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Radioelectronic and thermovisual support in display systems to aid in searching for sea-going ships from search & rescue helicopters

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Abstract

This paper presents the basic principles of SAR (Search and Rescue) and CSAR (Combat Search and Rescue) missions, with the SAR support systems installed on-board Polish and German military helicopters presented in more detail. Mi8/17 and W3PL "Głuszec" helicopters with an integrated avionics system (designed and constructed in the Air Force Institute of Technology) used in combination with an on-board weaponry system are designed to undertake CSAR missions. A TOPLITE observation-targeting head (with TV and FLIR thermal cameras, for day and night operation respectively) and a RSC125G on-board radio direction finder were used to search for survivors. The weaponry system of the W3PL "Głuszec" helicopter is involved in supporting CSAR search-rescue tasks, e.g. functions of targeting with the use of a Head-Up Display (HUD) (through the integrated ballistic computer) and imaging with the use of a TOPLITE head monitor.

Introduction

Analysing the military conflicts waged since WWII, it can be seen that helicopters have become the main means of conducting military, as well as humanitarian, missions in the world. They play very important roles equally in times of peace and war. The capability of low level flight at a relatively high velocity and the ability to land in severe terrain make helicopters very useful when it comes to performing search and rescue missions. The success of such missions depends especially on the helicopters' onboard avionics equipment. For the execution of aviation search-rescue missions, the Polish Air Forces have helicopters for combat search and rescue (CSAR), whose main task is to perform coordinated actions according to previously developed procedures and tactics in order to detect, identify and save a pilot-survivor (crew) who has been shot down or after an emergency landing in enemy territory during times of crisis or war, or other personnel in danger. The integrated avionics system, which was developed by the Air Force Institute of Technology (AFIT) enables the control of munitions and search-rescue equipment through the use of a digital MIL1553B data bus (Pazur, 2008).

One of the basic elements used in search-rescue missions is the Head-Up Display (HUD), which supports the pilots' work during the execution of search and rescue (SAR) and CSAR missions (NATO AAP-6 PL, 2001). The CSAR search system installed on-board the W3PL "Głuszec" ensures the detection of, and determination of the bearing to, a survivor's signal source, supports the survivor search process over a specified area, supports the process of lifting the survivor aboard the helicopter and enables communication with the survivor and receipt of GPS coordinates of the survivor's radio location. CSAR missions are defined as undertakings that involve: detection, localisation, identification and rescue of flight crew (aircraft crew) in territory occupied by an enemy or in potentially hostile territory. They may occur during times of crisis or war. SAR missions are also carried out in order to rescue isolated personnel, other than flight crew, equipped and trained to cooperate with CSAR forces (Joint Publications 350.2, 0, 0, 1996; Joint Publications 3-50.21, 1998; Machaj, 2004).

Searching for and localisation of shot down flight crew or other personnel in CSAR actions can be carried out visually or via electronic means. The selection of the appropriate search method depends on the rescue equipment of those calling for help, as well as the forces and means used for searching. While searching by electronic means, in order to obtain audio communication and a bearing, the emergency radio stations of flight crews, radio direction finders on the aircraft, emergency radio stations with GPS systems, SAR satellite systems (e.g. COSPAS-SARSAT), night vision equipment and televisual equipment (e.g. installed in so-called observation heads) are used.

A search with the use of electronic means is performed when the survivor is equipped with transmission rescue equipment. By using the properties of directional reception of radio waves (with the use of special equipment mounted in the aircraft), satellite tracking systems, radio tracking ground stations and, most simply, by establishing communication with the shot-down personnel, or with a witness of the event, it is possible to obtain information about the survivor's location which allows for locating the survivor both at sea and on land. In CSAR missions, owing to the use of special encryption keys, electronic means are also used in the preliminary identification of the survivor; however, final identification takes place just before pickup of the rescued person on the basis of information collected and prepared before starting the mission (including, among other things, photos and other details that unambiguously allow for the identification of a person).

A visual search is the easiest method of searching. Unlike electronic searches, they are characterised by a shorter range of recognition and fewer possibilities for identifying objects; therefore, searches are more complicated and long-lasting. During a visual search in combat conditions, the risk of detection and destruction of the rescue vehicle increases. The implementation of a visual search largely depends on, among other things, the determination of the search area, weather conditions, type of object search for, specification of observation conditions (time of day, season, marking of the object to be found, flight altitude) and assessment of the existing risk level in the searched area (FM 1-112, 1997; FM 1-113, 1998; Joint Publications 350.2, 0, 0, 1996; Joint Publications 3-50.21, 1998).

This article discusses the technical solutions, functions and installations of systems for supporting CSAR missions mounted in the Polish W3PL and German CH53 helicopters.

Systems supporting CSAR missions in the W3PL helicopter – Organisation of the integrated avionics system in CSAR mode

The integrated avionics system of the W3PL helicopter operates in various modes. The following systems are integrated: navigation system, communication system, CSAR system and weapon control system (Pazur, 2008). One of the above-mentioned is a search and rescue mode – CSAR. Operation management of the integrated avionics system is implemented by selecting the operating mode with the use of function keys on the MW1 multi-function monitor's keyboard. There are three MW1 displays, one each for the crew commander, second pilot and rescue team commander. The access to the operating modes is presented in Table 1. Each operating mode

Table 1. Access to the different modes of the MW1 keyboard (green colours – CSAR boards)

SWITCH	1 press	2 press	3 press
MAP	ROUTE	PICTURE	ORTOPHOTO
WSK	START	FLIGHT	LANDING
ATTACK	ID_UZBR	ATAK_ZEW [EXTERNAL ATTACK]	ATAK_WEW [INTERNAL ATTACK]
CSAR	BEARING	SEARCH	LIFTING
RADIO	RADIO NAVIGATION	RADIO COMMUNICATION	–

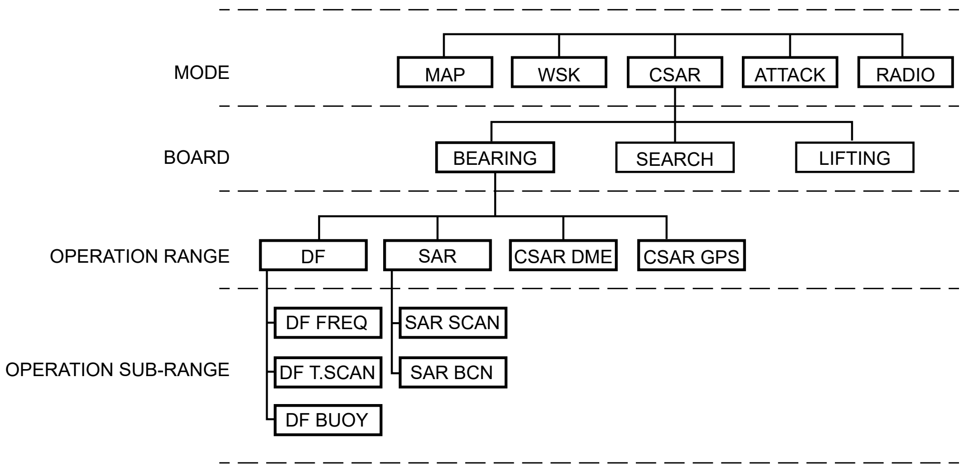

Figure 1. Organisational diagram of the integrated avionics system's operation in CSAR mode (AFIT)

is accompanied by mode-specific imaging of data and access to control functions. It is possible to prepare the whole mission on an external device called a Mission Planning Station. This allows the pilot to prepare for the task before debriefing, to discuss all the important aspects of mission realisation and then load the mission to the helicopters' onboard computer via a USB slot in the cockpit (Sajda, 2008).

An organisational diagram of the integrated avionics system's operation in search and rescue mode (CSAR) is presented in Figure 1.

Organisation of the CSAR BEARING board

The BEARING board allows for the detection of a signal source, and identification of the bearing to that source, (e.g. a survivor's radio station) with a specific frequency. All the necessary information for carrying out this task is provided by the RSC125G direction-finding system, which provides the integrated avionics system with the following data:

- radio bearing to the signal source (operating ranges: DF, SAR, CSAR DME);
- signalling of the time of flight over the sonobuoy – (DF operating range, DF BUOY sub-range);
- radio bearing and distance to the electric beacon (radio station) operating at the selected frequency and with the assigned identification code (ID) – as a response to single questions – CSAR DME operating range;
- radio bearing and distance to the electric beacon (radio station) operating at the selected frequency and with the assigned identification code (ID) – as a response to continuous questions – CSAR DME operating range;
- audio communication with a survivor – CSAR DME and CSAR GPS operating ranges;
- GPS data on the survivor's location – CSAR GPS operating range;
- reception and transmission of a free text or canned message.

The composition of the RSC125G direction finder includes the following elements (Figure 2):

- LPT125G processing unit – the main element of the direction-finding system including transmission and reception systems and signal processors;
- ANT430 type direction finding antenna – receives high-frequency signals and determines the bearing;
- UHF antenna – used for communication with the survivor in CSAR DME and CSAR GPS operating ranges.

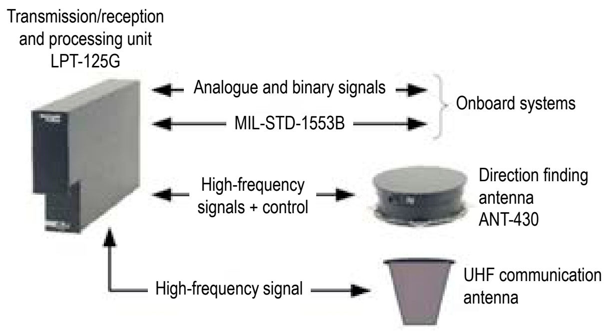

Figure 2. RSC125G system (Rockwell Collins, 2005)

The direction-finding system communicates with the other parts of the avionics system via a MILSTD 1553B data bus interface standard. The signals that control the direction finder (selection of the operating range, frequency of received signals, etc.) and information sent by the direction finder are received via the data bus. Detailed data on the direction-finding system installation are provided in the literature (Rocwell Collins, 2005).

The information available in the CSAR mode's BEARING board is presented on three MW1 multi-function monitors in the form of a CSAR panel and a bearing indicator for the signal emission source. These elements are displayed in the fundamental field of the monitor's screen set against a map. Within the failure field, in case of incorrect operation of the CSAR system, a SCSAR red warning flag is displayed, and the survivor's signal detection (or loss) is each time confirmed by acoustic signal generation.

The bearing indicator (Figure 3) presents a graphical depiction of a relative bearing (154°) to the signal source (location of the survivor) provided in the 5th field of the CSAR panel. The centre of the bearing indicator shows the location of the helicopter on the map. Taking into consideration that the helicopter is on a heading of 190°, the bearing to the survivor, to be transmitted to the SAR coordinator or other SAR unit, is 344°. In cases of a lack of information regarding the signal source bearing, or with no signal detected, the bearing indicator is not displayed. In the case of reception of GPS coordinates of the survivor's location (in the CSAR GPS subrange), instead of an arrow on the map, the survivor's location is illustrated.

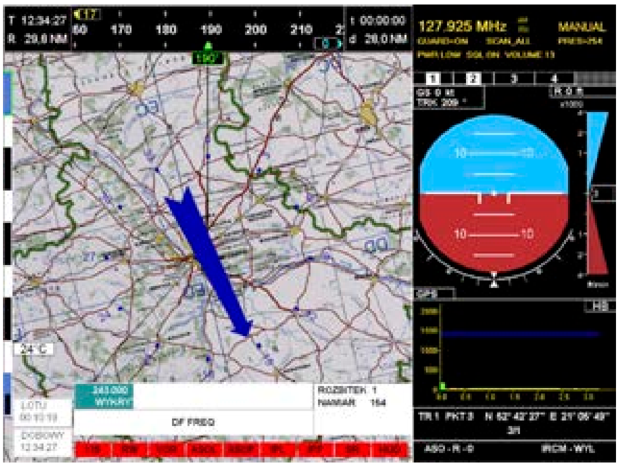

Figure 3. CSAR mode BEARING board showing relative bearing to the survivor (AFIT)

The CSAR panel is displayed in the lower part of the fundamental field of the MW1 monitor's screen (Figure 4). It is divided into 6 information fields, displayed and completed with information depending on the system's operating subrange.

Fields 1–4 are not always displayed. The number of displayed fields depends on the system's operating subrange. In the 5th field, the survivor's number and the numerical value of the relative bearing to the signal source are provided.

<table>
<tr><td>FIELD 1</td><td>FIELD 2</td><td>FIELD 3</td><td>FIELD 4</td><td rowspan="2">FIELD 5</td></tr>
<tr><td colspan="4">FIELD 6</td></tr>
</table>

Figure 4. CSAR panel (AFIT)

The 6th field displays the name of the range and the subrange in which the CSAR system is operating (e.g. DF FREQ, SAR SCAN, CSAR DME) and the number of the received canned message or the content of any message (only CSAR GPS range); for the SAR BCN subrange, the name of the country that the COSPAS-SARSAT electric beacon belongs to is also shown.

A detailed description of the CSAR panel is provided in the literature (Sajda, 2008; 2009).

Instead of visual information, the CSAR detection system is also a source of acoustic signals, which are generated:

- at the time of the PBIT test initialisation;
- at the time of signal detection, which allows the determination of the bearing to its source;
- at the time of loss of signal reception, which allows the determination of the bearing to its source;
- and at the time of detection of the signal at emergency frequencies, in DF T.SCAN and SAR SCAN subranges.

The visual information from the CSAR search system is available on three MW1 monitors; however, control is only possible from the second pilot's multi-function monitor. The selection of the system's operating range and subrange and the data input are carried out via MENU. Feedback from the crew (selection of the tracked signal source, questions, etc.) is implemented by using numeric keys 1–3 of the second pilot's MW1 multi-function monitor.

Organisation of the CSAR SEARCH board

The SEARCH board makes it easy to find a survivor in a searched area. Searched areas are introduced to the system at the stage of mission preparation. Before starting the search process, the operator must select one of the defined, previously introduced areas in MENU on the SEARCH board.

After selection of the SEARCH board, the following elements will be displayed on the MW1 monitor (Figure 5):

- the map in North-up display mode with a marked position of the helicopter (red dot);
- exploration area;

- the distance to the head's observation surface position;
- a line at the edge of the search area, the colour of which indicates whether the search area blurring function is turned on or off.

Blurring the search area is associated with the observation head's searching process. The pilot, while manoeuvring the helicopter during searching, marks (in pink) the places through which the head's observation surface diameter is crossed. The pilot's task is to search the declared search area in such a way as to not leave the area unmarked.

When the pilot searches the declared area, the operator observes the image presented on the head's monitor, at the same time searching for the survivor. A description of the control and search methods available in the W3PL helicopter's system can be found in the literature (Sajda, 2008; 2009).

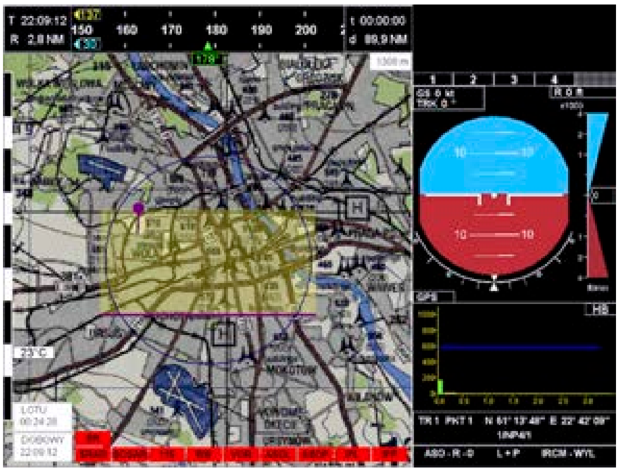

Figure 5. SEARCH board (AFIT)

The searching process is supported by a visualisation obtained from the TOPLITE surveillance system which consists of a turret with a sensor package and electronics (EOP) and a Control and Monitoring Unit (CMU). The TOPLITE is suitable for aerial, maritime and ground platforms and withstands the most demanding military requirements in those arenas.

The TOPLITE EOP provides the following operational capabilities:

- Day/night target detection, recognition, and identification;
- Day/night target acquisition (manual and automatic target tracking).

Examples of visualisation from the TOPLITE's TV and FLIR surveillance system cameras are presented in Figure 6.

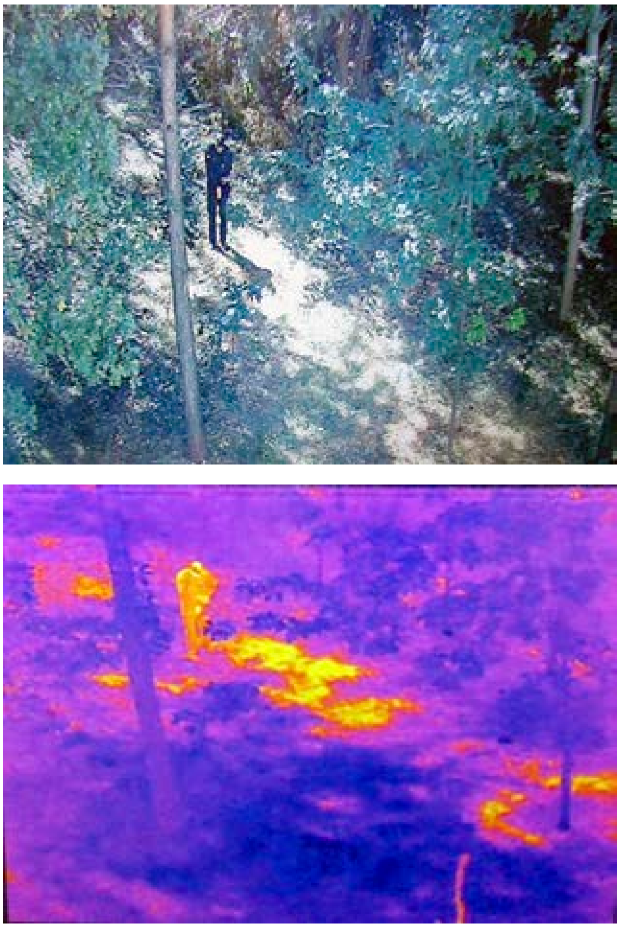

Figure 6. TV and FLIR TOPLITE camera visualisation of a survivor's whereabouts (AFIT)

Organisation of the CSAR LIFTING board

In the CSAR search and rescue mode's LIFTING board the search system provides information supporting the process of bringing the survivor aboard the helicopter while hovering. Calling up the LIFTING board results in the display of a lifting indicator (Figure 7), against the map on the MW1 monitors, in the fundamental field.

The direction of movement of individual lines on the indicator informs the crew about the necessary

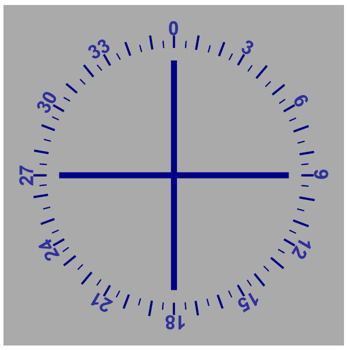

Figure 7. Lifting indicator (hovering) (AFIT)

direction of movement so as to keep the helicopter as precisely as possible over the hovering point. The horizontal line relates to fore-aft movement, and the vertical one to left-right movement. Owing to the installation of four-channel autopilot at the time of modernisation, while lifting the survivor it is possible to correct the helicopter's position with the use of a manipulator at the winch operator's position.

Modernisation programme of CH53 helicopters of the German armed forces for the needs of performing CSAR type tasks

The German armed forces have joined the organisation of CSAR type forces. This was dictated by the need to implement these types of task with their own resources during missions outside the territory of the country (e.g. within the framework of ISAF forces). It was decided that CSAR missions in areas with an increased threat will be implemented by CH53GS/GE type helicopters, modernised on the basis of the CH53 helicopters currently used.

The choice of this type of the helicopter was supported by its size, range, possible flight duration and its availability and reliability.

Until 2004, in the German armed forces there were 80 CH53 type helicopters in service, including 20 of the CH53GS version and 60 of the CH53G version. The CH53GS helicopters, unlike other helicopters of this type in the service, were equipped with additional external fuel tanks, electronic protection systems and SATCOM type communication, and had the capability to perform low altitude flights at night. In accordance with the modernisation plan, the German fleet of CH53 helicopters was to consist of helicopters based on the CH53G/GS type platforms, but equipped with new on-board systems (Schneider, 2010).

The basic objectives of the performed work include the relatively fast enhancement of the capabilities of the helicopters that are currently in service, including the ability to undertake searches for, and the bringing aboard of, ISAF crew. This is to be implemented by equipping CH53GS/GE helicopters with new on-board systems, e.g. mounting bases for the observation and search systems, antennas and cabling, and, as a second "element" of modernisation, the development and implementation of a portable and easily removable, on-board CSAR task set (Figure 8). These sets are planned to be implemented as palletised modules, allowing for easy mounting and dismounting on the helicopter and will include the operator's workstation, observation and search systems, interrogator and a broadband detection finder.

Figure 8. CSAR operator's station (AFIT)

A CSAR operator's station must provide:

- communication to the individual PLB emergency radio station of PRC434GSV and PRC112B1 types (possibility of sending text messages, GPS coordinates, voice);
- satellite communication (data and voice) to various systems of data transmission (Link 11, Link 16, Link 22);
- implementation of bearings to the electromagnetic radiation sources with a frequency of 30,400 MHz;
- communication with radio stations in VHF/UHF bands with the use of HaveQuick and SATURN systems;
- integration of information based on the digital map of the Falcon View type;
- implementation of tactical level identification with the use of a camera system (TV, LLTV, IR, LRF);
- concentration of all required functions in the form of a single operating station adapted to operation on board the CH53GS/GE type transport helicopter;
- ergonomic user interface (at the software and hardware levels) suitable for performing long-lasting missions;
- presentation of the additional map and camera steering control with the use of an additional (portable) monitor mounted in the crew's cockpit;
- portable tablet, integrated in the assault compartment, which displays an additional map and allows for camera control.

The distribution of the system's elements within the helicopter is presented in Figure 9.

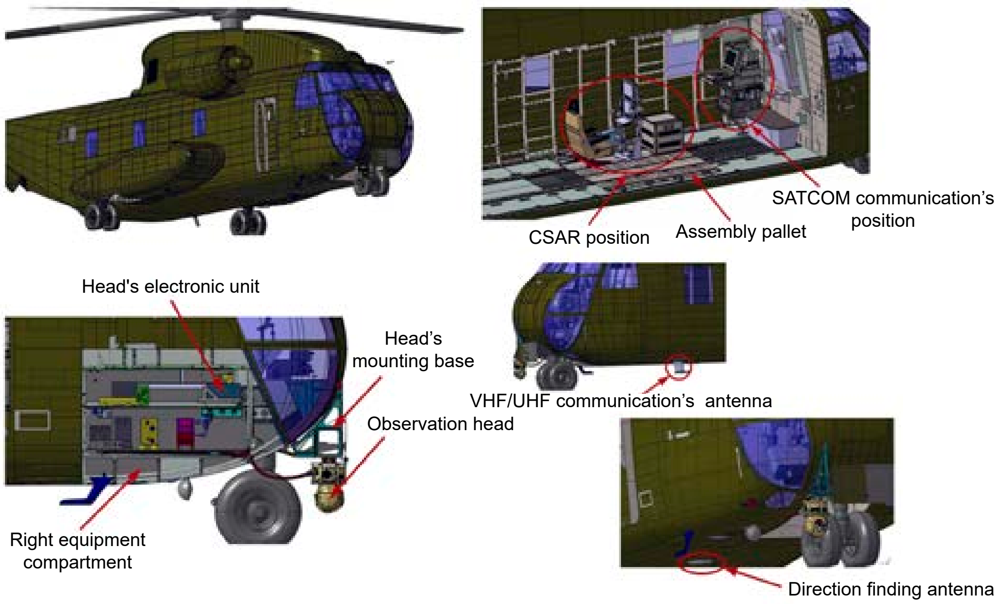

Figure 9. Distribution of the system's elements in the helicopter (AFIT)

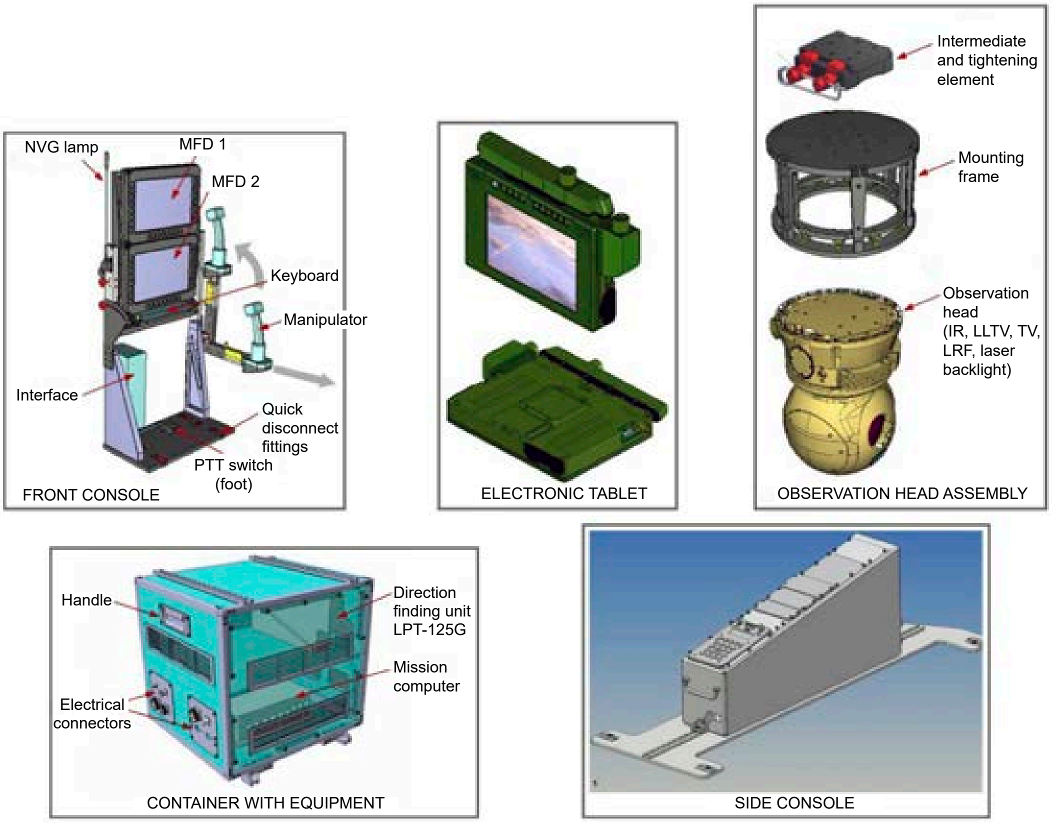

Figure 10. Components of the CSAR system (AFIT)

The CSAR system elements are shown in Figure 10.

The modernisation of CH53 helicopters to enable the undertaking CSAR mission includes:

- application of the launcher of radar traps;
- mounting of gun systems to guard the helicopter;
- application of ballistic covers (armour);
- mounting of an assault rope/rescue winch;
- adaptation to the use of NVG;
- application of SATCOM communication;
- provision of communication with PLB 434/PLB 112 COSPAS-SARSAT individual transmitters;
- mounting of the detection finder (30410 MHz);
- application of the digital map (FalconView);

- mounting of the FLIR search head;
- introduction of the possibility of refuelling in the air;
- use of the weather radar/radar to perform flights according to the area profile;
- data transmission system application.

Conclusions

In this article, two systems that support the search for survivors in CSAR missions and are installed on board helicopters were discussed. They are examples of slightly different approaches to the implementation of the issue from a technical point of view. The system mounted on the W3PL helicopter is fully and "permanently" integrated with the aircraft's avionics; however, the German solution is an example of a system in which the elements can be mounted on board only if necessary while preparing for a specific mission.

When it comes to the searching techniques employed, they include electronic and visual approaches. Searching via electronic means requires that the survivor be equipped with a transmission rescue set. The effectiveness of the visual search conducted during combat actions also largely depends on pre-flight preparation of rescue crews, who should develop an appropriate method of searching, prepare maps and make the necessary navigational calculations and familiarise themselves with the characteristics of the searched object/person, data of recognition and data of spying.

Acknowledgments

This paper contains results of original construction works and achievements of the AFIT, the only company in Poland that – in cooperation with PCO S.A. – produces the helmet-mounted imaging system and the helmet-mounted targeting system. It is also the designer and solution-provider for the Integrated Avionics Systems and Integrated Communication System used by Polish Air Force helicopter crews. The paper provides a selection of crucial basic technical parameters and data so as to characterise the mentioned products and systems while maintaining professional secrecy. The manner of preparing and submitting the article is in accordance with the quality management procedure applicable at the AFIT and does not require additional declarations or permissions.

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