Christine Boomer, senior marketing manager, Micro Pulse LiDAR, part of Hexagon

FINGER ON THE PULSE

Icing is a very serious problem for smaller fixed wing aircraft, helicopters and drones. A new method of supercooled water detection may provide an answer

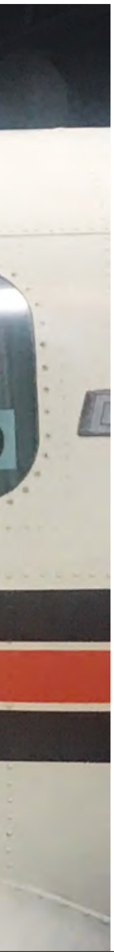
Miles above Earth, aircraft encounter a variety of challenging weather conditions, including wind, rain, snow, clouds, lightning and extreme cold. A particularly dangerous situation occurs when supercooled liquid water (SLW) freezes onto the wings and bottom of an airplane. This accumulation of ice changes the airflow, reduces lift and increases drag and weight, making flying difficult and dangerous. Although de-icing before take-off is a standard procedure when icing conditions are forecast, once a plane is in the air there is no effective method to directly detect SLW and avoid icing en route.

For fixed wing aircraft alone, the US National Transportation Safety Board (NTSB) reported that from 2010 to 2014 there were 52 inflight icing accidents resulting in 78 fatalities. For rotary wing aircraft, where there is much less wing surface area and the aerodynamics of the equipment is more sensitive, the icing threat is even more pronounced. In lieu of a foolproof method of de-icing in the air, more accurate real-time measurements of cloud characteristics and identification of icing potential using remote sensing techniques would help pilots avoid threats before an aircraft encounters a problem.

CLOUD EXPERTISE COMBINED WITH LIDAR TECHNOLOGY

An investigation into combining data from existing sensors to successfully identify ice clouds is being pursued by Richard Stone, owner of RHS Consulting, and Justin Fisher, director, Micro Pulse LiDAR, part of Hexagon. Stone is a weather modification expert who flies in icing conditions routinely and has been studying and interacting with clouds for over 30 years. RHS Consulting provides operational cloud seeding and weather research services, which are in demand on a global scale to meet agricultural needs in increasingly dry regions.

"Cloud seeding and ice cloud avoidance are both applications that rely on measuring the size of water droplets – one to find water and one to avoid it," says Fisher. "By using our



Mini Micro Pulse lidar installed on an RHS cloud seeding aircraft

> "Even a low SLW content cloud can create hazardous conditions if you fly through it for long enough"
>
> Richard Stone, owner, RHS Consulting

Mini Micro Pulse Lidar technology (MiniMPL), we felt there was a great opportunity to reach a new level of understanding about the SLW content of clouds based on Stone's experience in searching for cloud moisture."

Cloud seeding involves locating excess moisture in clouds. When silver iodide particles are introduced into a cloud, the available moisture condenses and freezes around the particles, and the resulting ice crystals grow and fall to the ground. To identify the best rainmaking opportunities with current methods, pilots rely on weather forecasts and sensors mounted on seeding aircraft to measure cloud moisture content and temperature. These measurements are restricted to thin ribbons in the sky that an aircraft has already passed and don't provide advance warning of hazards.

Remote sensing offers a huge advantage for detecting icing before an aircraft passes through icing conditions, and provides an opportunity to avoid the conditions altogether. The MiniMPL specializes in identifying cloud particles as ice crystals or water droplets and quantifying these particles in the cloud from a distance. This hasn't been possible using current methods. Ice crystals by themselves don't present a hazard to aviation, so being able to detect the difference between SLW drops and ice crystals is crucial.

"Even a low SLW content cloud can create hazardous conditions if you fly through it for long enough, so you really need to identify all the types of particles, and their sizes and density, to improve your chances of successful rainmaking or avoid icing conditions for general aviation," explains Stone. "The MiniMPL offers that opportunity."

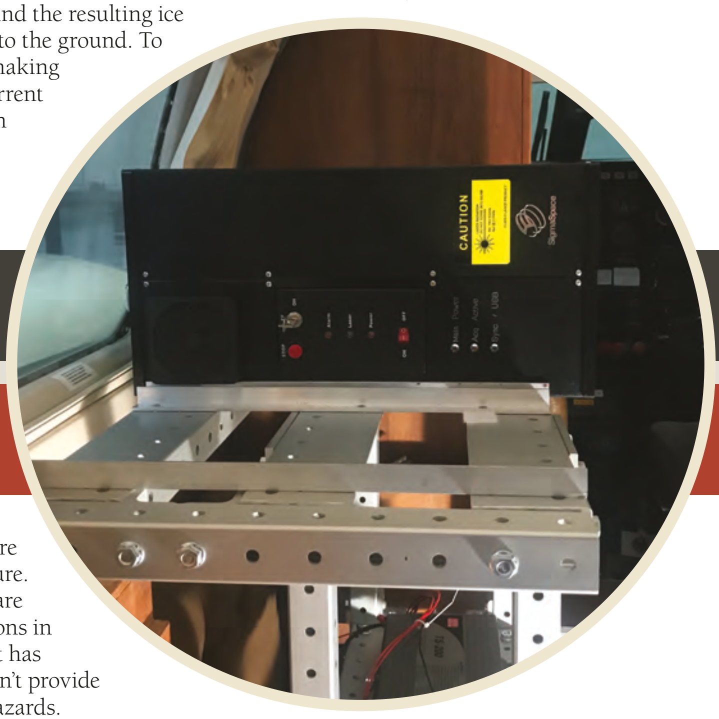
WHAT CAUSES DANGEROUS ICING?

Along with seeking better cloud seeding methods, aviation safety is a major concern. Clouds are composed of water droplets that can stay in a liquid state at below normal freezing temperatures. If an airplane runs into these SLW droplets, they freeze to the surface of the aircraft. Larger droplets don't freeze immediately and will bleed back from the leading contact edges and freeze on the underside of wings and airframe.

Specifically, supercooled water droplets larger than 30µm create the biggest hazard for aircraft. Smaller droplets can also stick to the leading edges of wings, but wing de-icing systems are designed to shed the moisture. Large droplets present a much more dangerous situation because they can accumulate all over the aircraft, where there are no systems in place to remove the ice. Accumulated ice makes flying much more difficult. Aircraft are particularly vulnerable when flying slowly, at less than 300mph (483km/h), which is the situation when they are preparing to land. Avoiding these icing conditions entirely is the best option.

"Icing is a very serious problem, especially for smaller fixed wing aircraft, and even worse for rotorcraft," says Stone. "Drones also are negatively impacted in icing conditions, particularly because a remote operator cannot actually feel how the aircraft is flying or see icing on the wings. If ice accumulates rapidly, an operator can lose control with no indication of a problem."

Current onboard systems available for aircraft only detect icing once it has already formed on the hull or wings. Weather charts, pre-flight planning and briefings from meteorologists are used to predict where there might be problems during a flight, but often the pilot resorts to looking out the window to assess the situation. This tactic is not especially helpful at night.



The Mini Micro Pulse lidar fixed to a custom bracket for test flights

MINI MICRO PULSE LIDAR DELIVERS REAL-TIME UPDATES

To provide a solution to the vulnerability of aircraft to icing, a sensor is needed on the aircraft that identifies cloud content and measures droplet size in the air space far enough ahead of the plane that the pilot can alter course to avoid potential ice hazards. For several years Sigma Space (now part of Hexagon) has been experimenting with different wavelengths on the MiniMPL and flying lidar and other instruments to feed data into algorithms. By adding RHS Consulting to the effort, the research team reaps the benefits of Stone's many years of studying clouds in search of better ways to deliver moisture to the ground.

In late March 2018, Stone tracked a fast-moving set of medium-sized vorticity centers passing over the Sierra Nevada

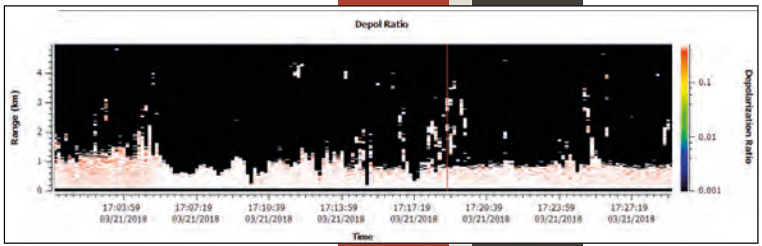


Figure 1: Depol ratio from test flight #1 still able to detect ice droplets up to 5km (3 miles), even with bias from plastic window

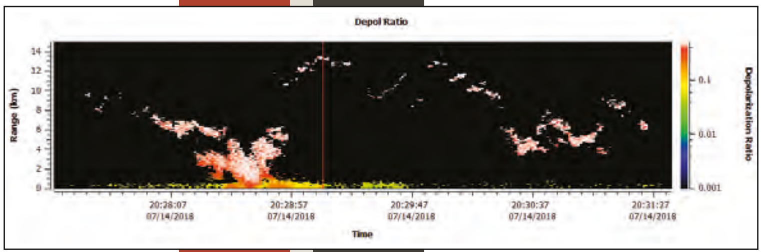


Figure 2: Test flight #2 data showing greatly improved resolution and cloud detection

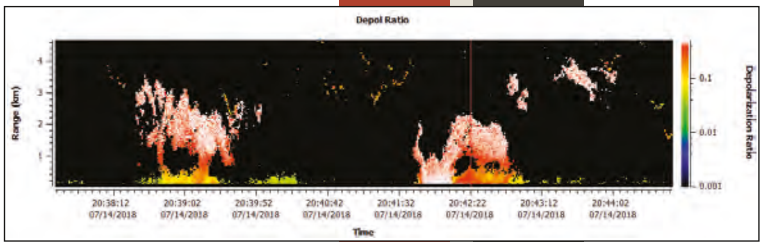


Figure 3: Test flight #2 data showing multiple cells

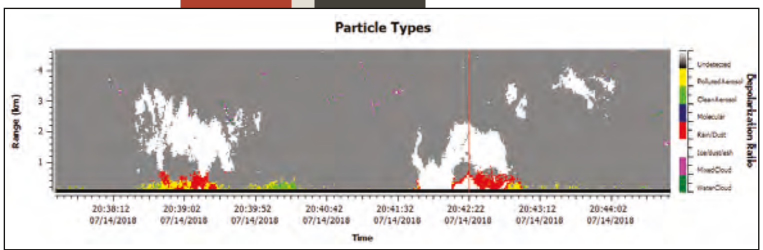


Figure 4: Cells classified. Future advances will enhance range and mixed phase detection limits

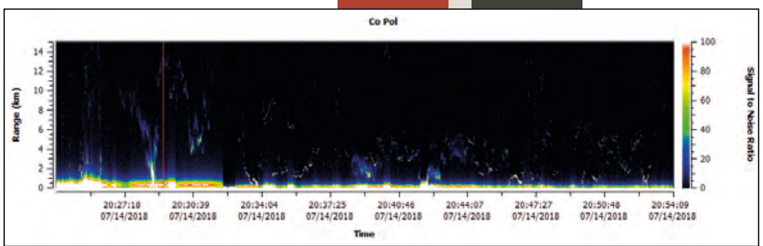


Figure 5: Glass window solved CoPol signal issues and greatly improved the range of detection

mountains near Minden, Nevada. Moist southwesterly flow continued across the Minden area as a ridge strengthened over the Rockies and a deep trough rotated eastward across the California coast as the storm came on shore. The storm looked suitable for a test flight, so Stone took off with a variety of sensors, including a MiniMPL and a G-band radiometer that provides data complementary to lidar and senses moisture at longer ranges.

Raw data from the MiniMPL viewed onboard showed it was detecting ice and water droplets up to 5km (3 miles) from the aircraft (Figure 1). This compared with a 15km (9-mile) range when the unit was operated at the hangar, viewing wave clouds from the surface instead of through a plastic window. To improve the sensor's viewing range in the air, and remove potential depol bias, the plastic viewing port on the aircraft was replaced with optical glass. With the addition of a suitable glass view port, a detection range of 15km (9 miles) is reached and has significantly improved depolarization measurements (Figures 2-5).

The depolarization ratio provided by MiniMPL is used to characterize hydrometeor type, such as droplets, raindrops and ice crystals, as a function of time and range. The dual polarization backscatter measurements enable very high accuracy – better than 0.7%. The data enables operators to discriminate between the occurrence of pure water clouds and the presence of dirt/water cloud mixtures, with measurements and analyses completed and reported in seconds.

The initial test flight data was collected with a 10-second sample integration time and 15m (49ft) range bin size (Figure 1). After replacing the window, subsequent data was collected at one-second sample integration times and 5m (16ft) range bins to improve resolution, and enable more detailed analysis. As testing continues, results from different wavelengths and multiple sensors mounted on various parts of the plane will be investigated.

"Future designs of an ice cloud detector could include multiple wavelengths in a MiniMPL sensor on a pivoting gimbal that is able to point straight ahead for flight, then switch to nadir and zenith for landing and take-off, respectively," explains Fisher.

ENCOURAGING RESULTS

Several key factors that influence icing on aircraft – particle concentration and particle size – are measurable with the MiniMPL to a high degree of accuracy. In addition the MiniMPL has a range of up to 15km and the data can be processed within seconds – both valuable features for a remote sensing solution that will help pilots detect and avoid ice clouds.

The detailed analysis of the first trial flights by RHS Consulting shows that most of the cloud was classified as ice with some mixed phase and SLW droplets interspersed throughout. Understanding the characteristics of each cloud, along with wind speed, temperature and other measurements, supports good decision making and maintains safety standards.

"The MiniMPL technology is showing a lot of potential on board aircraft for improving remote sensing to provide early warning for icing hazards," says Stone. "I also find the level of detail the data provides, used in conjunction with other sensors, to be very useful for our cloud-seeding activities." ∎