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TERRAIN DATABASES FOR CIVIL APPLICATIONS

Military Avionics Advances Benefit Civil Applications

Ground proximity warning based on a military terrain-following system is the first of several military-to-civil conversions being developed in the United Kingdom by GEC-Marconi Avionics.

by Don Parry

Much has been said and written about the problem of controlled flight into terrain (CFIT). It had reached serious proportions in the late 1960s, which led to a requirement for a ground proximity warning system (GPWS) and its installation on commercial carrier aircraft by the mid-1970s.

A typical GPWS uses radio altimeter information from 50 to 2,450 feet, with the barometric descent rate derived from an air data sensor. Operation of the aircraft close to the ground, with the landing gear or flap not in the landing configuration, results in a GPWS warning.

In operational terms, there was an immediate and marked reduction in CFIT-related accidents with GPWS. The problem has not been entirely eradicated, however, because most current GPWS systems only operate effectively and reliably over terrain that is relatively flat or that has a constant gradient. Over more hilly areas, there is a tendency for many systems to produce nuisance warnings or, conversely, not to generate a warning early enough for effective action to be taken.

One approach to these problems is being undertaken by GEC-Marconi Avionics, which is applying its experience on military aircraft terrain-following systems to ground proximity warning.

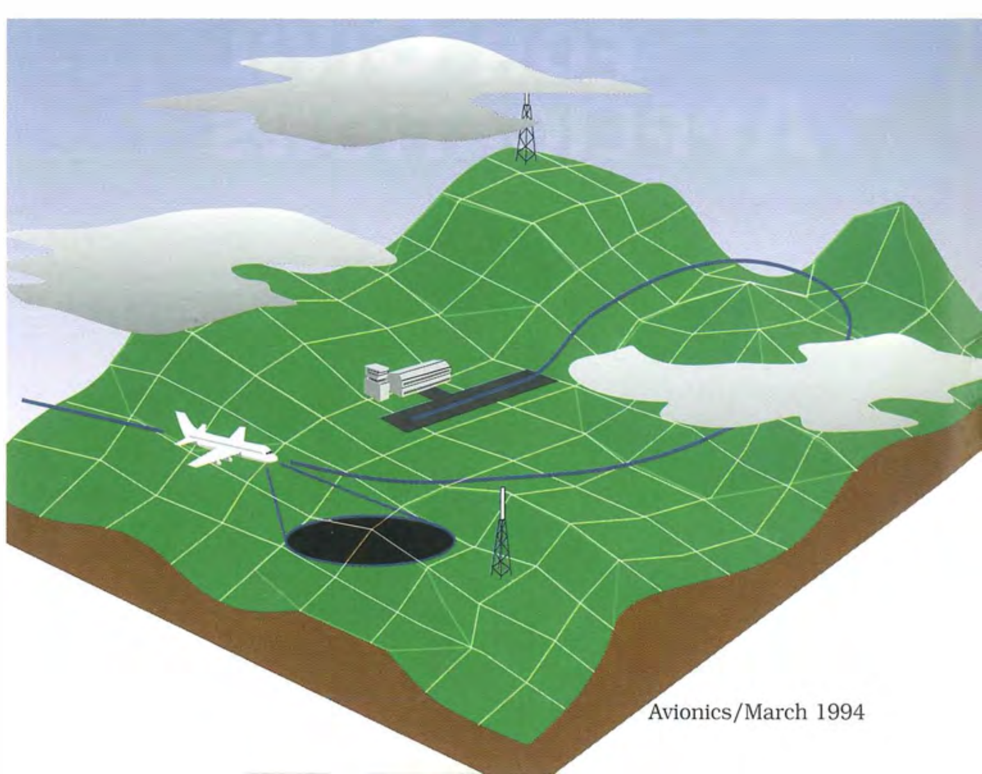
The terrain-following system the company developed for the Tornado allows the aircraft to fly at very low levels, at high speed and with hands off. As explained by Marion Moon, a marketing executive with GEC's Display Systems Group, this can provide the basis of a much more capable ground proximity warning system.

Basically, if there is a terrain base available and present position is known, then the pilot can be made aware of what lies ahead of and around the airplane. If it is flying over flat ground, but heading toward a sheer cliff face, then a warning will be given, something not available on most contemporary systems. Moreover, there is the advantage of knowing what the terrain is like on either side of the flight path. In some circumstances, it may be inadvisable to turn in a particular direction due to natural or manmade obstacles, and this restriction will be made obvious to the pilot.

Such a system has considerable promise, and discussions have already taken place with a number of interested carriers, including British Airways. Much of the work to date has concerned the Ground and Obstacle Collision Avoidance Technique (GOCAT), using a digital map of terrain contours and obstacles that are stored in an onboard database. Techniques already developed for military use allow very rapid access to the database, from which aircraft position, height of terrain, and obstacles along the flight path are determined and passed to the pilot and aircraft subsystems.

An advantage of GOCAT over some current systems is that it has an accurate knowledge of the area—nuisance and missed alarms due to unpredicted changes in topography are thereby eliminated. The system also assumes that the pilot is aware of his actions until it becomes apparent that he is not. Consequently, a warning is not generated until it is necessary for the pilot to take deliberate avoiding action. This takes into account the climb performance of the aircraft, the energy state at that time, and the terrain safety margin.

The system predicts whether the current flight path, followed by a hard pull-up, will result in the aircraft becoming dangerously close to the terrain or obstacle. If it does, then a warning is generated, taking all factors into consideration and so allowing the pilot to react in time. This is achieved by projecting the current flight path sufficiently far ahead to allow for reaction time and then generating a search area covering a swath to either side of the



Representation of a civil airliner's environment as portrayed by a digital terrain database.

predicted flight path.

The extent of the search area is bounded by the aircraft's permitted rate of climb and energy status. This search area is then compared with the terrain and obstacle elevation database and the necessary clearance is calculated. The result of this process determines whether a warning is generated. GOCAT also ensures that a wings-level, straight-ahead pull-up is possible, to allow for an initial reflex escape maneuver when a warning is generated.

An additional feature is that the system will generate "no turn" warnings to indicate the presence of high terrain or obstacles to either side of the predicted flight path that cannot be safely cleared.

Choice of algorithm for any particular type of airplane ensures that all flight envelope limitations are observed, while enabling the pilot to retain full control of the airplane at all times.

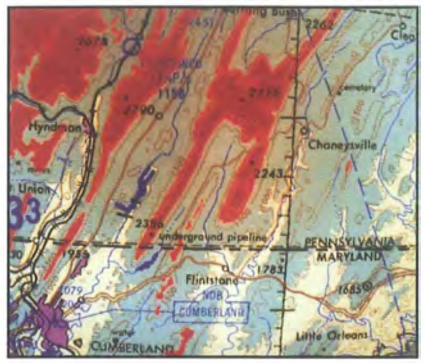
Acknowledging GEC's past experience with the Tornado system, it is tempting to suggest that GOCAT could activate climb procedures via autothrottles and flight director inputs. Moon acknowledges that this is possible and even desirable, but stresses they are not developing it beyond a warning system at this time. To add any additional automation would be entering areas of flight control, with all the attendant complications of certification and the need to satisfy the regulatory authorities of the operational implications.

At present GEC is defining the system and reviewing all of the operational requirements. It will be of advantage to seek commonality between military and civil systems to create a general-purpose database using all available navigation sensors, including GPS.

Unlike military systems, which require fine-grain detail to permit extended operations at 100 to 200 feet, the civil requirement is concerned with clearances of 1,000 feet or more, except in the final stages of the approach. This allows the data content to be of a much lower resolution and subject to relatively infrequent revision, offering a significant saving in cost.

For civil use, the database track width will be some 20 nautical miles square, centered on the aircraft's position. If the system is accepted by the airlines, it will mark the first time a civil aircraft will have flown with a terrain-following database. Current timescale is for a debut in 1996 or 1997.

It is likely that an element of international cooperation will emerge as market potential is explored. For example, the military has a certain requirement for GPWS, and there is a drive in the United States for a ground collision avoidance system (GCAS) for general-purpose flying.



Colors that depict height relative to the aircraft change with the aircraft's altitude.

Other Projects

Though work on GOCAT is well advanced, it is just one element of a larger program in which military technology is being reviewed for use in civil aviation. The program, Terrain Referenced Avionics Functions For Integrated Civil Cockpits (TRAFFICC), is an attempt to use these techniques in three specific areas: systems that assist in improving a pilot's situational awareness; those that improve autonomous navigation; and the application of solid state mass memory modules.

Although some of these applications require considerable high-tech inputs, the overall driver is to develop systems that will improve performance and enhance the revenue prospects of the carriers.

Much of the technology derives from an earlier project called Real Night, a demonstration program carried out with the U.S. Navy in 1983. The intent was to show that a variety of onboard systems could be used for covert, low-level flying. The aircraft involved was an A-6E, using experience already gained in work for the U.K. Ministry of Defence. An onboard database was provided to create maps and terrain-referenced navigation, which could be viewed on head-down displays supplied by GEC. Also included were a head-up display (HUD) and night-vision goggles.

A podded, forward-looking infrared sensor and digital terrain system was mounted on one side of the aircraft and a laser radar pod on the other. The complete system was intended to provide clearance from terrain and obstacles and also to determine whether it was feasible to detect unmapped obstacles, particularly wires or cables.

The program was successful, and the map performance was so good that it is the foundation for current work. As development equipment, the elements were necessarily larger and heavier than could be operationally acceptable, and there was need for further refinement and development. The wire and cable detection was excellent and created interest among the helicopter fraternity. A system for that application, however, would have to be even smaller and lighter, while the processing would also have to be changed. This latter requirement is being generated by the A-6, which requires long range and relatively narrow beam characteristics, while helicopter operations require less range but a wider beam.

Moving Maps

GEC-Marconi Avionics has also developed digital, color moving maps for military aircraft and is currently delivering a digital map generator (DMG) for the RAF Harrier aircraft. The information is stored in the form of digitized charts that are rapidly accessed and processed to provide a video image, which rotates and scrolls relative to aircraft movement.

The map may be integrated with an EFIS for the overlay of routes and information. As a result of the Real Night program it is possible to use colors to indicate surrounding ground height. Elevation data permits the depiction in red of all ground that is higher than the aircraft. It is a dynamic presentation and changes as the aircraft's height varies, to create a true situation awareness display.

The DMG is also used as the basis of an airport position locator system. Flight crews are well aware that many of the world's airports spend considerable sums on the main buildings in sight of the passengers and then save on the airfield lighting budget. The result is often a series of black holes and difficulty in finding one's way around confusing sets of taxiways and intersecting runways.

GEC's solution is to generate a map of the current terminal area, showing the aircraft's position. The DMG has a "slew" feature that allows the pilot to manually fix the position of the aircraft in relation to the map. The position is determined when the inertial navigation system is initialized at the gate or as the aircraft crosses the runway threshold on landing. The necessary airport information can be stored in the mass memory units of the electronic library system (ELS).

By integrating existing onboard navigation systems with a terrain-referenced navigation system, plus GPS, it is possible to improve all-around navigation accuracy. With terrain database information, it is practical to develop a precision, poor-weather approach aid. Existing techniques can permit an approach to decision height with an accuracy of ±60 feet horizontal and ±20 feet vertical, say GEC engineers. Their system uses inertial navigation and radio altimeter inputs and compares the measured flight terrain profile with the map stored in the database.

In support of the system, GEC points out that GPS as the sole navigation aid is not recommended for poor-weather approaches. A number of reasons are cited, including the fact that GPS relates aircraft position with respect to an approximation of the shape of the world, the well-known oblate (WGS84) spheroid, and does not relate directly to the terrain. Consequently, additional information has to be provided to factor the positional information. In addition, GPS does not provide information on obstacles.

In contrast, a terrain-based system is independent of sensors outside the aircraft; it relates to the actual terrain being overflown and about to be overflown and offers information on all mapped obstacles.

Solid-State Memory

The basis of all of these proposals is the ability to store large amounts of data that can be randomly accessed very quickly. In developing military systems, it was necessary to determine the media most suited to real-time use in an adverse environment.

The main criteria are low cost per megabyte, low volume, ruggedness, low power requirements, high reliability, and very high data read/write rates.

A number of options are available, but after considerable research, GEC has come to the conclusion that a solid-state mass memory system is superior—in terms of performance, reliability, and maintainability—to other solutions, including the erasable optical disc.

Current solid-state memory units are produced as modules within systems to suit a particular requirement. It is intended that over the next two years, stand-alone, high-capacity memory units will become available. Until recently, only low-capacity devices were available, but the pressure of the commercial market has led to the development of high-capacity devices. It is now a practical possibility to store 320MB of data on one electronic store card.

The solid-state mass memory can also be linked to an ELS, which may use magnetic media or an optical disc system. Optical storage media can be used for the slow time collection and distribution of data, while the solid-state mass memory deals with real-time demands.

Marion Moon emphasizes that TRAFFICC has been developed as a series of modular functions for commercial aircraft systems that can be integrated using a shared database.

Interfaces will be ARINC 429/629, with point-to-point links between systems. More ideas are being studied, and TRAFFICC is likely to become more active as the airline economic recovery increasingly takes effect.