The Art of Precision Machining

It has been called the world's most accurate lathe, the world's most precise large machine tool. With the groundbreaking for the Large Optical Diamond Turning Machine (LODTM) in 1981, the Laboratory solidified its place at the top of state-of-the-art precision machining.

More than 20 years later, the machine's precision is such that LODTM (pronounced "load-em") still outperforms the measurers—the National Institute of Standards and Technology cannot corroborate the accuracy of its work. LODTM can machine metal to a mirror-smooth accuracy within one-millionth of an inch—1,000 times more accurate than conventional machine tools. It can handle a workpiece with a diameter up to 1.65 meters, a height up to 0.5 meters, and a weight up to as much as 1,360 kilograms.

Like a lathe, LODTM spins a workpiece as a tool cuts the revolving surface. But the similarity ends there, because LODTM leaves behind a gleaming reflective surface that often needs no further polishing. Since its construction, LODTM has been the tool of choice for contractors making lenses for heat-seeking missiles and other weaponry, exotically shaped optics for lasers, and mirrors for powerful telescopes such as Keck in Hawaii and NASA's space-based lidar-system, SPARCLE. When the Shoemaker–Levy comet collided into Jupiter in 1994, it was witnessed in real time, thanks to mirrors turned on LODTM and then installed at Keck.

Almost since its inception, the Laboratory has been among the leaders in the development of advanced techniques for precision measurement and manufacture to meet the demands of programmatic work. Livermore's first diamond turning machine was built in the late 1960s, and by the early 1970s, one-millionth of an inch precision was achieved. The idea of the LODTM arose later in the decade when researchers began considering the development of powerful lasers as an element of missile defense. The laser system's optics had to be extremely large, exotically shaped, and fabricated with a precision that corresponded to a small fraction of the wavelength of light. No machine had the needed capabilities.

Livermore's Precision Engineering Program, under the guidance of Jim Bryan, Jim Hamilton, Jeff Klingmann, Dennis Atkinson, and others, designed LODTM. The culmination of previous Laboratory research in machine tool accuracy, LODTM incorporated exhaustive analysis and elimination of factors that caused errors in machine tools—from the heat of the human body to the vibration from a heavy truck passing by.

LODTM opened in 1983, two years after its groundbreaking. It continues to produce one-of-a-kind prototype optical devices. LODTM's next big project may be producing optics for NASA's next generation of telescopes.

A Hero of U.S. Manufacturing

Literally billions of dollars worth of machine tools have been tested with a small measuring device invented by Jim Bryan, who made wide-ranging contributions to metrology and precision machining in 32 years of service at the Laboratory. In the 1980s, Bryan reworked an old British invention called a fixed ball bar by adding a telescoping arm to the instrument. Today, versions of Bryan's ball bar are used around the world to test machine tool performance quickly. For this invention and other achievements, which include leading the design and construction of record-breaking diamond turning machines in the 1970s, Bryan was recognized in 2000 by *Fortune* magazine as one of six "Heroes of U.S. Manufacturing."

Machining metal up to 1.65 meters in diameter and at a precision of 2 micrometers is possible with LODTM.