Imagine knowing enough about a hurricane to get the right people evacuated. Or knowing enough about Earth’s atmosphere to predict climate trends and to stop negative human impacts. Consider a time when advances in medical procedures retire the scalpel to the museum. And think about precision-oriented manufacturing which brings consumer costs down because of its efficiency.

One advance in technology can enable these 21st century goals — it is the laser. The laser is already integrated into our daily lives, in supermarket scanners, video and compact disks, as a tool to make dental work, in cosmetic plastic and general surgery, and in industry where it is used to align equipment and even cut out fabric for clothes.

Lasers are also changing how scientists conduct research, and they are an important tool for atmospheric studies at NASA Langley Research Center.

**What is a laser?**

A laser* is a unique kind of light, more intense and concentrated than anything in nature. Laser light differs from white light (such as sunlight, the light we use in lamps or flashlights) in several ways. Light from most sources spreads out as it travels so that much less of it hits a given area as it moves farther from its source. Traveling as a tight, unbroken beam, the laser light does not disperse as much as it moves away from its origin. Also, while white light is a mix of colored light waves, laser light is monochromatic, having a single wavelength which corresponds to one specific color. Identical wavelengths travel parallel to one another for reinforcement, creating a strong beam that can be focused down to less than 0.001 inch in diameter. Laser light can be controlled very precisely as a steady, continuous beam or in bursts or pulses.

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*Light Amplification by Stimulated Emission of Radiation

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Light waves from the flashlight are different colors and different lengths; however, the laser light waves are all of the same wavelength and have only one color.
In 1985, NASA Langley performed its first airborne laser mission: to study water vapor and the density of aerosols (small particles) in our atmosphere.

Less than 10 years later, in 1994, NASA Langley joined with industry to put an atmospheric laser sensor in space to probe the atmosphere. The Lidar In-Space Technology Experiment (LITE) was flown aboard the Space Shuttle Discovery (STS-64). During its 12-day mission, LITE measured the Earth’s cloud cover and tracked aerosols in the atmosphere. The laser used on this mission was a component of a Lidar (Light Detection And Ranging). Lidar is similar to radar, but instead of bouncing radio waves off its target, a lidar uses short pulses of laser light to bounce or reflect off particles — even molecules — in the atmosphere. The reflected light comes back to a telescope where it is collected and measured.

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The LITE data is being analyzed and archived and has proven so effective in presenting a global picture of the Earth's atmosphere that NASA Langley scientists are now exploring the feasibility and potential advantages of using lidar instruments on satellites.
That same year NASA Langley accomplished another lidar mission. Flown on the high-altitude ER-2 aircraft, which is a modified U-2 spy plane, the Lidar Atmospheric Sensing Experiment (LASE) used the first tunable laser to function autonomously. The lidar used in this mission was designed to measure atmospheric elements which are typically hard to detect, such as water vapor and pollutants. This Differential Absorption Lidar (DIAL) uses two laser beams pulsed at different wavelengths, one tuned to a specific particle or gas which absorbs it, and one tuned to remain unabsorbed. By measuring the difference between the two beams as they come back to the telescope — one partially absorbed and one intact — scientists can determine the amount of a particle or gas present.

NASA Langley's work in the development of laser technology has naturally found application in medicine and manufacturing. NASA Langley engineers were instrumental in the development of the diode pump laser which is currently state of the art because of its efficiency, reliability and long life. In response to an industrial need for such a laser, NASA Langley teamed with others to take the diode semi-conductor from being a lab curiosity to a product which industry has since commercialized.

NASA Langley also contributed greatly to the development of a more efficient laser for special medical applications, such as incisions and arterial repairs.

**The Future**

LASE and LITE collected data on a wide range of phenomena, from aerosols in the upper atmosphere to cloud droplets, pollutants, and Earth's protective layer of ozone. Future lidar instruments will be tailored to specific purposes.

NASA Langley engineers are currently building lasers with different characteristics for remote sensing needs. These lasers are very specialized, one-of-a-kind instruments which often require uncommon wavelengths and unusual pulse or light burst formats. They must be able to survive the rigors of launch and the harsh space environment and operate reliably for long periods. NASA Langley's goal is to have a laser operating unattended in space for five years, or an equivalent of five billion pulses. NASA Langley scientists have already tested a laser's ability to pulse that number of times. The next step is to have it do so in space.

NASA Langley engineers are designing a laser to measure wind velocity. Global wind-velocity measurements taken from space help determine air circulation. Such knowledge would improve weather forecasting and determine the path of severe storms more accurately. Local air or ground readings would enhance aircraft safety by

In 1994 the LITE instrument flew aboard the Space Shuttle Discovery. An international team of scientists at over 50 locations around the world helped collect data to confirm the measurements taken from space.
determining hazardous wind conditions. Laser wind sensors can detect strong downdrafts called wind shear, which have been implicated in fatal airplane crashes. These lasers would also improve airport terminal efficiency by offering better information to those making air traffic decisions. This more sophisticated laser can determine vortices (horizontal tornadoes which are generated off the tips of larger airplane wings) which can upset smaller aircraft landing too close behind. These lasers can also determine when vortices are dispersed by local wind conditions which would allow smaller aircraft to land more efficiently.

NASA Langley engineers continue to develop more sophisticated lasers to measure atmospheric water content. These instruments would provide information for longer-term rain forecasts which could improve the allocation of already scarce water resources.

Laser technology is also being developed for potential future missions to measure ozone and other greenhouse gases which are main contributors to global warming and cooling. It is important to understand more about these atmospheric constituents in order to understand and respond to global climate changes. NASA Langley is helping the U.S. in a joint project with Canada to develop spaceborne laser missions to learn more about atmospheric ozone. This international effort comes after satellite data has recorded ozone depletion near both of the Earth’s polar regions. An advanced lidar system called ORACLE (Ozone Research with Advanced Cooperative Lidar Experiments) will provide key information needed for understanding global change, atmospheric, chemistry, ozone depletion, meteorology and other environmental issues.

In response to the increased concern for Earth’s atmosphere, NASA Langley is researching new ways to collect and analyze this important data. As researchers develop the technology necessary to do this, they bring us closer to understanding how to protect our atmosphere.

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