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Building Highways in the Sky

By Harry Kraemer | December 1, 2003
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The synthetic highway in the sky (HITS) has become a reality in aircraft cockpits, and Chelton Flight Systems has been key in making it so. The Boise, Idaho-based avionics manufacturer gained Federal Aviation Administration (FAA) certification of the world's first electronic flight instrument system (EFIS) with synthetic vision, in January 2003. Chelton's FlightLogic EFIS has been certified for all Part 23 aircraft, according to Gordon Pratt, president of Chelton Flight Systems. "We'll begin Part 25 STCs [supplemental type certificates] in early 2004," he adds. The FlightLogic system also comes with the first certified TSO-C146a WAAS (wide area augmentation system) GPS navigator, approved March 27, 2003.

Chelton's system is unique in that the pilot has all essential flight information on the PFD. In addition to giving the pilot the basic attitude of the aircraft, the PFD includes terrain contours and obstacles, traffic, weather, 3D predictive flight director (FD) and navigation information. All of this is in an easy to read and understand format that is not at all overwhelming or confusing to the pilot.

The system certification came about a year after FAA selected Chelton to provide FlightLogic systems, with the Universal Access Transceiver (UAT) data link, for its Capstone Phase II program in southeast Alaska. (The UAT data link was provided by UPS Aviation Technologies, now part of Garmin International and known as Garmin AT.) The contract covers the cost of about 200 systems. By Oct. 15, 22 aircraft–ranging from a Cessna 172 to a King Air–were equipped or in the process of being equipped with the Chelton package.

The HITS concept is not new. Avionics firms have experimented with the concept since the advent of digital terrain databases. Chelton's HITS uses such a database to create its Skyway symbology, which guides the pilot to a predetermined destination. HITS was conceived to help reduce workload and enhance safety in nearly all weather conditions. It also is meant to pave the way for future Free Flight air traffic management systems.

And while the Chelton name may seem relatively new to some, Chelton Flight Systems–part of the Chelton Group, a subsidiary of UK-based Cobhan plc–has been providing products to the aerospace industry for more than 50 years.

System Description

Starting at $75,000 dollars, the FlightLogic EFIS includes two to four integrated, liquid crystal displays (LCDs), each of which can be configured either as a primary flight display (PFD) or a multifunction display (MFD). Imagery can be shifted from one screen to the other at the touch of a button. With a depth of only 4 inches (10.2 cm), the 6.25-inch (15.9-cm) diagonal, landscape-format displays fit even in the small Cessnas and Pipers participating in Capstone II.

The FlightLogic package also includes the following:

- Solid state gyroscopics (attitude heading and reference system, or AHRS);
- Air data computer, which calculates airspeed, altitude, vertical speed, fuel flow and outside air temperature;
- Fuel totalizer;
- WAAS GPS receiver from Freeflight Systems (formerly Trimble Navigation). WAAS, commissioned by the FAA in July 2003, currently allows more than 500 approaches;
- Flight management system (FMS);
- Integral voice warning system;
- Terrain awareness warning system, or TAWS;
- Graphical flight planner; and
- Flight data recorder.

TAWS C is standard in the FlightLogic package for fixed-wing aircraft and is upgradable to TAWS A or B. TAWS B is standard on rotorcraft and is upgradable to TAWS A. FlightLogic also interfaces with L-3 Communications' Stormscope WX500, the Ryan International TCAD 9900B and 9900BX, L-3 Skywatch, Garmin AT automatic dependent surveillance-broadcast (ADS-B) system, and WSI's weather link. It can receive traffic information service-broadcast (TIS-B) data by interfacing with TIS-B-capable transponders from Garmin or Honeywell.

A New Idea

HITS technology represents a giant step forward from the venerable flight director and horizontal situation indicator (HSI). Essentially a three-dimensional "predictive" flight director, the FlightLogic HITS creates box-shaped outlines on

the PFD, which vary in size to depict a flight path perspective in front of the aircraft. To follow the flight path the pilot simply "flies" the flight path marker (an airplane symbol) through the boxes.

The 3D Skyway symbology provides a vivid picture of the aircraft attitude. Its imagery also shows the environment outside the aircraft, including traffic, obstacles, terrain and weather. It displays the ground in a brown color and, for added situational awareness, the sky at the horizon in light blue and above the horizon in darker blue. The PFD also can be configured to display a conventional HSI.

Terrain Database

The FlightLogic system's terrain database uses the U.S. Geological Survey data applied to terrain awareness warning systems. Its obstacle database in the United States comes from FAA and the Federal Communications Commission (FCC) and is updated every 56 days. Nav data in the FlightLogic system comes from Jeppesen and is updated every 28 days.

Each FlightLogic display has its own processor, a 1-GHz Pentium III with error-correcting random access memory (RAM). The graphic software is approved to DO-178B, Level C, standard. Pratt says it will be tested for approval to the Level A standard by March 2004, in preparation for certification in Part 25 (transport category) aircraft.

Pilot Friendly

The FlightLogic PFD replaces the conventional attitude indicator, airspeed indicator, turn indicator, heading indicator and altitude indicator. It has an airspeed tape running vertically along the display's left side and the altimeter tape, along the right side. Critical airspeeds–best angle of climb (Vx), best rate of climb (Vy), dynamic stall speed (stall speed that considers the aircraft's attitudes, i.e. bank angle), etc.–are marked on the left-hand tape, using color coding. A numerical indication of the airspeed appears in a window. Likewise, a numerical indication of altitude appears in a window on the right-hand tape.

The airspeeds are tail number-specific. Every aircraft has a "personality chip" that indicates its performance specifications. Installers of the FlightLogic system program and then install the chip in the displays' mounting trays. The display processors, therefore, can be swapped out without affecting the spec database.

There are eight buttons, four vertically on each side of each display. The vertical buttons are labeled by function, such as flight planning, FMS, nearest navaid and nearest airport. In addition, there is a brightness knob in the lower left-hand corner, and a SCROLL/PUSH SELECT knob in the lower right-hand corner. The SCROLL/PUSH SELECT knob operates a popup menu that appears in the lower right-hand corner of the display. The knobs are labeled and designed for easy use, even when flying in turbulence. You turn the knob to select a display function and then push the knob to activate it.

Out of Gaithersburg

For my demonstration flight, I met with Pratt and Randy Shimon, Chelton's manager of the company's Eastern dealer program and my demo pilot, at the Montgomery County Airpark (KGAI) in Gaithersburg, Md. After a brief introduction, we climbed into Chelton's Cessna 421. On the activation of the avionics, FlightLogic automatically displayed the local altimeter setting, based on

the surveyed elevation of the nearest runway touchdown zone. There was no chance of my miss-setting the altimeter and impacting terrain on an IFR departure.

As the aircraft advanced along the taxiway, Randy noted that the PFD displays the runway in its proper perspective relative to our position. Narrow runways therefore appear narrow on the display, and wide runways appear wide. This helps prevent inadvertently encroaching on an active runway.

Once airborne and after a short acclimation period with some basic attitude instrument flying, I found I was able to keep altitude within plus/minus 20 feet and heading within a few degrees simply by flying through the HITS boxes. The PFD gave me plenty of information but wasn't overwhelming. The maneuvering speed, stall speeds, Vx, Vy, marker beacons and above ground level (AGL) altitude were all easy to find. No search for individual instruments was required.

TAWS Test

Wanting to check out the TSO-C151b-compliant TAWS, I steered the Cessna toward the mountains between Camp David, in Maryland, and Martinsburg, W.Va. We flew parallel between two ridges, below their altitudes–low enough to show mostly brown on the PFD.

Chelton took care in designing colors into the display. The terrain for the TAWS display on the navigation display is colored black when it is more than 2,000 feet below the aircraft, dark olive when it is between 500 and 2,000 feet below the aircraft, dark brown when the terrain is within 500 feet but still below the aircraft, and light brown when the terrain is at or above the aircraft's altitude. The multiple colors are to give the pilot more situational awareness and indicate a controlled flight into terrain (CFIT) threat only when it truly exists.

Pratt explains that, with a forward-looking terrain awareness (FLTA) function and knowledge of the aircraft's airspeed and heading, the Chelton TAWS can refine its calculation to determine if the aircraft actually is heading toward terrain. "We don't want to have pilots seeing red all the time," he says, regarding the color used to indicate terrain above the aircraft's altitude and imminent danger. "Ours is a more arresting display. If you see red on our system, then the pilot really needs to take heed." The FLTA function uses amber and red to show hazardous terrain in front of the aircraft.

In addition to the color-coding, the PFD shows a digital readout of the AGL altitude any time the aircraft is 2,500 feet or less above terrain. Towers and antennas are clearly visible on the PFD as vertical amber lines. However, so long as the lines remain below the display's horizon, the obstacles pose no threat.

TAWS Features

In addition to the FLTA, FlightLogic's TAWS provides the following functions:

- Terrain display,
- Premature descent alert,
- Excessive rate of descent,
- Excessive closure rate to terrain,
- Sink rate after takeoff or on the first leg of a missed approach,
- Flight into terrain when not in landing configuration,

- Excessive downward deviation from an instrument landing system (ILS) glideslope, and
- A 500-foot "wake-up call."

For our return flight, I selected the VOR 14 approach into KGAI by pressing the "ACTV" (FMS) button on the PFD's left side. This brought up a list of waypoints in the current flight plan. I turned the control knob to highlight the KGAI and pushed the knob to select enter. Again using the control knob, I highlighted "IFR APPR" and pushed it for enter. I then turned the control knob once again to select VOR 14.

The PFD showed the approach as a white course line on the moving map, along with the approach waypoints. The active leg was displayed in magenta. When a precision approach is loaded, the PFD also displays the marker beacons as small flashing lights. (Marker beacon lights are displayed any time they are received, regardless of approach selection.)

Holding Pattern and Approach

Part of our approach included a holding pattern (for a procedure turn). No problem. The FlightLogic system automatically selected and drew the proper entry into the hold. If the system had been coupled to an autopilot, it would have entered the pattern and have flown the procedure for me. (FlightLogic will interface with any autopilot, according to Pratt.) Gone are the days of memorizing altitudes or looking down at an approach plate. Crossing altitudes accompany each waypoint and are shown in the PFD's upper right corner.

The three-dimensional Skyway symbology even will provide glide path reference on a non-precision approach and display a recommended stabilized descent to the missed approach point. Basically, the pilot just flies the Skyway to the minimum descent altitude.

I intentionally flew well below the normal approach glide path, to activate the premature descent alert (PDA) function. I received an amber-colored "Too Low" caution flag on the display, along with a voice alert, "Too Low Terrain!" As we descended through 500 feet AGL, the "wake-up call" issued its voice alert, "Five Hundred!" This one last alert is especially useful as a reminder to have all before-landing checks complete.

The busy airspace inside the Baltimore/Washington Area Class B airspace proved appropriate to evaluate the traffic avoidance system. FlightLogic displays the traffic on the PFD, using TCAS I symbology. Nearby aircraft appear either above the display's horizon (representing traffic above your aircraft) or below the horizon (traffic below your aircraft). And for added traffic awareness, the traffic symbols vary, depending on their location relative to your aircraft. A yellow circle is a Traffic Alert, meaning traffic within your immediate vicinity. A solid diamond means that traffic is within 6 nautical miles (nm) and 1,200 feet of your aircraft altitude. And an open diamond indicates that traffic is beyond 6 nm and 1,200 feet of your aircraft altitude.

PFD Waterline

A "waterline" symbol on the PFD indicates where the aircraft's nose is pointing. The symbol is fixed in the center of the display and performs essentially the same function as the white dot in the center of an attitude indicator. The number of degrees between the waterline and the flight path marker indicates the aircraft's crab angle.

The built-in integrated auditory caution/warning/advisory, or CWA, system constantly monitors a wide variety of parameters and provides the crew with auditory annunciations for situations/conditions that demand pilot attention. These annunciations can be either a voice warning or a chime. To help pilots determine the urgency of a situation, the annunciations are grouped into three categories: warning, caution and advisory.

- Warnings require immediate pilot action. They also are displayed on the PFD as a red flag in the display's lower left corner. A text message that indicates the warning condition is shown inside the flag. The audible portion of the warning is repeated until acknowledged by the pilot by pushing a MUTE button on the yoke or instrument panel.
- Cautions are not so urgent and are only annunciated once. They also are displayed on the PFD (lower left-hand corner) as a yellow flag.
- Advisories are informational and are displayed as a green flag or no flag, depending on the situation. Advisories are either in voice form or a chime. Volume is automatically adjusted, based on the level of threat.

Added Safety

Chelton describes FlightLogic as a "pilot centered" system that is meant to keep the pilot in the loop. "Everyone involved in developing the system is a pilot," says Pratt. "We hire engineers who are pilots."

The company claims the FlightLogic system presents all the information essential for the current situation, allowing the pilot to make informed decisions regarding the flight. An engine failure provides an example of essential information delivery. In this situation, the pilot must fly the aircraft while also troubleshooting the cause. In addition, the pilot must select a landing area, hopefully the nearest airport. GPS and moving maps have made this task easier, but they don't indicate whether or how to reach the nearest landing site.

The FlightLogic system helps make that decision. The MFD displays a glide area, a cyan ring around the aircraft symbol that changes shape and size according to wind conditions, terrain, the aircraft's descent rate, and the nearest airport's position relative to the aircraft. If, for example, the descent rate increases, the cyan ring becomes smaller. The size of the ring reflects system calculations regarding the altitude gained while slowing to the best glide speed (shown on the airspeed tape) and pilot reaction time.

Should the pilot inadvertently enter an unusual attitude (pitch exceeding +/- 25 degrees), the PFD enters into an "Unusual Attitude Recovery" (UAR) mode. Only essential information needed for recovery is displayed while in this mode. Items such as navigation, terrain and obstruction in formation are removed. And no matter how excessive the pitch attitude, a sliver of blue or brown will remain on the PFD to keep the pilot oriented and aid in recovery.

Reliability

The FlightLogic system's calculated failure rate is 17,000 hours. In addition to having its own processor, each display has dual backlight systems and a dedicated power supply for each backlight. An optional backup battery on an essential bus

provides emergency power in the event of an electrical system failure. And since each display is a line replaceable unit (LRU), fleet operators need only stock one part number for either the PFD or MFD, for either an airplane or helicopter.

For added reliability and safety, the solid state Crossbow AHRS functions without needing information from either the air data computer or GPS. It is the first unaided micro electromechanical system (MEMS) sensor to receive FAA certification. "The MEMS gyros do produce some drift, but Crossbow developed algorithms to correct for this," says Pratt. The system also has a built-in test (BIT) capability that continuously monitors all of the sensors and electronics.

Universal's Vision 1

Chelton Flight Systems isn't alone in producing a synthetic vision system for aircraft. Universal Avionics claims to have the first certified synthetic vision system (SVS), having received technical standard order (TSO) approval in June 2002. But its Vision-1 system was approved for a multifunction display (MFD) only and not for a primary flight display (PFD), as with Chelton's FlightLogic EFIS.

Universal took a different approach in developing its SVS. In a two-phase development program, it produced a display that shows the "exocentric" view of the aircraft and its flight path. On the MFD the pilot sees the aircraft symbol over a three-dimensional view of digitized terrain from the offset viewpoint of a remote position that is slightly behind, above and to the right of the aircraft. It's a kind of "guardian angel" point of view.

A white line on the display indicates the aircraft's flight path, generated from the flight plan in the flight management system (FMS). If the aircraft wanders off course, the display produces a trend vector in red. Vertical lines, or poles, extending below the white line to the ground, providing a perspective of the flight path relative to the terrain. The display also shows active waypoints and includes a compass symbol below the aircraft.

Universal's SVS can be used for situational awareness only and not navigation. It interfaces with the Tucson, Ariz.-based company's terrain awareness warning system (TAWS) and is presented on its MFD 640 display. The Vision-1 processor, containing the terrain database, is a remotely mounted 2-MCU line replaceable unit that weighs 9.7 pounds (4.4 kg).

Vision-1 is capable of generating two different images. For the system's second phase, Universal will make available a display that presents an "egocentric" view (from the pilot's perspective), approved on a PFD. Both the egocentric and exocentric views are now accessible on the displays in Universal's King Air 350 test bed aircraft. The company hopes to have the egocentric PFD certified before the end of 2003.

Universal's new display differs from Chelton's PFD, however. Like the FlightLogic EFIS, Vision-1 will replace the conventional attitude indicator with a digitized terrain rendered in green, brown and blue. But unlike the Chelton system, its PFD will not include the concentric windows through which the pilot "flies" the airplane symbol. Universal believes the windows create too much clutter and, thus, will present only a flight director cue. Vision-1 provides a highway in the sky, but it remains in its exocentric form on the MFD.

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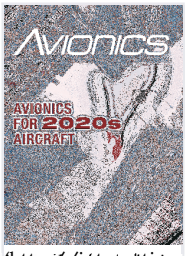

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