AEROMISSION – AN AIRBORNE SYSTEM FOR MARITIME SURVEILLANCE

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ABSTRACT

Maritime Surveillance aircraft have to perform a number of mission types, e.g. Search and Rescue, environment monitoring, fishery control, as well as general border patrol task related to illegal immigration, smuggling and piracy. For these tasks, efficient and high reliable mission system using state of the art technology is required. In 2005, Aerodata AG has developed AeroMission, which has been implemented into Dornier DO 328 turbo prop aircraft for the purpose of Search and Rescue missions in Australia. The paper describes the technical solution (sensor, mission management, communication) and the related modifications of the aircraft. It is shown, how the subsystems and the software contribute to the high efficiency and reliability of the system. The mission profiles in a maritime environment lead to challenging requirements for design, qualification and testing. Examples for respective solutions are given. Finally, an example provides operational results and experiences obtained during test flights in order to give an impression of the work of the crew using AeroMission installed on a special mission aircraft.

1. SCOPE OF THE SYSTEM

AeroMISSION is an airborne Maritime Patrol, Surveillance and Search and Rescue system, which provides an integrated solution for sensor operation, sensor data acquisition and sensor fusion.

AeroMISSION is capable to support maritime and coastal airborne operations, e,g,

- Search and Rescue (SAR)
- Maritime Surveillance
- Border Patrol
- Pollution Detection and Mapping
- Fishery Control
- Anti Smuggling Patrol
- Offshore Oil Field Monitoring
- Research Applications

Recently, AeroMission has been installed into Dornier 328 aircraft which are used for Search and Rescue operations in Australia.

FIG. 1: AeroMission equipped DO 328 aircraft

Search and Rescue operations are not based on scheduled flights but on ad-hoc flights, i.e. after notification regarding an accident (ship disaster, aircraft crash, etc.) the respective aircraft gets a mission order and a high speed ferry flight to the area of concern is performed. After arrival in that area, typically a low altitude, low speed search flight (500 ft to 1,500 ft) is performed.

The search is performed by surveillance radars, electro-optical sensor, and by scanning and direction finding equipment, which is used to localize specific transmitters of beacons which have been activated during the accident. Once the target (person, ship, aircraft) is found, specific equipment (life raft, pumps) is dropped out of the aircraft. The target position and other details are reported to the mission control centre in order to initiate further rescue activities.

2. SYSTEM DESCRIPTION

2.1. 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 (FIG. 2) gives an impression on the complexity of the system.

The basic system components include:

- Surveillance Radar
- FLIR (Forward Looking InfraRed) sensor
- IR/UV (infrared/ultraviolet) Scanner
- Mission Management and Guidance System
- SAR Homing Device
- HF, VHF, UHF, Satellite Communication
- Intercom including Communication Relay
- Photo/Video Camera
- Ergonomic Operator Work Stations

As an option, other sensors like SLAR (Side Looking Airborne Radar) or MWR (Micro Wave Radiometer) can be integrated.

The operational environment for the operation crew provides maximum benefit from current technology. The operator has a Windows based multi-tasking Graphical User Interface (GUI). The system supports either single or dual screen concepts which allow the 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 manoeuvre.

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, on scene coordination and top cover role, the system provides the following capabilities:

- storage and visualisation of radar and FLIR sensor data and video
- storage and visualisation of scanning, direction finding (DF)
- sensor and DF operation
- visualisation of AIS (Automatic Identification System) 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 centre
- 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

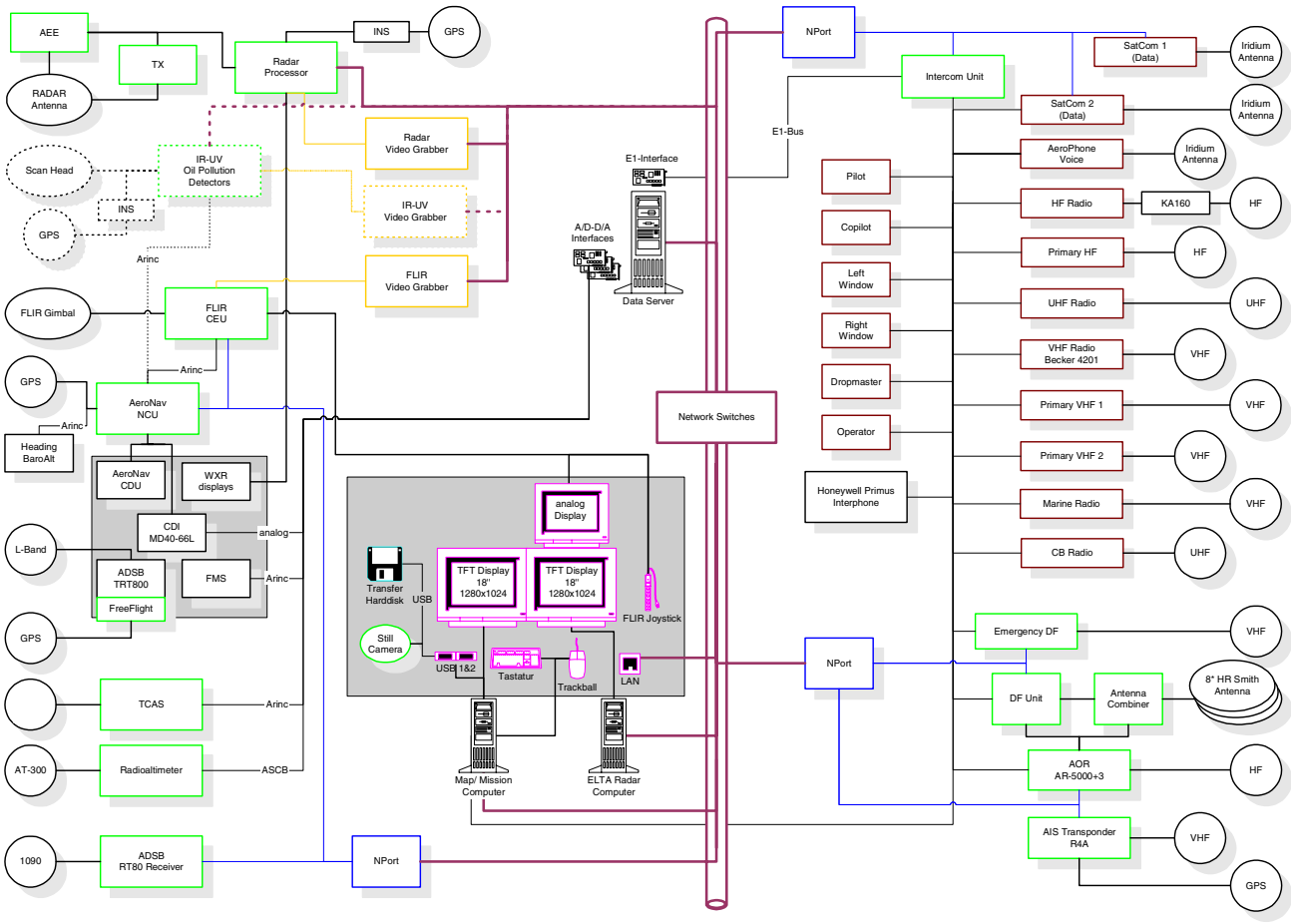


FIG. 2: Example Block diagram of AeroMission

2.2. Sensors

The AeroMission system for the DO 328 based surveillance solution is capable to process any kind of MPA/SAR related sensor data. Typically, the following sensors are implemented:

- 120 deg surveillance radar (nose mounted)
- electro-optical payload (FLIR)
- AIS Transponder
- IR/UV scanner
- Direction finder (DF)
  - Scanner and DF (2 MHz – 500 MHz)
  - SAR ADF (Automatic Direction Finder) for all maritime distress frequencies

2.2.1. Surveillance Radar

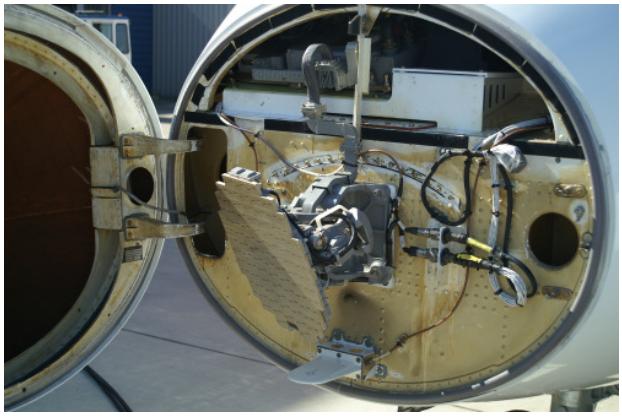


FIG. 3: Nose mounted Surveillance Radar antenna

A surveillance radar with a nose mounted antenna (see FIG. 3) 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. It provides the Air-to-Sea modes:

- Surface Surveillance for target detection;
- Strip Search capability for Pollution detection;
- Moving Targets Indication (MTI) Navigation and Weather mode for performing a long range search with raw video display of weather and ground returns;
- Doppler Beam Sharpening (DBS) for improved mapping in coastal operation and target discrimination;
- Synthetic Aperture Radar (SAR) for high resolution mapping and imaging/ discrimination of targets;
- Inverse SAR (ISAR) for target classification in high sea states;
- Range Signature for range profiling of tracked surface targets;
- SART (Sailor Search And Rescue Transponder) antenna capability

2.2.2. Electro-Optical/Infrared Sensor

The electro-optical/infrared (EO/IR) sensors are mounted in a common, stabilized turret in the centre 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 thermal imager (infrared sensor) provides a wavelength from 3µm to 5µm and focal plane array of 640x480 pixels. Multiple fields of view are selectable.

The Day TV Spotter Scope provides capabilities for long-range daylight search operations. This is possible through the combination of the spotter scope with electronic haze penetration filtering using advanced algorithms.

FIG. 4: The turret of the electro-optical/infrared sensor

The FLIR system includes a central electronics unit, which interface the turret with the aircraft environment and provides the necessary computation capabilities. A control unit is available to control the system from the operator's place.

The EO/IR System can be slaved by the mission system, geo-pointing is supported. Thus, once a target (e.g. a boat) has been detected, the mission system and the EO/IR sensor can maintain a continuous observation of this target, even if the aircraft attitude and direction changes significantly. All EO/IR video streams are be recorded digitally.

2.2.3. AIS and Direction Finder

Automatic Identification System (AIS) transponders are installed on ships to broadcast information of the respective ships on dedicated frequencies. An AIS transponder is also part of AeroMission to continuously monitor these messages, to store the messages and to display all ship information on a layer of the moving map of the mission management system (see below). Thus, AIS and radar information can be linked.

Scanning and Direction Finding equipment (antennas and receivers) are also part of AeroMission to monitor the communication in the area of concern and to localize the source of this communication or the source of specific distress messages which have been activated in case of a disaster.

The system integrates a high performance scanner. This scanner receives the following frequencies:

Band	Frequencies
HF (2 - 27 MHz)	2182 kHz 3023 kHz 4125 kHz 5680 kHz 5695 kHz 6215.5 kHz 8364 kHz

Direction Finding is realized via the combination of a scanner and an additional DF device. For special emergency frequencies a dedicated DF is used.

Band	Frequencies
HF - UHF	27 MHz Citizen's Band 123.20 MHz 156.30 MHz Marine VHF Ch88 224.00 MHz 381.00 MHz UHF Citizen's Band Emergency Beacons (121/234/406 MhZ) SAR Datum Boys (119/238 MHz)
VHF	121.50 MHz 123.10 MHz 156.80 MHz (Marine VHF Ch16) 243.00 MHz Emergency Beacons (121/234/406 MHz)

The respective antennas are installed underneath the fuselage.

2.3. Mission Management

The Missions Management Suite is an integrated solution and consists of equipment and software for

- sensor operation and control
- sensor data gathering
- sensor data storage
- sensor data evaluation
- mission reporting
- communication control and recording

2.3.1. Mission Management and Situational Awareness Displays

Two screen setups are used to display the Graphical User Interface for Mission Management and Situational Awareness. The first display (FIG. 5) shows the mission data, map applications, aircraft information (position, heading, attitude, etc.), maintains the target data base and generates the mission report. The second screen is used to display the Radar (FIG. 6) and FLIR (FIG. 7) video.

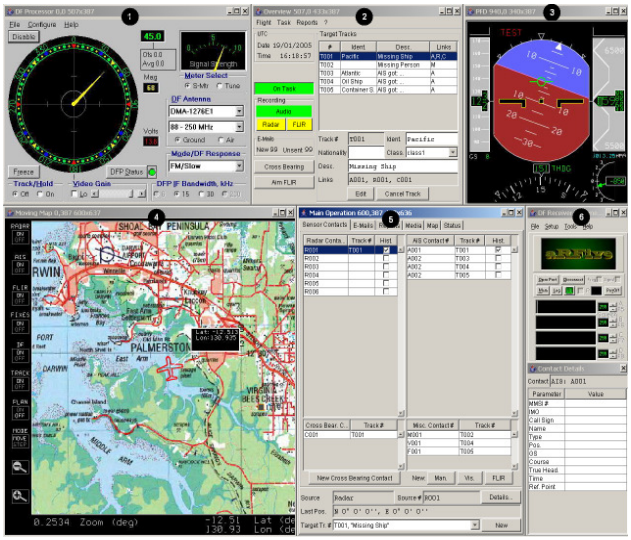


FIG. 5: Example of the Mission Management Display

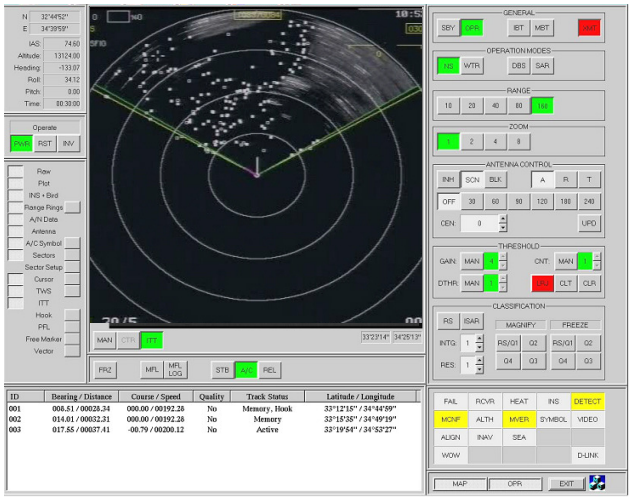
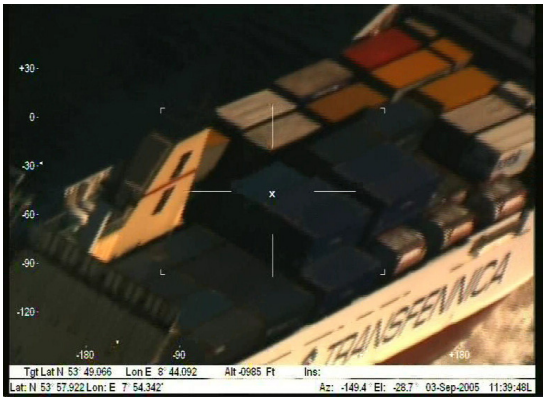


FIG. 6: Example of the Radar Display and Control

a)



b)

FIG. 7: Example of the FLIR display, infrared (a) and visible band (b)

2.3.2. Moving Map

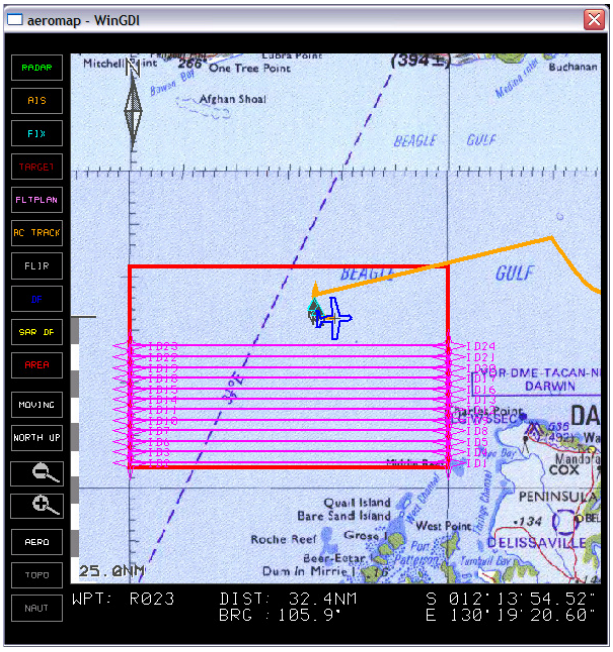


FIG. 8: Example of the moving map including a/c track, search area and search pattern

The moving map display concentrates all tactical information and is based on standard maps. The map is shown in FIG. 8.

The moving map system provides multiple selective layers with user selectable set of maps for

- SLAR, FLIR
- AIS
- Targets
- User defined areas
- Nautical information
- Aeronautical information
- Mission Planning
- Way Points
- Search Patterns

2.3.3. Data Recording, Data Management, and Reporting

Report Name	Generation	When
Operation message	on request	start of task; can be updated during task
Departure report	on request	departure
On Task report	on request	on arrival in search area
Environmental report	on request	
Position report	continuously	update frequency configurable, if required.
Target report	continuously	update frequency configurable, target reports for aircrafts (fast target) can be sent with a higher update rate, if required.
Asset status report	continuously	update frequency configurable; frequency selectable for on task/off task, if required.
Equipment drop report	on request	on dropping of any items during task
Off task report	on request	on completion of the assigned task or if aircraft has to go off task
Landing report	on request	after landing
General Report	on request	
Post Mission report	on request	end of mission

TAB.1: The AeroMission reporting System

The digital media recorder 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.

The digital media recorder is controlled through the Mission Software. The Mission Software contains controls to start and stop the channel. The video recording is coupled to the on/off task (active part of a mission) event, audio is recorded, whenever the system is on task.

Data for audio and video recordings are also stored in the database. The information stored on the retractable hard disk can be used to for the purpose of post-flight analysis.

AeroMission provides a sophisticated reporting system for in flight report to ground stations or post mission reporting. The reports are detailed in TAB.1. Any recordings obtained during the mission (video, audio, pictures, position, altitude, time, etc.) can be added to the reports.

2.3.4. 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 (see section 2.4.3) and can be transferred to the Flight Management System (FMS) of the aircraft via ARINC 429. 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 work load for flight planning.

Search pattern and waypoints can also be received from the ground stations and transferred the 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.

The Artificial Horizon gives the operator all information about the current aircraft status (FIG. 9).The details of this item depend on the aircraft used.

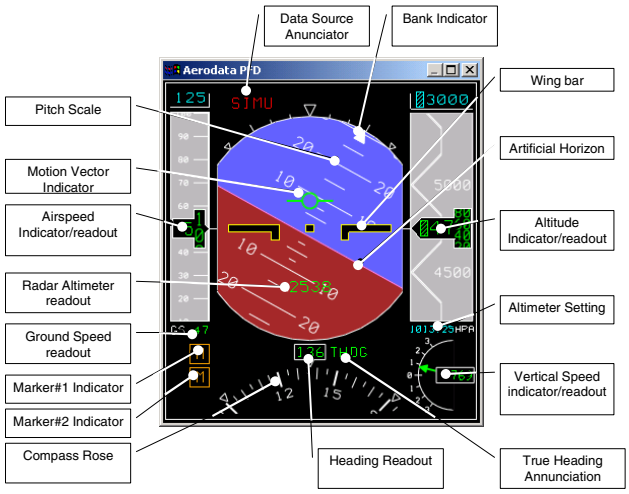


FIG. 9: Example of the artificial horizon display of AeroMission

2.4. Communication Suite

The implemented communication system consists of:

- Digital Intercom System
- Communication Transceiver Suite (HF, VHF, UHF, Satcom)
- Satcom systems for data, report and image exchange
- Integrated digital Communication Relay

To fulfil the various requirements concerning the communication between flight crew, cabin crew and external agencies a state-of-the-art fully digital system is used. The system is completely observable and controllable by the mission system computer via a dedicated "communication GUI". The relay function can easily be initiated and controlled. Every communication source can be recorded automatically or on demand. The following block diagram shows the basic parts of the system.

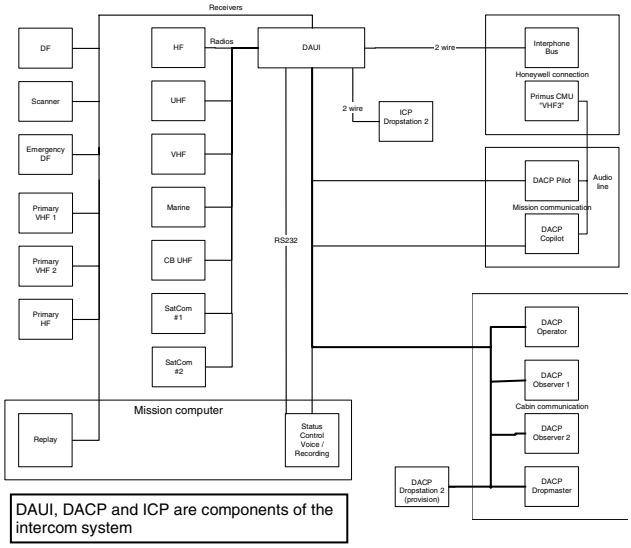


FIG. 10: Block Diagram of Communication System

For voice and data communication with the ground station, Aerodata's AeroPhone using the Iridium satellite network is implemented. The AeroPhone enables world-wide communication.

The communication relay function allows to link different means of communication, e.g. an incoming call on the satellite phone with a maritime VHF connection. In this example, the mission control centre on ground can directly talk to a vessel on the ocean over very long distances, while the aircraft serves as a relay station. This function, as well as the ability for different cabin crew members to use several transceivers simultaneously, are added values of AeroMission and reduce the work load and increase the overall efficiency.

2.5. Operator Workspace

The Operator Workstation forms integral part of the AeroMission system. It is designed to serve most advanced requirements. The outstanding features of this workstation (see FIG. 11) are

- modularity and expendability
- ergonomic design
- equipment mainly operated by software functions
- separate FLIR Controller
- minimum size and weight
- quick change capability
- designed to meet EASA/FAR part -23, -25, -27, and –29 requirements

FIG. 11: Operator Workstation of AeroMission

Due to the modular design of the system, the arrangement of the subsystems and the display can easily be adapted to specific cabin cross sections and operational needs for helicopters and fixed wing aircraft.

The operator's workstation includes:

- the necessary control panels for
  - the different radios (HF and VHF/UHF)
  - SAR Direction Finder
  - Frequency Scanner
  - intercom
  - the sensor equipment control
- two dedicated TFT screens (18 inch)
- trackball with 3 function keys (mouse like) and keyboard

3. THE DORNIER 328 PLATFORM

3.1. Basic Aircraft

The basic DO 328 turbo prop aircraft provides a number of features which are appropriate for maritime surveillance and SAR missions. It is a high wing aircraft with high cruising speed, very low noise level in the cabin, and it has an integrated avionics system with a five tube EFIS system. In addition, the operating and maintenance cost are low.

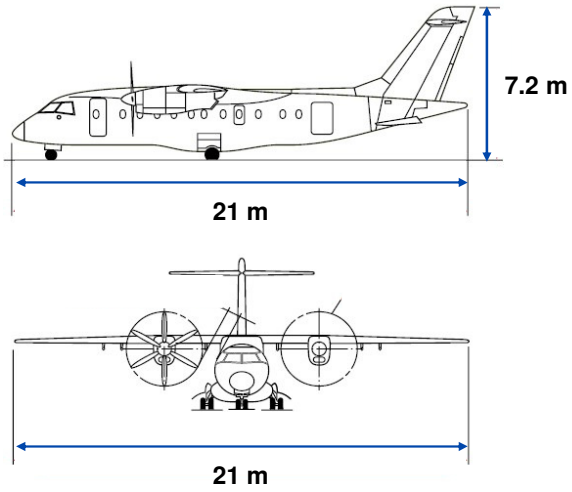


FIG. 12: Dimensions of the DO 328-100 TP

FIG. 13: Flight deck of the DO 328-100 TP

3.2. Mission Related Aircraft Modifications

The integration of the sensors, the mission management system, and the communication system required of number of aircraft modifications to be performed. In addition, two of the standard passenger windows have be enlarged to enhance the view for the observers in the cabin.

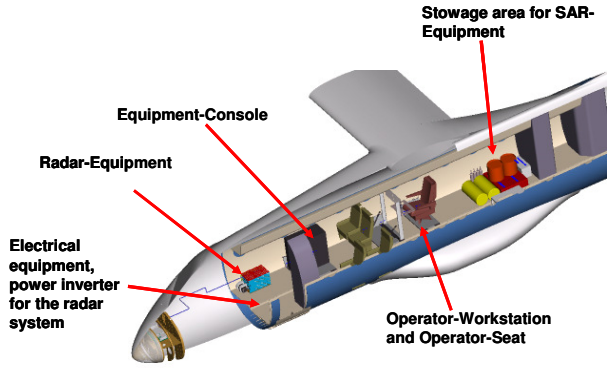


FIG. 14: Modifications on the DO 328-100 TP

FIG. 15: Cabin view of the installed AeroMission work station

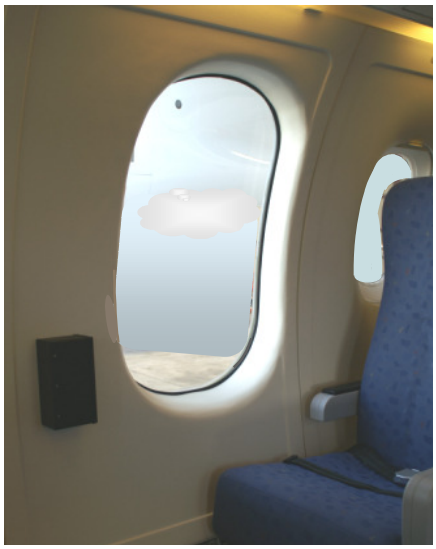


FIG. 16: The enlarged observation windows (DO 328)

4. DESIGN, 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 EASA.

The original nose mounted weather radar was replaced by the surveillance radar, which also provides a weather radar mode without having been certified according to RTCA DO 173. Hence, the complete surveillance radar and the related installation had to be certified accordingly. This included dedicated weather radar displays, since the integrated avionics system of the DO 328 does not provide an interface for third parties weather radars.

For the airframe modifications (e.g. cut out for the FLIR, enlargement of the windows), strength analysis, damage tolerance analysis (DTA), finite element analysis (FEM) as well as non technical objection (NTO) statements have been performed.

In order to enable dropping of life rafts, etc. during low level flight, one of the existing emergency exit doors has been certified to be opened in flight. A specific drop device and safety measures for the crew have been developed and the related performance has been proven during test flights.

Also the mission system and its components have to prove environmental qualification in accordance with RTCA DO 160 D as well as analysis in order to prove the respective airworthiness. The maritime environment is extremely challenging due to low level flight, salt spray, weather conditions, etc. Thus, ruggedized components are essential.

A number of components, e.g. the mission system computers, the equipment rack, the operator work stations, have been developed by Aerodata. These new components had to be qualified. Special emphasis was given to the electromagnetic compatibility (EMC) testing due to the number of computers, transceivers and sensors which form part of AeroMission. Both aspects were of concern, the non-interference with the primary avionics as well as the high reliability and stability of the mission system itself. Besides the hardware components, also the software was designed and qualified to be efficient and reliable. Consequently, 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.

5. OPERATIONAL EXPERIENCES

5.1. Mission Profile Example

An example for an extensive Search and Rescue Mission is given below. In this particular case, the benefits of AeroMission fully can be applied, i.e. the ability also to serve as an airborne on scene coordination platform for other aircraft of ships contributing to the missions.

Typical deployment patterns may include:

a) First day. Visual search. Standard crew, with possibly additional Air Search Observers.
b) First night. Electronic search and/or visual night search. Full Flight Crew and either one or both SAR Crew (depending on search capability provided).
c) Second day. Visual search and/or On Scene Coordination. Standard crew, possibly with additional Air Search Observers for visual search.
d) Second night. Electronic search and/or night search. Full Flight Crew and either one or both SAR Crew (depending on search capability provided).
e) Third day. On Scene Coordination and/or visual search. Standard crew, possibly with additional Air Search Observers (visual search)

On Scene Co-ordination functions which may be delegated to the aircraft SAR crew include:

- Coordinate allocated airborne resources in a defined geographical area.
- Facilitate exchange of information (revised tasking, intelligence) between the rescue control centre (RCC) and:
  - Other airborne SAR assets in the search area; and
  - Other surface or land based SAR assets in the search area.
- Recommend to the Search and rescue mission coordinator (SMC) modifications to the search action plan based on prevailing environmental conditions and implement tactical changes authorized by the SMC.
- Monitoring of the performance of other assets participating in the search.
- Under direction of the SMC, implement the rescue plan (when needed).
- Using radar, TCAS and AIS track SAR assets in the search area and provide the plot to the RCC.
- Receive weather and aeronautical information and distribute to SAR assets in the search area.
- Provide regular updates) on weather and search conditions to the RCC.
- Facilitate flight following and SAR watch for SAR aircraft. This maybe achieved by relaying “Ops normal” calls to Air Traffic Services, or receiving updates from aircraft, and passing them onto the RCC.
- Report the arrival and departure of SAR aircraft in the search area to the RCC.
- At the request of the RCC acquire and provide other information on request, EG Latest Divert Time, Endurance, person on board (POB), estimated time of arrival (ETA)
- Respond to an urgency or distress call.

Once, the target has been identified and localized, specific equipment may be dropped, e.g. life rafts, de-watering pumps, heliboxes, storpedos, smokes, markers, SAR datum buoys (including self locating datum marker buoys in the future), or message bags.

A storpedo can safely deliver a wide range of equipment, radios, medical supplies, spare parts, emergency rations, and can, if required, deliver 20 litres of liquid.

The dropping requires precise locating of the drop position and harmonized operation of flight deck crew and SAR crew in the cabin, especially at night and under severe weather conditions.

5.2. Achieved Performance and Reliability

During the test flights and also during the first 10 months of operations, AeroMission installed in a DO328 aircraft has given evidence of high reliability and efficiency. The overall availability was better than 99%.

Especially the complex dropping of SAR equipment was proven to work excellent due to the integrated mission system that coordinates mission tasks, sensor outputs, and navigation.

The communication suite including the extensive reporting system works highly efficient and decreases the work load of the SAR crew by automated procedures.

6. SUMMARY AND OUTLOOK

AeroMission fully meets the requirements of a state of the art integrated and modular maritime surveillance system. The operational experience is excellent. By having two Dornier DO 328 turbo prop aircraft with AeroMission installed already are operating successfully in Australia, until February 2007 five of these aircraft will be operational.