Fermilab

Closeout Presentation

Director's Independent Design and CD-2/3 Review of the LHC CMS Detector Upgrade Project

May 28-30, 2014

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Executive Summary

A Fermi National Accelerator Laboratory (Fermilab) Director's Review of the Large Hadron Collider (LHC) Compact Muon Solenoid (CMS) Detector Upgrade Project (CMS project) was held on May 28-30, 2014. The purpose of this review was to assess the project's progress and readiness to proceed to CD-2/3 (CD-2, Approval of Performance Baseline and CD-3, Approve to Start Construction) based on requirements as specified in DOE O 413.3B.

The CMS project, funded by the Department of Energy (DOE) and National Science Foundation (NSF), will upgrade CMS detector components provided by the original CMS detector construction project. The project is to design, construct, test, and commission upgrades to the Hadron Calorimeter (HCAL), Forward Pixel detector (FPIX), and parts of the Trigger (TRIG or L1T) to sustain current performance with increasing LHC luminosity.

The project's Key Performance Parameters (KPPs) are clearly outlined and the lower bounds are established for success such that dependence on the LHC operating schedule or down times can be avoided. Given the performance objectives of each technical area – HCAL, FPIX, TRIG – the scope is appropriate and the design is sufficiently mature. The design is well documented in the Technical Design Report (TDR). The committee found that the CMS project design is well advanced in maturity – above 75% in all areas – and provides a sound basis for establishing the cost, schedule, and technical baseline.

The project has developed a detailed Resource Loaded Schedule (RLS) with supporting basis of estimates. A contingency analysis has been completed which considers maturity of design, risk assessment, and a top-down management judgment. Together these elements provide the basis for establishing a Total Project Cost of $42.57M, of which 35% is identified as cost contingency on work to go, and a project completion date of Q1 FY20, including a 13 month schedule contingency. While the time-phased performance measurement baseline and budget authority/obligation profile is much healthier than that presented at CD-1, areas of concern still remain and need to be addressed.

The CMS project has seen significant staffing changes since CD-1 approval. The current team has strong experience from the original CMS detector construction project and operation of the existing system. A capable management team is in place with integration between the collaborating institutions. All project documents required by DOE 413.3B and the Fermilab system exist with some specific areas requiring attention to ensure consistency and detailed accuracy. The project currently lacks data related to earned value management – specifically cost/schedule performance - and complete understanding still needs to be demonstrated by the team.

There are several areas noted in this report where additional improvements will be needed prior to a DOE CD-2/3 Review planned in early August. After addressing these recommendations, the CMS project should proceed to its DOE CD-2/3 review.

1.0 Introduction

A Director's Independent Design and Critical Decision (CD)-2/3 Review of the Large Hadron Collider (LHC) Compact Muon Solenoid (CMS) Detector Upgrade Project was held on May 28-30, 2014 at the Fermi National Accelerator Laboratory. The objective of this review was to assess the level of maturity of the Project's design and to determine if the project meets the CD-2/3 (CD-2, Approval of Performance Baseline and CD-3, Approve to Start Construction) requirements as specified in DOE O 413.3B. To meet the design requirements for CD-2 the design has to be at the preliminary level or greater, and for CD-3 the design has to be at the level of final or near final design.

Additionally, the committee assessed the Project's progress on addressing the recommendations from prior reviews and assessments; DOE CD-1 Review performed on August 26-29, 2013, Director's CD-1 Review performed on July 16-18, 2013, Director's Impendent Conceptual Design Review conducted on May 14-16, 2013 and the Director's Cost and Schedule Assessment performed on May 15-16, 2013. The charge included a list of specific questions to be addressed as part of the review. The assessment of the Review Committee is documented in the body of this closeout presentation.

This closeout report is broken down into two basic sections. The first section provides the assessments of the project's design of technical deliverables and project management. Each area within this first section is generally organized by Findings, Comments and Recommendations. Findings are statements of fact that summarize noteworthy information presented during the review. The Comments are judgment statements about the facts presented during the review and are based on reviewers' experience and expertise. The comments are to be evaluated by the project team and actions taken as deemed appropriate. Recommendations are statements of actions that should be addressed by the project team. The second section of this presentation has the committee's answers to the review charge questions.

The LHC CMS Detector Upgrade Project is to develop a response to the review recommendations and present it to the Laboratory Management and regularly report on the progress during the Project's Project Management Group Meetings (PMGs) and at the Performance Oversight Group (POG). The recommendations will be tracked to closure and a documented status of the project's resolution will need to be available for future reviews.

2.0 Technical

2.1 Hadron Calorimeter – HCAL

Primary Writer: Dmitri Denisov

Contributors: Adam Gibson and Jose Repond

Findings

- The present CMS hadron calorimeter will not be able to provide an adequate performance for the high luminosity LHC operation. To maintain the physics performance in the high luminosity running the CMS hadron calorimeter requires significant upgrades/modifications (WBS 401.2).

- The hadron calorimeter upgrade project consists of three sub-projects: 401.02.02 – forward hadron calorimeter (HF) front-end electronics upgrade; 401.02.03 – barrel/endcap hadron calorimeter (HB/HE) front-end upgrade; and 401.02.05 – backend electronics upgrade.

- The project is concentrated on the upgrades of the readout electronics to improve the detector's performance in high luminosity environment, including replacement of photodetectors in barrel and endcap calorimeters with SiPMs.

- Technical performance of the proposed upgrade is described in the Technical Design Report (available).

- The project has a well-defined organizational structure with all managers identified.

- The US CMS hadron calorimeter upgrade is a part of the CMS experiment upgrade where a significant number of US CMS members play critical roles.

- The US CMS hadron calorimeter upgrade is being carried out by an international collaboration led by US CMS.

- The KPPs are well identified. The threshold KPP includes delivery of all upgrade equipment to CERN and tests of their functionality. The objective KPP extends to the complete installation of the equipment and demonstration of the system's full functionality within the rest of the CMS experiment.

- The project schedule covers period from FY13 (start of the project) to FY19 (completion of the project).

- The project has developed a work breakdown schedule, a resource-loaded schedule, and a corresponding set of milestones.

- The total HCAL upgrade project cost is $16 million, split between NSF (~30%) and DOE (~70%).

- 18 HCAL-specific risks with a probability-weighted cost of $141k have been identified.

- The US groups involved in this upgrade were also responsible for the CMS calorimeter construction and operation in Run I.

Comments

- The hadron calorimeter (HCAL) upgrade design is mature, technically sound and well documented in the Technical Design Report.

- Prototypes of the majority of components have been assembled and tested. The project is ready to start production on the schedule presented.

- The HCAL project design readiness is at 81% level. There are no major technical issues to be addressed. The remaining elements to be designed are not on the critical path. The HCAL upgrade is on a clear path to the final design.

- The HCAL project has developed a resource loaded schedule. The schedule looks reasonable and achievable. The schedule has a reasonable level of contingency.

- The project developed a detailed cost estimate which is based on extensive experience, vendors' quotes, and cost estimates provided by the involved university groups. The cost contingency is estimated based on strict rules (common for all parts of the US CMS upgrade project). The average cost contingency of 29% is reasonable for the current stage of the project.

- The detector safety system to prevent accidental damage to the detector elements is well designed and is expected to provide adequate protection.

- The HCAL project team is experienced, with many members deeply involved in the original CMS detector design and construction, and has the full potential to successfully complete the project.

- The hadron calorimeter upgrade project identified project risks, performed a qualitative and quantitative risk assessment, and proposed ways of mitigating these risks. Both the list of risks and ways to address them are reasonable. Some risks have already been closed (QIE11 performance is satisfactory; custom ASIC replaced by commodity FPGA).

- Completion of the HCAL upgrade project is likely to be achievable within the specified time frame. The division between Threshold and Objective Key Performance Parameters (KPP's) is prudent.

- The project organization and staffing levels are adequate to manage the work and achieve CD-4. The team demonstrates deep understanding of all relevant project details and is motivated to accomplish the project on time and on schedule.

- The HCAL upgrade group satisfactorily addressed the recommendations of the DOE CD-1 Review, the Director's CD-1 Review, the Independent Conceptual Design Review and the Director's Cost and Schedule Assessment.

- Unifying the format of the review presentations as well as verifying the uniformity of the presented schedules and cost tables will be of benefit for future project reviews.

- Presentations during the review and answers to the committee questions were of high quality and professionalism. We congratulate the HCAL upgrade team with developing an excellent project and being ready to execute it.

Recommendations

1. There are many test setups to validate the upgraded elements. Verification that all of them are done according to the safety rules and reviewed is required.

2. Continue development of the forward funding options which might be required in the case of accelerated radiation aging and/or faster luminosity delivery by the LHC to speed up replacement of aging elements in comparison with the planned schedule.

3. Results of test beam studies at CERN and Fermilab confirm anticipated performance of the project deliverables. Continuation of such studies, especially with final production boards/elements, will assure in-depth verification of the performance parameters.

4. The US CMS HCAL upgrade WBS 401.2 is recommended to proceed to the CD-2/3 DOE review planned for August 2014.

2.2 Silicon Pixel Detector – FPIX

Primary Writer: Jim Brau

Contributors: Kevin Einsweiler and Hartmut Sadrozinski

Findings

- The current CMS Pixel Detector will continue to lose efficiency after LS1 as the LHC luminosity exceeds 10^{34} cm^{-2} s^{-1}, seriously impacting physics performance. Specifically, track seeding, primary and secondary vertex reconstruction, and b-tagging will all be degraded. Upgrades are required to avoid these detrimental effects.

- The CMS Collaboration has developed an upgrade design to address this degradation, which is documented in the CMS technical proposal for an upgrade pixel system; the US Technical Design Report (TDR) for the forward pixel (FPIX) upgrade is based on this document.

- The project is budgeted for the Objective Key Performance Parameters, which include production of four half cylinders with three disks each and tested components for a spare half disk. The Threshold Key Performance Parameters specify the four half cylinders but not the spare half disk components. The components for a spare half disk represent scope contingency.

- The FPIX upgrade project involves only US collaborators, no non-US members; however, the project relies on CERN support for aspects that are contributed at no cost to the US. Also, the FPIX project relies on PSI to supply the Pixel Readout Chip as well as test setups purchased by the US FPIX project.

- The CMS Pixel Collaboration has assigned responsibilities for the various electronics components. The US team is responsible for the Token Bit Managers (TBM) and relies on foreign collaborators for the Readout chips (ROCs), DC/DC Converters, Detector Readout cards (FEDs) and optical receivers.

- Latest TBM issues are being corrected with 15 specific changes to the TBM08 design in a “Rocket” submission that is due to produce devices within weeks.

- Performance and physics studies have been done for the full pixel system upgrade, barrel and forward, using the digital readout chip (PSI46dig-v2.1). Significant improvements in signal efficiencies of 50-60% are demonstrated.

- The FPIX upgrade project implements significant cost reduction measures compared to the original detector, such as using a single module everywhere, going to 6 inch wafers for sensors, and using a cost effective US bump bonding vendor.

- The upgraded FPIX system comprises 44 million pixels on 672 modules, mounted on 12 half-disks; the upgrade increases the forward pixel layers from 2 to 3, which increases the typical number of hits per track from 3 to 4 for eta<2.5 when combined with the barrel pixel detector. The system is designed to survive an integrated luminosity of 500 fb^{-1}.

- In order to complete the needed 672 modules plus 20% qualified spares, the construction plan includes production of 1000 modules and assumes 85% yield.

- Sensors will be sole source ordered through a collaborating university (Kansas) with NSF funding.

- Modules are being produced in parallel at Purdue and Nebraska. To date fourteen pre-production modules using university setups have been built, demonstrating the collaboration can build working modules.

- The FPIX critical path is driven initially by the availability of half disk mechanics. Complete designs and procedures for building the disks and cooling system have been produced and full prototypes for the disks and cooling are in progress. A four blade prototype demonstrated the required heat transfer resulting in less than 10^{o} C differential from sensor to coolant. A seventeen blade outer half disk prototype is being prepared for testing. The FY14 schedule also calls for testing of an eleven blade inner half disk prototype.

- A pilot system involving eight modules will be installed in the CMS experiment in September, 2014 and operated during LHC Run2. The main purpose of this pilot system is to practice aspects of the installation and commissioning, to facilitate conversion of the software and to gain operations experience for the final project.

- FPIX installation is on the critical path for the US CMS upgrade project schedule.

- The schedule is designed for delivery to CERN of the last Half Cylinder by July 2016, handover to CMS operations by August 2016, to meet the installation target during the Extended Technical Stop early in 2017.

- Risks are documented in the Risk Register, identifying 27 risks: 24 threats and 3 opportunities.

Comments

- The FPIX team brings a large experience base to the project based on their significant role in the original CMS pixel project and current CMS pixel system.

- Given the performance objectives, the scope is appropriate and the design is mature and nearly complete. The upgrade is designed to handle 2 x 10^{34} $cm^{-2}s^{-1}$ in luminosity with pileup up to 100 interactions per beam crossing and an integrated luminosity of 500 fb^{-1}. The upgrade results in higher efficiencies, lower fake rates, lower dead-time/data-loss and extended lifetime of the detector.

- The design is well documented in the technical design report with reasonable cost estimates and documented basis of estimates.

- The scope contingency represented by the difference between Objective Key Performance Parameters and Threshold Key Performance Parameters is appropriate.

- The Risk Register has a thorough collection of risks with analysis of potential impacts. Readout chip and Token Bit Manager developments are currently at critical phases and should performance fall short of success the project will need to react quickly and effectively to protect the schedule.

- Even though the number of spares is large, the module yield assumption (85%) may be aggressive. The yield from previous U.S. experience with the FPIX detector for both bump-bonding and assembly was 72% (Basis of Estimate). The criteria placed on the acceptable dead pixels/ROC and HV requirements have been softened based on experience and only high quality modules are accepted. The large number of spares provides insurance against lower yields. Given these changes, the 85% assumption is reasonable at this time.

- The mechanical support design is innovative and very low mass. The prototype half disks under development and test will provide critical validation of the concept and implementation.

- Early pre-production module assembly might be possible using pre-production components.

- The funding profile is much healthier than the profile presented for CD-1.

- All documentation (TDR, BOE, Risk Register, WBS, etc.) should be reviewed to ensure consistency of all details, such as numbers of components, costs and schedule.

Recommendations

5. Complete heat flow tests of the two half disk mechanical prototypes before CD3 review.

6. Investigate advancing the procurement of the mechanical components (graphite for the rings, carbon fiber for facing and TPG for blades) in order to relax the critical path.

7. Consider early pre-production module assembly using pre-production components to prepare for final module production as a hedge on the schedule.

8. The US CMS Pixel Upgrade Project is ready for CD-2 review. They will be ready for CD-3 approval subject to a successful outcome of the ongoing tests of the Readout chip and the upcoming test of the engineering run of the Token Bit Manager, which is expected within two months. The ROC is in final test and is likely to be useable for the final production modules. The recent TBM submission will produce devices within weeks. Tests of these devices will determine if the performance of the latest design is suitable for the final modules.

2.3 Level 1 Trigger

Primary Writer: Eric James

Contributors: Sarah Demers and Jonathan Lewis

Findings

- The upgraded trigger systems are required to maintain or improve current trigger performance in an environment of increased pile-up (~50 interactions/crossing), increased center-of-mass energy (8 to 14 TeV), and shorter bunch spacing (50 to 25 ns).

- Upgraded trigger designs are based on high-bandwidth, commercial optical fiber links and large, flexible FPGAs.

- The upgraded trigger systems will be installed and commissioned in parallel with the current systems in order to decouple the project from the LHC schedule and to allow for partially upgraded triggering capabilities on the shortest possible timescale.

- The WBS for the trigger upgrade project consists of separate tasks for each of the hardware components to be fabricated and includes parallel subtasks for hardware production, software and firmware development, as well as testing, installation and commissioning tasks.

- Many of the same people who were involved in the design and construction of the current trigger systems also have a substantial involvement in the upgrade project.

- A fully loaded schedule was presented indicating firmware design as the critical path component for project completion.

- The estimated cost for the trigger upgrade project is $6.6M incorporating a 27% estimate uncertainty.

- A risk registry was presented, which incorporated a number of low-level risks including the potential loss of key personnel. The potential impact of risks on the project leads to the assignment of an additional contingency on the order of $100k.

- No unusual ES&H or QA/QC issues are associated with the trigger portion of the upgrade project. Standard procedures as outlined in the relevant documentation are being followed.

Comments

- The requirements for the trigger upgrade are clearly defined, and it has been clearly demonstrated that the proposed hardware designs meet those requirements.

- Working prototypes for each piece of trigger hardware to be produced exist and the results of reported standalone and integration tests clearly demonstrate that the designed systems will meet performance specifications.

- The plan presented for the production, installation, and commissioning of the upgraded trigger systems is very likely to result in the achievement of both the threshold and objective KPP goals defined for this portion of the project.

- The resource-loaded schedule for this part of the upgrade is well developed. The BOEs for M&S costs are in almost all cases based on firm quotes from vendors. The methodologies applied for labor estimates are reasonable but are only minimally documented in the associated BOEs.

- Some discrepancies were noted when comparing costs contained in Primevera with those found in the cost book.

- Spares for non-active components such as the optical fiber patch panels for the upgraded muon trigger system should be incorporated into the project plan.

- Opportunities likely exist for sharing resources between the on-project endcap muon trigger upgrade and off-project overlap-region muon trigger upgrade, which share common hardware components. Potential synergies should be included as an opportunity within the risk register.

- Industry standards ensure the QA/QC of the trigger upgrade hardware. Software and firmware quality are being verified by typical HEP practices incorporating both reviews and checking the results of data processed by the hardware with software emulation.

- The maturity of the estimated cost is high due to the fact that firm quotes are in hand for the majority of hardware components to be constructed. The largest uncertainties are associated with labor contributions to firmware and software development.

Recommendations

9. Further scrubbing of the project cost and schedule contained within Primevera should be performed and additional support for software and firmware BOEs should be provided prior to the DOE CD-2/3 review.

3.0 Cost and Schedule

Primary Writer: Elmie Peoples-Evans

Contributors: Jim Curley and Richard Marcum

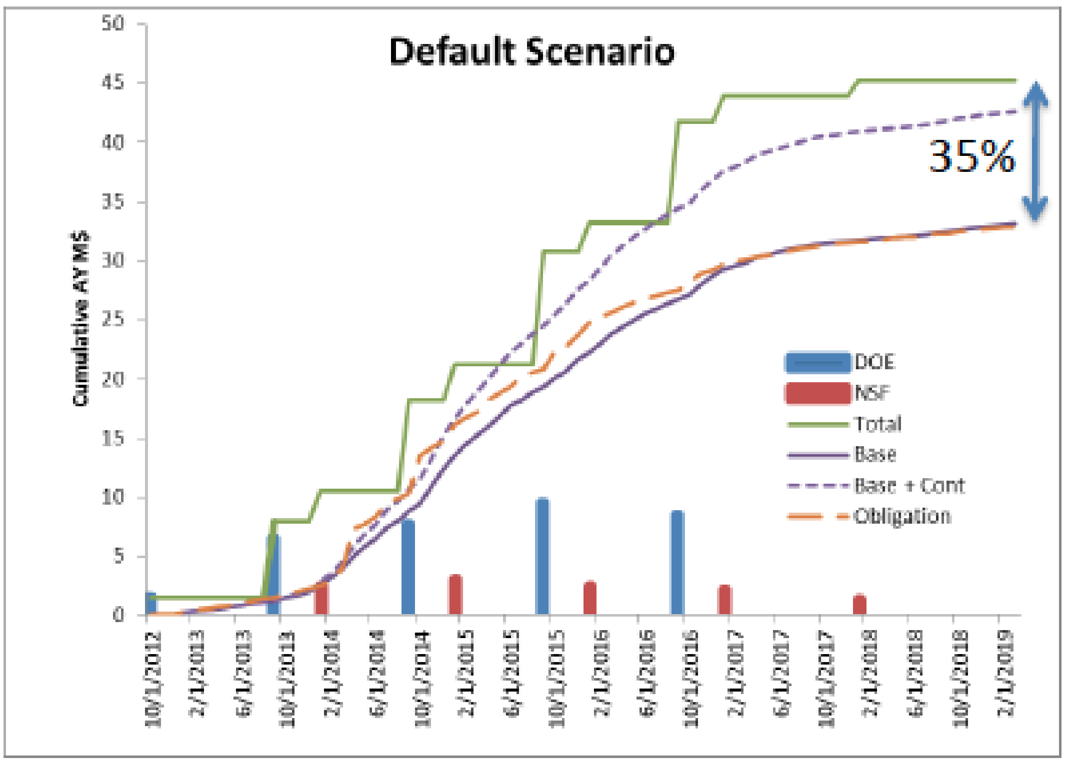
3.1 Cost

Findings

- The CMS Upgrade Project has a total TPC of $42.57M in $AY, which includes $9.47M of contingency. The separation of cost between the DOE and NSF scope is summarized in table 1. A funding profile versus obligations is provided below.

Funding Source	Base Cost	Contingency	TPC
DOE	$25.24M	$7.49M	$32.73M
NSF	$7.86M	$1.98M	$9.84M
DOE + NSF	$33.1M	$9.47M	$42.57M

Table 1: Cost summary for DOE and NSF Scope



- The BA vs BO chart shown reflects a cash flow problem in FY15. The Project Team stated they are working on scenarios to address this problem.

- The project has 14 control accounts managed by 10 control account managers (CAMs) and approximately 28 chargeable task codes for collecting actuals and doing earned value (EV) reporting.

- Contingency methodology was well defined and reflected proper risk analysis.

- The costs presented in the cost book and presentations negated the NSF in-kind and CMS Ops components, while the BOEs and RAM included these aspects. As a result, the unburdened base units matched the BOEs and supporting documentation in most cases.

- EVM data was not presented during the review due to issues with Cobra and a lack of groundwork to turn the crank on EVM reporting. The project stated they plan to have 3 months (April, May and June) of EV data for the DOE CD-2/3 review.

- The CAMs showed great confidence and understanding of their scope, cost and schedules during the CAM interviews/Drilldowns. The interviews revealed not all CAMs had the same level of understanding of EVM (understanding terminology) and their CAM responsibilities.

- CAMs have been trained in EVM processes, but have not actually worked through the complete process. A plan for utilizing the laboratories standard EVM practices and procedures was presented.

Comments

- High-level managers and CAMs were very knowledgeable about their scope, schedule, and budget. For the most part, CAMs were able to identify what their control accounts were and took **ownership** of those accounts.

- CAMs are able to access their schedules in P6 and are comfortable using the tool.

- It would be helpful if the CAMs were identified early on in the presentations.

- Many L2 managers and CAMs have not been CAMs before. It is difficult, without a few more months of practice, to determine whether or not CAMs will be able to handle roles and responsibilities. Even though they have all received a 2-day EVMS training, it was observed that they are not familiar with FNAL procedures and will need more training on the FNAL practices.

- The Project Team is experimenting with using reflections in P6 to streamline the status reporting process.

- The project team should consider performing more Q/A on the data, documentation and presentations to ensure consistency. Updating the supporting documentation with information about the line items and associated quantities used to derive the cost estimates would be helpful and make it easier for the CAMs to demonstrate adequate backup.

- The obligation profile is very optimistic and shows a cause for concern in FY15. We highly encourage discussions with the budget office to confirm all funding will be provided all at once in a given year, rather than quarterly.

Recommendations

10. A few months of EVM data is on the list of required documentation for CD-2/3 approval. There's a possibility the laboratory may not be able to resolve the Cobra issues keeping the project from going forward with practicing EVM reporting. The laboratory needs to develop an alternative strategy in conjunction with the project team for satisfying this requirement.

11. Before posting documents for the CD-2/3 Review, scrub and check P6/Cobra data to ensure consistency. Consider requesting PCS support from the Lab for peer reviews.

12. Conduct mock sessions with CAMs, with emphasis on drill-down, terminology, and standard review questions.

13. The Project Team should consider performing what-if analysis for the various scenarios related to the FY15 cash flow issue, in order to make a final decision on the solution before the CD-2/3 review.

3.2 Schedule

Findings

- The Project has a RLS with 3,386 activities which includes 5,976 relationships. The project has a completion date of December 2018 to meet the threshold KPPs and February 2019 to meet the objective KPPs (according to L3 milestones).
- The project has a well-developed WBS Structure and WBS dictionary, which was used as the foundation for the P6 schedule.
- Logic ties between activities in different L2 WBS elements are incomplete.
- CAMs were familiar with scheduled activities and were clearly involved in the schedule development.
- The project schedule has been extensively modified and developed since CD-1 including the removal of most funding constraints enabling a free-flowing technically-driven schedule.
- The use of change control was not demonstrated. 401.02 is using an "informal change control" to keep track of changes made to the schedule during development of the baseline.
- The critical path for the entire project flows through HCAL and FPIX.
- The project used monte carlo analysis to determine the 13 months of float on the backend of the schedule.
- Most activity durations are short enough to allow objective performance evaluation.

Comments

- The Project Team members are knowledgeable of the schedule and able to demonstrate how the work will be executed.
- The Project Team should consider using a common schedule layout view that organizes schedule data in the same manner as presented in BOE and cost book reports.
- Good effort by 401.02 in breaking out activities (batches) for better visibility, improved ability to accurately status/progress, and it enabled them to stagger work without having to use lags.
- The project should consider modifying the schedule such that they are able to demonstrate a critical path on the project without manipulation. The review team believes this is necessary to properly manage float throughout the project's life cycle.

- Objective measures have been assigned in the schedule, but have not been reviewed or approved by all CAMs. The FPIX L2 Manager has done a great job with using steps and specifying leads and lags where required.

Recommendations

14. The project needs to do some schedule cleanup before the CD-2/3 review. For example, including the logic link between HCAL and Trigger, assign predecessors and successors to all activities, and clearly label obligation activities.

4.0 ESH&Q

Primary Writer: John E. Anderson
Contributors: Kathy Zappia and Amber Kenney

Findings

- Project Management
  - All CD1 recommendations have been addressed.
  - Project ESH&Q Coordinator appointed.
  - Project electronic and mechanical engineers have been appointed.
  - Necessary ESH&Q documents for CD 2/3 are complete.
  - Strong design teams all addressing ESH and QA activities.
  - Each of the participating institutions has well established ESH&Q programs.
  - Project has significant experience working between multiple institutions and countries.
  - Quality assurance aspects for testing and calibration of components and modules are being implemented into the design, prototyping, and construction activities.
  - Testing/validation procedures have been incorporated at the right check-points throughout the production/assembly processes.
- HCAL
  - All HCAL prototypes and pre-production electronics are thoroughly tested prior to final design. Once in production, each board will be tested and pre-installation testing/burn in will occur at CERN.
  - QA databases - one for each HCAL component - limit access to students to their own work. Master database in the end will contain all documents for all components. Only project access. Project management has access to all databases.
  - Design quality is leaning heavily on the prototype and pre-production testing.
  - The HCAL team has many years of experience juggling all of the players (international vendors, universities/students, etc.) involved in developing and producing the HCAL upgraded components.

- FPIX
  - FPIX has included how they are handling quality assurance and is presented throughout their presentations.
  - Quality assurance and assembly tracking database in use at Purdue.
- Trigger
  - Significant testing of trigger pre-production hardware already completed.

Comments

- Project Management
  - The Project Team should be able to point to ESH&Q reviews that have been performed.
- HCAL
  - The HCAL table of all of the components, the number required for the detector, number of spares needed, and production location helps give an overall picture for reviewers.
- FPIX
  - FPIX Pilot System overview could include more on how they are handling quality assurance to be more in-line with Components and Assembly overviews and presentations.
- Trigger
  - Incorporate quality assurance activities into the Trigger breakout presentations.
  - Make sure that when referencing ES&H that "Q" is also included – it was excluded in the cost and schedule breakout presentations.

Recommendations

Project Management

15. A cross connect matrix should be developed to identify the component, assigned QA Plan - ESH&Q Risk Level, and the actions being implemented to meet the requirements of table 1 of the QA Plan.
16. pHAD, QAP, and ISM Plan need some minor edits to fix references to obsolete documents or missing documents.

General (HCAL, FPIX, & Trigger)

17. Ensure design, acceptance testing, component qualification documentation is updated for any changes prior to pre-production reviews. This would include travelers or electronic records needing to be developed to identify, report, correct, and trend nonconformance situations prior to starting production.

18. Ensure vendor qualification and certification is complete along with QA representative approval for ESH&Q Risk Level 1 and 2 components prior to starting production.

    - Review more formalized SQA (software quality assurance) requirements for software and firmware development.

5.0 Management

Primary Writer: Elaine McCluskey
Contributors: Marc Kaducak

Findings

- The project has seen significant staffing changes since CD-1 approval, with a new project manager, addition of a deputy project manager, one new L2 manager, added project engineers, and a new project controls manager. Staffing plans for the remaining WBS L4 positions were described.

- Key Performance Parameters (KPPs) to reach CD-4 are documented in the PEP at both the threshold and objective levels. The scope/cost/schedule to reach the objective KPPs are presently in the project and represent about $1M of scope contingency.

- Change control has not been executed on the project to date. Change control thresholds are documented in the PEP and the Configuration Management Plan. The Configuration Management Plan states that changes above the PM level require approval by the Federal Project Director and the ALD for Particle Physics. The PEP does not recognize a role or threshold for the ALD in change approvals. No change control role is noted in either document for the actual line manager for project oversight, the Head of Particle Physics Division, nor the CMS collaboration.

- The WBS is well developed and adequately covers the work scope. The WBS Dictionary clearly describes the scope, but does not identify the scope as to NSF or DOE funding.

- No specific lessons learned were presented from other projects, although the project manager noted that preparations for CD-2 were being done cooperatively with two other Fermilab projects and found it very beneficial.

- Nine monthly reports were made available for the review. They are mainly text documents on technical performance, with no cost/schedule performance data. No EVMS reports were available.

- A complete set of required documents for the DOE 413.3B process and for the FNAL project management system was presented. Documents required by DOE include the Acquisition Strategy, PEP (including Safety/Vulnerability Assessment, life cycle costing, discussion of alternatives), Risk Management Plan, TDR, Hazard Analysis, QA program, and NEPA determination.

- An extensive quantitative risk analysis was performed and presented in detail. The methodology is sound and the outputs of the analysis are clear. Eighty risks are being actively managed, some risks have been retired or become obsolete. Unknown unknowns by fiscal year are identified and tracked in the risk register.

- The project is implementing Statement of Work documents for all involved institutions. These documents will be updated annually and funded in quarterly increments. The total number of SoWs is 28, 18 of which involve DOE funds and will have purchase orders issued through FNAL. The remaining ten involve NSF funds and will be issued through University of Nebraska. Eight SoWs (all DOE/FNAL) are complete with purchase orders issued, and all others are in process. For work where SOWs have not been prepared and purchase orders issued, the project stated that some work is proceeding, forward funded by universities.

- A Responsibility Assignment Matrix (RAM) was provided mapping the CAM/CA to lowest levels of the WBS.

- A Procurement Plan was presented with a listing of significant and critical procurements with anticipated award date, value, and initiating institution. This does not include university purchase orders to fund project effort. The largest procurements will be performed at universities.

- A Key Assumptions document was provided that outlines the cost, schedule, programmatic, and technical assumptions upon which the project is based. There is an assumption that FYx funds will not be available until Jan.1, but the resource-loaded schedule does not reflect this.

Comments

- The project is adequately staffed to complete the project in the long run, and has the support of the CMS Operations program as required. No managerial interface issues are anticipated. Although project controls staffing has changed thrice, the presently assigned staff is an experienced manager from NOvA and expected to remain long-term. The project management team appears to be working well together. Consider including staffing plans for areas not yet staffed as part of the management presentations at the DOE CD-2/3 review.

- The role of Fermilab management and the CMS Collaboration should be clarified in the change control approval process, as well as how DOE and NSF might jointly be engaged in approvals.

- Where possible, consider amending the WBS Dictionary to include the funding source, or reference the "Proposal for the Joint Monitoring of DOE and NSF Earned Value Management Information" in the dictionary for clarification.

- Monthly reports should include at least qualitative statements about cost/schedule performance. Consider the value of shorter technical progress and executive summaries in lieu of longer technical details.

- Project documentation needs a QA check to be sure all documents are updated and references between documents and those that include cost/schedule information are correct.

- The project management team is to be commended for demonstrating an in-depth, hands-on knowledge of project scope, cost, schedule, and risk including knowledge of the tools such as P6, Cobra, and Primavera Risk Analysis.

- The details of the EVM system such as change control, monthly status reporting, variance analysis, actuals and accruals collection, and work authorization are still in development. Following the development, the PM team and CAMs will need to have a clear understanding of and demonstrate these processes prior to CD-2/3. Training will be required to ensure understanding and consistency in their application.

- Although the risk management process is very mature and detailed, the overall score for each risk was not obvious in the risk register presented. The number of risks seems very large for a project this size and may be cumbersome to manage in the long run. The risk register should be assessed top down to ensure that the register represents the most concerning issues.

- Approximately twenty (20) SoWs are not yet complete through purchase order issuance, though many are in the final stages. The relevant procurement departments at FNAL and Nebraska should be apprised of the impending conversion of these quantities of SoWs into purchase orders.

- RAMs typically show the control account (and if the value is included, this is the dollarized RAM) as the intersection of the WBS and the Organizational Breakdown Structure (by institution and then by person). Consider reformatting the RAM to show the value of each control account at this intersection.

Recommendations

19. For review and management purposes, a simplified list of the highest level risks should be articulated and presented. These risks should be representative of the "things that keep the project up at night." Consider not including the unknown unknowns in this list.

20. Make EVM system preparedness a priority, including establishing the processes for all required components and then using them, e.g. change control, work authorization, monthly statusing, incorporation of actuals, variance analysis, and producing monthly performance reports.

21. Provide CAM training through the project management team on details of the project's implementation of EVM. Request assistance through OPSS as necessary.

22. Fermilab should conduct a follow-up review to assess readiness to execute EVM when May and June monthly statusing cycles are complete, likely in mid-July.

23. Update all project documentation prior to CD-2/3 review.

6.0 Charge Questions

6.1 Is the Project's design appropriately developed and well documented in their Technical Design Report (TDR)? Does the design satisfy the Project's performance requirements to carry out the scientific mission? Is the final design sufficiently mature so that the Project can start construction? For those elements of the design that are not finalized, has the Project shown there are no major issues that need to be addressed and that they are on a clear path to a final design?

The US CMS upgrade design is mature, technically sound and well documented in the Technical Design Report. Based on the available documentation and presentations the upgrade project is likely to provide CMS experiment with performance required to carry out scientific mission. The design of the upgrade is mature, many prototypes have been assembled and tested and the project is ready to start production as planned. For the forward pixel upgrade start of construction requires successful outcome of the ongoing tests of the readout chip and the upcoming test of the token bit manager. All tests are planned to be concluded early this summer. The project design readiness is at 84% level and a clear path to the final design exists.

6.2 Has the Project developed a resource loaded schedule that includes the Project's scope of work and is achievable?

Yes. The project has completed a significant amount of work on the resource loaded schedule since CD-1, and presented a technically-driven resource loaded schedule with free-flowing schedule logic. Continued development of the schedule to include any logical relationships between the three subsystems and the LHC installation windows may help create a more coherent project critical path and generate the desired confidence toward meeting the project completion target.

6.3 Does the Project have credible cost and schedule estimates? Do they include adequate scope, cost and schedule contingency?

Yes, the project's cost and schedule estimates are credible and include adequate scope, cost and schedule contingency.

6.4 Has the Project documented the Basis of Estimate (BOEs) that supports the baseline cost and schedule presented?

Yes, but there were inconsistencies in some areas of the data that made it difficult to make this determination.

6.5 Is the scope of work clearly defined between what is funded by DOE or NSF, and is this reflected in the cost, schedule and risk assessment presented to the committee?

Yes. The funding from DOE and NSF is clearly defined and reflected in the cost, schedule, and risk assessment documentation as presented to the committee. Each funding source is tracked using unique coding, which directly tracks to either DOE or NSF funding sources. Each Control Account (CA) uses the established project standardized resource coding throughout the controls tools including Basis of Estimates

(BOE), Primavera P6 schedules, Cobra cost reporting, and risk assessments. However, the funding scope differentiation is not clearly defined in the scope documentation such as the WBS Dictionary. This is primarily due the intertwined funding complexity of work scope. This has been addressed in CMS-doc-12216 “Proposal for Joint Monitoring of DOE and NSF Earned Value Management Information”.

6.6 Has the Project implemented risk management by identifying risks, performing a risk assessment (qualitative and quantitative) and developing mitigation plans?

Yes. Full risk assessment and mitigation have been performed and risks are being managed.

6.7 Is CD-4 achievable with the Project’s risks and within the DOE approved Total Project Cost?

Yes, through bottoms up estimating and risk assessment, CD-4 is achievable within the TPC.

6.8 Has the Project updated required project management documents per DOE Order 413.3B for CD-2/CD-3 and per the Fermilab Project Management System?

Yes, all documents required by DOE 413.3B and the Fermilab system are in nearly final draft form or beyond. Specific areas requiring attention (for example configuration management/change control, ESH&Q, RAM, and the assumptions document) are mentioned in the body of this report.

6.9 Are the Project organization and staffing levels adequate to manage the work to get to CD-4?

Yes. The project has a strong and experienced organization consistent with and as part of the overall CMS organization, and showed adequate staffing levels to get to CD-4.

6.10 Are the ESH&Q aspects being properly addressed?

Yes, although some of the quality assurance documentation should be improved. See the ESH&Q recommendations.

6.11 Does the Project’s process for monthly statusing and reporting satisfy DOE and Laboratory requirements?

Not yet. The project is aware of the requirements and is working toward them, but the system could not be demonstrated since EVMS performance data was not available at the time of the review.

6.12 Has the Project addressed the recommendations from the DOE CD-1 Review, the Director’s CD-1 Review, the Independent Conceptual Design Review and the Director’s Cost and the Schedule Assessment?

Yes, the project presented satisfactory responses to each recommendation.

6.13 Is the CMS Upgrade Project ready for a DOE CD-2/3 review in August?

Yes, after addressing the recommendations identified in this report – specifically regarding engineering runs and testing within the FPIX WBS; complete monthly reporting; and documentation updates with improved consistency – the CMS project should proceed successfully to its DOE CD-2/3 review.