be needed for the types of experiments described in the LCLS First Experiments document. Development of advanced detector concepts that are essential to LCLS will be included as R&D.

1.6.5.1 Beam Imaging Detector

Specify, procure, and test a detector capable of imaging the LCLS x-ray beam in any of the experimental stations with better than 10 micron resolution and 120 Hz image collection rate.

1.6.5.2 2D X-Ray Detector

Specify, procure, and test a detector suitable for x-ray diffraction experiments at LCLS, studying diffuse or sharp scattering features. An active area of at least 1000x1000 100-µm pixels is needed, and an image collection rate of 120 Hz is required.

1.6.5.3 Beam Intensity Detector

Specify, procure, and test a detector for measuring the LCLS x-ray beam intensity with 1% accuracy on a shot-by-shot basis.

1.6.5.4 Streak Camera

Specify, procure, and test a detector for LCLS x-rays with single-shot time resolution of better than 500 fs.

1.6.6 System Installation & Alignment

This element provides for System Installation and Alignment in all areas of the X-Ray Endstation system (Front End Enclosure, Near Hall, Tunnel, and Far Hall). Specifically, this includes controls, computer and network systems, safety systems, experimental chambers and their vacuum components, laser systems, x-ray detectors and infrastructure for atomic physics experiments. This also includes the integration of the X-Ray Endstation system with other components of the LCLS source, such as the LCLS timing system, beam diagnostics and conventional facilities.

1.6.6.1 Front End Install

1.6.6.2 Near Hall Install

1.6.6.2.1 Near Hall Install Controls

1.6.6.2.2 Near Hall Install Mech/Vac

1.6.6.2.3 Near Hall Install Laser

1.6.6.2.4 Near Hall Install Detectors

1.6.6.2. 5 Near Hall Install Atomic Physics

1.6.6.3 Tunnel Install

1.6.6.4 Far Hall Install

1.6.6.4.1 Far Hall Install Controls

1.6.6.4.2 Far Hall Install Mech/Vac

1.6.6.4.3 Far Hall Install Laser

1.6.6.4.4 Far Hall Install Detectors

1.6.6.4.5 Unused

1.6.7 Unused

2. LCLS PROJECT: R&D, SPARES AND COMMISSIONING

2.6 X-RAY END STATION SYSTEMS (OPC)

OPC Summary for the X-Ray End Station System. It includes effort and costs associated with R&D, Spares, and Commissioning.

2.6.1 Unused

2.6.1.1 Unused

2.6.2 Controls Subsystem

2.6.2.1 Cabling

This element covers the effort associated with commissioning Cabling in the X-Ray End Station functional area.

2.6.2.2 Network

This element covers the effort associated with commissioning the Network.

2.6.2.3 PC Support

This element covers the effort associated with commissioning PC Support.

2.6.2.4 Beamline Controls

This element covers the effort associated with commissioning Beamline Controls.

2.6.2.5 X-Ray PPS

This element covers the effort associated with commissioning X-Ray PPS in the X-Ray End Station functional area.

2.6.2.6 X-Ray MPS

This element covers the effort associated with commissioning X-Ray MPS in the X-Ray End Station functional area.

2.6.2.7 Laser PPS

This element covers the effort associated with commissioning Laser PPS in the X-Ray End Station functional area.

2.6.2.8 User Safeguards

This element covers the effort associated with commissioning User Safeguards in the X-Ray End Station functional area.

2.6.3 Mechanical/Vacuum Subsystem

2.6.3.1 Unused

2.6.3.2 Vacuum Components - Mechanical/Vacuum

This element covers the effort associated with commissioning Vacuum Components.

2.6.3.3 Experimental Chambers

This element covers the effort associated with commissioning Experimental Chambers in the X-Ray End Station functional area.

2.6.4 Laser Subsystem

2.6.4.1 Oscillator Laser & Pump

This element covers the effort associated with commissioning the Oscillator and Pump Laser in the X-Ray End Station functional area.

2.6.4.2 Laser Diagnostics

This element covers the effort associated with commissioning Laser Diagnostics.

2.6.4.3 Laser Supplies & Optical Transport

This element covers the effort associated with commissioning Laser Supplies and Optical Transport.

2.6.4.4 Laser Timing

This element covers the effort associated with commissioning Laser Timing.

2.6.4.5 Laser Amplifiers

This element covers the effort associated with commissioning the Laser Amplifiers in the X-Ray End Station functional area.

2.6.5 X-Ray Detectors

2.6.5.1 Beam Imaging

This element covers the effort associated with commissioning the Beam Imaging Detector.

2.6.5.2 2-D X-Ray Detector

This element covers the effort associated with commissioning the 2-D-X-Ray Detector.

2.6.5.3 Beam Intensity

2.6.5.4 Streak Camera

2.6.6 X-Ray End Station System Commissioning

2.6.6.1 Unused

2.6.7 Atomic Physics

This element covers the R&D costs to specify, design, procure and test the hardware and software needed in the areas of samples, diagnostics, data analysis, and detectors for initial LCLS Atomic Physics experiments as recommended by the Atomic Physics advisory group. This includes also specific sample handling equipment and its control and diagnostics.

2.6.7.1 Atomic Physics Samples

This number covers the R&D costs to specify, design, procure, and test the hardware and software needed to handle the Atomic Physics samples. This includes offline sample characterization equipment and special laser equipment needed to create the required sample state.

2.6.7.2 Atomic Physics Diagnostics

This number covers the R&D costs to specify, design, procure, and test the hardware and software needed for checking the operation of the Atomic Physics experiments, including x-ray and laser beam characterization, online sample characterization, and timing characterization.

2.6.7.3 Atomic Physics Data Analysis

This number covers the R&D costs to specify, design, procure, and test the hardware and software needed for analysis of the Atomic Physics experimental data.

2.6.7.4 Atomic Physics Detectors

This number covers the R&D costs to specify, design, procure, and test the hardware and software needed for detection of the Atomic Physics experimental data. This may include modification of other LCLS detectors, or development of specialized detectors.

LCLS WBS DICTIONARY
1.9 CONVENTIONAL FACILITIES

1.9 CONVENTIONAL FACILITIES

The Conventional Facilities for the Linac Coherent Light Source (LCLS) will include renovations to the existing SLAC facilities and the development of new facilities. Included will be all major systems and subsystems contained herein that will be required to support the facilities related to the LCLS programmatic requirements. The scope of the WBS will include 13 elements: Sector 20 Injector Facilities, Magnetic Measuring Facility, Main Control Center Modifications, Linac Upgrades, Beam Transport Hall, Research Yard Modifications, Undulator Hall, Front End Enclosure, Beam Dump, Near Experimental Hall, X-Ray Transport & Diagnostic Tunnel, Far Experimental Hall and the Free Electron Laser Center. Activities included within these elements are, site preparation and development (including establishment of survey monuments for site alignment), beam line housings including a beam dump, renovations to existing facilities, buildings, service buildings, utility systems (including cooling systems), fire protection systems, roads, sidewalks, landscaping, berms, fencing and parking areas.

1.9.1 System Management & Integration

This element will provide the overall project management to implement and integrate the design, construction and close-out for all phases of the project related to conventional facilities.

1.9.1.1 Management

This element will provide overall support for conventional facilities to include reports, attendance of meetings, insure integration of other systems interfacing with conventional facilities, travel as required, manage the WBS including cost, schedule and resources; coordinate Title I, Title II and Title III efforts with AE firms and in-house support staff engineers, designers and drafters; coordinate Title III with subcontractors (including architectural and engineering firms) and general contractors, and manage close-out activities, manage.

1.9.1.2 Cost Account Managers (CAM)

This element will provide SLAC project management support during Title I, Title II and Title III activities throughout the WBS. The UTR will provide oversight for subcontractors (including architectural and engineering firms), labor service and in-house labor. During the construction phase (Title III), the UTR has the responsibility to monitor construction activities including tests for bolt torque, welding, concrete strength, pressure certification, fire systems and electrical testing for project compliance with technical specifications and regulatory compliance.

1.9.1.3 Construction Management

This element will provide a support role for various construction management activities in support of the WBS. CM will support all phases of activities to include pre-construction services, bidding, field supervision and close-out. Particular emphasis will be given to validation of WBS schedules and estimates, value engineering and general construction support activities including quality control and preparing bid packages to release for construction.

1.9.1.4 Mechanical Design (MD)

This element will provide SLAC MD drafting support and drawing research for as-builts in support of the WBS for Title I and Title II activities.

1.9.1.4.1 Mechanical Design Title I (Linac Not Included)

This element will provide MD effort (excluding Linac) in support of Title I activities.

1.9.1.4.2 Mechanical Design Title I Linac Facility

This element will provide MD effort directly related to the Linac in support of Title I activities.

1.9.1.4.3 Mechanical Design Title II (Linac Not Included)

This element will provide MD effort (excluding Linac) in support of Title II activities.

1.9.1.4.4 Mechanical Design Title II Linac Facility

This element will provide MD effort directly related to the Linac in support of Title II activities.

1.9.1.4.5 Mechanical Design Title III Linac Facility

This element will provide MD effort directly related to the Linac in support of Title III activities.

1.9.1.4.6 Mechanical Design Title III (Linac Not Included)

This element will provide MD effort (excluding Linac) in support of Title III activities.

1.9.1.5 Site Engineering & Maintenance (SEM)

This element will provide SLAC SEM effort in support of the WBS for utility upgrades and misc engineering in-house support and project coordination in support of for Title I and Title II activities (Pre-Title I and Pre-Title II). Activities included in this element are field surveying, gathering user requirements, developing design criteria packages, obtaining user review and approvals, assisting in the request for proposal packages for engineering and construction firms, assisting in job walks for engineering and construction firms.

1.9.1.5.1 SEM Engineering Title I (Linac Not Included)

This element will provide SLAC SEM effort (excluding Linac) in support of Title I activities.

1.9.1.5.2 SEM Engineering Title I Linac Facilities

This element will provide SLAC SEM effort directly related to the Linac activities in support of Title I activities.

1.9.1.5.3 SEM Engineering Title II (Linac Not Included)

This element will provide SLAC SEM effort (excluding Linac) in support of Title II activities.

1.9.1.5.4 SEM Engineering Title II Linac Facilities

This element will provide SLAC SEM effort directly related to the Linac activities in support of Title II activities.

1.9.2 Title I & Title II Conventional Facilities

This element will provide both SLAC in-house engineering, drafting support, and subcontractor architectural/engineering support for the Title I and Title II design efforts for the following WBS elements: Sector 20 Injector Facilities, Magnetic Measuring Facility, Main Control Center Modifications, Linac, Beam Transport Hall, Research Yard Modifications, Undulator Hall, Front End Enclosure, Beam Dump, Near Experimental Hall, X-Ray Transport & Diagnostic Tunnel, Far Experimental Hall and the Free Electron Laser Center.

1.9.2.1 Unused

1.9.2.2 A&E Services Conventional Facilities (S20, MMF & MCC not included)

This element will provide architectural and engineering support for the WBS (excluding S20, MMF and MCC). Included will be Title I and Title II construction document development to include drawings, specifications, studies and analyses, engineering reports, cost estimates, renderings and engineering calculations.

1.9.2.2.1 Title I Design

This element will provide the preliminary architectural and engineering support for Title I phase of the design development for conventional facilities. This design phase further develops the conceptual design to include engineering studies and analyses, risk assessments, preliminary drawings and engineering specifications, cost and schedule estimates, and life cycle cost estimates. This phase will consume up to a third of the engineering effort.

1.9.2.2.2 Title II Design

This element will provide the final working drawings, specifications and complete bidding documents for conventional facilities. This phase commences after approval of the Title I design by the DOE.

1.9.2.3 A&E Services Conventional Facilities (S20, MMF & MCC included)

This element will provide architectural and engineering support for Sector 20 (shielding wall, rf hut and alcove modifications), Magnetic Measuring Facility and the Main Control Center upgrades. Included will be Title I and Title II construction document development to include drawings, specifications, studies and analyses, engineering reports, cost estimates, renderings and engineering calculations.

1.9.2.3.1 Title I Design (S20 Injector Facilities)

This element will provide the preliminary architectural and engineering support for Title I phase. This design phase further develops the conceptual design to include engineering studies and analyses, risk assessments, preliminary drawings and engineering specifications, cost and schedule estimates, and life cycle cost estimates. This phase will consume up to a third of the engineering effort.

1.9.2.3.2 Title II Design (S20 Injector Facilities)

This element will provide the final working drawings, specifications and complete bidding documents. This phase commences after approval of the Title I design by the DOE.

1.9.2.3.3 Title I Design (MMF)

This element will provide the preliminary architectural and engineering support for Title I phase. This design phase further develops the conceptual design to include engineering studies and analyses, risk assessments, preliminary drawings and engineering specifications, cost and schedule estimates, and life cycle cost estimates. This phase will consume up to a third of the engineering effort.

1.9.2.3.4 Title II Design (MMF)

This element will provide the final working drawings, specifications and complete bidding documents. This phase commences after approval of the Title I design by the DOE.

1.9.2.3.5 Title I Design (MCC Upgrades)

This element will provide the preliminary architectural and engineering support for Title I phase. This design phase further develops the conceptual design to include engineering studies and analyses, risk assessments, preliminary drawings and engineering specifications, cost and schedule estimates, and life cycle cost estimates. This phase will consume up to a third of the engineering effort.

1.9.2.3.6 Title II Design (MCC Upgrades)

This element will provide the final working drawings, specifications and complete bidding documents. This phase commences after approval of the Title I design by the DOE.

1.9.3 Title III Conventional Facilities

This element will provide the final construction phase of activities to cover the receipt, inspection, assembly, and test of the project conventional facilities, as well as any changes that are required during construction. Included will be support buildings, buildings, tunnels, shielding blocks, control rooms, preparation areas, laser rooms, experimental hutches, cooling systems, electrical systems, cable trays, ventilation systems, HVAC systems, drainage systems and utility systems. Final as-built drawings, operation and maintenance manuals, on-site equipment training and other documentation of the facility are also prepared as part of Title III close-out activities. At the end of Title III the project is ready for activation and operation by the operations staff. [Note: cable tray within the Linac is not included].

1.9.3.1 Sector 20 Injector Facilities

This element will provide the requirements for Sector 20 Injector Facilities including the removal of existing and placement of a new shield wall; RF Hut at approximately 200 square feet; Alcove modifications to include a new Laser Room, Load Lock Room and Control Room. This existing area consists of approximately 1,700 square feet of floor space at grade level adjacent to the Klystron Gallery. The area is in need of total renovations including roofing, siding, lighting, power, utilities, hvac and other interior modifications. The Laser Room and Load Lock Room will be environmentally controlled equivalent to a class 100,000 clean room.

1.9.3.1.1 Site Preparation

This element will provide the preparation of the site for construction activities, selective demolition, site grading and landscaping if required. This element covers the cost of general grading to create a suitable site and to control drainage and provisions for erosion control. The removal of existing site utilities as needed. Installation of temporary fencing is also included.

1.9.3.1.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, equipment pads, rebar, bolts, base plates, building and support columns, roof and ceiling steel joists, open web joists, roof and floor decking. Also included in this element is the installation of the shielding wall to include concrete, lead (Pb) and iron (Fe) with their appropriate structural supports.

1.9.3.1.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.1.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.1.5 HVAC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required controlling the room temperature and relative humidity for support buildings, rooms, enclosures and shafts.

1.9.3.1.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.1.7 Interior

This element will provide the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring, painting and epoxy coating.

1.9.3.1.8 Unused

1.9.3.1.9 Unused

1.9.3.1.10 Close Out

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.2 Magnetic Measuring Facility

1.9.3.2.1 Site Preparation

This element will provide the preparation of the site for construction activities to include demolition. This element covers the cost of removing and relocating existing site utilities as needed. Removing and providing temporary and permanent fencing as required. Included will be the tasks of unloading storage racks.

1.9.3.2.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, equipment pads, rebar, bolts, base plates, building and support columns, roof and ceiling steel joists, open web joists, roof and floor decking. Included will be the installation of two (2) cranes.

1.9.3.2.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.2.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.2.5 HVAC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.2.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.2.7 Interior

This element will provide the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring, painting and epoxy coating.

1.9.3.2.8 Unused

1.9.3.2.9 Unused

1.9.3.2.10 Project Close Out Magnetic Measurement Facility

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.3 Main Control Center Facility Upgrades

1.9.3.3.1 Site Preparation

This element will provide the preparation of the site for construction activities including selective demolition. This element covers the removal of existing utilities as needed. Installation of temporary fencing is also included.

1.9.3.3.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns, roof and ceiling steel joists, open web joists, roof and floor decking.

1.9.3.3.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.3.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water.

1.9.3.3.5 HVAC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.3.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.3.7 Interior

This element will provide the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring material, fixtures, painting and epoxy coating.

1.9.3.3.8 Unused

1.9.3.3.9 Unused

1.9.3.3.10 Project Close Out Main Control Center Facilitiy

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.4 Linac Facility

1.9.3.4.1 Unused

1.9.3.4.2 Unused

1.9.3.4.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase.

All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.4.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will 3be delivered to within 25 feet of the equipment.

1.9.3.4.5 Unused

1.9.3.4.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.4.7 Unused

1.9.3.4.8 Unused

1.9.3.4.9 Unused

1.9.3.4.10 Project Close Out Linac Facility

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.5 Research Yard/ B102, B211, B113 & Storage Trailers

This element will provide the various activities required by SLAC (SEM) department and a general contractor (GC) within the existing SLAC Research Yard. Some of the buildings that will be affected as a result of the LCLS project are building #064 Final Focus Test Beam, building #113 (hi-bay portion only), building #211, building #102, various storage containers and trailers #204, #4031, #4079, #4080 and #4081.

1.9.3.5.1 Site Preparation

1.9.3.5.1.1 Site Preparation SEM

This element will provide preliminary support activities of the site in advance of general contractor activities, including selective demolition, site grading and landscaping if required. This element covers the cost of general grading to create a suitable site and to control drainage and provisions for erosion control. The removal and or modifications of existing site utilities as needed. Site clearing and grubbing to remove stockpiling of topsoil from construction site if required. Installation of temporary fencing is also included. This element will provide asbestos removal.

1.9.3.5.1.2 Site Preparation GC

This element will provide the preparation of the site for construction activities, selective demolition, site grading and landscaping if required. This element covers the cost of general grading to create a suitable site and to control drainage and provisions for erosion control. The removal of existing site utilities as needed. Site clearing and grubbing to remove stockpiling of topsoil from construction site if required. Installation of temporary fencing is also included.

1.9.3.5.2 Structural

1.9.3.5.2.1 Structural SEM

This element will provide preliminary support activities in advance of general contractor activities to support the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns, roof and ceiling steel joists, open web joists, roof and floor decking.

1.9.3.5.2.2 Structural GC

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns, roof and ceiling steel joists, open web joists, roof and floor decking.

1.9.3.5.3 Electrical

1.9.3.5.3.1 Electrical SEM

This element will provide preliminary support activities in advance of general contractor activities to support the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase.

1.9.3.5.3.2 Electrical GC

This element will provide the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase.

All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.5.4 Utilities

1.9.3.5.4.1 Utilities SEM

This element will provide preliminary support activities in advance of general contractor activities to support the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.5.4.2 Utilities GC

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.5.5 HVAC

1.9.3.5.5.1 HVAC SEM

This element will provide preliminary support activities in advance of general contractor activities to support the installation of air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.5.5.2 HVAC GC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.5.6 Special Systems (Fire Protection)

1.9.3.5.6.1 Special Systems (Fire Protection) SEM

This element will provide preliminary support activities in advance of general contractor activities to support the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.5.6.2 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.5.7 Interior

1.9.3.5.7.1 Interior SEM

This element will provide preliminary support activities in advance of general contractor activities for the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring material, fixtures, painting and epoxy coating.

1.9.3.5.7.2 Interior GC

This element will provide the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring material, fixtures, painting and epoxy coating.

1.9.3.5.8 Unused

1.9.3.5.9 Unused

1.9.3.5.10 Project Close Out Research Yard

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.6 Access Road & Beam Transport Hall

The new Beam Transport Hall commences from the end of the Linac to the beginning of the Undulator Hall and replaces the existing Final Focus Test Beam enclosure. The existing Linac finish floor is approximately one foot lower than the required elevation of the new facility which will be at 247.25'. The BTH will have roughly the same general footprint of the FFTB extending from the BSY wall in the direction of the beam at 172 meters (length) x 4.5 meters (width) x 4.5 meters (height).

The existing north access road will need to be modified to accommodate vehicular traffic over the portion of the new Undulator Hall that extends out into the Research Yard. Provisions will be made to allow access to either side of the Beam Transport Hall.

1.9.3.6.1 Site Preparation

This element will provide the preparation of the site for construction activities, selective demolition, site grading, asphalt and landscaping if required. This element covers the cost of general grading to create a suitable site and to control drainage and provisions for erosion control. Included in this element will be the labor required for the removal of utilities in support of the FFTB system. The removal of existing site utilities as needed. Site clearing and grubbing to remove stockpiling of topsoil from construction site if required. Installation of temporary fencing is also included. This element will include the removal of existing shielding blocks for the existing FFTB, Beam Dump and Muon shielding.

1.9.3.6.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns, roof and ceiling steel joists, open web joists, roof and floor decking.

1.9.3.6.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.6.4 Utilities

This element will provide for the removal of existing utilities in preparation for the demolition of the existing FFTB structure. This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.6.5 HVAC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.6.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.6.7 Interior

This element will provide the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring material, fixtures, painting and epoxy coating.

1.9.3.6.8 Unused

1.9.3.6.9 Unused

1.9.3.6.10 Project Close Out Beam Transport Hall

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.7 Undulator Hall

1.9.3.7.1 Site Preparation

This element will provide the preparation of the site for construction activities, selective demolition, site grading and landscaping if required. This element covers the cost of general grading to create a suitable site and to control drainage and provisions for erosion control. The removal of existing site utilities as needed. Site clearing and grubbing to remove stockpiling of topsoil from construction site if required. Installation of temporary fencing is also included.

1.9.3.7.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns.

1.9.3.7.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.7.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.7.5 HVAC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.7.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.7.7 Interior

This element will provide the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring material, fixtures, painting and epoxy coating.

1.9.3.7.8 Unused

1.9.3.7.9 Tunneling

This element provides the installation of a cavern style tunneling effort utilizing a standard road-header type of equipment. The excavation, muck removal, initial and final reinforcing, shotcrete lining, drainage, temporary power, temporary lighting and ventilation is included. Entry portal will be located between Pep Ring Road and berm.

The tunneling length starts at the berm and goes in the direction of the beam for 130 meters. There will be a thermal barrier at each end of the Undulator Hall. Thermal and vibration parameters are established. There is an exposed portion (45 meters) of the Undulator Hall that will remain covered by fill within the Research Yard.

1.9.3.7.10 Project Close Out Undulator Hall

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.8 Front End Enclosure

1.9.3.8.1 Site Preparation

This element will provide the preparation of the site for construction activities, selective demolition, site grading and landscaping if required. This element covers the cost of general grading to create a suitable site and to control drainage and provisions for erosion control. The removal of existing site utilities as needed. Site clearing and grubbing to remove stockpiling of topsoil from construction site if required. Installation of temporary fencing is also included.

1.9.3.8.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns.

1.9.3.8.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.8.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.8.5 HVAC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.8.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.8.7 Interior

This element will provide the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring material, fixtures, painting and epoxy coating.

1.9.3.8.8 Unused

1.9.3.8.9 Tunneling

This element provides the installation of a cavern style tunneling effort utilizing a standard road-header type of equipment. The excavation, muck removal, initial and final reinforcing, shotcrete lining, drainage, temporary power, temporary lighting and ventilation is included. Entry portal will be the same as used for the Undulator Hall.

The tunneling length begins at the end of the Undulator Hall and goes in the direction of the beam for 40 meters.

1.9.3.8.10 Project Close Out Front End Enclosure

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.9 Beam Dump

1.9.3.9.1 Site Preparation

This element will provide the preparation of the site for construction activities, selective demolition, site grading and landscaping if required. This element covers the cost of general grading to create a suitable site and to control drainage and provisions for erosion control. The removal of existing site utilities as needed. Site clearing and grubbing to remove stockpiling of topsoil from construction site if required. Installation of temporary fencing is also included.

1.9.3.9.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns, roof and ceiling steel joists, open web joists, roof and floor decking.

1.9.3.9.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.9.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.9.5 Unused

1.9.3.9.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.9.7 Unused

1.9.3.9.8 Unused

1.9.3.9.9 Tunneling

This element provides the installation of a cavern style tunneling effort utilizing a standard road-header type of equipment. The excavation, muck removal, initial and final reinforcing, shotcrete lining, drainage, temporary power, temporary lighting and ventilation is included. Entry portal will be the same as used for the Undulator Hall.

1.9.3.9.10 Project Close Out Beam Dump

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.10 Near Experimental Hall

1.9.3.10.1 Site Preparation

This element will provide the preparation of the site for construction activities, selective demolition, site grading and landscaping if required. This element covers the cost of general grading to create a suitable site and to control drainage and provisions for erosion control. The removal of existing site utilities as needed. Site clearing and grubbing to remove stockpiling of topsoil from construction site if required. Installation of temporary fencing is also included.

1.9.3.10.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns, roof and ceiling steel joists, open web joists, roof and floor decking.

1.9.3.10.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.10.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.10.5 HVAC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.10.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.10.7 Interior

This element will provide the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring material, fixtures, painting and epoxy coating.

1.9.3.10.8 Unused

1.9.3.10.9 Unused

1.9.3.10.10 Project Close Out Near Experimental Hall

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.11 X-Ray Transport & Diagnostics Hall

1.9.3.11.1 Site Preparation

This element of site work will already be in place as a result of the site work established for the Near Experimental Hall.

1.9.3.11.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns.

1.9.3.11.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.11.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.11.5 HVAC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.11.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.11.7 Interior

This element will provide the installation of all interior requirements including all general architectural features such as finishes onto masonry walls, gypsum board and metal stud walls, ceilings, flooring material, fixtures, painting and epoxy coating.

1.9.3.11.8 Unused

1.9.3.11.9 Tunneling

This element provides the installation of a cavern style tunneling effort utilizing a standard road-header type of equipment. The excavation, muck removal, initial and final reinforcing, shotcrete lining, drainage, temporary power, temporary lighting and ventilation is included. Entry portal will be located west of Pep Ring Road.

The tunneling length begins at the east end of the Near Experimental Hall and goes in the direction of the beam for 290 meters.

1.9.3.11.10 Project Close Out X-Ray Transport and Diagnostics

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.12 Far Experimental Hall

1.9.3.12.1 Unused

1.9.3.12.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns.

1.9.3.12.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.12.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.12.5 HVAC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.12.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.12.7 Interior

This element will provide the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring material, fixtures, painting and epoxy coating.

1.9.3.12.8 Unused

1.9.3.12.9 Tunneling

This element provides the installation of a cavern style tunneling effort utilizing a standard road-header type of equipment. The excavation, muck removal, initial and final reinforcing, shotcrete lining, drainage, temporary power, temporary lighting and ventilation is included. Entry portal will be same as used for X-ray Transport Diagnostics tunnel.

1.9.3.12.10 Project Close Out Far Experimental Hall

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

1.9.3.13 Central Lab Office Building (CLOB)

1.9.3.13.1 Site Preparation

This element will provide the preparation of the site for construction activities, selective demolition, site grading and landscaping if required.

This element covers the cost of general grading to create a suitable site and to control drainage and provisions for erosion control. The removal of existing site utilities as needed. Site clearing and grubbing to remove stockpiling of topsoil from construction site if required. Installation of temporary fencing is also included.

1.9.3.13.2 Structural

This element will provide the delivery, sorting and installation of the building frame system including concrete footings, slabs, foundations, rebar, bolts, base plates, building and support columns, roof and ceiling steel joists, open web joists, roof and floor decking.

1.9.3.13.3 Electrical

This element will provide the installation of the project primary electrical distribution systems to the main panel source of the area. The distribution of electric power will follow downstream and will include secondary electrical panels, transformers, disconnects, panel boards, switch gear and grounding for 480V, 3 phase; 208/120V, 3 phase; and 120V single phase. All power will be delivered to the vicinity of the technical system components to within 25 feet. This element will include the installation of general lighting, quad outlets and duplex outlets for 120V electric power.

1.9.3.13.4 Utilities

This element will provide the installation of the project utilities including domestic water, sanitary sewer, compressed air, storm drains and low conductivity water. Utilities required for technical system components will be delivered to within 25 feet of the equipment.

1.9.3.13.5 HVAC

This element will provide air handling and cooling systems, including ductwork, HEPA filters, chillers and pumps as required to control the room temperature and relative humidity for support buildings, rooms and enclosures and shafts.

1.9.3.13.6 Special Systems (Fire Protection)

This element will provide the installation of a wet sprinkler fire protection system, including ancillary components such as valves, risers, etc.

1.9.3.13.7 Interior

This element will provide the installation of all interior requirements including all general architectural features such as masonry walls, gypsum board and metal stud walls, ceilings, flooring material, fixtures, painting and epoxy coating.

1.9.3.13.8 Unused

1.9.3.13.9 Unused

1.9.3.13.10 Project Close Out Central Lab Office Building

This element will cover the receipt, inspection, assembly, and test of the project facilities and hardware, as well as any changes that are required during construction or assembly. Included in this final phase will be the receipt of operating and maintenance manuals, testing and on-site training for maintenance personnel, as-builts, and start-up of all equipment for validation of project (specification and drawing) compliance. At the end of the close out phase, the project will be ready for activation and operation by the operations staff.

2. LCLS PROJECT: R&D, SPARES AND COMMISSIONING

2.9 Conventional Facilities – Other Project Costs

None