Alaska: Pioneering new vision for pilots

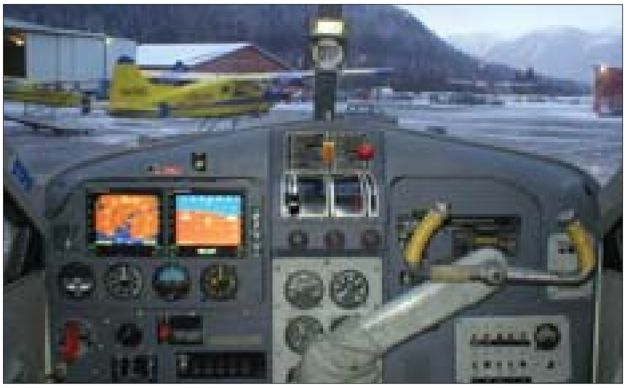
Like mice in a granite maze, commercial pilots who fly small unpressurized aircraft—and provide 90% of Alaska's population with food, mail, and supplies—are often forced to navigate precipitous terrain and narrow, dog-legged mountain passes at breakneck speeds as they move people and goods throughout the region.

The task is manageable enough when the weather is good. In bad weather, however, it becomes the subject of all too many accident reports. While the names change, the scenarios and causes are often the same:

"The route of flight was along fjord-type terrain, consisting of steep mountain slopes above a long inlet of water….The airplane did not arrive at the intermediate airport (about 10 minutes' flying time down the fjord from the departure point), and no further communication was received. An aerial search located the wreckage in an area of steep forested terrain, 300 ft above the inlet water….Low cloud conditions prevailed along the route of flight."

That National Transportation Safety Board report describes the fate of a Piper PA-32 single-engine, six-seat aircraft that crashed in Haines, Alaska, on January 15, 2002, killing the commercial certified air taxi pilot, the plane's sole occupant.

A de Havilland Beaver, part of the Capstone 2 program, sports its brand new high-tech panel built by Chelton Flight Systems.



The accident rate for commercial pilots in Alaska is abysmal in comparison to that of mainland U.S. pilots. The most recent national accident statistics from the NTSB show that in the first six months of 2002, there were 26 nonscheduled air taxi accidents in total, 10 of which occurred in Alaska (38%); there were three scheduled air taxi accidents nationwide, two of which happened in Alaska as well. In 2003, the FAA reported an overall decrease in the number of light aircraft accidents in Alaska, but an increase in the number of fatalities.

A new approach

Rather than accept wanton destruction as inevitable when man and machine meet untamed country, the local FAA authorities in the 1990s decided to accelerate the rate at which new safety-enhancing technologies could be placed in cockpits. The latest flight deck entrant—a synthetic vision system—will give a select group of Alaska's commercial pilots an artificial but accurate sense of the terrain ahead no matter what the weather outside the windscreen. This should bolster position awareness and, ideally, cut down on the number of accidents.

In a larger sense, the system's introduction will make Alaska a kind of incubator for how computer-generated renderings of the real world may come to revolutionize airborne navigation throughout the U.S. and the world by giving pilots a clear "view" of the surroundings at all times.

"Alaska is the perfect place to stress the system to the max—and to take the lessons learned to the lower 48," says Dejan Damjanovic, head of air and marine transportation solutions at Colorado-based Space Imaging. Damjanovic has been working with the FAA and NASA to provide high-resolution 3D terrain, obstacle, and airport databases for synthetic vision applications.

Capstone's progress

As part of a project the FAA calls Capstone 2, the government is installing, free of charge, synthetic vision and moving map displays built by Chelton Flight Systems of Boise, Idaho, into as many as 200 aircraft of commercial operators in the Juneau area of southeastern Alaska. The $75,000 Chelton synthetic vision system, which replaces traditional "steam gauge" dials and gauges, features two liquid crystal displays that can present data in ways seen before only in research applications and video games.

The Chelton system shows the pilot a flight path marker with a blue sky above and a terrain below fashioned from a "fishnet" grid drawn over a brown background. It also displays a highway-in-the-sky flight path indicator—a series of boxes through which the pilot flies to track a preprogrammed course from takeoff to landing, a much easier task in bad weather than navigating through space using the needles and dials of heritage avionics. Accompanying the synthetic view is a navigation display that shows a top-down 2D view of the ground, where the color of the terrain indicates its distance below the aircraft.

As part of Capstone 2, the FAA plans to equip about 150 aircraft and 50 helicopters with Chelton synthetic vision systems, which include the Capstone 1 features, under the $4.7-million contract. Under Capstone 1, the FAA equipped commercial operators in Bethel, Alaska, with a GPS-based moving map showing aircraft position, weather information, and real-time locations of similarly equipped aircraft via a network of ground stations. These stations also relayed position reports back to air traffic control—a bonus for search and rescue expeditions if a Capstone 1 plane should go down.

Several dozen installations have been completed so far. The FAA estimates that

Capstone technologies as a whole can decrease the accident rate by 38%, though it is too soon to know with certainty. One Capstone 1-equipped aircraft has crashed to date, killing the pilot, but authorities have not yet ruled on the cause.

Data technology advances

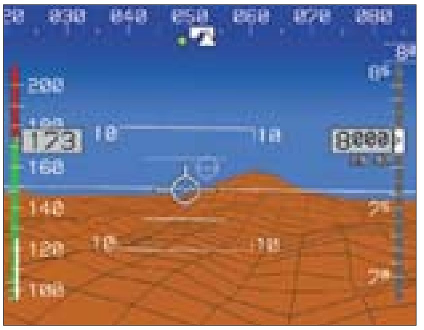
Interest in synthetic vision has increased in the aviation industry, fueled partly by the Alaska efforts and partly by the maturation and convergence of three types of digital data: position, attitude, and terrain. With position and terrain in the same reference frame, a computer system can render a 3D location in space; by adding digital attitude, it can construct a virtual view out of the cockpit window for the enroute, approach, or taxiing segments of a flight.

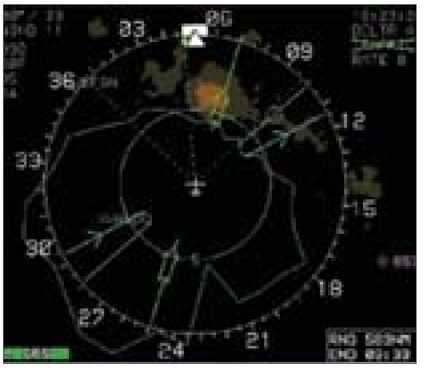
Digital position information accurate to 10-20 m is now readily available with low-cost GPS equipment; receivers that incorporate the FAA's Wide Area Augmentation System provide 3-m accuracy. Attitude, once the realm of analog gyroscopic gauges, is now available in digital format through Attitude/Heading Reference Systems, or AHRS.

Combined terrain, obstacle, and airport databases, on the other hand, are the least mature of the three technologies at this point. Honeywell was one of the first avionics manufacturers to invest company resources to make a digital terrain database, partly in response to calls for some type of onboard ground-awareness devices following the December 1995 crash of an American Airlines Boeing 757 near Cali, Colombia.

The crash, which killed 160 people, was blamed in part on the crew's lack of situational awareness of the mountainous terrain between the aircraft and the airport. Christine Ellis, Honeywell's database engineering manager, led a team that collected more than $1 million worth of terrain maps from governments worldwide and digitized the data as part of the company's effort to build a ground proximity warning system for airliners.

Because there was no single source for worldwide data, Ellis had to merge maps from the U.S. Geological Survey (USGS), the National Oceanic Atmospheric Administration, and those that could be purchased from foreign governments—a task made easier with the end of the Cold War in the late 1980s.





Chelton Flight Systems' synthetic vision system shows the pilot a "fishnet" representation of terrain on the primary flight display (top right) and a top-down view of terrain, with elevation-keyed color, on the navigation display (bottom right). Above is the actual terrain.

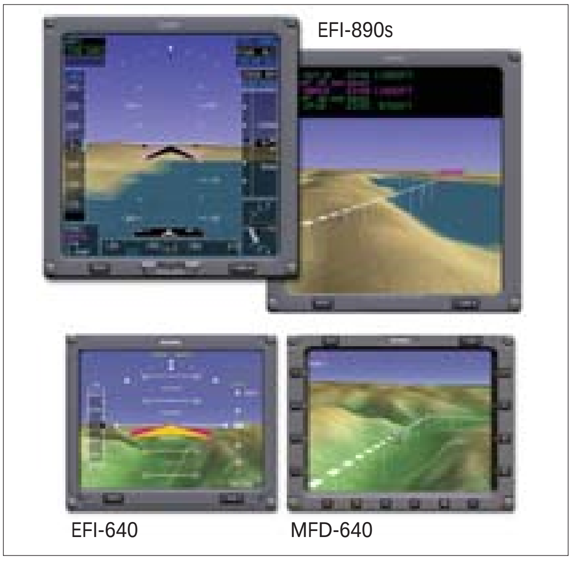
Ellis's database varies in resolution from 900 to 180 m, depending on the terrain of interest (water can be lower resolution, mountainous airports higher) and on the application (helicopters need the highest resolution database). While there are holes in the data, particularly for countries where the information is missing or falsely modified, Ellis says crews are "far better off" having the warning system than not.

After the Cali crash, it was clear that regulators would eventually require terrain warning systems—and hence, terrain databases—as standard equipment on commercial aircraft. Other avionics manufacturers began building the 3D terrain awareness databases as well, providing the seeds for synthetic vision systems. Chelton's combined terrain awareness and synthetic vision system earned FAA approval last year. It uses a 180-m resolution terrain database derived from USGS data, merged with a database on towers, buildings, and other obstacles. The latter is maintained by the FAA and the Federal Communications Commission.

The next step

Partly because synthetic vision is so new, but more so because of FAA concerns about the accuracy and resolution of terrain databases for anything other than ground proximity warning systems, any forward-looking synthetic vision systems approved for the time being—including those in Alaska—can be used as situational awareness aids only. This means pilots cannot legally fly

Universal Avionics is completing its FAA certification of a synthetic vision system that shows an egocentric view on the primary flight display and an exocentric view on the navigation display. The unit does not include highway-in-the-sky guidance.



an airplane using only the computer-rendered view of the outside world.

Going to the next step—using synthetic vision to navigate and land—will require proving to the FAA that the digital information is of the highest quality and truly matches terra firma.

"When you can validate the synthetic vision system with forward-looking radar or other schemes, then you'll see the doors open," says J. Lowell Foster, a flight test aerospace engineer with the FAA's small aircraft directorate in Kansas City.

NASA and the research community are spearheading efforts to populate terrain databases with more precise information and to find ways of locating the information while in flight. A proven way to boost the accuracy and resolution of 3D digital representations of the world is to use satellite and airborne remote sensing to build databases. These can include elevation data overlaid with imagery data (for photorealistic effects), obstacles, and airports.

Improving accuracy and resolution

A wealth of elevation data will soon be available from the government courtesy of the Shuttle Radar Topography Mission (SRTM), flown on STS-99 in February 2000. Using a radar system in the shuttle bay, the mission gathered 30- and 90-m-resolution elevation data between 60° North and 54° South latitude around the globe. The digital elevation maps, which are being released sequentially by country as officials verify the data, will offer an improvement in terrain elevation accuracy over traditional digitized maps, particularly in areas where government sources are less reliable.

Resolutions in the tens of meters will likely be adequate for using synthetic vision in the enroute segment of a flight. However, approaches to airports and taxi operations on runway surfaces will require a quantum jump in resolution—as will navigating through mountain passes in Alaska.

Several ongoing projects are providing a growing, albeit hodgepodge, collection of high-resolution data, as well as some techniques to update the information. Taken as a whole, the various projects are maturing the state of terrain, obstacle, and airport databases that are becoming available, although there is not yet a comprehensive library available that includes one database of all three.

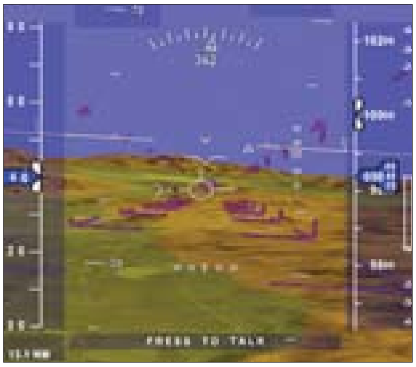
NASA activities

Intermap Technologies, an airborne mapping firm headquartered in Calgary, Canada, and Space Imaging are working with NASA to build high-resolution elevation and imagery models of 11 of the most hazardous mountain passes in Alaska. The effort began partly in response to rescue agencies in the state that wanted to make simulations available for pilot training and partly for synthetic vision research. "Aircraft attempting to transition these passes often crash due to adverse weather, the inability to climb, and simply being lost," Space Imaging's Damjanovic points out.

Intermap used SRTM-like sensors on its Learjet aircraft to collect digital elevation data for the passes. Space Imaging collected 1- and 4-m imagery using its Ikonos satellite (imagery overlays the elevation data to provide a photorealistic terrain texture). The cost for the service is quite high at the moment—NASA is spending \$3.4 million for 52,000 km^2 of terrain that encompasses the passes. The benefit of having the higher resolution data, however, is particularly noticeable in mountainous areas, where coarse data used as synthetic vision view may make a pass appear closed off when in fact it is a viable path.

NASA has been using the photorealistic data from one of the passes for human factors symbology studies to see how pilots react to different pathway guidance (highway-in-the-sky) displays when navigating in and around extreme terrain. The work complements other human factors research that includes finding the optimum field-of-view for the forward-looking scene, and the best texture for terrain, whether constant-color fishnet, elevation-based coloring, photorealistic, or a mixture of several.

NASA and Rockwell Collins will begin testing a database integrity system this summer. The system is designed to spot-check the accuracy of a synthetic vision database during approaches and landings in real time, as well as to reveal objects on the airport that cannot be found in a database—newly erected towers, construction cranes, and other aircraft. The integrity system will check to see that the relationship between the aircraft and the virtual terrain is the same as for the real world, within certain bounds.



NASA Langley continues to perform human factors research on which types of highway-in-the-sky guidance work best for pilots. This display, called the tunnel/dynamic crow's-feet option, indicates that the pilot is too close to the bottom of the tunnel and should increase altitude to get back to center.

For vertical direction, the system checks the database by computing the terrain height (GPS-derived altitude minus radar altimeter height) and compares it to the database terrain height at that instant. In the forward direction, the system will use a modified weather radar on the aircraft to measure the actual distance to terrain and obstacles (terrain shows up as a shadow in the weather radar return) and compare it to the database distance.

The test will also use weather radar to map out nontraditional targets—such as construction equipment on the runway—and to outline the runway edges for a real-time integrity check with the synthetic vision-rendered runway edges.

From a larger perspective, the NASA and Rockwell Collins test will also mark the first time anyone has integrated a full slate of synthetic vision products into one aircraft, in theory giving the pilots enough information to safely taxi, take off, and land with no windows.

Full-fledged systems with all of these bells and whistles will not likely hit the market for five or 10 years. But the pathfinders of synthetic vision are today flying on 27 aircraft near Juneau, Alaska, where, as one FAA official put it, "We needed this yesterday."

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