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Helmet-mounted display and cueing systems as pilot aids for aviation/maritime search and rescue missions

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Abstract

The paper presents selected results of analytical and construction works executed at the Air Force Institute of Technology (AFIT) in the context of possibilities of supporting the actions of a helicopter crew, i.e., pilot-crew commander, pilot-operator of on-board systems, and on-board technician participating in aviation/maritime search and rescue missions. Such support is based on using the helmet-mounted display systems SWPL1 "Cyklop" and NSC1 "Orion" for information from the observation-targeting heads and verbal communication with the survivor. Selected imaging and verbal communication devices installed on aircraft operated by the Polish Armed Forces, which are used in aviation/maritime search and rescue actions, are discussed. Particular attention is drawn to the problems associated with the integrated avionics systems of helmet-mounted imaging of piloting-navigation parameters and the helmet-mounted imaging of information from the observation-targeting heads, i.e., the on-board radio direction finder system and emergency radio, which are part of the integrated communication system. Sample structural solutions for such systems and the possibilities of their application in search and rescue missions are presented.

Introduction

Recent dynamically developing on-board aircraft systems include the devices used for supporting the search-rescue missions implemented by the aviation components of the Polish Armed Forces. The main operational activities within the Polish maritime search and rescue are executed by the Naval Air Force Brigade. The air fleet of the brigade includes An28 Bryza (in patrol-reconnaissance versions of An28B1R and An28B1RM bis) aircraft, Mi14PŁ/R, SH2G Kaman, W3RM "Anakonda" and Mi2 rescue helicopters.

The main tasks of the SAR Service are searching for and rescuing humans whose lives are in danger at sea, regardless of the circumstances in which they become endangered, and confronting hazards, and oil and chemical contaminations of the marine environment. Other important tasks are detecting, tracking and destroying submarines, in cooperation with naval forces, carrying out reconnaissance and marking targets for ships, securing the Polish SSR (Search and Rescue Region) in the Baltic and the coastal zone, and the ecological monitoring of the Polish Economic Zone (PSE) in the Baltic Sea.

Military units ensure their forces and resources are in a state of constant readiness to receive and analyse information about threat to life and hazard and contamination events at sea. They plan, manage and coordinate military search and rescue missions and cooperate with other organisational units within the country and with the relevant services of other countries, to implement their statutory tasks.

The mentioned tasks are conducted by the SAR Service on the basis of a "Search and Rescue Action plan" (SAR Plan) and the "domestic plan for fighting

hazards and contamination of the marine environment". Duty crews of rescue helicopters are part of the domestic and international sea and air rescue system (Marciniak, 2009).

Figure 1. W3RM "Anakonda" helicopter during a search--rescue mission prior to taking a survivor on-board (Wikipedia.pl)

Typical SAR and CSAR (Combat Search and Rescue) helicopter equipment for the execution of medical and armament evacuations includes an installed winch (Figure 2) to recover a survivor, and a floodlight, or so-called "searchlight" (Figure 3), to search for and identify a survivor.

Figure 2. W3WA helicopter adapted for the needs of search and rescue missions with an installed winch (Wikipedia.pl)

Figure 3. Kaman SH2G "Seasprite" helicopter adapted for the needs of search and rescue missions with an installed floodlight (Wikipedia.pl)

In the version modified for SAR missions, the Kaman SH2G "Seasprite" helicopter (Figure 3) and Mi14PŁ/R helicopter (Figure 4) are intended to perform search-rescue missions over water and land, in different weather conditions, by both day and night. They are fitted with a thermal-imaging observation system, which increases the effectiveness of searching for survivors at night (Garstka, 2011).

Figure 4. Mi14PŁ/R helicopter adapted for search and rescue missions at sea (Wikipedia.pl)

In typical rescue missions, the crew consists of a crew commander, second pilot navigator (operator), on-board technician, medic and rescuer. To lift and evacuate a survivor, the Mi14PŁ/R is equipped with a sideboard crane with an electric winch intended for lifting people or lowering a rescuer and cargo with the use of rescue strips or a two-person rescue basket or stretchers. Thanks to inflatable floaters located around the hull, this helicopter can land on the water surface, near the survivor.

Mi8/17 and W3PL "Głuszec" helicopters (Figure 5) with an integrated avionics system cooperating with an on-board weaponry system are designed to perform CSAR missions. A TOPLITE observation-targeting head (with a TV for daylight and FLIR thermal camera) and a RSC125G on-board radio direction finder are used for searching for survivors.

Figure 5. W3PL "Głuszec" helicopter with an integrated avionics system cooperating with a digital observation-targeting head and a moving turret gun position (AFIT)

Functions of on-board instruments in search-rescue tasks

To support CSAR search-rescue tasks, the weaponry system of the W3PL "Głuszec" helicopter executes, i.a., the functions of a targeting process with the use of imaging from a TOPLITE head monitor and visualisation on a HUD display (Figure 6) through the integrated ballistic computer (Kowalczyk & Sajda, 2008).

The integrated avionics system developed by the AFIT enables munitions and search-rescue equipment to be controlled with the use of a digital MIL1553B data bus. One of the basic elements used in search-rescue missions is the HUD (Head-Up Display), which supports the pilots' work during the execution of SAR and CSAR missions.

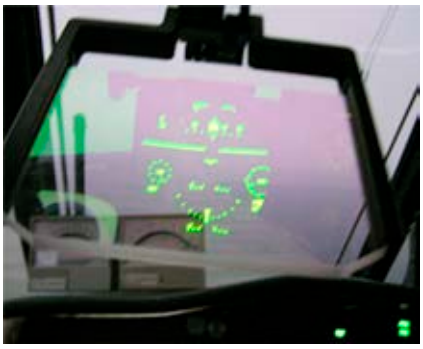

Figure 6. Piloting-navigational and targeting parameters imaging on a head-up display (HUD) of the W3PL "Głuszec" helicopter (AFIT)

The CSAR search system installed on-board the W3PL "Głuszec" ensures the detection and determination of the survivor's signal source bearing, supports the survivor search process over a specified area, supports the process of lifting the survivor on board the helicopter, and ensures phonic communication with the survivor and receipt of GPS geographic coordinates of the survivor's radio location.

The CSAR search package includes a RSC125G radio direction finder, composed of:

- LPT125G receiver block;
- ANT430 active bearing antenna;
- UHF antennas.

The CSAR function is presented on the MW1 multi-function monitor, on three screens: SEARCH, BEARING and LIFT. All users have access to the information received from the CSAR search system, but the whole selection of operational ranges and sub-ranges and control are possible only from the MW1 screen of the second pilot-operator. These screens are used during the respective mission execution stages of a search-rescue action.

On-board equipment functions in search missions

The main functions of the on-board equipment used during aviation search missions include:

- navigating according to a selected route or waypoints entered during the mission planning stage;
- navigating according to commands, with the use of commonly available radio-navigation systems (GPS, VOR, TACAN) or in automatic mode (INS, SWS);
- selection and execution of the search method over a selected area (e.g. used in the W3PL helicopter's CSAR system: sector, spiral, pendulum methods);
- locating a survivor with the use of on-board direction-finding devices (radio direction finder RSC125G);
- generating sound signals.

These are executed through the imaging presented on MW1 multi-function monitors, in the form of an appropriate screen, i.e. WSK (piloting-navigational indicators), MAP (flight map and route) and CSAR (SEARCH, BEARING, LIFT modes). The map display for the SEARCH screen displays the following data: search area, number and coordinates of the selected target (type of executed search method). The BEARING screen enables the display of information obtained from the signal source bearing (e.g. survivor's radio) from the range of the set radio frequency.

The bearing indicator (Figure 7) is a graphic depiction of the signal source (survivor) bearing. The centre of the bearing indicator shows the

Figure 7. The map and signal source bearing indicator (AFIT)

location of the helicopter against the map. If information is lacking regarding the signal source bearing or no signal has been detected, the bearing indicator is not displayed.

One of the basic search devices on board the W3PL "Głuszec" is the TOPLITE observation-targeting head. The imaging element is the head's monitor on the dashboard (Figure 8), which presents, i.a., TV camera and thermal camera image, location parameters and distance from the selected objective/object. The TOPLITE head operation modes are controlled from a panel which contains, i.a., a joystick to control the camera's orientation and a number of functional buttons.

Figure 8. Imaging in daylight from the TOPLITE observation-targeting head displayed on the head monitor for the second pilot-operator of a W3PL "Głuszec" helicopter (AFIT)

An integrated communication system, which is an element of the integrated avionics system, is installed on board the W3PL helicopter. This enables internal and external communication between the crew and the survivor, through on-board radios and the survivor's emergency radio.

The RSC125G radio direction finder is used to execute the function of survivor bearing determination, with the pilot having the option to define the bearing to the survivor's radio (operating in selected modes: active, listening, passive) adjust the data within the operational scopes of the system: SAR, CSAR DME and CSAR GPS selection, and enter the frequency for the widely-available SAR channel or the CSAR coded channel (Sajda, 2010).

Function of on-board equipment in rescue missions

The main functions of the on-board equipment used during aviation SAR missions include (Garstka, 2011):

- establishing communication with the survivor with the use of visual, verbal or smoke communication;
- identifying the general physical conditions of the survivor and assessment of the manner and possibility of recovery;
- recovering the survivor with the use of a winch.

The imaging presented on the LIFTING screen is used for these functions. The survivor lifting sZcreen (hovering helicopter) presents the following, i.a., data: horizontal line (front-back movement), vertical line (left-right movement), markings and description of the indicator scale, view of the lifted survivor from the TOPLITE camera (Figure 9).

Figure 9. Camera view of a lifted survivor displayed on the pilot-operator's head monitor in a W3PL "Głuszec" helicopter (Wikipedia.pl)

The aim of the CSAR system is to help the pilot/crew in searching for survivors. This task is executed through scanning the frequency in search of rescue signals, indication of the bearing onto the survivor and indication of the survivor position in GPS coordinates; establishing phonic connection with the survivor and connection with the survivor via text messages; indication of the fly-over route over the survivor; and displaying the region and search manner, cooperation with the observation system, and hover indicator during survivor lifting.

Auxiliary elements in the execution of search and rescue missions are the screens: ROUTE (if the approach to the search area is defined); PHOTO (if the search area photo is loaded to the mission plan); ORTOPHOTOMAP (selection of the search area, vertical cross-section of the area); FLYING TIME (according to the set flight parameters loaded to the mission plan); RADIONAVIGATION (use of radio-navigation systems and points); RADIOCOMMUNICATION (channel selection and setting of relevant frequencies); and LANDING (according to data regarding the true altitude from the radio-altimeter).

AFIT proposal for search-rescue equipment

One of the solutions supporting the execution of search-rescue actions is the introduction of the QuickDraw 2 device on board the Mi8/17 helicopters

(General Dynamics C4 Systems, 2008). Connected with the on-board VHF/UHF radio of the integrated communication system, the QuickDraw 2 can act as a CSAR search radio. Such a set cooperates with the AN/PRC112 survivor's radio, which can operate in the following frequency ranges:

- 121,500 MHz VHF/AM;
- 243,000 MHz and 282,8 MHz UHF/AM;
- Two programmable frequencies (A or B) from the 225–300 MHz UHF/AM range.

The QuickDraw2 device is powered with four AA batteries, which allows ca. 24 h of operation. In order to cooperate with the on-board radio, the QuickDraw 2 needs to be connected to the headphone circuit of the crew commander or pilot-operator of Mi8/17 helicopters withZ an integrated communication system (Figure 10).

Figure 10. Headphone circuit of a crew commander or pilot-operator of a Mi17 helicopter with an integrated communication system (AFIT)

Another solution for supporting the pilot in search-rescue missions is the helmet-mounted system for flight parameter display and imaging information from observation-targeting heads, developed at AFIT (Rash et al., 2010).

The first helmet-mounted imaging system introduced into operation is the SWPL1 "Cyklop" flight parameter display system (installed on Mi17 helicopters) (Figure 11). This enables head-on display of basic piloting-navigation parameters and special signals, which are divided into navigational and warning.

The main element enabling the cooperation between the SWPL1 "Cyklop" system and the pilot is the DWN1 (daytime) and NWN1 (night-time) helmet-mounted display, installed on the THL5 flight helmet (Figure 12). Thanks to this solution, the system enables the pilot to observe the area while

Figure 11. Mi171V helicopter with an installed SWPL1 "Cyklop" helmet-mounted flight parameter display system (Wikipedia.pl)

simultaneously monitoring the basic flight parameters and the technical condition of the selected helicopter's on-board systems, without moving line of sight to the dashboards. The information from the helicopter's on-board systems is processed and transferred to the helmet-mounted displays in the form of graphic symbols or in digital form.

Figure 12. NWN1 night-time display of the SWPL1 "Cyklop" and night vision goggles mounted on the THL5 helmet (AFIT)

Night vision goggles enable imaging in night-time conditions (Figure 13), which gives the pilot conducting the search-rescue missions the option to detect, locate, identify and save people in danger within a very short time (Borowski & Szporka, 2008).

In relation to a pilot-operator searching for a survivor, the helmet-mounted flight parameter displayed system is enhanced with presentation functions of daylight and infrared cameras images from the observation-targeting head, with its zeroing line being controlled by head movement. The helmet-mounted systems installed, i.a., in AH64 Apache and Eurocopter Tiger helicopters, have these functions for combat applications. This system, as

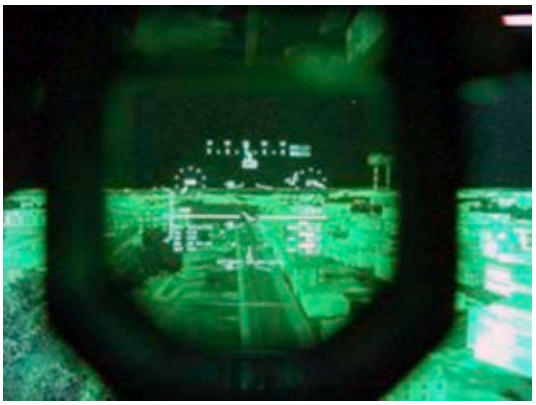

Figure 13. Piloting-navigational parameters imaging displayed on the NWN1 helmet-mounted display (AFIT)

Figure 14. The NSC1 "Orion" helmet-mounted targeting system (AFIT)

proposed and constructed at AFIT for the W3PL "Głuszec", is the helmet-mounted targeting system NSC1 "Orion".

The "ORION" helmet-mounted targeting system is designed for guiding controlled fire positions and other weapon systems and imaging targeting and piloting parameters by day and night. The functions may be implemented individually or in cooperation with an optoelectronic head (Szelmanowski, 2013).

A demonstration device for the technologies of a helmet-mounted imaging system for information from observation-targeting heads was constructed in order to present and verify the possibilities of the helmet-mounted visualisation system for images obtained during the execution of aviation search-rescue missions. The device uses daylight TV cameras, NVG residual light cameras and FLIR thermal light cameras. In this system, the images from the camera, which is guided by the helmet onto a selected survivor search area, are directly transferred to the on-board command position, enabling further analysis with the aim to, i.a., identify the survivor and define the options and manner of their evacuation (Szelmanowski et al., 2013).

Implementation of equipment for search tasks

As regards equipment for search tasks, the constructed demonstration device includes, i.a., TV cameras and thermal FLIR cameras with software enabling automatic detection of bodies with a set limit temperature (e.g. 36°C) or within a set temperature range (e.g. 36–42°C). It allows for the quick identification of objects with a temperature similar to human body temperature (potential survivors or other personnel).

A flight simulator station is used for training pilots to execute CSAR missions. This enables helicopter flights to be performed, navigating and observing land in the search area, as well as approaching a survivor and supervising their evacuation by a rescue squad in all weather conditions, both day and night (Figure 15).

Figure 15. The flight simulator with a helmet-mounted flight parameter imaging system (AFIT)

The constructed demonstration device uses the elements of the SWPL1 "Cyklop" helmet-mounted flight parameter imaging system. The functions of imaging information from daylight and infrared cameras were implemented by means of a matrix generating an image with high resolution and adjustable light intensity. The generated image is sent by an optic system to a semi-transparent mirror, which displays it onto the pilot's eye, together with the image of the surroundings reaching the pilot.

For the helmet-mounted control of the daylight and infrared camera zeroing line position control, the constructed demonstration device uses a micro-electronic movement parameter sensor, enabling the determination of spatial orientation angles of the pilot's helmet by measuring its angular velocities and linear accelerations. The angular

position of the pilot's helmet is calculated with the use of algorithms based on the artificial neuron networks technology.

The constructed system allows the pilot to carry out flights according to the previously loaded waypoints (with the use of the NAVIGATION screen) or on a current basis, according to the guidelines received via the radio from the on-ground operator (Figure 16).

The on-ground operator position enables guidance of the pilot via verbal communication (passing of information, communicating attitudes and emotions) and indicating new navigation points and new simulated hazards in search-rescue missions.

Figure 16. Simulated flight in the area in which the survivor is present, with the use of a helmet-mounted information imaging (AFIT)

Implementation of equipment for rescue tasks

A combat search-rescue mission can be supported by an on-ground operator. The position of an on-board operator is designed for the analysis of images received on a current basis from the helicopter conducting a search-rescue mission. Its aim is to support the search for the whereabouts of a survivor, and the determination of approach conditions and the possibility for immediate evacuation.

The large-screen computer set with software dedicated to the analysis of photos received from the FLIR thermal camera acts as the operator position in the constructed demonstration device. One of the numerous functions of that software is to enter a temperature range which allows automatic searching for objects with the same temperature as that of the body of the missing person/s.

The use of a thermal camera enables users to, i.a., define the condition of the survivor within a range

Figure 17. The on-board operator position (AFIT)

of their body temperature (degree of hypothermia), which allows them to determine the application of specific procedures and tactics for the forces dedicated for his recovery.

The demonstration devices constructed in AFIT allow users to test different versions of the used equipment within the ranges of their parameters (i.a., imaging latency time) and control algorithms, which can be used in search-rescue missions.

Conclusions

One of the essential strengths in a modern battlefield is having the option to recover personnel or equipment from an area of danger. Special military units were formed in the Polish Armed Forces for the execution of SAR and CSAR search and rescue tasks. The W3PL "Głuszec" helicopter with a mounted, integrated avionics system can support the execution of these tasks. It is fitted with a moving fire position (with the option of helmet-mounted control) and an observation-targeting system with a TOPLITE head, which enables the detection and identification of a survivor at large distances with the use of an integrated com-system and a RSC125G on-board radio direction finder. The construction of a demonstration device for the presentation and verification of the possibilities of a helmet-mounted visualization system for the images obtained from the observation-targeting heads was introduced by the operation of the SWPL1 "CYKLOP" helmet-mounted system and development of the NSC1 Orion helmet-mounted targeting system, as well as a base of gained experience. The presented technology allows an expansion of the possibilities and functions of the W3PL "Głuszec" helicopter regarding the execution of the principal SAR and CSAR tasks, with the main function being saving human lives.

Acknowledgments

The paper contains results of original construction works and achievements of the AFIT, the only company in Poland that – in cooperation with PCO S.A. – designe the helmet-mounted imaging system (implemented on Mi-17-1V helicopters) and the helmet-mounted targeting system (technology demonstrator for W-3PL helicopters). 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.

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