WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	05				X-RAY TRANSPORT & DIAGNOSTICS SYSTEMS	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	05	01			System Management & Integration	This element provides overall management for XTOD.
1	05	01	01		Management	This element provides overall management for XTOD safety, conceptualization, R&D, design, construction, testing, installation, integration, and commissioning.
1	05	01	01	01	XTOD Management - Technical	This covers a full time manager.
1	05	01	01	02	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	05	02			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	05	02	02		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	05	02	03		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	05	02	04		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	05	03			Mechanical & Vacuum Subsystem	Design pumps, pipes and stands for interconnecting the experimental tanks in the FEE, Near Hall, Tunnel and Far Hall.
1	05	03	02		Mech/Vac Front End	This covers the mechanical and vacuum specification, design, and procurement for the FEE.
1	05	03	03		Mech/Vac Near Hall	This covers the mechanical and vacuum specification, design, and procurement for the Near Hall.
1	05	03	03	01	NEH Hutch 1	This covers the mechanical and vacuum specification, design, and procurement for the NEH Hutch 1
1	05	03	03	02	NEH Hutch 2	This covers the mechanical and vacuum specification, design, and procurement for the NEH Hutch 2
1	05	03	03	03	NEH Hutch 3	This covers the mechanical and vacuum specification, design, and procurement for the NEH Hutch 3
1	05	03	04		Mech/Vac Tunnel	This covers the mechanical and vacuum specification, design, and procurement for the Tunnel.
1	05	03	05		Mech/Vac Far Hall	This covers the mechanical and vacuum specification, design, and procurement for the Far Hall.
1	05	03	05	01	FEH Hutch 1	This covers the mechanical and vacuum specification, design, and procurement for the FEH Hutch 1
1	05	03	05	02	FEH Hutch 2	This covers the mechanical and vacuum specification, design, and procurement for the FEH Hutch 2
1	05	03	05	03	FEH Hutch 3	This covers the mechanical and vacuum specification, design, and procurement for the FEH Hutch 3

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	05	04			Optical Subsystem	All elements used to manipulate the X-Ray beam.
1	05	04	02		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	05	04	02	02	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	05	04	02	03	Slit/Collimator A	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	05	04	02	04	Slit/Collimator B	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	05	04	02	05	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	05	04	02	06	TTF Damage Experiment	This WBS element covers the planning, procurement, running, analysis, and documentation of a series of measurements at the TTF VUVFEL facility. The purpose of these measurements is to measure damage thresholds of materials used at the LCLS under the conditions of high brightness and short times.
1	05	04	02	08	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	05	04	03		End Station Optics	This WBS element will provide specification, design, procurement, install and testing for: Optic Tanks for Near Hall.
1	05	04	03	02	Optics Tank - Near Hall	This is a 1 x 2 m turbo-pumped vacuum tank to house optical elements in the NEH.
1	05	04	04		Crystals & Gratings	This WBS element will provide specification, design, procurement, install and testing for the System Monochrometer and the Pulse Split and Delay System.
1	05	04	04	02	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	05	04	04	03	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	05	05			Diagnostics Subsystem	Provide diagnostics to characterize and measure beam performance for the users and the facility.
1	05	05	02		Modeling & Simulation	Develop Monte Carlo and Wave based numerical models of the LCLS FEL and spontaneous radiation for use in specifying diagnostics.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	05	05	02	01	Wave Model	This element covers the development and execution of programs modeling the wave properties of the diagnostics and optical elements.
1	05	05	02	02	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	05	05	02	03	Beam Simulation	This WBS covers the development of computer codes to simulate the expected levels of FEL and spontanious beams. Both monte-carlo and wave models will be developed and applied to each instrument.
1	05	05	03		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	05	05	03	01	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	05	05	03	02	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	05	05	03	05	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	05	05	03	06	Ion Pumped Diagnostic Tanks	These are smaller tanks, which are ion pumped to hold diagnostics in the FEE.
1	05	05	04		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	05	05	04	01	Commission 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	05	05	04	02	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	05	05	04	04	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	05	05	04	05	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	05	05	04	06	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	05	05	04	07	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.

WBS NUMBER					TITLE	DESCRIPTION
1	2	3	4	5		
1	05	06			X-Ray Transport System Installation & Alignment	This covers the mechanical and vacuum installation for the Front End Enclosure, Near Hall, Tunnel and Far Hall areas in the X-Ray Transport system.
1	05	06	01		Front End Enclosure Install	This covers the mechanical and vacuum installation for the FEE.
1	05	06	02		Near Hall Install	This covers the mechanical and vacuum installation for the NEH.
1	05	06	03		Tunnel Install	This covers the mechanical and vacuum installation for the Tunnel.
1	05	06	04		Far Hall Install	This covers the mechanical and vacuum installation for the FEH.
2	05				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	05	01			System Management & Integration	This summary element covers the management and integration for the X-Ray Transport system.
2	05	01	01		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	05	02			Controls	This covers commissioning the control system for the X-Ray Transport system.
2	05	02	02		Slow Controls	This covers the commissioning of the slow controls.
2	05	02	03		Fast Controls	This covers the commissioning of the fast controls.
2	05	02	04		Femto Controls	This covers the commissioning of the Femto controls.
2	05	03			Mechanical & Vacuum Subsystem	This summary element covers commissioning the mechanical and vacuum for the X-Ray Transport system.
2	05	03	02		Mech/Vac Front End	This WBS element covers the commissioning of the mechanical and vacuum systems in the Front End Enclosure.
2	05	03	03		Mech/Vac Near Hall	This WBS element covers the commissioning of the mechanical and vacuum systems in the near Hall.
2	05	03	04		Mech/Vac Tunnel	This WBS element covers the commissioning of the mechanical and vacuum systems in the x-ray transport tunnel.
2	05	03	05		Mech/Vac Far Hall	This WBS element covers the commissioning of the mechanical and vacuum systems in the Far Hall.
2	05	04			Optical Subsystem	This summary element covers the optics commissioning for the X-Ray Transport system.
2	05	04	01		Optical Systems Engineering	This WBS element covers R&D into FEL induced damage of the optical and Diagnostics systems.
2	05	04	02		Facility Optics	This WBS element covers the commissioning of the slits, solid attenuator, fixed masks, flipper mirror, and the gas attenuator.
2	05	04	03		End Station Optics	This provides the optics for the Endstation system.
2	05	04	04		Crystals & Gratings	This WBS element covers the commissioning of the pulse split delay system, and the monochromator.
2	05	05			Diagnostics Subsystem	This summary element covers the diagnostics commissioning for the X-Ray Transport system.
2	05	05	02		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	05	05	03		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	05	05	04		Commissioning Diagnostics	This WBS element covers R&D aimed at the development of the commissioning Diagnostics.