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# THE ELECTRONIC TERRAIN MAP

## - A NEW AVIONICS INTEGRATOR -

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## ABSTRACT

This paper will discuss the concept of a digital Electronic Terrain Map (ETM) and its associated technologies. Further, this paper discusses the ETM as an integrating element in a modern avionics system which can enhance an airborne mission capability against sophisticated threats, while potentially reducing the constraints imposed by night and adverse weather. An existing brassboard map and projected implementations of the ETM technology will be described in this paper with the application being in the context of a low altitude attack mission.

The Avionics Laboratory at Wright-Patterson Air Force Base is developing the ETM and it's associated technologies described in this paper. A discussion of the features (including typical specifications) of an ETM and the impact of adding an ETM to an avionics system will be included. The resulting avionics system, by containing an ETM, may improve the avionic subsystem performance and provide better utilization of the aircraft in the areas of navigation; terrain following/avoidance; threat avoidance, analysis, warning and display; terrain masking; weapon delivery; and route planning.

## INTRODUCTION

Currently, the Air Force has in the inventory paper and film map systems, which were developed to support the high and level flight environment. These maps were an effective means of tapping the vast files of information stored in the Defense Mapping Agency (DMA) data base, when the crew had time to study and interpret them (in fact, much of their value was actually obtained from pre-flight mission preparations). Interviews with pilots indicate that paper maps are less useful for low altitude flights. Film maps with CRT annotation are somewhat better, but still have a fundamental limitation in that it takes an operator to access any information. That is, it is not possible to transfer information directly from the data base to any other avionics system when it is stored on paper or film maps in what is essentially an analog form.

The map reading process is a demanding task that can be simplified by using a digital map subsystem which accesses the information needed and presents it in a form which can be easily interpreted. At low altitude, and with a line of sight limited to the next ridge line, it's very difficult to interpret standard paper maps, which are presented as a vertical projection of a large area. An electronic map subsystem can generate perspective scenes, which are essentially computer generated images of the surrounding area, and an electronic map should be much easier to interpret. In addition, essential information from the map data base can be placed on the pilots Head Up Display, reducing the need for head down operations.

The Air Force is in transition from yesterday's high altitude level flight situation to tomorrow's low altitude, day and night (unconstrained) operations. Increased pilot workload and survivability are two of the generally recognized problems associated with low altitude operations. Pilot workload is always a serious consideration, and in the case of single seat aircraft, it is now critical. Ways must be found to reduce the workload in the single place aircraft by integrating the many sources of information.

Added to the low altitude requirement is the need for improved survivability and the ability to penetrate heavily defended areas. In response to this, missions are now increasingly concerned with low altitude flight, threat avoidance, and the reduction of emission profiles to counter the very efficient, mobile, and prolific ground defenses that enemy forces may deploy.

## BACKGROUND

Recognizing the need for a digital map system in 1976, Avionics Laboratory started work on an all electronic map for aircraft display applications with the in-house effort, "Electronic Terrain Map System (ETMS)". Follow-on projects in this area were the

"Airborne Electronic Terrain Map Applications Study", completed in October 1979, and the design and fabrication of an "Airborne Electronic Terrain Map System (AETMS)" started in May 1980. The AETMS effort demonstrates the state-of-the-art in electronic map technology. Hence, the basic exploratory work necessary to develop a successful map system has already been initiated to provide the Air Force with this new capability for the tactical and strategic environment.

Over the past four years, the Avionics Laboratory has been developing the technologies required for future ETMs. Typical technologies/attributes, obtained from the AETMS program, for the ETM are: large mass memory (probably bubble) that utilizes DMA data to store up to a quarter million square miles of terrain and cultural data; high speed processors (70 operations a micro second) to support the real-time display update requirement; and display generation and pictorial display hardware and software.

## WHAT IS NEEDED

The delivery of the AETMS completes the first step in developing operational ETM hardware for future avionics systems. Experiments with AETMS, by demonstrating the feasibility of providing on-board storage and retrieval of digitized cartographic data, should establish the needs of future ETMs. Also, these experiments, by exploring the needs of future avionics systems, will establish the advantages of using ETMs. The needs of future avionics systems, that the ETMs may be required to simultaneously fulfill, are: real-time updates, displaying out-the-window true perspective and contour scenes and providing digital values. Future ETMs should have the capability of accepting extensive real-time updates (i.e. route planning and weapon delivery). Future ETMs should provide terrain data for out-the-window scenes with variable shading, sun angle and scales. These scenes will not be restricted to one of DMA's standard map scales. Future ETMs should provide digital values of elevation for terrain following, threat avoidance and scene correlation applications.

Future aircraft avionics suites should be constructed in a form suitable for laboratory and flight testing so that the concepts proposed can be fully evaluated. An ETM subsystem should be developed including the flyable map hardware, and associated software, and the data base necessary for laboratory and flight tests. Also, support hardware and software necessary to support the ETM subsystem and its data base will be required. The design of the AETMS brassboard provides an architecture which may be used as a baseline for comparative purposes. Additionally, results of on-going in-house efforts in the Avionics Laboratory may be used to establish performance guidelines. The planned Avionics Laboratory's map simulation capability may also be used to evaluate proposed algorithms. Future ETMs should include efforts for hardware, software, data base, and support. The data base and support equipment tasks should include the development of software, equipment and procedures to convert the DMA data and allow for data base manipulation to meet the scenario requirements. An interface should be developed which supports the exchange of terrain and cultural data with other members of the avionics suite at the rates necessary to support simultaneous operations of all avionics subsystems. Special purpose processing equipment necessary to support non-display related applications of the ETM should be developed. The resultant avionics suite should be capable of being installed, on a pallet, for flight testing in a bomber, fighter or cargo aircraft.

The ETM should be integrated into an aircraft avionics system suite. Advanced concepts for threat avoidance, navigation, TF/TA and weapon delivery subsystems using the ETM should be incorporated into the design of future avionics suites.

## FUTURE AIRCRAFT SYSTEM

The purpose of adding an ETM subsystem to a future avionics suite is to provide map data and displays that can be interfaced with other subsystems to improve the performance of the terrain following/terrain avoidance (TF/TA), threat avoidance and navigation avionics subsystems. The requirement for the simultaneous exchange of processed map data by three or four avionics subsystems will be the most difficult objective and important feature of the ETM. Development and incorporation of the advanced ETM concepts and technologies will be required to augment future threat avoidance, navigation, TF/TA, and weapon delivery avionics subsystems. Applications/examples of using these ETM concepts and/or technologies and the utilization of an ETM subsystem as a source of information follows.

### TF/TA

The first example will be the automatic TF/TA avionics subsystem. Our existing automatic TF subsystems operate using only active sensors as sources of terrain profile information (i.e. radar). This makes the subsystem totally dependent on the limitations of this single information source. In case of radar, range is limited to line of sight. Absolutely no information is available beyond line of sight. This forces the TF subsystem to provide unnecessarily large clearances over ridges to avoid the following peak which may or may not be imminent. Further, the TF subsystem must radiate on an almost continuous basis to provide a continuous terrain profile. Consequently detection and jamming are TF subsystem vulnerabilities. A digital terrain map could provide a second source of information to the TF flight command processing subsystem and the use of the map could serve as a backup in case of radar failures or jamming. The ETM could provide information concerning beyond line of sight conditions, enlarge the total field of view scanned for turning, and avoid the reduction of the duty cycle of the radar emission. In fact, this ability to scan the terrain to the side without turning and looking beyond the line of sight makes it possible for the first time to consider true automation of the TA function. Because of limitations in the existing DMA data base, the approach should be cautious and an active sensor will be needed to make absolute clearance measurements. None the less, the application of stored data, to the TF/TA problem can potentially have tremendous impact on Air Force capabilities in the low altitude flight mission.

## THREAT AVOIDANCE

The second example will be the threat avoidance avionics subsystem. The whole purpose of low altitude missions is to reduce the probability of detection and attrition. If the threat avoidance problem is solved without regard to the location and lethal range of threats, the resultant path may place the aircraft in greater jeopardy than before. Terrain masking and launch dynamics limitations must be exploited to the fullest. Careful selection of the aircraft's routes to the target may be done by the crew or automatically. In either case, a digital map is required to provide the terrain information and the position of the threats identified by the avionics system. Pre-mission planning can provide a starting point for this analysis, but the dynamics of the threat assessment makes it essential that the crew be able to redefine the mission as new information is received from command and control functions or via the aircraft's own suite of threat defense sensors.

## NAVIGATION

The third example will be the navigation avionics subsystem. With the addition of a correlator to the avionic suite and using the on-board sensors together with the ETM, navigation can be accomplished. Also, by displaying the ridge lines derived from stored terrain data on the head up display, passive navigation is possible. Hence, the ETM could also improve the utilization of the navigation subsystem.

## TYPICAL ETM SPECIFICATIONS

Typical ETM specifications for interfacing/connecting the ETM subsystem to the other avionics subsystems, including both display and non-display map uses, will be discussed. The specifications for a future ETM may be divided into the following functions:

## REGIONAL MEMORY

The Regional Memory (RM) is the portion of the ETM memory where the terrain and cultural data is stored. The RM should have the following characteristics:

1. Storage of up to 400 meg bits.
2. Storage of up to 500 mi. sq. of terrain and cultural data.
3. Modularity; that is, memory configurations packages ranging from 50000 to 400 meg bits.
4. Variable format; that is, the word size memory packing should be variable.
5. The RM should contain both terrain and cultural (cartographic) data.
6. The RM should be capable of random access.
7. The RM should be partitioned to allow for the accessing of detail data; that is, "zoom".
8. The RM should be capable of simultaneous read and write operations.

## DATA PROCESSOR

The Data Processor (DP) calculates the elevation values and controls the ETM operations. The general purpose low-speed data processing and control operations should be performed by an Embedded Avionics Processor. The DP may perform the following functions:

1. Control both inputting and outputting of messages.
2. Calculate the elevation values.
3. Control the simultaneous data exchanged with the other avionics subsystems. The ETM will be required to provide simultaneous terrain and cultural data for up to four different subsystems. Each avionics subsystem (TF/TA, threat analysis, navigation, weapon delivery, display, etc) will require individual scales and rates.

4. The DP should be dynamically programmable; that is, where appropriate, use one microprocessor to perform many functions.

5. The processing speed required for the calculation of the elevation values is aircraft dependent. However, for the simultaneous operation, the elevation values calculated at 1 million elevation points per second or faster may be required.

6. The DP should contain separate memory from the RM. This separate memory may contain the main program, subprograms (for the programmable microprocessors), special features and other data.

DISPLAY GENERATOR

The ETM may be connected to a Display Generator (DG). If so, the characteristics required for the DG are:

1. Special Displays.

a. Threat Display.

b. TF/TA Display.

c. Navigation Display.

d. Weapon Delivery Display.

e. Approach Plates.

2. Display formats.

a. Plan view.

b. True Perspective.

3. Display Types.

a. Raster (standard TV).

b. Stroke (heads up display - HUD).

SUPPORT EQUIPMENT

The support equipment (SE) required for the ETM should be used for development, testing, demonstration, and maintenance of the ETM. The SE should perform the following functions.

1. Stand alone operation and testing.

2. Navigation Simulation to exercise the ETM subsystem.

3. Data base formation (loading and reformatting DMA data).

SUMMARY

It is now possible to integrate external data from Intelligence, $C^3$ sources, threat and target sensors to optimize total situation information presented to the pilot, while simultaneously providing timely cultural and terrain (cartographic) data to other on-board systems. The avionics system of the future, by containing an advanced version of the ETM, may potentially improve avionic subsystem performance and provide better utilization of the aircraft in the areas of navigation; terrain following/avoidance; threat detection, warning and display; terrain masking; weapon delivery; and route planning. Potential ETM applications are the integration of map data base with (1) radar and inertial data for terrain correlation and navigation; (2) GPS and inertial navigation data for completely passive terrain following; and (3) navigation data, threat sensor intelligence and $C^3$ data for threat avoidance with terrain following. Each application should draw upon the ETM subsystem as a source of information - A New Avionics Integrator.