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GETTING ONE-TON, PHONE-BOOTH-SIZED OPTIC MODULES INTO THE WORLD'S LARGEST LASER

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ABSTRACT

The National Ignition Facility (NIF), currently under design and construction at Lawrence Livermore National Laboratory (LLNL), will be the world's largest laser when complete. The NIF will use about 8,000 large optics of 41 different types to focus up to 192 laser beams on a dime-size target. Each laser component will be packaged into a line-replaceable unit (LRU) made up of a mechanical housing, laser optics (lenses and mirrors), utilities, actuators, and kinematic mounts. Given the constraints of the operating environment, such as high cleanliness and limited space, the tasks associated with LRU interchange require unique and flexible hardware system designs. This paper introduces the Optical Transport and Material Handling designs that will be used to deliver the LRUs in the NIF Laser Bays. These systems use a novel and versatile automated guided vehicle (AGV) for transport. The transport and handling hardware is being designed to allow autonomous, semiautonomous, and manual operations.

KEYWORDS

Line-replaceable unit; optics modules; automated guided vehicle; transport and handling; delivery system

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) is currently planning and building the National Ignition Facility (NIF). The NIF is an advanced, high-power laser facility for inertial confinement fusion (ICF) research and applications.[1] This facility is expected to reach fusion ignition and to make significant contributions to DOE's Defense Programs Stockpile Stewardship mission. The NIF will have two primary buildings: the Optics Assembly Building (OAB) and the Laser and Target Area Building (LTAB). The OAB will provide the facilities necessary for assembling and aligning the components that make up the optical path of the laser. The LTAB, the size of a stadium. will house the laser system and the spherical target chamber.

The design philosophy for the NIF is to modularize the laser optical components. Each laser component will be packaged into a line-replaceable unit (LRU), which will allow efficient, safe, and cost-effective assembly, transportation, installation, and removal. An LRU will typically comprise a mechanical housing, laser optics (lenses and mirrors), utilities, actuators, and kinematic mounts. Most LRUs will be assembled and aligned in the OAB; LRU subcomponents will be processed as they are needed. The NIF project's Optical Transport and Material Handling team is developing the systems that deliver the LRUs to the beamline. The delivery systems provide the methodology and equipment necessary for transporting the optical LRU assemblies between their installed positions and maintenance/assembly facilities, as well as installing and removing them.

2.0 TECHNICAL APPROACH

Five types of delivery systems are being developed for the NIF project: laser bay bottom loading (Figure 1), laser bay top loading (Figure 2), laser bay side loading (Figure 3), switchyard loading, and target area loading. This paper focuses on the three delivery systems for the laser bays, which are designed to maintain the optical LRU assemblies' specified shock, vibration, cleanliness, and environmental requirements during all operations.

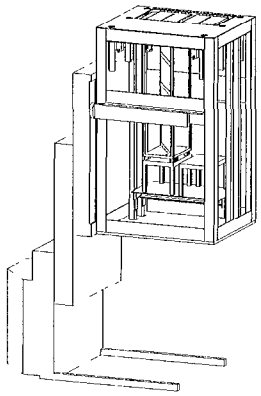

Figure 1. Bottom loading delivery system.

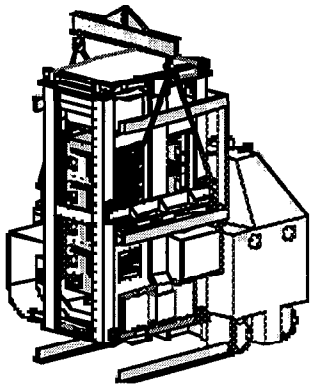

Figure 2. Top loading delivery system.

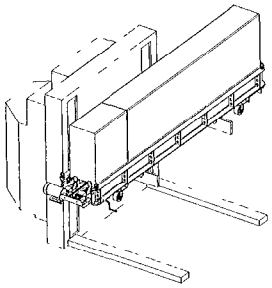

Figure 3. Side loading delivery system.

The delivery systems are designed to transport and install 41 different types of optical LRUs, some as large as phone booths and weighing up to a ton. There are two classes of optical LRUs: "bare" and "enclosed." Bare LRUs have exposed glass and must be delivered in an enclosure or canister to preserve the cleanliness and environment of the optics. Enclosed LRUs are housed inside an enclosure or box; these optics are already protected. The LRUs have various locations throughout the laser bays, switchyards, and target area (see Figure 4).

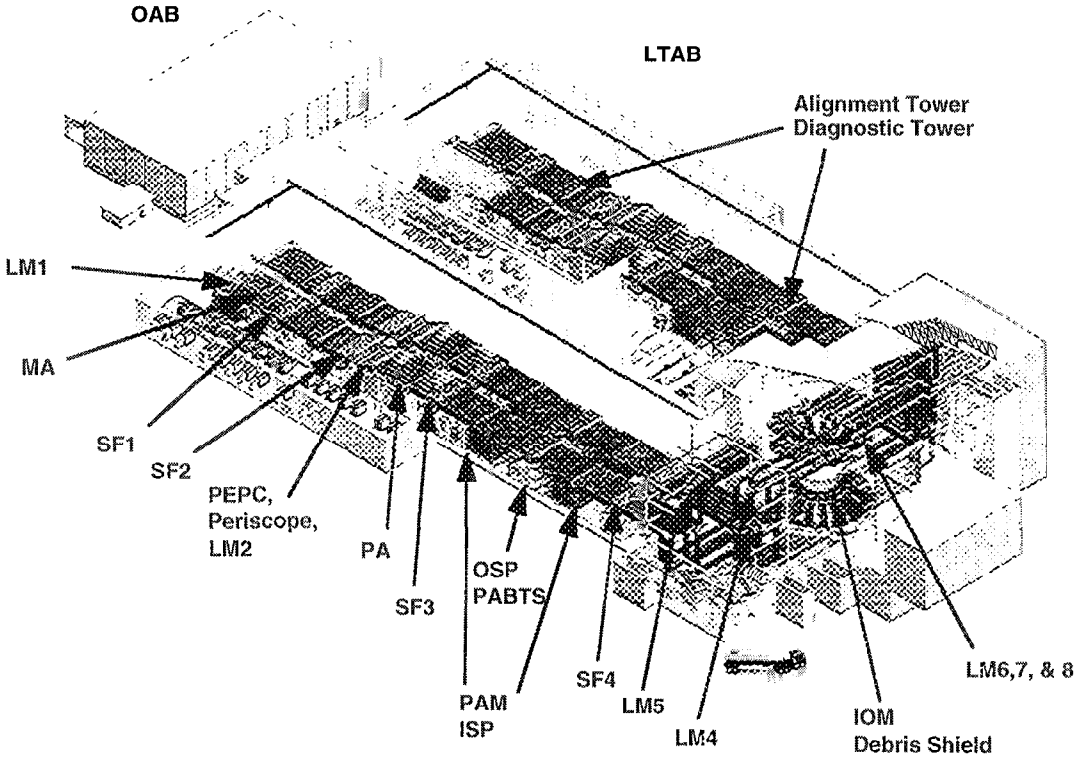

Figure 4. The LRUs are assembled and aligned in the OAB and then installed throughout the LTAB.

The major design requirements specified for each of the delivery systems include the following:

- Preserving the cleanliness (Mil Std 1246 level 50) of the LRU optics.
- Preserving the LRU's functionality and alignment.
- Maximizing commonality for the delivery systems for the LRUs.

The functions of the delivery systems are specified in a three-step process: get it *there*, get it *close*, and get it *in*.

Several measures are being implemented to ensure cleanliness: cleanroom-compatible components for the ball-screws and other linear actuators; materials and greases approved by the NIF Contamination Control Group; and cleanliness-conscious design concepts. The bottom- and top-loading delivery systems will also incorporate a ULPA airflow system inside the canisters, creating a mini-cleanroom environment. The hardware will be tested to verify that cleanliness requirements have been met. Below we briefly describe the transporter system (get it *there* and get it *close*) and the three main laser bay delivery systems (get it *in*).

2.1 Transporter

The delivery systems used in the laser bays (bottom loader, top loader, and side loader) use a commercially provided AGV. An AGV transporter design was chosen over a manually driven forklift for several reasons, including better maneuverability and fewer personnel requirements (and thus potentially significant cost savings over the 30-year life of the NIF). The AGV uses a laser head and retroreflectors for its guidance system and can move autonomously. The AGV is described more fully by Grasz and Tiszauer.[2]

2.2 Bottom-Loading Delivery Systems

The bottom-loading delivery system philosophy is to keep as much in common as possible of the system designs for the 18 different bottom-loaded LRUs. The design study resulted in three canister designs: an amplifier-slab configuration for installing the laser amplifier slab cassettes, a flashlamp configuration for installing the flashlamp cassettes, and a "universal" configuration for installing all of the other bottom-loaded LRUs. There are over 2,700 individual bottom-loaded LRUs. Each type of LRU has unique design constraints, including size, weight, insertion travel, kinematic mounts, and beamline gas environment. The bottom-loading delivery systems will transport, lift, dock, and align the LRUs for installation in and removal from the laser bay beamlines. There are three different types of installation processes: single-stage, two-axis, and multistage installation. The process for a single-stage installation is described below.

The delivery system is transported to the OAB basement. After docking to the OAB floor, a Class-100-clean LRU is inserted into the canister, which is then moved to the LRU's LTAB insertion location. The AGV lifts the canister to within an inch of the structure. The transporter/canister compliance system activates and completes the docking by having its kinematic docking balls self-align to the structure's receivers. The compliance system allows the canister six degrees of freedom to the transporter. The canister's pneuma seal (inflatable seal) is activated, sealing the canister to the structure. The HEPA airflow system is activated. The cover-removal mechanism is activated, removing both the canister cover and the beamline cover. The vertical ballscrew insertion mechanism lifts the LRU to a height in the beam structure where the LRU's kinematic mounts are activated. The insertion mechanism lowers the LRU onto the kinematic mounts. The insertion mechanism continues to lower the empty carriage back into the canister. The cover-removal mechanism reinstalls the covers. The pneuma seal is deflated, and the transporter moves the empty canister back to the OAB.

2.3 Top-Loading Delivery System

The top-loading delivery system will use a clean canister for transporting and inserting the three different top-loading LRUs. The LRU sizes have been standardized to simplify the delivery system design. This delivery system is maximizing design commonality with the bottom-loading delivery system to increase reliability and minimize

cost. These LRUs are top-loaded due to space limitations below the beamline structures. The clean insertion of LRUs will be accomplished by using a cover-removal system similar to the bottom-loading system in which the dirty outer surfaces of the vacuum and canister covers are sandwiched together and removed as a unit. The major subsystems on the canister are the insertion mechanism and the cover-removal mechanism. The process for an installation is described below.

The delivery system is transported to the loft of the OAB. An LRU is inserted into the canister. The AGV moves the canister to the laser bay, where the laser bay bridge crane lifts the canister off the AGV. The crane docks the canister to the center vessels of the cavity or transport spatial filter (these vessels support the NIF's huge, steel laser beam tubes). This process also seals the canister to the center vessel. The cover-removal mechanism activates and removes both the beamline and canister covers. The LRU is lowered onto the kinematic mounts at the bottom of the vacuum vessel by the ballscrew insertion mechanism. The insertion mechanism then moves the now empty carriage back inside the canister. The covers are replaced and the canister is undocked by the bridge crane. The crane places the empty canister onto the AGV for transport back to the OAB.

2.4 Side-Loading Delivery System

The side-loading delivery system comprises several delivery systems. The most complex system is the one that transports the preamplifier module (PAM) LRU. The PAM delivery system uses a skid to transfer the PAM LRU into the support structure. A battery-operated tug moves the skid (which rolls on wheels) to transport the LRUs from the PAM maintenance area to the laser bay. In the laser bay, the skid is picked up by the laser bay transporter, which then positions and aligns the skid for docking. There is a docking mechanism on the skid that engages pins into receptacles in the support structure for alignment and support. Fine alignment of the skid to the support structure (in pitch and yaw) is done by using the vertical lift and fine alignment system of the transporter. The PAM LRUs have wheels on which they roll from the skid into the support structure. A rack and pinion mechanism on the skid inserts the LRUs into (and retracts them from) the support structure. The LRU is connected to the drive mechanism by a rotary latch. The skid is then removed and returned to its point of origin.

3.0 SUMMARY

The Optical Transport and Material Handling delivery systems are being designed to meet the NIF requirement of rapid installations and removals of the LRUs. The systems will accommodate the numerous constraints from the OAB and the LTAB facilities, the laser support structures, the laser beam enclosures, and the various LRUs. Commonality is being maximized for all the systems.

4.0 ACKNOWLEDGMENTS

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