MINI-SLAR DELIVERY SYSTEM

by

D. Alstein
Ontario Hydro, Bruce A
P.O. Box 3000
Tiverton, ON N0G 2T0

and

K. Dalton
Spectrum Engineering
P.O. Box 687
Peterborough, ON K9J 6Z8

CA9700729

ABSTRACT

In the Spring of 1993, a need to complete Spacer Location and Repositioning (SLAR) on the Bruce 'A', Unit 1 Reactor was identified. An alternate SLAR delivery system was required due to conversion constraints that prevented the existing Bruce SLAR System from being used in Unit 1.

A Portable SLAR Delivery System called MINI-SLAR Delivery System was developed, designed and fabricated in a 14 month period, then used to successfully SLAR 109 channels.

The system is a portable remotely operated Nuclear Class I registered fitting that is independent of the Fuelling Machine, allowing the station to continue normal Fuelling and Maintenance activities. It is designed to a Level "D" faulted condition of HPECI Pressure thus minimizing PHT Heat Sink configuration requirements and minimizing outage set-up times. The system is based on a modular design allowing for easy fabrication, assembly and repair. It consists of a Snout Assembly, a Closure Plug Assembly, Shield Plug Assembly, SLAR Ram assembly, Work Table Assembly and Control Panel. Controls are through a Programmable Logic Controller with software tested and certified to a Software Quality Assurance of Level III.

INTRODUCTION

In the spring of 1993, the Canadian Nuclear industry was rocked by Ontario Hydro's decision to cancel the retubing of Units 1 & 2 Reactors at Bruce 'A'. It was decided that Unit 2 would be "laid up" beginning in September of 1995 and Unit 1 would be run until it met its Fuel Channel Life Limits.

In developing a "Life Cycle Management" Strategy for Unit 1 Fuel Channels, the station quickly realized that it must address the grave issue of potential pressure tube to calandria tube contact that results from channel annulus spacers moving from the design location, or face a shutdown of that unit as early as the Spring of 1997. At Bruce, Units 3 & 4, Spacer Locating and Repositioning (SLAR) has been quite successful and is performed using two specially converted fuelling machines. This system could not be used, however, as the Fuelling Machine Trolley could not reach Unit 1 and the equipment could not be converted to another trolley in time to meet project commitments. Thus was born the need for an alternate delivery system.

Although the need for SLAR of Bruce Unit 1 fuel channels was first identified following the cancellation of the proposed retubing of Unit 1 in the spring of 1993 work on a delivery system did not begin until the summer of 1994. In spite of a late start to the design process and the complex challenge of designing, building and commissioning a replacement for the SLAR delivery system in just 14 months, the project succeeded in completing SLAR of 109 channels in unit 1 in 31 days of SLAR processing at a very substantial saving to Bruce A. The purpose of this paper is to describe the process followed to develop the mini-SLAR system, to discuss the distinct aspects of this approach and examine what made this project successful. The technical description of the mini-SLAR mechanical design has been documented by others [1.] and this paper concentrates on the organizational aspects of the project.

The mini-SLAR delivery system is a small scale fuelling machine-like device. It was used in 1995 to deliver a SLAR tool into a fuel channel from tooling mounted on a fuel channel maintenance platform. The design requirements of the delivery system were to manually home and clamp onto a fuel channel under shutdown conditions, extending the heat transport pressure boundary, remove the closure and the shield plug and install a liner sleeve into the end fitting from either the inlet or outlet ends of a fuel channel. The target channel processing rate for the system was 2 channels per day. Both the SLAR processing and the delivery machine systems performed extremely well overall. The average time required to perform SLAR operations once on the channel was 1.8 hours, and the time required to move between sites was 1.3 hours, with an average 4.3 hours required for tool calibration, equipment maintenance, tool replacement and other support activities [2.]. SLAR processing rate was slow initially, and gradually improved as the crews became more experienced with the equipment and resolved some initial operational problems.
Ultimately the SLAR processing of Unit 1 was completed in less time than originally scheduled, and processed 25 percent more channels than originally planned. This has made it possible for Unit 1 fuel channels to continue to operate safely until the year 2000.

What distinguished the Mini-SLAR project from other similar tooling development jobs pursued at Bruce, such as West Shift, SLAR and Retube, was that the project management group was a site based team, highly accessible to and in regular contact with station personnel as well as the design organizations. The project team strongly influenced the design, but more importantly ensured that the design adapted to the needs of the site organization. The availability of existing retube tooling as a basis for some of the design and development gave the project a running start in the testing area, heading off many potential problems and guiding the direction of the project based on solid practical experience. The opportunity to assemble and play with simple and sometimes crude prototype equipment may not have been "doing it right the first time" but it led to some very interesting results.

- "Americans don't do it right the first time, they just don't. But when that second time comes around, not even the stars are out of reach."

"Doing it right the first time and zero defects may be expectations, but as messages to Americans they're more debilitating than motivating; they make Americans feel controlled and restricted."

from the book INCREDIBLY AMERICAN, RELEASING THE HEART OF QUALITY

CONCEPT DEVELOPMENT

Upon determining the need for a Delivery System, a "Skunk Works" Team of Engineers, Technical Staff and Trades was assembled. The team developed an approach of mounting a number of existing Retube Tools on a sliding plate. A fixed plate with a snout that attached to the End Fitting would remain in a permanent position with the sliding mechanism behind to align individual tools to an access port in the fixed plate. An 'O' Ring Seal would form the pressure boundary between boundary and the two plates. With little more than sketches, the two plates were fabricated and rudimentary cycle tests and pressure tests were undertaken.

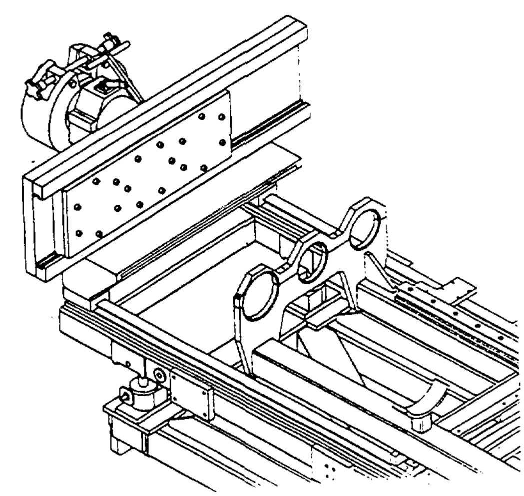

FIGURE 1
SLIDING PLATE
TEST ARRANGEMENT

Having passed these tests, the team now had a concept tool, a reference that was physical, against which improvements could be measured and could be used to validate the feasibility of the project. The team could now proceed with confidence in scoping out the project, seeking out proper approval for funding, then move on to designing and building a prototype.

PROJECT TEAM

The project team members had four distinct roles, to manage, design, build and implement. While one person was primarily responsible for each of these areas, the entire project team was collectively involved in key decisions and met frequently to review progress. The team consisted of staff with a varied background from fuel handling, operations, retubing, SLAR, fuel channel design, and mechanical maintenance.

Members of the project team brought widely varying individual view points and experience and as a result contributed to a broader internal review of the design which was constantly evaluated by the team in addition to more formal review by staff in the customer's organization. In addition, the team members had a wide and varied range of personal contacts. This provided a source of informal communication that was important to an understanding of the customer's need at all levels.

CUSTOMER CONTACT

The close working relationship between members of the project team and station staff resulted in ongoing formal and informal discussion of design requirements and design preferences. The articulation of design requirements required frequent meetings and discussion with station staff at every stage of the project.

Numerous design ideas resulted from discussion with station staff during design review, information presentations and training. More importantly, many of the staff who were eventually involved in the end use of the system, were also involved and had opportunities for input during the design and testing process. Frequently, the groups of staff visiting the training and mock up facility to witness prototype system operation, gained an impression that the design had already been completed and was not subject to change. This impression was discouraged. Suggestions for improvement were encouraged and acted upon whenever possible. The site organization was encouraged to develop a sense of design ownership and involvement.

USE OF EXISTING FACILITIES AND COMPONENTS

Site partnership in the design process was possible because of the existence of many tools and components that were used in the design and testing of the delivery system. Key site individuals with direct experience in developing tools of this type were involved in testing and experimentation with various equipment already available to the site. As the design progressed off site, it was possible for a parallel development effort to proceed at the station.

DESIGN FLEXIBILITY

It was necessary for the design to adapt to changing design requirements resulting from field development feedback and evolving customer requirements. Examples of this are the addition of shield plug and liner handling to the basic function of the system, the increase of design pressure from 5 to 8 MPa, shortening of the system to fit into airlock 2, as well as complete redesign of the support structure, the snout locking mechanism, and the sliding plate drive system to resolve performance problems. The use of a PLC control system to automate steps in the process allowed for the closure plug removal sequence to be modified and tested during the final weeks before the equipment was put into service. By implementing a modular design of hardware and software, it was possible for hardware and software development and testing to proceed in stages. The modular nature of the delivery system is illustrated in the following overview. This shows how the shield plug, closure plug and SLAR ram modules are independently mounted stand alone devices built into a modular support frame.

INFLUENCE OF PROTOTYPE TESTING

The use of a complete prototype system for testing and training was an invaluable aid to implementation as it allowed many potentially serious problems to be resolved ahead of time. Examples of this were the need for a Z drive brake on the shield plug removal tool, the need for rotary stops on the shield plug drive to prevent over torquing of the latch mechanism, and the identification of various design improvements to provide smoother, more reliable operation.

The control system was extensively proof tested on the prototype system to establish its performance characteristics. This proved to be vital to fine tuning the control software for smooth and consistent operation of the system. Although apparently straight forward, the protective stops and interlocks built into the controls for equipment protection created practical performance problems which were resolved through a process of testing and modification. A list of hardware and software deficiencies were gradually resolved through a process of realistic full scale simulation of the field operation of the equipment.

Training of 40 fuel handling operators and mechanics on the operation of the system was possible using the realistic rehearsal facilities used for prototype testing. These included a full scale mockup of the reactor vault, maintenance platform, and F/M bridge full length pressurized channels as well as dry cutaway channels for viewing the internal operation of the equipment, and a remote control console, complete with viewing and communication systems.

Integration testing using the actual SLAR inspection system was made possible by the parallel development of a transportable SLAR control trailer. The interface with the SLAR control system was designed to emulate the existing fuelling machine interface to provide the least possible redesign of the existing SLAR system.

Bruce A has been historically dependent on outside sources for design support and has not developed a strong design capability or culture. Site is more comfortable with practical results rather than a dependence on analysis and procedures of design. From the outset, the site team based many decisions on actual performance of field equipment, and on the intuition and judgement of field personnel rather than accepting the paradigms of a traditional design approach.

The sliding plate mechanism is a case in point. This is an unconventional design, not recommended by various designers, but supported by the site team as a simple solution to the problem of tool indexing. In spite of concerns raised by experts to the advisability of this approach, the site team went ahead to fabricate and demonstrate the design. In a more traditional conservative design culture this simple approach would have been rejected although in practice it has performed reliably with minimal development. This points out how a risk averse tendency in our traditional design approach can result in missed opportunities. When necessity is the mother of invention, some interesting and useful discoveries can be made.

Is this just luck? Is it equally likely that in a future design project, this design approach would fail to produce acceptable results? The answer to this question may be yes, but if we look at the track record of the "conventional" design approach we see that there are any number of unsuccessful designs that have failed to produce results in spite of the best available design talent being brought to bear.

We believe that in the field of nuclear station maintenance equipment design, the most demanding problems are not technical ones. The technology associated with what we need to do is not only readily available, but in most cases it has become relatively commonplace. The most important issue is design acceptance by field personnel and the field implementation organization. As designers, by focusing on more elegant technical solutions we risk alienating the people who have to use our products at the end of the day.

The Mini-SLAR project is an illustration of an alternative organizational approach intended to address field involvement and acceptance issues. There were both positive and negative aspects to the project, and some important lessons to be learned.

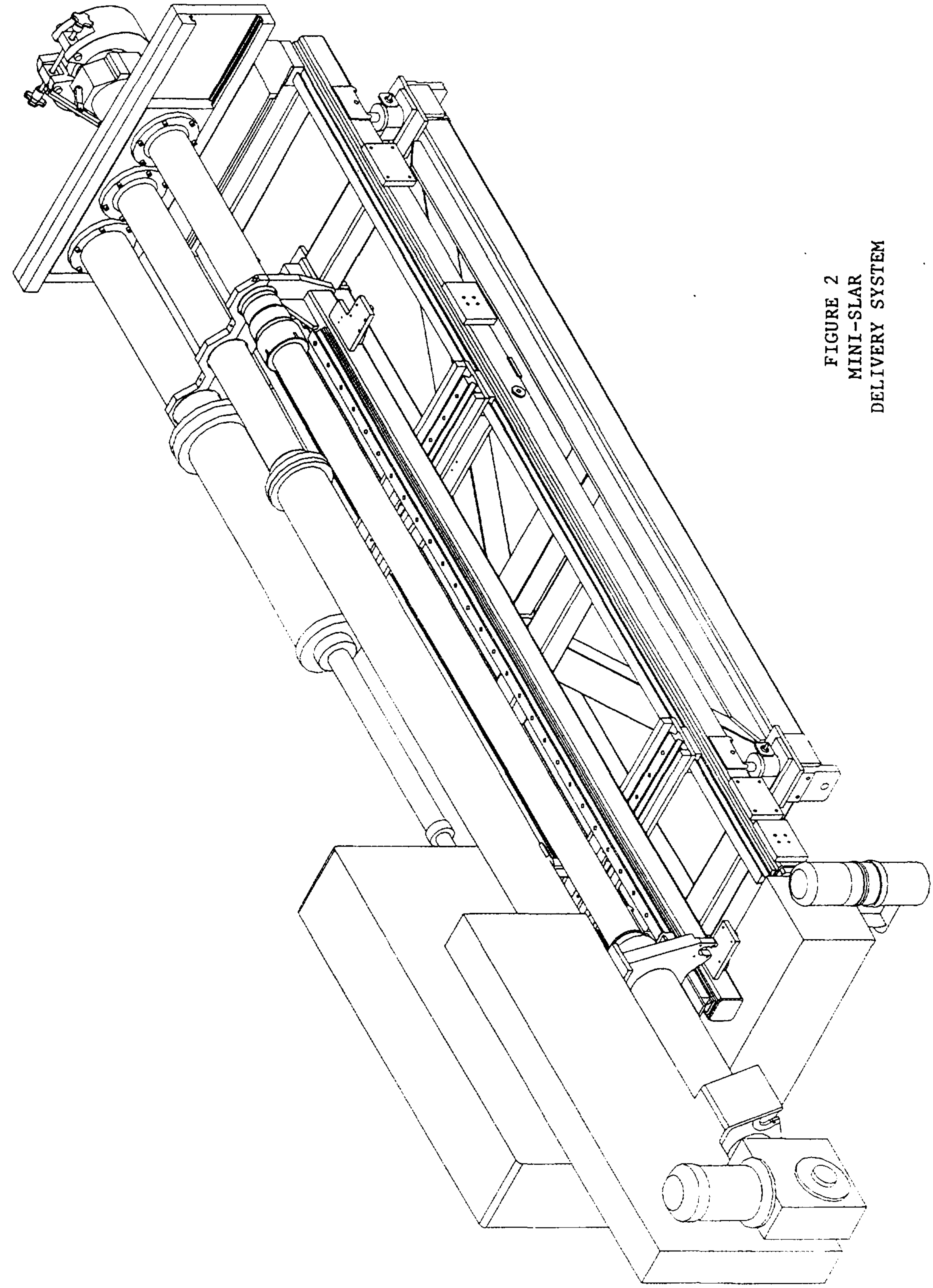

FIGURE 2
MINI-SLAR
DELIVERY SYSTEM

The project team was proud of the fact that in spite of a short implementation schedule, it was able to deliver a system capable of replacing the existing fuelling machine based SLAR delivery system, with a project justification, design build and test duration of approximately 14 months.

The business case for Mini-SLAR was based on a need to SLAR an estimated 110 fuel channels in Unit 1 by spring of 1995 or face the need to perform a series of CIGAR inspections, scrape samples and fuel channel replacement of 27 channels at risk. Based on a realistic estimation of the cost of channel inspections and replacements, the mini-SLAR project was expected to save Bruce A a significant capital cost associated with channel replacement, and 100 outage days based on then current multi fuel channel replacement techniques. The actual performance of the system was somewhat better than expected. A total of 109 channels were SLARed in 31 days of SLAR processing time, exceeding the target rate of 2 channels per day by a significant margin. All but one channel required spacer repositioning to extend its operating life [2]. An estimated 27 channel replacements were avoided, and work was completed with minimal impact on the critical path duration of a planned 103 day boiler chemical clean outage. Total direct and indirect savings to Ontario Hydro are considerable and Hydro has gained some very valuable experience.

Like any successful job there were many hurdles to overcome, the most demanding one was project schedule. Many activities had to be performed in parallel in order to meet the required completion date. The resulting process operated in the reverse of the usual design process. Fabrication and testing preceded the formal design activity, and the GE Canada and NTS SLAR design teams had to frequently adjust their priorities to respond to the practical requirements of the fabrication and testing schedule. Equipment was assembled and tested in an emerging prototype form and the design organization, while trying to analyze and formally document the design was at the same time responding to frequent requests for changes from the field organization. The flexibility demonstrated by our key designer, GE Canada, while no doubt frustrating for them, was key to ensuring the final product was accepted in the plant. In spite of the effort made to maintain frequent contact with the design group, it was apparent that the design process could have been more efficient if the designers had been working together with the fabrication and testing team at the station. The circumstances of this project allowed the design and field organizations to be on a more equal basis than most design build projects. From the beginning, the field organization had a rough prototype to work with using various retube equipment on hand. Whenever possible existing components were used to reduce the design and test time. Significant upgrades of the equipment were required but many of the basic mechanical concepts were available for testing before the design process started. This allowed the field team to begin hands on experimentation and to provide early feedback to the designers to correct various deficiencies in the equipment and to refine the understanding of the operating characteristics of the system. Valuable design input was provided by the field organization based on the experience with the mechanical prototype system that contributed to a more useable piece of equipment when it went into service. The control system, and the SLAR inspection system were dovetailed into the design later in the project schedule, and required an intense dedicated effort by site staff as well as by NTS SLAR site team and GE Canada designers. Because of the modular nature of the design it was possible to marry the control systems for the delivery system and the SLAR inspection system with a minimum of testing problems. Much of the credit for this accomplishment is due to the effective communication between GE Canada and NTS SLAR designers who developed a detailed interface specification at an early stage in the design.

SITE FABRICATION AND TESTING

Fabrication and testing of the prototype delivery system at site resulted in a much greater site awareness of the project although not everyone was comfortable with the way the work was allocated. Half way through the fabrication and testing process, the team had to negotiate a revised work assignment to reflect the emerging trend toward greater operations staff participation in projects of this type. This was disruptive to progress, but in the end the staff who were involved in the development and testing were able to be closely involved in the field support of the equipment and were largely responsible for finding and efficiently solving problems during implementation. The construction and operations trades staff involved in this job worked closely and effectively together exhibiting a high standard of professionalism and dedication.

At the time the Mini-SLAR system was built the Bruce site organization was not authorized to fabricate this type of nuclear class 1 equipment. However, the MCCR granted a concession for the assembly and testing of the pressure boundary, and the fabrication of the NF support structure for this project. In future, a site fabrication certification will make the assembly of this kind of equipment more practical. The advantages of site fabrication and assembly were the responsiveness to schedule requirements, direct supervision and high standard of workmanship. The fabrication of the equipment on site contributed to a sense of design ownership and a highly effective review of manufacturability of the design. The hands on involvement of field personnel led to a detailed understanding of the maintenance requirements for the equipment.

INDEPENDENT OPERATION

The use of the station fuel handling systems for reactor maintenance and inspection has been a common practice to the extent that the fuel handling system availability for fuelling is becoming restricted. The original strategy considered for Unit 1 SLAR was based on extensive use of the fuel handling system for shield plug and liner sleeve handling. This was reviewed with station fuel handling staff at the outset of the project and it became immediately apparent that a design strategy with the least involvement of station fuel handling systems was a basic design objective. Ultimately the mini SLAR system was able to replace the fuelling machines for all aspects of the project except fuel removal and replacement. Defuelling was completed as a batch process using flow assisted defuelling methods in a period of 17 days following shutdown. Fuel replacement was accomplished by transferring fuel from Unit 2 during the Unit 2 layup defuelling at a substantial fuel cost saving.

Independence from station systems was assured by providing independent power supplies, and the capability of operating on channel independent of the state of the heat transport system. The system was designed to withstand fuel channel pressures up to 8.3 MPa and was capable of operation of up to 1.38 MPa. This made it possible to perform SLAR operations during all phases of boiler chemical cleaning. Defuelling at the start of the outage also made the vault accessible throughout the balance of the outage up to the start of refuelling. This provided unrestricted access for other outage work to proceed in parallel.

FUTURE PROJECTS

The mini SLAR system has numerous potential future uses. In the immediate future it is being adapted for mounting in the fuelling machine carriage with a remote homing and locking capability, for use in draining Unit 2 during lay up. In addition to improving drawing efficiency this equipment is also useful in providing pressure relief during fuel channel isolation. This alleviates the need for the F/M during channel isolation. A second mini SLAR system will be built and used to perform SLAR on Unit 4 in 1997, using two SLAR systems in parallel. As an upgrade for this project, the Unit 4 system will be designed to defuel the Unit 4 channels by pushing fuel into a fuelling machine at the opposite end of the channel. This method of defuelling allows for economical fuel shuffling, avoiding the disposal of partially utilized fuel. Defuelling during a shutdown with this technique is much more efficient than the fuel grappling alternative. It avoids the need to operate the heat transport pumps to permit flow assisted defuelling, and can be performed from either the upstream or the downstream end of a channel.

The use of a mini-SLAR type device for general fuel channel maintenance and inspection has many advantages over current practice. The equipment can be picked up by the fuelling machine bridge, and requires a very little vault time to install. Once in place, the equipment can deliver a variety of special purpose tools to aid in inspection and maintenance activities while placing few demands on the existing fuel handling system. Since the delivery system is modular in design, it can be easily reconfigured to accommodate special purpose devices in place of or in addition to the existing modules. Examples of some potential future applications are the delivery of tools for channel inspection and gauging, isolation, closure seal repairs, pressure tube wet scrape, fret blending and replication, and visual inspection. In the longer term similar devices may be used to assist in fuel channel replacement.

CONCLUSION

Site based project teams are assuming an important role in providing specialized design and equipment needs for OHN. The mini-SLAR project demonstrated how a site project management team can be more responsive to the specific needs of an individual project, and provide greater levels of site involvement in the design while maintaining a high standard of quality. Emphasis on using available resources to speed the development cycle, keeping the design simple and flexible and encouraging very broad participation by the user organization were key elements of the success of this project. Future projects should address the need for qualified site fabrication capability, and a closer working relationship between the design organization and the fabrication and testing group. These factors would improve the efficiency of the design feedback process and ensure an effective site fabrication and testing process

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