THE AIR FORCE RESEARCH LABORATORY

Directed Energy Directorate

Speed of Light to the Fight by 2020

Air Force Research Laboratory Directed Energy Directorate
Starfire Optical Range (SOR)

Space Situational Awareness

Freedom to maneuver in space is critical to meeting the United States Air Force's mission to fly, fight, and win in air, space and cyberspace. The ability to exploit the characteristics of space gives the war-fighter a competitive edge in virtually all engagements.

As satellites get smaller and the number of space objects increases dramatically, research in imaging and identification of space objects is paramount to meeting the Air Force's mission.

To provide leadership in the area of space situational awareness, the Air Force conducts research in laser guide star adaptive optics, beam control, and space object identification.

About the Starfire Optical Range

The Air Force Research Laboratory's Starfire Optical Range (SOR) is a vital resource in achieving the Air Force's mission to operate freely in space. This world-class optical research facility and center for Air Force strategic optical exploration is located on a hilltop site (6,240 feet above sea level) on Kirtland Air Force Base, New Mexico. The SOR's primary mission is to develop optical sensing, imaging, and atmospheric compensation technologies to support Air Force aerospace missions.

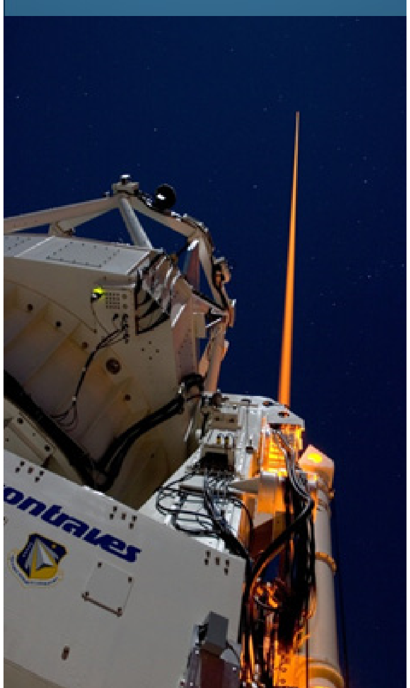
This facility leads the industry changing technology of laser beacon adaptive optics for military uses and civilian applications such as astronomy. It is a major component of the Air Force Research Laboratory's Directed Energy Directorate.

The SOR operates one of the world's premier adaptive-optics telescopes capable of tracking low-earth orbiting satellites. It has a 3.5-meter (11.5 feet) diameter primary mirror and is protected by a retracting cylindrical enclosure that allows the telescope to operate in the open air. Using adaptive optics, the telescope distinguishes basketball-sized objects at a distance of 1,000 miles into space.

In addition to the 3.5-meter telescope, the SOR includes two additional major optical mounts: a 1.0-meter beam director and a 1.5-meter telescope. All are capable of tracking low-earth orbit satellites and all are equipped with large scale, high performance adaptive optical systems and high resolution cameras.

Other instrumentation includes numerous smaller telescopes and beam directors, multiple laser systems, and a variety of optics, electronics, and mechanical laboratories.

Nearby the SOR is the Telescope and Atmospheric Compensation Laboratory (TACLab). This facility includes extensive optics, electronics, computer, and mechanical laboratory space for equipment design, construction, and testing before integrating with telescopes and other experiment hardware. The building also includes a large mirror coating chamber for the required periodic recoating of the SOR's 3.5-meter telescope's primary mirror.



The SOR and TACLab staffs include physicists, mathematicians, astronomers, electronic and mechanical engineers, optical designers and technicians, sensor and computer specialists, laser technicians, meteorologists, electricians, plumbers, welders, machinists, and a variety of specialists.

3.5-Meter Telescope Details

The primary mirror of the 3.5-meter telescope was cast in a spinning furnace. The lightweight, honeycomb-sandwich primary mirror weighs 4,500 pounds and has a one-inch-thick glass face sheet. The surface is precisely polished to a tolerance of 21 nanometers, or 3,000 times thinner than a human hair. The mirror is supported by 56 computer controlled actuators to maintain its shape while the telescope is moving. Installed in August 1993, the mirror received "first light" images on February 10, 1994.

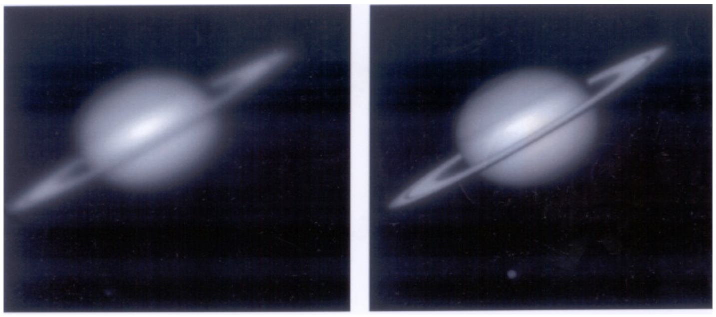
The combined weight of the telescope, gimbal, optics, and support structures exceeds 100 tons. The telescope sits on a massive steel-reinforced concrete pier that weighs more than 700 tons. Isolated from the rest of the facility, the pier is anchored in bedrock with long steel rods.

A dynamic feature of the 3.5-meter telescope is the protective enclosure that collapses around the telescope through a 35-foot-diameter shuttered opening in the roof. The walls consists of three rings, with the top ring 71 feet in diameter, the middle ring at 69 feet and the bottom ring is 67 feet in diamter. To expose the telescope, the top ring slides down past the middle ring and these two rings slide down past the bottom ring, leaving the telescope in the open. This allows the telescope the freedom to slew around and track a fast-moving orbital object as it traces across the sky.

The enclosure's cylindrical operating mechanism is often compared to an inverted collapsible cup used by campers. Such a method has two major advantages over conventional domes that are normally equipped with narrow slits: the enclosure does not have to be rotated at high speed while satellite tracking, and it improves image quality by releasing warmer "trapped" air, negating temperature fluctuations that could create optical distortions.

The protective enclosure was emulated when building a telescope on Starfire Optical Range's sister site in Maui, the Air Force Maui Optical and Supercomputing (AMOS)site, which houses a 3.6-meter telescope. Both sites perform complementary research and on occasion perform experiments together.

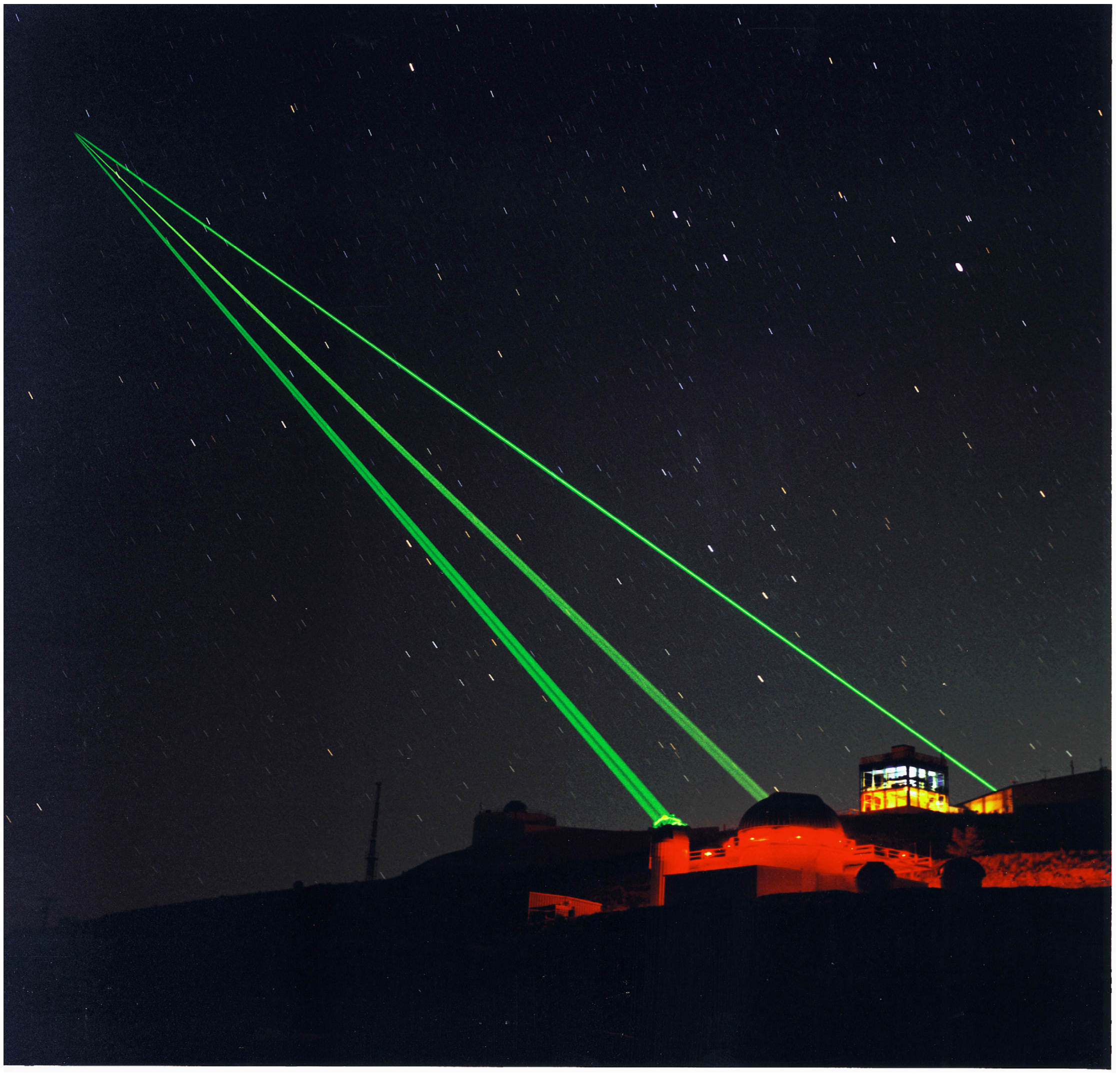
Thermal control of the telescope and facility is essential to maintain the highest image quality. A unique feature of the 3.5-meter telescope facility is the removal of heat by a closed-cycle water system chilled by a large "ice house" located ¼ mile from the telescope. The concept is to make ice in the daytime and store it in an underground pit for use at night. Unlike conventional air conditioning systems, this method prevents heat from being released into the air near the telescope.



Using adaptive optics, objects outside Earth's atmosphere become much clearer as shown in this photo of Saturn.

The 30-foot pit beneath the floor of the physical plant can hold 4.5 million pounds of ice. These propane-fired boilers can generate up to 2 million BTUs for hot water, which is also supplied to the 3.5-meter facility. Very precise temperature control of optical labs and equipment is achieved by mixing the right proportions of hot and chilled water which then conditions air and equipment in the facility.

The SOR is widely recognized as one of the world's leading adaptive optics and beam control research sites. With its work in field experiments in the technology areas of real-time atmospheric compensation, atmospheric turbulence physics, and satellite acquisition, pointing, and tracking, the Starfire Optical Range is truly a national asset.



Laser beams projected from all three telescopes at the Air Force Research Laboratory's Starfire Optical Range on Kirtland Air Force Base, N.M. The green lasers take advantage of Rayleigh scatter in the atmosphere to measure the atmospheric turbulence in front of the telescopes.

About the Directed Energy Directorate

Located at Kirtland AFB, N.M., the Directed Energy Directorate is the Air Force's center of expertise for directed energy and optical technologies. The Directed Energy Directorate focuses on four research areas: Lasers Systems, High Power Electromagnetics, Weapons Modeling, Simulation and Analysis, and Directed Energy and Electro-Optics for Space Superiority. The Directed Energy Directorate consists of 700 plus military, civilian and on-site contractors dedicated to providing the Air Force with game-changing technology.

The Directorate operates on 4,325 acres of land with over 860,000 square feet of laboratory and office space. In addition to the numerous state-of-the-art research laboratories and testing structures at Kirtland AFB, unique facilities on Kirtland include the Starfire Optical Range, the Environmental Laser Test Facility, the High Energy Microwave Laboratory where high energy microwave testing is done inside an anechoic chamber, and the Air Force Maui Optical and Supercomputing site in Hawaii.

The lab pioneered the first and only megawatt class airborne laser and is a leader in ground-based space imagining using adaptive optics with its 3.5-meter telescope in New Mexico and a 3.6-meter telescope in Hawaii. The Directorate is transitioning transformational counter-electronics weapon technologies that can degrade, damage or destroy electronic systems with minimum collateral damage.

The sodium laser guide star excites the sodium atoms in the ionosphere to create a point of light 90 kilometers above the Earth. The adaptive optics system looks at the "twinkle" of this point of light caused by atmospheric turbulence. The system then sends signals to activators that can alter the curvature of the mirror many times per second to compensate for the atmosphere's distortion of the image.

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