WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	**03**				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	**03**	**01**			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	**03**	**01**	**01**		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	**03**	**01**	**01**	**01**	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	**03**	**01**	**01**	**02**	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	**03**	**01**	**01**	**03**	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	**03**	**01**	**01**	**04**	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	**03**	**01**	**01**	**05**	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	**03**	**01**	**01**	**06**	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

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	03	01	01	07	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	03	01	03		Travel	Linac group project-related travel expenditures.
1	03	01	04		Linac Management	Linac group costs related to management; administration, personal computers, productivity software, as well as simulation and modeling software.
1	03	02			Linac Controls & Power Conversion Subsystem	System Summary
1	03	02	01		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	03	02	02		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	03	02	03		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	03	02	04		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	03	02	04	01	Beamline Power Supplies - (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	03	02	04	02	Beamline Power Supplies - (Quad 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	03	02	04	03	Beamline Power Supplies - (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.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	03	02	04	04	Beamline Power Supplies - Misc Hdwr	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	03	02	05		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	03	02	06		Controls - E-Beam Diagnostic	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	03	02	06	01	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	03	02	06	02	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	03	02	06	03	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	03	02	06	04	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.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	03	02	06	05	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	03	02	06	06	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	03	02	06	07	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	03	02	06	08	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	03	02	06	09	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.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	03	02	06	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	03	02	06	11	Controls - Protection Collimator	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	03	02	06	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	03	02	06	13	Controls - X-Band Accel Structure	System Summary
1	03	02	08		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	03	02	09		Controls - Vacuum	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	03	02	09	01	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	03	02	09	02	Vacuum Instrumentation & Controls	These are High Voltage power supplies, controlled current, to pump down and maintain design operating pressure in the accelerator.
1	03	02	10		Software & 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	03	02	10	04	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	03	02	10	05	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	03	03			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	03	03	01		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.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	03	03	02		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	03	03	03		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	03	03	04		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	03	03	05		LTU Quad	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	03	03	07		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	03	03	08		Corr_(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	03	03	09		BYD_(Dump Bend)	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	03	03	10		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	03	03	11		BYPM_(Safety Dump)	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	03	03	12		BYKIK_(Single Beam Kicker)	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	03	03	13		BYW_( )	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	03	04			Linac Vacuum Subsystem	Section Summary
1	03	04	02		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.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	03	04	03		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	03	04	04		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	03	04	05		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	03	04	06		Dumpline 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	03	05			Linac Electron Diagnostics	System Summary
1	03	05	01		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	03	05	02		Beam Position Monitors	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	03	05	02	01	BPM's - Linac Standard (4ea)	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	03	05	02	02	BPMs - RF (8ea)	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	03	05	02	03	BPMs - FFTB (37ea)	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.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	**03**	**05**	**02**	**04**	BPMs - BC1 & BC2 (2ea)	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	**03**	**05**	**03**		Toroids (9ea) Beam Charge	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	**03**	**05**	**04**		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	**03**	**05**	**05**		Profile Monitors (5ea)	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	**03**	**05**	**06**		E/O Bunch Length Monitors (1ea)	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	**03**	**05**	**07**		Bunch Length Monitors (4ea)	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	**03**	**05**	**08**		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	**03**	**05**	**08**	**01**	Beam Loss Monitors (10 PIC)	The PIC is designed to be placed locally downbeam from devices that are candidates for beam divergence during system failure modes.
1	**03**	**05**	**08**	**02**	Beam Loss Monitors (2 PLIC)	The PLIC is a distributed region device that averages over a long region of the system to identify beam loss.
1	**03**	**05**	**09**		Single Beam Dump (1ea)	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	**03**	**05**	**10**		Electron Safety Beam Dump (1ea)	The electron beam dump is the endpoint for the electron beam in the LCLS system after the beam passes through the undulator system.
1	**03**	**05**	**11**		Protection Collimators (6ea)	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	**03**	**05**	**12**		Movable Collimators (7ea)	Movable collimators are designed to tune the electron beam characteristics by limiting the beam dimension in either the X or Y axes.
1	**03**	**05**	**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	**03**	**06**			Linac RF Subsystem	System Summary

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	03	06	02		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	03	06	03		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	03	06	04		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	03	06	05		X-Band High Power System	System Summary
1	03	06	05	01	X-Band HP 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	03	06	05	02	X-Band HP 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	03	06	05	03	X-Band HP 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	03	06	06		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	03	06	07		RF Distribution System	System Summary
1	03	06	07	01	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.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	03	06	07	02	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	03	06	07	03	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	03	06	07	04	Controls Interfaces	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	03	06	07	05	Beam Phase 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	03	06	07	06	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	03	06	07	07	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	03	06	07	08	Experimentors F.O. RF Electronics	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	03	06	07	09	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	03	07			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	03	07	01		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.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	03	07	02		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	03	07	03		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	03	07	04		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	03	07	05		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	03	07	06		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	03	07	07		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	03				LINAC SYSTEM (OPC)	OPC Summary for the Linac System. It includes effort and costs associated with R&D, Spares, and Commissioning.
2	03	01			System Management & Integration	OPC Summary for Linac Integration
2	03	01	01		Linac Mechanical Integration	This element covers commissioning costs.
2	03	02			Linac Controls & Power Conversion Subsystem	System Summary
2	03	02	04		Power Conversion	This element covers special processing spares required for this section.
2	03	02	04	01	Spare Power Supply (Dipole Type)	This element covers special processing spares required for this section.
2	03	02	04	02	Spare Power Supply (Quad Type)	This element covers special processing spares required for this section.
2	03	02	04	03	Spare Power Supply (Trim Type)	This element covers special processing spares required for this section.
2	03	03			Linac Magnets & Supports	System Summary
2	03	03	01		Bend Magnet (BX1_BC1)	This element covers special processing spares required for this section.
2	03	03	02		Bend Magnet (BX3_LTU)	This element covers special processing spares required for this section.
2	03	03	03		Bend Magnet (BX2_BC2)	This element covers special processing spares required for this section.
2	03	03	04		Bend Magnet (BY_LTU)	This element covers special processing spares required for this section.
2	03	03	05		Quad Magnet (Quad_LTU)	This element covers special processing spares required for this section.
2	03	03	07		Quad Magnet (QE)	This element covers special processing spares required for this section.
2	03	03	08		Corrector Magnet (Type 4)	This element covers special processing spares required for this section.
2	03	03	09		Bend Magnet (BYD_LTU)	This element covers special processing spares required for this section.
2	03	03	10		Quad Magnet (QA)	This element covers special processing spares required for this section.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
2	03	03	11		Bend Magnet (BYPM_LTU)	This element covers special processing spares required for this section.
2	03	03	12		Bend Magnet (BYKIK_LTU)	This element covers special processing spares required for this section.
2	03	03	13		Bend Magnet (BYW_LTU)	This element covers special processing spares required for this section.
2	03	04			Linac Vacuum Subsystem	System Summary
2	03	04	01		Linac Vacuum Subsystem Operations Equip	This element covers special processing spares required for this section.
2	03	04	02		Linac Beamline Vacuum System	This element covers special processing spares required for this section.
2	03	04	03		BC1 Vacuum System	This element covers special processing spares required for this section.
2	03	04	04		BC2 Vacuum System	This element covers special processing spares required for this section.
2	03	04	05		Linac to Undulator (LTU) Vacuum System	This element covers special processing spares required for this section.
2	03	04	06		Dumpline Vacuum System	This element covers special processing spares required for this section.
2	03	05			Linac Electron Diagnostics	System Summary
2	03	05	01		Wire Scanners	This element covers special processing spares required for this section.
2	03	05	02		Beam Position Monitors	This element covers special processing spares required for this section.
2	03	05	03		Toroids Beam Charge	This element covers special processing spares required for this section.
2	03	05	04		Stoppers Tune Up Dump	This element covers special processing spares required for this section.
2	03	05	05		Profile Monitors	This element covers special processing spares required for this section.
2	03	05	06		E/O Bunch Length Monitors	This element covers special processing spares required for this section.
2	03	05	07		Bunch Length Monitors	This element covers special processing spares required for this section.
2	03	05	08		Beam Loss Monitors	This element covers special processing spares required for this section.
2	03	05	09		Single Beam Dump	This element covers special processing spares required for this section.
2	03	05	10		Electron Safety Beam Dump	This element covers special processing spares required for this section.
2	03	05	11		Protection Collimators	This element covers special processing spares required for this section.
2	03	05	12		Movable Collimators	This element covers special processing spares required for this section.
2	03	05	13		Safety Dump	This element covers special processing spares required for this section.
2	03	06			Linac RF Subsystem	System Summary
2	03	06	05		X-Band High Power System	This element covers special processing spares required for this section.
2	03	06	07		RF Distribution System	This element is a summary of RF Distribution Spares.
2	03	06	07	01	Modulator	This element covers special processing spares required for this section.
2	03	06	07	02	Solid State Sub Booster	This element covers special processing spares required for this section.
2	03	06	07	05	Bunch Length Electronics	This element covers special processing spares required for this section.
2	03	06	07	07	RF Distribution L2 & L3	This element covers special processing spares required for this section.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
2	03	06	07	08	RF Fiber Optics Electronics	This element covers special processing spares required for this section.
2	03	07			Linac System Commissioning	System Summary
2	03	07	01		Linac L01 System Commissioning	This element covers the effort associated commissioning with the specific Linac functional area.
2	03	07	02		Linac BC1 System Commissioning	This element covers the effort associated commissioning with the specific Linac functional area.
2	03	07	03		Linac L02 System Commissioning	This element covers the effort associated commissioning with the specific Linac functional area.
2	03	07	04		Linac BC2 System Commissioning	This element covers the effort associated commissioning with the specific Linac functional area.
2	03	07	05		Linac L03 System Commissioning	This element covers the effort associated commissioning with the specific Linac functional area.
2	03	07	06		Linac LTU System Commissioning	This element covers the effort associated commissioning with the specific Linac functional area.
2	03	07	07		Linac E-Dump System Commissioining	This element covers the effort associated commissioning with the specific Linac functional area.