13 Management, Cost, and Schedule Summary

The LZ Project (the Project) is international in scope, funding, and organization. This chapter presents an overview of the overall Project organization and a summary of the Project cost and schedule. The integrated overall Project Management organization is also described here. This Project organization has authority and responsibility over all aspects of the Project, including those funded by DOE, SDSTA, and non-U.S. agencies: the U.K.'s Science & Technology Facilities Council (STFC); Portugal's Fundação para a Ciência e a Tecnologia (FCT); and Korean-funded scope. The functions of the Project Advisory Board (PAB) are also described. A detailed discussion of Project Management, management systems, and approaches is described separately in the *LZ Project Execution Plan* (PEP) document.

13.1 LZ Project Organization

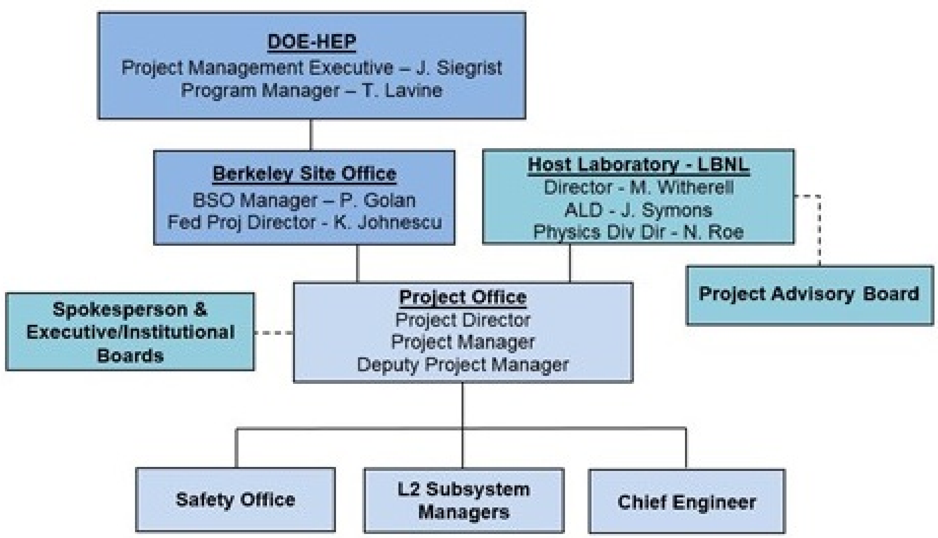

Figure 13.1.1: LZ Project reporting and responsibility organization chart, with an emphasis on the relationship to DOE.

The Projects organization from the perspective of DOE is summarized in Figure 13.1.1. LBNL is the DOE lead laboratory for LZ. As lead laboratory, LBNL will be responsible for Project management and funding from DOE and for ensuring that essential manpower and necessary infrastructure are provided to the Project during the R&D, construction, and operations phases. The Project Director and Project Manager will be from the lead laboratory and will report to the Physics Division Director of LBNL. These two Project positions must be jointly approved by LBNL and by the collaboration Executive Board (EB). The LBNL Project

Management Office (PMO) will review and provide oversight of the Project and its management systems to ensure that all DOE project guidelines and procedures are followed.

Figure 13.1.2 presents the internal organization of the Project. The Spokesperson is elected by the collaborating institutes to represent the scientific interests of the collaboration. The roles and term of the Spokesperson are defined in a governance document. The current Spokesperson is Prof. Harry Nelson (University of California, Santa Barbara). The Spokesperson chairs the EB, which is a representative, elected body of senior collaboration members. The EB will help guide the Project organization in its goal of delivering the experimental apparatus and software that will meet the scientific requirements of the LZ collaboration. An Institutional Board (IB), with representatives from each collaborating institution, meets regularly with the Spokesperson and Project team.

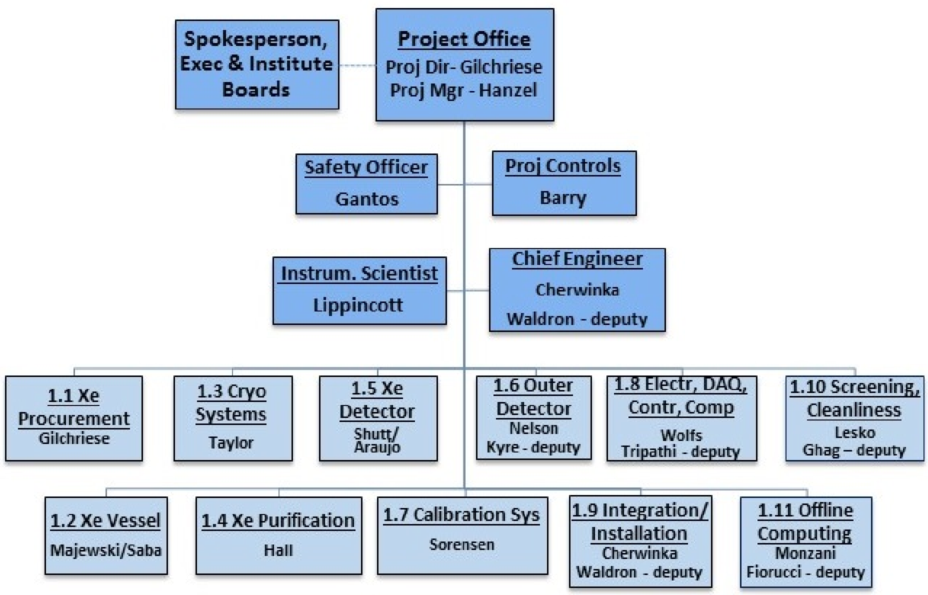

Figure 13.1.2: LZ Project organization.

13.1.1 Project Advisory Board

The PAB is an external board, gathered from the U.S. and non-U.S. scientific communities, that has expertise in large scientific projects. This board will provide valuable guidance and advice to the Project over the course of the construction life cycle. The PAB is charged by, and reports to, the Physics Division Director of LBNL. The current members are: David McFarlane (SLAC-chair), Jay Marx (Caltech-retired), Chris Bebek (LBNL), Elaine McCluskey (Fermi National Accelerator Laboratory [FNAL]), Bob McKeown (Jefferson National Accelerator Facility [J-LAB]), Mark Thomson (Cambridge), and Dan Dwyer (LBNL). The PAB will be supplemented as required to provide advice on a specific subject and for specific reviews.

13.1.2 Project Management Office

PMO personnel include Project Director M. Gilchriese (LBNL), Project Manager K. Hanzel (LBNL), Deputy Project Manager W. Edwards (LBNL), Instrument Scientist H. Lippincott (FNAL), Chief Engineer J. Cherwinka (Physical Sciences Laboratory, University of Wisconsin), Deputy Chief Engineer W. Waldron (LBNL), Safety Officer J. Gantos (LBNL), and Project Controls Officer M. Barry (LBNL). Systems engineering and QC/QA functions are also under the direction of the PMO.

13.1.3 Project Work Breakdown Structure

The LZ Work Breakdown Structure (WBS) has 12 major categories, as shown in Table 13.1.1.

Table 13.1.1: LZ Work Breakdown Structure (WBS) shown at L2 and description of what each element covers

WBS	WBS Title	WBS Description
1.1	Xenon Procurement	Specification and procurement of the Xe necessary for the LZ experiment. Xe storage & transportation vessels are covered in WBS 1.4, Xe Purification & Handling.
1.2	Xenon Vessel (Cryostat)	Labor, materials, and equipment associated with the design, prototyping, materials selection, construction, certification, and delivery, as well as planning and oversight of assembly and testing efforts on site, for the cryostat vessel system, its tanks, connecting flanges, insulation, and support structures.
1.3	Cryogenic Systems	Labor, materials, and equipment associated with the design, prototyping, procurement, construction, assembly, testing, and delivery of the liquid nitrogen cryogenic system and nitrogen purge system.
1.4	Xenon Purification & Handling	Labor, materials, and equipment associated with the production of high-purity LXe, its storage, delivery to, and recovery from the TPC. This element covers the online purification system, the Xe purity analysis systems, the automated fail-safe Xe recovery system, and selected radon-reduction systems. A major subcomponent of this element is the stand-alone krypton-removal system, which will be used to purify the Xe prior to experimental operations.
1.5	Xenon Detector	Labor, materials, and equipment associated with the design, prototyping, fabrication, testing, and assembly planning for the central Xe detector. This element covers the central detector region with its PMTs and the accompanying field-shaping electrodes and reflecting walls. It includes the skin veto region outside the main TPC volume and its PMTs. Included are the cathode, anode, and gate HV power supplies and the cathode HV umbilical connection to the TPC cathode and the grid structures, as well as the internal Xe liquid fluid system that brings liquid into the TPC region, providing cooling surfaces for temperature control. Also included is monitoring equipment for temperature, pressure, fluid flow, and other necessary measurements.
1.6	Outer Detector System	Labor, materials, and equipment associated with the design, fabrication, testing, and assembly planning for the outer detector system. This includes the acquisition of the acrylic vessels, construction of the scintillator filling system, the acquisition and testing of the outer detector PMTs, the mixing and handling of the gadolinium-loaded liquid scintillator, procurement of reflector materials, as well as all the support infrastructure required. It also includes the planning, procedures, and oversight, plus the installation tooling required during the assembly of the system inside the water tank.
1.7	Calibration	Labor, materials, and equipment associated with the design, prototyping, construction, delivery, assembly, and testing of the calibration system for the Xe detector and the outer detector system, along with the mechanisms, plumbing, valves, and radiation sources required to implement the calibration systems. Included are safety and administrative custodial requirements for source security, handling, and shipping.
(continued on next page)		

Table 13.1.1: (continued)

WBS	WBS Title	WBS Description
1.8	Electronics, DAQ, Controls, Computing	Labor, materials, and equipment associated with the design, prototyping, construction, delivery, assembly, and testing of the analog and digital electronics for the Xe and outer detector PMTs, the DAQ and trigger systems, the PMT HV system, the detector control system, and the online and offline hardware and software. This element includes the external signal, PMT HV, and network cables. Not included are the internal HV and signal cables for the PMTs (covered by WBS 1.5) and the detector sensors/instruments required for detector control. This element provides standard interfaces for detector sensors/instruments; custom interfaces required to connect custom sensors/instruments to the detector control system will not be provided by this element.
1.9	Integration & Installation	Labor and materials necessary to integrate the design effort of the subsystems into an overall detector design, maintain CAD models of the LZ detector and Davis Campus, upgrade the SURF infrastructure to support the detector assembly and operation, and perform on-site surface-level assembly of the detector and installation into the Davis Campus underground. Other subsystem elements maintain the responsibility to support integration by communicating design requirements, interface issues, subsystem CAD models, infrastructure needs, and assembly and operation needs. WBS 1.9 supplies planning, management, and skilled labor for assembly and installation, and the subsystems supplies experts on site to support this as needed.
1.10	Cleanliness & Screening	Labor, materials, and equipment associated with specification of radioactive background-level tolerances in the experiment; material radioassaying and control of radioactive background contaminants in the Xe resulting from component outgassing; control of ambient radioactivity; and establishing cleanliness controls, monitoring, and maintenance procedures for manufacture, transport, storage, handling, assembly, and integration of detector components.
1.11	Offline Computing	Software professional labor and computing hardware needed to begin operations of the LZ experiment. Interface to collaboration responsibilities for data processing, analysis, and simulation software.
1.12	Project Management	The cost of labor, travel, and materials necessary to plan, track, organize, manage, maintain communications, conduct reviews, and perform necessary safety, risk, and QA tasks during all phases of the Project. Subsystem-related management and support activities for planning, estimating, tracking, and reporting as well as their specific EH&S and QA tasks are included in each of the subsystems.

13.1.4 Project Subsystem Organization

The current Subsystem Managers (at Level 2 of the WBS and selected Level 3 Managers) and lead engineers are listed in Table 13.1.2. The LZ Technical Board comprises the WBS Level 2 Managers (**Bold**), their deputies, and the Project Office.

The Level 2 or Subsystem Managers, in addition to being members of the LZ Technical Board, are responsible for overseeing the development of the Project baseline with regard to their subsystems. They work with the Project Office to establish a level (L3) organization, helping to ensure that adequate technical resources have been identified, and defining the subsystem-specific requirements as they flow down from the overall Project. The L2 Managers oversee the development of the technical design as well as the schedule and cost estimates associated with design, fabrication/execution, assembly, and test of their subsystems. They are also responsible for producing design reports and internal and external reviews. Ultimately, they are responsible for executing the Project Plan with respect to their subsystems.

Design reviews are held for all relevant subsystems and are organized by the PMO. Each major subsystem and procurement undergoes multiple reviews (typically preliminary, final, and production readiness) as the design of the particular subsystem matures and reaches readiness for construction.

Table 13.1.2: The LZ Project Level 2 and 3 managers and lead engineers.

WBS	Description	L2/3 Manager	Deputy or Co-mgr.	Lead engineer
1.1	**Xe Procurement**	**M. Gilchriese (LBNL)**		
1.2	**Xe Vessel**	**P. Majewski (RAL)**	**J. Saba (LBNL)**	**E. Holtom (RAL) / J. ODell (RAL)**
1.2.1	Design	E. Holtom (RAL)		
1.2.2	Material Selection	P. Majewski (RAL)		
1.2.3	Fabrication	J. ODell (RAL)		
1.2.4	Cleaning	J. ODell (RAL)		
1.2.5	Transportation	J. ODell (RAL)		
1.2.6	Acceptance, Assembly, Installation	J. ODell (RAL)		
1.2.7	Subsystem Management	P. Majewski (RAL)/J. Saba (LBNL)		
1.3	**Cryogenic Systems**	**D. Taylor (SDSTA)**		
1.3.1	Nitrogen Distribution	D. Taylor (SDSTA)		
1.3.2	Thermosyphons	D. Taylor (SDSTA)		
1.3.3	Vacuum System	C. Maupin (SDSTA)		
1.3.4	Breakout	C. Maupin (SDSTA)		
1.3.5	Controls and Power	C. Maupin (SDSTA)		
1.3.6	Subsystem Management	D. Taylor (SDSTA)		
1.4	**Xe Purification/Handling**	**C. Hall (UMd)**		
1.4.1	Xenon Sampling	C. Hall (UMd)		
1.4.2	Kr Removal	D. Akerib (SLAC)		
1.4.3	Xe Storage & Transport	T. Benson (UW-PSL)		
1.4.4	Xe Gas Delivery & Recovery	T. Benson (UW-PSL)		
1.4.5	Xe Gas Recirculation	J. Cherwinka (UW-PSL)		
1.4.6	Liquid Xe Tower	H. Lippincott (FNAL)		
1.4.7	LXe Transfer Lines	J. Cherwinka (UW-PSL)		
1.4.8	Undergnd Instal. Planning	C. Hall (UMd)		J. Cherwinka (UW-PSL)

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Table 13.1.2: (continued)

WBS	Description	L2/3 Manager	Deputy or Co-mgr.	Lead engineer
1.4.9	Subsystem Management	C. Hall (UMd)		
1.4.10	Xe Recovery & Cont. Man.	E. Dahl (Northwestern)		
1.5	**Detector**	**T. Shutt (SLAC)**	**H. Araujo (Imperial)**	**J. Saba (LBNL)**
1.5.1	Cathode High Voltage	D. McKinsey (UCBerkeley)		W. Waldron (LBNL)
1.5.2	U.S. PMT Systems	R. Gaitskell (Brown)		
1.5.3	U.K. PMT Systems	H. Araujo (Imperial)		
1.5.4	Field Cage	J. Saba (LBNL)		
1.5.5	Grids	W. Wisniewski (SLAC)		K. Skarpaas
1.5.6	Xe Monitoring System	H. Kraus (Oxford)		
1.5.7	Internal Fluid System	T. Shutt (SLAC)		
1.5.8	Skin System	H. Lippincott (FNAL)		
1.5.9	Assembly and Installation	J. Saba (LBNL)		
1.5.10	Screening Coordination	R. Webb (TAMU)		
1.5.11	System Test	K. Palladino (SLAC)		
1.5.12	Subsystem Management	T. Shutt	H. Araujo	
1.6	**Outer Detector System**	**H. Nelson (UCSB)**	**S. Kyre (UCSB)**	**D.White (UCSB)**
1.6.1	Scint. Vessels	S. Kyre (UCSB)		
1.6.2	Reflector System	S. Kyre (UCSB)		
1.6.3	LS Filling System	D. White (UCSB)		
1.6.4	Liquid Scint.	M. Yeh (BNL)		
1.6.5	Water Tank	D. White (UCSB)		
1.6.6	PMT Supports	S. Burdin (Liverpool)		D. White (UCSB)
1.6.7	PMTs	S. Fiorucci (LBNL)		
1.7	**Calibration System**	**P. Sorensen (LBNL)**		
1.7.1	Internal Radioact. Sources	S. Hertel (UCBerkeley)		
1.7.2	Calibration Source Delivery	M. van der Grinten (RAL)		
1.7.3	Radioisotope Sources	P. Sorensen (LBNL)		
1.7.4	Photoneutron Sources	P. Sorensen (LBNL)		

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Table 13.1.2: (continued)

WBS	Description	L2/3 Manager	Deputy or Co-mgr.	Lead engineer
1.7.5	DD Neutron Source	D. Huang (BrownU)		
1.7.6	Assembly and Installation Planning	P. Sorensen (LBNL)		
1.7.7	Subsystem Management	P. Sorensen (LBNL)		
1.8	**Electr., DAQ, Controls, Computing**	**F. Wolfs (URochester)**	**M. Tripathi (UCDavis)**	
1.8.1	Analog Electronics	M. Tripathi (UCDavis)		R. Gerhard (UCDavis)
1.8.2	Data Sparsification System	E. Druszkiewicz (URochester)		E. Druszkiewicz (URoch)
1.8.3	Data Acquisition System	W. Skulski (URochester)		W. Skulski (URoch)
1.8.4	External PMT HV, Signal	F. Wolfs (URochester)		
1.8.5	Slow Control	V. Solovov (Coimbra)		TBD (FNAL)
1.8.6	PMT HV Supplies	M. Tripathi (UCDavis)		R. Gerhard (UDavis)
1.8.7	Online HW	J. Buckley (Washington U)		M. Olevitch (WashingtonU), P. Zarzhitsky (UAlabama)
1.8.8	Online SW	J. Buckley (Washington U)		
1.8.9	Assembly & Installation Planning	F. Wolfs (URochester)		R. Gerhard (UCDavis), E. Druszkiewicz (URoch)
1.8.10	Subsystem Management	F. Wolfs (URoch)		
1.8.11	Detector Response Simulations	H. Kraus (Oxford)		
1.9	**Integration & Installation**	**J. Cherwinka (UW-PSL)**		
1.9.1	SURF Infrastructure	S. DeVries (LBNL)		
1.10	**Cleanliness & Screening**	**K. Lesko (LBNL)**	**C. Ghag (UCL)**	
1.10.1	Screening for Fixed Contaminants	P. Scovell (Oxford)/A. Cole (LBNL)		
1.10.2	Radon Emanation Screening	R. Schnee (SDSMT)		
1.10.3	Cleanliness Maintenance	A. Manalaysay (UCDavis)		
1.10.4	Background Simulations	A. Lindote (Coimbra)		

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Table 13.1.2: (continued)

WBS	Description	L2/3 Manager	Deputy or Co-mgr.	Lead engineer
1.10.5	Information Repository	J. Busenitz (UAlabama)		
1.11	**Offline Computing**	**M.E. Monzani (SLAC)**	**S. Fiorucci (LBNL)**	
1.11.1	U.S. Data Center	C. Tull (LBNL)		
1.11.2	U.K. Data Center	A. Vacheret (Imperial)		
1.11.3	Infrastructure Software	S. Patton (LBNL)		
1.11.4	Simulations	J. Dobson (UCL)		
1.11.5	Analysis Software	C. Carmona (Penn State)		
1.11.6	Subsystem Integration and Validation	M.E. Monzani (SLAC)		
1.11.7	Subsystem Management	M.E. Monzani (SLAC)	S. Fiorucci (LBNL)	
1.12	**Project Management**	**M. Gilchriese (LBNL)**	**K. Hanzel (LBNL)**	**J. Cherwinka (UW-PSL)**

13.2 Safety

Personnel safety, protecting the environment, and equipment safety are high priorities for the LZ Project. Its scientific goals cannot be achieved without an effective safety and environmental protection program that is integrated into the overall management of the experiment. The details of the EH&S organization are described in an *Integrated Safety Management* document. A separate *Hazard Analysis Report* (HAR) describes the hazards that will be encountered and their associated controls during the execution of the Project. The HAR received significant input from the L2 Subsystem Managers who are, and will remain, closely involved in identifying and mitigating these hazards. Many hazards will be similar to those found in past operation of similar experiments (e.g., LUX and Daya Bay). The LZ Project work will take place at multiple institutions in addition to LBNL. Safety of the work at each institution will be the responsibility of the institution and work will be performed in accordance with the requirements and management systems of the home institutions. A sharing of lessons learned for the various locations is expected. Additionally, the LZ Project team will assist collaborating institutions as requested to address any hazard concerns.

Final assembly of the LZ experiment and its operation will take place at SURF, where integrated safety management is well established and will be employed in all phases. SURF EH&S rules and responsibilities will apply to all LZ activity at the SURF site, and SURF will provide relevant safety training for all members of LZ who work on the site. SURF has established an external EH&S panel that will review the LZ Project during the construction period and prior to commissioning and operations. This panel has completed the first review of LZ and provided review of the HAR.

13.3 Risk

The LZ risk program has several key aspects. The first is the early identification of potential risks in each of the detector elements as well as the system as a whole. Second, an early R&D program focuses on understanding, reducing, or eliminating the identified risks. Third is the formal tracking of the remaining risks and mitigation strategies throughout the life of the experiments construction phase. Last is an accounting for technical, cost, and schedule risk in developing the contingency analysis for the cost of the experiment. These first three components (ID, R&D, tracking) will be discussed in this chapter. A *Risk Registry* for LZ has been assembled and is updated and reviewed regularly. A Risk Management Plan has also been completed.

Subsystem Managers have performed a risk assessment of their technical systems. These have been gathered by the Project Office and disseminated back out to the Subsystem Managers, key engineering leads, and the rest of the Project leadership team. The *Risk Registry* will be reviewed and discussed regularly in subsystem and overall Project meetings. Updates to the *Risk Registry* are considered monthly as the Project proceeds, as more information and experience are gathered and risk status changes.

13.4 Operations

Experiment Operations will be managed centrally from an Operations Project office in much the same way the construction phase of the Project is managed. Our plan is based on the successful experience operating the LUX detector at SURF and other projects. The collaboration will provide much of the necessary resources for shifts and on-call experts. A small engineering and technical group will provide maintenance planning, oversight, and the resources for achieving them. A small computing and software maintenance group will ensure high availability of computing hardware and software and will support the collaborations data production and analysis activities.

The elements of the LZ operations support are:

- **LBNL operations manager.** Provides oversight of budget and EH&S matters.
- **Engineering support.** Provides engineering oversight during operations, particularly during the early phases of operations.
- **On-site EH&S officer.** Provides on-site EH&S oversight. This is an SDSTA employee under contract to LBNL.
- **On-site operations technical staff.** Provides on-site maintenance, support, and interface to SURF staff. This will involve both operations aspects and technical support. Multiple positions are planned and these will be SDSTA staff under contract to LBNL.
- **Procurement.** Obtains materials, supplies, consumables (e.g. liquid nitrogen) and equipment necessary for operations and maintenance. Under the direction of the LBNL operations manager.
- **University travel support.** Provides support of travel to the site. Under the direction of the LBNL operations manager.
- **Computing support.** Provides support for professional services for computing hardware and software.

Transition-to-operations support for LZ-related travel of scientific staff began in FY 2016 and will necessarily expand as work on site increases.

13.5 Cost and Schedule Summary

The overall LZ Project plan is summarized in this chapter, including an overview of the Project schedule and the concept for the division of scope and cost among the various funding sources. The planned contributions supported by DOE, SDSTA, the U.K.'s Science & Technology Facilities Council (STFC), Korea, and Portugal are outlined. This is a joint project with an international collaboration, and the cost-accounting approaches differ. Therefore, we have attempted to utilize the U.S. DOE cost-accounting approach for the costs summarized in this chapter.

13.5.1 Project Schedule

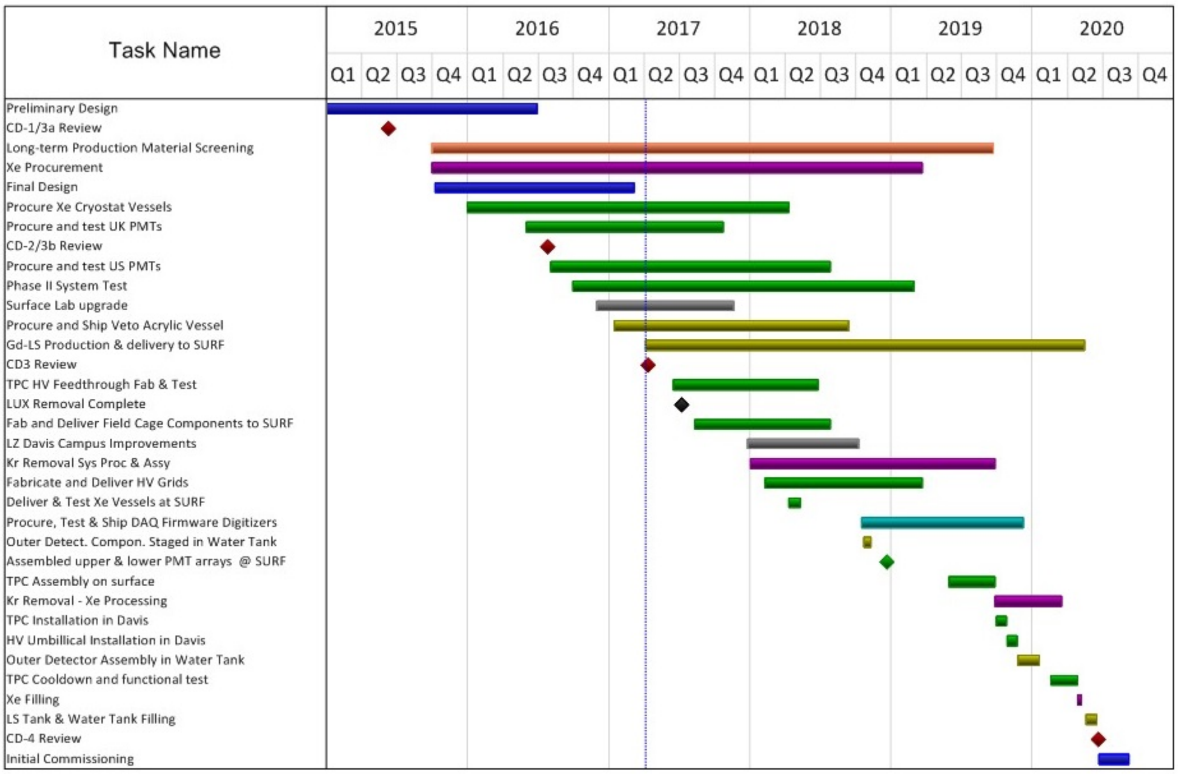

Figure 13.5.1: Summary of LZ schedule. The dates are in U.S. fiscal year quarters.

The goal is to begin commissioning and early operations by early 2020. Infrastructure improvements (to surface laboratories) began in September 2016. Components begin to arrive at SURF in mid-2017. Underground installation begins in mid-2018. The DOE critical decision milestones in this plan are CD-1/3a obtained in April 2015, CD-2/3b obtained in August 2016 and a CD-3(all remaining items) review in January 2017. The procurement of long lead items (Xe, the cryostat vessels, PMTs, outer detector acrylic vessels and others) has already started. A more complete view of the Project schedule is shown in Figure 13.5.1. The dates shown in this schedule correspond to early-finish milestones.

13.6 Project Scope

The Projects technical scope has been described in previous chapters. The complete LZ Project includes the detector elements – purified Xe, cryogenic systems, Xe detector, cryostat, veto system, calibration system, electronics, DAQ, trigger, online and offline software – as well as all the integrating activities – system tests, system integration, assembly/installation, on-site infrastructure, and project management.

The planned scope division among the various U.S. and non-U.S. agencies is summarized briefly here.

- The major elements of U.K. scope deliverables include about one-third of the low-background PMTs for the Xe detector, the cryostat set (inner and outer), elements of the low-background counting capability, contributions to integrated system tests, the source calibration delivery mechanism, and extensive contributions to computing and software.
- Korea is expected to contribute PMTs for the outer detector, low-background assay capability, and software.
- Portugal is expected to contribute to control systems, software, and a measurement system for TPC quality control.
- The SDSTA scope includes above- and belowground modifications to required facilities and much of the Xe needed for the experiment.
- The NSF is assumed to support scientific efforts for those U.S. collaborating institutions funded by NSF but will not contribute to the Project scope.
- The DOE is assumed to fund all remaining Project scope.

13.7 Cost Summary

The U.S.-based cost estimate associated with the above scope is shown in Table 13.7.1 in at-year dollars without contingency. U.S. contingency amounts to about 25% of the DOE - funded amount.

Table 13.7.1: LZ Project U.S.-equivalent base cost (without contingency) in at-year kilo-dollars. The equivalent U.S. costs for non - DOE items are also shown.

WBS (2)		DOE Funded		NONDOE Funded	
1.01 -	Xe PROCUREMENT	$k	420	$k	9846
1.02 -	Xe VESSEL SUBSYSTEM	$k	5	$k	1466
1.03 -	CRYOGENIC SUBSYSTEM	$k	1881	$k	-
1.04 -	Xe PURIFICATION SUBSYSTEM	$k	7399	$k	-
1.05 -	Xe DETECTOR SUBSYSTEM	$k	10332	$k	2838
1.06 -	OUTER DETECTOR SUBSYSTEM	$k	4191	$k	661
1.07 -	CALIBRATION SUBSYSTEM	$k	727	$k	98
1.08 -	ELECTRONICS, DAQ, CONTROLS & COMPUTING SUBSYSTEM	$k	5274	$k	34
1.09 -	INTEGRATION & INSTALLATION SUBSYSTEM	$k	5379	$k	1971
1.10 -	CLEANLINESS AND SCREENING SUBSYSTEM	$k	1153	$k	650
1.11 -	OFFLINE COMPUTING SUBSYSTEM	$k	2322	$k	-
1.12 -	PROJECT MANAGEMENT	$k	4733	$k	-
Total		$k	44,817	$k	17,661