The Human-machine interface for UAV ground control station

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***Abstract*—This paper describes the design of a Human-machine interface for UAVs and presents general HMI requirements for the operator (commander). The design was created for a ground control station that is tasked with safely and efficiently controlling several UAVs at once. The goal was to create an environment that provides the operator with an overview of each UAV, mission planning and execution.**

Keywords—UAV, Ground control station, design, HMI

I. Introduction

In today's era of constant technological advancement and the increasing importance of unmanned systems in all areas of human activity, the Human-Machine Interface (HMI) is becoming a key element connecting humans with technology. From the perspective of UAV (Unmanned Vehicle) research and utilization, HMI can fundamentally affect the efficiency, safety and success of missions. Ground Control Station (GCS), as the central point of management and control of UAV operations, represents an important node of connection between the operator and technology. Thus, the selection of an appropriate GCS screen design is one of the important elements of the system. Its efficiency and clarity can either simplify the operator's work and increase efficiency, or on the contrary, represent a source of confusion and risk for errors. HMI is appearing in multiple sectors from industry to avionics. This interface is also used in Industry 4.0, where it presents the state of the environment and sensors **Chyba! Nenalezen zdroj odkazů.Chyba! Nenalezen zdroj odkazů.Chyba! Nenalezen zdroj odkazů.**.

During UAV operations, emphasis is placed not only on the aesthetic aspects of design, but above all on the ability of the HMI to present relevant information to the operator in a clear and intuitive form. Proper GCS screen design can not only make the operator's job easier, but also eliminate unnecessary stress, increase decision-making efficiency, and improve overall mission performance. This paper focuses on the importance and process of GCS screen design for UAV operators and analyzes the key factors that affect its effectiveness **Chyba! Nenalezen zdroj odkazů.Chyba! Nenalezen zdroj odkazů.**.

Specifically, a graphical GCS design for a swarm of UAVs operating as a reconnaissance squadron will be described. This swarm of UAVs will be fully automated and will perform terrain reconnaissance and data collection in a variety of environments and conditions. The following section will describe the operational procedures that form the basis for the HMI design. Another important aspect can be considered the way data is presented, which may vary depending on the nature of the mission and the operator's level of UAV knowledge **Chyba! Nenalezen zdroj odkazů.Chyba! Nenalezen zdroj odkazů.**.

II. Operation procedures

The Ground Control Station is the central point of control and management of UAVs operations. Effective execution of these operations requires carefully defined procedures that include several key phases. From the Home Screen to mission planning, pre-flight preparation, and actual mission execution, each phase is critical to the successful and safe conduct of the operation. The following paragraphs will describe each step of the GCS operational procedures in more detail, including their importance and impact on the overall effectiveness and safety of UAV missions.

The GCS is planned as a portable station, with only one 1920x1080 pixel monitor. This design was created for a user who has only received basic knowledge as a UAV operator. Thus, an operator with a broader knowledge and subconscious understanding of UAVs is not considered to control a swarm of drones. The GCS does not support the ability to directly control individual UAVs. The overall flight will be fully automated. Thus, from this perspective, even the mission planner is simplified to the level that the operator only enters high-level information and the system creates individual flight plans for the UAV. The transmission of in-flight telemetry information is also simplified, and symbolic methods are chosen to display the status of individual UAVs.

The HMI design is intended for use in emergency services. These emergency services can use unmanned vehicle technology to gain situational awareness. For the Ambulance Service, the technology would be useful in providing an overview of mass car crashes, or other larger incidents. The military could use the system for reconnaissance of an area and use it as a source of information for intelligence purposes. A similar use could be found for the Police. The design is therefore designed for a wider range of security forces, and it is possible to modify it for different types of use in different forces.

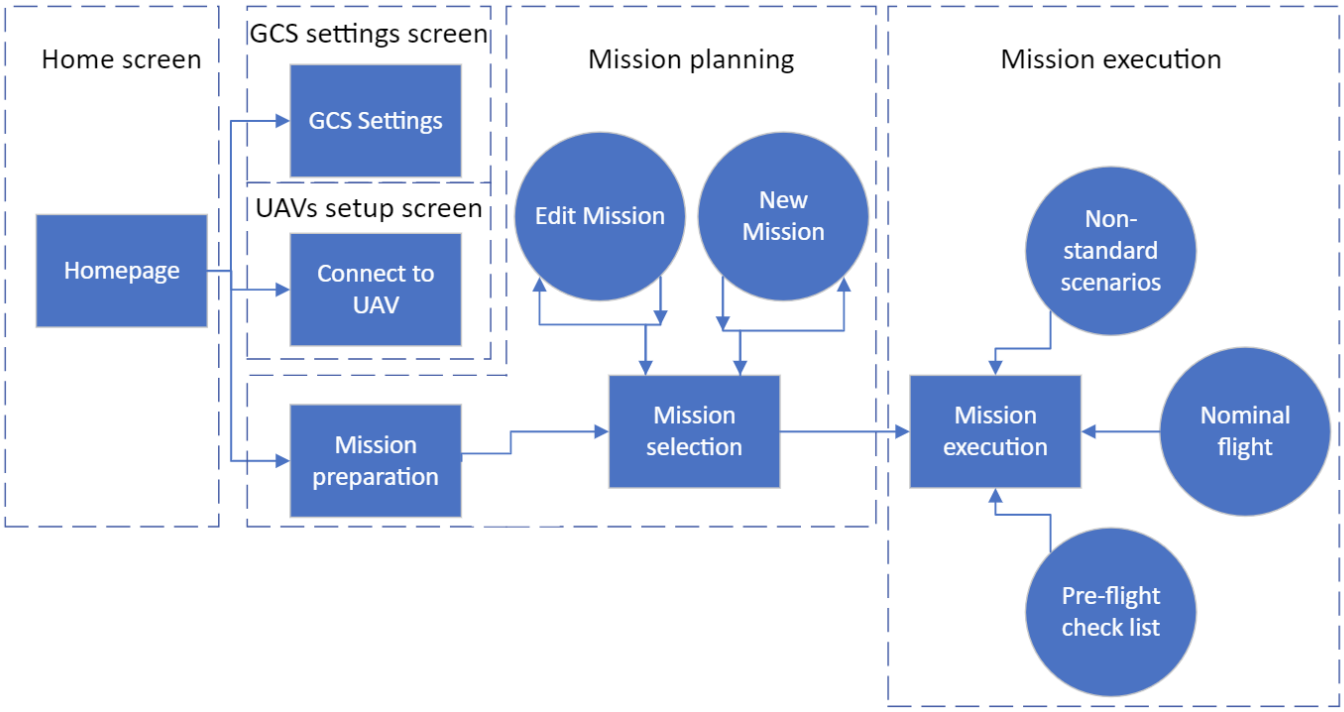

Fig. 1. Block diagram of the mission flow with individual screens

A. *Home screen*

The Start screen is the operator's entry point into the GCS environment and provides an overview of the basic GCS functions. A well-designed start screen should be intuitive and provide the operator with a quick and easy transition to the next phases of the mission. This section of the operating procedures includes an analysis of the available features. From the start screen, one can proceed to the GCS settings, where one can set the connection to the UAV, change the screen contrast, and other functions (GCS settings). It is also possible to progress from the Home screen to the screen where individual UAVs can be connected to perform sensor calibration and detailed setup and inspection. The final path from the Home screen leads to the mission planning screen where the operator creates a mission for a swarm of UAVs.

B. *Mission planning*

Mission planning is the step before the actual execution of the operation. The operator can select a pre-planned mission from the database, edit it, or create a new mission. If the operator chooses to edit or create a new mission, the GCS operator uses area delineation and flight parameter determination to achieve the mission objectives. Careful mission planning can minimize risks and increase the efficiency of the operation. Proper GCS screen design for this phase should provide the operator with interactive planning tools, terrain visualization, flight plans, and waypoint lists. The operator enters the area of interest, the lowest flight level, the highest flight level (UFL - upper flight level, LFL- lower flight level) and the information of interest in that area. This can be radiation sensors, photogrammetric map using thermal camera, multispectral camera, etc. The GCS is able to use this information to decide what and how many UAVs are needed to cover the selected area. It will plan a flight plan for each UAV so that no collisions occur during the flight.

C. *Pre-flight preparation*

Pre-flight preparation for flight safety of UAVs. This phase includes checking and setting up the UAVs hardware, verifying GPS signal availability, calibrating sensors, checking the status of batteries and other important elements. The GCS pre-flight preparation screen should provide the operator with an overview of all the necessary tasks and information that need to be checked and performed prior to launch. A list (Check List) will open where the operator will find all available systems to check. The Check List should be fully automated.

D. *Mission execution*

The actual execution of the mission is the main phase of the whole operation. During this phase, the operator actively monitors and indirectly controls the UAV in accordance with the defined mission objectives and parameters. During mission execution, the GCS screen provides the operator with relevant real-time information on the UAVs position, battery status, environment and other relevant factors to effectively react to changes and situations during the mission.

III. GRAPHIC DESIGN OF SCREENS

The graphical design of the screens is a Human-Machine Interface (HMI) element that has a major impact on the efficiency of UAV operations. As already mentioned, before the design it is necessary not only to describe the procedure of the expected operations, but also to describe the operator in terms of knowledge and skills. Another aspect is the hardware

capabilities of the GCS itself. In this proposal, a GCS with only one screen is assumed. The GCS should be part of the command post, be mobile and convey information clearly and quickly.

A. *Selection of icons and symbol*

This element of the graphic design of GCS screens has a significant impact on user-friendliness and clarity. Iconography is often used to visually represent functions, states and actions, allowing for quick operator identification and orientation within the interface. When choosing icons and symbols, it is important to consider the principles of simplicity, clarity and consistency. Icons should be intuitive and easy to identify so that the operator can quickly recognize their meaning. A thorough analysis of the user needs and context of use is essential for the proper selection of icons and symbols that effectively communicate the desired information and functions without unnecessary confusion.

The choice of colours and the simplicity and clarity of symbols and symbols are also important, contributing to easy identification and visual organisation of information on the GCS screen. Colours can be important not only from an aesthetic point of view, but also from a functional point of view, for example in indicating statuses and priorities. It is important to choose an appropriate colour scheme and apply it consistently throughout the interface. For the graphic design, dark colours were chosen for the background to add contrast when the sun illuminates the screen. Four primary colours were chosen to convey the information. White for informational messages, green for nominal status indication, orange for warning (alert) indication and red for critical failure indication. Simplicity and clarity of symbols and symbols are key to minimising user error and confusion. Symbols that are too complex and unclear could lead to misinterpretations, resulting in incorrect decisions or inadequate operator response. Therefore, it is imperative that icons and symbols are clearly defined and intuitive to the user, which will contribute to the effective use of GCS screens and the overall success of UAVs operations. For example, in the Fig. 2 you can see the UAV icon from the North Atlantic Treaty Organization (NATO) perspective and the icon selected for this design. For use in military operations, NATO symbology will need to be used. A custom design has been chosen for this design which can also display the UAV's status by changing the background color.

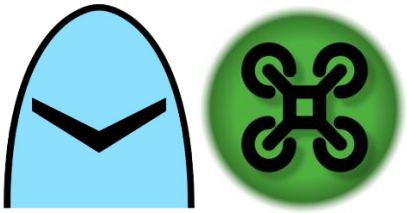

Fig. 2. The UAV icon for NATO (left) and the created icon for this design proposal (right) [4].

B. *Design procedure*

The process of designing the graphic design of GCS screens requires careful planning and a systematic approach. It starts with an analysis of user needs and identification of the key features that GCS screens must postroad. This is followed by defining the functionality and information layout requirements. Wireframes and prototypes are used to visualize the designs and test them with users. An iterative process involves refining designs based on feedback and testing until the optimal design is achieved.

C. *Final design*

The final graphic design of GCS screens is based on an analysis of user needs and functionality requirements. It includes visual elements such as colour schemes, typography, icons and graphic elements that are designed to provide simplicity, clarity and ease of orientation for the user. The detailing of each element and its placement on the screen creates a functional design that will trigger the user to perform at their best. The following photos describe the individual screens designed for an operator managing a swarm of UAVs to explore areas.

1) *Home screen*

The home screen shows the signpost for the operator. It is designed simply and shows only the time, the system logo, and buttons leading to other screens.

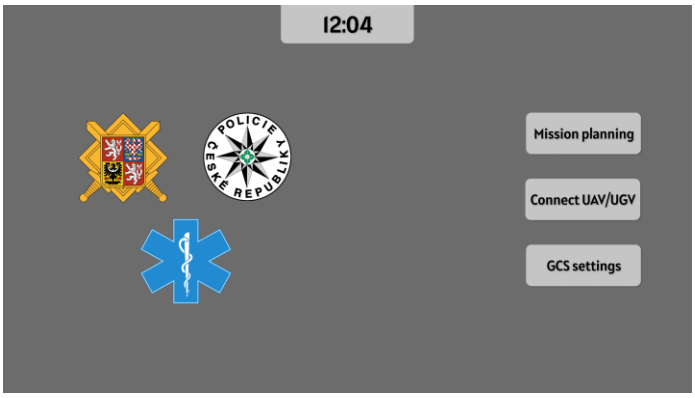

Fig. 3. GCS home screen for controlling a swarm of UAVs

2) *Mission planning screen*

This screen is very variable. It varies depending on the choice of operator. In the first phase, it is possible to select a preplanned mission and either edit, delete or select it. The operator can also create a new mission. The new mission creation screen is shown in Fig. 4.

Fig. 4. Mission planning screen

3) Mission execution screen

It is the most critical and important screen of the entire proposal. It must convey mission progress information and basic telemetry information of the UAVs to the operator. It must also transmit real-time information about the threats detected by the selected sensors and write them directly to the map base. It is possible to monitor the mission progress of the entire swarm of UAVs during the operation, or to monitor the image stream from a selected UAV. This screen is also needed to inform the operator of any messages coming from the UAVs. The Messages window in the right corner is used for this purpose. In the upper right corner is basic telemetry information about each of the UAVs. These are presented by symbols in three colours. Each of the colours represents the status of each system. By clicking on the desired UAV, detailed telemetry data can be displayed and detailed information about the UAV status can be transmitted.

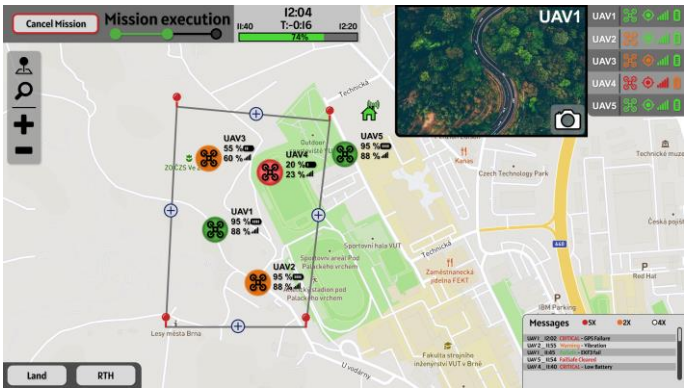

Fig. 5. Screen during the progress of a scheduled mission

High-level telemetry uses four icons. The first icon is the multicopter symbol, which shows the status of the UAV (internal sensor calibration and HW status). The second icon shows the GNSS (Global Navigation Satellite System) status, another signal strength between the UAV and the GCS. The last icon shows the battery status. The icons can be seen in the following Fig. 6.

Fig. 6. Icons for high-level telemetry. From right: UAV status, GNSS, GCS connection strength, battery status

D. Verification of the functionality of the designs

Verifying the functionality of the proposed GCS screen designs is a step before deploying them in real operation. Testing involves examining the user interface, interaction elements and navigation within simulated environments or real-world situations. The goal is to ensure that the graphical design supports effective use of the GCS and contributes to the safety and success of UAVs operations. These validations are performed iteratively where information and suggestions are gathered from test operators. The wider the diversity of operator focus, the better the potential design flaws can be detected.

E. Limitations

Despite efforts to optimize and improve the graphic design of GCS screens, there may be limitations that can affect its effectiveness and usability. These constraints may include limited screen size, insufficient system resources, ergonomic limitations of the operator's work environment, and other technical and operational factors that must be considered when designing and implementing the graphic design. The proposed graphic design has several of these constraints. The first is the hardware limitation of a single screen, where there is not enough space to display all possible information. Another is the choice of the map background, where a dark contrasting map would be better for outdoor use.

IV. Conclusion

This paper has dealt with the graphical design of GCS for automatic swarm of UAVs. The design is based on several iterations. The mission planning process and the various nominal scenarios that this design reflects were described. Custom icons were created to communicate high-level information to the operator and justify some of the main design elements. This design has several limitations and can therefore only be used for the purpose for which it was created. A total of three screens were presented, with more in the design itself, with many additional modifications. This graphic design can be implemented after subsequent additional evaluations and the programming itself. This design can be linked to the back-end to form a complete GCS.

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