All photos courtesy of FLARM

Soaring Safe

Lightweight Collision-Avoidance System

Alan Cameron

Quick — how many life-saving decisions can you make in 18 seconds? Pilots often must take such rapid action, especially when other airborne bodies suddenly come too close. This can happen in an eyeblink aloft, as pilots must concentrate on a multitude of sensory data, instrument readings, and other data.

Commercial aviation requires large aircraft to carry air collision avoidance systems (ACAS), based on powerful onboard primary radar interrogating nearby transponders similar to ground-based radars. Aircraft in the General Aviation category — all flights other than scheduled airlines and military planes — typically do not carry such large, heavy, and expensive systems. So pilots of small planes, helicopters, and gliders, all of whom operate under Visual Flight Rules (VFRs) live by their eyes only.

Now a newly designed Swiss system uses GPS to add a significant measure of safety to such airborne adventures.

Each year, about 20 mid-air collisions occur in General Aviation, half of them fatal to pilots. One-third of these collisions involve gliders. There is an acute need for a reasonably priced system with a small footprint and low energy consumption, that effectively and efficiently warns pilots of dangerous traffic in the area and thus optimally supports them in airspace surveillance.

To Market

Drawing from their professional backgrounds, electrical engineer Urs Rothacher and physicist Andrea Schlapbach, both experienced glider pilots, designed a lightweight GPS-based flying alarm system dubbed FLARM (see **Figure 1**).

"These were our challenges," said Schlapback. "First, understand the problem and the users in detail — largely a non-technical issue. Then, define the requirements. This includes aircraft movement models, behavior patterns of aircraft and pilots, such as local aircraft clusters, frequent exchange between potential and kinetic energy, frequent speed and track changes, team flying, and ridge-soaring dynamics. Also, installation factors such as vibration, size, power consumption, and voltage spikes, and environmental aspects such as sunlight, heat, and reflections.

"Finally, choose appropriate technologies to meet our requirements: radio band and frequency, range considerations, radio protocol layers, transceiver, GPS Kalman filters, and more," he added.

Rothacher and Schlapback introduced their first product in early 2004. Within six months, half of the Swiss glider aircraft population had been equipped with FLARM. By spring 2005, more than 2,500 FLARM devices were in use in Germany, France, Switzerland, Austria, New Zealand, and South Africa. Recently the Swiss Air-Rescue (Rega) adopted the FLARM anti-collision device for the 10 rescue helicopters it operates from several bases in Switzerland transporting medical assistance to the scene of an accident.

How It Works

The device utilizes position and movement information obtained from an integrated WAAS-enhanced GPS receiver and an embedded barometric sensor.

Internal algorithms predict a glider's future flight path and the unit transmits it over low-power, short-range radio as a very short digital message once per second. Other compatible units within range receive these messages and compare them with their own predicted flight paths.

Each aircraft also compares its own flight path with a stored database of fixed obstacles in the area, such as cables, antennas, aerial railways, and power lines.

If the FLARM system determines a dangerous approach, it warns the pilot with an audio alarm and a bright multi-LED display indicating the direction of the target and the time to impact. It gives directional advice in horizontal and vertical planes. The first alarm level usually is issued 18 seconds prior to potential impact.

Not By Distance Alone. In the Alps and other popular gliding regions, and during gliding competitions, concentrations of 20 or more aircraft riding a single thermal up for height are not uncommon. Alarms based on proximity alone would be useless in these cases, as they would constantly go off. False alarms can be reduced by smart motion prediction that only warns if future flight paths will cross in close proximity, but a high relative accuracy of the position and especially the height is also very important. Thus the key role of GPS in the system.

FLARM can handle more than 50 aircraft inside its 2–3 kilometer range, which may vary according to antenna installation. The system is intended to support a VFR pilots, but it cannot take over their duties.

If the system issues an alarm, it asks the pilot to visually check for approaching aircraft in the indicated direction and further intensify airspace scanning. The system does not recognize any other aircraft not equipped with a compatible device.

"We selected the GPS receiver for different reasons besides size, power consumption, receiver sensitivity, price and availability," stated Rothacher. "We were looking for a GPS with fast times-to-first-fix (TTFFs) from cold-start without any aiding (no almanac data, no ephemeredes data, no time, no rough location) to reduce the parts needed (battery, own real-time clock), with a PPS available and a GPS with Kalman filters that are suitable for our aviation movement models.

"Most inexpensive GPS are optimized for ground and vehicle applications, therefore vertical position, velocity, precision and stability are not adequately addressed. Even with the chipset we selected and in aviation dynamic modes, horizontal errors are reduced for the sake of vertical error."

Second Filter

"To enhance the vertical data further, we built a second Kalman filter after the GPS' own Kaman filter, where barometric and GPS-altitude data is dynamically corrected, partially based on VDOP and vertical accuracy estimates.

"It's important that we have very little relative vertical error when two aircraft are close-by; absolute errors are not as important," Rothacher added.

"Differential effects do not always help us because aircraft bank when flying a curve and this may produce different sky-views, so those two aircraft might base their GPS navigation solutions on non-identical sets of satellites, and the differential effect is lost."

The system's software modules (see **Figure 2**) include radio reception/transmission; data preparation; own track prediction (defines current energy altitude and appropriate vertical and lateral safety cushions, also based on movement model, flight mode and GPS HDOP, VDOP, and accuracy, then predicts its own future 3D flight path); obstacle database query; and danger-level assessment.

In the Air. "On a good soaring day, I was flying in the Austrian Alps," reported glider flight instructor Hans Fitterer, "when FLARM automatically switched from traffic to caution mode, beeping loudly while displaying a target at 11 o'clock, slightly below my own flight path. Some seconds later, it switched to warning mode.

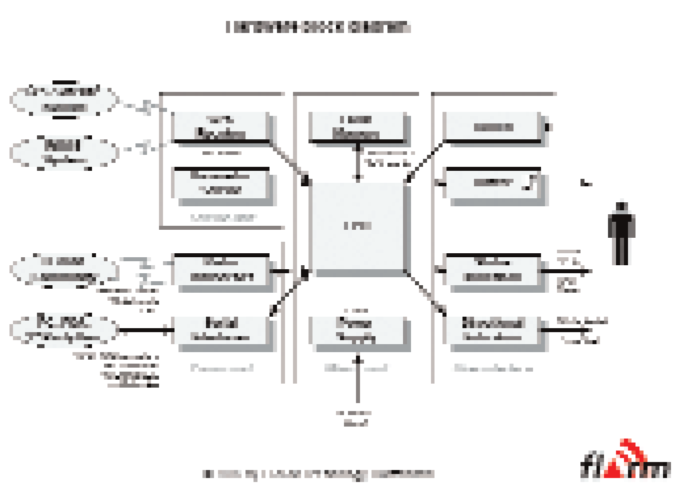
"Despite my intense visual search for the opposite traffic, I did not find the target, so I pulled up a bit with a bank to the right side. The target on my display moved to the left, as expected, and finally I saw the other aircraft passing by — closer than 100 meters away. Without my intervention, we would have been very close." ⊕

▲ **THE FLARM SYSTEM** mounted atop a glider pilot's instrument console, with the man serving as a second pilot or passenger

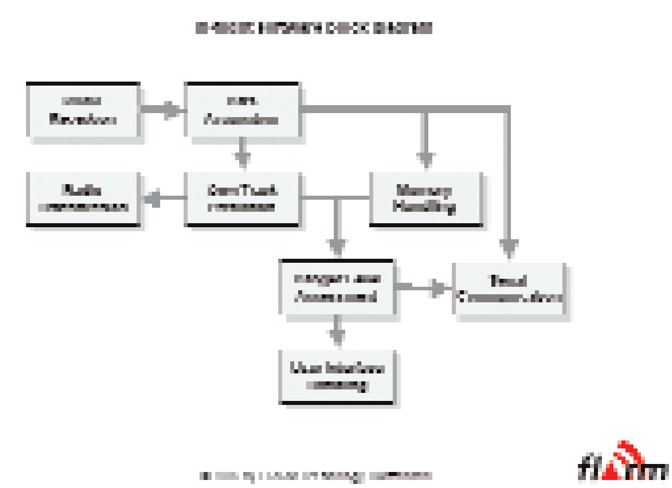
Manufacturers

FLARM uses a a 16-channel *TIM-LP* GPS chipset from **u-Blox AG** of Thalwil, Switzerland. FLARM is a non-profit society, founded by glider pilots, to develop and distribute affordable collision warning devices at cost.

ALAN CAMERON is Senior Editor of *GPS World*.



▲ **FIGURE 1** depicts how FLARM hardware components integrate.



▲ **FIGURE 2** System software modules