Illustration courtesy Honeywell

Elegant integrations enhance cockpit situational awareness

Decades of avionics research and development are about to yield full-time unlimited visibility.

By Alan Staats
Contributing Writer

One possible iteration of Honeywell's soon-to-be-unveiled technology package, which includes a synthetic vision system. Invited guests at this year's NBAA Convention witnessed a full-motion widescreen preview of the system. Typical reactions were highly favorable.

In many ways, 2005 has been a watershed year for avionics. Incredibly sophisticated and capable products literally decades in development by manufacturers large and small have begun practical field-testing—and the results are nothing short of spectacular. Data bus throughput and integration technologies now offer the opportunity for avionics manufacturers to compile, compute, compare, format and display enough information to make the term "flying blind" obsolete and offer the eventual prospect of full situational awareness for all.

And, because R&D efforts on many of the systems now coming to market began after the beginning of the "digital revolution," the architecture that forms the basic structure of these new systems was designed with virtually limitless capabilities. Rockwell Collins Pro Line 21 is a perfect case in point.

A Rockwell Collins white paper on the system's architecture, written in 2000, states this philosophy perfectly: "The system architecture definition is driven by several key attributes. These attributes include reduction of installed system cost, modularity of system elements to provide desired flexibility, maximizing the reusability of hardware and software system elements and system concepts and improvement of system availability."

As a result, operators of aircraft with earlier digital cockpits can look forward to exponentially increasing the overall capability of their aircraft at a far more economically pragmatic cost. In addition, operators of older but nonetheless capable and economical airframes are replacing their first and second-generation EFIS displays (and in some cases, their "steam gauge" displays) with avionics suites

Chelton Flight Systems' FlightLogic EFIS has its roots in the Sierra Flight Systems EFIS 1000 and 2000 displays, offered initially to the experimental aircraft community.

just as capable as those found on the newest offerings.

Integration is the key. Clearly, the days of flying blind will soon be a thing of the past for most of us.

The concept of the synthetic vision system (SVS) is not new. Several players in the avionics industry have been performing R&D work on viable systems for decades—in the past 2 years, the fruits of these efforts have begun to make a significant impact in cockpit display technology. Several SVSs have been certified already—Universal Avionics Vision-1 Exocentric View (which displays an aircraft pictogram from behind and to the right, along with database-generated terrain) received TSO-C113 authorization in Jun 2002, and in Oct 2005 the company's next-generation system Vision-1 Egocentric View (which presents a pilot's-eye view of terrain and navigation trend information) received TSO and STC approval.

Chelton Flight Systems (née Sierra Flight Systems) began fielding its EFIS 1000 and EFIS 2000 to the experimental market in 1997. It was an immediate sensation, as it provided builders with a display and navigation package that rivaled (and in some cases surpassed in terms of display symbology) the highest-end certified EFIS systems then available. In addition, EFIS 2000's "highway in the sky" (HITS) replaced traditional flight director cues with a series of boxes stretching out to infinity in the display, which would allow pilots to perceive present and future aircraft positions. When compared with terrain depictions, these would also inform the pilot where he was, and where he would be, relative to potential terrain hazards.

As an aside, HITS-type symbology is not a new concept. It was first postulated in a 1952 report by the US Army–Navy Instrumentation Program under the direction of George Hoover, which serves to illustrate how long some of the concepts now being developed have been studied.

Chelton now markets its descendant of the EFIS 2000—the certified FlightLogic Synthetic Vision EFIS that combines WAAS GPS, ARINC 429-capable ADC and digital AHRS, as well as "traditional" nav inputs, with data contained in a USGS terrain database to provide the topographical displays. While terrain display rendition is somewhat primitive in appearance when compared with, say, Universal's entrants, the system is extremely capable and reliable, provided that the terrain being overflown is contained in the unit's database—an area we will discuss later in this article.

The magic of integration

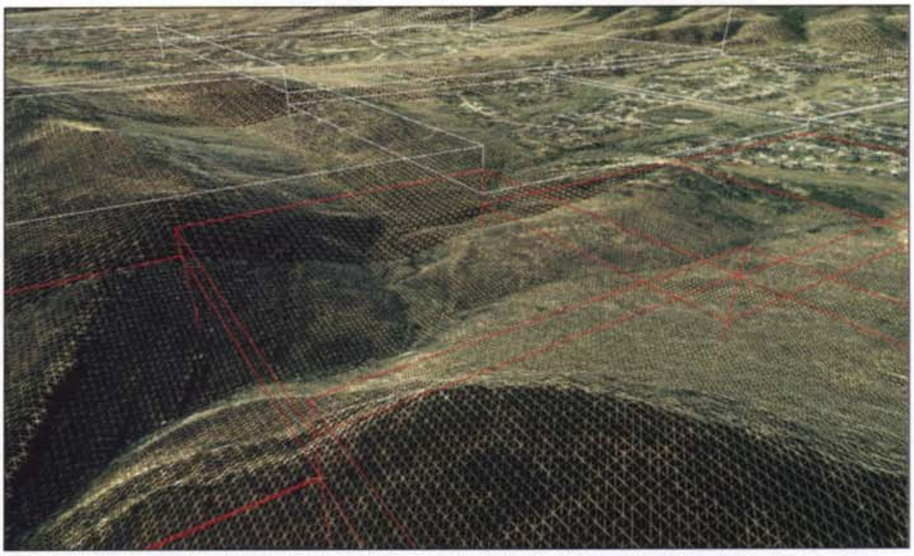
Concurrent with the development of SVS over the past 20 years has been the progress made in the areas of computer speed and data throughput, acquisition and management, as well as display hardware and rendering software. Today's digital data busses, capable of handling exponentially greater amounts of data at much higher speeds than their analog predecessors, have facilitated integration of these hardware and software advances, as well as data collected from external sensors, to the point where several manufacturers are now in the final phases of developing and testing a practical and, eventually, certifiable SVS.

This last phrase—"certifiable SVS"—is the key.

Virtually anyone with sufficient time, money, talent and computer horsepower can build a highly detailed and accurate display, based on existing terrain database information and depicting the physical world as seen from the perspective of a cockpit window. Add highly accurate 3D position and velocity information, as a cue to determine what, from that database, should be displayed on screen and voilà—you have an SVS that will show a flightcrew where they are and what the physical environment around them looks like, regardless of weather conditions or time of day.

The first step was to design cockpit (and HUD) display architecture and software to replace the traditional "blue-over-brown" EFIS PFD rendering, in order to take advantage of (and render quickly) terrain mapping data. Using the Jeppesen Terrain Database, NASA Shuttle Radar Mapping, Space Imaging Ikonos 1-meter and USGS 10-meter data, as well as proprietary terrain data obtained by individual companies, the data is then processed using a variety of software solutions.

One of the most powerful of these is TerraMetrics' TerraBlocks technology, development of which was funded, in part, under contract to NASA Langley Research Center's Aviation Safety and Security Program (AvSSP). While TerraBlocks is still under development, the company is in discussions with major avionics manufacturers and



Wireframe version of terrain rendering using TerraMetrics' TerraBlocks technology, in which terrain data vertices are displayed as a regular grid of triangles. Discrete TerraBlocks volumes are outlined—red, near-field blocks are rendered at their full, original level of detail, while far-field blocks are rendered at correspondingly lower levels of detail, based on viewpoint distance.

government contractors with an eye toward incorporating the technology into SVSs on the horizon, so to speak. According to company literature, "this innovative technology uses wavelet-encoded source terrain elevation datasets coupled with a run-time, terrain-block extraction and rendering process to achieve higher levels of data storage efficiency, rendering accuracy and rendering display rates."

Translated for those of us without several postgraduate degrees in computer science, the TerraBlocks engine can store, retrieve and send imagery to a display processor extremely efficiently while offering worldwide detail equivalent to (or better than) 1 meter per pixel detailed texture map overlay.

In addition, TerraBlocks software is written so that surface details of individual terrain blocks are rendered on a spherical basis, meaning that the digital surface on which the detail is built has a curve algorithm built in rather than a series of interlocking flat planes composited to create some of the existing terrain displays.

The TerraBlocks data engine also incorporates several interesting data priority functions as they relate to the various flight regime display configurations. For example, the display data fed to the SVS central display unit during cruise flight is assigned a lower digital priority—and therefore retrieved, processed and transmitted along the data bus at a much lower speed—than data needed for terminal and approach guidance renderings. In addition, the data for near field (ie, objects and terrain close to the aircraft), mid field and far field is assigned different resolutions and data transmission rates, with high-resolution near field data taking "data pipe" priority in terms of both processing and transmission rates.

Again in plain terms, while on an approach, an SVS display using the TerraBlocks engine renders a mountain 100 miles out from the nose of the aircraft in low resolution and at a low refresh rate, while the airport environment is rendered in the highest available resolution and at the highest possible refresh rate.

Regardless of whether the display symbology fits the "need to know" category—which depicts fairly crude renditions of terrain environments with simple color schemes to provide instant recognition of potential hazards—or "nice to know" renditions—showing everything down to the last building in a scene—the word "certifiable" again takes on special importance.

First, there is the terrain database itself. Tim Etherington is prime system engineer at Rockwell Collins' Advanced Technology Center in Cedar Rapids IA. One of the basic problems with terrain databases, he explains, is that "the moment you complete it, it's obsolete and inaccurate. If a rock rolls down a mountain, or someone builds an office building or a cellular tower, or if a river floods and changes course, the real world is not reflected in your database."

This is a statistical problem, says Etherington. While modern databases are extremely accurate overall, "There are areas where there are errors that came in the data collection process, so there's no way to assign an error value without talking about specific databases."

At present, certified synthetic vision systems are relatively expensive. NASA has tasked Operator Performance Laboratory (OPL) with researching optimal display characteristics of a low-cost SVS. OPL's Synthetic Flight Bag, shown here, is the result.

Photo courtesy OPL

Etherington adds that some type of gross-level database integrity monitoring would be desirable—most likely as part of overall product certification.

While Etherington is impressed by the work done by TerraMetrics, he voices other concerns about the sheer volume of detail it could present: "We want to be clear that we are not doing photorealistic texturing of the synthetic image—the idea is not to replicate exactly all of the clutter in the real world. We want to have some minimal information of what the pilot really needs to perform the task. For instance, finding an airport the first time you fly there among all of the city, the ground clutter, the buildings—everything that typically surrounds an airport—is a fairly difficult task. Imagine how easy that task would be if we stripped off all the buildings and everything else and only put the runway environment into the picture."

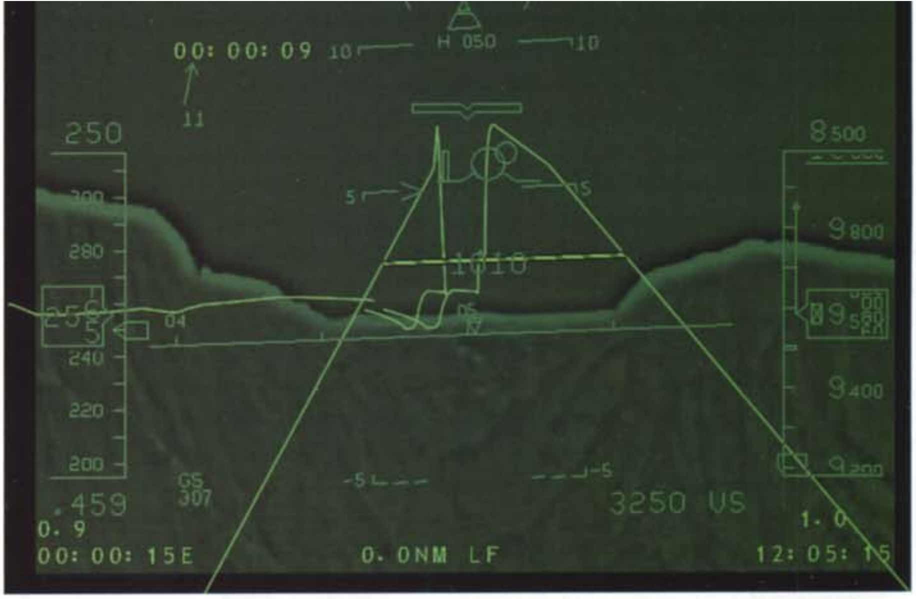
Chad Cundiff, who directs Honeywell's SVS efforts, also speaks of the terrain database collection that his company has assembled: "[It] has been compiled from a number of different sources. Terrain data is not necessarily the easiest thing to come by and, as of today, although there is a promise in the future of free terrain for everybody, there is not a single source of terrain data that is worldwide that gives the accuracy and fidelity that we feel we need for this type of device."

Honeywell has compiled much of its own data, he says. "We are leveraging our [EGPWS] database along with some data based on different sources that we've acquired or gone after in the past—it's almost approaching a 15-year project for us."

Given the concerns regarding database integrity (and availability), a major issue concerning SVS certification for all flight regimes (especially for terminal and approach guidance) is the ability to determine the system's complete accuracy. This is where both companies' experience in systems integration is making the difference.

With the recent near-explosive growth of the IR-sensor-driven enhanced vision market, and the promulgation of FAR Part 91.175, which sets out approach certification, training and operational guidelines, Honeywell and Rockwell Collins have integrated EVS data into their proposed SVS displays.

Rockwell Collins, whose proposed system is known as Synthetic Enhanced (SE) Vision, designed the software architecture for its Pro Line 21 avionics suite nearly 10 years ago in anticipation of being able to incorporate an SVS at some point in its product life cycle. The latest iteration of Pro Line 21 fuses a database-generated synthetic depiction of terrain features with IR EVS data provided by Portland OR-based Max-Viz. This fusion provides what the company



During approach tests into RNO (Reno-Tahoe NV), conducted on a Rockwell Collins Boeing 757 test bed, data from a specially modified WXR2100 weather radar system was used to ascertain "ground truth," thus verifying that the terrain displayed synthetically corresponded to terrain outside the aircraft. This photo shows a HUD version of the display.

Photo courtesy Rockwell Collins

calls "ground truth"—a state attained when SVS terrain depiction matches precisely the imagery generated by the real-time IR enhanced vision data. Both images are then composited within the display.

Rockwell Collins and Max-Viz have demonstrated the SE System successfully in a number of different aircraft under the auspices of a joint NASA/USAF/FAA program. One test, in a Boeing 727, saw the system used in high-speed, low-level flight over the New Mexico desert. Pilots from a variety of professional backgrounds flew the aircraft using both HUD and head-down SE Vision displays at 650 ft AGL and 260 KIAS.

Another series of tests used a NASA Boeing 757 test bed to fly approaches into RNO (Reno–Tahoe NV). Ground truth conformity was provided by a combination of enhanced vision sensor data blended with a modified WXR2100 MultiScan weather radar system, which was used in the tests to provide radar imagery of the surrounding terrain and the airport environment.

The latest series of flight tests incorporated still another sensor technology—millimeter wave (MMW) radar—data from which was fused by Max-Viz, along with their IR EVS data, into the final HUD/head-down SE System display aboard a NASA Gulfstream V.

Fusion of MMW data into the final display presents one of the most difficult challenges, as the imagery it provides tends to be very "noisy"—presenting a great deal of clutter that must be refined out of the data.

As Max-Viz Dir of Technology Roger Watson explains, "[MMW] data certainly adds to the capability of the [SE Vision] system as it will render imagery, through the densest fog, up to 5 miles out from the runway threshold. The problem we are working on right now is to keep the imagery it presents from overwhelming the display with clutter."

In a related program, Max-Viz is working with the Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany's NASA equivalent, to develop a ground correlation algorithm which, when incorporated into systems using EVS and MMW sensors, will ensure that the data displayed presents what Rockwell Collins terms ground truth.

While Honeywell has also reportedly tested and flown a similar system and was, in fact, offering selected potential customers an opportunity to view a widescreen depiction of imagery from its current technology at the 2005 NBAA Convention, it has not released any details yet. On the basis of a surreptitious 60-second glimpse of the display as it was being installed and tested at the convention, Honeywell's research has yielded an SVS with an impressive amount of detail, augmented by enhanced vision imagery which the company attributes to a Kollsman cooled mid-band IR sensor package.

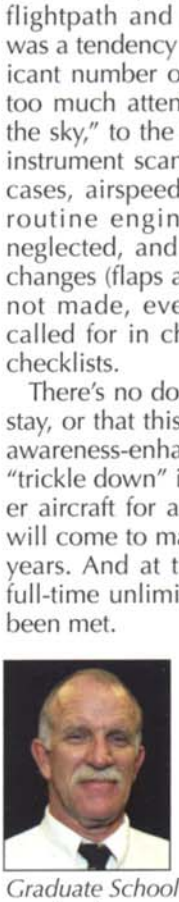
The future—not tomorrow, but closer than you think

Both Honeywell and Rockwell Collins have been studying and developing the possibility and potential of synthetic vision systems for long enough to have planned digitally for this eventuality in system architecture designed when some of the current engineering staff were still in grade school. Advances in sensor technology (and deployment in real-world application), as well as technological leaps in display, database, data storage, processing and throughput technology have enabled researchers to begin fielding workable SVSs.

Impediments to bringing such systems to market remain, though, not the least of which is certification. No matter what term is used, companies will have to be able to prove that their SVSs are as failsafe—and, more importantly, failure redundant—before FAA or any governing body allows their use on a routine basis.

There is also the question of final symbology formats. While Hoover's "tunnel in the sky" is seen as a likely candidate for flightpath cueing, there have been problems. In a 1998 Stanford University study conducted in Alaska, test subjects flew a Beechcraft Queen Air test bed equipped with a prototype SVS designed and purpose-built for the study. While test subjects maintained greater situational awareness with regard to where the aircraft was, relative to the projected flightpath and nearby terrain, there was a tendency in a statistically significant number of subject pilots to pay too much attention to the "tunnel in the sky," to the detriment of a normal instrument scan. As a result, in some cases, airspeed targets were missed, routine engine management was neglected, and aircraft configuration changes (flaps and landing gear) were not made, even though they were called for in challenge-and-response checklists.

There's no doubt that SVS is here to stay, or that this and other situational-awareness-enhancing technology will "trickle down" into smaller and smaller aircraft for a price far below what will come to market within the next 5 years. And at that point, the goal of full-time unlimited visibility will have been met.



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