UCRL-JC-130309
PREPRINT

Precision Assembly and Alignment of Large Optic Modules for the National Ignition Facility

P. Hurst
E. Grasz

This paper was prepared for and presented at the
2nd International Conference on Engineering Design and Automation
Maui, Hawaii
August 9-12, 1998

May 12, 1998

Lawrence Livermore National Laboratory

PRECISION ASSEMBLY AND ALIGNMENT OF LARGE OPTIC MODULES FOR THE NATIONAL IGNITION FACILITY

P. Hurst and E. Grasz (with S. Bailey, M. Simmons and H. Wong)
Lawrence Livermore National Laboratory, P.O. Box 808, L-447, Livermore, CA, 94551
(510) 422-0246—Fax (510) 423-7390—hurst2@llnl.gov
(510) 423-6556—Fax (510) 423-7390—grasz1@llnl.gov

ABSTRACT

The National Ignition Facility (NIF), currently under design and construction at Lawrence Livermore National Laboratory (LLNL), will be the world's biggest laser. The optics for the multipass, 192-beam, high-power, neodymium-glass laser will be assembled and aligned in the NIF Optics Assembly Building (OAB), adjacent to the huge Laser and Target Area Building (LTAB), where they will be installed. To accommodate the aggressive schedule for initial installation and activation, rapid assembly and alignment of large aperture optics into line replaceable units (LRUs) will occur through the use of automated handling, semi-autonomous operations, and strict protocols. The OAB will have to maintain rigorous cleanliness levels, achieve both commonality and versatility to handle the various optic types, and allow for just-in-time processing and delivery of the optics into the LTAB without undoing their strict cleanliness and precise alignment.

This paper describes the Project's design philosophy of modularity and hardware commonality and presents the many design challenges encountered. It also describes how, by using a mixture of commercially available and newly designed equipment, we have developed unique systems for assembly and alignment, inspection and verification, and LRU loading and transfer.

1. Introduction

The National Ignition Facility (NIF) is a multiapplication, stadium-size laser currently under construction at Lawrence Livermore National Laboratory (LLNL) for use primarily in the U.S. Department of Energy's Stockpile Stewardship Program. The NIF will be complete in 2003 and will use about 8,000 large optics of 26 different types (reflecting mirrors, neodymium-doped laser glass, etc.) to focus up to 192 laser beams on a dime-size target. The path of the laser will be completely contained within the huge Laser and Target Area Building (LTAB), but critical to the NIF's success will be the adjacent Optics Assembly Building (OAB).

The OAB is a separate facility whose role will be the assembly and alignment of the large NIF optics.[1] Should one optic suffer damage, it will need to be removed and replaced quickly, safely, and cost effectively. Line replaceable units (LRUs) are the optics module packages used for quick assembly, transportation, installation, and removal of the optics components and usually hold two or four separate optics.

The OAB will need to maintain rigorous cleanliness levels, achieve both the commonality and versatility to handle the various LRUs, and deliver those LRUs into the LTAB while preserving their strict cleanliness and precise alignment. This will be the first time that such large optics, some weighing up to 3,000 lb, will be assembled in a Class 100 clean-room environment. In addition, the Project's severe time and cost requirements are placing great demands on the precision alignment and transport of these optics.

2. OAB Facility Description

The OAB and LTAB are collocated to optimize the OAB's efficiency. As Figure 1 shows, the 25,000-ft^2 OAB comprises a loading dock, mechanical and optic transfer areas, a mechanical parts cleaning room, and an assembly and alignment area to manufacture, align, and test the LRUs. Both mechanical and optic components arrive at the OAB loading dock and undergo a receiving inspection in an enclosed area. After this inspection, they go into separate Class 10,000 unpackaging and preparation rooms; these transfer areas contain component handling mechanisms, cleaning stations, and a staging area.

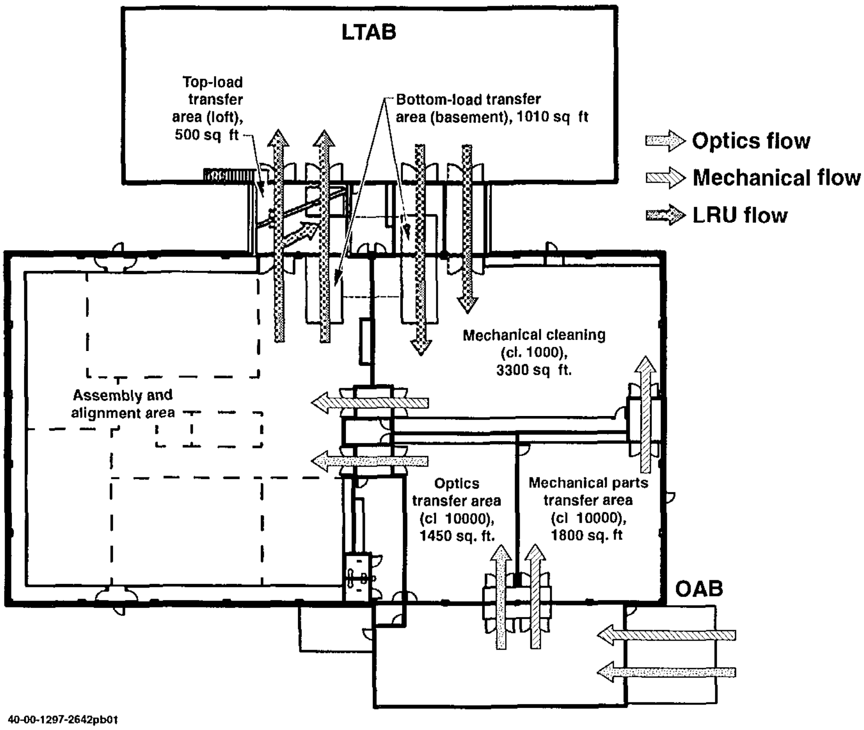

Figure 1. The NIF Optics Assembly Building is designed for assembly and precision alignment of all NIF large optics before delivering them to the Laser and Target Area Building.

All LRU mechanical parts are required to be cleaned to MIL-STD-1246C Level 50A standard or better prior to assembly. The precleaning systems consist of a self-contained, high-pressure spray with surfactant, if required. The precision cleaning system will use an ultrasonic bath with surfactant, rinse bath, high-pressure spray, and drying station. The optics arriving at the OAB have previously been processed and cleaned by the manufacturer.

From the mechanical and optics transfer and cleaning areas, the components are distributed to various locations within the assembly and alignment clean room. This Class 100 clean room has five assembly areas, each equipped with high-payload handling equipment (described in Section 3). In these areas, the separate components are assembled into LRUs for use in the LTAB.

3. Assembly and Alignment

The tasks to be performed in the assembly and alignment area of the OAB are unprecedented. The Class 100 clean assembly of large optical components is complicated by the fact that "off-the-shelf" equipment does not exist. Most modern clean rooms handle components and assemblies that weigh no more than 20 lb; the components in the OAB weigh from 150 to 3,000 lb, some the size and shape of a phone booth. Figure 2 shows examples of the various weights and configurations of the LRUs. From a protocol perspective, we will achieve the cleanliness level by limiting the exposure of individual components and the LRUs to particle generators and by providing delicate handling and maneuvering. To meet these challenges, we are teaming with industry and leveraging designs that cleanly handle these large assemblies.

Spatial filter alignment tower, 3,000 lb (top loaded)	Periscope, 1,500 lb (bottom loaded)	Spatial filter lens (bottom loaded)	Laser mirror structure (switchyard)

Figure 2. Typical LRUs to be assembled, aligned, and transferred within the OAB.

3.1 Rotating assembly table

One key piece of equipment, known as a rotating assembly table, is a three-degree-of-freedom mechanism with one translational and two rotational axes. It is used to hold the LRU frames during their assembly. Prototype and test efforts are necessary to verify that the mechanisms are Class 100 clean room compatible and to assure that their load capacities are not exceeded. Figure 3 shows a rotating assembly table (left photo) as part of the prototype assembly station.

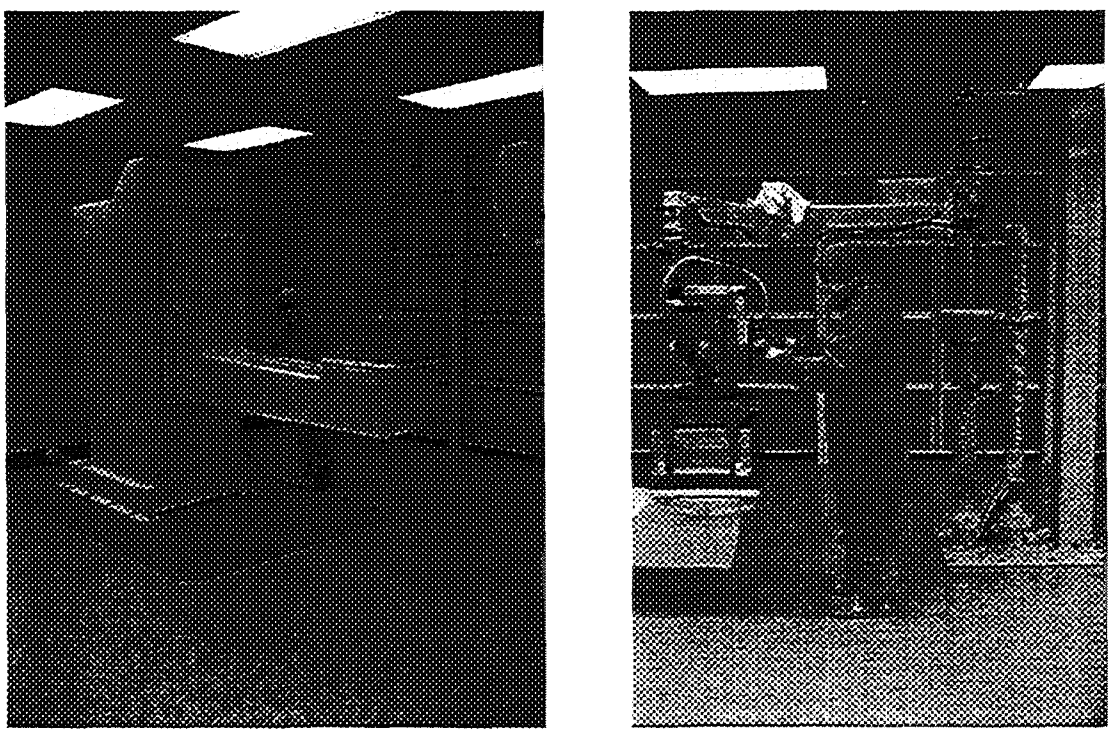

Figure 3. Prototype OAB assembly station, including rotating assembly table (left) and new optic insertion device (NOID) (right).

3.2 Optic insertion mechanism

Another key piece of assembly hardware is the New Optic Insertion Device (NOID), an electromechanical system allowing the operator to lift significant loads (up to 800 lb). Each assembly and alignment area will have a NOID to install large optic and mechanical components into LRU frames. Where possible, the NOID's manipulators are common end attachments (end effectors) that directly interface and handle the components. Due to the sensitivity of the optics and some mechanical components, we are designing and developing custom end effectors. A prototyping effort will both validate the mechanical operation and robustness of the NOID and verify its cleanliness levels. Figure 3 shows the NOID (right photo) as part of the prototype assembly station.

3.3 OAB transport vehicle

Transporting assembled LRUs within the OAB requires a common transport mechanism that functions with all of the different LRU sizes and weights. This will be accomplished with the OAB's LRU. This transporter moves fully assembled LRUs to the next processing station within the OAB and to the transfer area for loading into their canisters. With the maximum LRU loads of 3,000 lb and lift height exceeding eight ft, the transporter must be able to both hold the load and distribute it across the OAB's raised floor. Prototyping will determine the proper handling methods and techniques for the completed LRU and will test the lifting fixtures for function and cleanliness.

4. LRU Loading and Transfer

The cleanliness of the LRUs must be maintained during transport. With so many different LRU designs, we have had to design three different clean mechanisms for transferring the LRUs out of the OAB to their proper place in the LTAB: direct airlock transfer to a forklift, top-loading into a clean canister, and bottom-loading into a clean canister. The two canister mechanisms include a special transfer vehicle, as well as a cover-removal mechanism that serves as a barrier between the OAB and the dirty basement and loft. The loft and basement allow the vehicles to perform top- and bottom-loading (from either above or below the OAB's main floor, respectively). When an LRU needs to be replaced or repaired, this process will be reversed. We have designed the transfer mechanism so that the interface between the OAB and the transfer vehicle is identical (or nearly identical) to the interface between the transfer vehicle and the LTAB.

5. Conclusion

The NIF facility will use about 8,000 large optics to carry a high-power laser through a stadium-size building and will do so on a very tight schedule and budget. The collocated OAB will be used to assemble and align, in a clean-room environment, the NIF's large optics, the biggest ever assembled in such an environment. By using a mixture of off-the-shelf and newly designed equipment and by working with industry, we have developed innovative handling systems to perform the clean assembly and precise alignment required for the full variety of optics, as well as for postassembly inspection. We have also developed a set of loading mechanisms that get the clean optics safely to their places in the main NIF building.

6. Acknowledgments

The OAB design, the material handling designs, and the results noted in this paper have been prepared with the support of the Optical LRU Assembly and Alignment Design Group within the NIF Operations Engineering Section at LLNL. This dedicated team includes Leslie Allison, Rudy Carpenter, Brett Hall, Alan Havassy, Ray Iaea, Sudair Jain, Bob Koczian, Kent Lueng, Mike McDaniel, Roy Merrill, Ken Montgomery, Sandra Owens, Mark Perez, Jo Sander, Dennis Silva, Kay Sivori, Ed Schmitt, Ladonna Willis, and Marty Yeoman.

This work is performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

7. References

The following documents are internal to Lawrence Livermore National Laboratory, but are accessible by contacting the author (hurst2@llnl.gov).

1. *Title II Planning Document for NIF Operations Engineering, WBS 1 9*, NIF-0002560 (June 1997).

Technical Information Department • Lawrence Livermore National Laboratory
University of California • Livermore, California 94551