Diagnostics & Common Optics Design, Baseline, & Risks

Yiping Feng – DCO Lead Scientist
Eliazar Ortiz – DCO Lead Engineer

LUSI CD-2 Lehman Review
August 20, 2008

Lead Engineer: Eliazar Ortiz
Mechanical Engineer: Marc Campell
Mechanical Engineer: Nadine Kurita
Design Engineer: Rick Jackson
Designer: Don Arnett
Designer: Ben Bigornia

Outline

- Physics requirements
- Safety
- Components distribution
- Engineering/design status
- Value engineering/management
- Basis of estimate
- Procurement strategy
- Costs & schedule
- Critical path
- Risk analysis
- Summary

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DCO Team

- Specifications and component concept developed by
  - DCO scientific/technical team
    - Yiping Feng, DCO lead scientist
    - Instrument liaisons & DCO scientists
      - David Fritz, XPP instr., attenuator, harmonic rejection mirrors
      - Marc Messerschmidt, XPP instr.
      - Sébastien Boutet, CXI instr., slits system, pulse picker
      - Aymeric Robert, XCS instr., focusing lens, offset monochromator
    - Niels van Bakel, X-ray detectors support
    - Gunther Haller/Dieter Freytag, EE support
- Components engineered by
  - DCO engineering team
    - Eliazar Ortiz – Lead Engineer
    - Marc Campell – Mechanical Engineer
    - Nadine Kurita – Mechanical Engineer
    - Rick Jackson – Design Engineer
    - Don Arnett – Designer
    - Ben Bigornia – Designer

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DCO Scope

Scope/CD-2 Includes:
Physics support & engineering integration (WBS. 1.5.1)
Diagnostics (WBS 1.5.2)
Pop-in Profile/Wavefront Monitor (WBS 1.5.2.1)
Pop-in Intensity Monitor (WBS 1.5.2.2)
Intensity-Position Monitor (WBS 1.5.2.3)
Common Optics (WBS 1.5.3)
Offset Monochromator (WBS 1.5.3.1)
X-ray Focusing Lenses (WBS 1.5.3.2)
Slit System (WBS 1.5.3.3)
Attenuators/Filters (WBS 1.5.3.4)
Pulse Picker (WBS 1.5.3.5)
Harmonic Rejection Mirrors (WBS 1.5.3.6)

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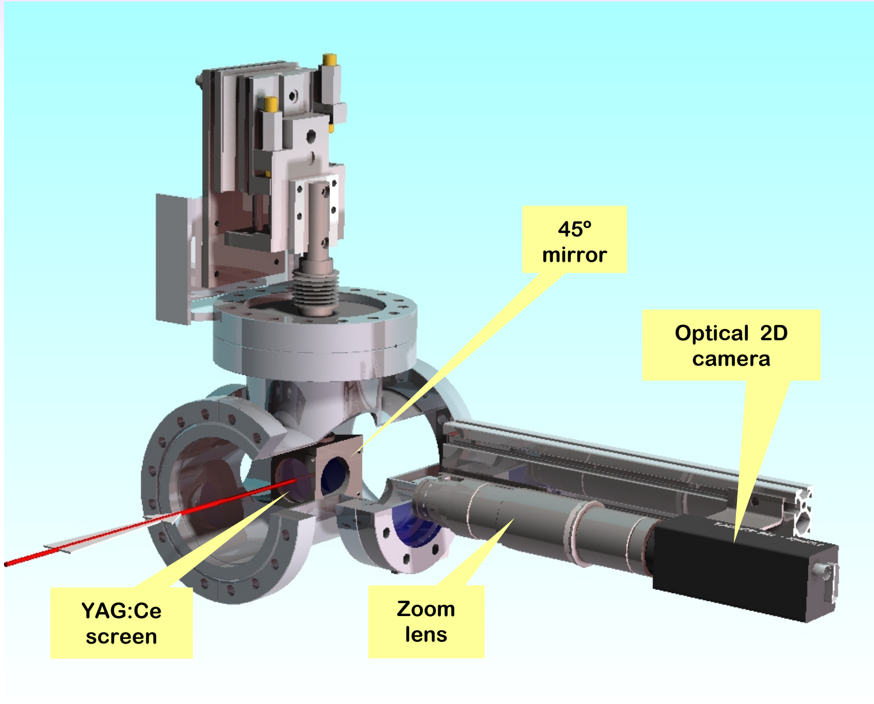
Pop-in Profile Monitor (WBS 1.5.2.1)



- Requirements
  - Destructive; Retractable
  - Variable FOV and resolution
    - At 100 μm resolution, 24x24 mm^2 FOV
    - At 8 μm resolution, 2x2 mm^2 FOV
  - Capable of per-pulse op. @ 120 Hz if required

- Purposes
  - Aid in alignment of X-ray optics
    - FEL is serial operation, automation enables maximum productivity
  - Characterization of X-ray beam spatial profile
    - FEL spatial mode structure
    - Effects of optics on fully coherent FEL beam
  - Characterization of X-ray beam transverse spatial jitter
    - FEL beam exhibits intrinsic spatial fluctuations

- Implementation
  - X-ray scintillation
    - 50-75 μm thin YAG:Ce single crystal scintillator
  - Optical imaging
    - Capable of diffraction limited resolution if required
    - Normal incidence geometry w/ 45° mirror
    - Motorized zoom lens
    - 120 Hz optical 2D sensor

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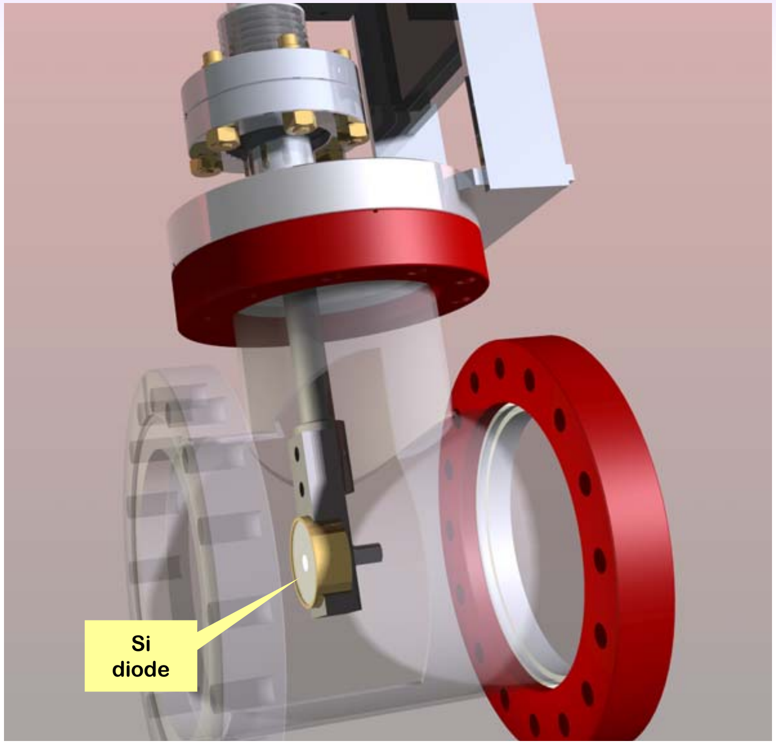
Pop-in Intensity Monitor (WBS 1.5.2.2)



- Requirements
  - Destructive; Retractable
  - Relative accuracy < 1%
  - Working dynamic range 100
  - Large sensor area 20x20 mm^2
  - Per-pulse op. @ 120 Hz

- Purposes
  - Aid in alignment of X-ray optics
    - FEL is serial operation, automation enables maximum productivity
  - Simple point detector for physics measurements
    - In cases where 2D X-ray detector is not suitable

- Implementation
  - Direct X-ray detection using Si diodes
    - Advantageous in cases of working w/ spontaneous or mono beams
    - Capable of high quantum efficiency (> 90% at 8.3 keV)
      - 100 – 500 μm depletion thickness
    - Using charge sensitive amplification
      - Applicable to pulsed FEL
    - Commercially available
    - Large working area (catch-all) easily available simplifying alignment procedure

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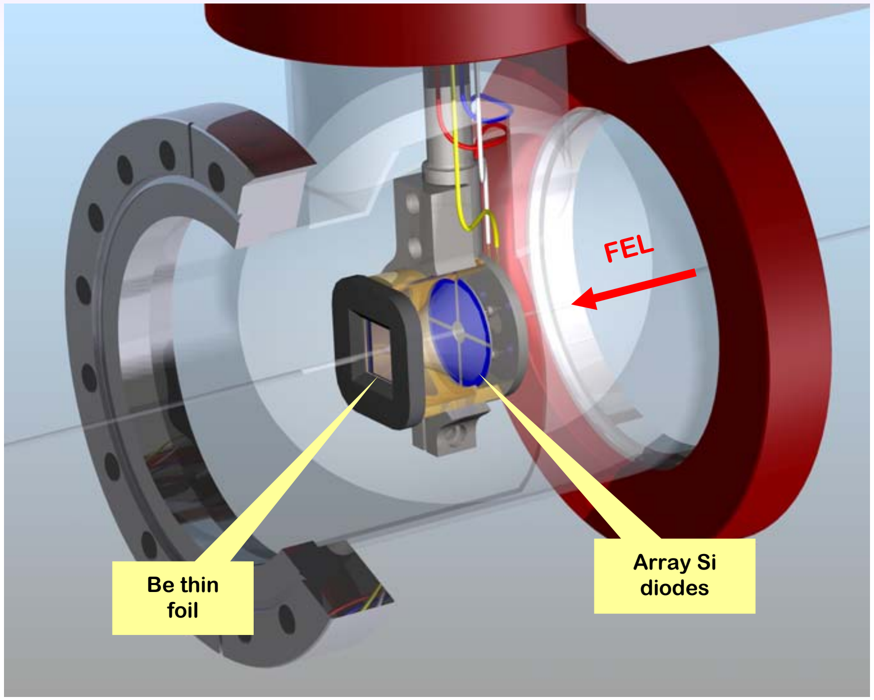
Intensity-Position Monitor (WBS 1.5.2.3)



- Requirements
  - In-situ, retractable if necessary
  - Highly transmissive (> 95%)
  - Relative accuracy < 0.1%
  - Working dynamic range 1000;
  - Position accuracy in xy < 10 μm;
  - Per-pulse op. at 120 Hz;

- Purposes
  - Allow precise measurement of the intensity for normalization
    - Critical to experiments where signal from underlying physics is very small
  - Characterization of FEL fluctuations
    - Positional jitter ~ 10% of beam size
    - Pointing jitter ~ 10% of beam divergence
    - Slitting beam down creates diffraction which may cause undesirable effects

- Implementation
  - Based on back scattering from thin-foil
    - Detecting both Compton scattering & Thomson scattering
    - Using Low-z (beryllium) for low attenuation especially at low X-ray energies
  - Using Si diode detectors
    - Array sensors for position measurement
    - Pointing measurement using 2 or more monitors

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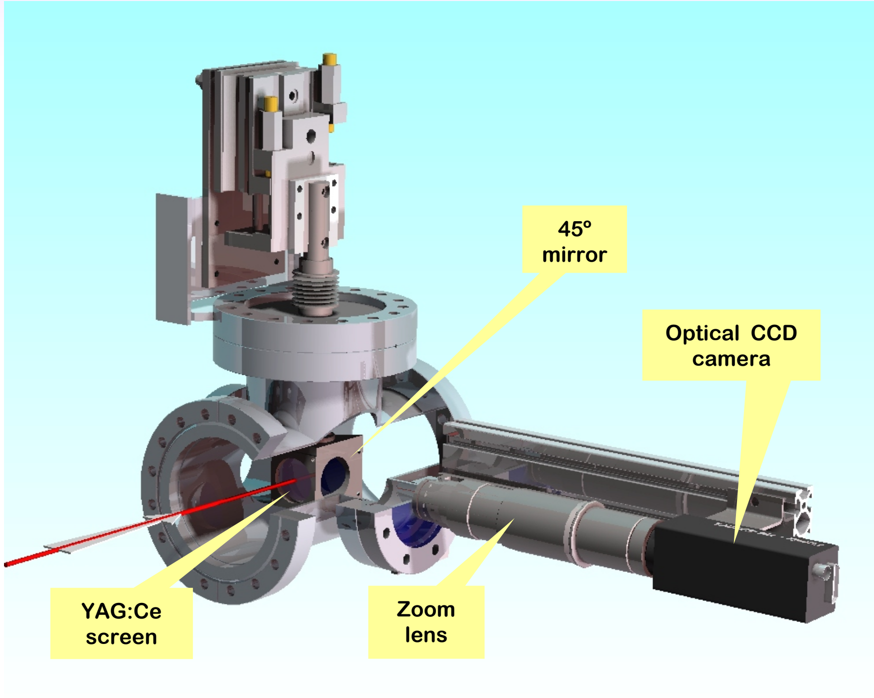
Wavefront Monitor (WBS 1.5.2.1)

[in lieu of wavefront sensor]



- Requirements
  - In-situ; Retractable
  - Variable FOV and resolution
    - At 100 μm resolution, 24x24 mm^2 FOV
    - At 50 μm resolution,12x12 mm^2 FOV
    - At 4 μm resolution, 1x1 mm^2 FOV
  - Per-pulse op. @ 120 Hz

- Purposes
  - Wavefront characterization of focused X-ray beam at focal point
    - Wavefront measurement at focal point is not feasible by conventional methods due to damages
  - Providing supplemental scattering data in low Q w/ high resolution
    - Resolution obtained using X-ray direct detection is limited by detector technology, i.e., pixel sizes and per-pixel dynamic range

- Implementation
  - X-ray scintillation
    - 50-75 μm thin YAG:Ce single crystal scintillator
  - Optical imaging
    - Capable of diffraction limited resolution if required
  - *Using computational algorithm for reconstruction of wavefield at focus*
    - *Iterative, post processing only if no large computer farm*

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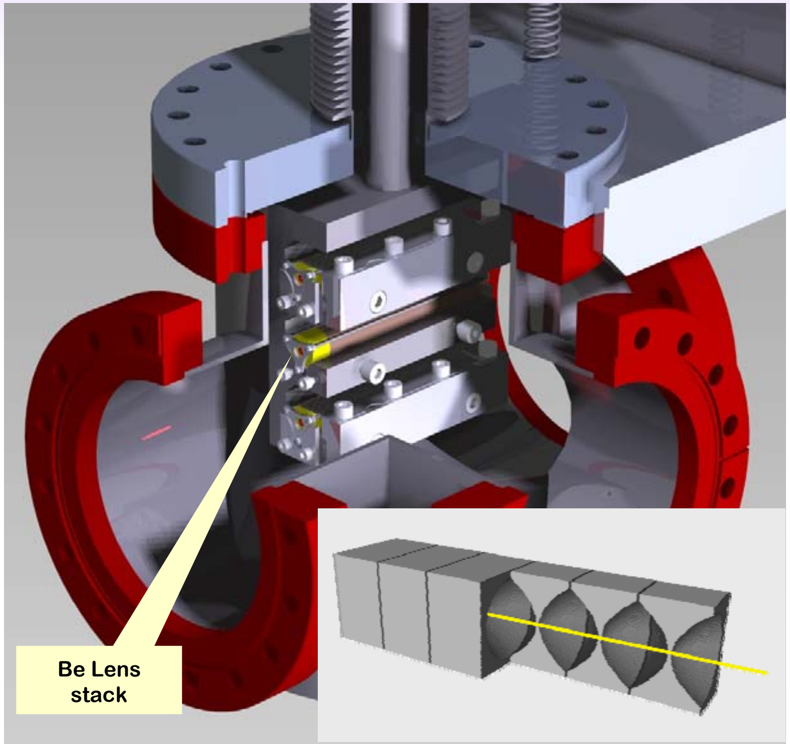
X-ray Focusing Lenses (WBS 1.5.3.2)



- Requirements
  - Produce variable spot size
    - For XPP instrument
      - 2-10 μm in focus
      - 40-60 μm out-of-focus
  - Minimize wavefront distortion and coherence degradation
  - Withstand FEL full flux

- Purposes
  - Increase the X-ray fluence at the sample
  - Produce small spot size in cases where slits do not work due to diffraction,
    - i.e., sample too far from slits

- Implementation
  - Based on refractive lenses concept*
    - Concave shape due to X-ray refractive index $1\text{-}\delta\text{+}i\beta$
  - Using Beryllium to minimize attenuation
    - In-line focus
    - Simpler than KB systems
    - no diff. orders as in Fresnel lens
    - Chromatic
      - Con: re-positioning of focal point
      - Pro: Providing harmonic isolation if aperture used
    - Some attenuation at very low X-ray energies ~ 2 keV

*B. Lengeler, et al, J. Synchrotron Rad. (1999). **6**, 1153-1167

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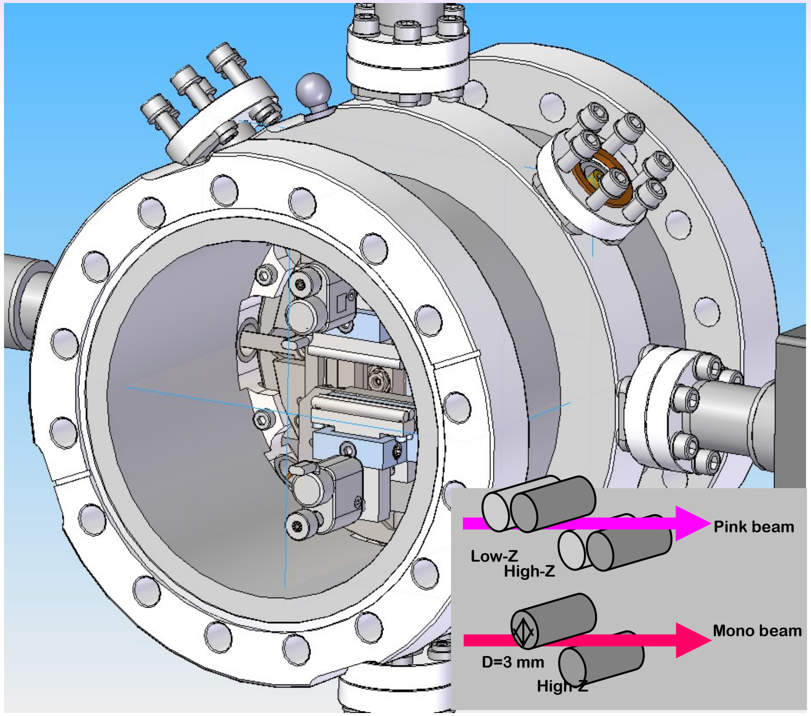
Slits System (WBS 1.5.3.3)



- **Requirements**
  - Primary, guard, and mono types
  - Precise (0.5 μm) & coarse (5 μm)
  - 0 – 10 mm gap setting
  - 10^{-9} in transmission from 2-8.3keV
  - 10^{-8} in transmission at 25 keV

- **Purposes**
  - define beam transverse sizes
    - Pink and mono beam
  - Clean up scatterings (halo) around beam perimeter

- **Implementation**
  - Based on cylindrical blades concept*
    - Minimize scattering from edges and external total reflections
    - Offset in *Z* to allow fully closing
  - Using double-blade or single-blade configurations for pink or mono beam applications
    - Primary coarse & precise
      - 1st blade: Si_3N_4, 2nd blade Ta
      - sample distance < 1m
    - Guard coarse & precise
      - Single blade Si_3N_4
    - Mono coarse & precise
      - Single blade Ta

*D. Le Bolloc'h, et al, J. Synchrotron Rad. (2002). 9, 258-265

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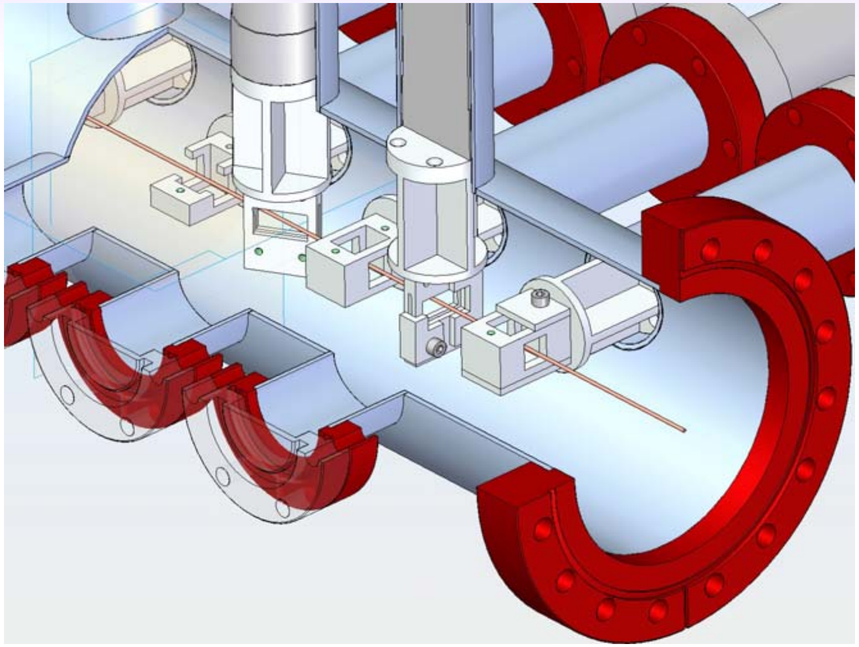
Attenuator/Filters (WBS 1.5.3.4)



- **Requirements**
  - 10^8 attenuation at 8.3 keV
  - 10^4 attenuation at 24.9 keV
  - 3 steps per decade for > 6 keV
  - Minimize wavefront distortion and coherence degradation
  - Withstand unfocused flux

- **Purposes**
  - Reduce incident X-ray flux
    - Sample damage
    - Detector saturation
    - Diagnostic saturation
    - Alignment of optics and diagnostics

- **Implementation**
  - Using Si wafers of various thicknesses
    - Highly polished to minimize wavefront distortion & coherence degradation
    - For a given attenuation, use one wafer whenever possible
    - Commercially available (< 1 nm rms roughness)
  - For energies < 6 keV in NEH-3 and in pink beam
    - Employing a pre-attenuator, i.e., LCLS XTOD gas/solid attenuators

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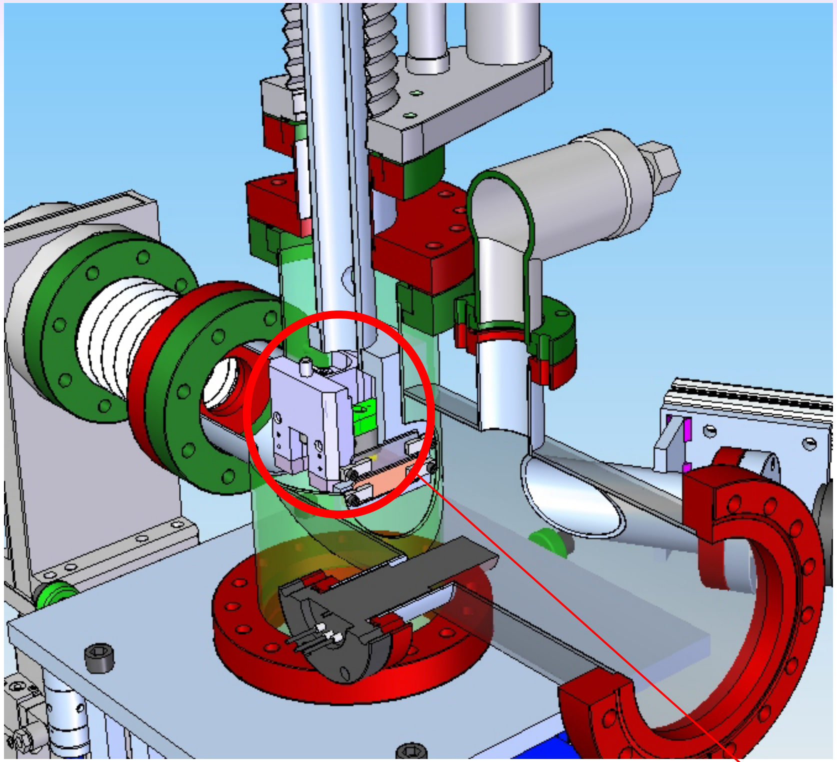
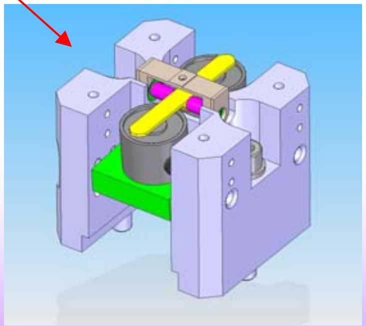
Pulse Picker (WBS 1.5.3.5)



- Purposes
  - Select a single pulse or any sequence of pulses
  - Reduce LCLS repetition rate to < 10 Hz
    - Important if longer sample recover time is needed
    - Damage experiments - sample needs to be translated
- Implementation
  - Based on a commercial mechanical teeter-totter*
    - Steel blade fully stops beam
    - Capable of ms transient time
    - Simple to operate
      - Use TTL pulses
    - Requires 100 μm Si_3N_4 to protect the steel blade

- Requirements
  - < 3 ms switching time
  - < 8 ms in close/open cycle time
  - Only for < 10 Hz operation
  - Withstand full LCLS flux



*http://www.azsol.ch/

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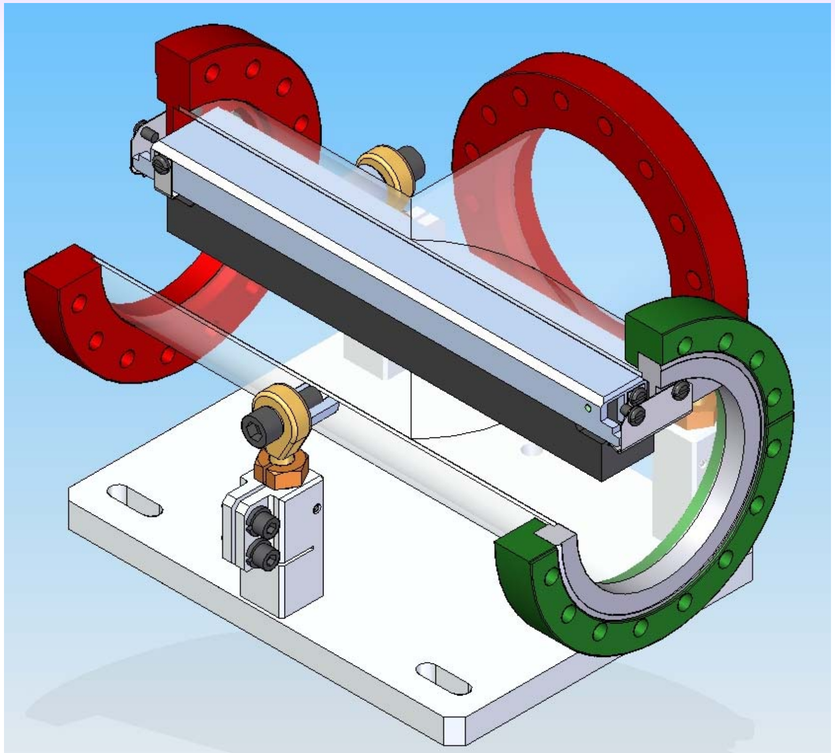
Harmonic Rejection Mirrors (WBS 1.5.3.6)



- Requirements
  - Energy range: 6-8.265 keV
  - 10^4 contrast ratio between fundamental and the 3rd harmonic
  - 80% overall throughput for the fundamental

- Purposes
  - Provide isolation of FEL fundamental from high harmonics
    - LUSI detectors not designed to be energy resolved

- Implementation
  - Low pass filter using X-ray mirrors at grazing incidence
  - Using highly polished Si single crystal substrates
    - 3.5 mrad incidence angle
    - 300 mm long
    - No pre-figure, no bender
    - Figure-error specs defined to ensure FEL natural divergence not effected
    - Roughness specs to minimize wavefront distortion and coherence degradation

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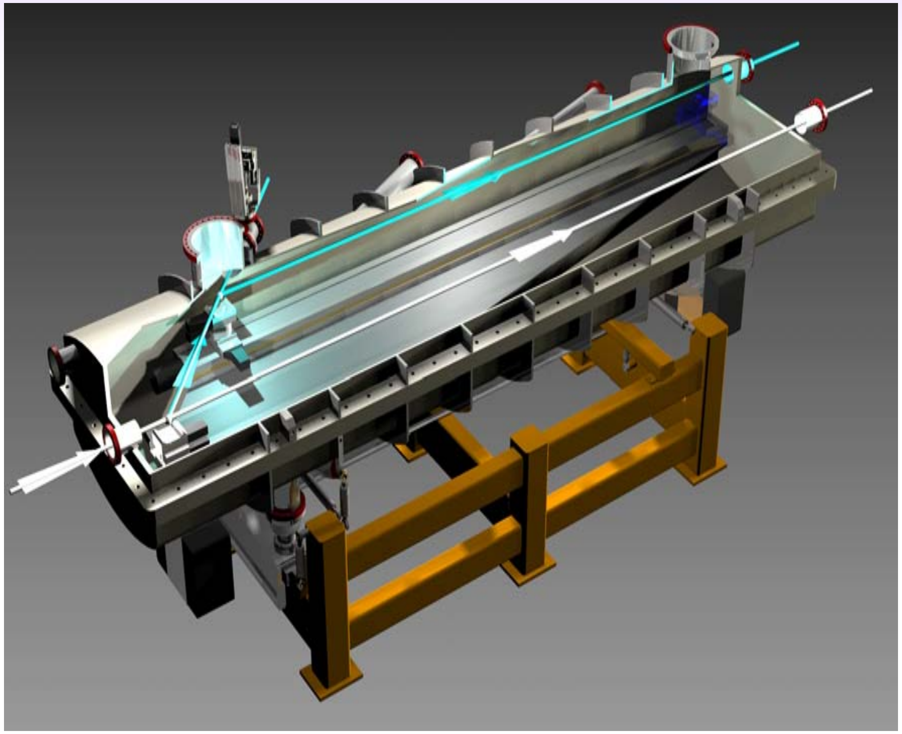
Offset Monochromator (WBS 1.5.3.1)



- Requirements
  - Provide large 600 mm offset
  - 6-25 keV operating energy range
    - Continuously tunable
  - Mechanical stability at 10% of beam size

- Purposes
  - Obtain narrower X-ray spectrum
    - Mitigate spectral fluctuations of the LCLS
    - Increase longitudinal coherence length
  - Create offset for mono beamline to move off main line

- Implementation
  - Si double-crystal monochromator
    - Non-dispersive configuration

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Safety

- Safety issues are considered at every stage of the design, fabrication and installation process per SLAC Integrated Safety and Environmental Management System
  - Define Work
  - Analyze Hazards:
    - Identify hazards associated with the design and operation of the LUSI project
    - Each design review addresses appropriate safety considerations for the level of completion of the design and the particular item covered
  - Develop Controls
    - Controls are planned to mitigate or eliminate hazard capable of causing injury to personnel, harm to the environment, or damage to critical hardware
  - Perform Work
  - Obtain feedback and improve
- The Hazards Analysis Report (HAR), PM-391-001-34 R0, documents the safety analysis of the LUSI instrument design/build/install & test
- Safety considerations (some examples)
  - Pressure/Vacuum Vessel Safety
    - Compliant with 10CFR851
  - Seismic Safety
    - Designs compliant with: Seismic Design Specification for Buildings, Structures, Equipment, and Systems, SLAC-I-720-0A24E-002-R002
  - Mechanical
    - Engineered solutions that prevent potential “pinch-points” with moving machinery
  - Hoisting and Rigging
    - Hoisting and rigging is performed by qualified personnel only with an approved lift plan.

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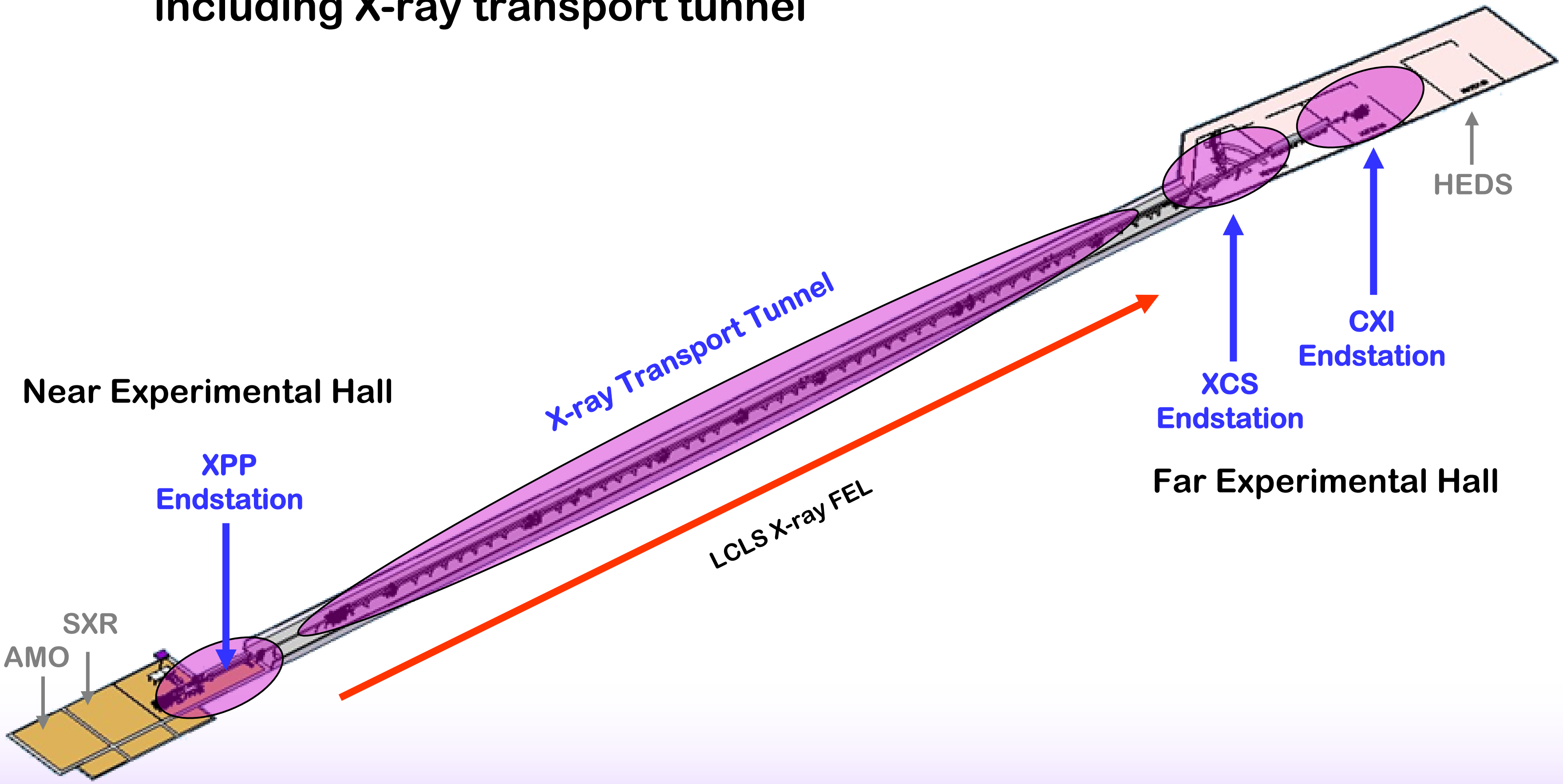
Components Distribution

- Components locations
  - Distributed throughout the XPP, CXI, and XCS instruments, including X-ray transport tunnel



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Components Distribution (cont.)

Diagnostics/Optics	XPP	CXI	XCS	Total	PRD	ESD
Pop-in Profile Monitor	3	4	5	12	Released R1	pre-release
Wavefront Monitor		1		1	Released R0	In Work
Pop-in Intensity Monitor	2	2	5	9	Released R1	pre-release
Intensity-Position Monitor	3	3	5	11	Released R1	pre-release
Monochromator			1	1	pre-release	N/A
X-Ray Focusing Lenses	1		1	2	Released R1	Pre-release
Slit System	3	4	6	13	Released R1	pre-release
Attenuators-Filters	1	1	1	3	Released R1	pre-release
Pulse Picker	1	1	1	3	Released R1	In Work
Harmonic Rejection Mirrors	1		1	2	Released R1	In Work

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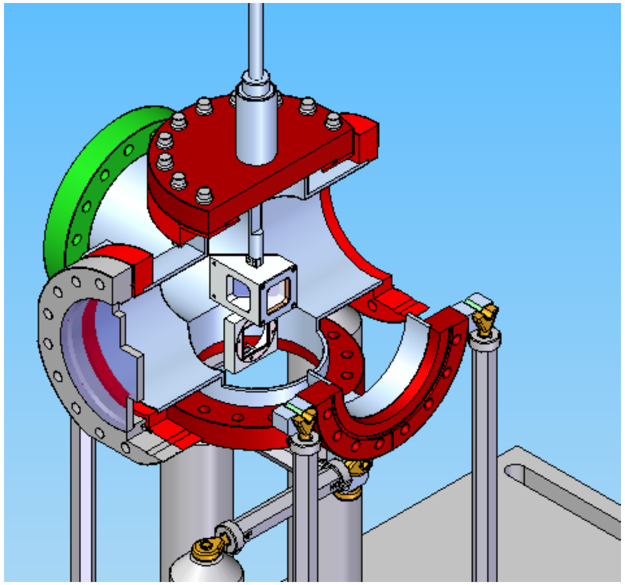
Engineering Status - Diagnostics

- Pop-In Profile & Intensity Monitor – WBS 1.5.2.1 & WBS 1.5.2.2
  - Destructive to the beam
  - Measures profile & intensity
  - PRD released
  - ESD nearly ready for release
  - Preliminary designs in process
  - Current plan to combine the two devices
  - PDR scheduled for Q4FY08



- Intensity-Position Monitor - WBS 1.5.2.3
  - Non-destructive to the beam
  - Measures intensity & position
  - PRD released
  - ESD nearly ready for release
  - Investigating customized “off the shelf units”
  - Preliminary “in house” concept developed
  - PDR scheduled for Q4FY08

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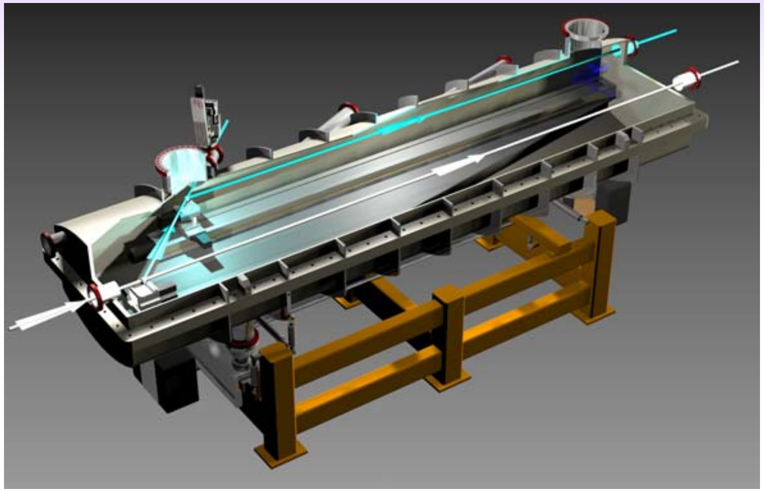
Engineering Status – Optics



- Monochromator– WBS 1.5.3.1
  - Added to the scope in June 2008
  - Design-build project
  - PRD in work
  - ESD/Technical Specification will be based off of recent Statement of Work for Argonne monochromator
    - Larger energy range and offset
    - LUSI device is twice as long with more stringent pointing stability requirements
  - Submit Budgetary Inquiry soon
    - Vendor capabilities
    - Feedback on specifications
    - Cost and schedule
      - Based on Argonne quotation
      - SLAC in house bottoms up estimate

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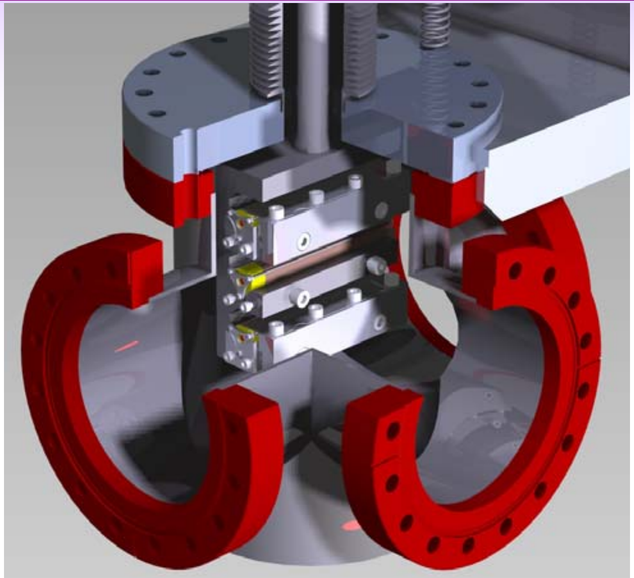
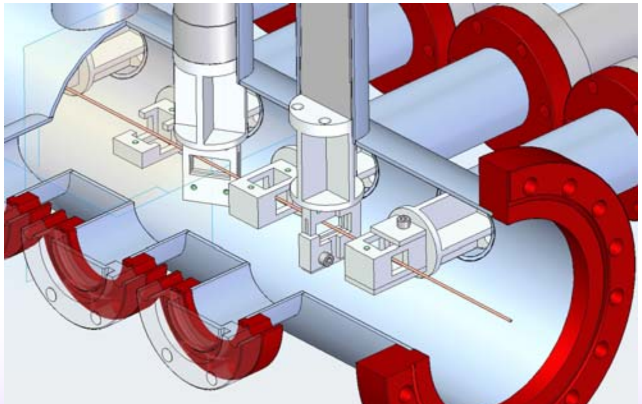
Engineering Status - Optics

- Be Lens System – WBS 1.5.3.2
  - Focuses beam and sets the focal length and waist size.
  - PRD Released
  - ESD out for signature
  - Conceptual design in work
  - Design based on proven ESRF design
  - PDR scheduled for Q4FY09



X-ray Focusing Lens

- Attenuators – WBS 1.5.3.4
  - PRD Released
  - ESD out for signature
  - Conceptual design complete
  - PDR scheduled for Q4FY09



Attenuator

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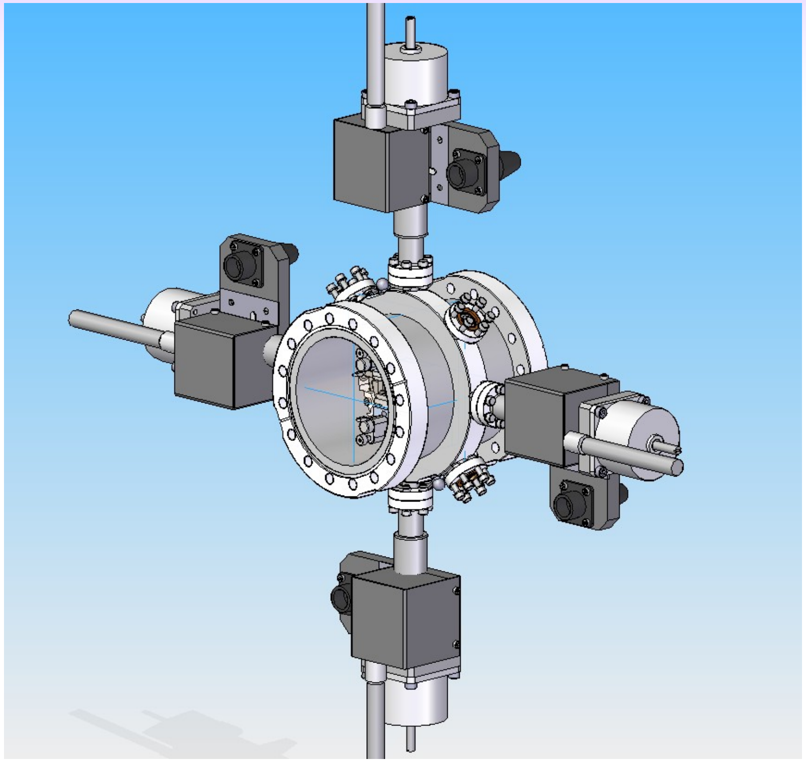
Engineering Status – Optics

- Slits– WBS 1.5.3.3
  - Defines the beam size & position
  - PRD released
  - Slit ESD out for signature
  - Off the shelf slit device with custom polished cylindrical blades
  - Obtained Silicon Nitride Material for evaluation
  - Investigating “dual blade” slit device
    - Employs pico-motors to tip the blades to perform beam based alignment of the blades relative to each other (1μm).
    - Use 2 single blade devices
  - PDR is scheduled for Q1FY09



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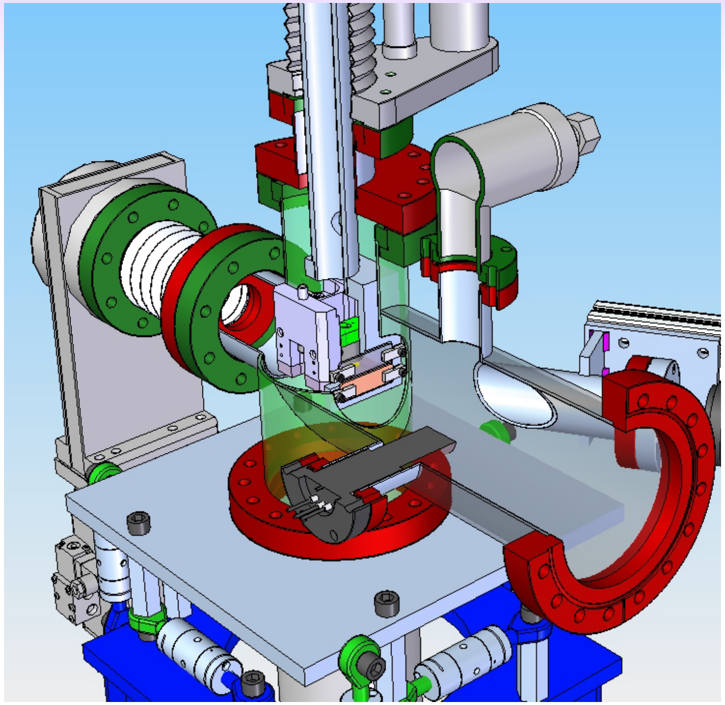
Engineering Status - Optics

- Pulse picker – WBS 1.5.3.5
  - Picks a single pulse or any pattern less than 30 hertz
  - PDR released
  - ESD in work
  - Shared design with AMO
    - Employs same commercial pulse picker
    - Need to compact the AMO design
  - First article pulse picker received
  - PDR scheduled for Q4FY09



LUSI LCLS Ultrafast Science Instruments

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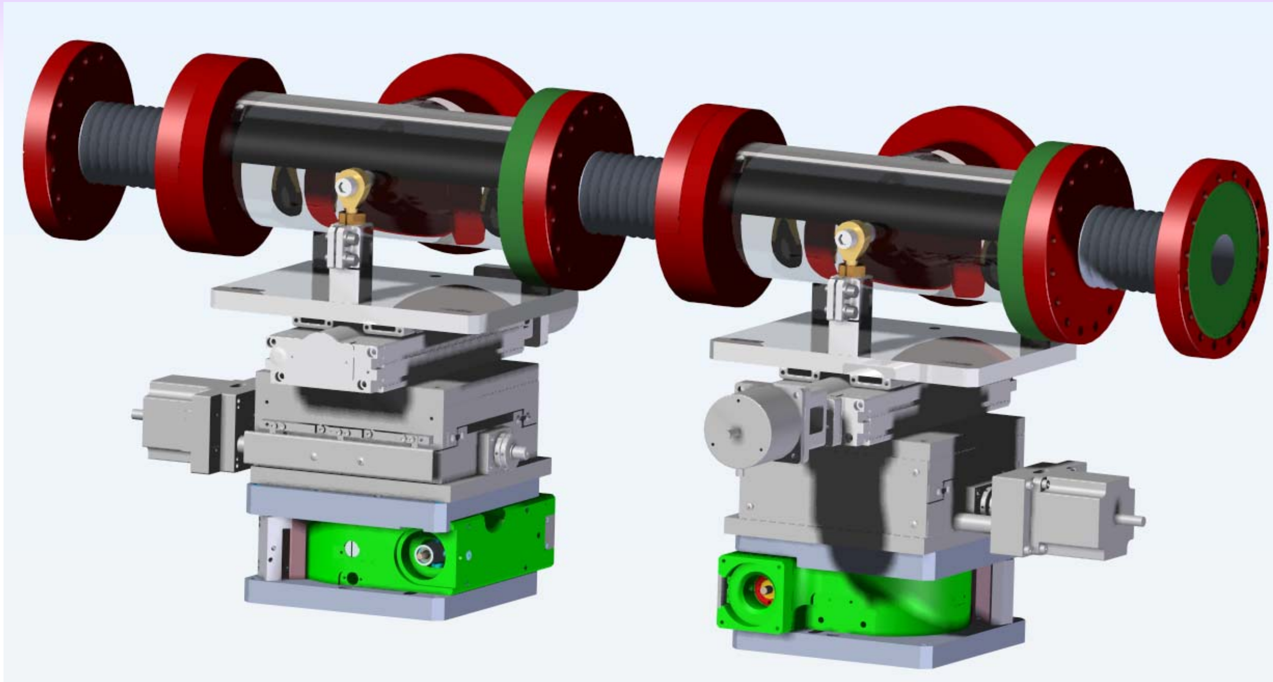
Engineering Status – Optics



- Harmonic rejection mirror (HRM) – WBS 1.5.3.6
  - HRM conceptual design in process
  - PRD released
  - ESD in work
  - Required for late XPP operation and XCS operation
  - PDR scheduled for Q3FY09

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Engineering Status

- Major Upcoming Milestones
  - Q4 FY2008 – PDR Pop-In Profile Monitor
  - Q4 FY2008 – PDR Pop-In Intensity Monitor
  - Q4 FY2008 – PDR Pulse Picker
  - Q1 FY2009 – PDR Intensity-Position Monitor
  - Q1 FY2009 – PDR Slit System
  - Q1 FY2009 – FDR Slits system
  - Q1 FY2009 – FDR Pulse picker

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Value Engineering / Management

- *Many trade-offs have been considered throughout the design of DCO components*
- *The DCO team will continue to purse cost effective approaches for all the component aspects (design, fabrication, testing, Installation)*

Component	Value Management /Design Alternatives Considered
Diagnostics	*All the diagnostics requirements were optimized to meet the experimental needs for all the instruments. Significant cost savings can be realized from common designs, both in PED, as well as in manufacturing.*
Optics	*The following optical components requirements were optimized to meet the experimental needs for all the instruments: Pulse Picker, Attenuator, Harmonic Rejection Mirror and Be Lenses. Significant cost savings can be realized from common designs*
Pop-In Profile Monitor & Pop-In Intensity Monitor	*Design alternatives were studied for functionality and cost savings, as well as space savings was found in combining the Pop-In Profile Monitor with the Pop-In Intensity monitor.*
Intensity-Position Monitor	*Investigating cost savings for modifying commercial units versus SLAC in house design*
Slit System	*Investigating alternative designs for the double blade slits. Also re-examined the functionality and requirements for this unit. Cost comparison of using 2 commercial slit units versus a new double slit design.*
Actuators	*Planning on using common actuators to limit the number of designs. Performed a cost comparison of the controls between pneumatic actuators and steppers with smart motors.*
Vacuum Assemblies	*Combining units to reduce the number of vacuum chambers, thus reducing material cost, as well as labor for assembly.*

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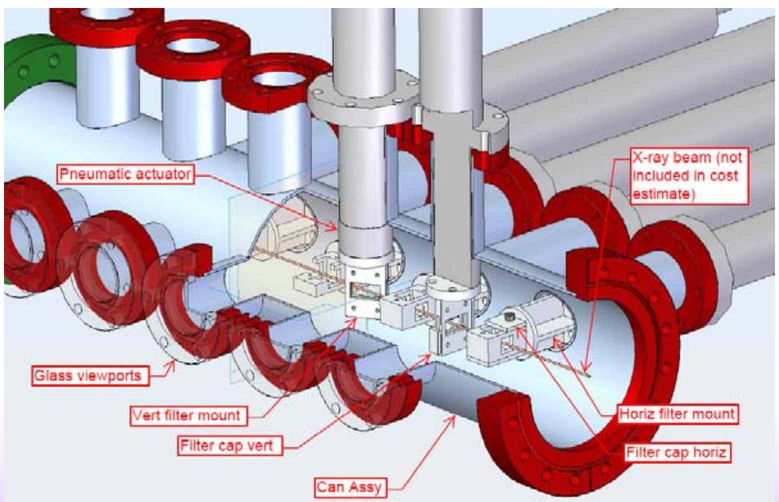
Basis of Estimate

- Contains the following
  - Description of the component
  - 3D model if applicable and available
  - Detailed cost estimate
    - Part number, drawing number, vendor, notes, weight, qty, and cost.
  - Supporting quotations, drawings, catalogs, etc.
  - Configuration controlled with the CD2 baseline
  - Cross referenced to P3 activity ID's



LUSI "X-Ray Optics"
WBS 1.5.3.4 — Attenuator 10 Way

Estimator — Defever/Arnett/Kurita

if alignment of the can is necessary, a bellows would be required on each end of the can, as well as means of external adjustment. This is the preferred design (compared to stepper motors) due to the 1 second actuation requirement

Indirects SLAC Labor	20.0%
Indirects Purchases	4.6%
Burden - Fringe	27.9%
Burden - Leave	20.7%

ACTIVITY ID	INDENT	PED	Part Number	Material	Man Weeks	Resource	Hours	QTY	Unit Cost [$]	Tot Hours	Engineer Man Hours	Designer Man Hours	Engineer Man Weeks	Designer Man Weeks	cleaning	assembly	mech Fab	inspection/Alignment	Direct Total
		Sub Total																	$48.69K
											75	150	0.875	3.75	20	100	34	0	
DI 06920		ESD			1.00	Engineer	40				40								$2.30K
		Design																	
DI 06960		Preliminary			3.75	**Des Total**	150				35	150	0.875	3.75					
DI 06960					0.88	**Eng Total**	35												
DI 06960		Vacuum Assembly	391-900-00		1.50	Designer	60												$4.08K
DI 06960					0.25	Engineer	10												$0.57K
DI 06960		Actuator Assy	391-900-02		0.50	Designer	20												$1.36K
DI 06960					0.25	Engineer	10												$0.57K
DI 06960		Filter Assy	391-900-04		1.50	Designer	60												$4.08K
DI 06960					0.25	Engineer	10												$0.57K
DI 06960		Alignment			0.25	Designer	10												$0.68K
DI 06960					0.13	Engineer	5												$0.29K
DI 07020		Final			2.00	**Des Total**	80												
DI 07020					0.63	**Eng Total**	25												
DI 07020		Vacuum Assembly	391-900-00		0.50	Designer	20												$1.36K
DI 07020					0.13	Engineer	5												$0.29K
DI 07020		Actuator Assy	391-900-02		0.25	Designer	10												$0.68K
DI 07020					0.13	Engineer	5												$0.29K
DI 07020		Filter Assy	391-900-04		1.00	Designer	40												$2.72K
DI 07020					0.13	Engineer	5												$0.29K
DI 07020		Alignment			0.25	Designer	10												$0.68K
DI 07020					0.25	Engineer	10												$0.57K
		Prepare for Reviews																	
DI 06970		Preliminary			1.00	Engineer	40												$2.30K
DI 06970					0.25	Designer	10												$0.68K
DI 07050		Final			1.00	Engineer	40												$2.30K
DI 07050					0.25	Designer	10												$0.68K
		Reviews																	
DI 06980		Preliminary			0.10	Engineer	4												$0.23K
DI 06980					0.10	Designer	4												$0.27K
DI 07070		Final			0.10	Engineer	4												$0.23K
DI 07070					0.10	Designer	4												$0.27K
		Documentation																	
DI 07040		Detail (25 drawings)			3.13	Designer	125												$8.50K
DI 07040					0.63	Engineer	25												$1.44K
DI 07045		Checking			1.88	Designer	75												$5.10K
DI 07100		Assembly drawings (5)			1.00	Designer	40												$2.72K
DI 07100					0.13	Engineer	5												$0.29K
DI 07140		Manufacturing documents			1.00	Engineer	40												$2.30K
		Support Design for Dual Pop-In																	
DI 07155		Preliminary			0.09	Engineer	16												$0.92K
DI 07155					0.18	Designer	32												$2.18K
DI 07160		Final			0.04	Engineer	8												$0.46K
DI 07160					0.09	Designer	16												$1.09K
DI 07165		Detail Drawings (5 drawings)			0.14	Designer	25												$1.70K
DI 07165					0.03	Engineer	5												$0.29K
DI 07170		Check and Release			0.08	Designer	15												$1.02K
		MSL																	
		Sub Total																	$58.11K

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Procurement Strategy

- *A variety of sources are used to design, build, test and install DCO components.*
  - *SLAC effort where skill set exists.*
  - *Vendor design – build used where available.*
  - *Previous designs and Off-The-Shelf components are used whenever available.*

DCO Work Breakdown Structure		Resource Source		
WBS	TITLE	Design	Build	Test/Install
1.5	**Diagnostics & Common Optics**			
1.5.01	Diagnostics & Common Optics System Integration &			
1.5.02.01	Pop in Profile/Wavefront Monitor			
1.5.02.02	Pop in Pop intensity Monitor			
1.5.02.03	Intensity Position Monitor			
1.5.03.01	Monochromator			
1.5.03.02	X ray Focusing Lenses			
1.5.03.03	Slit System			
1.5.03.04	Attenuators / Filters			
1.5.03.05	Pulse Picker			
1.5.03.06	Harmonic Rejection Mirrors			

Previous Design/OTS	
SLAC	
Domestic Vendor	
Foreign Vendor	
Long Lead Procurement	

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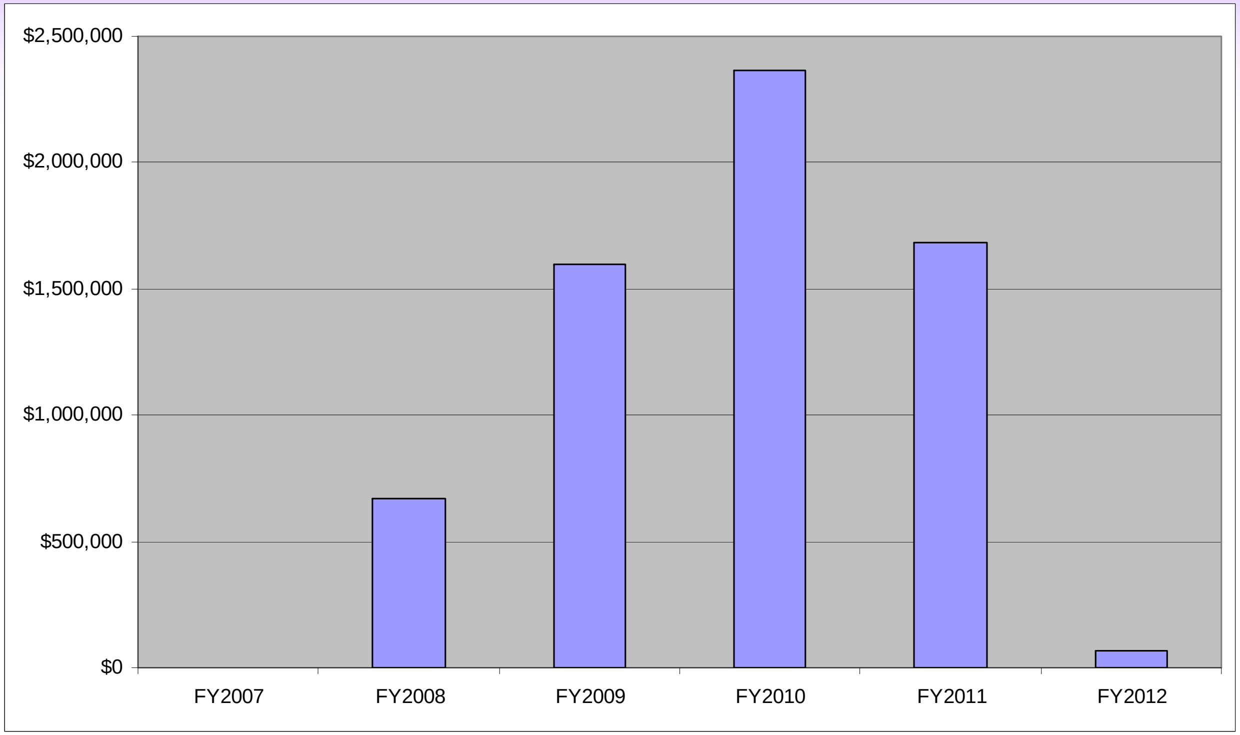
DCO Cost & Schedule

- **WBS Budget Profile**



Control Account	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	Cumulative
1.5.01 Diagnostics & Common Optics System Integration & Design	$0	$425,202	$321,933	$308,333	$211,124	$66,793	$1,333,385
1.5.02.01 Pop-in Profile Monitor	$0	$41,893	$156,295	$219,317	$148,664	$0	$566,169
1.5.02.02 Pop-In Intensity Monitor	$0	$42,092	$64,342	$108,047	$111,602	$0	$326,083
1.5.02.03 Intensity-Position Monitor	$0	$44,616	$122,512	$308,170	$212,393	$0	$687,692
1.5.03.01 Monochromator	$0	$0	$387,623	$845,895	$0	$0	$1,233,518
1.5.03.02 X-ray Focusing Lenses	$0	$14,385	$148,711	$13,148	$183,500	$1,520	$361,263
1.5.03.03 Slit System	$0	$66,154	$92,598	$251,284	$250,285	$0	$660,321
1.5.03.04 Attenuators / Filters	$0	$4,427	$99,061	$75,773	$150,270	$0	$329,531
1.5.03.05 Pulse Picker	$0	$32,350	$138,987	$164,443	$139,546	$0	$475,327
1.5.03.06 Harmonic Rejection Mirrors	$0	$0	$62,396	$70,761	$276,494	$1,056	$410,706
Control Account Totals	$0	$671,120	$1,594,457	$2,365,170	$1,683,879	$69,369	$6,383,995

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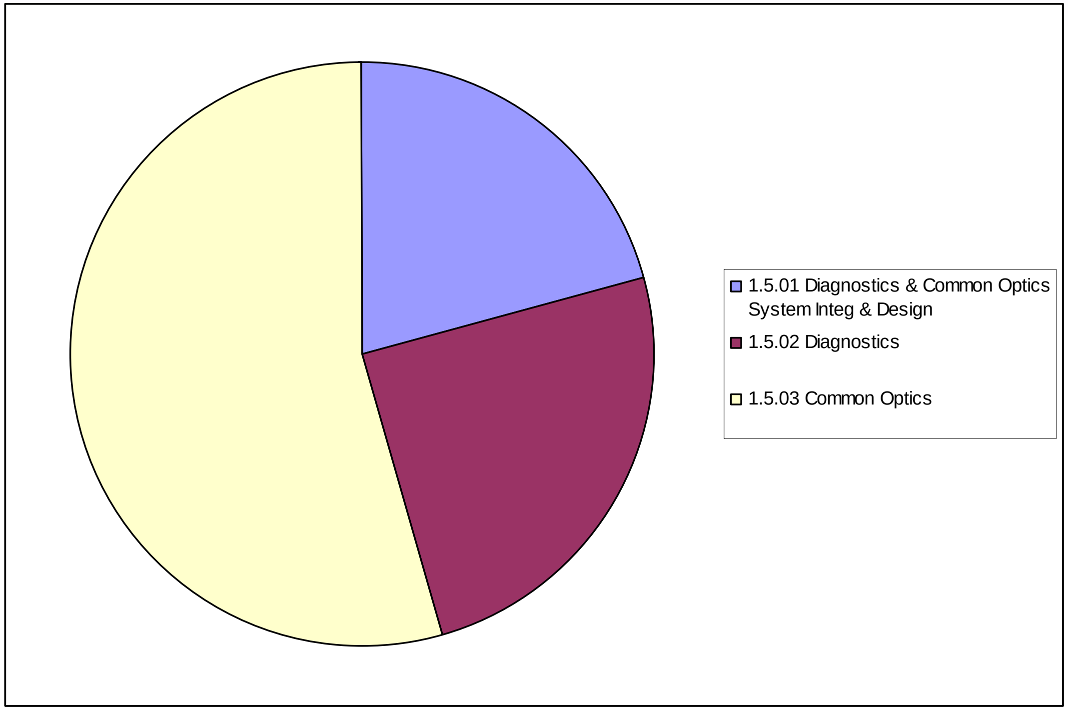
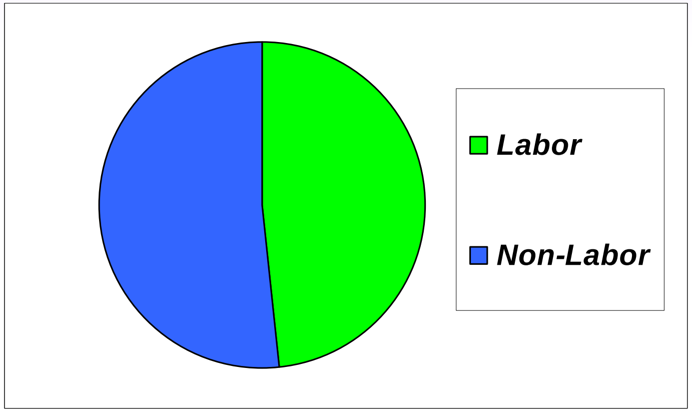
DCO Cost & Schedule

Cost by account and resource





WBS 1.5	
Resource Type	Value
Labor	$3,093,109
Non-Labor	$3,290,886
Total BAC	$6,383,995

WBS 1.5	FY07	FY08	FY09	FY10	FY11	FY12	Cumulative
1.5.01 Diagnostics & Common Optics System Integ & Design	$ -	$ 425,202	$ 321,933	$ 308,333	$ 211,124	$ 66,793	$ 1,333,385
1.5.02 Diagnostics	$ -	$ 128,602	$ 343,149	$ 635,534	$ 472,659	$ -	$ 1,579,943
1.5.03 Common Optics	$ -	$ 117,316	$ 929,376	$ 1,421,303	$ 1,000,096	$ 2,576	$ 3,470,667
WBS Totals:	$ -	$ 671,120	$ 1,594,457	$ 2,365,170	$ 1,683,879	$ 69,369	$ 6,383,995

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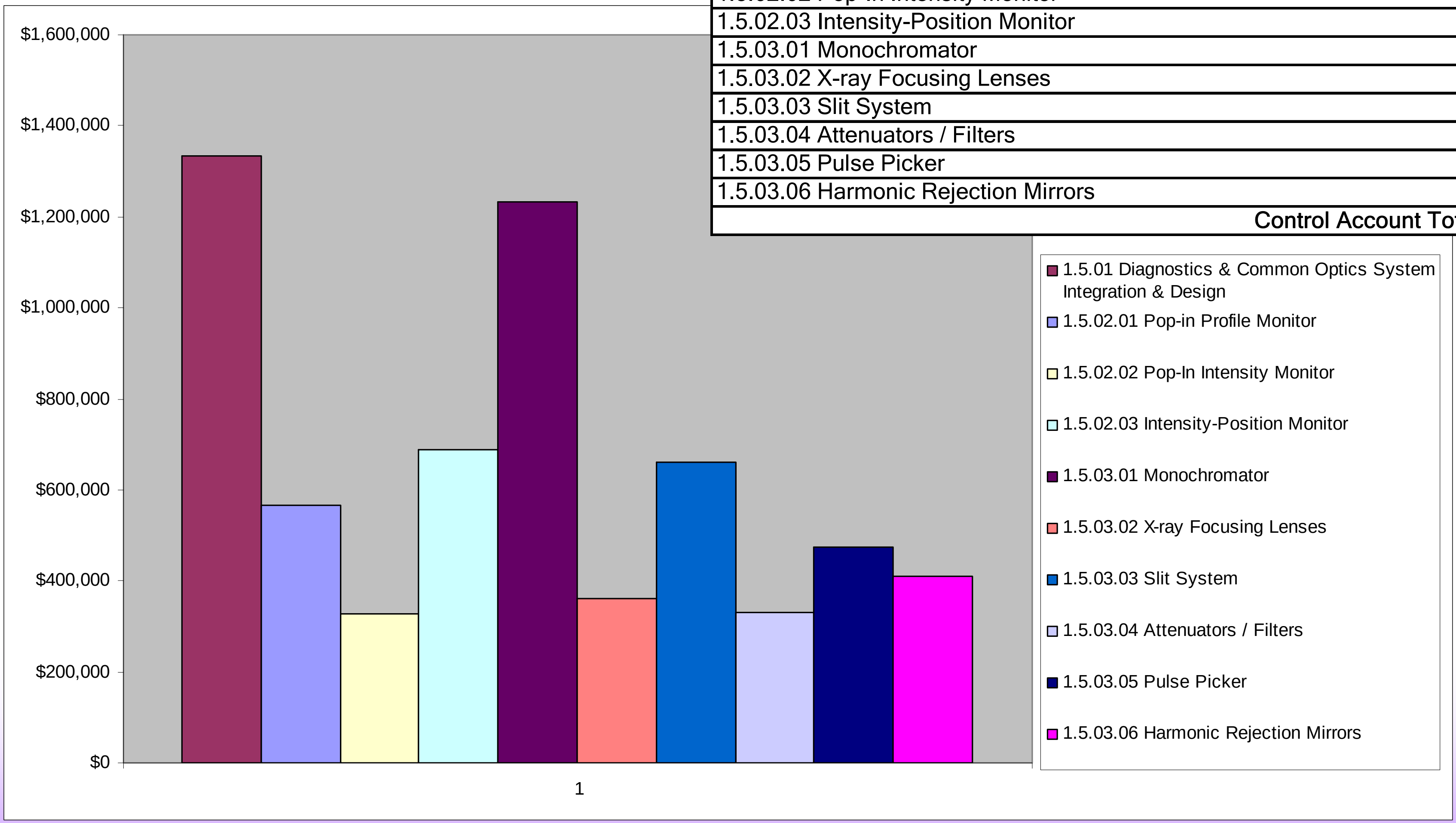
Cost by Control Account

Control Account	Cumulative
1.5.01 Diagnostics & Common Optics System Integration & Design	$1,333,385
1.5.02.01 Pop-in Profile Monitor	$566,169
1.5.02.02 Pop-In Intensity Monitor	$326,083
1.5.02.03 Intensity-Position Monitor	$687,692
1.5.03.01 Monochromator	$1,233,518
1.5.03.02 X-ray Focusing Lenses	$361,263
1.5.03.03 Slit System	$660,321
1.5.03.04 Attenuators / Filters	$329,531
1.5.03.05 Pulse Picker	$475,327
1.5.03.06 Harmonic Rejection Mirrors	$410,706
Control Account Totals	$6,383,995



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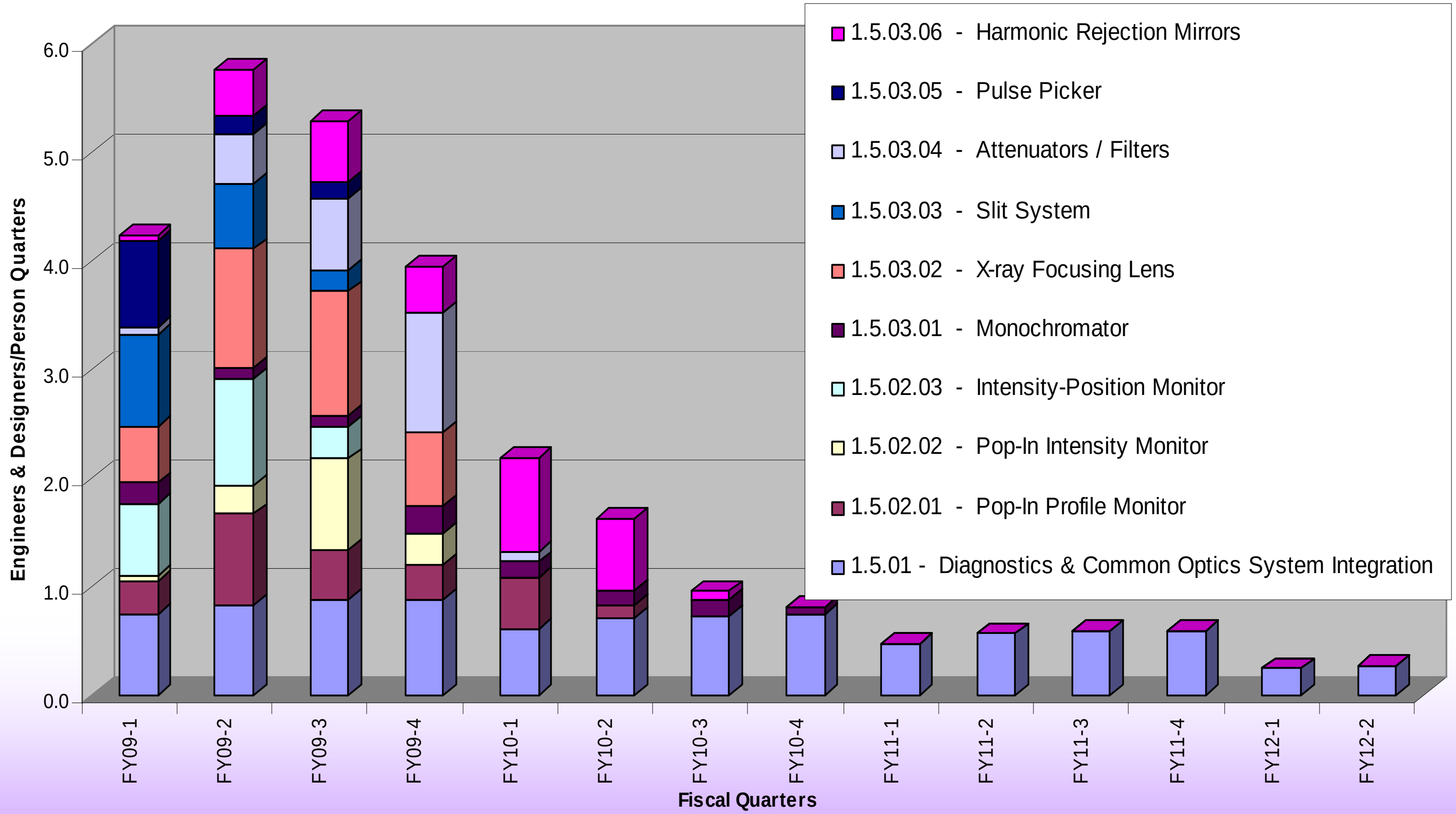
DCO Cost & Schedule

- Resource Loading
- Durations
  - Person quarter = 444h
  - Person year = 1776h
  - Person month = 148h



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DCO Cost & Schedule

- **Long Duration Procurements**

Activity ID	Activity description	Budgeted cost
DI 60440	AWARD: XCS Monochromator (FOREIGN)	1,158,831.40
DI 09560	AWARD: PO - XPP XFL Long Lead Parts	11,770.00
DI 14200	AWARD: PO - XCS XFL Long Lead Parts	12,320.00
DI 41040	AWARD: PO - XPP Slits Long Lead Parts	75,881.19
DI 41210	AWARD: PO - CXI Slits Long Lead Parts	103,066.04
DI 42110	AWARD: PO - XCS Slits Long Lead Parts	158,854.08
DI 12820	AWARD: PO - XPP Pulse Picker - Long Lead Parts	14,980.00
DI 14105	AWARD: PO - CXI Pulse Picker - Long Lead Parts	15,260.00
DI 16005	AWARD: PO - XCS Pulse Picker - Long Lead Parts	15,680.00
DI 10445	AWARD: PO - XPP HRM Long Lead Parts	49,280.00
DI 14840	AWARD: PO - XCS HRM Long Lead Parts	49,280.00

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Deliverables

	CD-4A	CD-4B	CD-4C
XPP	Pop-In Profile Monitor Pop-In Intensity Monitor Intensity-Position Monitor Slit System Pulse Picker		Harmonic Rejection Mirrors X-Ray Focusing Lens Attenuators
CXI		Pop-In Profile Monitor Pop-In Intensity Monitor Intensity-Position Monitor Wavefront Monitor Slit System Pulse Picker Attenuators	
XCS			Pop-In Profile Monitor Pop-In Intensity Monitor Intensity-Position Monitor Attenuators Harmonic Rejection Mirrors X-Ray Focusing Lens Slit System Pulse Picker Monochromator

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Critical Path

- 1st Critical Path
  - Driven by funding milestones on long duration part procurement
    - AWARD: PO - XCS XFL Long Lead Parts
- 2nd Critical Path
  - PDR - Prelim Design Review - Intensity Position Mon
  - AWARD: PO - XPP IO Mon 1st Article Parts
  - AWARD: PO - XCS HRM Long Lead Parts
- Additional float could be generated by allocating procurement funds to DCO earlier
- TOTAL SCHEDULE FLOAT for DCO is 80 days.

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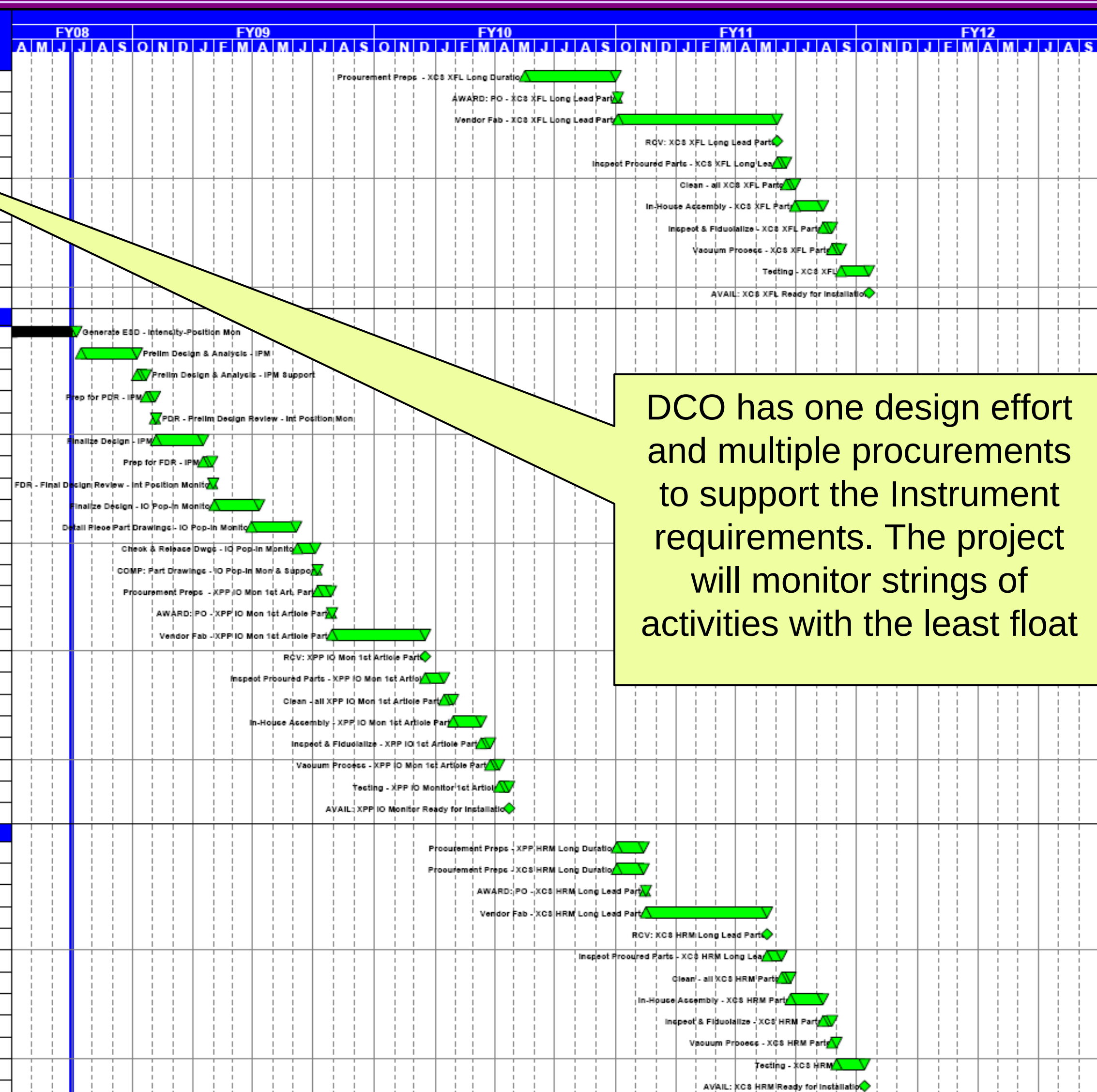
DCO Schedule Critical Path

Activity ID	Activity Description	Total Float	Early Finish	Late Finish
80				
DI 14180	Procurement Preps - XCS XFL Long Duration	80	10/01/10	02/08/11
DI 14200	AWARD: PO - XCS XFL Long Lead Parts	80	10/04/10	02/09/11
DI 14220	Vendor Fab - XCS XFL Long Lead Parts	80	06/01/11	09/21/11
DI 14240	RCV: XCS XFL Long Lead Parts	80	[illegible]8/01/11	09/21/11
DI 14340	Inspect Procured Parts - XCS XFL Long Lead	80	06/15/1[illegible]	10/05/11
DI 14380	Clean - all XCS XFL Parts	80	06/29/11	[illegible]
DI 14400	In-House Assembly - XCS XFL Parts	80	08/10/11	12/07/11
DI 14420	Inspect & Fiducialize - XCS XFL Parts	80	08/24/11	12/21/11
DI 14440	Vacuum Process - XCS XFL Parts	80	09/07/11	01/12/12
DI 14460	Testing - XCS XFL	80	10/19/11	02/28/12
DI 14480	AVAIL: XCS XFL Ready for Installation	80	10/19/11	02/28/12
84				
DI 02960	Generate ESD - Intensity-Position Mon	84	07/08/08	11/03/08
DI 03000	Prelim Design & Analysis - IPM	84	10/06/08	02/17/09
DI 03190	Prelim Design & Analysis - IPM Support	84	10/20/08	03/03/09
DI 03025	Prep for PDR - IPM	84	11/03/08	03/17/09
DI 03040	PDR - Prelim Design Review - Int Position Mon	84	11/04/08	03/18/09
DI 03060	Finalize Design - IPM	84	01/15/09	05/13/09
DI 03095	Prep for FDR - IPM	84	01/29/09	05/27/09
DI 03100	FDR - Final Design Review - Int Position Monitor	84	01/30/09	05/28/09
DI 02320	Finalize Design - IO Pop-In Monitor	84	04/10/09	08/06/09
DI 02340	Detail Piece Part Drawings - IO Pop-In Monitor	84	06/05/09	10/01/09
DI 02342	Check & Release Dwgs - IO Pop-In Monitor	84	07/03/09	10/29/09
DI 02343	COMP: Part Drawings - IO Pop-In Mon & Support	84	07/06/09	10/30/09
DI 02580	Procurement Preps - XPP IO Mon 1st Art. Parts	84	07/27/09	11/20/09
DI 02600	AWARD: PO - XPP IO Mon 1st Article Parts	84	07/28/09	11/23/09
DI 02620	Vendor Fab - XPP IO Mon 1st Article Parts	84	12/17/09	04/28/10
DI 02640	RCV: XPP IO Mon 1st Article Parts	84	12/17/09	04/28/10
DI 02760	Inspect Procured Parts - XPP IO Mon 1st Article	84	01/14/10	05/12/10
DI 02780	Clean - all XPP IO Mon 1st Article Parts	84	01/28/10	05/26/10
DI 02800	In-House Assembly - XPP IO Mon 1st Article Parts	84	03/11/10	07/07/10
DI 02810	Inspect & Fiducialize - XPP IO 1st Article Parts	84	03/25/10	07/21/10
DI 02820	Vacuum Process - XPP IO Mon 1st Article Parts	84	04/08/10	08/04/10
DI 02840	Testing - XPP IO Monitor 1st Article	84	04/22/10	08/18/10
DI 02860	AVAIL: XPP IO Monitor Ready for Installation	84	04/22/10	08/18/10
85				
DI 10440	Procurement Preps - XPP HRM Long Duration	85	11/12/10	03/29/11
DI 14820	Procurement Preps - XCS HRM Long Duration	85	11/12/10	03/29/11
DI 14840	AWARD: PO - XCS HRM Long Lead Parts	85	11/15/10	03/30/11
DI 14860	Vendor Fab - XCS HRM Long Lead Parts	85	05/18/11	09/14/11
DI 14880	RCV: XCS HRM Long Lead Parts	85	05/18/11	09/14/11
DI 14980	Inspect Procured Parts - XCS HRM Long Lead	85	06/08/11	10/05/11
DI 15020	Clean - all XCS HRM Parts	85	06/22/11	10/19/11
DI 15040	In-House Assembly - XCS HRM Parts	85	08/10/11	12/14/11
DI 15060	Inspect & Fiducialize - XCS HRM Parts	85	08/24/11	01/05/12
DI 15080	Vacuum Process - XCS HRM Parts	85	08/31/11	01/12/12
DI 15100	Testing - XCS HRM	85	10/12/11	02/28/12
DI 15120	AVAIL: XCS HRM Ready for Installation	85	10/12/11	02/28/12



DCO has one design effort and multiple procurements to support the Instrument requirements. The project will monitor strings of activities with the least float

Sheet 1 of 2

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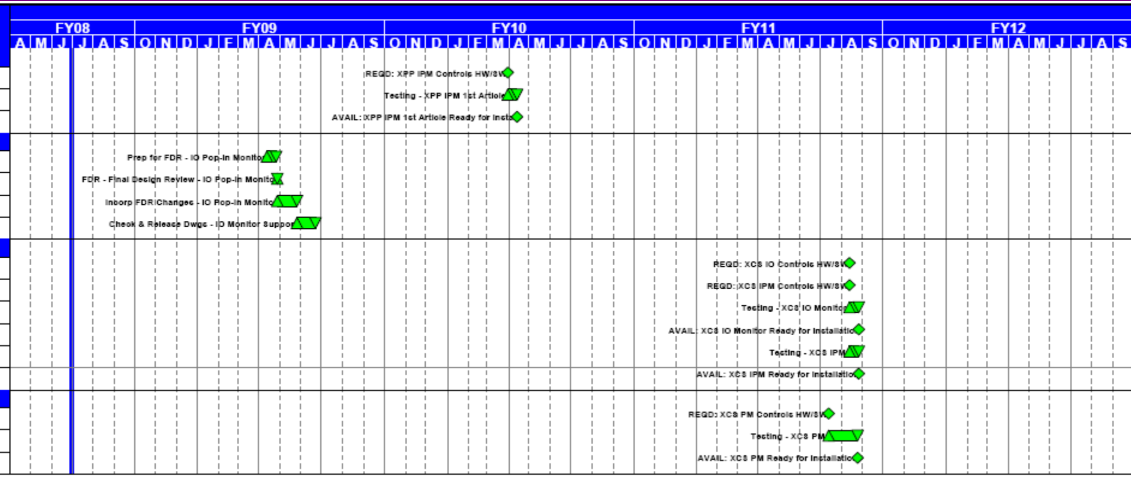
DCO Schedule Critical Path

Activity ID	Activity Description	Total Float	Early Finish	Late Finish
91				
DI 03575	REQD: XPP IPM Controls HW/SW	91	03/30/10	08/04/10
DI 03580	Testing - XPP IPM 1st Article	91	04/13/10	08/18/10
DI 03600	AVAIL: XPP IPM 1st Article Ready for Install	91	04/13/10	08/18/10
93				
DI 02345	Prep for FDR - IO Pop-In Monitor	93	04/24/09	09/02/09
DI 02360	FDR - Final Design Review - IO Pop-In Monitor	93	04/27/09	09/03/09
DI 02380	Incorp FDR Changes - IO Pop-In Monitor	93	05/25/09	10/01/09
DI 02480	Check & Release Dwgs - IO Monitor Support	93	06/22/09	10/29/09
97				
DI 13805	REQD: XCS IO Controls HW/SW	97	08/11/11	01/10/12
DI 14125	REQD: XCS IPM Controls HW/SW	97	08/11/11	01/10/12
DI 13820	Testing - XCS IO Monitor	97	08/25/11	01/25/12
DI 13840	AVAIL: XCS IO Monitor Ready for Installation	97	08/25/11	01/25/12
DI 14140	Testing - XCS IPM	97	08/25/11	01/25/12
DI 14160	AVAIL: XCS IPM Ready for Installation	97	08/25/11	01/25/12
98				
DI 13485	REQD: XCS PM Controls HW/SW	98	07/13/11	12/05/11
DI 13500	Testing - XCS PM	98	08/24/11	01/25/12
DI 13520	AVAIL: XCS PM Ready for Installation	98	08/24/11	01/25/12



Sheet 2 of 2

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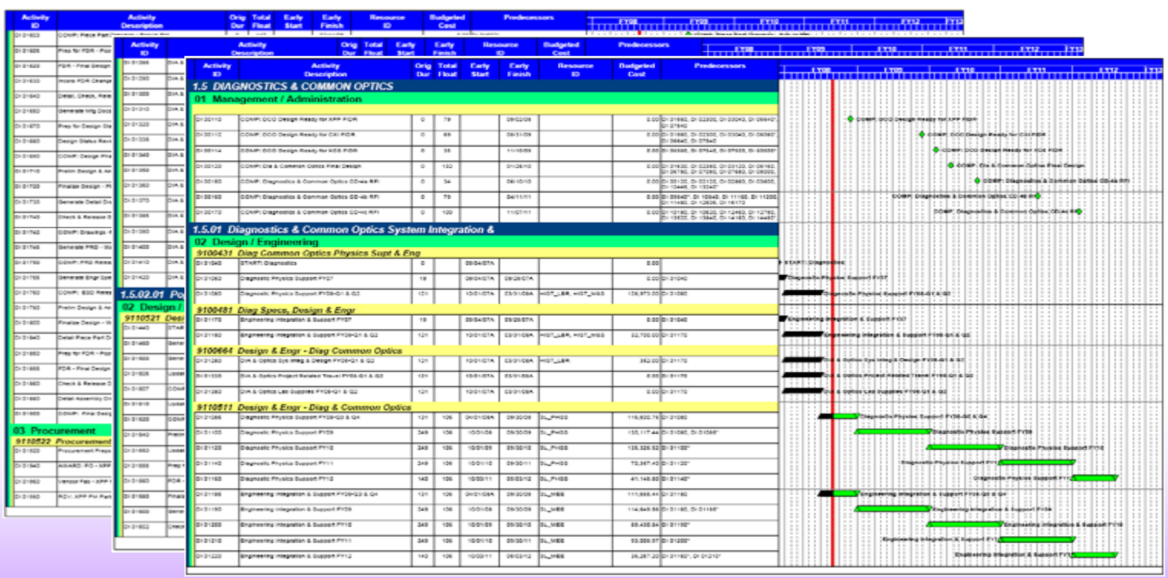
DCO Cost & Schedule

- Resource loaded schedule completed and has been fully implemented into the project management
- DCO
  - 139 milestones L4 and L5 specific to DCO
    - *L4 = systems*
    - *L5 = interface-handoff*
  - *37 milestones L6*
    - *L6 = commitments-awards*



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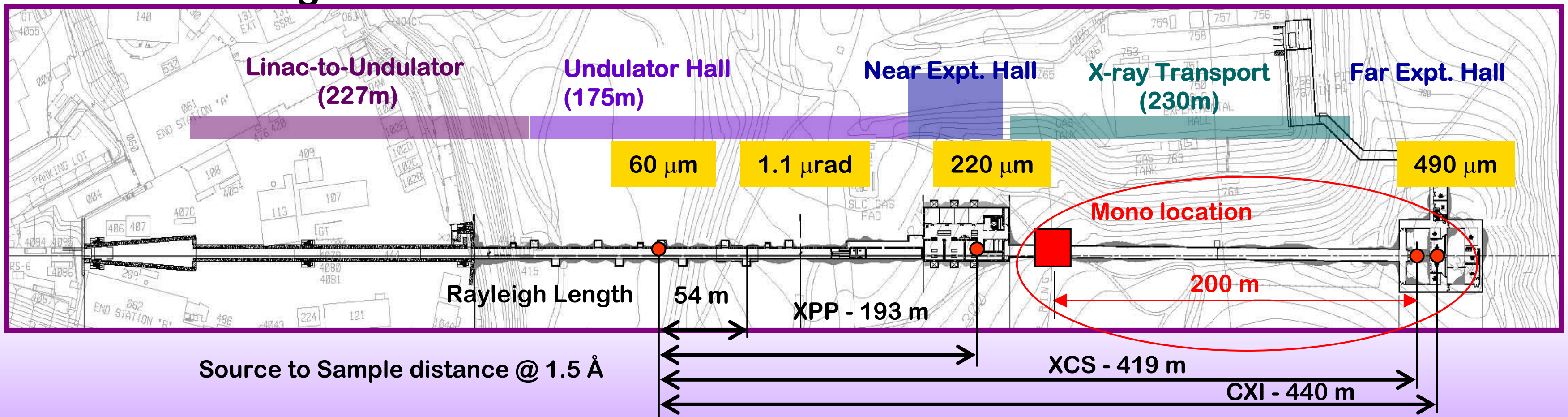
Risk Analysis

- DCO major risks identified per LCLS risk management plan, PMD 1.1-002-r4
  - Risk: Mono mechanical stability not met
    - Required to maintain position stability to 10% of beam size
  - Mitigation:
    - Ensure requirements are clearly stated and agreed prior to award and fabrication
    - Implement a stringent vendor selection process
    - Implement regular visits to vendor
    - Implement frequent and measurable status reports
    - Maintain constant communication with the vendor prior to and during design and fabrication



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Summary

- Scope of DCO components for XPP, CXI, and XCS instruments fully defined
- The design of key diagnostics devices and optical components is mature and based on proven developments
  - at FLASH, SPPS, synchrotron sources worldwide
  - by LCLS-XTOD group
- DCO components have a consistent cost estimate.
- Resource loaded schedule developed through end of project
- Critical Path is defined
- Advanced Procurements identified
- DCO is ready for CD2 approval!

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