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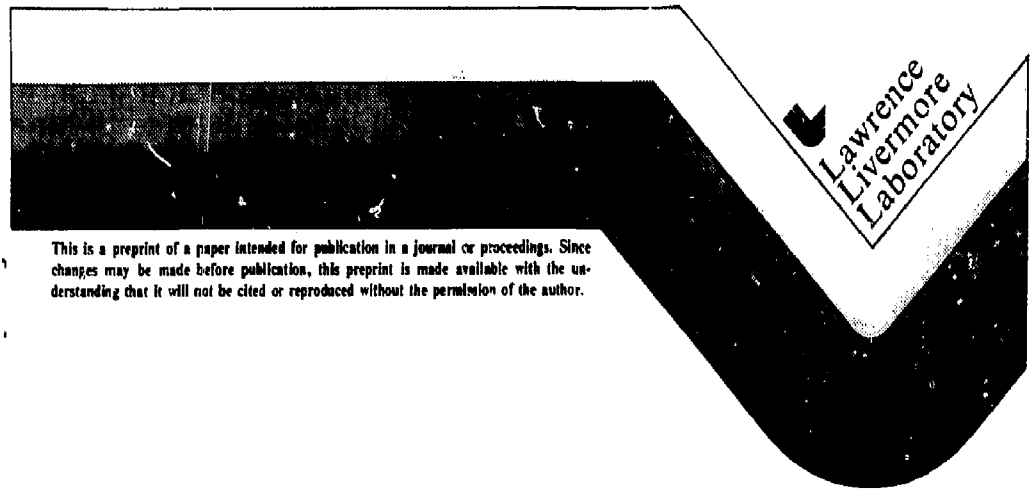

MANAGEMENT OF SHIVA OPTICS*

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Abstract

In the design and procurement of a high power laser system such as the Shiva Fusion Laser at LLNL, the optical components are the single most important aspect for optimum laser performance. The cost, schedule and quality of the optics are the driving parameters for the entire program and many factors are involved in controlling, monitoring and evaluating these parameters. These factors include 1) the procurement cycle, 2) knowledge of the vendors, 3) realistic specifications, 4) understanding of the fabrication process, and 5) the quality control and test requirements. Guidelines and examples of the methods used in the procurement and qualification of the optics in Shiva will be presented.

Introduction

The Shiva Laser system involves integration of numerous technical disciplines. This paper will look at one area - Optics, and present some guidelines and methods that were used on Shiva to manage, control, and monitor the complete optical procurement cycle from design to finished product.

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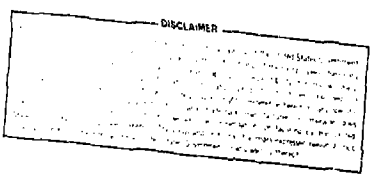
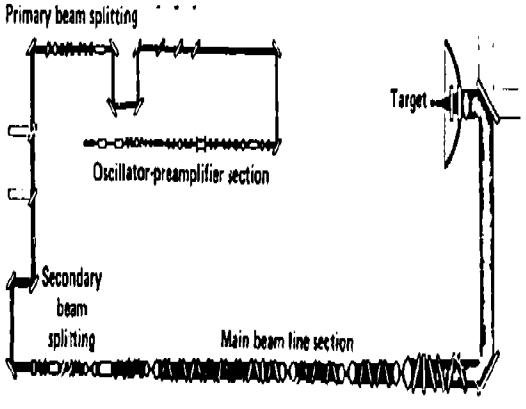


TABLE 1

SHIVA TOLERANCE SPECIFICATIONS
AND BEAM LINE COMPONENTS

Type of component	Per arm	Total	Typical achieved or estimated peak to valley wavefront quality per assy at 1.064 μm
Beam splitter	1	20	λ / 19
Path adjuster	2	40	λ / 14
Spatial filter/ relay lens	12	240	λ / 12
Rod	2	40	λ / 10
Polarizer	14	280	λ / 9
Faraday rotator	2	40	λ / 9
KD*P	2	40	λ / 7
Window	4	80	λ / 7
Laser disk	25	500	λ / 10
Turn mirror	2	40	λ / 10
Focus lense	1	20	λ / 7
Window	1	20	λ / 7
Debris shield	1	20	λ / 7
	69	1380	


Primary beam splitting
Target
Oscillator-preamplifier section
Secondary
beam
splitting
Main beam line section

The Shiva laser

Shiva was designed and built at LLNL as part of the High Energy Laser Facility for inertial confinement fusion experiments. It is a neodymium doped silicate glass system operating at 1.06 μm with pulse lengths from .1 to 3 nanoseconds. Shiva has twenty arms each capable of producing in excess of 1 kilo joule of energy in less than 1 nanosecond. All 20 arms were fired in November 1977 yielding 10.2 kJ in .9 nanoseconds. The laser has operated continuously since 1977 averaging 20 - 30 shots per month on a variety of target and physics experiments.

The system is in two sections: the main laser bay containing the laser amplifiers, spatial filters, rotators and polarizers, and the target bay containing the turn mirrors, focusing optics and diagnostic optics. The optical train from oscillator to target is approximately 132 meters in length and contains almost 4 meters of solid glass.

The schematic of the optical train from oscillator to target is illustrated in Figure 1. In all, the Shiva laser has about 2500 individual optical components not including 25% spares. About 1500 of these components are for propagation of the laser beam and 1000 are for diagnostic, alignment and control. Apertures range from 25 mm diameter to 200 mm diameter for the final amplification and focusing optics. The majority of the optical surfaces are flat but a significant number of

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components are f/2.8 to f/11 lenses which are aspherized for removal of spherical aberation. The lenses are used for spatial filtering, diagnostics and final focusing.

A summary of the quantity, and tolerance specifications of the optics is shown in the Table I. Cost of the optics used on Shiva were approximately $6 million. This included material, fabrication and coating.

The optics on Shiva were procured within budget, schedule and specification. How this was achieved, what management tools were used and some guidelines will be reviewed.

Managing the Shiva optics

In Shiva like any other large state of the art procurement, three basic elements must be understood, monitored and controlled. These are:

.Schedule

. Costs

. Quality

Each of these elements effect the other and how one handles the initial preparation of schedules, understands the cost elements in a fabrication cycle, and prepares realistic specifications that can be manufactured within the cost and schedule guidelines, will determine the success or failure of the program.

Schedule

Initial schedules are prepared early in the program planning stages.

As details are clarified, and the types of components are specified the schedule can be refined and milestones established. Factors effecting schedule that require control are:

. Procurement cycle
  Bid process
  Bid review and evaluation
. Prototype development
. Manufacturing cycle
. Monitoring, follow-up

Procurement cycle

At LLNL like most industries the procurement cycle is a long and tedious one. RFQ's must be processed, reviewed, vendors surveyed, technical exchange and interaction with vendors completed and so on. This process takes time and must be factored into detailed schedules.

Prototype development

Often state of the art programs require a prototype development to prove processes and fabrication techniques. These are often costly in schedule time and dollars but may be the difference between success and failure of a difficult procurement. Examples of this will be given later.

Manufacturing cycle

The knowledge of the entire manufacturing process is essential to

intelligent review of the vendors involved, the bids, schedules and the test and qualification plan. Further, the bidders must be given adequate time to provide intelligent quotes that reflect all the technical parameters.

Monitoring and follow-up

Once the fabrication cycle has started, it is imperative to maintain contact with vendors to review and clarify schedules and technical problems, monitor progress, and provide backup and technical assistance.

At LLNL a technical liaison has proved to be invaluable. This person interfaces with the Livermore's purchasing department, clarifying specifications and other procurement requirements. At the same time this person is the technical contact between LLNL and the vendor. In this way this technical liaison can monitor schedules and costs and be able to anticipate potential problems and reduce their effect on delivery.

Costs

Many factors effecting cost must be evaluated and controlled. Among them are:

- Specifications
- Materials
- Vendor understanding of technical requirements
- Adequate fabrication and test facilities
- Realistic delivery

Specifications

Specifications must be clear, logical, consistent, and realistic. If the procurement is state of the art or pushes the capability of vendors under consideration it may require a development program. This will obviously add to the cost but the end result may be a less costly and trouble free procurement cycle. In one instance on Shiva, several prototype contracts were placed with optical coating companies to develop methods and processes for coating laser rods, polarizers, and turn mirrors. In another case, a prototype development contract was placed on large polarizers to evaluate fabrication techniques and establish optimum aspect ratios for the specified optical performance. The end result in these cases were successful procurements, on schedule, and budget, that left no surprises for the vendors or LLNL.

Materials

On procurements involving large quantities and high quality glass LLNL decided early on that costs could be controlled better if LLNL bought the glass and provided it to the fabrication vendors.

The reasons for this approach were numerous and bear consideration in all large procurements. 1) The quantity of glass on Shiva allowed us to get high quality, better schedules, and lower costs by buying in large volume. 2) Letting individual vendors buy for each procurement would have increased costs and stretched schedules since glass manufactures would not see the magnitude of the requirement at an early stage and be prepared for it. 3) The availabilty of glass at LLNL allowed control

of distribution to best fit our schedule requirements. 4) Vendors were assured of obtaining the best quality material. Overall it proved to be an effective and cost saving approach.

Technical understanding

A thorough understanding of the technical requirements and specifications by the vendors is essential to keeping costs under control. This understanding starts early in the procurement cycle and includes preliminary evaluation of requirements and budgetary pricing from vendors. This gives the vendor an opportunity to question specifications, schedules, test procedures, etc. without the constraints of a bid closing date and to evaluate their needs and requirement for a cost effective bid.

Adequate fabrication and test facilities

It is essential that vendors have adequate fabrication and test facilities, or at least the foundation to build on. In evaluation of Shiva vendors, it was found that flat work vendors were not always the best finishes of lenses and vice-versa. Knowing the degree of capability allowed optimization of fabrication procurements by directing bids to appropriate companies. For example, with optical coatings, the stringent requirements for high damage levels, and coating uniformity, dictated that we utilize coating houses that were well equipped. In most cases coatings were handled as separate procurements. Costs were better controlled because fab vendors did not have to provide contingencies in their bids for poor coating runs and could concentrate on the role they

did best. First-hand knowledge of a vendors capability made these decisions obvious in most cases.

Realistic delivery

Last, is to provide realistic and achievable delivery requirements. Undue pressure on vendors can result in costly mistakes and short cuts that effect all aspects of schedule, cost and performance.

Quality

Factors that should be considered and evaluated are:

- Optical and material specifications
- Vendor assessment
- Manufacturing processes
- Quality control

Optical and material specifications

On Shiva and all lasers built at LLNL, once the optical layout and the operating parameters are established for the entire laser, each component is thoroughly evaluated for its function, performance and contribution to the overall system. The components are designed with a goal of meeting the performance requirement without over specifying the optical parameters.

As mentioned previously the specifications must be realistic, with legible drawings, and consistent in dimensions and tolerances.

Vendor assessment

A cardinal rule of any optical procurement is "Know your vendors". Leaving the bidders list to the purchasing department can lead to difficulty except in very simple procurements. Prior and during any procurement process vendors must be evaluated and assessed for capabilities in the following areas:

- Technical and manufacturing capability
- Test facilities
- Management
  - Management stability
  - Financial stability
  - Prior performance
- Communication

Technical and Manufacturing Capability

This evaluation can only be done by visiting the various vendors and personally assessing the capability. On Shiva each and every vendor was visited and evaluated by qualified optical people. Knowledge and experience in the optical industry helps immeasurably in assessing these requirements.

The rapport established between LLNL and vendors was an important factor. During Shiva great emphasis was placed on establishing direct contact with the technical, management and sales staff and developing a good working relationship. This allowed good technical exchange,

openness in the event of problems either technical, and/or schedule, and permitted ready follow up throughout the procurement cycle.

Test Facilities

As mentioned earlier, the manufacturing and test facilities must be adequate to handle the job or able to be improved to do the task. In many instances on Shiva, fabrication, test, and inspection techniques were developed at LLNL and transferred to the vendors, and in some cases new equipment requirements were incorporated in the contract.

Management

The management of any company and its financial outlook must be reviewed and assessed. Prior performance and stability are factors to be evaluated. This is not to say that new companies cannot be viable vendors but the management, technical staff, and financial background must be carefully reviewed. A company that goes out of business or has serious financial difficulty can be very costly to any procurement.

Communication

The vendors are the life blood of any program and constant communication is essential to stay on top of any situation. Progress reports were required in many instances on Shiva and proved to be a valuable monitoring tool. Patience understanding and a degree of flexibility are essential ingredients to any successful procurement.

Quality control

Finally, we will look at quality control, the heart of any successful procurement. Factors to be considered are:

- Provision for test and inspection reports
- Qualification of test facilities and equipment
- Technical assistance and source inspections
- Source inspections
- Ability to test anything you buy

Inspection Reports

Shiva vendors were made aware of the requirements for detailed, accurate inspection reports and that they be available at the time of inspection. In most instances, LLNL personnel assisted in layout of the inspection procedures and reporting format.

Qualification of Test Facilities

Vendors test facilities were usually qualified by retesting specific finished components at LLNL early in the procurement cycle or evaluating some specific component at both facilities. In evaluating test capability vendors were encouraged to provide permanent and stable test set-ups and facilities.

Technical Assistance and Source Inspections

Technical assistance by LLNL staff was provided to vendors to help upgrade facilities, and qualify tests procedures.

Source inspections were required on almost all procurements. With the volume of components, this lab could not have tested each one after receival. Source inspection provided the mechanism to satisfy the requirement of meeting specifications, and maintaining a continual vigal on vendors. Optics were usually inspected 100% on the first and second visits, and as confidence grew in the vendors capability the percentage of items inspected was reduced. If vendors continued to show poor performance the inspection level remained high. Marginal or questionable test results were re-evaluated at LLNL and disposition made accordingly.

Ability To Test What You Buy

The rule at LLNL is that we should be able to test anything we purchase in the optics area. This is an expensive approach but test equipment such as interferometers, spectrometers, and photometers, are constantly required for final assembly operations, so LLNL is well equipped in this regard. History on Shiva and other programs proves that this capability reduced rejects and tended to keep vendors on their toes regarding the quality of components and certification of data.

Conclusion

The guidelines presented here are intended to help in the organization and management of a major optical procurement and allow

control and optimization of schedule, cost and quality. Due to constraints of money, facilities and/or manpower, not all of these guidelines can be implemented by everyone, but awareness of these factors and incorporating as much as possible into large procurements will be helpful.

At Livermore these same methods are already being applied to our newest laser program Nova which will have 10x the output power of Shiva. This laser will be operational in 1983.