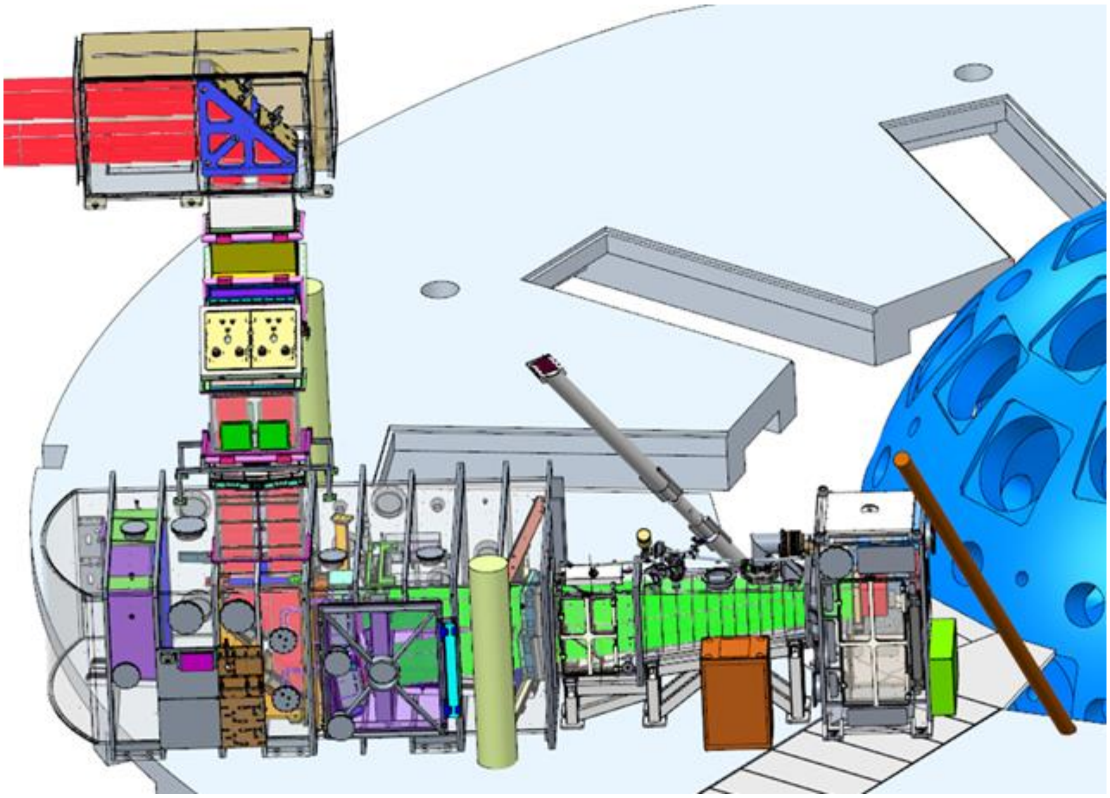
NIF DLI User Guide



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1. Introduction

The NIF Direct Laser Impulse facility represents a new test capability to explore shock and impulse effects on materials, sub-systems, and systems. The facility has been designed to support large area impulsively loaded structural and shock experiments with user-supplied test objects with adequate flexibility in system design and laser produced environments to support user test requirements. This guide provides information to potential users about the facility, how it works, and how to utilize its capabilities. For more information on the NIF, NIF operations, and User logistics, please refer to the NIF User guide < https://nifuserguide.llnl.gov/; click *Home*>.

NIF DLI operations include operating the laser (energy and pulse shape), laser diagnostics, safety interlocks and command control systems and are integrated with other NIF operations. Also, note that all tests using NIF DLI can operate concurrently but independently with shots to the main Target Chamber. The NIF DLI control and data acquisition system has been designed to allow independent control of test area diagnostics, data acquisition and storage by users independently of the NIF command, control, and data acquisition system.

It is envisioned that most, if not all, of the NIF DLI shots will occur as ride-along experiments on shots to the main Target Chamber that will have priority. All proposed DLI experiments, including the test object, must go through the standard NIF reviews. The National Security Applications (NSA) Team in coordination with NNSA, DTRA, and AWE shall decide on shot priorities and schedule. The NIF senior management team and the NSA Team shall determine the allocation of DLI experiments to be supported in a fiscal year.

2. Mission

Accurately predicting the response of reentry systems and other space assets to impulsive loading from material vaporization following intense x-ray exposure is important for predicting their survivability in hostile nuclear environments. The direct generation of intense bursts of x-rays has been developed at NNSA's high energy density (HED) facilities. NIF and the Z machine at Sandia National Laboratories have developed a suite of capabilities to test materials across a wide range of x-ray energies and over a wide range of fluences. This has enabled material response testing of new and legacy materials. The limitation has been that test articles were limited to small, planar samples. Complex, 3D geometries have not yet been explored. Without a giant technological leap in x-ray output on current facilities, or construction of new HED test facilities, complex, 3D geometries will not be able to be tested in the appropriate test environments. This challenges the certification of new materials or modified designs. NIF DLI provides a new technique to study the effects of impulsive loading on materials and structures while overcoming prevous size and geometry restrictions.

3. Background

Joint US-UK experiments on the Los Alamos National Laboratory (LANL) Trident laser, the UK ORION laser, and the Lawrence Livermore National Laboratory (LLNL) Janus laser have developed a technique to simulate intense x-ray effects on coupon scale targets. These experiments validated models in which the samples were directly illuminated by the laser. Further, they have developed techniques to significantly enhance the laser coupling using thin layers of optically transparent “tamping” layers and laid the foundation for the development of a large area direct impulse effects test capability on NIF. “Tamping” layers have been shown to increase the laser coupling by more than 10 times [1, 2] and to produce stress waves and impulses that simulate the effects from high fluence x-ray irradiation. In collaboration with NIF and Z experiments, the DLI experiments have demonstrated that the prompt impulse and stress (shock) wave magnitude and shape effectively simulate the effect generated by the absorption of an intense x-ray pulse.

4. Project Description

4.1 Overview

The DLI facility utilizes two beams of the NIF laser that are delivered into a dedicated DLI vessel, converting the light to 526 nm, and overlapping both beams onto a wide test plane in a large test volume. A layout of the NIF DLI system is shown in Figure 1, which shows NIF beamlines 351 and 352 being directed into CV2 using an insertable pickoff mirror. This allows independent use of beams 351 and 352, so the facility can support a DLI test as a ride-along to main Target Chamber shots without interference. The test area is 31.6 cm x 31.6 cm (1,000 cm^2), and the test volume extends forward and back from the test plane (on the order of +400 mm, -780 mm). The two laser beams are polarized orthogonal to each other, and, as a result, do not create an interference pattern at the test plane despite that fact that they are overlapped. Users should note that the test volume is reduced as one moves forward or backward away from the test plane due to the changing overlap of the two beams. This is discussed in more detail in **Section 6.3**.

The DLI facility design separates the DLI test area from the laser optics and beam transport areas as shown in Figure 1. This separation will ensure that the laser transport optics are protected, kept in a stable environment, and, thus, require minimum maintenance. The laser optics and beam transport area will be maintained at a constant pressure (local atmospheric) to maintain temperature and humidity. Two vacuum windows separate these areas. To ensure integrity of the vacuum window during DLI shots, the system will use two disposable debris shields per beam. Currently, the test area operates at local atmospheric pressure, however, a vacuum capability will be commissioned during FY25 which will provide the option to conduct experiments at vacuum ($\sim 10^{-4}$ torr). The option to conduct experiments at vacuum will be available no earlier than FY26; for more information, please reach out to the DLI laser scientist and experimental lead.

This design allows the system to provide the required shot rate and system availability with minimum impact to the NIF workforce. Adequate baffling has been added in the space between the vacuum window at the interface of the laser-transport area and the test-area volume to ensure no potential damage can be caused by light reflected by the test object.

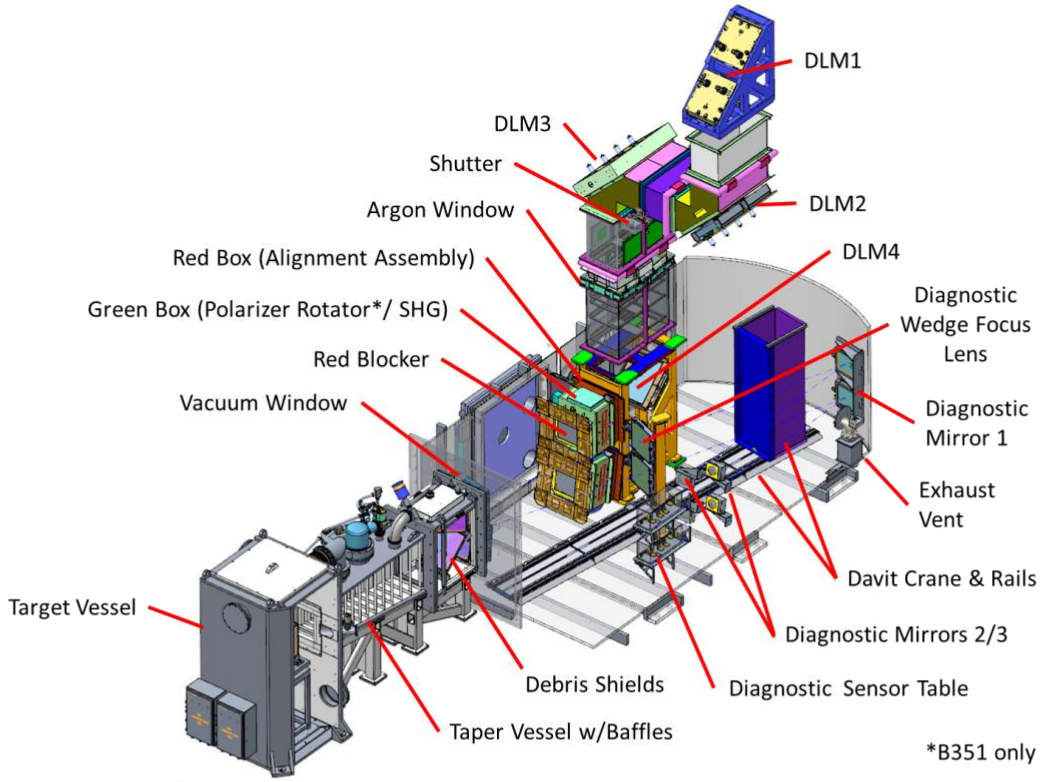


Figure 1. NIF DLI layout next to compressor vessel 1 (CV1) showing component in CV2 for the laser transport and conversion from 1ω to 2ω.

4.2 Test Area

The test area was designed to maintain a separation between the test area and the laser optics and beam transport area. Access to the test area is via a large target area access door as shown in Figure 2 (details in NIF-1010892837) and is the primary access point for installation and removal of test objects. There is also a top access port that can be utilized for insertion of larger test objects with additional preparation effort. The test chamber dimensions were limited by the available space around the location of CV1 and CV2. The inside volume of the target area is 120 cm x 120 cm with a total height of 250 cm. The top access port is 95 cm x 95 cm. Figure 2 again shows the location of the two disposable debris shields per beam.

4.3 Target Mount Infrastructure

Figure 3 shows a dimensional drawing of the target vessel and schematics of the test stand and vibration isolated breadboard. The centerline of the test plane (where the two beams fully overlap) is 147.8 cm above the vessel floor and the figure shows the location of a 36.8 cm cube in the test volume. The test area at the test plane is 1,000 cm^2 (31.6 cm x 31.6 cm).

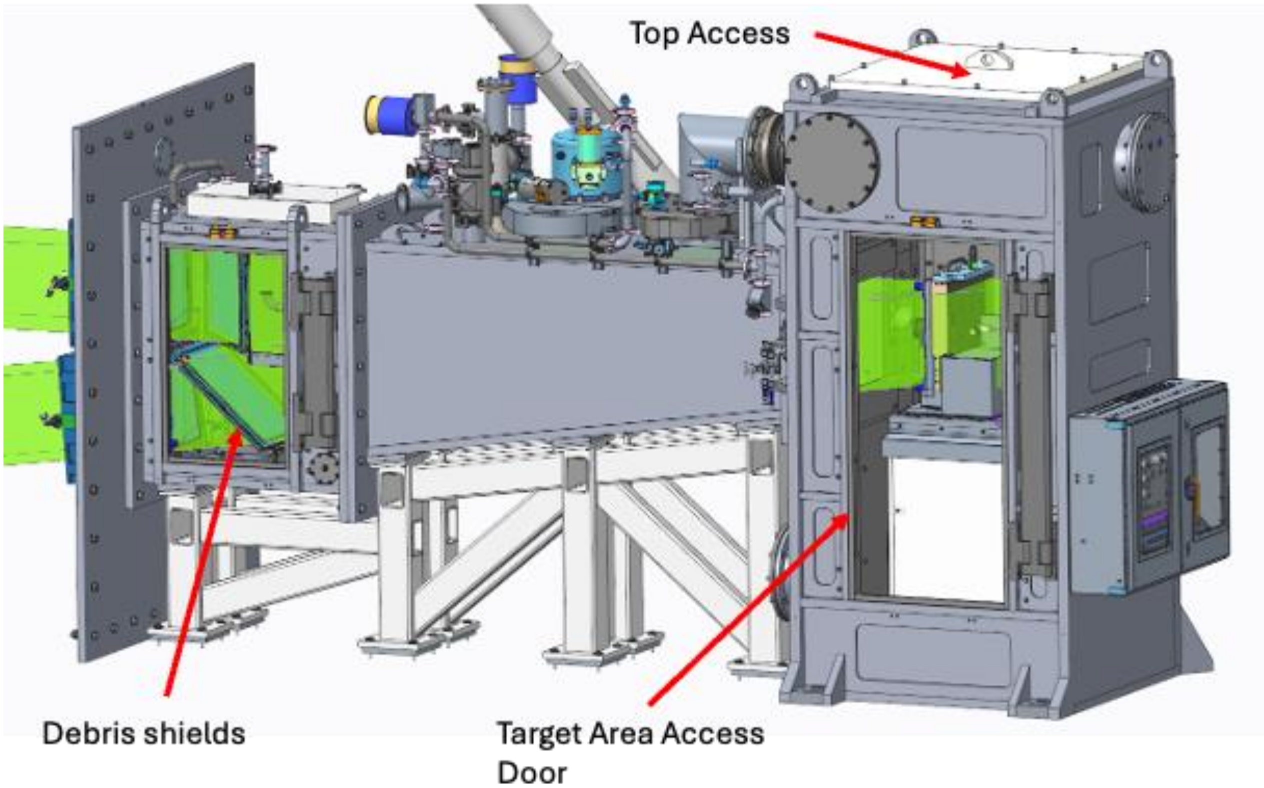


Figure 2. Schematic of Target Area showing access for debris shield replacement and main target area access door.

The target interfaces either to the stand via a shock-isolated kinematic mount or via a kinematic mount at the base of the target vessel. The interface control document (ICD) governing how targets are mounted to the target stand is NIF-1010892837. The ICD governing NIF Target Bay Transport and Handling Stay-Out-Zones (SOZ) to the DLI Target Vessel is NIF-1011285011. The details of the mounts can be found in NIF-1006174247 and NIF-1005891631 for the stand and chamber mounting mechanical drawings.

The interface drawings can also be obtained from the Material Radiation Effects (MRE) team lead if you do not have access to the LLNL Enterprise Lifecycle Management (ELM) system. The floor plate has 20 M8X1.25X14 inserts for floor mounting objects. See 1006174247-AB for hole pattern. The vibration isolators on the target stand are Newport ND40-B NewDamp Elastomeric Isolators and can be used for shock isolation for test objects mounted to the floor.

The target stand is a stainless-steel frame with a kinematic, vibration isolated breadboard. The breadboard has an M6 threaded pattern, with 25 mm spacing. The front edge of the mounting surface is 15.5 cm below and 12.6 cm in front of the target plane. Kinematic features on the target booth floor allow for floor mounted test objects and user-customized stands. The user is responsible for providing vibration isolation for floor mount configuration.

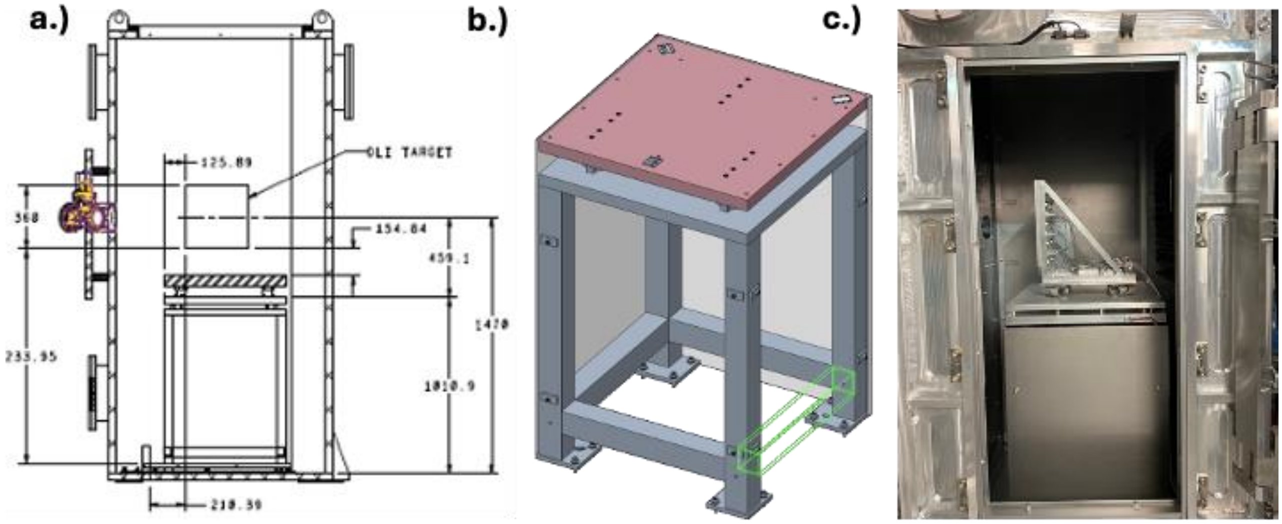
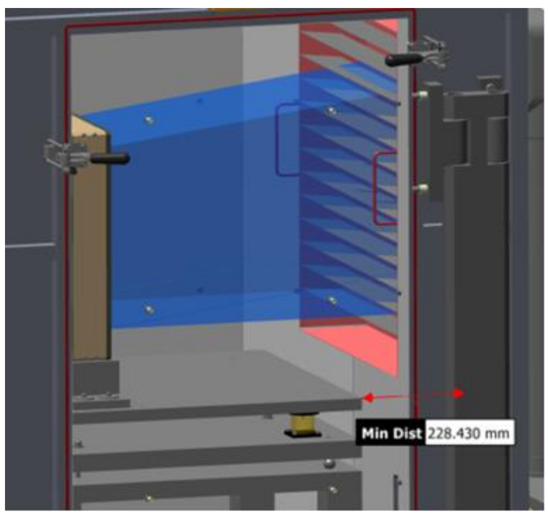


Figure 3. a.) Dimensional drawing of the target test stand within the DLI target vessel; b.) CAD model image of the DLI target test stand; c.) Image of a DLI target installed on the test stand within the target vessel.

Figure 4 shows the location of a laser beam dump on the back wall of the Test Chamber. The beam dump is 734 mm tall, 689 mm wide, and protrudes 150 mm from the back wall. The target stand is 228 mm from the back wall. Interference with the beam dump will occur if the target extends 78 mm beyond the edge of the target stand mounting surface (it may hit the beam dump handles first – 30 mm from edge of target stand). The distance from the floor of the booth to the bottom of the beam dump is 1175 mm.

Figure 4. Schematic of laser beam dump on back wall of target vessel.



5. NIF DLI Capabilities and Restrictions

5.1 Capabilities

The NIF DLI system performance capabilities as designed for the system are:

- Laser fluence uniformity at the test plane to be better than 5% rms at spatial scale lengths greater than or equal to 1 cm. Note that fluence non-uniformities will be a function of the position relevant to the test plane (see **Section 6.3**).
- Reproducibility and accuracy of the total laser energy delivered to the test plane shall be consistent with NIF 1-omega laser design capability (~5% shot to shot),
- Test volume can operate at either vacuum ($\leq 10^{-4}$ torr) or 760 torr. Currently, the test volume is operated at 760 torr. The vacuum capability will be commissioned in FY25.
- Test area at the test plane is 1,000 cm^2 (31.6 cm x 31.6 cm).
- The DLI system can currently deliver up to 12 J/cm^2 to the test plane. The system will eventually be commissioned to 20 J/cm^2; for additional information regarding the DLI laser capabilities, please reach out to DLI laser scientist or DLI experimental lead.
- The laser energy that can be delivered to test objects is variable and is pulse width dependent. As of the publishing of this guide, the following square laser pulses have been used on NIF DLI: 2 kJ/beam, 2 ns; 4 kJ/beam, 5 ns; and 6 kJ/beam, 10 ns. Users are encouraged to reach out to the DLI laser scientist or experimental lead to discuss current DLI laser capabilities and desired pulse shapes for upcoming experiment(s).

For more information on laser energy, pulse shape and timing, users are referred to the NIF User Guide <**https://nifuserguide.llnl.gov/**; click *Home*>.

5.2 Restrictions

The NIF DLI system shall abide by the NIF facility Safety Basis, the NIF Facility Safety Procedure (FSP), and the NIF Operational Safety Procedure (OSP) and its appendices. Examples include the use of hazardous and/or radioactive materials that will be managed by the applicable NIF procedures and management plan. A difference in NIF DLI is that the target and the diagnostic are part of the same assembly and the volume for the NIF DLI target vessel is substantially smaller than the NIF Target Chamber. As a rule, it is recommended to avoid materials that are hazardous or could become hazardous as part of the experiment. Hazardous materials may be approved for use if they are in an approved sealed container that has been shown to not rupture under the expected loads through commissioning shots. Review and concurrence by the Target and Laser Interaction Sphere (TaLIS) expert review group, NIF operations, and the NIF Hazards Review Committee are required before any hazardous material may be approved by the NIF Operations Manager and allowed to be used on DLI experiments. Materials that will not be sealed will need additional review for potential explosive power as compared to the rupture strength of the debris shields and vacuum windows. Additional restrictions for materials that may be aerosolized before, during, or after the shot will need to be reviewed for toxicity to humans by the NIF Hazards Review Committee. Currently, the volume inside the target vessel is exhausted to the Target Bay and may require additional safety documentation, controls and procedures as part of the approval. Significant additions or changes to the authorized operations require a Work Authorization Point or Prestart Review as determined by the NIF Operations Manager. The NIF DLI system was not designed to include any exposed hazardous materials; as such, the introduction of hazardous materials may result in significant DLI system re-design and or procedural changes.

Concave curved surfaces on the target surface that face the NIF laser are discouraged. Features larger than 1 mm with a concave radius of curvature between 1 m and 20 m will require review and approval by TaLIS. The reason for this is that the feature will cause the reflected beam to focus on the NIF DLI optics, which may damage optics. NIF DLI is not planned to be run in a fashion that would require an optics loop (repairing damaged optics), so damage to the optics will be kept to a minimum.

Item	Concern	Mitigation
National or California hazardous materials in target or that can be generated from a shot (includes tamper materials).	Target vessel volume is exhausted to the Target Bay. Target area operators will enter the target vessel volume.	All materials will need to be reviewed by TaLIS*, HRC, NIF operations, and approved by NOM. A safety analysis and plan including a mitigation plan and procedures may be required. Some materials may need to be contained within the target as prescribed.
Potentially explosive materials as part of the test object. This includes HE or anything that could ignite due to the laser energy deposited in the target.	Explosive materials may rupture the debris shields and vacuum window which would damage NIF DLI optics.	Explosive materials will need to be reviewed by TaLIS*, the NIF HRC, NIF operations, and approved by the NOM and the LLNL explosives authority for total explosive potential with respect to the yield strength of the NIF DLI system. Insensitive explosive materials will need commissioning shots before use unless below the NIF DLI yield strength for total potential energy. A prestart review is required.
Beryllium used in test objects.	Beryllium disease from Be dust or particles.	Test objects with Be will need to be reviewed by TaLIS*, the NIF HRC, NIF operations, and approved by the NOM for potential to generate Be dust, reviewed by the HRC and approved by the NOM.
Concave objects larger than 1 mm in diameter with a radius of curvature between 1 m and 30 m.	Reflected light may focus on NIF DLI optics resulting in catastrophic damage.	All test objects that have features inside the stay-out zone will need a commissioning, ramp-up plan. Users will need to supply diagnostics to show that the reflected light cannot cause damage. Existing diagnostics are not sufficient for commissioning on NIF DLI. Users will need to supply appropriate diagnostics as required by BLIP** and TaLIS.* A WAP may be required prior to authorization.
Target features are limited to angles less than +/- 18º in the vertical and +/- 10º in the horizontal.	Debris wind not well characterized for interaction with weldments on test and tapered chambers.	As part of the commissioning plan for the NIF DLI system, targets with full 40x40 cm tampers will be tested to validate the models of the debris wind working group on NIF. Once validated the restrictions may be

Item	Concern	Mitigation
		relaxed or additional shielding may be added to the weldment areas.
Target venting.	Test area pump down time.	Test objects to be used for shots at vacuum should be provided with appropriate vents/pump out paths to allow the vessel to meet pump down requirements. Objects to be used at vacuum should be vacuum compatible and meet applicable outgassing requirements.
Target cleanliness.	Contamination of DLI system with materials/debris that could produce by products that pose risk to optics.	All materials to be fielded on NIF DLI will need to be evaluated by the NIF Cleanliness Steering Committee and NIF HRC and approved by the NIF Operations Manager.

* TaLIS: Target and Laser Interaction Sphere <review group>

**BLIP: Beamline and Laser Integrated Performance <review group>

6. Test Environments and Test Considerations

6.1 Test Environments

This section provides users with information on DLI technology, expected results, and test limitations. Previous experiments have shown that with the addition of an optically clear "tamping" layer on the front of the test object, appropriate laser irradiation parameters (intensity, pulse-shape, and pulse width) induce stress (shock) waves and impulse in test materials comparable to intense x-ray pulse absorption found in nuclear environments. The basic laser interaction phenomenology is shown in Figure 5, which illustrates how the thin transparent layer acts as an inertial "tamper" for the laser interaction and enables efficient laser energy coupling to the test material. Additional information related to targets and target mounting is provided in Section 4.3 and Section 7.1.

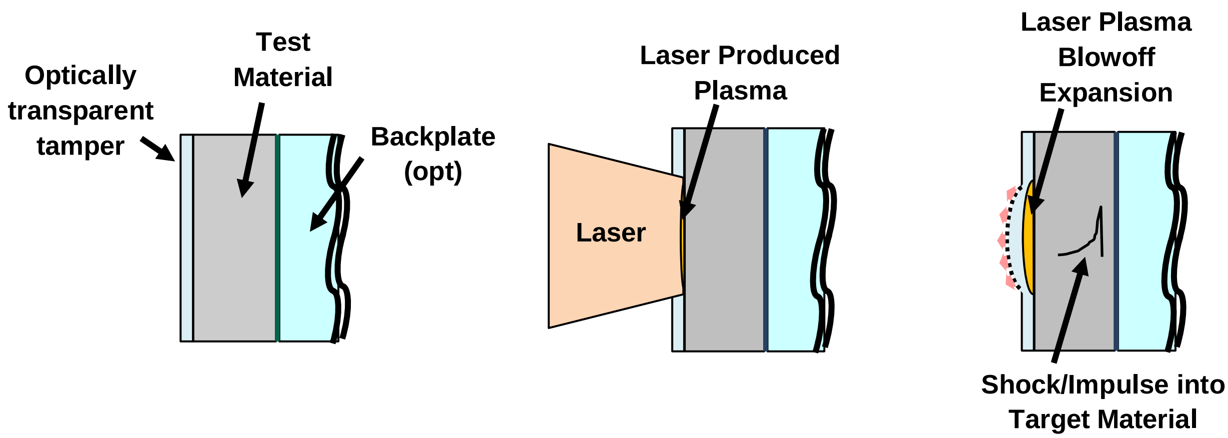


Figure 5. Schematic of laser interaction with optically clear tamper on the test material.

6.2 Previous results and additional resources

There is a limited data set over the full range of laser fluences of interest with multiple tamper materials and thicknesses. An example of how the generated impulse scales with the incident laser fluence for various tamper materials is shown in Figure 6. An example of the measured stress profile for an Al sample is shown in Figure 7. For more information on recent experiments and results, please reach out to the NIF DLI scientific lead, NIF NSA program manager, or DLI User Group point of contact. Additionally, background information on laser generated impulses, confined laser ablation, and tamper performance can be found in the following references:

[1] S. Ly, J. Lee, A. M. Rubenchik, J. C. Crowhurst, C. D. Boley, V. N. Peters, and W. J. Keller, "Tamper performance for confined laser drive applications," *Optics Express*, **31**, 14 (2023)

[2] R. Fabbro, J. Fournier, P. Ballard, D. Devaux, J. Virmont, "Physical study of laser-produced plasma in confined regime," *Journal of Applied Physics*, **68**, 775 (1990)

[3] C. R. Phipps, Jr., T. P. Turner, R. F. Harrison, G. W. York, W. Z. Osborne, G. K. Anderson, X. F. Codis, L. C. Hayes, H. S. Steele, K. C. Spicochi, and T. R. King, "Impulse coupling to targets in vacuum by KrF, HF, and CO_2 single-pulse lasers," *Journal of Applied Physics*, **64**, 1083 (1988)

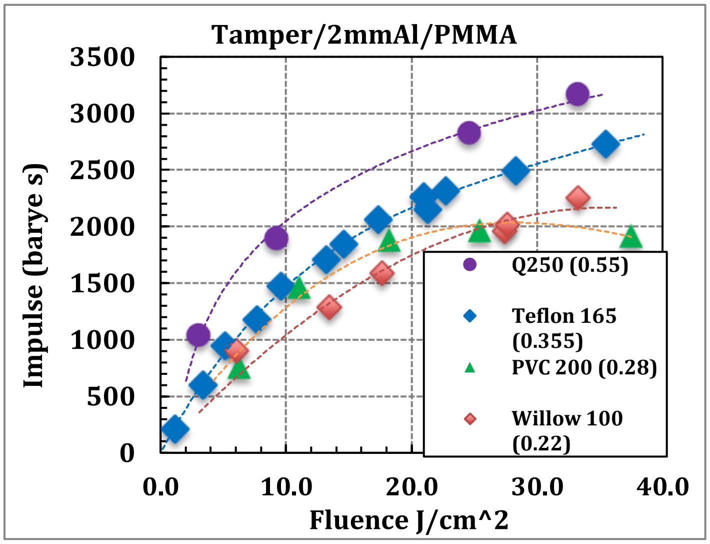


Figure 6. Summary of impulse vs. fluence measurements for different tampers; 250 µm quartz, 165 µm Teflon©, 100 µm Corning Willow© glass and 200 µm PVC.

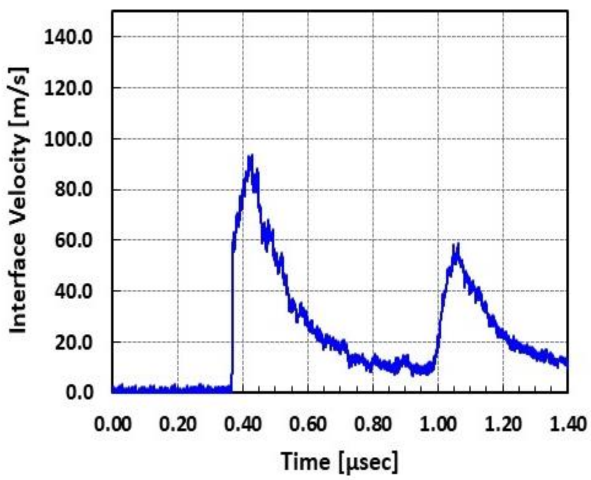


Figure 7. Example stress wave measured on the rear surface of a Teflon-tamped Al sample.

6.3 Understanding the NIF DLI Interaction Volume

The NIF DLI interaction volume begins at the entrance to the target vessel and extends to the back of the target vessel. The beams cross at a 7.8° angle with respect to each other. Examples of the beam overlap at various positions within the target volume are shown in Figure 8. Units of the plots are mm. The interaction plane is the plane at which the two beams overlap each other (maximum overlap integral). Negative distances are toward the NIF laser and positive distances are toward the rear of the target vessel.

If fluence uniformity is a concern for your experiment, please contact the laser scientist for NIF DLI to discuss and obtain near-field images of the laser beams from previous experiments to determine the illumination profile that would be incident onto your chosen target.

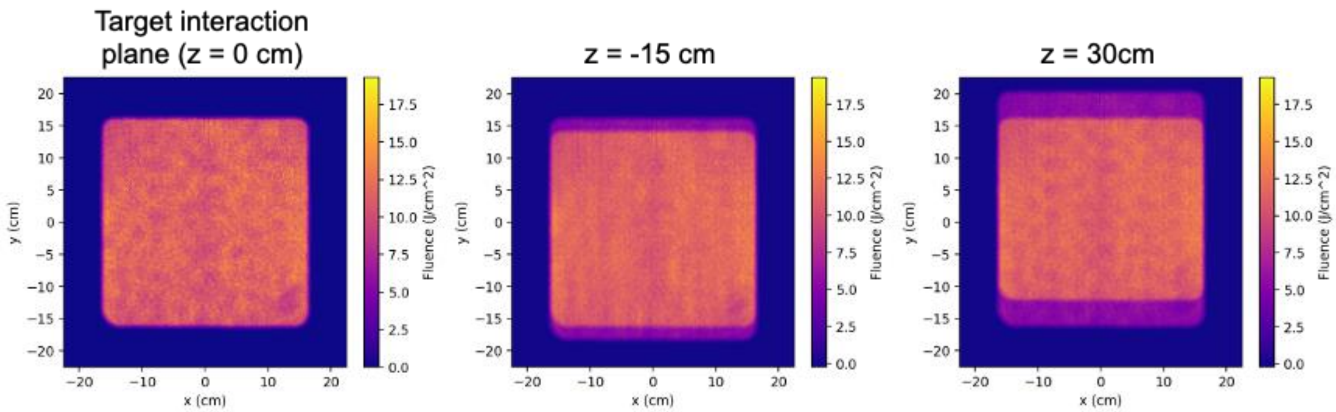


Figure 8. Simulated fluence profiles at multiple locations within the DLI target vessel demonstrating the change in beam overlap away from the Target Interaction Plane (TIP): at TIP (left), 15 cm in front of TIP (middle), 30 cm behind TIP (right).

6.4 Curved Surface Considerations

When designing a test for a curved object, the variation in the incident laser fluence as a function of angle will result in an angular dependence of the generated impulse. If there is no (or an insignificant amount of) laser energy loss in the tamper, the incident laser fluence will scale as the cosine of the angle of incidence. Additionally, some laser light is reflected at the surface of the tamper material. The magnitude of this reflection depends on the polarization of the laser light, the

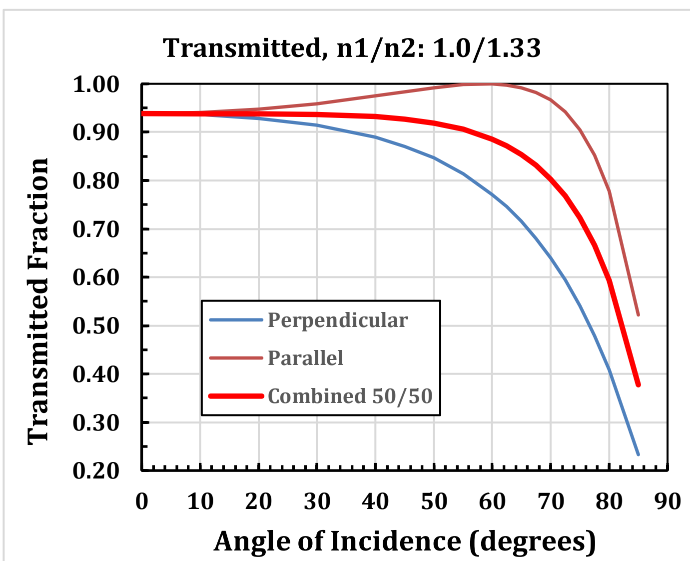


Figure 9. Light transmission versus angle for index of refraction ratio of 1.0/1.33.

tamper index of refraction, and the incident angle. On NIF DLI, each of the laser beams are linearly polarized at the target with orthogonal polarization, relative to each other (one beam is s-polarized and the other is p-polarized). An example transmission curve as a function of incidence angle for perpendicular polarization, parallel polarization, and combined (50/50) is shown in Figure 9.

7. Target Design, Standard Operations, and Collecting Data

This section provides some practical information for users on test objects, general shot planning, standard operations, facility diagnostics, and test object diagnostics.

7.1 Target Design Considerations

Users will be responsible to provide their own test objects and diagnostics for their test objects. Test objects will need to be coordinated with the NIF Materials and Radiation Effects (MRE) Engineering Team, which can provide design and fabrication assistance. The team can also provide guidance to ensure that your test objects and experiments will be within the facility capability and safety envelope or assist with the review and authorization of your experiment if it exceeds standard operating conditions.

Target assemblies must be designed to be compatible with NIF lifting/handling capability if the largest parts are such that they cannot be handled manually (e.g., >25 lbs or size/shape that cannot reasonably be handled by one individual). Target Area Operations will work with users to provide guidance on appropriate handling interfaces. A NIF rigging and handling plan must be approved by NIF engineering, with the user providing necessary input.

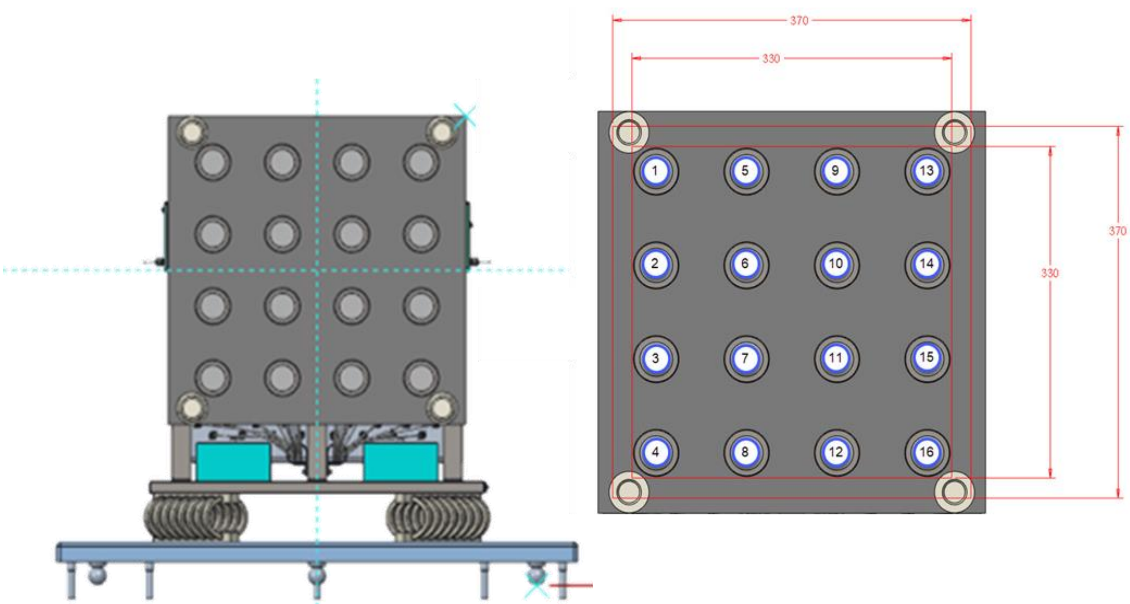


Figure 10. Sample-array target configuration. This target consists of locations for 16 individual, 40 mm diameter samples. The sample locations are evenly distributed within a 32 cm x 32 cm square.

The standard NIF DLI facility diagnostics (see **Section 7.4**) provide the laser fluence, uniformity, and as-delivered pulse shape to the test object. It is recommended that users field standard test coupons using their tamper material to validate the test environment and reproducibility for their data shots. For shots using an array of test coupons, it is suggested to use a “standard” configuration that can be provided by the MRE Team. The current (as of publication of this guide) configuration is shown in Figure 10. This target consists of 16 sample locations distributed over a 32 cm x 32 cm area. Each location can hold a 40 mm diameter specimen and is equipped with an optical probe to measure the rear-surface motion of the sample via Photonic Doppler Velocimetry (PDV). To obtain information on the most recent version of the sample array target or the rest of the DLI target infrastructure, users are encouraged to reach out to the MRE manager or DLI Scientific Lead.

The advantage of NIF DLI is the ability to test 3-D test objects with high spatial fluence uniformity. However, users must be aware of the usable test area (volume) and how the spatial profile of the incident fluence changes with position within the Target Chamber. For more information, see **Section 6.3**.

7.2 Standard Operation Procedures

NIF DLI operations (including laser diagnostics, safety interlocks and command control systems) are all integrated into NIF operations/control systems. As noted, all tests using NIF DLI can operate concurrently but independently with shots to the main Target Chamber. The NIF DLI control and data acquisition system has been designed to allow independent control of test area diagnostics, data acquisition and storage by system users independent of the NIF command, control and data acquisition system. (The DLI laser, however, is controlled by the NIF Integrated Computer Control System and is simply an alternate beam fate for the two main laser beams that are part of the main NIF laser.) For more information on NIF standard operation procedures, Users are referred to the NIF User guide < https://nifuserguide.llnl.gov/; click *Home*>.

NIF personnel using standard NIF operation procedures will:

a) be responsible for operating safety interlocks,

b) control the vacuum and test area venting,

c) install the test objects, (see **Figure 11**)

d) connect the test object diagnostic cables,

e) remove the test objects and diagnostic cables (as needed) after the shot,

f) replace the debris shields as required (to include the test area diagnostic camera) (see **Figure 11**),

g) clean debris and survey the target vessel area as required, and

h) inspect the vacuum window for damage and replace if damaged and replace as necessary for subsequent shots

The time duration of a DLI shot cycle will vary and be dependent on the required operations included in the above list. NIF personnel will handle all aspects of the installation and removal of the DLI test object as well as DLI debris shields as illustrated in Figure 11. DLI users, who have been qualified and authorized to work in side-labs may install and qualify any custom diagnostic probes that the user is providing. All work in the NIF Target Bay, where the DLI target chamber and the DLI data acquisition system are located, will be conducted by LLNL personnel.

NIF DLI spent test objects will be given back to the users at the end of their campaign and after radiological survey and free release by the facility. The users are responsible for either target rebuild or appropriate disposal. Users will pay for the debris shields that protect the DLI optics from target debris. NIF will be responsible for acquiring the shields and the installation of the shields. The approximate cost of the shields will range from $1,500 to $3,500 per shot depending on the debris created in the shot and the damage to the windows. Details about how this is to be arranged will be provided by the NSA program leader.

7.3 Standard Facility Diagnostics

NIF DLI has a standard set of laser diagnostics built into the system. As noted, NIF DLI operations are integrated into NIF operations. The laser beams transport, conversion from 1ω to 2ω wavelength, and beam alignment are integrated into the CV2 vacuum chamber. Each beam passes from the CV2 vacuum chamber into the test area through a vacuum window. A small percentage of the incident laser light is reflected from each of the two vacuum windows and directed to two laser diagnostics systems mounted in the CV2 vacuum chamber as shown in Figure 12. These diagnostics measure the energy of each beam at the wavelength impinging on

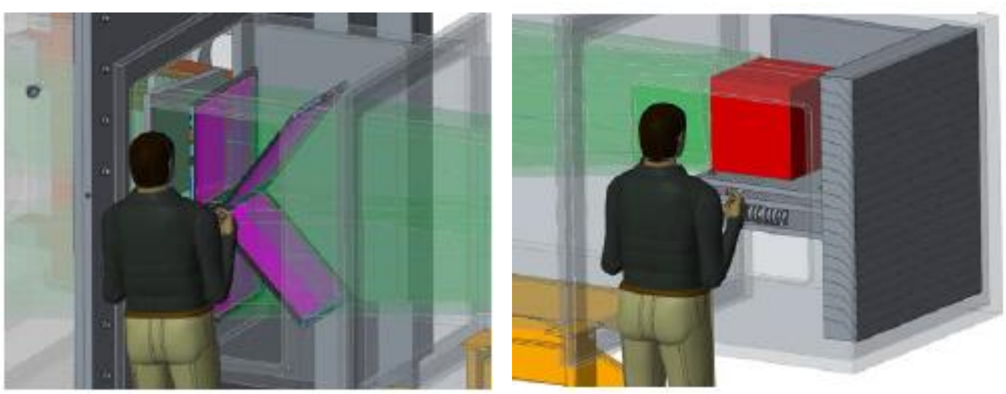


Figure 11. NIF personnel will support NIF DLI operations by changing out the debris shields and insertion/removal of the test object(s).

the sample plane to within 1% rms precision and 3% rms absolute. The system also measures the power impinging upon the target plane with at least 2.5 GHz bandwidth and 7-bit dynamic range. Finally, the system measures the beam uniformity with near field impinging upon the target plane with at least 250 um resolution and 11-bit dynamic range. Note that the vacuum windows have spatially non-uniform reflectivity profiles that impact the uniformity of the images recorded by the two near field cameras. The known reflectivity profiles can be deconvolved from the measured near-field images to recover accurate laser fluence profiles for each beam. The DLI laser scientist and DLI experimental lead will work with users to provide reflectivity-corrected images, so they have an accurate representation of the on-target laser fluence for their shot(s). Note that deconvolved near-field images have demonstrated r.ms. values that satisfy the uniformity requirement described in **Section 5.1**.

Provisions are provided for two cameras that can view the target interaction plane. Figure 13 shows a view of the target vessel with the location of the two target viewing camera ports. The target viewing camera can be placed in either of the two ports on the sides of the target vessel and the data can be collected locally or through the NIF shot archive system.

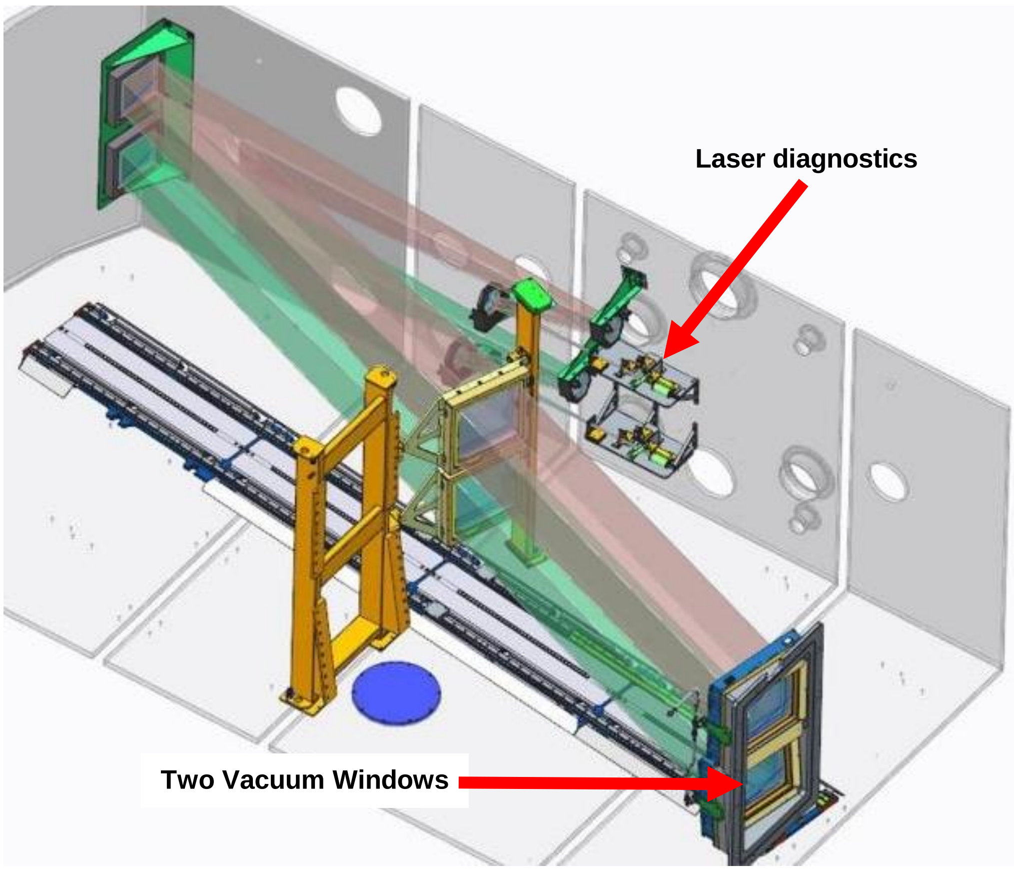


Figure 12. Standard laser diagnostics are contained within DLI laser transport volume using reflected light from the two vacuum windows.

One camera will be part of the standard NIF system diagnostics. Users will need to provide an additional camera and data acquisition if they need two on a shot. Details of the camera mount are shown in Figure 14. The camera sits inside a semi-cylindrical enclosure that is 60 mm in the wide horizontal dimension, 50 mm in the narrow horizontal dimension, and 106 mm tall. The enclosure attaches to the base with 4 M8X1.25X30 bolts. A user custom enclosure would need to have the same bottom interface for the bolts and top interface for the cabling. It would also need to include a camera mount. The NIF supplied target viewing camera is a BASLER

ACA2040-25GM and has the specification outlined in Table 1 below.

Table 1: Target Viewing System Camera Specifications	
Camera	BASLER ACA2040-25GM
Resolution (H x V pixels)	2048 px x 2048 px
Frame Rate	25 frames per second
Mono/Color	Mono
Interface	GigE
Video Output Format	Mono 8, Mono 12, Mono 12 Packed, YUV 4:2:2 Packed, YUV 4:2:2 (YUYVV) Packed

7.4 Target Diagnostics Infrastructure and Data Acquisition

As discussed in **Section 7.1**, NIF DLI users are responsible for providing their own test objects and associated diagnostics. There is a camera that has a view of the face of the target that can be used if desired by the user; otherwise there are no target diagnostics provided by the facility. Figure 15 shows the target vessel area and swing panel for connections to local or classified data acquisition (future capability), the target viewing camera port, and location of a spare flange for custom user connections. Cable feedthroughs are provided for target vessel internal cables and have connections on the rear/door side of the target vessel (Figure 16). In addition, there is a 12" port to which users can mount their own flange with vacuum feedthroughs and internal cables. The front facing port (see **Figure 13**), can be used for custom feedthrough plates. Each port is 12" in diameter but the working area is 8" in diameter.

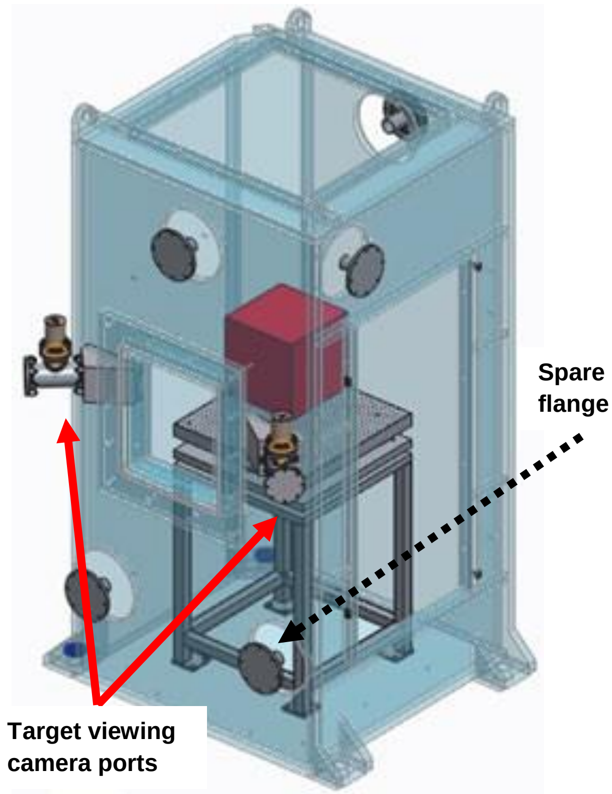


Figure 13. Test Area showing location for two target viewing camera ports and the spare flanges that can be used for custom feedthrough plates.

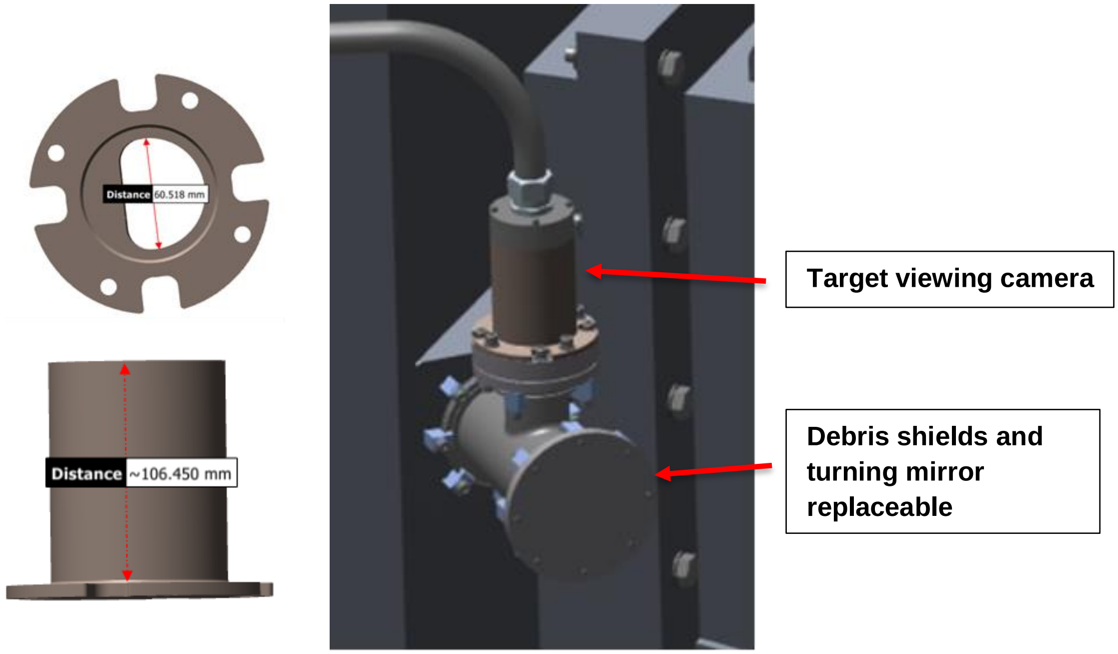


Figure 14. Details of target viewing camera with in- situ debris shield and turning mirror assembly.

Signal cables are to be run inside the test area from the target to a swing box mounted on the test vessel. User signal cables are then to run from the swing box to the user diagnostic equipment. The swing box will eventually provide the same signals to the classified racks in the classified control room. The connections (see **Figure 16**) that are currently available on the Target Chamber patch panel are:

- 24 fiber optic, SMF-28e
- 12 N-type Coax
- 16 BNC Twinax
- 2 Multi-connector (16-pin)

The MRE team has a mobile data acquisition system (DAS) that is available for use on DLI experiments. The DAS is housed in a mobile enclosure that is staged next to the DLI target vessel during an experiment and then removed following the shot. The mobile enclosure, shown in Figure 17, is 41 in. x 61 in. x 58 in. (L x W x H) and contains 44U of internal rack space. The standard configuration of the mobile enclosure consists of a 24-channel Photonic Doppler Velocimetry (PDV) system that includes three 8-channel, 2.5 GHz oscilloscopes. The mobile enclosure also includes a heat exchanger for up to 3 kW of heat removal since equipment cannot exhaust more than 50 W into the NIF Target Bay. As the DLI platform progresses, the diagnostic equipment available for use is anticipated to grow. Once users begin to plan and propose a NIF DLI experiment, they are encouraged to reach out to the MRE Lead or DLI PI to discuss their diagnostic needs. These early conversations will enable users to identify whether the available diagnostic equipment will be sufficient and/or begin the planning process for incorporating additional user-supplied equipment or systems.

All diagnostic systems that are proposed for use by users must be reviewed by the facility. Any diagnostic or support system that introduces a potential hazard into the target vessel or Target Bay must go through appropriate facility design review and approval. As this process can be lengthy, users are cautioned to start this process early (>12 months from scheduled shot dates) to avoid potential delays.

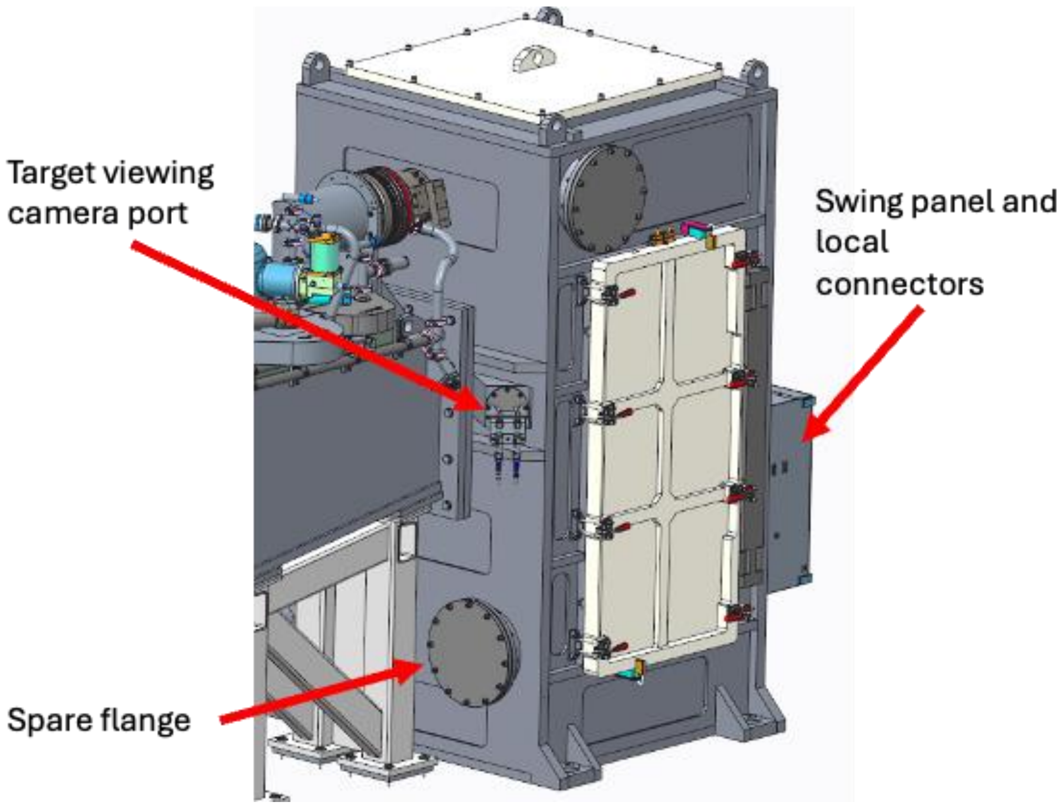


Figure 15, Target Vessel area showing swing panel for connections to local or classified data acquisition (future capability), target viewing camera port, and location of spare flanges for custom user connections.

8. Test Planning and Implementation

The National Ignition Facility management team and the LLNL National Security Applications Team, in coordination with NNSA, DTRA, and AWE shall decide on shot priorities, allocation and schedule.

8.1 Experimental Process Overview

Congratulations, you have decided to embark on the journey of conducting experiments on the NIF Direct Laser Impulse (DLI) test facility. Your testing needs may be nascent, or NIF DLI could be a component of a larger portfolio of impulse testing facilities. Either way, the NIF NSA and MRE teams are here to help you execute a successful experiment that delivers critical, mission-relevant data.

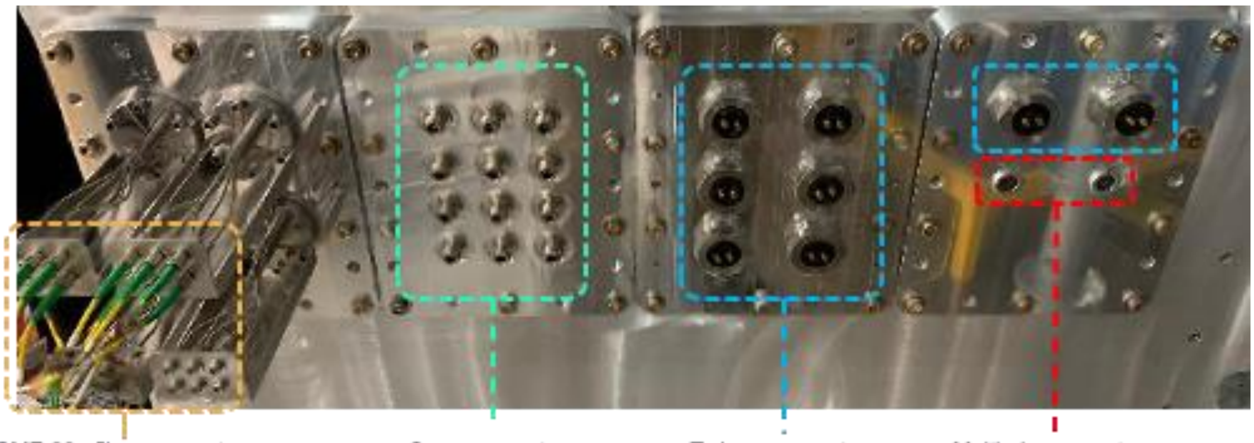


Figure 16. Available connections on the DLI target vessel.

The first step on your journey is to engage with the NIF NSA Team and the DLI Working Group to discuss your goals and requirements. This interaction should happen at least 1–2 years before an anticipated need date for the experiment. Based on these informal discussions, a formal proposal will then need to be submitted. The proposal will then undergo a rigorous peer-review process at which point the group of submitted proposals will be ranked in terms of mission impact and technical readiness. Figure 18 provides a general timeline from proposal, to scheduling, planning, and shot implementation. Experiments that are awarded time will then be scheduled and assigned a test date. Once a date is set, detailed planning is required to prepare for the test date. The NIF MRE Team will guide you through the various gates to assure that the test object, diagnostics, and facility configuration are all properly configured.

8.2 Proposal Submission and Review Process

Annual calls will be issued by the NIF User Office on behalf of the NIF Director for proposals for DLI experimental campaigns. The call will be published in early December with notification of awards to successful proposers in early-to-mid Spring. This will support scheduling the awarded DLI shot opportunities with compatible main-chamber experiments during the schedule process that takes place in the Spring for the coming government fiscal year. It is envisioned that most, if not all, of the NIF DLI shots will occur as ride-along experiments on shots to the main Target Chamber that will have priority during execution of the DLI experiment. All proposed

Mobile Enclosure External *Mobile Enclosure Internal*

Figure 17. Mobile enclosure used for data acquisition on DLI experiments. (Left) External view of the enclosure (Right) Internal view of the enclosure outfitted with 24-channel PDV system.

DLI experiments, including the test object, must go through the standard NIF reviews. The NIF senior management team and the NSA Team shall determine the allocation of DLI experiments to be supported in a fiscal year.

It will be possible for users to request a dedicated DLI experiment where the DLI shot has priority over the main chamber experiment. To request such a shot, the user will propose the dedicated DLI experiment to the National Security Applications call for proposals that is issued by the NIF User Office annually in August. It is assumed that awards of the NSA program time for dedicated DLI experiments will be very rare and DLI users will propose primarily through the DLI call for proposals.

A typical schedule would have one shot planned for any given day for a user campaign. The system was designed to support 3 shots per standard NIF shot day, and in some circumstances 4 shots per standard NIF shot day. However, DLI experiments will primarily be scheduled as ride-along experiments on a concurrently scheduled NIF main chamber experiment. The rate at which DLI shots will be performed will depend on the complexity of the DLI setup and the opportunities for appropriate main-chamber experiments on which the DLI experiment will ride along. In the early stages of fully commissioned DLI system operations, DLI experiments will likely be scheduled at a rate of no more than one per month.

All submitted DLI proposals are reviewed for scientific merit and program impact by panels of internal and external experts. Key elements of the proposal are:

- **Mission Impact**—Description of how the experiment will address critical questions, a timeline for addressing these questions, and decision points that are affected by the proposed experiments.

- **Scientific discussion**—Description of the purpose for the proposed experiment, the key scientific questions addressed, the proposed experimental method, the desired experimental platform, and the expected results.

- **Scientific team**—Descriptions of the researchers involved in the proposed concept development.

- **Required capabilities and resources**—A short estimate of the capabilities and resources required within and external to NIF to execute the experiment.

Proposals submitted to the NSA program call for dedicated DLI time will also need to present a modeling and simulation plan that will both guide and benefit from the awarded DLI shot time.

Part of the DLI proposal review is an evaluation by facility stakeholders of the readiness and capability by NIF staff to support the shots. The chair of the review committee summarizes the recommendations for each proposal in a report and sends the report to the NSA Program Director and the NIF Director. The principal investigator will receive a written notification from the NIF Director (sent by the NIF User Office) of the proposal evaluation and decision.

8.3 Scheduling Process

The NIF facility convenes a Facility Advisory and Scheduling Committee (FASC) meeting annually, usually in mid-May, to approve the baseline schedule for the following government fiscal year. The schedule that is discussed and approved has been developed in the preceding six weeks through a series of dedicated meetings with stakeholders. DLI shots will be paired with NSA main-chamber experiments during that six-week period (April to early May) after the main-chamber experiments have been tentatively scheduled. If a dedicated DLI shot date was awarded, the date would be directly scheduled in the scheduled building process. Once the schedule is approved by the FASC, changes are managed through formal, software-based schedule change requests (SCRs). Changes to the DLI experiment riding along on the main-chamber shot will be managed through the SCR tool.

8.4 Shot Preparations and Planning Process

Scheduled experiments are planned such that they meet physics goals while not compromising on facility safety. This is the longest phase of the experiment process, and the MRE Team will guide you through the process. The Shot Responsible Individual (RI) collaborates with the MRE Team on a target design that will allow the experiment goals to be achieved. The Shot RI specifies laser performance and pulse shaping, which may drive pre-experiment calibration activities or performance tests. Diagnostic requirements will need to be defined to ensure that sufficient resources are in place to make the required measurements. At various points in the planning phase, expert group members review the details of the experiment definition to ensure that the experiment falls within the laser and facility safety and security envelope. Iterations on experiment designs are common during this phase.

8.5 User Logistics Approaching the Scheduled Shot Time

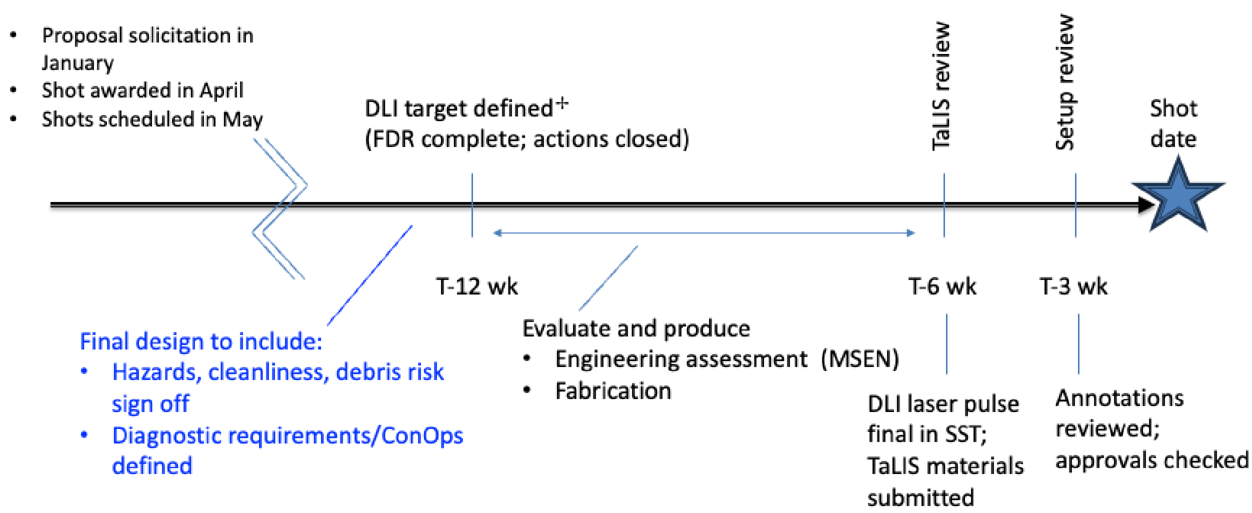


Figure 18. General schedule information on proposal submission, proposal reviews, planning, NIF Expert group reviews, and final shot implementation.

The DLI Shot RI, in coordination with the main chamber Shot RI, will finalize all setup parameters (laser pulse and target configuration) for the experiment using the NIF's Shot Setup Tool (SST). Once the parameters have been submitted in SST, multiple expert groups will review the submitted configuration to ensure that the target and laser pulse have been reviewed and approved for the requested use case. The approvals of the various expert groups (TaLIS, BLIP, and Hazards Review Committee) are tracked using NIF's Approval Manager (AppMan). All experiments go through the Setup Review three weeks before the shot date to ensure readiness and begin preparation for execution.

Once the setup is finalized and approved by all expert groups, the experiment is reviewed by the NIF Operations Manager (NOM) for final approval. The test object will need to be ready for delivery to the NIF facility two weeks prior to the shot, along with associated installation and connection procedures. NIF operations staff will load the test object into the chamber and connect any diagnostic cabling to the cable feedthroughs. Leading up to the shot, the DLI PI and the PI's team will have the opportunity to set up the required diagnostics and test their functionality with the installed test object. The NIF is a 24/7 facility and access to the DLI test chamber could be at any time of the day/night. Access will have to be done in coordination with the NIF Control Room to not interfere with other Target Bay activities. The day of the shot, the main-chamber shot RI and/or the DLI PI provide a pre-shot briefing to the Shot Director and

NIF Operations staff. Within hours after the experiment, the test object will be removed from the chamber.

8.6 Badging, Training, and Site Access

The NIF NSA Team will coordinate the required badging for NIF and/or site access. Any required training will be scheduled for you as well. Please allow two months of notice for any visits to LLNL so that proper arrangements can be made.

The NIF is an unclassified building, so a clearance transfer is not required to be present. It is beneficial to transfer one's clearance so that side discussions/meetings can take place. All on-site visitors and users are required to complete a standard series of institutional site training requirements. Additional training is required to access the specific areas of the NIF facility (e.g., Control Room, Target Bay, etc.) and to be qualified as a site radiation worker if needed. Additionally, performing work requires training as specified by the integration worksheet. Training requirements will be identified during the scope meeting with the host and will be sent to the visitor for completion prior to receiving facility access and work authorization.

For more information, Users are referred to the NIF User Guide
< https://nifuserguide.llnl.gov/; click *Home*>.

9. Classified Shots

As a future capability for DLI experiments, a classified data collection system will be designed and commissioned supported by NIF Facility and Infrastructure and Controls Engineering teams. DLI data acquisition equipment and diagnostic controls will be transferred into the NIF Target Area Control Room (TACR). The NSA Program will address the process to declassify and release data as part of this project. This capability is not expected to be available to users before FY26 at the earliest.

9.1 Safeguards and Security

The operation of the DLI system may generate classified data requiring safeguarding; the Project itself represents a large investment of government funds in assets that must be protected. For tests from DoD, the relevant Program Security Classification Guide (SCG) will provide guidance as well as the Defense Threat Reduction Agency (DTRA) Simulator Program SCG that will provide specific guidance regarding classification levels associated with DLI program information, including identification of Controlled Unclassified Information (CUI). For tests from the national laboratories, their respective security offices will be responsible to provide guidance on what data requires safeguarding and level.

10. Points of Contact

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Appendix

Revision History

Revision	Release Date	Change Description
AA	6/2022	Initial Release. Includes target limitations.
AB	5/2023	Disclaimer updated: guidance evaluation. Section 4.3 updated: includes Target Vessel ICD reference.
AC	9/2024	Update for as-built system performance and developing shot proposal/scheduling procedures.