Sensing and Monitoring Volcanic Ash for Air Travel Safety Using LabVIEW and PXI

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- Patrick Chazette, CEA/DSM/LSCE

The Challenge:
Locating residual layers of volcanic ash plumes accurately to assist in monitoring European airspace.

The Solution:
Using NI LabVIEW and PXI instruments to develop a light detection system rugged enough to detect ash distribution on demanding airborne missions.

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The eruption of the Icelandic volcano Eyjafjallajökull disrupted air travel across western and northern Europe in April and May 2010. At the request of the French government, various agencies set out to detect and characterize the volcanic ash over French airspace. The National Center for Research (CNRS), French Meteorological Service (Météo France), National Center for Space Studies (CNES), and French Aircraft and Environmental Research (Safire) used a Falcon 20 aircraft to conduct scientific flights for the mission (Figure 1).

The team based the airborne monitoring system on a light detection and ranging (LIDAR) system from Leosphere's optical head. The Atomic Energy Commission and Alternative Energies (CEA) and CNRS developed the LIDAR system in 2004 to control atmospheric particle pollution. The CEA evolved the instruments to be used for mobile applications such as cars, weather balloons, ultra light aircrafts, and oceanographic vessels for environmental and climate studies.

Controlled with LabVIEW graphical system design software, the LIDAR system includes three subassemblies for active remote sensing, which consist of a transmitter (laser), receiver (telescope or refracting telescope), and signal acquisition hardware (Figure 2).

The laser pulses at a broad frequency ranging from several to thousands of Hertz. We required a frequency of 20 Hz for the volcanic ash monitoring application. The laser transmission is synchronized with the time base of a digitizer, and the beam is transmitted to the atmosphere where it interacts with the air molecules, aerosols which volcanic ash are part of, and clouds. From this interaction, a small portion of the incident photons is backscattered to the receiver and converted into voltage by the chain of acquisition via the photomultiplier and digitizer. The user-defined width of the laser ray and sampling frequency determine the vertical resolution.

The original LIDAR, manufactured by Losphere, included an NI PCI-5122 14-bit digitizer integrated into a PC. However, to develop a system best suited for an airborne mission, the research team customized the LIDAR by choosing NI PXI instrumentation for better resistance to vibrations and shocks in the rugged airborne environment. The team used an NI PXI-1000B chassis capable of housing eight PXI modules. We implemented an NI PXI-5124 12-bit digitizer module to take measurements with a vertical resolution of the 0.75 m LIDAR with 200 MHz sampling, which gave us the ability to detect surface structures.

The digitizer acquires LIDAR signals simultaneously with GPS coordinates and flight parameters such as pitching, rolling, and heading. Data are transferred between the instruments and the PXI module through an NI PXI-8430/4 RS232 interface data acquisition (DAQ) module. We also selected an NI PXI-6221 DAQ module to control voltage on the photomultipliers of the LIDAR chain of detection and generate a TTL signal to synchronize the laser transmission and the digitization.

An Evolving Operational System

The LIDAR system based on LabVIEW acquired data that made it possible to accurately locate residual layers of plume from the volcanic ash in French airspace and above the Atlantic Ocean. Figure 4 demonstrates an example of plume detection and ash filament for a Falcon 20 flight on May 11, 2010.

The LIDAR provides information on the presence or absence of ash, but cannot determine the chemical nature or concentration of the ash. This requires additional chemical and size distribution measurements taken by another aircraft – the ATR 42 from the Safire unit. The research team coordinated flights of the two aircraft to extract as much data as possible and evaluate the volcanic ash mass concentration.

Because the research team customized the LIDAR system and added PXI modules for vibration resistance, we were able to accurately pinpoint ash plumes and assist the government in securing French airspace. The seamless integration between LabVIEW and PXI made customizations easy and gave us the ability to react quickly in the event of an environmental disaster. In addition, the solution is available for immediate use if a new volcanic eruption occurs. The team plans to make improvements to the control panel to display critical flight parameters in real time, including aircraft altitude. In addition, we will integrate a new inertial navigation system in the LabVIEW environment.

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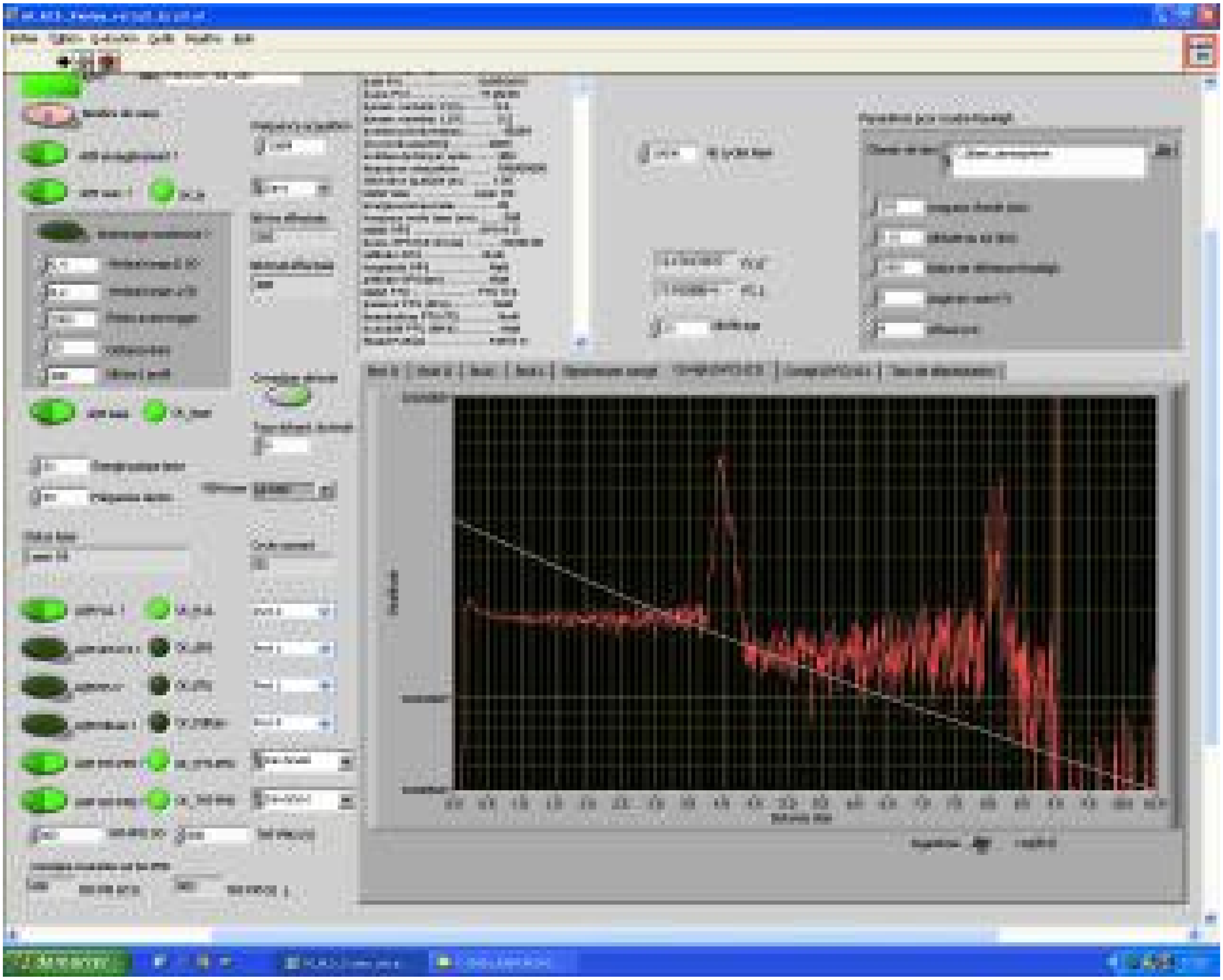
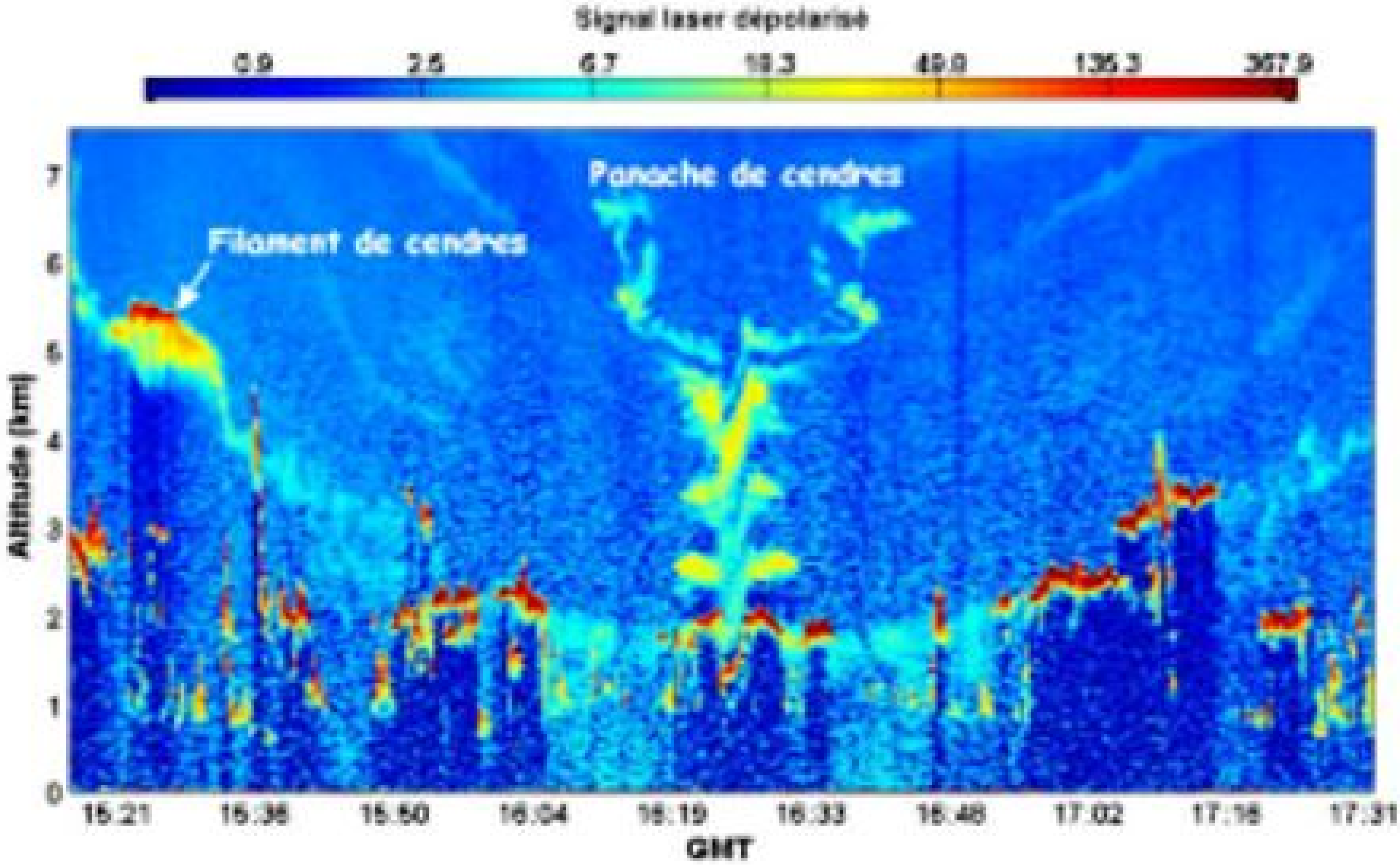
In the view of the LIDAR installed in the Falcon 20 aircraft in the Safire unit, the silica window makes it possible to maintain laser beam quality. ©Chazette



In the LabVIEW application in the LIDAR system, two layers of particles are visible as well as the surface echo on the Atlantic Ocean (far right).



Ash plume visible on the depolarization channel of the LIDAR system; the ash is not spherical so it will depolarize the laser light.
