German
Aerospace Center

Analysing the atmosphere – lidar technology improves safety in air transport

09 May 2011

The plume of ash from the Eyjafjallajökull volcano, seen from the Falcon aircraft during a flight on May 2, 2010.

Credit: DLR

After the eruption of the Icelandic Eyjafjallajökull volcano in April 2010, a cloud of fine-grained ash particles spread quickly towards central Europe. Large segments of the airspace were closed by the authorities because the engines of aircraft flying through ash clouds had been repeatedly damaged on previous occasions. Using lidar technology, scientists of the DLR Institute of Atmospheric Physics helped to re-define safety thresholds in aviation so that more far-ranging airspace closures could be avoided.

From April 15 to 20, 2010, 75 per cent of the European airspace remained closed. More than 100,000 flights were cancelled, 10 million passengers were stranded. The damage caused to national economies was immense, and airlines suffered turnover losses of up to 2.5 billion Euros. That they did not have to pay an even heavier penalty is partly due to the timely efforts of DLR scientists who measured the particle density and the spread of the ash cloud with lidar technology from a research aircraft. On their flights, they repeatedly but cautiously dipped into the ash cloud from above to measure the concentration of particles directly.

Lidar (light detection and ranging) works like radar (radio wave detection and ranging), the only difference being that it uses highly directional, coherent light waves instead of radio waves. These light waves are generated by a laser (light amplification by stimulated emission of radiation) working within a narrow frequency band. Whenever a laser pulse encounters atmospheric elements such as particles of dust or air molecules, a minute fraction of it will be reflected. The lidar uses a telescope and a highly sensitive detector to register such reflections. The distance to an object can be calculated from the runtime of the pulse signal and the speed of light, while the intensity and frequency of the light scattered back permits drawing conclusions regarding the object's properties and state of motion.

DLR has been actively engaged in lidar research since the early 80s. The first measurements of the back-scattering of light by aerosols were taken on the Falcon research aircraft. Since that time, both the efficiency and the range of applications of these measuring systems have increased considerably.

Scientists from two of DLR's main research areas, astronautics and aeronautics are involved in this project, which at the same time forms part of DLR's security research, a cross-departmental programme under which defence and security-related research and development activities are being planned and controlled.

Versatility in application

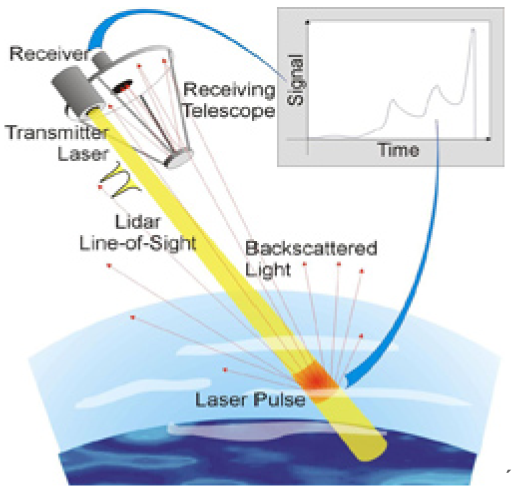
DLR's research aircraft, Falcon 20-E, as used during the volcanic mission, complete with instruments attached to the wings, a nose mast for wind and pressure measurements, and air intake vents.

Credit: Sergio Domingos/www.airliners.net

Since the early 80s, DLR's lidar department at Oberpfaffenhofen has been working on ground-, aircraft- and space-based lidar systems. They serve to detect meteorological parameters as well as trace gases in the atmosphere from a distance. The results they produce are used to explore our weather and our climate, and there are other conceivable applications besides: in the case of a nuclear accident, for example, lidar technology might be used to gather meaningful information about the position and concentration of radioactive clouds.

And there are yet other ways in which the lidar systems developed by DLR may enhance air traffic safety in the future. Aeronautics experts predict that they will acquire great importance in the next few years because they may serve to avoid capacity bottlenecks in the sky without infringing any of the stringent safety standards. Thus, the I-Wake EU project laid the foundations for the development of a warning sensor to identify the wake vortices that trail behind large aircraft.

WALES (water vapour lidar experiment in space) is designed to measure the concentration of water vapour, ozone, carbon dioxide, and methane and to determine the properties of aerosols and ice clouds. Natural-gas pipelines, for example, are being monitored from helicopters even today; the CHARM (CH4 airborne remote monitoring) lidar device used is capable of detecting even small methane leaks from pipelines.



Lidar layout.
Credit: ESA

Earth observation from space

Satellite-based lidar instruments have been observing the Earth for some time, including two lidar systems designed to determine polar-ice and aerosol-altitude profiles, ICESAT and CALIPSO, which have been in orbit around Earth for some years. A satellite system for measuring horizontal wind profiles called ADM-Aeolus will probably be launched into a near-Earth orbit by the European Space Agency (ESA) at the end of 2013.

In space, the high-energy lasers of lidar systems have to meet extremely stringent requirements regarding reliability, service life, pulse energy, beam quality, etc. There is still an urgent need to further develop these systems which are exposed to extremely great stresses in operation. Therefore, DLR actively supports the development of space-specific high-energy lasers as well as other technologies that are of importance for the operation of lidar instruments in space.

The lidar principle

The transmitter consists of a laser system emitting light pulses, which are partly backscattered within the atmosphere. Part of this light returns to the receiver (a receiving telescope and photodetector). The measured signal, as a function of signal runtime, is used to determine the distance of the target from the laser as well as some of its properties.

Contacts

Dr.rer.nat. Gerhard Ehret
German Aerospace Center (DLR)
Institute of Atmospheric Physics, Lidar
Tel.: +49 8153 28-2509
Fax: +49 8153 28-1841
gerhard.ehret@dlr.de

Prof.Dr. Markus Rapp
German Aerospace Center (DLR)
Director of the DLR Institute of Atmospheric Physics
Tel.: +49 8153 28-2521
Fax: +49 8153 28-1841
markus.rapp@dlr.de

Contact details for image and video enquiries as well as information regarding DLR's terms of use can be found on the DLR portal imprint.