Rescue Mission

GPS Applications in an Airborne Maritime Surveillance System

Airborne search and rescue missions at sea pose a set of challenging technical and operational requirements to meet the life-critical application involved. These require specialized navigation and flight management capabilities that, in turn, support a variety of other surveillance sensors and functions. A team of German engineers describe a system developed by their company to meet these requirements.

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Maritime search and rescue (SAR) operations do not fit the usual and customary operational modes for aircraft operations. Consequently, neither do their navigation and flight management system (FMS) requirements.

SAR missisions are not based on schedules but rather on ad hoc events and flights. Once the mission control center receives word of an accident (ship disaster, aircraft crash, etc.), an aircraft receives a mission order and begins a high-speed ferry flight to the area of concern. After arrival in the area of the incident, the aircraft typically performs a low-altitude (500 to 1,500 feet), low-speed search flight to locate survivors and the vessel.

In executing this search, the crew employs a suite of surveillance radars, electro-optical sensor, and scanning and direction finding equipment to localize transmissions of emergency beacons that may have been activated during the accident. Once the target (person, ship, aircraft) is found, the crew drops needed equipment, such as life rafts or pumps, out of the aircraft.

The target position and other details are reported to the mission control center in order to initiate further rescue activities. All of these activities require precise navigation and sensor control, which may be obtained by a number of GNSS/GPS applications on board the aircraft. This article describes an airborne surveillance system, AeroMission, developed by Aerodata AG, and the GPS/inertial navigation system (INS) that supports its operation.

In addition to SAR missions, AeroMission is also suitable for maritime surveillance, border and anti-smuggling patrols, pollution detection and mapping, fishery control, offshore oil field monitoring, and research applications.

System Overview

AeroMission has been developed to provide high reliability, redundancy, and efficiency. It was designed using

modular architecture and state of the art technology. A block diagram (Figure 1) gives an impression on the complexity of the system.

In supporting AeroMission, an integrated GPS/IMU navigation system — AeroNav — combines the GPS advantages of long-term stability and absolute accuracy with those of inertial navigation — short-term accuracy during phases of high dynamics in which GPS positioning may be lost or degraded. A separate GPS/INS system also provides attitude reference by using strapdown algorithms providing position and velocity solutions. Turn rates and accelerations given by the IMU are corrected by the GPS pseudorange measurements. These corrections are calculated by a Kalman filter.

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The basic system components include:

- surveillance radar (using the separate GPS-supported INS)
- forward-looking infrared (FLIR) sensor (using GPS services provided through AeroNav)
- infrared/ultraviolet (IR/UV) scanner (using a dedicated GPS-supported INS)
- Mission management and guidance system (using GPS services through AeroNav)
- SAR Homing Device
- HF, VHF, UHF, and satellite communication
- Intercom including communication relay
- Photo/video camera
- Ergonomic operator work stations

Other sensors such as side-looking airborne radar or microwave radiometer can be integrated as options into the suite.

AeroNav (see accompanying photo) has been certified by the German Airworthiness Authority LBA (Luftfahrt-Bundesamt) according to RTCA-DO-208/ TSO C-129a Class A1, which covers instrument flight rules (IFR) enroute navigation, terminal navigation, nonprecision approach, basic area navigation (B-RNAV), and FDE-Alignment according to FAA notice 8110.60 (Oceanic Approval).

The mission system features a Windows-based multi-tasking graphical user interface (GUI) that supports either single- or dual-screen concepts. This allows a user to monitor sensor outputs while simultaneously performing system control or previous sensor data analysis functions. At all times the operator is aware of the aircraft position and intended maneuvers.

Communication functions are considered an important factor in the execution of a maritime surveillance task and are improved by the fully integrated communication suite of AeroMission. The system concept enables the continuous communication among all airborne and land-based parties involved in a mission.

For visual search, coordination of efforts at the scene of the incident, and top cover role (the ability of the aircraft to provide a flying operation center for other aircraft, sea and ground vessels), the system provides the following capabilities: storage and visualization of

The integrated GPS/IMU navigation system

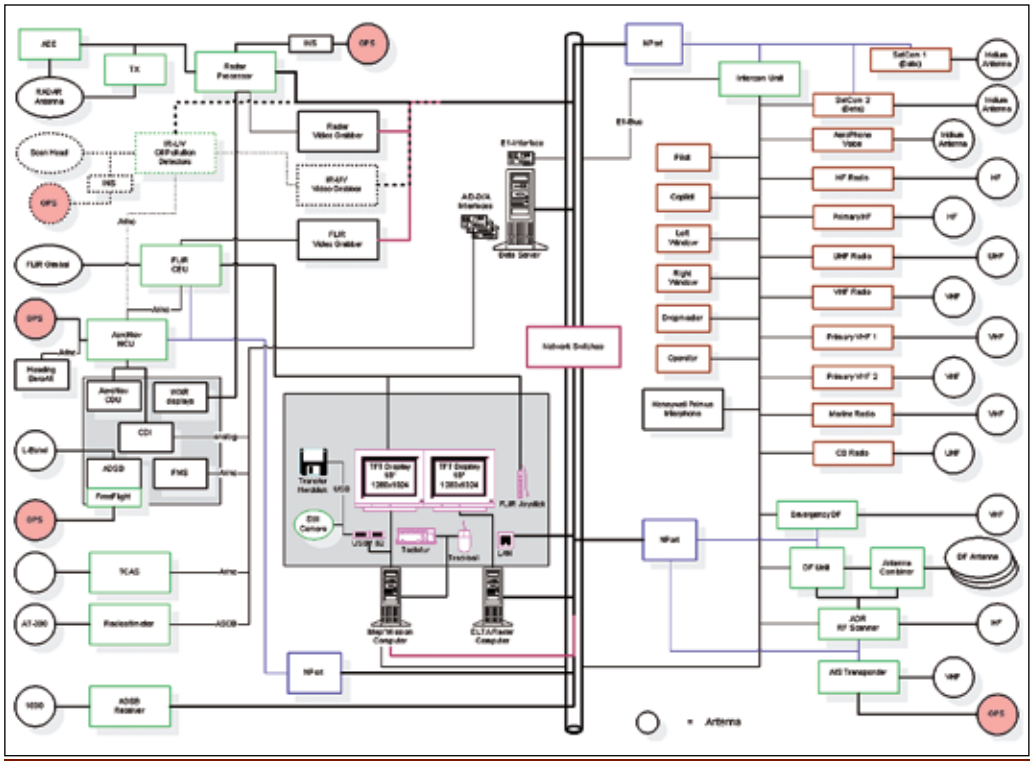
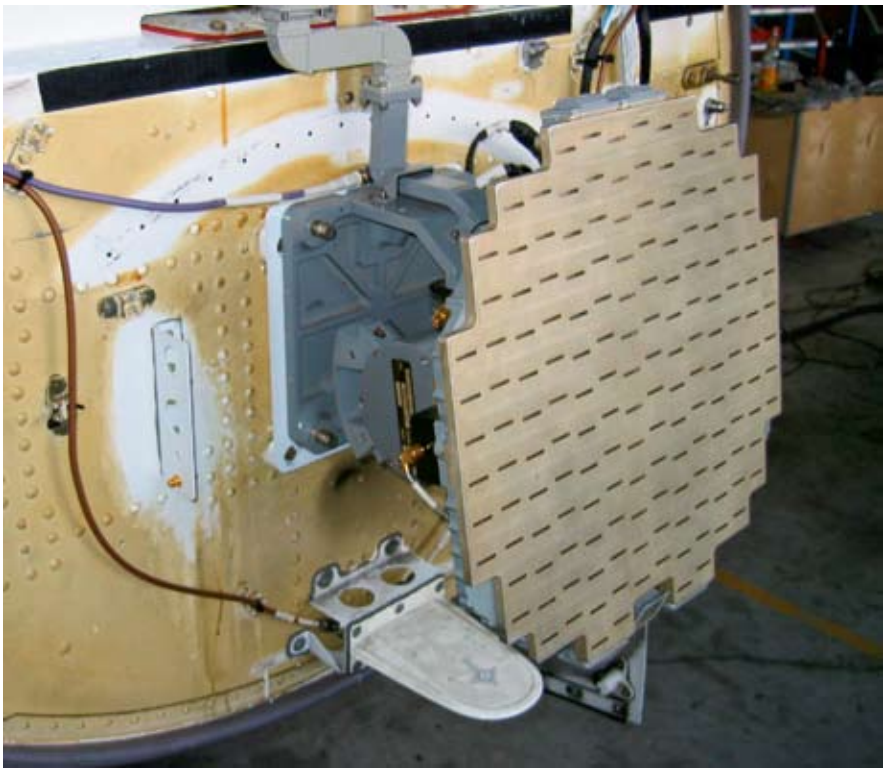


FIGURE 1 Block diagram of AeroMission (GPS antennas are marked red)



Nose-mounted surveillance radar antenna

The turret of the electro-optical/infrared sensor

radar and FLIR sensor data and video, scanning, and direction finding (DF); visualization of automatic identification system (AIS) transponder signals, moving map display with overlay of mission data, integrated mission data base, position storage, automatic and manual report generation, connection to internet via Iridium satellites, report exchange with mission control center, support of drop functions, mission guidance, transfer of mission/task order from ground station to aircraft, transfer of stored data from aircraft to ground station.

Sensor Suite

In addition to the navigation system, moving map display, system software, and databases, AeroMission incorporates a number of additional sensors to aid its surveillance and reporting functions.

Surveillance Radar. A surveillance radar with a nose mounted antenna (see photo) has been installed in the DO-328 aircraft. The radar supports aircraft Air-to-Sea and Air-to-Air missions. It is specially designed to fulfil the operational needs of small target detection at long range and high sea states. A GPS-supported INS allows accuracy control and referencing of the radar. This dedicated GPS/INS provides accurate position and attitude of the radar to trace back the radar line of sight. This information is used to calculate the respective radar sweep sector, target co-ordinates, and target ranges referenced to WGS84 coordinates.

Electro-optical/infrared sensor. The electro-optical/infrared (EO/IR) sensors are mounted in a common, stabilized turret in the center fairing, in this particular case a turret of a FLIR. The turret is configured with specific payloads to support missions under daylight and night conditions.

The EO/IR system can be slaved by the mission system and also supports geo-pointing, the ability to define a desired absolute lat/long (WGS84) for camera pointing. Thus, once a target (such as a boat) has been detected, the mission system and the EO/IR sensor can maintain a continuous observation of this target by locking to the line of sight desired lat/long, even if the aircraft attitude and direction changes significantly.

Again, the integrated GPS/IMU provides GPS-supported navigation/attitude information for the FLIR. By knowing this position/attitude, the required azimuth/elevation of the FLIR line of sight relative to the airframe is calculated and transmitted to the FLIR unit.

AIS and direction finding. Shipborne AIS transponders broadcast information of the respective vessels on dedicated frequencies. An AIS transponder incorporated into AeroMission continuously monitors these messages. The system stores the messages and can display all ship information on a layer of the moving map of the mission management system (discussed in more detail later). These capabilities enable the linking of AIS and radar information.

The on-board AIS unit also uses an integrated GPS receiver to obtain aircraft position, speed, and track independently from the aircraft's primary avionics. This information is transmitted via the AIS frequencies to all ships.

Many shipboard AIS transponders and emergency position-indicating radiobeacons (EPIRBs) incorporate GPS receivers, which simplifies the localization and rendevouz efforts of the SAR team. Otherwise, scanning and RF direction finding equipment (antennas

FIGURE 2 Example of the mission management display

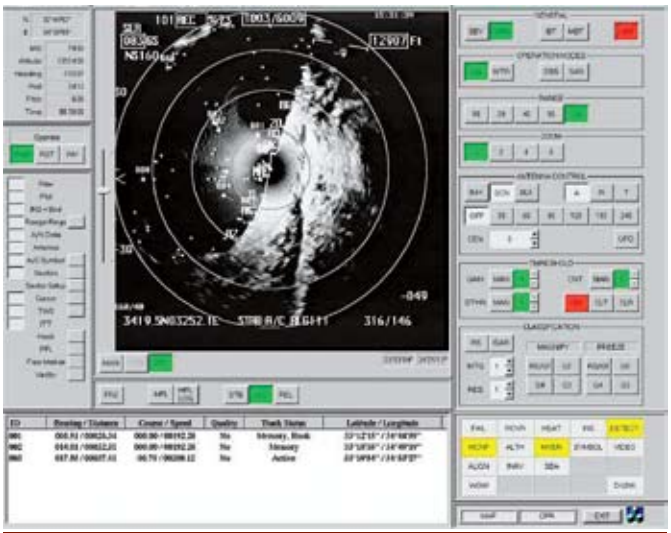


FIGURE 3 The radar display and control user interface

and receivers) are also part of AeroMission's positioning sensor suite.

These monitor communications in the area of concern and can localize the source of a communication or specific distress messages, which have been activated in case of an emergency. Direction finding is realized via the combination of a scanner and an additional DF device.

Mission Management

TheAeroMission management suite is an integrated solution that consists of equipment and software for sensor operation and control; sensor data gathering, storage, and evaluation; mission reporting, and communications control and recording.

Two screens display the GUI for mission management and situational awareness. The first display (Figure 2) shows the mission data, map applications, aircraft information (position, heading, attitude, etc.), and maintains the target database and generates the mission report. The second screen is used to display the radar (Figure 3) and FLIR(Figure 4) video.

The moving map display concentrates all tactical information and is based on standard digital cartography (see Figure 5). It provides multiple layers with user-selectable maps for SLAR and FLIR, AIS, targets, user defined areas, nautical information, aeronautical information, mission planning, waypoints, and search patterns.

The digital media recorder, controlled through the mission software, is a combination of a digital audio recorder and a digital video recorder. The video part allows recording of FLIR videos and of radar videos as well as respective snapshot pictures. The audio part supports digital recording of multiple audio streams. In addition, photos taken by the handheld camera can be stored. All recordings are stamped with precise time and position and attitude generated by the AeroMission's reference system.

FIGURE 4 Example of the FLIR display: infrared (a) and visible band (b)

AeroMission provides a sophisticated reporting system for in flight report to ground stations or post mission reporting. Any recordings obtained during the mission (video, audio, pictures, position, altitude, time, etc.) can be added to the reports.

Flight Deck Interface

The mission system has a number of interfaces to the flight deck in order to support the mission and decrease the work load of both, the cabin crew and the flight deck crew.

Waypoints and search patterns can be created with the mission system and transferred to the flight management system (FMS) of the aircraft via an ARINC 429 interface. Thus, the cabin crew can perform the flight planning in accordance with the actual mission needs, using all the information sources of the mission system. The flight deck crew subsequently activates the respective flight plans without any additional workload for flight planning.

Search pattern and waypoints can also be received from the ground stations and transferred to the FMS. Changes of the flight plan by the flight deck crew as well as flight status details (bearing, navigation, etc.) are reported to the operator in the cabin.

For oceanic operations, two independent GPS-based systems provide

FIGURE 5 Sceenshot of the moving map including track, search area, and search pattern

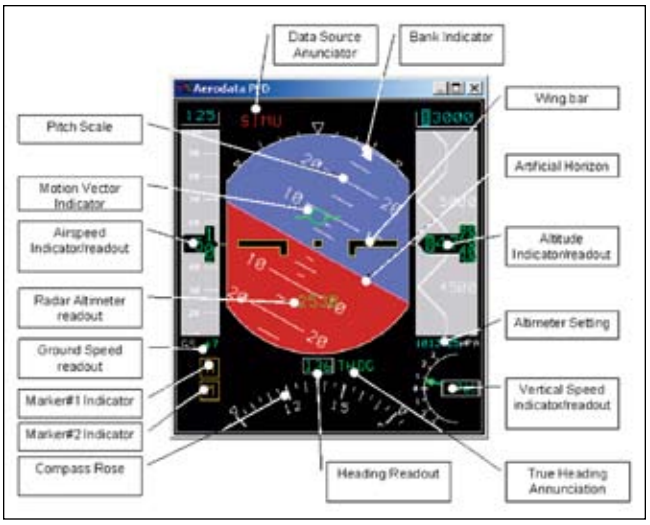


FIGURE 6 Example of the artificial horizon display of AeroMission

the long-range navigation information, because other RF based means of navigation are typically not available over the ocean. A separate GNSS unit (part of the primary glass cockpit) provides the primary long-range GPS navigation function, with AeroNav serving as backup. Both GPS NAV systems fulfil the operational requirements according to FAA Notice 8110.60 (Oceanic Operations) incorporating receiver autonomous integrity monitoring (RAIM) algorithms with fault detection and exclusion (FDE) capability.

An artificial horizon provides the operator with all information about the current aircraft status (Figure 6).

System Qualification and Certification

The qualification and certification process for the project was quite challenging. All modifications of the airframe have been certified through a Supplemental Type Certificate (STC) approved by European Aviation Safety Agency.

Special emphasis was given to the electromagnetic compatibility (EMC) testing due to the numerous computers, transceivers, sensors, and antennas (more than 30 antennas including 6 GPS antennas), which form part of AeroMission. Both aspects were of concern, non-interference with the primary avionics as well as the high reliability and stability of the mission system itself. The software has been developed in accordance with RTCA DO 178B.

Before the first aircraft was delivered, the performance of the mission system and its software as well as of the modified aircraft was verified during extensive test flights, most of them carried out during low-level flights in the North Sea area.

Operational Experiences

During the test flights and also during the first 10 months of operations, AeroMission installed in a DO 328 aircraft has demonstrated its reliability and efficiency with an overall service availability of more than 99 percent.

The integrated mission system that coordinates mission tasks, sensor outputs, and navigation has proven particularly important for the complex dropping of SAR equipment. The GNSS/GPS based applications contributed significantly to the excellent performance in this application.

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Four Dornier DO 328 turbo prop aircraft with AeroMission installed are already operating successfully in Australia, and by February 2007 five of these aircraft will be in service. The GNSS/GPS applications on board the aircraft play an important role regarding accuracy and safety.

Manufacturers

AeroNav, the integrated GPS/IMU unit from **Aerodata AG**, Braunschweig, Germany, incorporates a GPS receiver from **NovAtel, Inc.**, Calgary, Alberta, Canada, and an inertial navigation system from **Sagem Défense Sécurité,** Paris, France. AeroMission also includes a separate GNSSU, the Primus 2000, from **Honeywell, Inc.**, Phoenix, Arizona.

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