PROJECT MANAGEMENT IN LARGE COLLABORATIONS:
SNS LESSONS LEARNED FOR ITER

C. Strawbridge
Oak Ridge National Laboratory, Oak Ridge, TN

Abstract— Collaborations of research institutions and industry have been increasingly employed to accomplish the design, procurement, fabrication, assembly, installation, testing and commissioning of complex science facilities to support enhanced research capabilities in many areas. The large cost and significant breadth of technical knowledge, skills and abilities needed to bring into successful operation such complex facilities makes it likely that collaborations among national institutions and nations will become the norm for future facilities projects of this nature. The Spallation Neutron Source (SNS), a $1.4 billion accelerator-based facility for neutron science nearing completion at Oak Ridge National Laboratory (ORNL) in Tennessee, is a major collaboration among six US national laboratories and an industrial construction partner whose objective has been to design, construct and operate the world's most powerful neutron source to support world-class materials research. Some of the more important factors that have contributed to the success of the SNS collaboration include the development of an effective project management organization across institutional boundaries, a project focus on integration, involvement of partners to oversee procurements closest to the work, and top-level risk management to include a centrally-controlled reserve for unforeseen events. The lessons learned in planning, executing and managing this successful, multi-partner collaborative project have significance for the International Thermonuclear Experimental Reactor (ITER) project. ITER is a planned partnership among six national organizations (China, the European Union, Japan, the Russian Federation, South Korea and the United States) that is coming together to design, construct and operate a full-scale technology demonstration facility for producing power from fusion energy. The ITER project presents unique challenges for project management with its mix of "in-kind" and "in-cash" deliverables, the risks associated with the division of scope among the participants and the government-to-government agreements required. SNS lessons learned that can benefit ITER include the early assignment of experienced project leadership, a project-directed risk assessment and technical integration review, development of a realistic integrated project schedule, the creation of a reserve fund under project control to mitigate unforeseen risks, and the development and acceptance of a means for periodic, thorough review of overall project performance. Instituting successful project management within the ITER collaboration will require aligning the project management philosophies, accounting for cultural influences, understanding the participants' political environments, selecting and implementing useful management systems, and successfully incorporating the project management strengths and experience of the ITER partners.

Keywords-- *collaborations; project management; science facilities;*

I. INTRODUCTION

Collaborations of research institutions and industry have been increasingly employed to accomplish the design, procurement, fabrication, assembly, installation, testing and commissioning of complex science facilities. Such collaborations have been relatively common on a scale of two to three national participants, but broader arrangements have become increasingly sought among regional, national and international groups. The goal of such arrangements is to bring together the mix of intellectual, technical and industrial skills and resources needed to design, construct and operate the systems and facilities required to solve difficult scientific problems. The large cost and significant breadth of technical knowledge, skills and abilities required for these endeavors make it likely that collaborations among national institutions and nations will become the norm for future facilities projects. Recent examples of facility construction costs have approached or exceeded $1billion. Budgets of this magnitude drive the need for partnership arrangements to share such large financial burdens, and also demand increasingly effective methods of project management and control to ensure such science projects can compete effectively for funds in a constrained global economic environment.

II. THE SNS EXAMPLE

The Spallation Neutron Source (SNS), a $1.4 billion accelerator-based facility for neutron science nearing completion at Oak Ridge National Laboratory (ORNL) in the US, is the most recent example of a large, unique collaboration that was established to produce a new world-class science facility. SNS was formed as a partnership among five (later six) US national laboratories and a major industrial partner. The goal of the SNS partnership is to design, construct and operate the world's most powerful pulsed neutron spallation source to support world-class materials research. The SNS collaboration emerged from the cancellation in 1995 of efforts to design a reactor-based neutron source at ORNL (the Advanced Neutron Source), one of the last of a series of sophisticated research facilities envisioned by the Department of Energy within a long-range facilities plan. When ANS was re-conceived as a spallation source (SNS), it became evident that the skills required to

1-4244-0150-X/06/$20.00 (C) IEEE

design and construct this accelerator-based facility differed markedly from the extensive reactor experience present at ORNL, and a workable arrangement would be needed to tap the extensive accelerator skills within other DOE labs and institutions. Moreover, such a multi-party arrangement would need to ensure a simultaneous buildup and transition from other places of the knowledge and skills needed to successfully operate the facility to its full scientific potential following the construction period. In contrast to prior collaborations in the US, within SNS each partner would be responsible for major portions of technical scope and significant budget; hence the failure by any single participant to meet delivery or performance specifications could have major negative effects on the project as a whole. This performance concern was amplified by the fact that the DOE was under considerable scrutiny from Congress for overall project management performance in the wake of the cancellation of the Superconducting Super Collider. As a result of all of these factors, successful completion of SNS—technically, financially and within schedule—depended on developing and implementing effective project management practices within a large collaborative framework of six US national laboratories.

III. SNS Project Management Success Factors

There are many important factors and conditions within the SNS project collaboration that have contributed to its ongoing technical, budget and schedule success. A few of the more important factors will be discussed here.

A. In collaborations, an effective project management organization must be developed across organizational boundaries.

Of primary importance to effectiveness was the need on SNS to ensure that important management roles were filled by staff with project management as well as appropriate technical experience. Transition from conceptual design to systems acquisition with budget and schedule constraints requires personnel planning to ensure that project-experienced leadership and a sufficient management cadre is in place in time to be fully involved with the planning for project execution. With a team of project-experienced people in place, project objectives are more readily defined and decision paths and actions can be developed quickly. Once staffed, the project team must establish a framework to organize and manage the partnership effectively across the various national and/or institutional boundaries of the participating partners; for SNS this included six national laboratories and an industrial joint venture partner responsible for the civil construction. The later case was reasonably accommodated by a contract between SNS and the joint venture. For the participating national laboratories, however, arrangements were more complex. DOE national laboratories are government-owned but each is managed by private companies, universities or combinations thereof under contract to DOE. Each laboratory has over time developed and adopted management and financial systems and a unique organizational culture, most of which differ between laboratories. Moreover, the laboratory staffs in each institution naturally develop strong loyalties to their own organizations at both the laboratory level and within their technical divisions. To ensure a constant focus on project deliverables, the SNS management desired to organize the project as if it were being performed by a single institution at a single site where project resources are dedicated and communications and decision-making authority are clearly defined and largely contained within the project. This objective was successfully accomplished on SNS through the engagement and support of the participating laboratory directors and implementation of a uniform Memorandum of Agreement among the project participants. This MOA permitted the SNS project management to deal directly with SNS-assigned management staff within each participating lab, including selection of and input to the annual performance evaluations of those responsible for managing SNS work, plus establishment of formal SNS performance criteria within each laboratory's operating contract with DOE that could affect each lab's annual management award fee. Cost efficiency and a high level of top management oversight of SNS work was accomplished by organizing SNS work at each partner as a project with a large fraction of dedicated resources assigned within an SNS-dedicated division reporting to the Laboratory Director or a principal deputy. To avoid the costs associated with the adoption of SNS-specific management systems for accounting, procurement, scheduling, etc., the MOA specifically limited this approach unless the central project shared the costs involved. Practice confirmed that each laboratory staff operated most efficiently within their own familiar systems, and the SNS project, with the exception of some earned value management tools, largely avoided the expenses associated with acquisition, installation and training for project-unique systems.

B. The project team must focus on managing integration and interfaces between collaborating partners.

Another critical success factor to the SNS collaboration has been a focus by the central project management team on requirements definition, interface definition, configuration and document control and integrating activities such as installation. An early concept for building SNS envisioned largely independent partners with specifically defined hardware scope that would be delivered to SNS at ORNL and assembled and tested by loaned personnel from each lab (the "plug-and-play" concept.) This approach was quickly discarded with the realization that such an approach did not realistically account for the inevitable problems that would occur at all interfaces, that installation budgets as compiled by the contributors of each major hardware scope were not optimized and were collectively unaffordable, and that the transfer-- from experts within the collaborating labs to the site staff at ORNL-- of the knowledge essential to operations would not occur. Instead, SNS developed a hierarchy of interface documentation that governed the design interface, selected a document management system and methodology (which required revision after some experience), coordinated design reviews, exercised management oversight of the many procurements awarded by the partners, and developed a "lead-mentor-consult" approach to installation that carefully defined equipment interfaces and acceptance criteria, phased the equipment and supporting documentation turnover, installation and operation to accommodate a changing mix of the participating lab experts (high during lead or initial experience) and ORNL staff hires. SNS/ORNL assumed full responsibility for installation (and the sense of ownership that obtained) which was accomplished by construction subcontractors under the direction of the SNS technical staff. This approach has proved successful in transferring operational knowledge, in staffing for operations and by keeping costs contained; it also demonstrated that installation budgets are very difficult to estimate precisely and must therefore be allowed adequate contingency.

C. The project should oversee the administration of procurement contracts by the participants, who's technical staff will have the most knowledge of the design and the contracts with vendors.

SNS adopted a less-centralized management approach to hardware procurements with industry believing that the technical and procurement specialists within each collaborating lab could best ensure required technical performance, cost control and efficient contract administration with industry vendors. Within the US system of labs, it was recognized that procurement authorities and authorizations involved numerous legal, federal and contractor players at each partner, and it would be burdensome to attempt to manage and administer the hundreds of contracts planned for SNS from a central point. The general approach by SNS to all procurements was to accomplish these within industry (as opposed to in-house) in order to maximize competition and gain the best value: secondarily, the project also desired to minimize the potential diversion of project funds to develop infrastructure within some participants that would have little use to SNS in the future. Accordingly, SNS management developed and put in place within the SNS project procurement and quality assurance procedures provisions to ensure effective competition from industry; also developed was a centrally managed procurement systems information database that provided SNS management and all participants the visibility, communications and control needed to manage procurements within project cost and schedule baselines. SNS management had final approval on contract awards above established thresholds with the proviso that they would act within a very brief time (24-48 hours) or the award would proceed as scheduled. This authority was exercised periodically on SNS without detriment to the schedule and in several cases resulted in changes to the planned award that improved vendor accountability or price.

D. Top project management attention should be systematically applied to risks; the project should establish and manage a central reserve fund for unknown and unforeseen risks.

A final key SNS project success factor involved project-centralized risk management, including among mitigation approaches the development of performance incentives for construction contractors and project-level control of reserve (contingency) funds. Given the complexity involved with designing, constructing and commissioning over many years complex scientific facilities such as SNS and ITER, among others, it is essential to plan for the inevitable unknowns that will arise and could result in unacceptable budget and schedule growth or less than planned technical performance. In a collaboration, each partner naturally tends to embed budget reserves in the detailed work breakdown structure; when rolled up these reserves can result in an estimate that is higher than necessary. SNS took the approach that estimates should be developed realistically but aggressively, including estimating procurements based on a range of qualified vendor quotations and selecting a baseline goal that pushed the lower rather than the upper range figure. Cost estimates were reviewed to identify and capture "buried contingency" and eliminate risk-coverage overlap present within the detailed budget. Experience was employed to ensure realism within the detailed bottoms-up contingency estimates. Contingency funds were then managed centrally by the project through change control board procedures and employed as only one among several methods to accommodate cost growth. Other methods available to participants included retention of savings from favorable procurements, or adjustments/transfers of staffing or non-critical scope with the concurrence of SNS management. Risk assessments by each participant were updated monthly or more frequently if significant and centrally evaluated by the project top management team. The central project management of contingency has been an area of considerable dialog with participants throughout the SNS project; however, it has proved to be successful in protecting the project from unacceptable impacts resulting from design, fabrication and testing problems. With project completion scheduled in 8 months, SNS is poised to deliver full technical scope on time and within a budget commitment established over five years ago. For civil construction, which was managed by SNS/ORNL through a contract with a commercial Architect Engineer/Construction Manager joint venture, contract performance incentives were applied on annual and end-of-project bases that were oriented to achieve safety, schedule and cost objectives. These incentives proved extremely successful and resulted in the completion of over 4 million construction man-hours performed with no lost time incidents, facilities schedules have met all technical systems installation plans, and workman's compensation insurance costs for SNS have been less than 10% of the regional average.

IV. ITER Project Management Challenges.

The lessons learned in planning, executing and managing SNS as an effective, multi-party collaborative project have relevance for the International Thermonuclear Experimental Reactor (ITER) project. ITER is a partnership among six Parties (China, the European Union, Japan, the Russian Federation, South Korea and the United States) that is coming together to design, construct and operate a full-scale technology demonstration facility for producing power from fusion energy. The ITER project has dimensions that differ from recent US collaborative experience such as that on SNS, and understanding these differences is important to applying lessons learned. As an international collaboration, there is on ITER the added concerns of cost control among many currencies, the need for government-to-government agreement on management arrangements and the cultural differences the participating countries bring to communications and decision-making within the project. To at least partially deal with these concerns on ITER, each participating organization (the Parties, representing the 5 non-host countries and the EU host) will be responsible for deliverables "in-kind" (hardware and equipment) and "in-cash" (a pre-determined measure of staff effort and a share of a cash fund to cover installation and other common site expenses.) These contributions have been at this time provisionally allocated among the Parties to meet contribution targets, typically 10% for the non-host Parties. Technical risk exists in the many equipment and systems interfaces that are created from this approach, and considerable management risk exists in setting up an effective collaboration on such a broad international scale. While the countries participating in ITER have been engaged in fusion research and technical development for many years on smaller-scale projects, the successful completion of ITER will require transition to collaborative project management methods on a scale not yet experienced.

V. SNS Lessons Learned for ITER.

Several fundamental elements that support successful project management will be compared between SNS and ITER. First, a clear definition of project scope and deliverables by each participant is needed. This definition was achieved on SNS (although later than desired) principally through common recognition of the expertise of the participating institutions, institutional commitment to the MOA, and the establishment of a strong, experienced central project management team at the host site (ORNL.) Presently and in contrast on ITER, the assignment of scope has been made only partially on the basis of expertise and has been influenced by the additional factors of sharing high-low difficulty technical work and the need for proportional national representation. Moreover, while the ITER design is reportedly finalized and documented by a 2001 Final Design Report, additional work in the intervening years has led to numerous informal yet likely change proposals. During this period, the selection of the project permanent leadership has been delayed, and the ITER interim leadership and staff have suffered from declining influence, resources and a "wait and see" attitude by the participating countries pending a site selection. *It is essential that the key leadership of the ITER project organization be selected at the earliest opportunity and that they direct a top-to-bottom technical review with the objective of full scope definition and risk minimization. This review should consider the options to reduce technical risk and interfaces through reasonable adjustments in scope allocation among the parties, and the review results should be completed in time to influence the final negotiated agreement among the Parties (governments) that will formalize these boundaries.*

Next in importance, a project management team must bring together all participants and establish a realistic, integrated schedule and clear technical performance baselines. The SNS partners under the direction of the SNS central project management at ORNL were able to rapidly produce an integrated schedule and milestones early in the project, providing appropriate schedule contingency that has proved to be sufficient over the life of the project. Although somewhat delayed pending the initial selection and assignment of experienced technical management and staff to ORNL, a design review and integration of technical parameters, physics and selected overarching systems (diagnostics, global controls and conventional facilities) was achieved in time to meet equipment procurement schedules. On ITER, the overall schedule remains in doubt pending resolution of design changes and the assignment of experienced central leadership able to advocate the best interests of the ITER project. Additionally, despite the fact that the in-kind concept for providing hardware transfers much cost risk from the ITER project to the individual Parties, the ITER project leadership must consider the national budget constraints within which each Party must function—the in-kind arrangement has the negative effect of encouraging the Parties to behave more as vendors than true partners interested in the overall successful outcome of the project and limits the talent available to the ITER team to make decisions. *Once a project leadership team is in place, it is important for them to prepare an integrated schedule based on an accepted design and get the earliest agreement of all Parties so that potential impacts on resources within each Party can be realistically assessed and arranged. Effective configuration management and baseline control will be essential to maintaining schedule and ensuring that the parties can meet their in-kind and cash contribution obligations.*

Finally, meaningful accountability for project performance must be placed with the project management team and they must acquire the tools needed to meet this responsibility. On SNS, the authority of the Project Director was reinforced by the quasi-contractual arrangements in the MOA and in the individual partner's management and institutional performance evaluations. The entire SNS project budget as well as management reserves and contingency for unknowns was controlled by the central project team and all funds flowed through them. In turn, the project had the responsibility to continually assess and manage all risks closely, using contingency funds only when dealing with unforeseen and unknown problems. Despite these control mechanisms, underpinning the success achieved by the SNS collaboration was the collective desire of all participants to ensure that their contribution met all requirements, that SNS as a facility met all objectives and that they could look back with pride on a successful achievement of a challenging goal. Considerable management time and energy was expended early during the SNS project to bridge the institutional and cultural differences that existed in each partner. Change control boards, design reviews, weekly project videoconferences, monthly reviews of key project performance metrics and external reviews by DOE and other expert committees all served to help break down communication and institutional barriers among the partners. Acceptance and application of such methods and concepts on ITER has been slow to non-existent. Experience indicates that with a program of rigorous risk management, the central project will discover unforeseen problems at various phases of design and construction that cannot be reasonably assigned to the Parties, hence the need for a central reserve or contingency fund. Such a fund could be initially established through a rigorous, centrally managed system integration and value management process that allowed the Parties the opportunity to suggest improvements that would lower their costs while still meeting ITER technical requirements. The possible inclusion of additional Parties to ITER as the project progresses offers further opportunity to sustain such an approach to reserve funds. An effective tool for the project to utilize in risk management is a periodic comprehensive project review by technical and management experts who can advise the ITER Council, the body to whom the project management reports, of the progress and issues on the project as it evolves in order to allow the proactive identification and resolution of issues before they threaten project baselines. *The ITER project leadership must be forceful advocates for the concept of a central reserve fund to mitigate risk; they should assist the Parties through system-level integration and value management to find opportunities to reduce the costs of their in-kind contributions in order to help provide such reserves. Moreover, the ITER Council should be pro-active in providing a means to ensure thorough, periodic review and assessment of technical, budget, schedule and management performance by the ITER project throughout its duration.*

VI. Conclusions

Instituting successful project management within an international project as complex as the ITER collaboration will require aligning several project management philosophies, selecting experienced project leadership, providing effective performance evaluation and oversight, accounting for cultural influences, understanding the participants' political environments, selecting and implementing useful management systems, and successfully incorporating the project management strengths and experience of the ITER partners. Transferring the experience gained from successful national collaborations like SNS to the broader international forum of ITER is essential to ensure the continued success in providing for international use the complex science facilities needed in the future.

Acknowledgment

Thanks to S. Herron and R. Johnson of ORNL for their suggestions in preparing this paper.