Department of Energy/
National Science Foundation
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

LARGE HADRON COLLIDER (LHC) RESEARCH PROGRAM

April 2002

EXECUTIVE SUMMARY

The Department of Energy (DOE) and the National Science Foundation (NSF) conducted a review of the U.S. Large Hadron Collider (LHC) Research Program maintenance and operations (M&O) component on April 9-11, 2002. The U.S. LHC Research Program consists of those activities and functions required for active participation of the U.S. scientific community in the LHC physics research carried out with the ATLAS and CMS detectors. The review was completed at the request of the U.S. Large Hadron Collider (LHC) Joint Oversight Group co-chairs, Dr. John R. O'Fallon, Director, DOE Division of High Energy Physics, and Dr. John W. Lightbody, Jr., Physics Division, NSF Mathematical and Physical Sciences Directorate.

The U.S. LHC Research Program supports the participation of the U.S. CMS and the U.S. ATLAS collaborations in the international LHC scientific program. The U.S. LHC Research Program consists of M&O, which includes pre-operations, operations and maintenance; detector upgrade research and development (R&D); and Software and Computing (S&C), which include software, computing and networking required for effective U.S. participation in LHC physics. The S&C component was not addressed by this review, though the Committee was cognizant that both S&C and M&O are to be covered under the U.S. LHC Research Program funding. The Review Committee carried out its charge to evaluate proposed plans for U.S. participation in the detector pre-operations and operations, R&D plans for future detector upgrades, and proposed management arrangements and funding requests for these items.

Both U.S. ATLAS and U.S. CMS management have applied significant experience and analysis toward evaluating the costs and strategy for their respective pre-operations and operations and upgrade R&D efforts. This planning effort has met and still faces many challenges, including the transition from the construction to the start of operations, and the impact of a delay in the LHC start-up, which extends the pre-operations period. Though the Committee considered the M&O cost estimates and detailed backup information provided by U.S. ATLAS and U.S. CMS to be extensive, largely complete, and not unreasonable, large uncertainties remain. The delay in the LHC start-up has lead to a significant increase in the estimated costs of U.S. ATLAS and U.S. CMS M&O. Regarding R&D to enhance detector physics capability, the Committee was pleased that plans are being developed and that the cost has been estimated at this relatively early time.

DOE has recently provided funding guidance for FY 2002-FY 2007 for the U.S. LHC Research Program activities to be shared roughly equally between U.S. ATLAS and U.S. CMS.

The initial cost estimate for the M&O and S&C for U.S. ATLAS and U.S. CMS combined exceeds the budget guidance by $47 million for the six-year period of FY 2002-FY 2007. This assumes an NSF contribution of one-third the DOE guidance, though NSF has not yet decided on this ratio. This is also based upon the proposed distribution between M&O and S&C presented by U.S. CMS and U.S. ATLAS management. Initial management plans for both U.S. CMS and U.S. ATLAS have been developed for operations, and the Committee felt that these could benefit from further streamlining.

The Committee findings are similar in many respects for both U.S. ATLAS and U.S. CMS. Overall, the Committee recommends further examination of the research program costs, optimization of the planning for the extended pre-operations period, and evaluation of total resources (construction project, research program funds, and base program). This evaluation ultimately needs to look at the potential impact of a funding shortage and the funding profile on the research program M&O and S&C activities.

U.S. ATLAS and U.S. CMS management is attempting to balance a need to maintain minimal active and skilled subsystem experts until operations begins (a potential "standing army"), with the alternative (and any potential risk) of putting subsystems into storage and re-building new teams later. The need for detector subsystem commissioning, calibration, monitoring, and maintenance require careful consideration to balance cost, schedule, and available funding. The overlap of pre-operations with completion of the construction projects (the period FY 2002-FY 2005) introduces difficulties for agency funding profiles. The scope and estimated cost of these tasks at CERN also differ significantly from those of any previous U.S.-led and hosted detector project.

For the U.S. LHC Research Program, it is presently not clear how an optimal, consistent basis for decisions regarding distribution of total resources between M&O and S&C will be established. The initial approach is different for U.S. CMS and U.S. ATLAS, largely driven by the very different management structures within these collaborations and Host laboratories. As a next step, the Committee recommends that DOE and NSF decide on the scope of future reviews in consultation with the collaborations and host laboratories. This should initially include an assessment of the impact of research program funding for FY 2002-FY 2004 at the next U.S. LHC construction project and software and computing reviews, scheduled for June 2002. A comprehensive evaluation of the U.S. ATLAS and U.S. CMS programs should also follow. The review of these evaluations and total resources by DOE and NSF will be both challenging and important in guiding the successful transition into and execution of the U.S. LHC Research Program.

CONTENTS

1. INTRODUCTION

The U.S. high-energy physics (HEP) community has been an active participant in the construction of the Large Hadron Collider (LHC) facility at CERN in Geneva, Switzerland. When the beam turns on later this decade, the LHC will be the highest-energy accelerator in the world, operating at an energy level seven times higher than the Tevatron at Fermilab. Because it will be operating at the "energy frontier," the LHC has unparalleled opportunities for new physics discoveries, and U.S. scientists expect to play a leading role in those discoveries through their participation in the large LHC detector collaborations ATLAS and CMS. The U.S. ATLAS and U.S. CMS collaborations, roughly comparable in size and expected to grow, currently include over 500 U.S. scientists from over 60 U.S. universities and four DOE National Laboratories (Fermilab, Brookhaven National Laboratory, Argonne National Laboratory, and Lawrence Berkeley National Laboratory). U.S. ATLAS and U.S. CMS detector construction projects continue to make very good technical progress, and are each approximately 67 percent complete.

For this exciting physics program to be successful, the transition from the end of the LHC construction phase to first beam must be carefully planned and managed. This complex transition phase is referred to collectively as "Maintenance and Operations" (M&O) but it actually includes pre-operations, as well as conventional maintenance and operations. The U.S. ATLAS and U.S. CMS collaborations have developed detailed resource-loaded plans for their contributions to detector M&O, in consultation with their international partners and CERN. They have also developed management plans for the research phase. These plans, and their integration into the context of the international collaborations, were the subject of this review. Dr. John R. O'Fallon, Director, DOE Division of High Energy Physics, and Dr. John W. Lightbody, Jr., Physics Division, NSF Mathematical and Physical Sciences Directorate requested the Office of Science Construction Management Support Division to conduct this review of the U.S. LHC Research Program. The review charge letter is included as Appendix A.

The Committee, a team of experts in High Energy Physics detector construction, commissioning and operations, met at Fermilab from April 9-11, 2002 to review both U.S. ATLAS and U.S. CMS requests for M&O. The Review Committee members and participants are included in Appendix B, and the review agenda in Appendix C. The Committee tried to determine whether the costs and schedules presented were justified, and whether the proposed management plans were adequate. This report consists of the Committee's findings, comments, and recommendations to the agencies and the collaborations on these issues.

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2. U.S. ATLAS RESEARCH PROGRAM

2.1 Summary

The U.S. ATLAS management has successfully initiated planning for U.S. participation in detector pre-operations and operations at CERN. Major challenges to this planning include: the definition of a clear and acceptable boundary between completion of the construction project and the start of pre-operations and the impact of the delay in the LHC start-up. The delay of operations create uncertainties in the start and end points for the important pre-operations efforts (e.g., subsystem testing, commissioning, calibrations, monitoring, detector integration, and associated maintenance, etc.), and subsequent uncertainties and increases in associated cost and profiles for the period, FY 2002-FY 2007.

U.S. ATLAS has recently been provided DOE funding guidance for the U.S. ATLAS Research Program that falls short in meeting pre-operations and operations cost estimates made to date. This is particularly the case for the FY 2002-FY 2007 period, which overlaps with the U.S. ATLAS construction project funding. Concerning "steady-state" M&O costs, the latest CERN LHC start-up delay and potential impact of any delays in integrated detector turn-on and operations create some uncertainty in determining the pre-operations "ramp-down" and level of steady state M&O costs, and appropriate funding profiles for steady state operations in the years beyond FY 2007.

U.S. ATLAS management continues to plan for additional goals in detector subsystem construction beyond current baseline deliverables in the construction project, thereby placing pressure on remaining construction project contingency. Additional pressure on this contingency funding comes from the need to support detector subsystem completion and installation. How this contingency is ultimately applied could impact of the scope of what must be covered as pre-operations, the cost to the research program and the cost profile.

Within these constraints and uncertainties, the Committee judged that the cost estimate appeared to be reasonable, that U.S. ATLAS managers were largely in command of the issues and requirements, and that substantial experience and analysis has been brought to bear on the cost estimate, schedule, and management plan for the U.S. ATLAS Research Program. The Committee was also pleased to see that plans for R&D are being developed and that its costs have been estimated at this relatively early time.

The Committee recommends further examination of the research program cost estimate and its underlying assumptions, optimization of the extended pre-operations period at CERN, analysis of the software and computing plans, and evaluation of total resources (construction project and research program funds and base program), taking into account the impact of the current agency guidance for funding.

2.2 Cost and Funding

2.2.1 Findings

A summary of the total funding request for U.S. ATLAS operations, maintenance and upgrade R&D are presented in Appendix D. Over the period of six years extending from FY 2002-FY 2007, the request totals $62.9 million in as-spent dollars; all subsequent costs are presented as as-spent U.S. dollars. This sum includes a 25 percent management reserve, but not the projected expenditures for software and computing in the amount of $49.2 million. An overview of the combined U.S. ATLAS and U.S. CMS cost, staffing, and funding information is presented in Appendix D.

Based on the guidance received by the DOE on the possible funding for the U.S. ATLAS research program (M&O and R&D) and the assumption that the NSF will contribute one-third of the DOE to the operating costs, the collaboration assumes that they can expect funding at the level of $92.4 million for the period from FY 2002-FY 2007. Their current cost estimate for M&O (including R&D) plus S&C (based on the M&O/S&C distribution presented) exceeds this budget by $19.7 million.

The U.S. ATLAS construction project with a total budget of $163.8 million is currently about 67 percent complete, the remaining contingency of $25 million amounts to close to 50 percent of the cost-to-complete. However, the Trigger and DAQ subsystem are not yet baselined. Furthermore, the U.S. ATLAS management still hopes to expand the scope in a number of areas to cover the fabrication of essential components that had previously been removed from the project baseline to provide adequate contingency funds.

The U.S. ATLAS construction project covers subsystem design, fabrication, tests, pre-assembly, and installation at CERN, including on-detector electronics, utilities, and calibration and monitoring systems. The project also covers project planning and management costs. It does not cover an adequate supply of spares for all subsystems, commissioning, and pre-operation costs prior to the start of operation with beams.

The proponents have specified in detail, the level of staffing by year, specifically engineers and technicians from the operating budget. U.S. physicists active in pre-operation and operations, and maintenance of the detectors are to be funded from the base program.

2.2.2 Comments

The cost estimate and detailed backup information provided by the U.S. ATLAS team for the research program (M&O and R&D) is extensive and largely complete. U.S. ATLAS did a good job in general presenting the budgets and strategy. However, given the limited time the Committee found it difficult to extract and evaluate the various components of the costs and identify the basis of estimate. In addition, given the somewhat unclear boundaries between installation tasks (covered in the construction project) and commissioning and pre-operations tasks (covered by the research program), the scope of the tasks covered by the proposed operations budget (referred to as the Research Program) was difficult to understand in detail. DOE/NSF U.S. LHC project management has directed U.S. ATLAS management to include installation costs for U.S. deliverables in the construction project. The degree and level of installation varies among subsystems, depending on the construction project deliverables and the level of component pre-assembly.

In many cases the Committee members went into detail about the estimate. While overall the cost does not appear to be unreasonable, there remain large uncertainties. The collaboration is encouraged to refine the cost estimates, and reduce these uncertainties. As a result of this effort, the Committee expects that the reserve during the steady state operations phase can be significantly reduced.

Similarly, for the construction project, the level on contingency funds relative to the cost-to-complete for the project have stayed constant during the construction of the detector, whereas in many areas, the remaining risks have been reduced considerably.

Funding for R&D for replacement of components with limited lifetime and future upgrades, which is aimed at enhancing the physics capabilities, is considered very important and also an attractive means of engaging experts, highly trained staff, students, and post doctorates. The R&D costs listed, appear to be modest and well matched to the needs, though preparations for very high luminosity operations could probably be deferred until after the start of operation with beams.

Due to on-time completion of construction and assembly of a number of subsystems and the delay of the LHC start of operation, there is more time available for extensive commissioning of completed subsystems and integration of subsystems into the overall detector operation, like trigger and DAQ, calibration, and monitoring. While such tests are absolutely necessary for the detector to be fully ready to take data, they lead to a very significant increase in cost. The Committee questions whether the commissioning plans have been fully optimized for the time available and ask for further justification and analysis of the tasks foreseen.

Similarly, it is not obvious that the plans for computing and software development take into account that the beam start up has significantly slipped. A critical analysis of the schedule and staffing may also be appropriate for the planning of computing and software development.

2.2.3 Recommendations

1. Clearly identify, in the introduction to the cost backup books, the assumptions on which the estimate is based. For example, indicate the range of rates for salaries, overhead, manpower, travel costs, operating consumables, etc.

2. Provide a summary spreadsheet, which breaks out the cost profiles by category and subsystem. The categories should include: a) pre-assembly and installation (construction project); b) pre-operations and commissioning; c) maintenance & operations; d) R&D. These profiles should extend two years beyond the start of operations with colliding beams.

3. Provide a more detailed test and commissioning plan for the detector subsystems and the integration of the trigger, DAQ, slow controls, and other global systems. Maximize the tasks that can be performed in the U.S.

4. Re-evaluate the contingency needs, taking into account that the largest uncertainty during steady state operations should be parts and consumables.

5. Re-evaluate total resources, i.e., construction project funds, operations funds (research program), and the base program support, and try to match these resources to an optimized plan for the completion of the construction, the necessary tests, commissioning, and integration of the whole detector. This will maximize the readiness for first collision data.

2.3 Schedule

2.3.1 Findings

Based on the presentations, the schedule of all baselined subsystems for U.S. ATLAS appears to be on-track for completion in time for installation.

Due to the delay in the LHC start-up schedule there is a large schedule gap for many subsystems between completion of the construction and installation in the ATLAS Interaction Region UX15.

There is a clear mismatch between resources needed for the proposed pre-operation and commissioning schedule and the budget guidance from DOE.

2.3.2 Comments

If the subsystems continue to meet their schedules there will be sufficient time for appropriate levels of testing and commissioning.

The U.S. ATLAS collaboration needs to develop a plan that optimizes activities during this "stretched-out" period.

2.3.3 Recommendations

1. Re-evaluate the U.S. ATLAS proposed commissioning and pre-operations schedule to better provide a match between the agencies' funding profile and the cost profile presented.

2. Investigate the benefits of targeted pre-operation delays for specific subsystems, perhaps even storing subdetectors for months or longer with the goal of reducing long-term pre-operation costs.

2.4 Management

2.4.1 Findings

The recent delays in the LHC schedule have also meant delays in the installation and completion of ATLAS. Consequently, there are cost increases related to the large number of people who will work for an extended period on installation and pre-operations at CERN.

The collaboration presented preliminary plans for R&D related to operating the detector at design luminosity and future higher luminosities.

U.S. ATLAS has begun planning for the management of operations in the period following the end of the construction project.

2.4.2 Comments

The process and strategy for optimizing the endgame of U.S. ATLAS project has not been clearly explained. While the Committee strongly endorses conservative use of construction contingency, it also believes that completion, including the installation of the existing U.S. construction commitments, must take precedence over any new desired scope increases. Furthermore, the desire to use Research Program funds to protect construction project contingency puts additional pressure on S&C funds, which in turn may threaten the capability of the U.S. physicists to participate fully in data analysis. Although it is clear that CERN is under unprecedented financial stress, it is not clear that their situation is tighter than that in the U.S., and they might provide more help to the detector collaborations.

The Committee was pleased by the inclusion of preliminary R&D plans at this time. However, it was difficult to understand the division among work required for relatively simple maintenance, radiation damage at present luminosity, and upgrades for higher luminosity. It was unclear if some of this work might be supported from the base program.

The U.S. ATLAS Level 2 managers are in reasonable command of the issues and requirements needed for their subsystems to go from their present state through the end of the construction project and then through commissioning to a full detector ready for data taking.

Their strategies are based on substantial experience and analysis. It has been possible to understand the estimates in terms of a winding down construction project, an asymptotic level of M&O, and an intermediate profile of commissioning and integration.

The commissioning phase of the experiment requires a very large amount of physicist or skilled professional manpower for tasks such as calibration, testing, database construction, etc. Some current experiments have received substantial manpower from their collaboration base by setting normal "service" work to be contributed for each author in the collaboration, usually delivered by graduate students and post doctorates. U.S. ATLAS does not seem to have such a requirement.

2.4.3 Recommendations

1. Consider final installation of the detector on the beamline to be part of the construction project and not the Research Program. Unless CERN takes on the installation of a detector element, its installation cost must be part of the construction budget, not the Research Program.

2. Hold reviews that combine the construction project and the Research Program. The collaborations should describe their plans in terms of the completing the construction project; the asymptotic needs for operations and maintenance (with appropriate turn-on); the pre-operations (a.k.a., commissioning and integration) and Software and Computing. These reviews should assess the progress and plans for FY 2002, FY 2003, and FY 2004 and the plans for the out years. The planning should clearly distinguish between the commissioning phase that extends to data taking and the period of asymptotic data taking, including priorities and discussion of impacts if projected costs exceed the guidance. The cost estimates should have clearly identified assumptions, such as escalation, labor rates, overhead, etc.

3. Examine the costs of the "standing army" associated with the LHC schedule slip and try to optimize pre-operations and commissioning strategies in view of the very limited near term funding.

4. Consider introducing a "cultural norm" for service work.

5. Develop management plans that are more streamlined and suitable to operations.

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3 U.S. CMS RESEARCH PROGRAM

3.1 Summary

The U.S. CMS management has successfully initiated planning for U.S. participation in detector pre-operations and operations at CERN. Major challenges to this planning include: the definition of a clear and acceptable boundary between the completion of the construction and the start of pre-operations; and the impact of the delay in the LHC start-up. This delay of operations creates uncertainties in the start and end points for important pre-operations efforts (e.g., subsystem testing, commissioning, calibrations, monitoring, detector integration, and associated maintenance etc.), and subsequently uncertainties and increases in associated costs and profiles for the important period, FY 2002-FY 2007. For example, the CMS "slice-test" to commission key subsystem elements has been expanded resulting in increased costs over this extended period.

U.S. CMS has recently been provided DOE funding guidance for the U.S. CMS Research Program that falls short in meeting pre-operations and operations cost estimates made to date. This is particularly the case for the FY 2002-FY 2007 period where there is overlap with the U.S. CMS construction project funding. Concerning "steady-state" M&O costs, the latest CERN LHC start-up delay and potential impact of any delays in integrated detector turn-on and operations creates some uncertainty in determining the pre-operations "ramp-down" and level of steady state M&O costs, and appropriate funding profiles for steady state operation in the years beyond FY 2007.

Within these constraints and uncertainties, the Committee judges that the cost estimates appear to be reasonable, that U.S. CMS managers were largely in command of the issues and requirements, and that substantial experience and analysis has been brought to bear on the cost, schedule and management plan for the U.S. CMS Research Program. The Committee was also pleased to see that plans for R&D are being developed and that costs have been identified at this relatively early stage. U.S. CMS upgrade R&D cost estimates are distributed among subsystems and do not necessarily roll-up in a transparent way.

The Committee recommends further examination of the research program cost estimate and its underlying assumptions, optimization of the extended pre-operations activities at CERN, the analysis of software and computing plans, and evaluation of total resources (construction project and research program funds and base program), taking into account the impact of the current agency guidance for funding. The setting of priorities for U.S. funding and activities is

currently handled differently for U.S. CMS relative to U.S. ATLAS, due to lack of a single manager who can both represent the U.S. CMS collaboration and set priorities for U.S. funding.

3.2 Cost and Funding

3.2.1 Findings

A summary of the total funding request for U.S. CMS operations, maintenance, and upgrade R&D are presented in Appendix D in as-spent U.S. dollars. Over the period of six years extending from FY 2002-FY 2007 the request totals $58.6 million in as-spent dollars; all subsequent costs are presented as as-spent U.S. dollars. This sum includes a 31.7 percent management reserve, but not the projected expenditures for S&C in the amount of $61.3 million. An overview of the combined U.S. ATLAS and U.S. CMS cost, staffing, and funding information is presented in Appendix D.

Based on the guidance received by the DOE on the possible funding for the U.S. CMS research program (M&O and R&D) and the assumption that the NSF will contribute one-third of the DOE to the operating costs, the collaboration assumes that they can expect funding at the level of $92.4 million for the period from FY 2002-FY 2007. Their current cost estimate for M&O (including R&D) plus S&C (based on the M&O/S&C distribution presented) exceeds this budget by $27.5 million.

The U.S. CMS construction project with a total budget of $167.3 million is currently about 67 percent complete, the remaining contingency of $24.8 million amounts to close to 50 percent of the cost-to-complete. The project is on track to complete all deliverables by the end of FY 2005.

The U.S. CMS construction project covers subsystem design, fabrication, tests, assembly, and installation at CERN, including on-detector electronics, utilities, and calibration and monitoring systems. It is not clear that the construction project covers adequate supplies of spares for all subsystems (e.g., DAQ), though the U.S. CMS Construction Project Manager had directed the Level 2 managers to include the cost of spares on the construction project. The construction project does not cover commissioning and pre-operation costs prior to the start of operation with beams. DOE/NSF U.S. LHC project management has directed U.S. CMS management to include installation for U.S. deliverables in the construction project.

The proponents have specified in detail the level of staffing by year, specifically engineers and technicians from the operating budget. U.S. physicists active in pre-operation and M&O of the detectors are to be funded from the base program.

3.2.2 Comments

The cost estimate and the detailed backup information provided for the research program (M&O and R&D) is extensive and complete. Given the limited time, the Committee found it difficult to extract the various components of the costs and identify the basis of estimate. Presenting the results by categories (see recommendation) would have significantly aided the Committee in making judgments on the reliability of the estimate. Given the somewhat unclear boundaries between installation tasks (covered in the construction project) and commissioning and pre-operations tasks (covered by the research program) a better understanding of this separation would aid in establishing that all tasks have been covered. The degree and level of installation varies among subsystems, depending on the construction project deliverables and the level of component pre-assembly.

In many cases the Committee had detailed comments on costs from reviewing the estimates. While overall the costs appear reasonable, there remain significant uncertainties. The collaboration is encouraged to refine the cost estimates, and reduce these uncertainties. As a result of this effort, it is expected that the reserve during the steady state operations phase can be significantly reduced.

Similarly, for the construction project, the level on contingency funds relative to the cost-to-complete for the project have stayed constant during the construction of the detector, where as in many areas the remaining risks have been reduced considerably.

Funding for R&D for the replacement of components with limited lifetime and future upgrades, aimed at enhancing the physics capabilities, is considered very important and also an attractive means of engaging experts, highly trained staff, students, and post doctorates. The R&D costs listed, explicitly cover infrastructure support for such infrastructure activities, individual efforts are costed separately, to the degree they have been identified by the subsystems. Actual upgrade projects will be reviewed on a case-by-case basis, and funding is not included.

The Committee found it difficult to judge the steady-state M&O costs, since the cost profiles did not extend beyond 2007. It would be helpful to see the projected operations cost beyond the first two years after the start of beam.

Due to on-time completion of construction and assembly of a number of subsystems and the delay of the LHC start-of-operation, there is a period of up to two years available prior to installation in the CMS interaction region, UX5. CMS uses this time for extensive commissioning of completed subsystems and integration of multiple systems for trigger and DAQ tests. While such tests are absolutely necessary for the detector to be fully ready to take data, they lead to a very significant increase in cost. The Committee questions whether the commissioning plans have been fully optimized for the time available and ask for further justification and analysis of the tasks foreseen.

Similarly, it is not obvious that the plans for S&C development take into account that the beam start up has significantly slipped. A critical analysis of the schedule and staffing may also be appropriate for the planning of computing and software development.

3.2.3 Recommendations

1. Clearly identify, in the introduction to the cost backup books, the assumptions on which the estimate is based. For example, indicate the range of rates for salaries, overhead, manpower, travel costs, operating consumables, etc.

2. Provide a summary spreadsheet that breaks out the cost profiles by category and subsystem. The categories should include: a) pre-assembly and installation (construction project); b) pre-operations and commissioning; c) maintenance & operations; and d) R&D. These profiles should extend two years beyond the start of operations with colliding beams.

3. Provide a more detailed test and commissioning plan for the detector subsystems and the integration of the trigger, DAQ, slow controls, and other global systems. Maximize the tasks that can be performed in the U.S.

4. Re-evaluate the contingency needs, taking into account that the largest uncertainty during steady state operations should be parts and consumables.

5. Re-evaluate your total resources, i.e., construction project funds, operations funds (research program), and the base program support, and try to match these resources to an optimized plan for the completion of the construction, the necessary tests, commissioning, and integration of the whole detector. This will maximize the readiness for first collision data.

3.3 Schedule

3.3.1 Findings

Based on the presentations, the schedule of most of baselined subsystems for U.S. CMS, appear to be on-track for completions in time for installation.

Due to the delay in the LHC start-up schedule, there is a large schedule gap for many subsystems between the completion of construction and installation in the CMS Interaction Region UX5.

There is a clear mismatch between resources needed for the proposed pre-operation and commissioning and the budget guidance from DOE.

The CMS "slice test" is very extensive and occurs during a period when the Research Program funding profile will be particularly unfavorable.

3.3.2 Comments

If the subsystems continue to meet their schedules, there will be sufficient time for appropriate levels of testing and commissioning.

The U.S. CMS collaboration needs to develop a plan that optimizes activities during this stretched out period.

Insufficient information was presented to justify the length (approaching 18 months) of the CMS "slice test".

3.3.3 Recommendations

1. Evaluate schedule and goals of the CMS "slice test" optimizing for both effectiveness of detector commissioning and efficient use of resources.

2. Re-evaluate the proposed U.S. CMS commissioning and pre-operations schedule to provide a better match between the agencies' funding profile and the cost profile presented.

3. Investigate the benefits of targeted pre-operation delays for specific detector subsystems, perhaps even storing subdetectors for months or longer, with the goal of reducing the pre-operation costs.

3.4 Management

3.4.1 Findings

The agencies have given funding guidance in the form of a single profile for the sum of M&O (a misleading term since it includes the necessary one-time commissioning and integration (or pre-operations), as well as steady state M&O, S&C, and R&D for future needs and upgrades. Fermilab has organized the S&C as a project, and was given a budget largely based on a DOE/NSF review and baseline. Consequently, the M&O is the difference between the funding guidance and the S&C, and the resulting M&O budget is substantially less than U.S. CMS desires.

The recent delays in the LHC schedule have also meant delays in the installation and completion of CMS. Consequently, there are cost increases related to the large number of people who will work for an extended period on installation and pre-operations at CERN.

The collaboration presented preliminary plans for R&D related to operating the detector at design luminosity and future, higher luminosities.

U.S. CMS has begun planning for the management of operations in the period following the wind-down of the construction project.

3.4.2 Comments

The U.S. CMS collaboration has two projects, the U.S. CMS construction project led by Dan Green, and the U.S. CMS S&C Project led by Lothar Bauerdick. There appears to be no single individual who speaks for the U.S. CMS collaboration and sets priorities for U.S. funding. Specifically, the Fermilab Directorate has decided how to divide the combined S&C and M&O funds. It was stated that the divide was set more to honor the commitments to the S&C than to optimize the overall U.S. CMS efforts.

The process and strategy for optimizing the endgame of U.S. CMS project has not been clearly explained. While the Committee strongly endorses conservative use of construction contingency, it also believes that full completion of the existing U.S. construction project responsibilities must come before any desired scope increases. Although it is clear that CERN is under unprecedented financial stress, it is not clear that their situation is tighter than that in the U.S., and they might provide more help to the detector collaborations.

The Committee was pleased by the inclusion of preliminary R&D plans at this time. However, it was difficult to understand the division among work required for relatively simple maintenance, radiation damage at present luminosity, and upgrades for higher luminosity. It was unclear if some of this work might be supported from the base program.

The U.S. CMS Level 2 managers are in reasonable command of the issues and requirements needed for their subsystems to go from their present state through the end of the construction project and then through commissioning to a system ready for data taking. Their strategies are based on substantial experience and analysis. However, each seems to have somewhat independent conventions and assumptions with regard to funding. It has been difficult to understand the estimates in terms of a winding down construction project, an asymptotic level of M&O, and an intermediate profile of commissioning and integration.

The commissioning phase of the experiment requires a very large amount of physicist or skilled professional manpower for tasks such as calibration, testing, database construction, etc. Some current experiments have received substantial manpower from their collaboration base by setting normal “service” work to be contributed for each author in the collaboration, usually delivered by graduate students and post doctorates. U.S. CMS does not seem to have such a requirement.

3.4.3 Recommendations

1. U.S. CMS should consider creation of a leadership structure that can speak for the broader scientific interests of the U.S. collaboration.

2. Hold reviews that combine the construction project and the Research Program. The collaborations should describe their plans in terms of the completion of the construction project; the asymptotic needs for operations and maintenance (with appropriate turn-on), the pre-operations (a.k.a., commissioning and integration) and S&C. They should review the progress and plans for FY 2002, FY 2003, and FY 2004, and the plans for the out years. The planning should clearly distinguish between the commissioning phase that extends to data taking and the period of asymptotic data taking, including priorities and discussion of impacts if the projected operations costs exceed the guidance. The estimates should have clearly identified assumptions, such as escalation, labor rates, overheads, etc.

3. Examine the costs of the "standing army" associated with the LHC schedule slip and try to optimize pre-operations and commissioning strategies in view of the very limited near term funding.

4. Consider introducing a "cultural norm" for service work.

5. Develop management plans that are more streamlined and suitable to operations.