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PROJECT MANAGEMENT ON THE SUPERCONDUCTING SUPER COLLIDER: MEETING THE CHALLENGES FOR CULTURAL AND SYSTEMS INTEGRATION

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INTRODUCTION

Sponsored by the U.S. Department of Energy and the State of Texas, the Superconducting Super Collider (SSC) Project is one of the largest, most visible projects in America. With an estimated cost of nearly eight billion dollars and a nine year construction schedule, the project will employ thousands of people and dozens of companies and organizations.

The SSC will be one of the largest, most powerful scientific instruments ever built. At several time the energy of any existing particle accelerator, the SSC will allow high energy physicist from around the world the ability to explore and perhaps answer some of the most fundamental questions of mankind. What is matter composed of? What are the smallest particles? How did the universe begin? How might it end?

While research, feasibility studies and conceptual design activities related to the SSC have proceeded since 1984, the decision to begin construction was only made by the U.S. Government in late 1988. The contract to design and build the SSC was awarded in January 1989, to Universities Research Association (URA) a consortium of American universities. Since January URA with two partnering companies, EG&G Inc., and the Sverdrup Company, have transitioned to the site in Texas, are implementing project management systems, and are proceeding with preconstruction activities.

The challenges are immense. Some required technologies are yet to be developed. Funding is limited. But most of all, hundreds of different organizations, companies and participants, all from different organizational, national and environmental cultures, must be integrated into a project team. Project management systems, methods and tools must be implemented which are useful and used by all of the managers. Far from easy, it is a challenge being met by the SSC Project Management Office.

This paper describes the cultural, technical and management systems challenges being addressed by the SSC project management team. The approach to meeting these challenges is discussed and the current status of the project presented. Experience during the first year of the project is briefly described and areas of future management emphasis are presented.

Finally the emerging culture at the SSC Laboratory is indicated. That culture is evolving from a common vision shared by all project participants - the vision of the premier high energy physics laboratory, open to scientists and students from around the world, leading to discoveries which will benefit mankind.

Our objective is to present our plans and experiences on one of the worlds biggest, newest, and most visible science projects. It is our intent to share what we are learning and to invite INTERNET 90 participants to watch the SSC Project Management Team succeed in the decade to come. Management success on the SSC Project could very well mean a better world in the future for all of us.

THE SUPERCONDUCTING SUPER COLLIDER

The Superconducting Super Collider will be the world's largest particle accelerator, in effect a microscope of unparalleled power. It will accelerate two tiny counter-rotating beams of protons to an energy of twenty trillion electron volts each, and bring them into head-on collision in large underground experimental halls. Where computer controlled electronic detectors will catch the evanescent particles created in the collisions.

The SSC Machine

The SSC will accelerate two beams of subatomic particles (protons) in opposite directions around an oval underground racetrack 54 miles in circumference. The protons will circle the ring about 3,000 times per second. Traveling at nearly the speed of light they will meet head-on in violent, microscopic collisions, producing conditions that mimic the conditions of the early universe. Sprays of particles will stream out from the collision points, including some that may carry fundamental secrets of how we and our universe were created.

The beams of protons will be steered around the ring by magnetic fields produced by 10,000 magnets. These magnets will be built with superconductors, materials that at very low temperatures lose all electrical resistance. (A collider of the same energy built with conventional magnets would consume 100 times more electricity.) The protons will reach energy 20 times higher than available today by riding carefully timed bursts of radio waves. The beam pipe, magnets, radio wave sources, and most support systems will be buried in an underground tunnel for radiation protection.

The collision of two protons at SSC energies will not smash the protons into "pieces". The enormous energy of the colliding beams will actually create new particles. Some of these particles may not have existed since the earliest moments of the universe. Physicists will study these collisions with detectors in underground experimental halls placed at selected points around the ring, where the proton beams meet head-on. Figure 1 displays a conceptual model of the SSC.

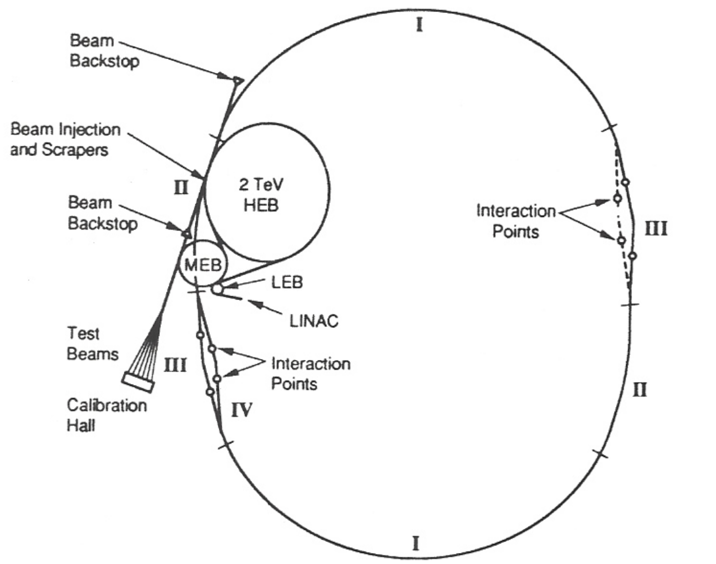

FIGURE 1: CONCEPTUAL MODEL OF THE SSC

The SSC Project

History - In the Summer of 1982, participants at a workshop sponsored by the American Physical Society agreed that exploration of fundamental particles at TeV energies was needed and a 20TeV accelerator (the SSC) was discussed.

The feasibility of the SSC was addressed in greater depth at a workshop in the spring of 1983. The conclusion was that, just as developments in physics made evident the need for a machine like the SSC, so developments in technology, especially in superconductivity, made the building of such a machine possible.

In July 1983, the High Energy Physics Advisory Panel of the Department of Energy unanimously endorsed detailed research into the feasibility of the SSC. With Congressional approval, funds were reallocated to support research and development on the new accelerator, especially on the superconducting magnets.

Succeeding years of SSC work have seen the preparation of the siting parameters document, the selection of a specific magnet type, and the publication of the Conceptual Design Report, a detailed account of all the systems needed for operation of the SSC as a fully functioning research facility. The reviews of this document formed the basis for the decision in January 1987 by President Reagan to endorse construction of the SSC.

The Department of Energy initiated the SSC site election process in April 1987 and asked the National Academies of Sciences and Engineering to review the proposals to identify several they considered best qualified. In December 1987 the DOE began a detailed evaluation of the recommended sites. As a result of this evaluation process, Secretary of Energy John Herrington in November of 1988 designated the Texas site, located in Ellis County (near Dallas and Fort Worth), as the preferred site for construction on the SSC. Figure 2 shows the location of the SSC near Dallas, Texas. In January, 1989, the URA team was designated as management and operations contractor for the SSC with Roy F. Schwitters, a professor of physics at Harvard University, as the Director of the SSC Laboratory.

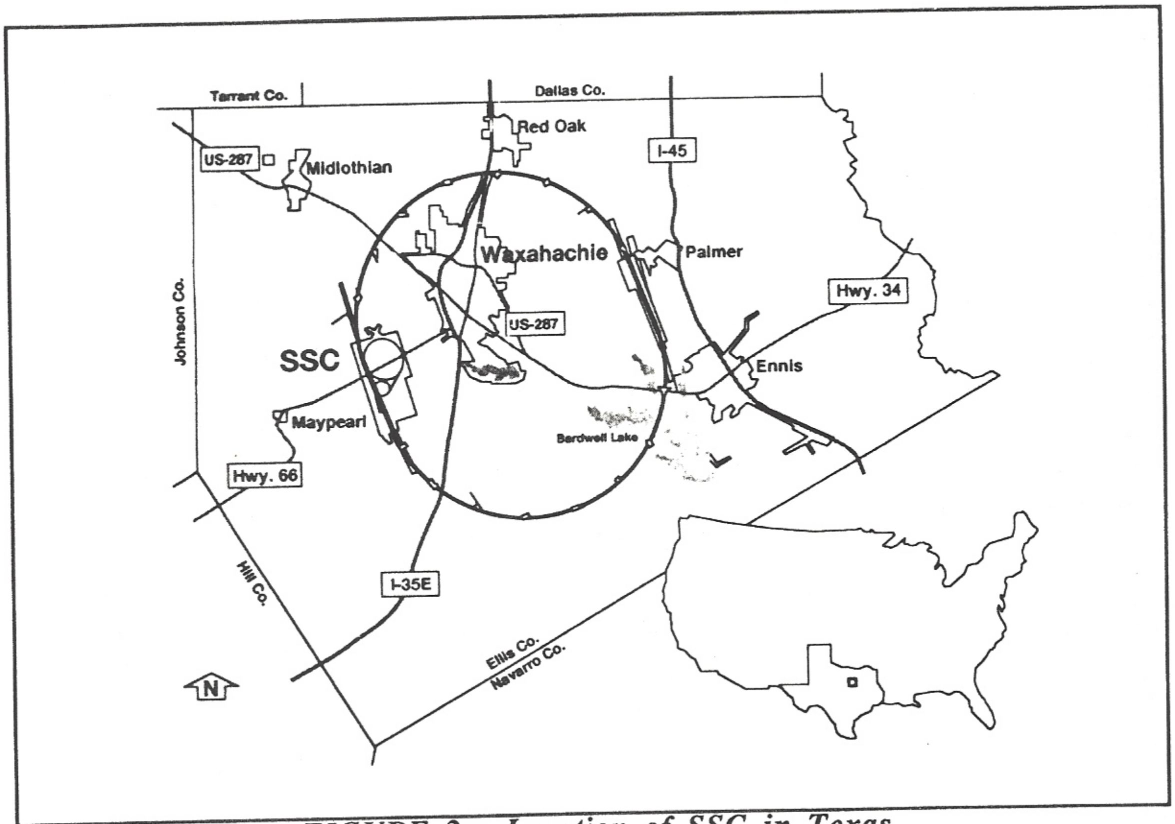

FIGURE 2: Location of SSC in Texas

Project Start up - Upon award of the contract to design and build the SSC, employees of URA and EG&G began the transition to the designated site in Texas. Officially the project had begun. Offices were located, hiring began and the project planning process was initiated in earnest.

Organizing the project team was a challenge from the beginning. Participants were joining the project office from universities, national laboratories, different companies and government, from locations around the United States. While a good deal of preliminary design and planning had occurred prior to 1989, everything now had to be tailored to the site in Texas. An Environmental Impact statement had to be prepared, the SSC Footprint finalized, geological analysis completed and various local organization involved. Most importantly the conceptual design of the collider, injectors, magnets and other SSC systems and components had to be updated. Associated with an updated conceptual design would be a new cost estimate and a schedule.

From January through October, 1989 the primary emphasis was on staffing and organizing the SSC Project Team and on implementing management systems. While those processes are continuing, in late summer, 1989, the focus shifted to the revised conceptual design and associated cost estimate. By November, 1989, it was apparent that the original $5.9 billion cost estimate would be inadequate to build a 20 TeV SSC. After much design activity, analysis and hard work a site-specific conceptual design was presented to DOE in January, 1990 with a corresponding cost estimate of $7.8 billion. Following a review by a blue ribbon panel of U.S. physicists, appointed by the U.S. Secretary of Energy, the revised design and cost estimate were endorsed by the DOE and presented to the President and Congress.

The SSC Laboratory

From the beginning of the project an SSC "Laboratory" orientation was established in Texas. The emphasis is on high energy physics research. High energy physicists will design the equipment and machinery to be used at the SSC as well as the experiments to be conducted.

An SSC Laboratory (SSCL) organization was established (See Figure 3) and the organizational infrastructure to support an operating physics laboratory is being established. Rather than a nine-year construction project, current activity is rather viewed as the current phase of a much larger process - building and operating the SSCL.

Major participating organizations and personnel are integrated into the single SSCL organization, with SSCL managers often employed by different companies. The emphasis is on integration and teamwork. Cultural influences are recognized and absorbed, since the SSCL organization is so young, everyone is literally a "new hire." No ingrained culture, represented by resistance to change or the status quo, exist.

In addition high level, international meetings and symposiums of high energy physicists are still involved in research activities occurring at other laboratories. SSCL scientists are keeping abreast of developments in accelerator and collider research and technologies; SSCL scientists and engineers are actively pushing the technologies of superconductors and super computing. Major communications networks have been established between the SSCL and other physics laboratories around the world. Papers, reports and books are already being published at the SSCL.

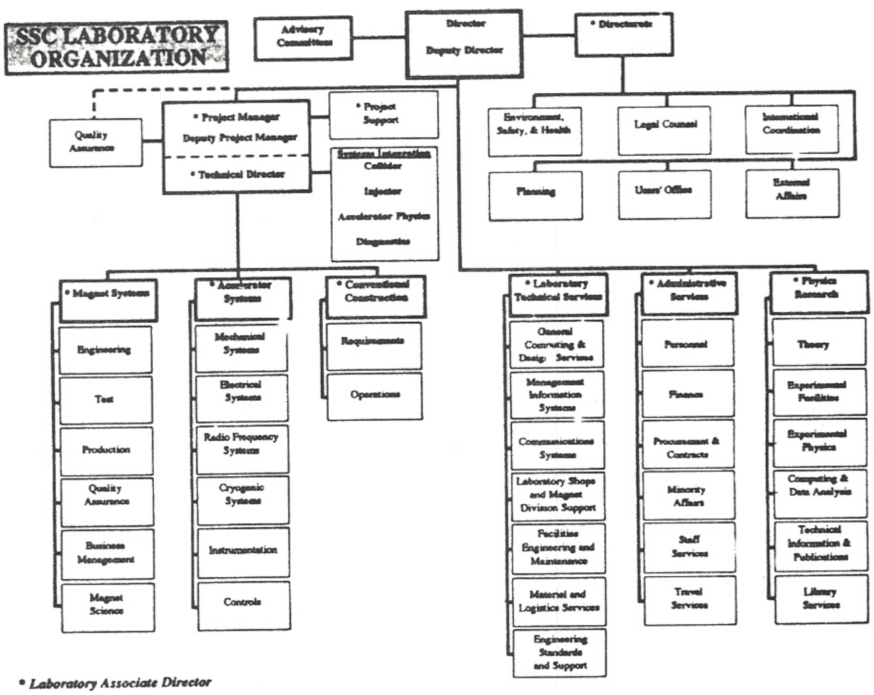

FIGURE 3: SSC LABORATORY ORGANIZATION CHART

THE CHALLENGES

Any mega-project of the size and complexity of the SSC will present a multitude of challenges to project management. A pioneering project like the SSC with its many participants from a wide spectrum of environments, backgrounds and cultures, magnify those challenges and offer new ones.

Technical Challenges

At a little over fifty miles (82 Kilometers) around, the SSC will be the worlds biggest accelerator as well as the most powerful. Figure 5 shows the design characteristics of the SSC. Tremendously large, complex and powerful systems and equipment will be required to satisfy those basic characteristics.

For instance the particle detectors which must be designed and built for the SSC will be more complex and expensive than any ever previously assembled. There will be more wires, more cells, more microchips, more electronics. The components will be faster and more sophisticated. In terms of sheer size, speed, precision and computing power, the SSC detectors will be built on a scale never seen before in high-energy physics. SSC detector electronics will have to be capable of making thousands of times more decisions than today's state-of-the-art detectors, and thousands of times faster. With so many more components they will also have to be small and use less power, to avoid generating excessive heat. The computing power required for triggering and data analysis will be equivalent to hundreds of supercomputers, or hundreds of thousands of smaller computers. But raw power will not be enough. The software will need to be easy to use and easy to change, so that it can be readily modified in response to new ideas and discoveries.

The challenges to SSC scientists and engineers are tremendous. Superconducting Magnet technology has never been demonstrated on the scale required at the SSC. Computing capacity will be challenged. Much needed equipment has never been built. SSC Project Management must manage R&D activities, design, development, procurement, installation and integration of components and systems, and construction of tunnels and facilities to house the machinery.

Physics Parameters:	
Proton energy	20 Trillion electron volts (TeV)
Number of protons per ring	130 trillion
Collisions per second	100 million
Dipole Magnets.	
Number per ring	3840
Length of each magnet	17.34 meters
Weight of each magnet	6759 kilograms
Quadrupole Magnets:	
Number per ring	888
Length of each magnet	4.32 meters
Weight of each magent	1114 kilograms
Main Ring:	
Circumference	82.944 kilometers
Number of magents (including all special purpose magnets)	10104
Weight of iron in magents	41,500 tons
Total length of superconducting cable	19,400 kilometers
Refrigeration:	
Quantity of liquid hellium	2 million liters
Quantity of liquid nitrogen	1 million liters
Cost: (1988 dollars)	
Main ring and injector	$1,520 million
Conventional facilities	$615 million
Engineering and design	$305 million
Management and support	$205 million
Contingency	$565 million
Total construction cost	$3,210 million
Additional costs (detectors, computers, R&D, etc.)	1,000 million (approx.)
Operating costs	$270 million/year

FIGURE 5: BASIC SSC DESIGN CHARACTERISTICS

Management Systems Challenges

The SSC Project can be described as a "green field" project. The project team has had to define and establish all information systems to be used on the project and at the new SSC Laboratory.

Due to the urgent need for accounting, procurement and personnel systems, interim information systems were implemented during 1989. Based on preliminary needs analysis and systems requirements, off-the-shelf software was procured for short term solutions. A

Project Management Software package was procured and implemented and a variety of personal computer based software/systems used for various information processing.

Now, however, the SSC project and laboratory must plan for the design, procurement and implementation of long-range management information systems (MIS). An important requirement will be the compatibility and integration of various technical and management information. It is a challenge appreciated by the managers and scientists in the project management office, who realize the paramount need to exchange information quickly and efficiently.

THE APPROACH

The SSC Project Management Office (PMO) have recognized three major critical success factors (CSF): Planning, integration and communication. In addition the common "Vision" of the future SSC Laboratory plays a major role in integrating project participants. These processes are being emphasized during project start-up and transition into construction.

Emphasis on Planning

Planning represents the major emphasis on the project to date. During the spring and summer of 1989 the planning and implementation of management systems were emphasized. Management Systems and Support Implementation Plans (MSSIP) were presented to the DOE in September, 1989 by SSC project management. Based on that successful presentation and review, the U.S. DOE authorized the SSCL to proceed with selection of an AE/CM contractor for construction work.

During August, September and October, 1989 the planning emphasis focused on the site-specific conceptual design, cost estimate and schedule. The entire SSCL staff was involved in this planning, which resulted in a concept supported by SSC Laboratory management, the U.S. DOE, and the U.S. Physics community. That detailed planning has continued over the winter and spring, 1990, with the goal of establishing a good baseline for the project in early summer, 1990.

Finally detailed systems and procedures are being established to ensure that all project work is identified and planned properly. A hierarchy of plans are being developed and implemented, from laboratory and project master plans to detailed cost account and work package plans which satisfy DOE's cost and schedule control systems criteria (C/SCSC).

Emphasis on Integration

Technically the SSC will require the development and integration of many incredibly sophisticated systems and equipment. A technical integration office has been established in the SSC PMO, headed by the project technical director, to ensure that injector and accelerator components and subsystems, including the many different types of magnets, are properly integrated during planing, design, fabrication and installation.

Systems engineering, configuration management and total quality are being emphasized in support of the complex integration requirements. Integration meetings are conducted weekly with engineers, scientists and managers from each of the SSCL divisions.

Overall integration is being emphasized during the design and implementation of Long Range Technical and Management Information Systems. Based on the need to communicate all types of data, and the opportunities provided by the early stage of development, common hardware, software and databases are being planned and developed.

Most importantly project participants are being integrated into a single SSC Laboratory, focussed on the SSC Project. Staffing continues at a tremendous pace with subsequent organizational pressures. The SSC PMO is working to promote cooperation, coordination and integration among participating companies, organizations and people.

Emphasis on Communication

A key to the successful organization and integration of participants on the SSC project is effective communication. All SSCL managers are kept informed by regular communications from both the Project Management Office and the Directors Office. A variety of meetings are conducted weekly, including Associate Directors' meetings, project integration meetings, magnet design and status meetings, schedule status meetings, and others.

The SSCL director conducts meetings of all SSCL employees periodically to review important events or issues which involve congress, the overall status of the project, Texas state or local polictics, or the public. These lab-wide meetings play an essential role in developing and maintaining the common purpose and vision for the SSCL.

Effective communication with the customer, the U.S. DOE, is also recognized as essential for SSCL success. The on-site DOE manager and his staff are involved in many high level decisions on the project, including staffing plans, facilities planning, major procurements, project milestones, and decisions related to the SSC site in Ellis County. Regular communications with the DOE SSC Program Office in Washington DC are maintained, with periodic meetings and reviews conducted at the SSCL.

Finally the SSC Project Monthly Progress Report is used as a major communication tool and is widely distributed within the SSCL, to DOE and to the state of Texas. The monthly report includes technical, schedule, and cost performance information and status, discussion of problems and review of upcoming events and meetings.

Emphasis on the Vision

Perhaps the most important management strategy on the project is the emphasis placed on "The Vision" of the future SSC Laboratory. That vision is constantly stressed by the Laboratory director and the project manager. Stories which appear in National and local newspapers, and publications on the SSC, all reference the overall purpose of the SSC.

Everyone working on the SSC, regardless of station or function, embrace the vision of a world laboratory which may uncover fundamental secrets of our world. The emphasis on education and research is so positive that employees take pride in discussing those objectives with outsiders. It's an exciting project for everyone, and, in Texas, everyone loves the SSC!

EXPERIENCE TO DATE

The SSCL is moving forward at a tremendous pace. Approximately fifty (50) people are added to the SSCL staff each month with a projected population of 2200 in 1992. Funding for the project was $225 million in 1990 and will grow to $400 million in 1991 and $700 million in 1992. To complete the SSC by the year 2000, annual funding will reach a peak of over $1 billion in 1995.

Project Planning

The updated Conceptual Design Report and associated cost estimate was presented to DOE in January 1990. Based on acceptance of that design and direction to proceed by DOE, the SSCL PMO is now working to have a total project baseline plan completed by late May, 1990. That plan will include a WBS and WBS dictionary (workscope). Final cost estimate plan is currently proceeding, with active participation by all SSCL managers organization. Directed by the PMO the baseline planning effort will result in a plan against which SSC project performance and status will be compared and reported. Figure 6 displays the summary WBS for the SSC Project.

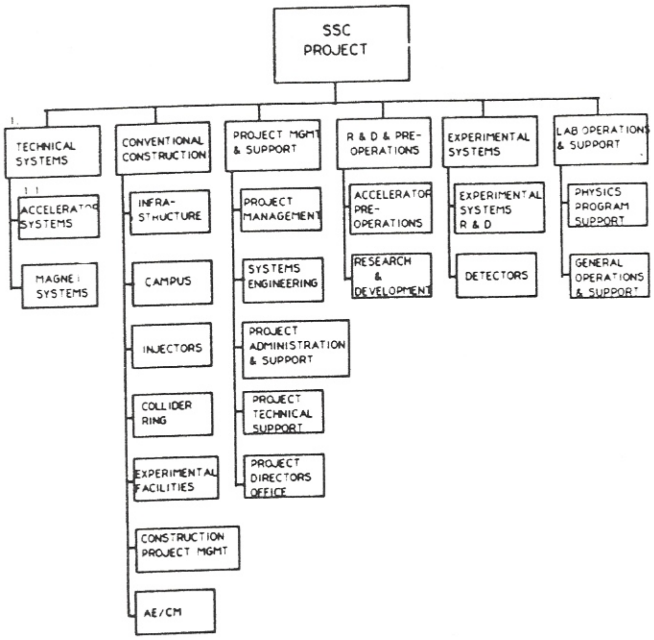

FIGURE 6: SSC Project Work Breakdown Structure

Because of the size and importance of the SSC project, DOE requires compliance with its Cost and Schedule Control Systems Criteria (C/SCSC). These criteria require that all near term work be planned in detailed cost accounts and work packages. On the SSC, all FY1990 work has been planned in cost accounts, with detailed planning of FY1991 activity now beginning.

Systems and procedures are in place to support these important planning processes. While the PMO directs and integrates planning activities and information, individual organizations and managers are responsible for doing the detailed planning. That information is given to PMO staff for integration, summarization and review.

Management Systems Implementation

Information systems are in place for project cost/schedule planning, control and reporting; for project financial management; for procurement tracking and management; for property management; and for human resource management. Systems for document control, configuration management and total quality management are in the planning stage. Upgrades or replacement of these existing systems are being addressed in Long Range MIS planning currently in process.

Technical Information Systems, including CAD/CAE, Geological databases, environmental protection and compliance, magnet design, physics research and others have been implemented and will be integrated into the overall SSCL MIS. In every case detailed implementation plans are required to ensure that systems are developed and installed effectively and efficiently.

Overall Project Status

Design work on injector systems components and the collider ring have begun. Since superconducting magnet development and mass production are critical to SSC completion, magnet systems planning and procurement activity are being emphasized. Magnets will represent close to $1 billion of procurement activity, so magnet design and production capabilities are being transferred to private industry from DOE's national laboratories under a "Magnet Industrialization" Program. Development and testing of prototype magnets are now being conducted at several national laboratories.

Planning of Physics Research experiments and experimental systems has started, with participation by American and foreign universities and laboratories. A $1 billion contract for Architectural Engineering and Construction Management (AE/CM) services was awarded in February, 1990. Detailed planning of tunnels and facilities at the SSC site is proceeding.

The "Footprint" of the SSC tunnel and campus was approved by DOE and acquisition of land by the state of Texas began. A site-specific Environmental Impact Statement is nearing completion. In all areas SSC Project Management is working in compliance with all DOE orders, requirements and regulations.

Organizational Effectiveness

Organizing and directing the growing SSC Laboratory and Project office have been accomplished with a great deal of effort, but not without problems. There has been much pressure to hire staff in order to accomplish the planning and technical tasks needed to get design and construction underway. With the different backgrounds of various participants, conflicts have occurred and reorganization has been necessary. The SSCL PMO has recognized these pressures, which are not uncommon during start-ups of mega-projects. They have maintained teamwork by emphasizing technical integration and by focussing on the common vision, the future SSC Laboratory.

The U.S. DOE has been slow in staffing their on-site office in Dallas, but now have a project office established and are participating in more SSCL planning and review activities. Communications have improved dramatically as the "customer's" representatives are more available for feedback and participation.

THE FUTURE

The future on the SSC Project is exciting. Construction will begin in 1991, experiments will be planned and more international participation will occur. As management systems come on line many frustrations should be relieved, and, in fact, dramatic advances made in information processing and exchange, understanding and decision making.

Transition to Design and Construction

With the selection of an AE/CM contractor and the approval of the SSC Footprint by DOE, construction planning is proceeding rapidly. Facilities planned for the SSCL Campus are needed as soon as possible, including magnet testing and development laboratories.

Design is now proceeding on all SSC subsystems. For equipment and components, large procurements will be utilized. For more "conventional" systems and facilities, the AE/CM contractor will perform much of the engineering design activity, and will manage contractors selected for tunneling, construction, infrastructure and utilities work.

During this transition period the SSCL organization will grow and expand, to accommodate the new organizations and their people. Care will be taken to account for additional cultural influences, and incorporation of new perspectives into the SSC Laboratory society.

Planning and Configuration Control

The emphasis on planning will continue. With the amount of R&D still involved with development of accelerator and detector components, changes will be frequent and often welcomed. SSC Project Management philosophies, policies, systems and practices must support the ability to revise plans, designs and approaches. Change control and configuration management are recognized keys to project control over the coming years. These processes will receive more emphasis, as project activity expands and documentation/information reach major proportions.

Emphasis on Team Building and Communication

At a minimum, the SSC will be a ten-year project. At its height upwards of 5000 people will be working on the project, at locations around the world. In order to achieve efficient and productive project performance, a great deal of emphasis will be placed on communication and team work. Again technical and managerial systems integration will be keys to achieving coordinated and high quality results.

Planning for team work must be addressed. Personnel development activities such as training will be provided. Meetings, oriented toward communication and team building will be established and conducted on a regular basis. Most importantly the "common vision" will be maintained and promoted, to keep the common cause clear to all participants. Top managements role in that process has already been clearly demonstrated.

Integration and Efficiency

Only through effective integration and team work can systems and people produce efficient results on the SSC Project. All technical components and subsystems must eventually work together with precision when the SSC comes on line in ten years. That integration will require the close coordination of hundreds of scientists and engineers over the life of the project.

Technical and management information must be communicated efficiently to most project participants. DOE and the state of Texas will require constant status information, of both a technical and administrative nature. True efficiency will be required to satisfy and involve the multitude of participating organizations, professionals and special interest groups. We are seeing that today. It will increase many fold in the next few years.

THE EMERGING LABORATORY CULTURE

The environment at the emerging SSC Laboratory is characterized by differences, in backgrounds and perspectives of people, in professional training and careers, in management philosophies and approaches, in degrees of discipline and freedom. The atmosphere is one of enthusiasm and hard work, excitement for new developments and frustration with limited equipment and systems, recognition of the need for planning and coordination, and amazement at bureaucratic processes.

A culture is emerging. It reflects support of the common vision and it recognizes that everyone is in "the same boat." The SSCL did not exist a year ago so everyone is a "new employee." All the systems are new and everyone is learning. It is an atmosphere of learning and open mindedness and of pushing onward with creation. The Laboratory director describes it to the press. Laboratory employees live it.

Large pioneer projects like the SSC provide an opportunity few other situations can offer. That is the opportunity to influence and direct all the systems and practices and policies and even the culture which will guide the laboratory in the years to come. For those involved in start-up it is an exciting opportunity and experience.

THE OPPORTUNITIES

For the Project Management team the SSC project offers opportunities in every aspect of the PM discipline, ranging from setting up systems to project leadership. Few projects offer so many chances to "do things right" the first time. Only start-up projects can, and one of the size and complexity of the SSC magnify them.

For SSC project participants it is an opportunity to contribute to the development of a world resource. If the vision comes to fruition the project could truly change the world. And we will have made that happen.

For the United States and society in general the SSC represents an opportunity to invest in the future. Based on the experience of other similar science projects, the benefits from the SSC will be significant. If all the predictions come true the world will gain a new understanding of the universe and the world around us. And in every aspect of the project technical advances will be made in the technologies required.

For science and the international physics community, the SSC represents a significant investment in education, science, and physics. If in fact the "standard model" of physics can be proven, or if the most fundemental particles can be described. then a miraculous understanding of the physical forces of nature could result. Something high energy physics have only dreamed about could become reality.

CONCLUSION

The SSC project is a huge, complicated, pioneering project, involving thousands of people and organizations, from around the world. The challenges are immense, but so are the opportunities. The Project Management Team at the SSCL in Dallas are addressing those challenges in a straight forward and systematic manner. And through it all an SSCL culture is emerging from the myriad of cultural backgrounds and influences of the participants. It is a process that is clearly visible, perhaps uncontrollable, but most certainly very very important to the managers of a project like the SSC.

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