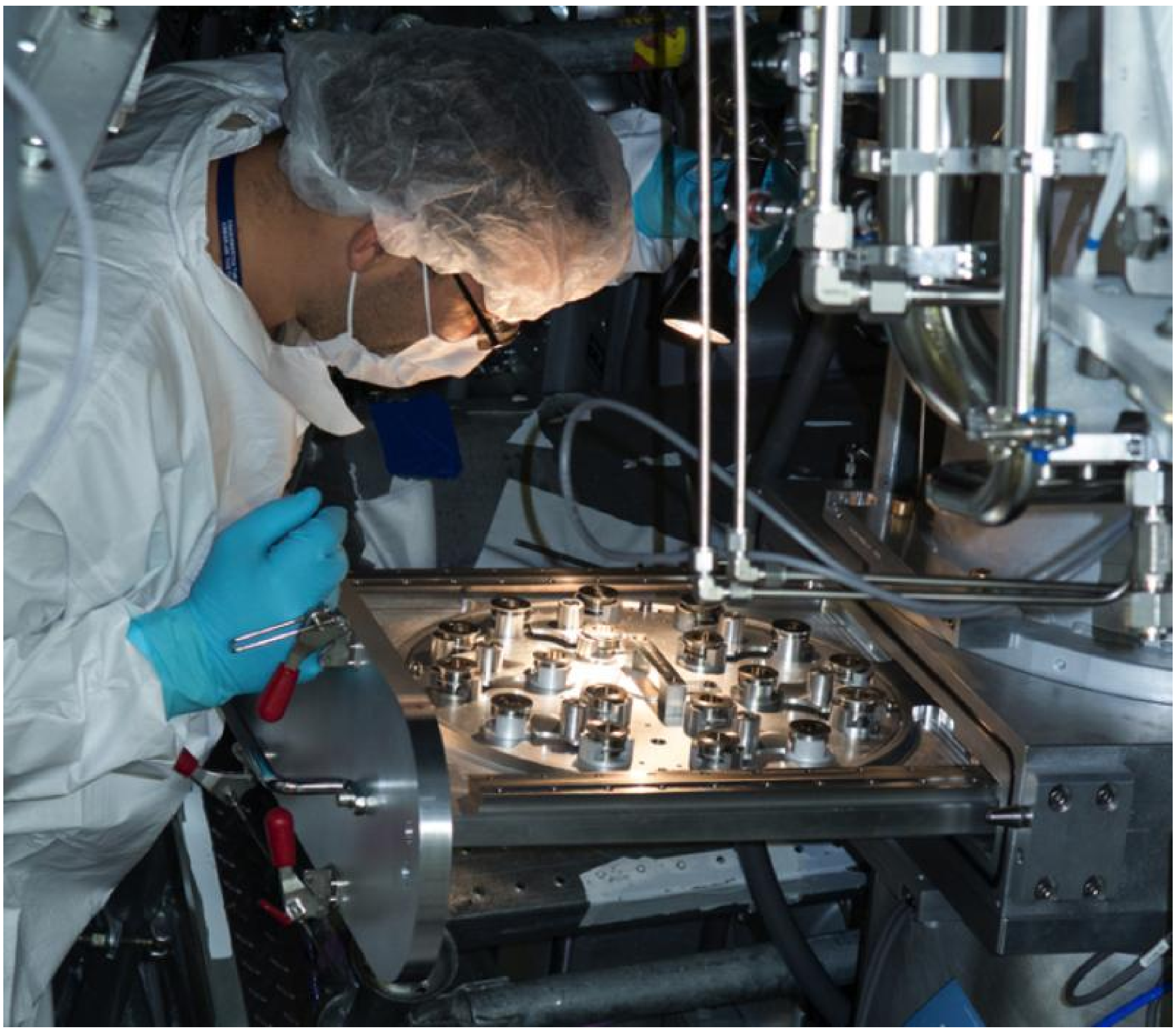
Measuring the National Ignition Facility's inferno

June 11 2015, by Breanna Bishop



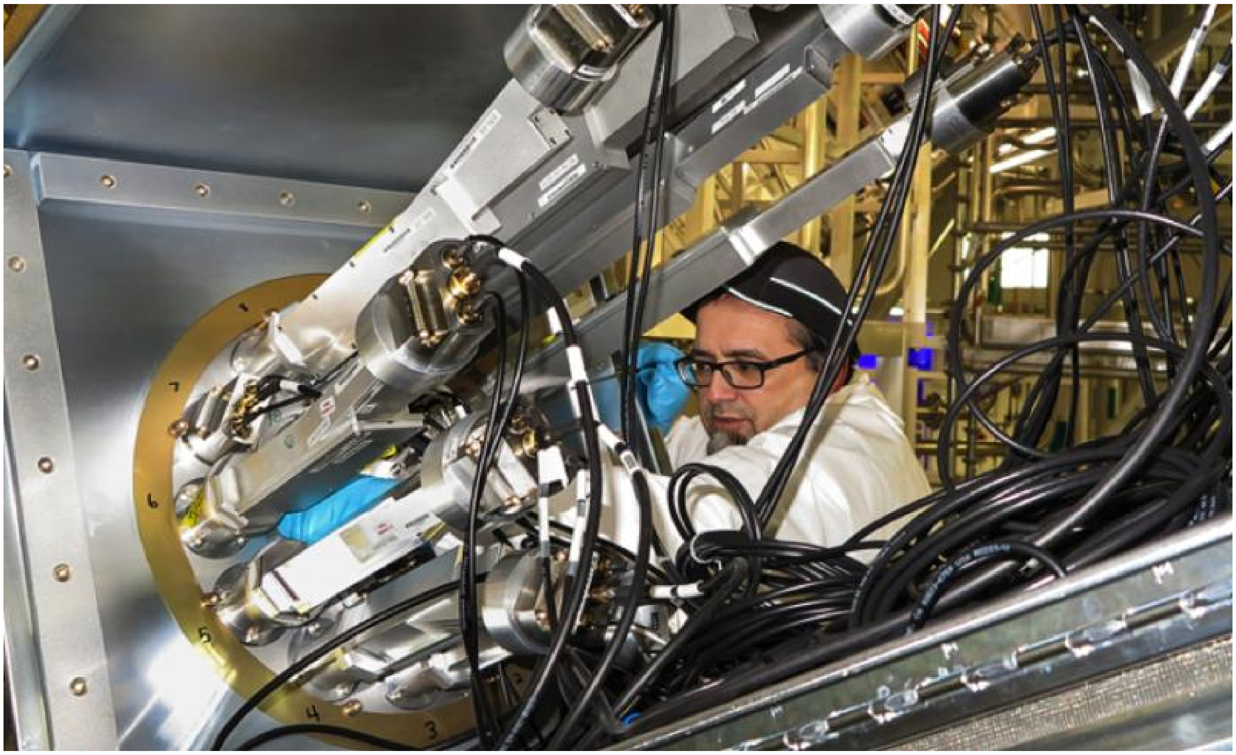
Target area operator Mike Morris inspects a Dante 1 filter wheel to ensure the delicate filters are intact before a shot. Credit: James Pryatel/LLNL

The smooth blue sphere of the National Ignition Facility's (NIF) target chamber bristles with diagnostics—nuclear, optical and X-ray instruments that together provide some 300 channels for experimental data. These diagnostics provide vital information to help NIF scientists understand how well an experiment performed.

Two of these diagnostics, known as Dante 1 and Dante 2, are pressed into service for nearly every shot. These broadband, time-resolved X-ray spectrometers measure the time-dependent soft X-ray power produced by the NIF lasers interacting with the hohlraum—the small gold cylinder that holds the NIF target capsule. The X-rays heat and ablate the outer surface of the capsule and drive the capsule's rocket-like implosion. The resulting data are used to calculate the radiation spectrum and infer the temperature of the radiation field inside the hohlraum. This information can be directly compared to hohlraum simulations to determine if the hohlraum and laser pulse are performing as designed.

"Dante is one of the workhorse diagnostics of NIF—it participates in almost every shot," said Alastair Moore, responsible scientist for Dante. "Even when a hohlraum is not used, it is one of the few absolutely calibrated soft X-ray diagnostics that can provide absolute measurements of the conversion efficiency of laser light into X- rays."

Each Dante diagnostic measures the voltage produced by 18 filtered X-ray diodes. Each diode is filtered to record the X-ray power in a specific part of the spectrum. Spectral ranges are controlled by filters, metallic mirrors and X-ray diode material. Dante 1 has five channels with mirrors, and Dante 2 has eight mirrored channels.



Target area operator Sky Marshall installs new apertures in the Dante 2 X-ray diodes. Credit: James Pryatel/LLNL

Because Dante is an absolutely calibrated system, every component must be calibrated and tracked, making it one of the more challenging diagnostics to maintain and operate. According to Moore, the calibration of each component typically involves approximately 100 measurements.

"On the two Dante systems, we maintain approximately 10 different filter configurations, each of which contains about 45 calibrated filters," he said. "The filters are pretty fragile components and debris from shots can damage them over time, requiring a continual replenishing of the stock of components."

In addition to the filters, approximately 50 X-ray diodes are calibrated on a cyclical basis and maintained along with about 20 grazing incidence X-ray mirrors. This adds up to an inventory of thousands of components that must be tracked, maintained and verified.

The Dante team recently transitioned to a new way of operating the diagnostic filter configurations, introducing standardized sets. This adaptation significantly reduced the overhead costs associated with building filter configurations and also reduced the error bars on the measurements, making better shot-to-shot comparisons possible. The team also is in the process of replacing the 18 oscilloscopes used to record the X-ray diode signals and automate the setup, reducing manual interactions required for each shot.

Looking to the future, the team is exploring a modification to some of the channels that measure the part of the spectrum containing M-band radiation from the hohlraum, an important measurement for inertial confinement fusion.

"This radiation can preheat the capsule significantly, resulting in an increase in instability growth," Moore said. "The upgrade will add multi-layer X-ray mirrors to these channels to provide a better constrained X-ray bandpass and a more accurate measurement of the power in this region."

The forerunner of the Dante diagnostic originated in the era of underground nuclear weapons testing, where it was developed for the same purpose as it is used today—to measure the absolute X-ray power produced. A multi-institutional team with members from Lawrence Livermore, Los Alamos and Sandia national laboratories, the UK's Atomic Weapons Establishment, National Securities Technologies and General Atomics contributed to adapting the diagnostic to its current use.

Provided by Lawrence Livermore National Laboratory