THE AFIT'S HELMET-MOUNTED DISPLAY SYSTEMS FOR POLISH MILITARY HELICOPTERS

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Abstract:

The paper has been intended to present selected results of the studies on the helmet mounted display systems developed in the Air Force Institute of Technology (AFIT) for polish military helicopters. In the first part of the paper there is presented the SWPL-1 CYKLOP helmet mounted display system (built in the AFIT's Department for Avionics for Mi-8, Mi-17 and Mi-24 helicopters). The second part is intended to present technology demonstration of the helmet mounted sight system NSC-1 ORION dedicated for polish military helicopters.

1. INTRODUCTION

Modern integrated avionics systems currently used on boards of military aircrafts use digital helmet-mounted flight manoeuvre, navigation and aiming information imaging systems and systems of warning about hazardous situations or malfunctions of supervised on-board equipment and installations to assist the pilot's work [2,3,4]. That is why, helmet-mounted imaging and indicating systems become the basic equipment of modern multifunctional combat aircrafts and helicopters. They also are an important bargaining instrument in the modernisation programs of technologically less advanced aircrafts. The main purpose of their use is increasing so-called pilot's situational awareness and flight safety as well as efficiency and effectiveness of the use of on-board weapons and survivability of crews on the modern battlefield [1].

Helmet-mounted data presentation systems in classic version use day vision ocular displays and night vision goggles (fig. 1), which are standard equipment of e.g. AH-1 Cobra and AH-64 Apache military helicopters [5]. They allow not only the direct (i.e. displayed in front of the pilot's eyes) informing about the flight manoeuvre and navigation parameters (which is very important during the manoeuvre flight), but also give directive commands (commanding activities necessary to complete the task) or warnings about emergencies or malfunctions (obtained from health check systems of on-board systems).

Fig. 1. Helmet-mounted ANVIS targeting system for AH-1 Cobra the helicopter (left) and ocular imaging in night vision (right) [5]

Modern helmet-mounted data display systems using, in the classic version, day vision oculars and night vision goggles (equipped in e.g. F-16, RAFALE, and MIRAGE-2000 military aircrafts, as well as AH-64 APACHE and TIGRE helicopters). They allow not only the direct (i.e. displayed in front of the pilot's eyes) informing about the flight manoeuvre and navigation parameters (which is very important during the manoeuvre flight), but also give directive commands (commanding activities necessary to complete the task) or warnings about emergencies or malfunctions (obtained from health check systems of on-board systems). Among numerous methods used to display flight parameters, indirect methods using head-up displays motionless in relation to the cabin (e.g. HUD-type) and direct methods, in which helmet-mounted displays (ocular or video) are permanently connected with the pilot or operator's helmet [6] are used. On the helmet's ocular or viewfinder, key information about, among others, flight velocity, altitude, and rate of climb as well as targeting data for all weapons are displayed. The display also shows information needed in an emergency. In daylight conditions, the image is projected through the viewfinder and is placed on the actual image area seen by the pilot. In turn, at night, the night vision goggles with the helmet-mounted display are applied.

2. THE SWPL-1 CYKLOP HELMET-MOUNTED DISPALY SYSTEM FOR MI-17-1V HELICOPTERS

In Poland, construction works on the first (performed on the basis of the domestic companies) helmet-mounted flight manoeuvre and navigation information display system were undertaken in the Air Force Institute of Technology (AFIT) in collaboration with the Przemysłowe Centrum Optyki [English: Industrial Optics Centre] (PCO) and the Military Aviation Works MAW-1 J.S.C. Łódź. The SWPL-1 system was awarded by the President of the Republic of Poland during the 17th International Defense Industry Exhibition (2009, Kielce, Poland). The SWPL-1 helmet-mounted flight parameters display system successively installed on the Mi-17 helicopters (fig. 2) allows piloting the helicopter both in day and at night (using the night vision goggles) without the need for continuous tracking the indications on the dashboard [7].

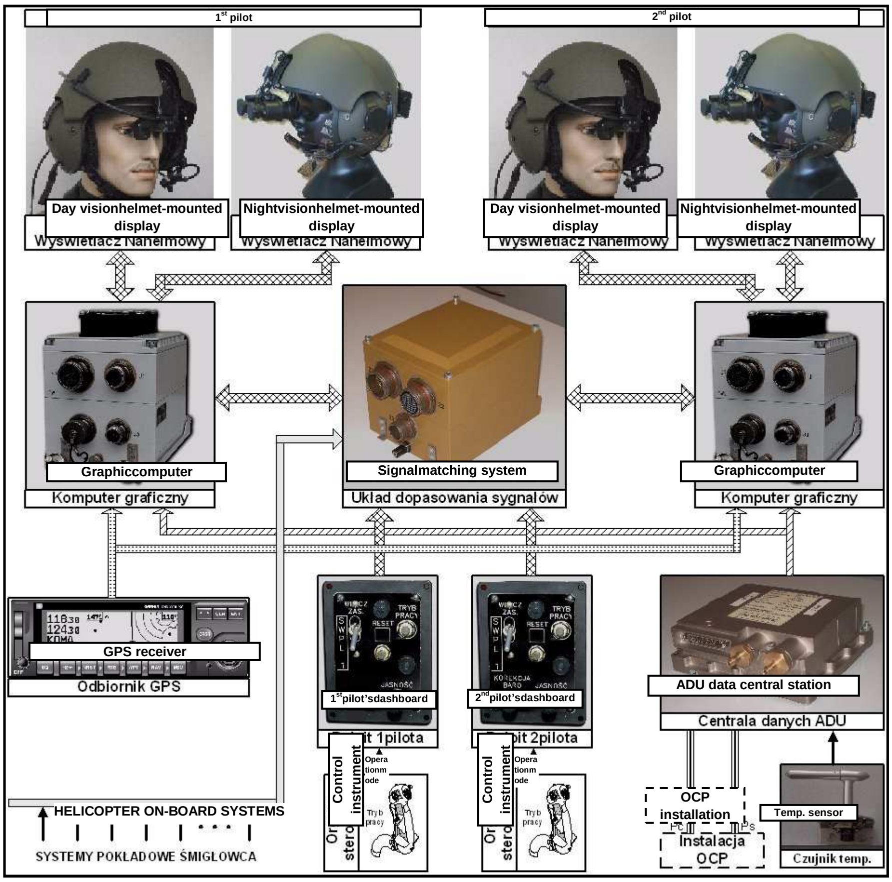

Fig. 2. Scheme of day-night SWPL-1 CYKLOP Helmet-Mounted Display System [AFIT]

The system is designed for the crew commander (the first pilot) and the second pilot and enables imaging the selected flight manoeuvre and navigation parameters as well as control of a drive unit operation. Flight parameters imaging in daylight is performed using the helmet-mounted head-up display DWN-1. At night, flight parameters imaging is performed using the night vision goggles and the NWN-1 helmet-mounted night display. The system also allows generation of WARN warning signals about dangerous situation on the helicopter's board and generation of FAIL signals informing the pilot about the failure of the on-board systems [7].

The source information from the on-board systems of the helicopter is passed to the UDS-1 signal matching system. In this system, transformation and standardisation of analogue and binary signals as well as implementation of logical functions related to the generation of the WARN and FAIL signals take place. Processed signals are transmitted to the KG-1 graphic computers. The graphic computer is the main element of the system executing data selection and transformation algorithms and generating information imaging signals to the helmet-mounted head-up display. It also cooperates with the on-board GPS satellite navigation receiver and the on-board ADU aerodynamic data system using the bus compliant with the ARINC-429 standard.

The SWPL-1 system enables the crew to observe the area and to control the basic flight parameters and the technical condition of the selected helicopter on-board systems at the same time. This system receives and processes information from the helicopter on-board systems and passes it to the helmet-mounted displays in the form of graphic symbols or in a digital form. The system enables imaging of selected flight manoeuvre and navigation parameters and the drive unit operation's parameters (fig. 3). In addition, the system executes the functions of signalling of exceeding the dangerous flight altitude, warning about the dangerous situation on the helicopter's board and malfunctions (errors) of the on-board systems [7].

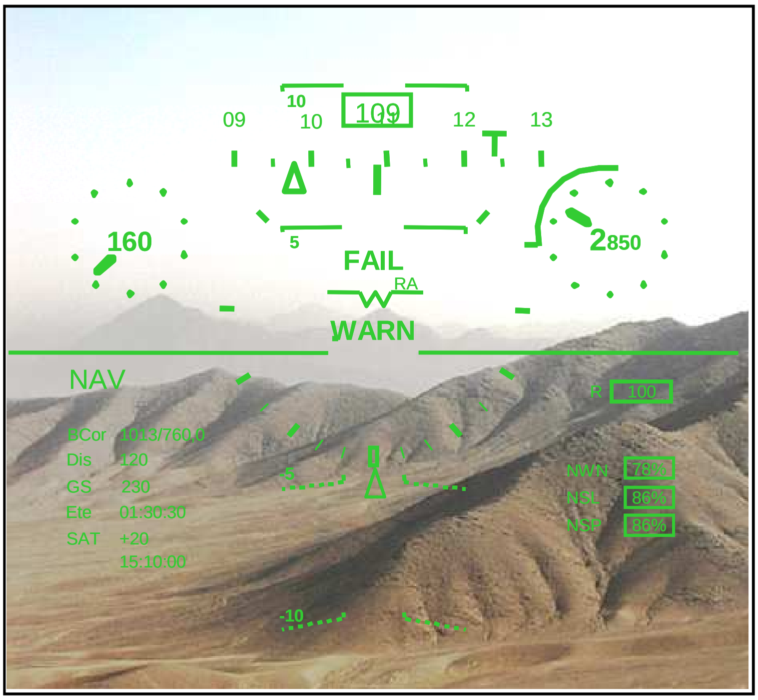

Fig. 3. Scheme of day-night SWPL-1 CYKLOP Helmet-Mounted Display System [AFIT]

On the board of the Mi-17 helicopter, it has a function of flight parameters visualisation for the first pilot (the commander of the crew) and the second pilot (the pilot/operator) in terms of information necessary for the accomplishment of a combat mission. The pilots have ability of independent selection of an operating mode and the appropriate imaging related to it depending on a current need and executed task. Control of the system operation is possible using dashboards and commutation elements mounted on the steering device [7].

The main element of the SWPL-1 system is the KG-1 graphical computer, which is a computing module processing signals about flight manoeuvre and navigation parameters received from the on-board transmitters (after their initial standardisation in the UDS-1 signal matching system) into the form of graphic symbols or in the digital forms required to imagine on the helmet-mounted displays. The SWPL-1 system in the version for the Mi-17 helicopter performs imaging of 16 flight parameters in three variants of sets (chosen independently by each of the pilots) and includes 28 emergency states in the warning (WARN) and error signalling (FAIL) system. Before each flight, the system performs automatic diagnosis of the technical condition of the basic modules of the system, with the ability to add corrective and navigation data.

One of the main scientific and technical problems in the SWPL-1 system is the assessment of the reliability of the information received from the flight manoeuvre and navigation parameters transmitters previously operated on the board of the helicopter. It is related to the analysis of their errors occurring both in static and dynamic conditions, when the flight parameters are variable (that is in manoeuvre states). In order to present these problems, a source of information in the field of a flight manoeuvre data transmitter on the example of an AGB-3K artificial horizon was chosen (fig. 4).

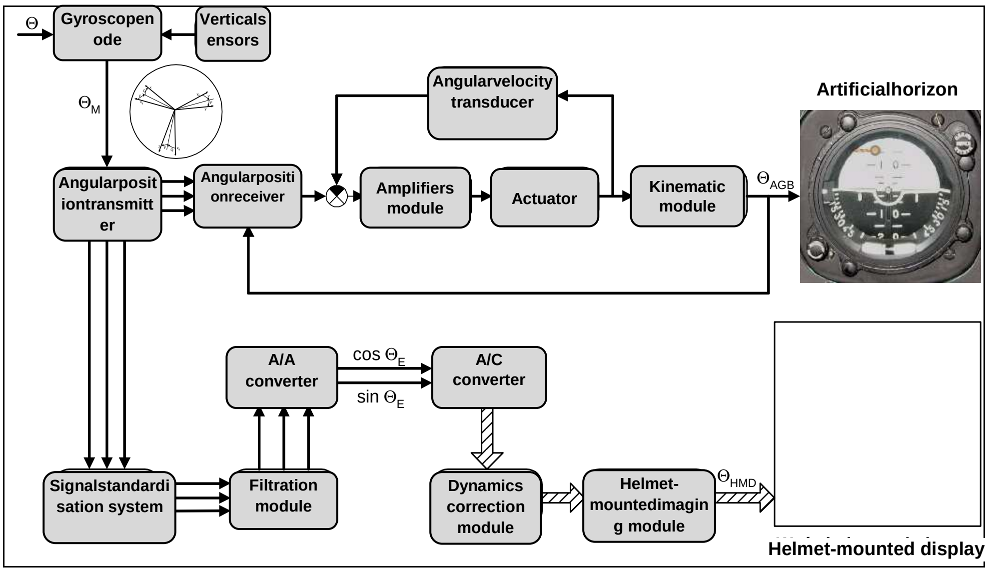

Fig. 4. Block diagram of the measurement chain of helicopter's yaw angle [AFIT]

The measuring chain of helicopter's yaw angle consists of a gyroscope node, in which the measuring axis is set in accordance with the direction of action of gravitational acceleration using correction systems, using information from vertical sensors [8]. Information about the yaw angle developed in the gyroscope node is converted into an electrical form using an angular position transmitter.

The signal from the transmitter is transferred via two chains. The first chain is associated with a classical information imaging in the AGB-3K artificial horizon, while the other one is associated with information processing and imaging in a helmet-mounted imaging system. The classic measurement chain uses information from the angular position receiver and further processes it using a follow-up system built of an amplifiers module, an actuator, a kinematic module, and an angular velocity transducer. The kinematic module rotates a movable pitch scale in the AGB-3K artificial horizon.

The measurement chain of the yaw angle associated with the helmet-mounted imaging system uses the original information from the angular position transmitter as well. This signal is further standardised and filtered and transferred to an A/A converter, in which the transformation of a synchronisation connection signal into the form of constant voltages proportional to the sine and cosine of the yaw angle. Such a processed signal is processed in an A/C converter into a digital form. The software algorithms include correction procedures of measurement chain dynamics, whose task is to ensure the compliance of dynamic properties of the mentioned measurement chains. The helmet-mounted imaging module implements generation of graphic characters controlled in accordance with the developed information about the helicopter's yaw. This information is projected in the form of a moving image onto the helmet-mounted head-up display [7].

One of the first stages of preparation of modernisation of helicopters with an analogue avionics system in terms of the helmet-mounted data presentation system (i.e. its "transformation" into a digital imaging version) is to assess the reliability of the information acquired from the sources already built-up on the helicopter's board. These tests include, among others, evaluation of the quality of interphase voltages obtained from the angular position transmitter circuits of the AGB-3K artificial horizon.

The idea of using analogue signals from particular transmitter circuits and their conversion into the digital form is based on the use of mathematical dependence enabling the determination of the yaw angle based on knowledge of the values of interphase voltages on the output of the angular position transmitter.

The dependency (1) gives the error of the angular position of yaw:

$$\Delta\theta_{WY}(\theta_M) = \theta_E - \theta_M = \text{arc tg}\left\{\frac{\sqrt{3}\cdot\left[U_{f3}(\theta_M)\cdot \text{sgn}(f3) - U_{f1}(\theta_M)\cdot \text{sgn}(f1)\right]}{2\cdot U_{f2}(\theta_M)\cdot \text{sgn}(f2) - \left[U_{f1}(\theta_M)\cdot \text{sgn}(f1) + U_{f3}(\theta_M)\cdot \text{sgn}(f3)\right]}\right\} - \theta_M \qquad (1)$$

where: $\Delta\theta_{WY}(\theta_M)$ – the actual error of the AGB artificial horizon's indication in the steady state in a function of the yaw angle of the artificial horizon; θ_M – the actual angle of the AGB artificial horizon on a 360 rig (or during a fixed spatial position of the helicopter); θ_E – the angle calculated on the basis of the value of the phase voltages; U_{f1}, U_{f2}, U_{f13}. – phase voltages from particular synchronisation circuits of the AGB artificial horizon synchro; sgn(f_1), sgn(f_1), sgn(f_1) – marks of the compliance of the voltage phase in relation to a reference voltage.

Analysis of differences of the interphase voltage at the selected phase of the angular position transmitter occurring at different directions of yaw angle's change enabled to identify the so-called characteristics hysteresis. However, deviation of the actual voltages from the perfect harmonic flow enabled to determine the so-called non-harmonics error.

The evaluation of the hysteresis is important in determining the acceptable level of errors in digital processing of analogue signals, while the non-harmonics errors' analysis allows to determine the so-called characteristics non-linearity and enables the assessment of instrumental errors.

The example hysteresis errors and non-harmonics flows for voltages are shown in Fig. 5.

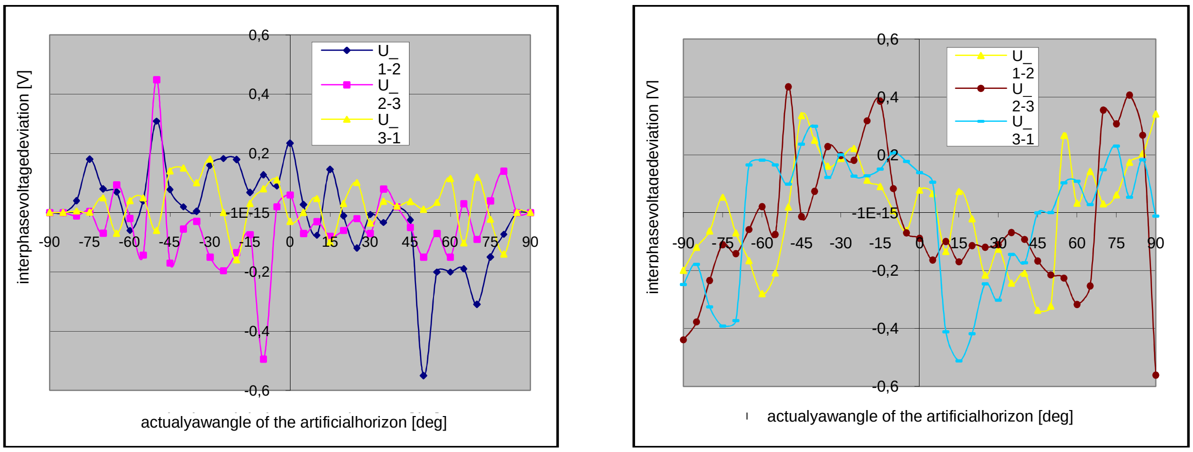

Fig. 5. Example deviation flows of voltages for hysteresis (left) and non-harmonics (right) of signals from the transmitter angular of the AGB-3K artificial horizon [AFIT]

The study of the AGB-3K artificial horizon on the CGW 360 rig showed that the value of hysteresis error for the interphase voltages is 0.54 V_{RMS} and their non-harmonics errors do not exceed 0.48 V_{RMS}. These values are related to the error of determining the yaw angle, which, for these values, is ± 0.3°.

The dynamic properties of the measurement of the yaw angle can be described with a transfer function. The measurement chain of the artificial horizon (Fig. 6) consists of a gyroscope node system, transmitter and receiver of the angular position, the amplifiers module, the actuator, the angular velocity transducer and the kinematic module).

The dynamic properties of particular elements of the measurement chain was identified and, on that basis, the transfer function of the whole measurement chain of the AGB-3K artificial horizon was designated, which may be described in the form of the dependency (2).

$$G(s) = \frac{\Theta_{AGB}(s)}{\Theta_M(s)} = \frac{G_{NT}(s) \cdot G_T(s) \cdot G_{WE}(s) \cdot G_S(s) \cdot J_M}{1 + G_{WE}(s) \cdot G_S(s) \cdot \left[G_{PT}(s) + G_T(s) \cdot J_M \right]} \tag{2}$$

where: $\Theta_{AGB}(s)$ – the Laplace transform of indications of the AGB-3K artificial horizon's signal indications; $\Theta_M(s)$ – the Laplace transform of the yaw angle signal of the gyroscope node; $G_{NT}(s)$ – transfer function of the angular position tranducer synchronisation circuit; $G_T(s)$ – transfer function of the angular position receiver; $G_{WE}(s)$ – transfer function of the electronic amplifiers module; $G_S(s)$ – transfer function of the actuator; $G_{PT}(s)$ – transfer function of the angular velocity traducer; $J_M(s)$ – describing function of the kinematic module; s – Laplace's operator.

The tests of dynamic properties of the measurement chain of the yaw angle for the sinusoidal force (simulating "ascent and descent" manoeuvre) executed in Matlab-Simulink showed that for the adopted boundary frequencies of changes in spatial orientation equal to 1 Hz and amplitude of force 5°, the dynamic error of indications does not exceed ±1°, while the delay of indications is less than 0.05 s. At the stepped force of 5°, the dynamic error disappears after approx. 0.25 sec.

The dependency (2) was used to optimise the measurement chain's parameters in the part related to the helmet-mounted imaging. Optimisation was based on determination of the optimal structure and parameters of the dynamics correction module structure in order to achieve compliance of dynamic properties of the classic measurement chain of the yaw angle and the measurement chain associated with the helmet-mounted head-up display.

The simulation models of the measuring chains were also helpful in determining the required processing resolution (quantisation) of analogue signals values and the required sampling and refresh rate of the imaged flight manoeuvre and navigation information so that the imaging was the most suitable for the pilot [7].

The example of test bench used to determine errors of the AGB-3K artificial horizon (on the left) and test bench used to integration of the SWPL-1 system are shown in Fig. 6.

Fig. 6. Test bench used to determine errors of the AGB-3K artificial horizon (left) and test bench used to integration of the SWPL-1 system (right) [AFIT]

3. THE NSC-1 ORION HELMET-MOUNTED SIGHT SYSTEM FOR W-3PL HELICOPTERS

The data presentation systems of flight manoeuvre and navigation data evolved significantly, starting from instruments mounted in the cockpit requiring taking the pilot's eyes, used in all fighter aircrafts flying to the end of the Vietnam War, to the HUD (Head-Up Display) system currently used in F-16 and other modern military aircrafts and helicopters. Currently, the helmet-mounted data presentation systems are also used in movable weapons of a moving aircraft's control (e.g. in terms of the helmet-mounted target indicator for a cannon or a guided missile) and in search and rescue systems (to control the angular position of an observation and targeting head or a suspended reflector). For example, the F-16's pilots have a digital image displayed on the helmet's viewfinder with the JHMCS (Joint Helmet-Mounted Cueing System) targeting-imaging system at their disposal. This system presents only targeting data and the pilots read flight information from the HUD display [3].

The development works of the helmet-mounted data presentation systems and on-board weapon control are helmets' constructions designed to operate in cyberspace, for example, the Helmet-Mounted Display System (HMDS) by the VSI company for the F-35 aircraft by the Lockheed Martin company [4]. The F-35 fighter's helmet allows the pilot to look literally through the fuselage. The HMDS system appropriately adjusts the image from the set of DAS (Distributed Aperture System) cameras placed on the outside of the aircraft. Thanks to that, the pilot obtains the image of the entire aircraft's environment (the pilot's looking down causes that the HMDS display shows the image below the fuselage).

In Poland, a similar project, funded by the Ministry of Science and Higher Education and the National Centre for Research and Development, included the construction of the NSC-1 Orion system (fig. 7.) as the main component of the helmet-mounted weapon control system of the W-3PL Głuszec helicopter [9]. This project was implemented by the Polish scientific and industrial consortium composed of: the Air Force Institute of Technology (Warsaw) as the leader of the project, the "PZL-Świdnik" S.A. company (Świdnik), Zakłady Mechaniczne [English: Mechanical Works] "Tarnow" S.A. company (Tarnów), FAS Mariusz Ficoń (Bielsko-Biała) and Przemysłowe Centrum Optyki/BumarŻołnierz S.A. company (Warsaw). The achieved world level and innovative technologies applied in this solution gained recognition at the 20th International Defence Industry Exhibition in Kielce, where, on September 6, 2012, the NSC-1 Orion helmet-mounted targeting system received the prestigious DEFENDER award.

Fig. 7. Elements of the NSC-1 Orion helmet-mounted targeting system (left) and a movable position with the WKM-B rifle (right) for the W-3PL Głuszec helicopter [9]

The NSC-1 Orion helmet-mounted targeting system was built into helmet-mounted control of the movable shooting position with the 12.7 mm WKM-B rifle and cooperation with the Toplite observation and targeting head (built in the W-3PL Głuszec helicopter's board). This system is electronically coupled with the integrated avionics system of the W-3PL Głuszec helicopter. Thanks to this, it is ready to operate in the so-called network centric system enabling implementation of an advanced flight training of a flight crew and meeting the conditions to use it in accomplishment of combat missions on the modern battlefield in all daily (day-night) conditions. In the development version, the system can control the angular position of the observation and targeting head (with the ability of helmet-mounted displaying the information received from it) and can be used in helmet-mounted target indication for guided projectiles ("air-to-air" and "air-to-ground" types).

The modernness of the NSC-1 Orion system lies in the fact that it is built in an open architecture, designed for mounting on helicopters of an adequate processability level, i.e. W-3PL Głuszec. To perform the function of the helmet-mounted control over the helicopter's weapons control, this system specifies, in the same coordinate systems, the position of the helmet, the head, and the movable position. The necessary data for the helmet mounting NSC-1 Orion targeting system are downloaded from the navigation part of an integrated avionics system built on the W-3PL Głuszec helicopter. To ensure ergonomics and shortening of the process of preparing on-board weapons to use, the flight manoeuvre and navigation parameters as well as data for targeting process are illustrated on the WND-1 integrated day-night display mounted on the pilot's helmet. The system cooperates with the latest (developed in the PCO company), miniaturised PNL-3M night vision goggles reducing load on the pilot's cervical spine.

Using the built NSC-1 Orion helmet-mounted targeting system, the angular location of the movable position with the 12.7 WKM-B rifle (in the version built within a technology demonstrator) and other elements of the on-board weapon system, among others the movable Toplite observation and targeting head and guided missile's coordinators (in the development version) can be controlled. In order to ensure its operation, this system is coupled with the KM-1 mission computer (built on the W-3PL Głuszec helicopter) and it requires a helmet-mounted angular position determination of the helmet and a helmet-mounted targeting process data imaging system (including a so-called reticule enabling the emergence of the targeting axis aim for the pilot's eye).

The construction of the helmet-mounted targeting system in the form of the NSC-1 Orion system, because of its nature and role on the military aircraft in terms of executed tasks [10], was associated with many research problems. They included both the scope of theoretical works (i.e. the development of the concept of the system operation and the used operating principle), as well as functional ones of the built system in the version of the technology demonstrator [11].

The example of test bench used to determine errors of the optoelectronic helmet-mounted unit of the NSC-1 system is shown in Fig. 8.

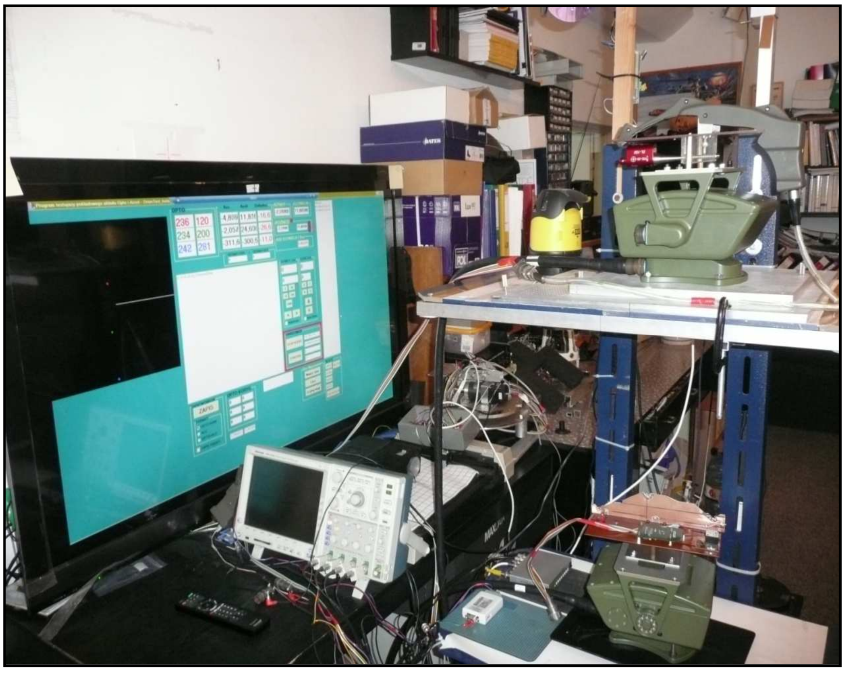

Fig. 8. Test bench used to determine errors of the optoelectronic helmet-mounted unit of the NSC-1 system [AFIT]

Among them, there were problems related to the connection of the built system with the W-3PL Głuszec helicopter's integrated avionics system (required in order to ensure the provision of navigation and targeting data for the system and the management of the helmet-mounted system), the helmet-mounted data displaying (using targeting data imaging on the helmet-mounted head-up display), miniaturisation of size and weight of the helmet-mounted display and the night vision goggles (the provision as smallest pilot's cervical spine as possible), the provision of rotation liquidity and positioning accuracy (fig. 8.) of the movable shooting position (and other helmet controlled on-board weapons of the W-3PL Głuszec helicopter).

The main issue was to identify helmet-mounted targeting systems functioning methods' opportunities and limitations (used on the selected or newly developed military aircrafts) analysed in the performed project of the NSC-1 Orion system's construction. The aim of the conducted works was to assess these methods (presented in their technical executions performed in the AFIT) concerning the accuracy of the determination of the angular position of the pilot's helmet and choice of the most advantageous one in relation to process capabilities in the country [9].

As a result of the executed analyses, the conceptual design of the helmet-mounted system of weapons control with the NSC-1 Orion helmet-mounted targeting system was developed. The block diagram of the built helmet-mounted weapons control system of the W-3PL Głuszec is presented in fig. 9.

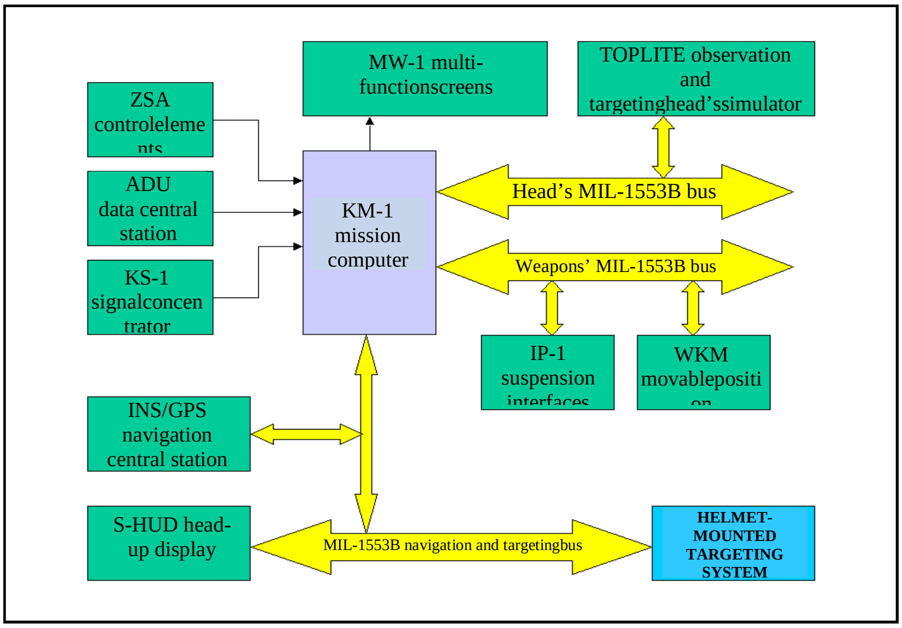

Fig. 9. Diagram of connection of the helmet-mounted targeting system as a new system with the W-3PL Głuszec helicopter's integrated avionics [9]

In terms of the used operation principle, the NSC-1 Orion helmet-mounted targeting system is an original, developed in the AFIT, development of the electro-optical method (corrected with its hybridisation with the inertial and magnetic system). It was executed using opto-electronic elements, indicating the position of the pilot's helmet, and algorithms based on an artificial neural network for determining its angular position.

As a system operating within the helmet-mounted weapons' control built for the W-3PL Głuszec helicopter, the NSC-1 Orion system executes functions of the helmet-mounted targeting process and controlling the operation of combat assets (the movable position with the 12.7 mm WKM-B rifle) and cooperates with the Toplite observation and targeting head. The NSC-1 Orion helmet-mounted targeting system, as the isolated system, uses the information from the integrated avionics system (installed on the board of the W-3PL Głuszec helicopter).

In particular, this system cooperates with a laser scope of the Toplite observation and targeting head and the on-board power grid's power system. Cooperation of the NSC-1 Orion system with the avionics system and other measurement systems on the helicopter is performed using interfaces: MIL-1553B, ARINC-429, RS-485, ETHERNET 10/100, and USB.

The element integrating the NSC-1 Orion helmet-mounted system is the KG-1HC graphical computer (fig. 10.) cooperating with the KM-1 mission computer consisting the main element managing the operation of the integrated avionics system of the W-3PL Głuszec helicopter.

The underbase of the technology demonstrator is the layout of the W-3PL Głuszec helicopter's cabin (made by the "PZL-Świdnik" company), on which the selected elements of the integrated avionics system, necessary to start the helmet-mounted system and check its interoperability with the integrated avionics (developed by the AFIT), and the movable position with the WKM-B rifle (made by the ZM "Tarnów" company) adapted to the needs of the project were built.

Fig. 10. The KG-1HC graphic computer of the NSC-1 Orion helmet-mounted targeting system (left) and the KM-1 mission computer (right) for the W-3PL Głuszec helicopter [9]

The NSC-1 Orion helmet-mounted targeting system's functions in the helmet-mounted weapons control system of the W-3PL Głuszec helicopter are: visualisation of the targeting symbols on the helmet-mounted head-up display (taking into account currently used weapons and their ballistic data); targeting the selected movable weapons system on the helicopter to the external target (by a system operator); measuring the azimuth and the pilot helmet's elevation angles in relation to the helicopter's cabin and sending them in the digital form to the application preparing ballistic and targeting data in the mission computer. In the field of control over the weapons system, the built technology demonstrator of the W-3PL Głuszec helicopter's helmet-mounted weapons control system includes adapted moveable shooting position (with the 12.7 mm WKM-B rifle) and the position for simulation of the selected functional parameters of the Toplite observation and targeting head (the SGT-1 simulator built in the AFIT).

In terms of process solutions, the presented NSC-1 Orion system is based on innovative solutions unprecedented in the world [9].The applied construction and process solutions in the built, integrated, helmet-mounted weapons control system of the W-3PL Głuszec helicopter are at the highest process level. A ground-breaking solution in the performed project is the use of artificial neural networks technology in determining the angular position of the pilot's helmet (developed in the AFIT) and the WDN-1 integrated day-night display (developed in the PCO company), used for the purposes of the helmet-mounted flight manoeuvre, navigation and targeting information imaging with the implementation of night vision technology (the PNL-3M miniatured night vision goggles built in the PCO company).

The operation of the NSC-1 Orion helmet-mounted system includes the helicopter's weapons control, in which the pilot's head movement in terms of azimuth and elevation causes an appropriate movement of a target axis of the movable shooting position with the 12.7 mm WKM-B rifle. This enables firing without taking hands off the control element and the helmet-mounted target indication and enables fast system’s switching on the observation and targeting head's signals used for precision shooting.

Preliminary testing accuracy of determining the spacial position's angles of the pilot's helmet for the NSC-1 Orion helmet-mounted targeting system were performed on the test station, built in the AFIT for teaching the neural network used in the electro-optical and hybrid methods [9]. This station for the tested application with the neural network provides: automated presetting and measurement of the azimuth and elevation angles of the targeting axis; automated measurement of the spatial position of the helmet with the determination of the azimuth and elevation angles of a helmet zeroing axis via a measurement system; sending these angles in the digital form to a measurement application for archiving and further analysis; determining the accuracy of the angular position determination.

The station in a simplified version (with modelling the helmet's position on a PAN/TILT turntable) enables presetting the spatial position of the helmet changing only the azimuth and elevation angles in relation to two perpendicular rotation axes, without lateral displacements. Performed testing for the hybrid method showed that accuracy of such determined azimuth and elevation angles of the helmet (for azimuth up to ±80° and elevation up to ±12°) is ±0.5° (for the azimuth) and ±0.2° (for the elevation).

The final accuracy of determining angles testing was conducted on the station in a full version, built in the cabin of the W-3PL Głuszec helicopter. The station in the full version (with the helmet placed on the system operator's head) allows for the actual presetting of the angular position of the helmet, including the lateral movements of the pilot's head and torso occurring in the targeting process. Performed testing for the hybrid method showed that accuracy of such determined azimuth and elevation angles of the helmet (for azimuth up to ±80° and elevation up to ±12°) is ±0.6° (for the azimuth) and ±0.3° (for the elevation).

On the basis of the results of tests conducted in the AFIT, it was found that out the most convenient method for application in the NSC-1 Orion helmet-mounted targeting system is the hybrid method. It is one of the ways to increase the accuracy of determining the angular position of the helmet combining several component methods (electro-optical and inertial). This system can be optimised in terms of the number and types of signals and ways of their processing (e.g. using the Kalman filter). A considerable advantage of the NSC-1 Orion system is its construction based on the integrated avionics system of the W-3PL Głuszec helicopter, using MIL-1553B (in terms of management of the helmet-mounted system operation) and MIL-1760 digital buses (in terms of controlling the weapons system). It allows to build it on other, new or upgraded, combat helicopters with the integrated avionics system [12].

The built NSC-1 Orion helmet-mounted targeting system as a technology demonstrator supports the testing process of new methods (and devices for their technical performance), and can provide a basis for their further development within the domestic industry.

4. CONCLUSIONS

The modern military avionics systems, navigation and targeting systems in particular, use the helmet-mounted data presentation systems more and more often. Use of the helmet-mounted data presentation systems in modern aircrafts significantly improves the piloting's safety. This is particularly important during accomplishing difficult missions at night or in poor visibility conditions. In such cases, the observation of the environment without taking eyes for observation of the instruments in the cabin greatly simplifies the piloting process and increases the chance to execute difficult tasks. It is expected that more and more pilots of modern military aircrafts will learn to fly with a helmet equipped with the HMDS functions. Research on prototypes of the HMD system have been in progress for over twenty years and show that both the air force academies' graduates and the pilots should have no problems with getting used to the new helmet-mounted data presentation system.

One of the most important elements in ensuring an adequate level of the pilot operating the helmet-mounted data presentation system's safety is an individually fitted helmet. It is extremely important both in terms of safety and data displayed in the helmet, because the functionality of the HMDS is based on the precise placement of optical instruments. The SWPL-1 system produced in AFIT with digital manoeuvre and navigation data processing is designed mostly for Mi-17 helicopters, but it can be implemented on other types of aircraft (e.g. Mi-24 helicopter, PZL-130 "Orlik" trainer aircraft).

The experience and technical skills gathered during designing and development of SWPL-1 system proved, that it is possible to build such a system for a brand new aircraft (with modern avionics), and adjusting the solution to the existing equipment (currently in service, with analogue avionics). As a result, the system collects and processes information from on board systems and installations and transfers it to helmet mounted displays in the format of graphic symbols or digital information essential for providing combat mission.

The NSC-1 ORION system is capable of providing helmet controlled target cueing of the turret gun 12,7 WKB-M and other W-3PL's guided weapon systems, simultaneously displaying pilotage-navigational and aiming information during day and night flights (using NVG). Above mentioned functions can be realized by the NSC-1 system independently or in cooperation with an optoelectronic surveillance system (e.g. TOPLITE system). The modernity of NSC-1 ORION is based on the fact, that the system is prepared in open architecture philosophy and is designed for aircraft with adequate technological level, e.g. W-3PL Głuszec.

The systems proposed by the AFIT: the SWPL-1 Cyklop helmet-mounted flight parameters display system and the NSC-1 Orion helmet-mounted weapons control system support the testing process of new devices and may be a basis for their further development within the domestic industry, including equipping the modernised military helicopters with such a system (e.g. for the PMC in Afghanistan).

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