МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Факультет аеронавігації, електроніки та телекомунікацій
Кафедра авіаційних комп’ютерно-інтегрованих комплексів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри

________ Віктор СИНЄГЛАЗОВ

“___”_______________2024 р.

КВАЛІФІКАЦІЙНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ

“БАКАЛАВР”

Спеціальність 151 «Автоматизація та комп'ютерно-інтегровані технології»
Освітньо-професійна програма «Комп’ютерно-інтегровані технологічні процеси і виробництва»

Тема: Безпілотний літальний апарат для пошуку постраждалих у надзвичайних ситуаціях

Виконавець: студент групи КП-402Ба Ляшенко Володимир Олександрович
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Київ – 2024

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
Faculty of Aeronautics, Electronics and Telecommunications
Department of Aviation Computer-Integrated Complexes

PERMISSION TO DEFEND
Head of the department

________ Viktor SINEGLASOV

“___”_______________2024 р.

QUALIFICATION WORK
(EXPLANATORY NOTE)

GRADUATE OF AN EDUCATIONAL DEGREE

“ BACHELOR”

Speciality 151 «Automation and Computer-Integrated Technologies»
Educational-Professional Program: «Computer-Integrated Technological Processes and Production»

Theme: An unmanned aerial vehicle for searching for victims in emergency situations

Performer: student of the group KP-402Ba Liashenko Volodymyr Oleksandrovych

Supervisor: docent Mykola Pavlovych Vasylenko

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Kyiv 2024

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аеронавігації, електроніки та телекомунікацій
Кафедра авіаційних комп'ютерно-інтегрованих комплексів
Освітній ступінь «Бакалавр»
Спеціальність 151 «Автоматизація та комп’ютерно-інтегровані технології»
Освітньо-професійна програма «Комп’ютерно-інтегровані технологічні процеси і виробництва»

ЗАТВЕРДЖУЮ
Завідувач кафедри, д.т.н., проф.__
Віктор СИНЄГЛАЗОВ
«___» ___________ 2024 р.

ЗАВДАННЯ

на виконання кваліфікаційної роботи здобувача вищої освіти

ЛЯШЕНКА ВОЛОДИМИРА ОЛЕКСАНДРОВИЧА

1. **Тема роботи:** «Безпілотний літальний апарат для пошуку постраждалих у надзвичайних ситуаціях».

2. **Термін виконання роботи** з 13.05.2024 р. по 3.06.2024 р.

3. **Вихідні дані до роботи:** статистична інформація щодо виробничих показників діяльності ТОВ АТА «КРУНК».

4. **Зміст пояснювальної записки:** загальні характеристики ТОВ АТА «КРУНК», аналіз виробництва, аналіз виробничої та фінансової діяльності авіакомпаній, нормативні документи, що регламентують діяльність компанії, існуючі та нові технології проведення пошуково-рятувальних робіт.

5. **Перелік обов’язкового графічного матеріалу:** Динаміка польотного часу, кількості перевезених вантажів і пасажирів, динаміка виручки авіакомпанії ТОВ АТА «КРУНК»

6. **Календарний план-графік**

№ п/п	Завдання	Термін виконання	Відмітка про виконнання
1.	Отримання завдання	13.05.2024 - 13.05.2024	
2.	Формування мети та основних завдань дослідження	13.05.2024-14.05.2024	
3.	Аналіз існуючих випробувальних стендів	14.05.2024-16.05.2024	
4.	Формулювання проблеми оптимізації	16.05.2024-20.05.2024	
5.	Підбір алгоритму	20.05.2024-22.05.2024	
6.	Моделювання електричної та механічної частин	22.05.2024-28.05.2024	
7.	Підбір компонентів	29.05.2024-3.06.2024	

7. **Дата видачі завдання** “13” травня 2024

Керівник: _____________________ Микола ВАСИЛЕНКО

Завдання прийняла до виконання ___________ Володимир ЛЯШЕНКО

NATIONAL AVIATION UNIVERSITY

Faculty of Air Navigation, Electronics and Telecommunications
Department of Aviation Computer-Integrated Complexes
Educational Degree "Bachelor"
Specialization: 151 “Automation and Computer-Integrated Technologies”
Educational-Professional Program: “Computer-Integrated Technological Processes and Production”

APPROVED BY
Head of Department,
Professor Dr. of Sc.
___________SINEGLASOV Viktor
«___» ____________ 2024 р.

TASK

for the bachelor degree thesis

LIASHENKO VOLODYMYR OLEKSANDROVYCH

1. **Theme of the project:** “An unmanned aerial vehicle for searching for victims in emergency situations”.

2. **Term of work performance:** from 13.05.2024 to 3.06.2024.

3. **Output data to the project (work):** statistical information on the production performance of JSB LLC “Krunk”.

4. **Contents of the explanatory note (list of questions to be developed)**:

general characteristics of JSB LLC “Krunk”, production analysis, analysis of the production and financial activities of airlines, regulatory documents governing the company's activities, existing and new technologies for search and rescue operations.

5. **List of compulsory graphic material:** Dynamics of flight time, number of cargoes and passengers transported, revenue dynamics of the airline ATA LLC “Krunk”

6. **Planned schedule:**

№	Task	Execution term	Execution mark
1.	Task receiving	13.05.2024 - 13.05.2024	
2.	Purpose formation and describing the main research tasks	13.05.2024-14.05.2024	
3.	Analysis of existing test tables	14.05.2024-16.05.2024	
4.	Formulation of the optimization problem	16.05.2024-20.05.2024	
5.	Algorithm selection	20.05.2024-22.05.2024	
6.	Modeling of electrical and mechanical parts	22.05.2024-28.05.2024	
7.	Component selection	29.05.2024-3.06.2024	

7. **Date of task receiving:** "13" may 2024

Diploma thesis supervisor: ___________________ Mykola VASYLENKO

Issued task accepted ___________________ Volodymyr LIASHENKO

РЕФЕРАТ

Пояснювальна записка до дипломної роботи «Безпілотний літальний апарат для пошуку постраждалих у надзвичайних ситуаціях»: 68 сторінки, 9 рисунків, 12 таблиць, 17 джерело, 1 додаток.

КЛЮЧОВІ СЛОВА: АВІАКОМПАНІЯ, АВІАЦІЙНІ РОБОТИ, ПОВІТРЯНЕ СУДНО, ПОШУКОВО-РЯТУВАЛЬНІ РОБОТИ, БЕЗПІЛОТНІ ПОВІТРЯНІ СУДНА, ЕФЕКТИВНІСТЬ, АВІАЦІЙНА ТЕХНІКА

Об'єкт дослідження – діяльність ТОВ АТА «КРУНК» з акцентом на впровадження пошукових операцій.

Мета дипломної роботи – довести ефективність використання безпілотних літальних апаратів у пошукових та рятувальних місіях та запропонувати нову технологію для виконання таких завдань.

Метод дослідження – використання експертного аналізу для визначення ринку робіт та послуг, а також техніко-економічних методів для обґрунтування доцільності виконання пошукових та рятувальних робіт і розрахунку економічних витрат.

Теоретична частина: містить огляд теоретичних аспектів пошуково-рятувальних операцій, ефективності використання авіаційної техніки і методів аналізу авіаційного підприємства.

Аналітична частина: присвячена аналізу виробничих показників ТОВ АТА «КРУНК».

Проектна частина: аналізує технологію виконання пошуково-рятувальних операцій і проводить розрахунки ефективності використання безпілотних літальних апаратів. Структура комплексу: наземна станція, безпілотник, обладнання, яке на ньому використовується і алгоритми роботи.

Матеріали дипломної роботи: рекомендовані для використання у практичній діяльності підприємств, що здійснюють пошуково-рятувальні роботи.

ABSTRACT

Explanatory Note for the Diploma Project: "Efficiency of Using Unmanned Aerial Systems in Search and Rescue Operations": 68 pages, 9 figures, 12 tables, 17 references, 1 addition.

KEYWORDS: AIRLINE, AVIATION OPERATIONS, AIRCRAFT, SEARCH AND RESCUE MISSIONS, UNMANNED AERIAL VEHICLES, EFFICIENCY, AVIATION EQUIPMENT.

Object of the Study: the activities of LLC ATA "KRUNK" with a focus on the implementation of search and rescue operations.

Objective of the Diploma Work: to substantiate the efficiency of using unmanned aerial vehicles in search and rescue missions and to propose a new technology for performing such tasks.

Research Methods: the use of expert analysis methods to determine the market for work and services, and techno-economic methods to justify the feasibility of conducting search and rescue operations, as well as calculation methods during the estimation of economic costs.

Theoretical Part: contains an overview of the theoretical aspects of search and rescue operations, the concept of efficiency in using aviation equipment, and methods for analyzing an aviation enterprise.

Analytical Part: dedicated to analyzing the production indicators of LLC ATA "KRUNK".

Project Part: analyzes the technology of performing search and rescue operations and performs calculations of the efficiency of using unmanned aerial vehicles. The structure of the complex includes a ground station, a drone, the equipment it uses, and the algorithms of its operation.

Materials of the Diploma Work: recommended for use in the practical activities of enterprises engaged in search and rescue operations.

LIST OF TERMS AND ABBREVIATIONS

UAV - Unmanned Aerial Vehicle

UAS - Unmanned Aviation Systems

AS - Aircraft

LLC - Limited Liability Company

ATA - Aviation Transport Agency

UN - United Nations

SAR - Search and Rescue

SRO - Search and Rescue Operation

ES - Emergency Situation

SAR Manager - Search and Rescue Manager

SAR Object - Search and Rescue Object

EMERCOM - Ministry of Emergency Situations

SES - State Emergency Service of Ukraine

FMM - Fuel and Lubricants

EGNSS - European Global Navigation Satellite System

EGNOS - European Geostationary Navigation Overlay Service

SAR Team - Search and Rescue Team

EU - European Union

CONTENT

INTRODUCTION

The main objective of this diploma work is to analyze the efficiency of using unmanned aviation systems in search and rescue operations (SAR). Presently, Ukraine encounters a significant number of emergency situations leading to a high number of casualties and fatalities, underscoring the necessity and relevance of search and rescue operations. This type of work is pivotal and falls within the realm of emergency response efforts. Additional measures are devised each year to enhance safety, conduct briefings at potentially dangerous sites, and patrol high-risk areas. However, emergency situations often occur uncontrollably, impacting the number of casualties and affected individuals.

Search and rescue operations represent some of the most critical activities conducted by rescue services globally. The primary objective of such operations is to locate, rescue, and provide emergency medical assistance to casualties. Search and rescue teams carry out these operations using both ground and aviation equipment. The advancement of modern technologies significantly enhances efficiency and optimizes the process of searching for and rescuing casualties at all stages. One modern solution is the use of unmanned aerial vehicles during search and rescue operations.

The utilization of unmanned aerial vehicles, instead of manned aircraft, shows promise and effectiveness. Unmanned aviation systems (UAS) are a modern development that remains insufficiently researched. However, in recent years, the application of UAS has rapidly expanded in both civilian and military aviation sectors.

The integration of UAS into search and rescue operations is at an early stage due to insufficient regulatory documents. The main obstacles to UAS application may include adverse weather conditions or technical issues. Currently, unmanned aviation systems cannot fully replace manned aircraft. Nevertheless, during search and rescue operations, UAS can be more effective and faster than ground and aviation equipment. The extensive modern equipment of unmanned aerial vehicles, such as high-precision cameras and thermal imagers, minimizes the need for human resources and increases operational efficiency. Additionally, their cost-effectiveness, compactness, maneuverability, and ease of use are advantageous.

Currently, in Ukraine, search and rescue operations are conducted solely using manned aircraft. This decision is based on insufficient research and regulatory acts governing the presence of UAVs in airspace.

In cases of emergency situations, search and rescue are the state's top priority tasks, with emergency services being the executors in such cases. To improve the quality and speed of operations, emergency services can mobilize additional resources.

The project proposal of the diploma work is the implementation of search and rescue operations using UAVs, as part of the list of services of the LLC "KRUNK". To identify opportunities and strategic directions of the enterprise, the following were studied: the existing fleet of aircraft, dynamics of financial and production activities, research of the target market, achievements, quantity and classification of services and aviation works performed by the company.

In the modern world, the use of advanced information technologies is necessary in almost all spheres of life. Technologies enabling information exchange cover practically all populated areas of the planet.

Research on technical capabilities in the field of search and rescue operations will open up opportunities such as:

- Continuous monitoring of potentially hazardous areas;
- Faster response to emergencies;
- Increased effectiveness of operations;
- Reduction in the number of casualties.

During this diploma work, the following analysis and research methods were used: SWOT analysis, PEST analysis, analytical method, expert analysis method, and calculation method. These methods allow for an investigation and evaluation of strengths and weaknesses, determining the feasibility of the proposed implementation. Additionally, they help identify the advantages and disadvantages of proposed development paths and identify relevant directions for project proposals.

To improve project proposals, scientific works of foreign and domestic researchers were analyzed. This information has been processed regarding the relevance of using unmanned aviation systems in search and rescue operations, the integration of modern technological developments in the field of systemic optimization, and the stages of search technology using UAVs during search and rescue operations. The application of advanced search technologies and systems will significantly reduce the time to locate casualties.

The diploma project explores the feasibility of conducting search and rescue operations and analyzes the effectiveness of using UAVs. Project proposals for implementing a new type of service using UAVs at LLC "KRUNK" are provided. Economic efficiency calculations are conducted based on the financial and production performance data of LLC "KRUNK".

CHAPTER 1
THEORETICAL PART

1.1. Definition of Search and Rescue Operations

A search and rescue operation is a complex of measures carried out by specially trained and equipped specialists in organizing search and rescue operations in disaster zones, natural or man-made disasters, complex weather or geographical conditions, with the aim of evacuating (removing, extracting) victims from the scene to a safe place, as well as providing them with first aid.

Search is the process of eliminating uncertainty about the possible location of a missing person.

The main factors determining the need for search and rescue operations are:

- Threat to the lives and health of the population.
- Threat of explosions, fires, and collapses.
- Oxygen content below 18%.
- Threat of collapses, drowning, and flooding.

The main search and rescue operations include:

- Water rescue.
- First aid and elimination of consequences of road traffic accidents on road transport.
- Reconnaissance, extraction of victims, provision of first aid in collapses, collapses, construction of passages, and elimination of blockages.
- Reconnaissance, rescue of victims, provision of first aid in floods, elimination of flood consequences.
- Reconnaissance, rescue of victims, provision of first aid in terrain, mountains, caves, and other hard-to-reach and extreme natural conditions.
- Reconnaissance, search, and rescue of victims, provision of first aid in accidents on railway transport, and elimination of consequences of such accidents.
- Reconnaissance, search, and rescue of victims, provision of first aid in

aviation transport accidents, and elimination of consequences of such accidents.

- Reconnaissance, search, and rescue of victims, provision of first aid in accidents on underground electric transport facilities, and elimination of consequences of such accidents.
- Reconnaissance, search, and rescue of victims, provision of first aid in water transport accidents (inland waters), and elimination of consequences of such accidents.
- Reconnaissance, search, and rescue of victims, provision of first aid in railway transport accidents, and elimination of consequences of such accidents.

Associated hazardous factors of search and rescue operations that determine the requirements for protective equipment include:

- Danger of explosions and fires.
- Danger of mechanical injuries.
- Danger of collapses, drowning, and flooding.
- Hazards during work at height, in deep places, hard-to-reach areas, low or high-temperature conditions.

The State Emergency Service of Ukraine is the central executive body whose activities are directed and coordinated by the Cabinet of Ministers of Ukraine through the Minister of Internal Affairs and which implements state policy in the field of civil protection, protection of the population and territories from emergencies and prevention of their occurrence, elimination of consequences of emergencies, rescue operations, firefighting, fire, and technogenic safety, emergency rescue services, as well as hydrometeorological activities.

The activities of the State Emergency Service of Ukraine in 2019 were aimed at implementing legislative acts, the President of Ukraine, the Action Program of the Cabinet of Ministers of Ukraine, relevant decisions of the Government in the field of powers of the State Emergency Service and performance of priority tasks.

During 2019, the bodies and formations of the State Emergency Service provided operational response to 146 classified emergencies (hereinafter referred to as emergencies), which were distributed by scale at the state level - 2, regional 7, local 63, object-level - 74. As a result of these emergencies, 199 people (including 23 children) were killed and 1,492 people (including 624 children) were injured. Compared to 2018, the total number of emergencies in 2019 increased by 14.1%, with the number of technogenic emergencies increasing by 25% (due to an increase in the number of emergencies due to fires and explosions, accidents in life support systems and sudden collapse of buildings and structures), and the number of natural emergencies - by 5.2% (due to a fourfold increase in the number of meteorological emergencies). During the reporting period, there was an increase of 78% in the number of injured (mainly due to medical and biological emergencies) and an 18.5% increase in the number of fatalities in emergencies (mainly due to emergencies resulting from transport accidents and fires, explosions in buildings and structures).

Among the technogenic emergencies in 2019, there was an increase in the number of emergencies due to sudden collapse of buildings and structures (no such emergencies were recorded in 2018), fires, and explosions (an increase of 23%), as well as emergencies in life support systems (a twofold increase). At the same time, there was an 11% decrease in the number of transport emergencies, but the number of fatalities in these emergencies increased by 19%. Also, against the background of the overall increase in the number of emergencies due to fires and explosions, the number of such emergencies in residential buildings decreased by 23.5%, while the number of fatalities in these emergencies remained almost unchanged, and the number of injured increased. Every year, the State Emergency Service of Ukraine keeps records of all emergencies that occur. Summary data on emergencies in Ukraine as of 2018-2019 are presented in Table 1.1.

Table 1.1

Data on Emergencies

Data on Emergencies	2018	2019	% Increase
Total Emergencies	128	146	14.1

Including:			
Technogenic	48	60	25
Natural	77	81	5.2
Social	3	5	66.7
State Level	2	2	0
Regional Level	6	7	16.7
Fatalities Due to Emergencies	168	199	18.5
People Affected by Emergencies	839	1492	77.8
Material Damage from Emergencies	496, 965	685, 269	37.9

Note: "UAH" stands for Ukrainian hryvnia, the currency of Ukraine.

From table 1.1, it can be observed that the number of emergencies of both technogenic and natural origin increased the most, leading to an increase in the number of affected and deceased individuals.

1.2. Organization of Search and Rescue Operations

A search and rescue operation is a complex of measures aimed at timely preparation, maintaining readiness at an appropriate level, and mobilizing search and rescue forces and resources to respond to emergencies while adhering to rules and norms.

A search and rescue operation includes:

- Organization of disaster alerts.
- Organization of duty shifts for search and rescue forces, resources, and control bodies.
- Organization and execution of search and rescue operations.

- Special training of aircraft crews, emergency rescue teams, and personnel involved in aviation search and rescue operations.
- Special training of crews regarding actions in emergency situations on board aircraft and survival of passengers and crew during aviation incidents.
- Briefing passengers on board aircraft about actions in emergency situations.

Normative legal documents regulating the organization of search and rescue operations in civil aviation in Ukraine include:

State normative legal documents:

- Constitution of Ukraine.
- Air Code of Ukraine.
- Civil Protection Code of Ukraine.

Departmental normative legal documents:

- Rules for search and rescue in Ukraine.
- Rules for search and rescue support of civil aviation flights in Ukraine.
- Guidelines for search and rescue support of civil aviation flights in Ukraine.

Main international documents regulating search and rescue:

- Annex 12 to the ICAO Convention "Search and Rescue".
- Annex 14 to the ICAO Convention "Airports".
- Manual on International Aviation and Maritime Search and Rescue.

The composition of the emergency rescue team at a civil aviation aerodrome consists of regular and non-regular units. Regular units include fire and water rescue units. Non-regular units of emergency rescue teams are formed from services such as medical, engineering-aviation, special transport service, aviation safety service.

Search and rescue operations and their coordination are carried out by air traffic service bodies of Ukraine, state disaster notification, search and rescue organizations, specialized fleet monitoring services, emergency rescue services, maritime safety services of shipowners, and other units. Coastal radio stations, specialized search and rescue maritime and air units (search and rescue units), designated participants of interaction, as well as other maritime and air vessels located in or near the accident area, are involved in search and rescue operations.

Search and rescue areas are established in maritime areas, within which search and rescue sub-centers are responsible for organizing effective search and rescue operations.

The tasks of the respective sub-centers include receiving disaster alerts, organizing search for people in distress at sea, providing them with medical assistance, supplying them with food, water, protective clothing, and other necessary supplies, evacuating them, and delivering them to shore.

Searching for and providing first aid to the injured is the main task of rescuers during emergency response. The search for the injured begins with familiarizing oneself with the reconnaissance results, studying the work area (location) of the operation, the nature of the emergency, and determining the search methodology. The goal of the search is to determine the location and condition of the injured within the disaster zone.

Search planning includes the following stages:

- Situation assessment based on the analysis of previous searches.
- Determining the location of the incident.
- Assessing the movement of survivors after the emergency and determining the probable error of such assessment.
- Determining the most effective search and rescue means from the available ones to ensure the highest probability of locating survivors.
- Developing a search plan.

At the initial stage of search and rescue operations, the "surface-spatial" search tactic is used. This involves searching the entire disaster zone in easily accessible areas, primarily in places where calls for help are heard. The advantage of this tactic is that it simultaneously covers almost the entire "disaster zone" with the use of a small number of technical resources and with minimal time expenditure. The disadvantage is that it requires a lot of resources.

Subsequently, after finding and extracting survivors from easily accessible places, the "identification of main objects" search tactic is applied. This involves identifying priority areas within the general disaster zone, i.e., areas where danger has developed (spreading fire, presence of combustion products, lack of oxygen, threat of flooding, etc.). Resources and efforts are concentrated in these areas to search and rescue survivors.

The advantage of this tactic is that it requires fewer resources. The disadvantage is that it reduces the search area, thereby increasing the time needed. If sufficient resources are available, both tactics are applied simultaneously.

To reduce the time required for search operations, the following general rules are used:

- The sequence of selecting objects for search is based on the principle of from simple to complex, i.e., searching is conducted in areas with minimal damage and low levels of danger first, then in areas with more significant damage, etc.
- When determining the most likely locations of the injured, consider the time of the incident: during working hours, people will be more likely in facilities and institutions, and less likely in residential buildings; conversely during non-working hours.
- Take into account the duration of the incident to determine where to search for the injured. If the emergency situation developed in such a way that people had time to escape from the danger zone, search for the injured along evacuation routes (corridors, exit doors, windows, staircases), if there was no time to leave the danger zone, search in work areas, rooms, under slabs of overlapping structures, etc.
- Conduct searches in silence.
- Conduct searches in pairs at a minimum.
- Prioritize rescuing living individuals, and in case of finding deceased individuals, do not rescue them but mark their location. Deceased individuals are rescued last.
- The search for survivors continues until it is determined that no one is left alive or deceased in the disaster zone.

After studying the work zone and the nature of the emergency situation (ES), rescuers choose the optimal method for searching for victims. Among the main methods for searching for victims are: visual, acoustic (sound), area sweeping, search by traces, probing, questioning witnesses, aerial search, search using special devices, and animals.

Visual Method: Approximately 90% of information is received by humans through sight. Therefore, the main method of searching for victims is visual. It involves examining the area and determining the location of the victims.

The visual search begins with inspecting the entire visible ES area. During this, the rescuer observes while stationary or moving. To increase the field of view, it is necessary to use elevated positions. To optimize visual search, binoculars, spotting scopes, magnifying glasses, periscopes, and night vision devices should be used. They allow observation at a distance and in conditions inaccessible to the naked human eye. To conduct visual search at night, in dark enclosed spaces, caves, fog, or smoke, projectors, flashlights, lamps, lighting flares, and night vision devices should be used. Lights from a big city are visible up to 60 km away, a vertical projector light up to 50 km, car headlight up to 10 km, bonfire light up to 8 km, and flashlight light up to 3-4 km. During daytime observation, tall towers, churches, elevators are visible at a distance of 18-20 km, settlements at 15-16 km, large buildings at 9-10 km, factory chimneys at 6-8 km, and smoke from them at 50 km. People are visible at a distance of 1.5-2.0 km.

Acoustic (Sound) Method: When visual search is difficult or impossible, the search is conducted based on sound signals from victims. The main sound signals include conversation, shouting, crying, whistling, knocking, gunshot, engine sound, and dog barking. The lengths of the sound waves of these signals determine the distance from which they can be heard, aiding in the search effort.

Table 1.2

Sound Wave Length of Signals

Sound Signal	Distance, km
Explosion	12.15
Train noise, siren	7.1
Gunshot	2.3
Tractor rumble	3.4
Car horn, dog barking	2.3
Human scream	1.0-1.5

Tree falling crack	0.8
Sleigh bells, wood sawing	0.5

In order to optimize the search for victims, sound signals can be provided by rescuers continuously, with short intervals for listening to possible responses. To obtain sound information, it is necessary to periodically stop all types of work simultaneously for a few minutes. During this time, everyone should carefully listen to the sound information, determine its location and direction of transmission, and begin searching for victims.

Accurate determination of the location of victims by sound signal is of great importance for the operational conduct of search and rescue operations. To avoid errors, it is necessary to repeatedly, and in some cases repeatedly, receive sound information from victims. This information should be constantly clarified during the work process.

To expedite the search for victims in large territories, aerial vehicles, river (maritime) vessels, and ground equipment are used. Special attention should be paid to the use of aviation in search and rescue operations, as aviation equipment is successfully used for visual search of victims in large areas. Taking photographs of specific areas of land or water with subsequent decryption of the obtained material is the most effective method in cases of aviation, maritime accidents, floods, forest fires. A significant advantage of aviation equipment is its ability to cover a large search area in a short time. Aerial search allows for efficient detection of the center of accidents, catastrophes, disasters, which in turn significantly reduces the search area.

UAVs are used to carry out search and rescue operations by emergency services units, such as the police, fire brigades, or other rescue teams, to search for missing people in need of assistance in extensive and remote areas. UAVs can transmit data in real-time mode and other information about the state of emergencies. They can also help locate a person who is lost in the forest or mountains.

During emergencies, search and rescue teams need to receive accurate information about the situation on the ground for quick response and to save time for making the right decisions. UAVs can quickly provide detailed information through video or images, reducing the costs and risks of search and rescue operations. An unmanned aircraft can not only provide detailed images and data from the air but also help crews reduce costs, form teams according to the provided information, and ensure the safety of personnel, ultimately speeding up the operation on the ground where every second counts.

It is mandatory to conduct special training for the crews of aircraft involved in aviation search and rescue duty. Also, before duty, the crew is obliged to:

- study the instruction of the search and rescue aircraft duty crew and the requirements of the Rules of Aviation Search and Rescue in Ukraine;
- check the availability and condition of emergency and rescue equipment;
- study the actual weather forecast;
- check the operability of communication channels;
- undergo pre-flight medical examination.

1.3. The use of Unmanned Aerial Systems (UAS) in Search Operations

An Unmanned Aerial System (UAS) consists of an unmanned aircraft, associated remote pilot stations (ground control stations), necessary control and monitoring lines, and other elements specified in the approved design of this complex. This complex can include several unmanned aerial vehicles.

A UAV (Unmanned Aerial Vehicle) is an aircraft that flies and lands without a pilot physically present on board.

A UAS includes:

- UAV
- Control station
- UAV communication system (radio communication or satellite communication)

Additional equipment necessary for transporting and servicing UAV

In all types of natural disasters, UAVs can help rescuers understand the situation and identify victims or individuals in need of assistance. This is especially relevant in hard-to-reach areas. Such tasks include avalanche rescue, firefighting, floods, or contamination, for example, in nuclear disasters. In these situations, UAVs can transmit not only visual information but also other data such as temperature, air quality, or radioactivity. Additionally, UAVs can provide communication to connect with inaccessible people or even deliver urgently needed tools.

UAVs have extensive capabilities for surveying large and remote areas. They can transmit images and sensor data from remote locations faster than conventional means, without risking harm to personnel monitoring the situation.

Fig. 1.1. View from the thermal vision camera provided on the UAV - search for missing people

The use of UAS is a promising field for conducting search and rescue operations and can play a crucial role in their successful outcome. UAVs can easily and quickly access inaccessible environments. They are agile, easily transportable, and exhibit autonomous behavior, providing precise and reliable air support. With built-in sensors that can adapt to external conditions, rescue teams can accurately investigate and map large areas in real-time (remote areas, roads blocked by debris or traffic congestion), directing rescue teams to target locations and thus expanding search capabilities to find people in need.

Probability distribution maps can be used by UAVs to plan flight trajectories. To support prioritized search, UAVs fly over areas with a higher probability and provide visual support using an onboard sensor. Conversely, data collected by UAVs can provide rescue teams with the necessary information to update probability distribution maps.

After an earthquake or other catastrophe, UAVs can provide information about the area of destruction, location, and severity of building damage, detect victims under rubble, and provide support in developing appropriate strategies. The Haiti earthquake in 2010 marked the beginning of UAV exploitation and the assessment of structural integrity of buildings, roads, and other infrastructure, carried out faster and with greater accuracy. The chances of survival for people trapped in damaged buildings largely depend on the types of building damage. Therefore, rapid mapping of the affected area allows damaged buildings to be characterized and classified according to the losses they have suffered, on a specific scale corresponding to the assessment of rescue groups, to optimize their work.

The approach to conducting operations can vary significantly depending on a combination of external factors such as weather conditions, time of day, location of the search and rescue operation, etc. Generally, search schemes can be divided into four groups, including visual search, electronic search, search during the dark period of the day, and ground search. The most commonly used is visual search, which, in turn, is divided into:

- Sector search
- Search by expanding squares
- Line of movement search
- Contour search

Sector search is applied when the location of the search object is precisely known and the search area is small. This allows for the quickest and most probable detection of victims and the provision of assistance.

Search by expanding squares is most effective when the location of the search object is known with relatively high precision. However, compared to sector search, it is more resource-intensive and requires more time.

Line of movement search is used when an aircraft or vessel disappears without a trace while following a known route.

Contour search is used if the incident occurred in mountainous terrain.

Extreme caution should be exercised during mountain searches, canyons, and valleys. Using UAS for such operations is particularly appropriate due to the high maneuverability of UAVs and the exclusion of the risk of harm to the crew.

1.4. Using modern technologies in search and rescue operations

When natural disasters, technological catastrophes, industrial accidents, and collapses of urban infrastructure occur, the first few hours are crucial. And not only in these cases—people can get lost in forests, mountains, or end up in open seas. When it comes to saving lives, the use of advanced technologies can play a key role.

In 1991, at the initiative of international rescue teams responding to earthquakes in Armenia in 1988 and Mexico City in 1985, the International Search and Rescue Advisory Group (INSARAG) was established. This UN organization facilitates information exchange among national urban search and rescue organizations and coordinates on-site activities during emergencies.

The types of incidents requiring search and rescue operations vary from country to country due to regional specifics, equipment availability, and theoretical training of specialists. However, in every region, new and improved technologies play a significant role in enhancing the safety of rescuers and the overall effectiveness of search and rescue operations.

The search and rescue technology market is segmented into equipment for operation planning and communication, search equipment, medical and technical equipment. Communication is one area that has seen significant improvements. With mobile phones and other devices, one can call for help from almost anywhere on the planet and get oriented on-site.

There are also specialized systems, such as geoDVR from RemoteGeoSystems, which allows viewing, recording, and geotagging geographical coordinates on a map. Unlike traditional video recording systems, geoDVR records video with geolocation data tied to time using GPS. This data is crucial for rescuers to make optimal decisions about where and how to use resources based on the exact location of individuals and the level of danger. With the ability to compare and record information remotely, rescue missions can become significantly more efficient.

DJI Airworks is an annual international conference that advances the drone industry. AirWorks serves as an innovation and growth hub, allowing participants in this ecosystem to exchange ideas, gain more control over UAV technology, and steer the future development of the industry.

Drones have saved at least 279 lives worldwide, as announced by Romeo Durscher, Director of Public Safety Integration at DJI, during AirWorks 2019. And this number is likely much lower than the actual cases, as many incidents were not officially documented or mentioned in major global media.

In recent years, drones have been increasingly used to support public safety and search and rescue operations. Perhaps the most notable example was the use of UAVs during and after the 2019 fire at Notre-Dame Cathedral in Paris.

DJI Technology is one of the pioneers and market leaders in UAVs, a drone market innovator, controller for UAVs, and stabilizing equipment for video shooting. Their Agras series drones were first used for disinfecting areas potentially infected with coronavirus in China in an attempt to contain the virus; for spraying special liquid on rice fields in Tanzania, preventing malaria spread; delivering medicines to remote areas of the Dominican Republic where people often die without necessary medical assistance.

Chinese drones compete successfully with American UAVs, for example, Zipline's rescue drones that deliver donor blood and medicines in Rwanda; MultiCopter from 3D Robotics; the modern search and rescue UAV system C-astral (Slovenia); Heliguy products (UK) adopted by over 40 emergency services in the UK and police; and many other brands.

Modern UAVs feature compact designs, improved stabilization, some models equipped with powerful portable TV cameras. They can carry several useful payloads, such as gas leak detectors or spotlights. They can fly in challenging conditions like fog, smoke, at night, and allow selecting different data display modes, combining information from visual and thermal cameras to detect details not visible to the naked eye, setting specific temperature ranges for higher contrast and better visibility. This drone feature helps in search and rescue missions to locate people in dense forests and allows firefighters to identify hot spots during fires.

UAVs offer numerous capabilities for various tasks in the search and rescue field, from surveillance to search, rescue, or providing first aid and delivering essential supplies, which is why they are highly valued by emergency services and volunteers.

A drawback and restraining factor for the development of this promising industry is the weak state funding for search and rescue services, which in turn hinders the growth of such equipment market, mainly because search and rescue operations do not have potential for financial growth.

1.5. Concept of Efficiency in Search and Rescue Operations

The term "efficiency" is a highly complex and multifaceted concept actively used in various fields. Thus, the most commonly accepted yet generalized definition would be as follows: Efficiency is the ratio of the beneficial effect to the costs incurred to achieve it.

Overall, three approaches can be distinguished in defining the essence of the category "efficiency":

1. Achievement of an effect or result;
2. Ratio of result to costs;
3. Realization of goals with an acceptable ratio of costs and results.

In the modern scientific world, there are several identical concepts somehow related to the concept of efficiency, and one of the key ones is effectiveness. Considering efficiency in terms of performing search and rescue operations, it can be conditionally divided into three types: economic efficiency of enterprise activities, efficiency in performing search and rescue operations, and UAV (Unmanned Aerial Vehicle) efficiency.

Economic efficiency is the result of the financial and economic activities of an economic entity covering all costs incurred and containing the net profit remaining for business development. Accordingly, the economic efficiency of an enterprise is determined by the following main factors:

- Implementation of maximum achievable economic goals oriented towards the full potential of the enterprise;
- Identification of changes necessary for the complete realization of the enterprise's potential;
- Implementation of necessary changes to achieve set strategic goals.

It is worth noting that all factors are interrelated since achievable goals must be set.

The effectiveness of performing search and rescue operations is determined based on indicators such as: response speed to the emergency scene or search area; technical specifications of the equipment used; qualification of rescuers and other individuals in the search and rescue team; speed of victim detection and quality of search operations. Predicting the effectiveness of a search and rescue operation in advance is very difficult because the approach to performing these tasks in mountainous terrain or conducting such operations on water varies significantly. However, effectiveness can be increased by choosing optimal search strategies, selecting appropriate equipment, and using available resources most rationally.

UAV Efficiency: There are many indicators that affect UAV efficiency. Most of these indicators relate directly to UAV characteristics, namely: autonomy, weight, maximum useful payload, speed, preparation time, flight altitude, image quality, control range, and other factors. These and other characteristics directly affect the efficiency and quality of work performance, so when choosing UAVs, it is necessary to consider these mentioned indicators first.

Known limitations in UAV use that affect the effectiveness of search and rescue operations include complexity in UAV use, which is also accompanied by a number of other known limitations. For example, UAV vulnerability due to their low weight and low power. The well-known issue of extreme cold temperatures affecting battery capacity, and consequently, UAV flight time, which can be reduced by up to 50%. Maintaining sufficient battery temperature before flight is a common problem for which some technical solutions are being developed, such as using a heated and thermally insulated block. Several tests have been conducted in various precipitation conditions, demonstrating UAV capability to fly under adverse conditions. However, it is acknowledged that moisture in electrical circuits and components can cause short circuits or other problems, so having modifications to avoid these issues is important. Ordinary UAVs during operation are also vulnerable in certain meteorological conditions, such as winds and turbulence caused by the earth's surface (due to air flow encountering obstacles like terrain relief and vegetation), which can have a detrimental effect on their flight ability. At the same time, such disturbances can significantly contribute to reducing the likelihood of detection (the flicker effect of computational vision). Work can be carried out under less than optimal lighting, which can significantly reduce UAV effectiveness. Possible solutions to these operational issues include using external lighting on the ground or incorporating lighting into the UAV itself (depending on its useful payload) and research oriented in this direction.

1.6. Methodology of Aviation Enterprise Activity Analytics

The analysis of enterprise activity can be conducted either by its own economic-financial structural units or with the involvement of consulting organizations or audit firms. The analysis is carried out by studying operational statistics data. The purpose of activity analysis is to determine the volumes and structure of periodic changes in the system of economic indicators that characterize the efficiency of activities of individual production-commercial units, the efficiency of resource utilization (material, financial, or labor), and the quality of services provided compared to past periods or with a similar average indicator in the industry or with other competing enterprises.

The reasons for negative performance indicators or shortcomings of specific structures are also identified.

The main criterion for enterprise activity is profitability. While indicators such as competitiveness, market satisfaction level, service quality, and other related factors are extremely important, profitability should be the primary focus. Activity analysis allows for more effective adaptation to market changes, predicts possible trend changes in partners' behavior and customer needs. The most widespread methods of analysis are strategic analysis, SWOT analysis, and PEST analysis.

Strategic Analysis involves a comprehensive study of factors influencing the economic position of the enterprise in the long term. This analysis also helps better define the purpose, tasks, volumes, and production structure, essentially composing a business plan for long-term periods. In other words, strategic analysis helps specify the development vector of the enterprise. The analysis is usually conducted in two stages: setting planned indicators expressing the idea, mission, and goals of the enterprise and comparing them with the real possibilities proposed by the environment, and establishing a gap between them, determining alternative strategic plan options (possible development scenarios).

SWOT analysis involves identifying a company's strengths, weaknesses, opportunities for expansion in activities and market segments, and threats from the external environment. On practice, several slightly different forms of conducting SWOT analysis are applied:

- Express SWOT Analysis - the most common (due to simplicity) qualitative analysis method, which allows identifying the organization's strengths that help deal with threats and utilize opportunities from the external environment, as well as weaknesses that hinder this. However, this method has its drawbacks in practice: only the most obvious factors end up in the cells of the table, and even then, some of these factors disappear in the cross matrix as they cannot be used.
- Summarized SWOT analysis, which should include the main indicators characterizing the company's current activity and outlining prospects for future development. The advantage of this analysis form is that it allows giving a quantitative assessment of the identified factors (even in cases where there is no objective information about these factors in the company). Another advantage is the ability (based on conducting all types of strategic analysis) to immediately move on to strategy development and devise a set of measures necessary to achieve strategic goals. The obvious drawback is a more complex analysis procedure.
- Mixed SWOT analysis, an attempt to combine the first and second forms of analysis. To do this, at least the main three types of strategic analysis are conducted in advance (usually this includes STEP analysis, Porter's five forces analysis, and internal environment analysis using one of the techniques).

PEST analysis is a marketing tool designed to identify political, economic, social, and technological aspects of the external environment influencing a company's business. Government regulations and legal issues affect a company's profitability and success. Issues to consider include:

- Tax policy;
- Copyright and property rights;

- Political stability;
- Trade regulations;
- Social and environmental policies;
- Employment laws and safety regulations.
- Companies also need to consider local government and its impact on business.

The economic factor examines external economic problems that may play a role in the company's success. Pay attention to:

- Interest rates;
- Inflation rate;
- Unemployment;
- Gross domestic product;
- Credit availability.
- Analyzing the socio-economic environment of the market in your industry helps understand how consumer needs are formed and what was the main factor for purchase. Phenomena to study include:
- Demographics;
- Population growth rates;
- Age distribution;
- Work attitude;

Labor market trends.

Changes in culture and society, such as a desire for a healthy lifestyle and environmental concern, reducing the number of children in families, influence how consumers make their purchases.

- Technology plays a huge role in business, and it can have both negative and positive impacts. Introducing new products, technologies, and services can take a significant amount of time and require larger investments. Therefore, businesses need to assess this factor comprehensively. Specific elements to study include:
- Government spending on technological research;
- Lifecycle of modern technologies;

- Internet role and possible changes in it;
- Impact of potential changes in information technologies

CHAPTER 2
ANALYZING PART

2.1. Analysis of the Cost per Flight Hour for Piloted Aircraft

A new era in the history of civil aviation in Ukraine began in October 1992 when the state aviation authority, Ukraaviatsiya, was established, coinciding with the initiation of market relations in civil aviation. This change provided freedom for initiatives and the creation of new national airlines of various ownership forms. As a result, Ukraine's aviation sector managed to avert a crisis despite a significant drop in domestic transportation volumes and limited legal framework for international flights. In September 1992, Ukraine became a member of ICAO, and in May 1993, it adopted its own Air Code.

Thanks to these factors, young aviation enterprises started to emerge, aiming to meet market demands. One such enterprise is LLC ATA "KRUNK," which was registered on July 30, 1993. The founder and first director of LLC ATA "KRUNK" was Vasyl Ivanovych Kryvozub, who served as the general director until 2007. After him, Alina Vasylivna Zaichenko became the director. Currently, the company's general director is Maria Valeriivna Medvedieva. The company was founded and registered in the State Register on July 30, 1993. The enterprise identification code (EDRPOU) is 19367246. The organizational and legal form of ownership is a limited liability company (code 240).

Over the years of its fruitful activity in the field of civil aviation in Ukraine, LLC ATA "KRUNK" has reached a new level in the sphere of corporate relations, as the enterprise regularly confirms its level of competence. It also boasts a high level of business reputation, a base of regular clients, suppliers, and contractors, with successful interactions underpinned by years of experience.

The execution of search and rescue operations involves the use of standby search and rescue aircraft, as well as the significant involvement of auxiliary resources and personnel, including non-standard aircraft. However, the costs associated with conducting search and rescue operations increase substantially during prolonged searches. Therefore, reducing these costs by rationally employing aircraft while adhering to necessary requirements is highly relevant.

To carry out aviation search and rescue within the aviation search and rescue region of Ukraine, the State Emergency Service and Ukraerorukh have implemented the standby of search and rescue aircraft with qualified personnel and emergency rescue equipment (Table 2.1).

Table 2.1

Base Locations of State Emergency Service Standby Aircraft

Aircraft Type	**Base Location (Airfield)**	**Readiness for Departure**	**Range, km**
Mi-8	Nizhyn	Day/20 min.	250
		Night/1 hr. 30 min.	
An-32	Nizhyn	Day/20 min.	750
		Night/1 hr. 30 min.	
An-32	Odesa	Day/20 min.	750
		Night/1 hr. 30 min.	
Mi-8	Kharkiv	Day/20 min.	250
		Night/1 hr. 30 min.	

From this table, it follows that the fleet of aircraft in Ukraine used for search and rescue operations on a regular basis, particularly for standby duty, consists of Mi-8 and An-32 aircraft. This is due to the fact that these aircraft are multipurpose, meaning they can be employed in various situations that arise. However, these aircraft are outdated and less economical compared to modern helicopters. In 2019, Ukraine signed a contract with France to purchase 55 H225 Super Puma helicopters, three of which have already been delivered for the State Emergency Service. This is expected to significantly update the current fleet of aircraft and enable more efficient execution of tasks related to search and rescue operations, firefighting, and medical missions.

2.2. Cost per Flight Hour for Search and Rescue Operations

Conducting search and rescue operations involves not only the use of standby search and rescue aircraft but also the need to engage additional resources and forces, including non-standard aircraft. The costs of conducting search and rescue operations increase with the duration of the searches. As the flight hours increase, more resources are required. Therefore, the cost of conducting search and rescue operations is a pressing issue that can be addressed through the rational use of aircraft while adhering to necessary requirements. For this purpose, we will analyze the volume of search and evacuation operations (Figure 2.1).

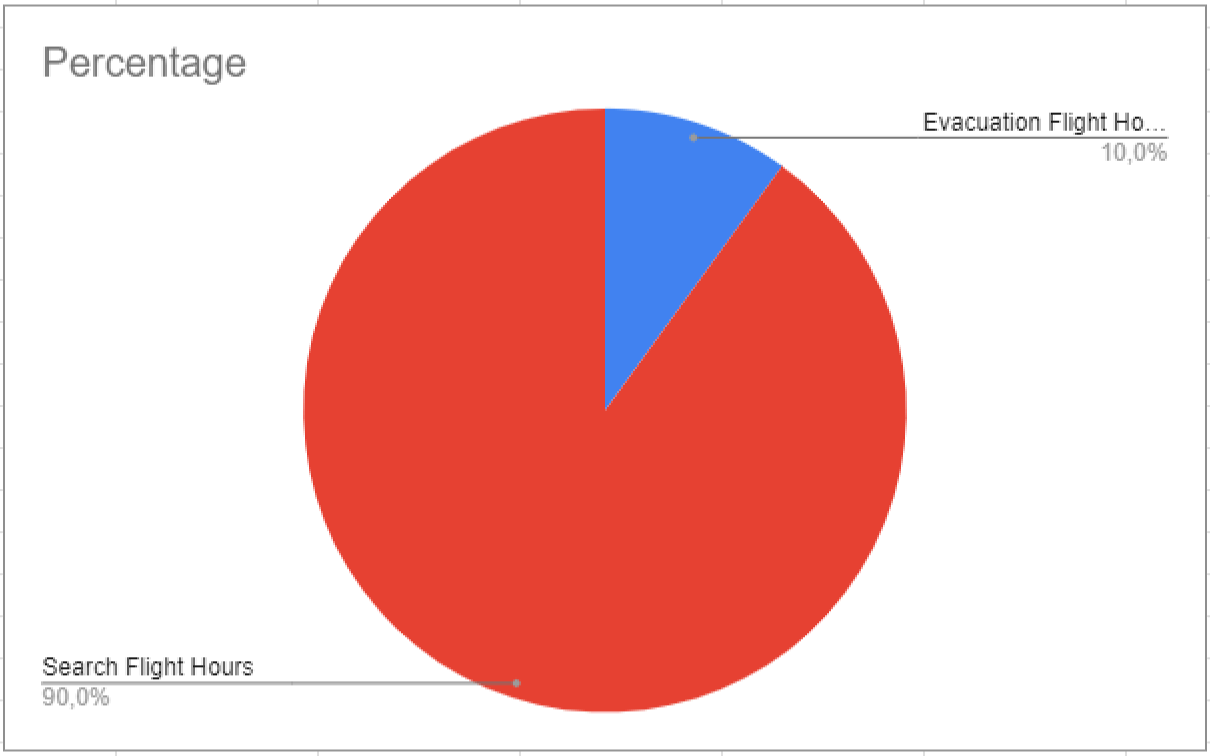

Fig 2.1. Average Flight Hours Share for 2010-2022

Analyzing the provided Figure 3.1, it is evident that the primary financial expenses for employing aviation in search and rescue operations (SAR) are concentrated during the search phase. This is due to the high complexity of performing SAR, particularly under conditions that prevent obtaining sufficiently accurate information regarding the probable location of the object of search (OOS).

Consequently, a larger area must be searched, which in turn increases the flight hours spent on searching for the OOS. Therefore, to enhance the efficiency of these operations, it is necessary to optimize the search process by selecting the most cost-effective aircraft.

The average cost of operations for some aircraft used worldwide for SAR is presented in Figure 2.2.

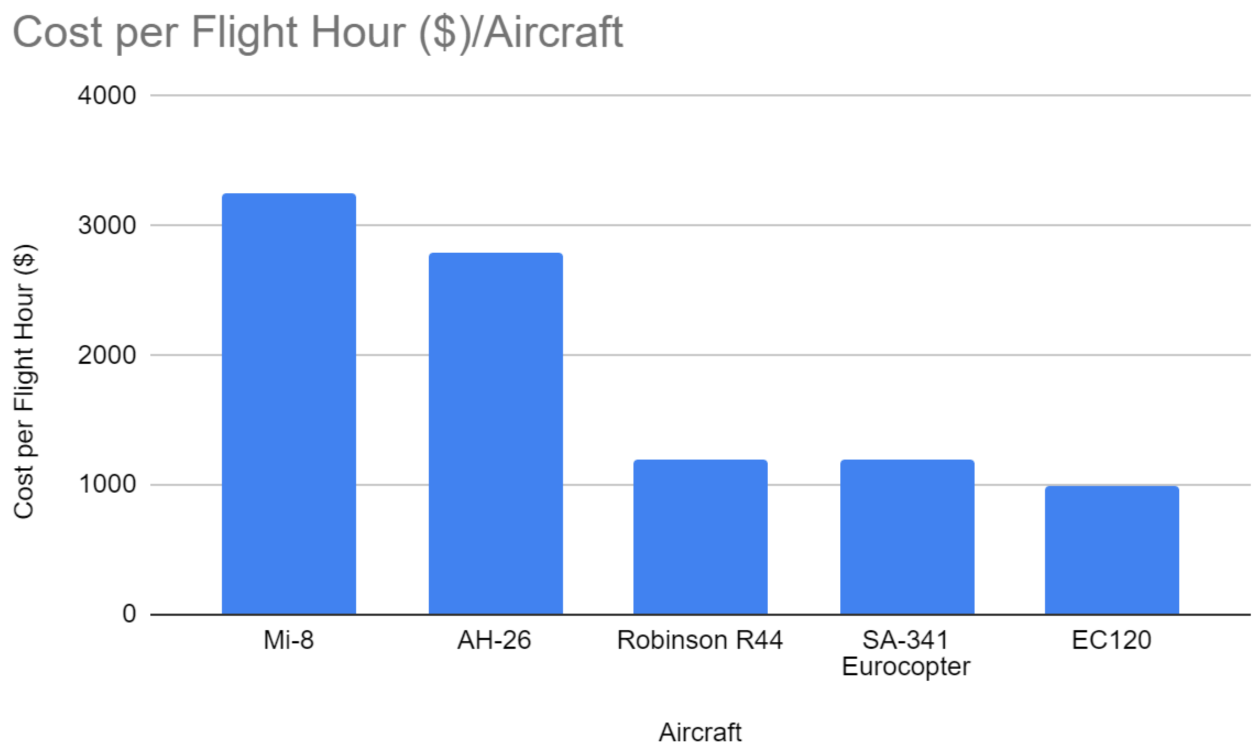

Fig 2.2. Cost per Flight Hour for Search and Rescue Operations

The high cost per flight hour of the Mi-8 includes significant expenses on fuel and lubricants, aircraft depreciation, maintenance, and the multifunctionality of this aircraft. The Mi-8 possesses operational search and rescue capabilities, such as deploying search and rescue teams via parachuting, rappelling, and hoisting survivors in hover mode.

However, it is important to note that according to international search and rescue regulations, aerial visual search is conducted at altitudes up to 600 meters with a recommended flight speed for helicopters and light aircraft of up to 180 km/h. Consequently, the search productivity, defined as the area of land or water surface that an aircraft can visually inspect or scan using search radio equipment within one hour, is identical for both helicopters and airplanes. Therefore, the multifunctionality of the Mi-8 during search operations is not a priority.

Enhancing the efficiency and cost-effectiveness of search and rescue operations can be achieved by using light aircraft as an alternative to heavy ones. This approach will result in:

- Faster response times due to reduced preparation time for takeoff, as larger aircraft require more extensive pre-flight servicing.
- Lower financial costs for operational and technical maintenance, particularly in terms of fuel and lubricants, thanks to smaller engine volumes and lighter weight.

CHAPTER 3
PRACTICAL PART

3.1. Project Proposals for Implementing New Enterprise Activities

The use of UAVs is gaining increasing attention for use in most sectors of civil aviation as an alternative to helicopters or airplanes. Many government organizations and private companies are considering the possibility of using UAVs in search and rescue operations, and some are already actively and successfully employing them.

As a project proposal, a technology for conducting search and rescue operations using UAVs is presented (see Fig. 3.3).

Table 3.1

Technology for Conducting Search and Rescue Operations Using UAVs

1. Receipt of the first information	The PRR System receives information about the occurrence of an emergency situation with a certain object or in a certain area.
2. Initial actions	Preliminary actions, which are carried out with the aim of notifying the management bodies and forces of the PRR System and obtaining additional information.
3. Planning of search works	Development of operational plans for searching the scene of the incident and searching for victims.
4. Operational search measures	Dispatch of the BPS to the scene, assessment of the emergency situation.
5. Transfer of information	Receiving all operational data from the scene of events from the BPS to the ground control center, transmitting information to the rescue team.
6. Planning of rescue operations	Development of operational plans for rescuing victims, providing them with first aid. Their evacuation.

7. Operational rescue measures	Direction of helicopters with a rescue team to the scene. Provision of first aid to victims, their evacuation.
8. Termination	Returning the forces and means of the aviation search and rescue system to the base, where the search and rescue group surveys, refueling, replenishment of supplies and preparation for other operations are carried out. Compilation of reports.

The use of unmanned aviation complexes in search and rescue operations appears very promising. However, for successful practical application, it is essential to combine several key factors:

- Range of the UAV
- Availability of a trained team for launch and control
- Established technology for using UAVs
- Developed tactical deployment scheme
- Availability of high-quality equipment

In the initial stages of search and rescue operations, it is proposed to use unmanned aviation complexes. The advantage of this approach is that preparing UAVs for flight takes significantly less time than, for example, pre-flight preparation of helicopters. Additionally, UAVs do not require a specialized takeoff site, allowing their launch from virtually any open area. Thus, the control center of the search and rescue operation, led by the operation coordinator, will immediately receive real-time information from the UAV cameras. This allows for analyzing the emergency situation, developing a subsequent rescue plan, and forming the necessary number of rescue teams. Additionally, if necessary, UAVs can quickly deliver first aid supplies, provisions, or communication tools.

Using helicopters with rescue teams is justified only in cases where rescue operations are conducted in hard-to-reach places, such as mountains or at sea, or when there is little time left for rescue. However, in such situations, the use of the "UAV+helicopter" complex is very effective. While the UAV gathers information, the helicopter with the rescue team prepares for departure to the incident site.

During the operational rescue measures, medical assistance is provided to the victims, and evacuation from the emergency site is conducted. At this stage, using UAVs allows for better coordination of all search and rescue units' actions.

Upon completing the search and rescue operation, it is necessary to dismantle the UAV complex: land the UAV, transport it to the storage location, perform a technical inspection, refuel, and prepare for subsequent operations.

All information regarding the emergency is sent to the Main Aviation Coordination Center for Search and Rescue as a priority according to the emergency plans and interaction plans.

3.2. Application of Auxiliary Technologies Based on Other Countries'

In current search and rescue approaches, numerous methods are used, such as detecting isolated victims with chemical detectors, unmanned ground robots, thermal imagers, dogs, and more. However, there are situations where rescuers lack information about the presence of people in the area where these methods are used, as they do not have direct access to the area, such as in mountainous regions or unstable areas after earthquakes, heavy snowfalls, or hurricanes. Additionally, entry to the disaster site can be dangerous for rescuers in the event of chemical or nuclear disasters. In such cases, the key point is the speed of determining the presence and number of victims for further planning of search and rescue operations.

To address this issue, Orbital Critical Systems, supported by the European Union, developed the MOBNET search and rescue system. This project received funding under the EU's Horizon 2020 research and innovation program.

MOBNET is a search and rescue system integrated for use with UAVs. It can provide continuous monitoring of the emergency area at low costs without posing a threat to rescuers' lives. The system significantly speeds up the process of detecting victims over large areas.

The main goal of MOBNET is to search for isolated victims during natural disasters (see Fig. 3.4). Additionally, MOBNET can perform search operations for fugitives or smugglers hiding in buildings.

Fig 3.2. Example of MOBNET System Usage

To implement this system as a technology, the use of EGNSS, which includes both EGNOS and the Galileo satellite system, plays a key role, combined with digital satellite communication technology (see Fig. 3.5).

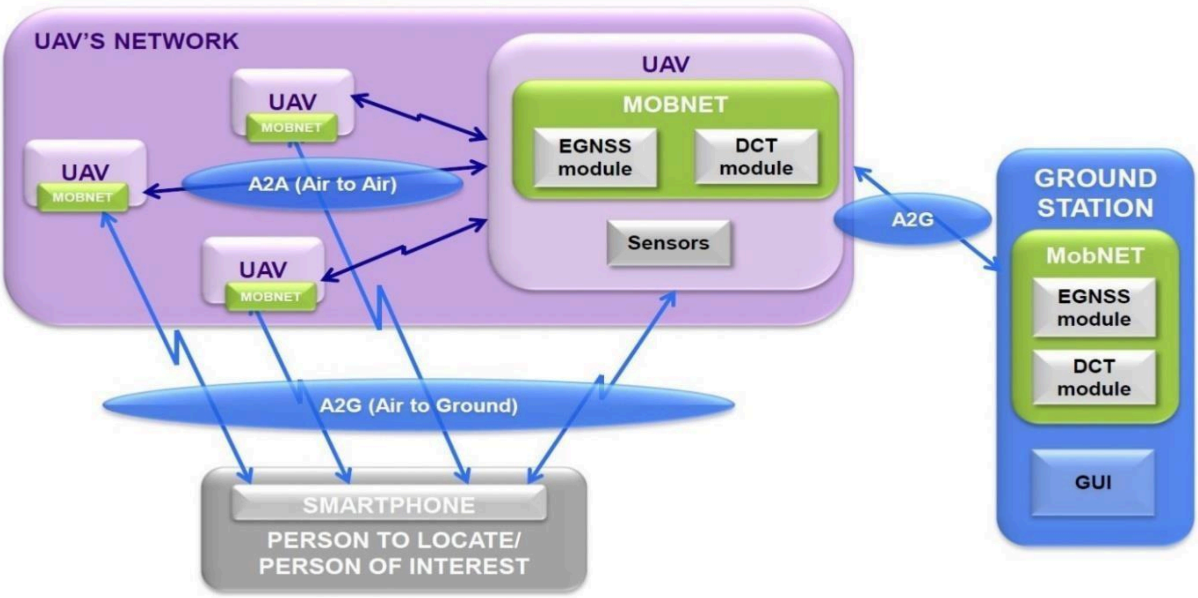

Fig 3.3. MOBNET Interaction System

The MOBNET system is best suited for situations where it is difficult, dangerous, or even impossible to reach emergency sites. The task of locating people in the field who have gone missing due to various emergencies remains relevant. Even detecting a person and determining their coordinates does not provide information about their current state. The use of unmanned aerial systems (UAS) in mass search and rescue operations is advisable to prioritize tasks, using UAS as a tool for quickly locating victims and analyzing their condition. Thus, the UAS activities at different stages of the task require constant communication with the operator, which prevents the simultaneous use of multiple devices to search for objects over a large area. Additionally, constant communication with the operator requires significant energy resources from the UAS.

Using technical vision improves the UAS management process and minimizes human involvement in management. The most effective type of UAV for this task is the multicopter, as it has several advantages for this kind of work, such as:

- Low cost
- High reliability
- Compactness
- Excellent maneuverability
- High payload capacity relative to its mass
- Ability to hover
- Relatively low training costs for personnel

Currently, algorithms for identifying objects (human faces) in images obtained from the front camera of the UAV are being actively developed and implemented. When determining the position of an object in the frame and tracking the found object, flight control commands for the UAV are formed based on a trajectory-following system. This approach can also be applied for obstacle identification and automatic flight path adjustment to avoid them.

This decision system allows for real-time face detection and minimizes the likelihood of UAV collisions with environmental objects.

The CAMShift tracking algorithm is built on a combination of a skin color probability map, allowing it to focus on objects based on their color. The advantages of this algorithm include flexible search radius adjustment, low computational resource requirements, and high likelihood of object detection even when partially occluded. The downside of CAMShift is that it works only with pre-known objects.

3.3. Selection of UAV Type for Search Operations by LLC ATA "KRUNK"

When performing search and rescue operations using UAS, UAV control is typically performed by an operator, usually in automatic mode. The onboard navigation complex also includes:

- A transponder that provides information reception and transmission;
- An instrument system that measures the UAV's altitude and speed;
- A control panel;
- A computer equipped for information processing and visualization.

The application of UAVs in civil aviation sectors attracts increasing investments, as this field appears very promising. There are already many types of UAVs available for performing various tasks. It is essential to assess the specific nature of this work and select a type of aircraft that will best fulfill the set tasks and meet the following criteria:

- Adequate target payload capacity;
- High flight range;
- Autonomous mode availability;
- Operating radius;
- Flight duration;
- Capability to operate under challenging weather conditions.

For search and rescue operations, we will consider the following unmanned aviation complexes: M-7D Sky Patrol, Observer SM1, Spectator, Raybird-3, and DS700 THOR. The M-7D Sky Patrol is a Ukrainian twin-engine unmanned aerial vehicle developed by NAU NVCBA "VIRAJ" (see Fig. 3.4).

Fig 3.4. M-7D Sky Patrol

In this modification, the engines are installed on the wings. The M-7D Sky Patrol is designed for cartography, aerial photography, and real-time video surveillance. The flight and technical characteristics of the M-7D Sky Patrol are presented in Table 2.3.

Table 3.2

Flight and technical characteristics of M-7D Sky Patrol:

Characteristic	Indicator
Maximum takeoff weight	150 kg
Maximum speed	192 km/h
Cruise speed	150 km/h
Practical range	800 km
Payload weight	20 kg
Maximum flight altitude	5000 m
Flight duration	5.3 hours

These characteristics make the M-7D Sky Patrol effective and versatile for performing various tasks from cartography to video surveillance.

ObserverSM1 is a Ukrainian multi-purpose unmanned aerial vehicle developed by the Odessa Design Bureau "YumikAerospace." Its application area is quite extensive, including patrolling, aerial photography, cartography, and search and rescue operations.

Table 3.3

Flight and technical characteristics of ObserverSM1

Characteristic	Indicator
Maximum takeoff weight	240 kg

Cruise speed	80 km/h
Maximum speed	120 km/h
Radius of action	500 km
Maximum flight altitude	5000 m
Flight duration	4.1 hours
Payload weight	40 kg

Spectator-M1 is a Ukrainian reconnaissance unmanned aerial vehicle developed by "PolytekoAero," a company founded by graduates of the aerospace faculty of the KPI. It made its first flight in 2014. Spectator is designed for reconnaissance, aerial photography, and can also be used in search and rescue operations, forest monitoring, water areas, and border surveillance.

Table 3.4

Flight and technical characteristics of Spectator

Characteristic	Indicator
Flight speed	40-120 km/h
Flight duration	120 min
Payload weight	1.5 kg
Maximum takeoff weight	7 kg
Launch type	Hand or catapult
Radius of action	30 km
Flight duration	2 hours

The Raybird-3 unmanned aerial vehicle system is a serially produced small tactical class UAV for various long-endurance missions and search and rescue operations. It was developed by the Ukrainian company AVC "Skyeton," founded by a group of engineers and pilots in 2006. Since 2016, Raybird-3 has been in service with the Armed Forces of Ukraine (see Fig 3.5).

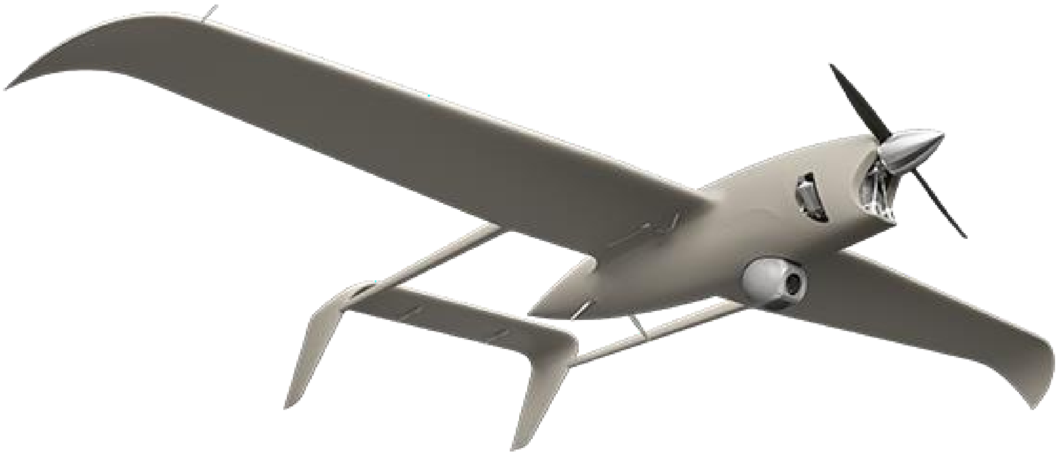

Fig 3.5. Raybird-3

The Raybird-3 unmanned aerial vehicle system is a serially produced small tactical class UAV for various long-endurance missions and search and rescue operations. It was developed by the Ukrainian company AVC "Skyeton," founded by a group of engineers and pilots in 2006. Since 2016, Raybird-3 has been in service with the Armed Forces of Ukraine (see Fig 2.6).

The flight and technical characteristics of Raybird-3 are provided in Table 2.6

Table 3.5

Flight and Technical Characteristics of Raybird-3

Characteristic	Parameters
Length	1.83 m
Wingspan	2.98 m
Maximum takeoff weight	20 kg
Cruise speed	120 km/h

Maximum speed	160 km/h
Payload mass	5 kg
Radius of operation	30 km
Takeoff technology	Catapult
Flight duration	15 hours
Service ceiling	3000 m

The DS700 THOR was designed as a universal UAV, thanks to a wide selection of additional equipment that can be customized according to specific objectives. DS700 THOR can be equipped with a thermal imager, HD camera, multispectral cameras, measuring equipment, or other useful gear.

Table 3.6

Flight and Technical Characteristics of DS700 THOR

Characteristic	Parameters
Maximum takeoff weight	6 kg
Cruise speed	60 km/h
Maximum speed	90 km/h
Radius of operation	30 km
Flight duration	1 hour
Payload mass	1.5 kg

The selection of UAVs for search and rescue operations should focus primarily on indicators that can improve search results or optimize the execution process. Key performance indicators that directly impact effectiveness include flight duration, cruise speed, payload mass, and operational radius. To comprehensively compare UAVs based on these characteristics, we will create a graph (see Figure 3.6).

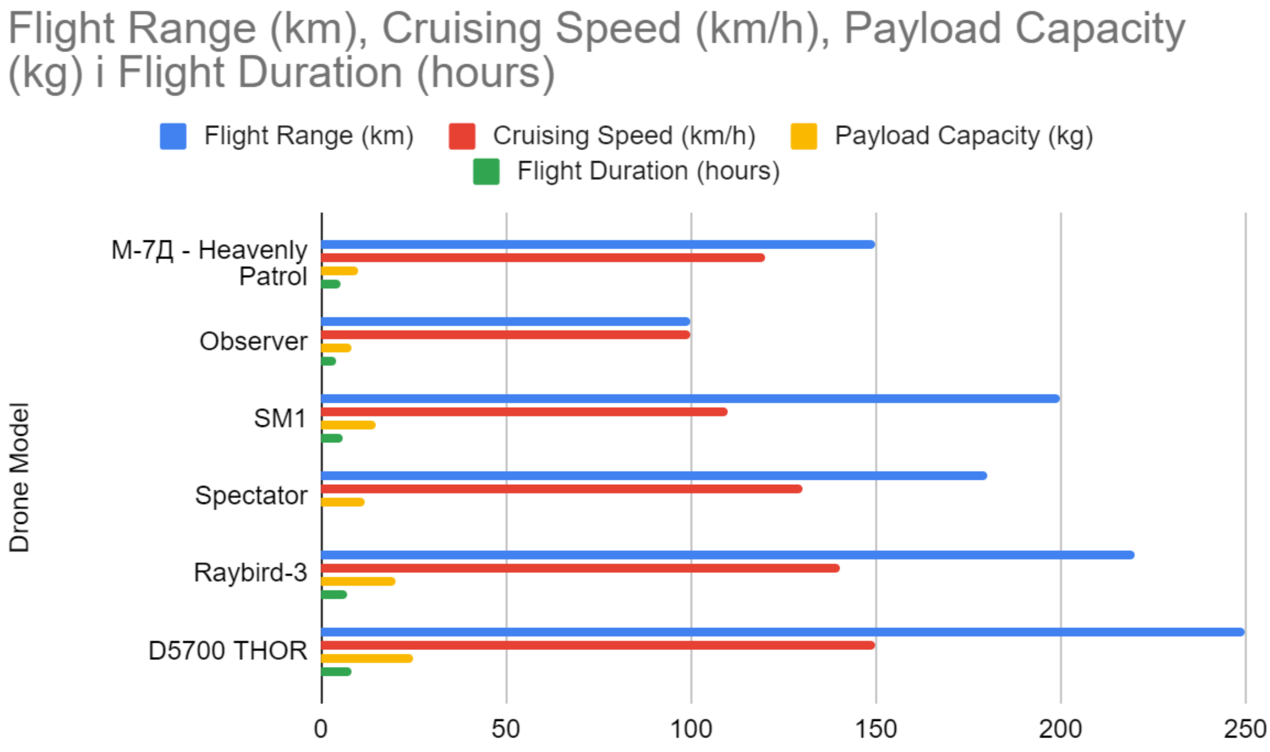

Fig 3.6 Comparative Chart of UAV Metrics

Analyzing the data provided, we conclude that the M-7D Sky Patrol is the best UAV in terms of operational radius and cruise speed. However, for search and rescue operations, a more comprehensive evaluation is necessary.

When choosing a UAV, it's essential to consider its structure. Among the UAVs listed, DS700 THOR stands out the most as a multirotor. This type has several crucial advantages for search and rescue operations, such as hover capability, high maneuverability, and controllability, especially in mountainous terrain. However, it also has drawbacks like low payload capacity, limited operational radius, constant operator control requirement, and short flight duration.

For search and rescue operations, the Raybird-3 UAV was chosen due to its excellent cruise speed, which is essential for quick response scenarios. While payload mass is not the sole criterion, it's sufficient for using search equipment.

3.4. Calculation of Economic Efficiency of the Proposed UAV

The development of UAVs has advanced significantly in recent years, with leading countries investing heavily in this field for various civil aviation tasks.

For search and rescue operations, we'll compare the economic efficiency of the Raybird-3 UAV with the Mi-171 helicopter, which is the most modern in the ATAKRUNK fleet today and can be used for search and rescue operations.

To calculate the hourly cost of flying the Mi-171, we'll process the average statistics for the past quarter provided by ATAKRUNK, as shown in Table 3.7.

Table 3.7

Components of Mi-171 Hourly Operating Cost

Indicator	Amount (UAH)
Aircraft rental	30,430
Pilot salaries	13,300
Technical maintenance	6,350
Overhead costs	2,590
Insurance	4,830

Summing up the figures in the table, we get the hourly operating cost of the Mi-171 helicopter, which amounts to 57,500 UAH excluding VAT.

The calculation of the hourly operating cost will be based on an expected annual flight time of 700 hours.

The technical and economic indicators of the Raybird-3 UAV, necessary for calculating its efficiency, are provided in Table 3.8.

Table 3.8

Technical and Economic Indicators of the Raybird-3 UAV

Characteristic	**Indicator**
Takeoff weight (W)	11 kg
Maximum useful load	5 kg
Cruise speed (Vcruise)	120 km/h
Average fuel consumption per hour	0.6 kg
Range with maximum payload (Lmax)	700 km
Takeoff-landing/recovery time (min)	10 min
Cost of UAV (VPS, million UAH)	5,400,000 UAH

We'll proceed with the economic efficiency calculation based on these parameters.

BAS operators team:

- Search and Rescue Operation Supervisor – 1
- Analyst Operator – 1
- Driver-Expeditor – 1

The cost of one flight hour (C_f.h.) includes both Direct Operating Costs (C_d) and Indirect Non-Operating Costs (C_nd). The formula for calculating the cost of one flight hour is as follows (Equation 3.1):

$$C\_f.h. = C\_d + C\_nd \quad (3.1)$$

The calculation of direct costs is performed using the formula (Equation 3.2):

$$C\_d = C\_fuel + C\_full\_rec + C\_maint + C\_lab + C\_soc + C\_ins \quad (3.2)$$

where:

- C_fuel – fuel and lubricant costs, UAH/hour
- C_full_rec – full recovery costs, UAH/hour
- C_maint – maintenance and repair costs, UAH/hour

- C_{lab} – labor costs for BAS crew members, UAH/hour
- C_{soc} – social expenses, UAH/hour
- C_{ins} – other flight costs, UAH/hour

Fuel and lubricant material costs (C_{fuel}) are determined by the formula (Equation 3.3):

$$C_{fuel} = (1 + E_{non\_prod}) \times g \times P_{fuel} \quad (3.3)$$

where:

- E_{non_prod} – coefficient considering non-production flight hours (equals 0.05)
- g – average fuel consumption per hour, tons/hour ($g = 0.0006$ tons/hour)
- P_{fuel} – fuel price per ton

$$C_{fuel} = (1 + 0.05) \times 0.0006 \times 25000 = 15.75 \text{ UAH/hour}$$

The full recovery costs (C_{full_rec}) are calculated using the formula (Equation 3.4):

$$C_{full\_rec} = D_{rate} \times C_{BAS} / T_{op} \times 100 \quad (3.4)$$

where:

- D_{rate} – depreciation rate for full recovery of BAS (10%)
- C_{BAS} – BAS cost (5.4 million UAH)
- T_{op} – annual operating hours (700 hours)

$$C_{full\_rec} = 0.1 \times 5400000 / 700 \times 100 = 2.7 \text{ UAH/hour}$$

Maintenance and repair costs (C_{maint}) are calculated using the formula (Equation 3.5):

$$C_{maint} = C_{full\_rec} \times K_{maint\_rep} \quad (3.5)$$

where:

- K_{maint_rep} – coefficient accounting for maintenance and repair costs (0.35)

$$C_{maint} = 2.7 \times 0.35 = 0.945 \text{ UAH/hour}$$

Labor costs are determined by the formula (Equation 3.6), taking into account that the commander's wage is 1000 UAH per hour and other crew members' wage is 700 UAH per hour of flight time.

$$C_{lab} = C_{comm} + n \times C_{crew} \quad (3.6)$$

$$C_{lab} = 500 + 2 \times 700 = 1700 \text{ UAH/hour}$$

Expenses for mandatory state social insurance are calculated using formula (3.7):

$$C\_soc = C\_lab \times K\_soc\_ins \quad (3.7)$$

where:

- K_soc_ins – coefficient for mandatory state social insurance contributions (0.4596).

$$C\_soc = 1700 \times 0.4596 = 781.3 \text{ UAH/hour}$$

Insurance costs (C_ins) are calculated using formula (3.8):

$$C\_ins = K\_ins \times C\_BAS / T\_op \quad (3.8)$$

where:

- K_ins – coefficient considering insurance costs (0.015);
- C_BAS – aircraft cost.

$$C\_ins = 0.015 \times 5{,}400{,}000 / 700 = 115.7 \text{ UAH/hour}$$

We substitute the obtained data into formula (3.2):

$$C\_d = 15.75 + 2.7 + 115.7 + 781.3 + 1700 + 0.945 = 2616.4 \text{ UAH/hour}$$

Assuming C_nd is 40% of C_d, we determine C_nd using formula (3.9):

$$C\_nd = 40\% \times C\_d \quad (3.9)$$

$$C\_nd = 40\% \times 2616.4 = 1046.5 \text{ UAH/hour}$$

Substituting the obtained data into formula (3.10):

$$C\_f.h = 2616.4 + 1046.5 = 3662.9 \text{ UAH/hour}$$

After calculating the cost, it was found that the cost of one flight hour for the Raybird-3 BAS will be 3662.9 UAH/hour. The comparison of the cost of one flight hour for the Mi-171 helicopter and the Raybird-3 BAS is presented below:

Table 3.9

Cost of one flight hour for Mi-171 and Raybird-3

Types of Aircraft	Cost of one flight hour (UAH/hour)
Mi-171	57500

Raybird-3	3662.9

Based on the obtained data, we construct a comparative diagram of the cost of one flight hour (Figure 3.7).

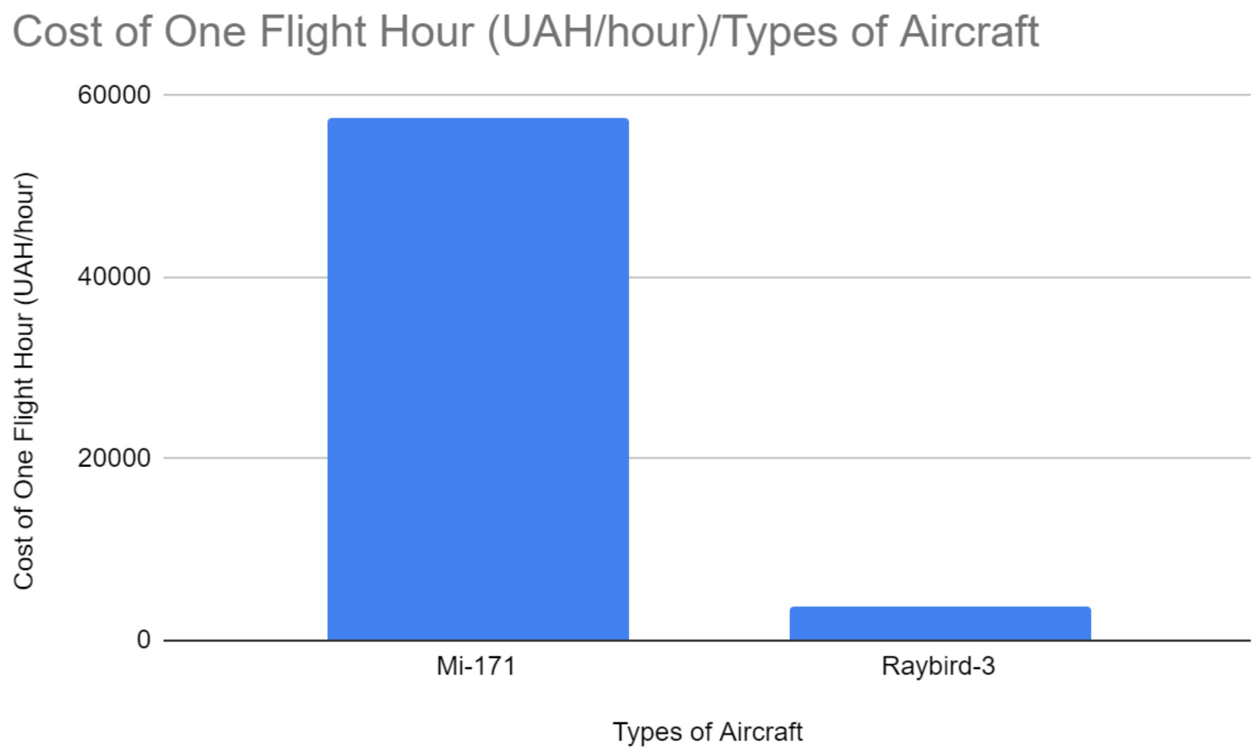

Figure 3.7. The cost comparison of one flight hour for Mi-171 and Raybird-3.

The diagram illustrates that the use of Raybird-3 BAS is economically more than 15 times cheaper compared to the Mi-171 helicopter.

Now let's calculate the economic efficiency of using Mi-171 and Raybird-3 aircraft.

To calculate the profitability of the Mi-171 helicopter for one hour of work, we will multiply the cost of one flight hour, taking into account all expenses, by the profitability coefficient - 15% using formula (3.10).

$$R = C\_f.h \times 15\% \quad (3.10)$$

For Mi-171:

$$R = 57500 \times 15\% = 8625 \text{ UAH}$$

To calculate the efficiency of Raybird-3 BAS for one hour of work, we will take an increased profitability coefficient of 150% and perform the calculation using formula (2.11).

$$R = C\_f.h \times 150\% \quad (3.11)$$

For Raybird-3:

$$R = 3662.9 \times 150\% = 5494 \text{ UAH}$$

Income tax is calculated as the product of profitability from one hour of work and the tax rate - 18% using formula (2.12).

$$B = R \times 18\% \quad (3.12)$$

For Mi-171:

$$B = 8625 \times 18\% = 1552.6 \text{ UAH}$$

For Raybird-3:

$$B = 5494 \times 18\% = 989 \text{ UAH}$$

Let's calculate the cost of one flight hour without VAT as the sum of the cost of one flight hour considering all expenses, income tax, and profitability from one hour of work using formula (2.12).

$$C\_f.h1 = C\_f.h + B + R \quad (3.12)$$

For Mi-171:

$$C\_f.h1 = 57500 + 8625 + 1552.6 = 67677.6 \text{ UAH}$$

For Raybird-3:

$$C\_f.h1 = 3662.9 + 5494 + 989 = 10145.9 \text{ UAH}$$

Let's calculate the cost of one flight hour including VAT using formula (3.13), where the tax rate is 20%.

$$C\_f.h2 = C\_f.h1 \times 20\% \quad (3.13)$$

For Mi-171:

$$C\_f.h2 = 67677.6 \times 20\% = 81201.1 \text{ UAH}$$

For Raybird-3:

$$C\_f.h2 = 10145.9 \times 20\% = 10343{,}7 \text{ UAH}$$

3.5. Results of calculation

Let's calculate the expected profit of the enterprise for 700 flight hours. We calculate it using formula (3.14), which is the product of the profitability from one flight hour and the expected flight hours.

$$P = T\_g \times R \quad (3.14)$$

For Mi-171:

$$P = 700 \times 8625 = 6{,}037{,}500 \text{ (UAH)}$$

For Raybird-3:

$$P = 700 \times 5494 = 3{,}845{,}800 \text{ (UAH)}$$

Thus, by calculating the cost of one flight hour, we can conclude that using the BAS for search and rescue operations is more economically advantageous compared to using a piloted aircraft, specifically the Mi-171 helicopter. Despite the expected profit for the Mi-171 over 700 flight hours exceeding that of Raybird-3, it's important to consider the cost-effectiveness and other expenses associated with using the helicopter.

CHAPTER 4
TECHNICAL PART

4.1. Technical Specifications of the UAV System for Search and Rescue Operations

System Overview

The UAV system designed for search and rescue operations comprises two main components:

- Ground Control Station (GCS)
- Unmanned Aerial Vehicle (UAV)

Ground Control Station (GCS)

The Ground Control Station (GCS) is the pivotal element in UAV operations, managing flight control and data processing. Equipped with the latest technology, the GCS ensures efficient communication and seamless operation of the UAV. Here's a detailed breakdown of its components and functionalities:

Control Interface

The control interface is engineered for user-friendliness, enabling operators to handle flight routes, monitor UAV status, and control onboard equipment effortlessly. Featuring touch screens, joysticks, and customizable control panels, the interface integrates advanced software providing real-time feedback on UAV performance, flight conditions, and sensor data. Operators can easily adjust flight parameters, set waypoints, and initiate automated missions.

Communication System

A robust communication system is essential for real-time data transmission between the UAV and the GCS. This system employs secure, high-bandwidth communication channels to maintain uninterrupted data flow. Redundant communication links, such as radio frequency (RF) and satellite communication, ensure continuous operation in case of signal loss or interference, with encryption technology safeguarding sensitive data.

Monitoring Equipment

The GCS includes multiple HD monitors displaying live video feeds and sensor data from the UAV, offering operators a comprehensive view of the UAV's surroundings and the mission area. The monitoring setup supports split-screen displays, enabling simultaneous viewing of multiple data streams, which is crucial for situational awareness and decision-making during search and rescue operations.

Power Supply

To support long-duration missions in remote areas, the GCS is equipped with portable, robust power systems, including high-capacity batteries and generators ensuring an uninterrupted power supply. These systems are designed for easy transportation and quick setup in the field, with redundant power sources ensuring continuous operation even in case of a primary power failure.

4.2. Unmanned Aerial Vehicle (UAV)

The UAV is engineered for optimal performance in various search and rescue scenarios, featuring advanced technology that enhances its efficiency, durability, and versatility. Here's a detailed look at its components and functionalities:

Airframe and Propulsion

Airframe

The airframe is constructed from lightweight, durable materials like carbon fiber and high-strength aluminum alloys, providing the necessary strength to withstand harsh conditions while keeping the UAV's weight minimal. The design is optimized for aerodynamic efficiency, reducing drag and enhancing flight stability.

Propulsion System

The propulsion system comprises high-efficiency motors and propellers, allowing extended flight times and improved maneuverability. The motors offer high thrust-to-weight ratios, enabling the UAV to carry heavy payloads without compromising performance, while the propellers are designed for low noise and vibration, ensuring smooth operation. Redundant power sources ensure continuous operation in case of a motor failure.

Sensors and Cameras

High-Resolution Cameras

The UAV is equipped with 1080p HD cameras for real-time video streaming and recording, essential for situational awareness and damage assessment. The high-resolution images captured enable operators to identify and analyze details that might be overlooked.

Thermal Imaging

Infrared cameras are integrated to detect heat signatures, crucial for locating survivors in low visibility conditions. The thermal cameras can detect even slight temperature variations, allowing operators to pinpoint human bodies and other heat sources accurately.

Zoom Capabilities

The UAV's cameras feature optical and digital zoom capabilities. Optical zoom allows magnification of distant objects without loss of image quality, while digital zoom provides additional magnification for detailed inspection, particularly useful for identifying obstacles and hazards from a safe distance.

Communication and Navigation

GPS and GNSS

The UAV uses Global Positioning System (GPS) and Global Navigation Satellite System (GNSS) for precise location tracking and navigation. These systems provide accurate positioning data, enabling the UAV to follow predefined flight paths and return autonomously. GPS and GNSS are also essential for geotagging images and videos.

Data Links

Secure and robust data links ensure uninterrupted communication between the UAV and the GCS. Using advanced encryption protocols, the UAV is equipped with multiple communication modules, including RF and satellite communication, providing redundant communication channels.

Obstacle Avoidance

Equipped with advanced sensors and algorithms, the UAV can detect and avoid obstacles. Sensors include lidar, ultrasonic, and optical sensors scanning for potential hazards. The obstacle avoidance system uses real-time data to adjust the UAV’s flight path, ensuring safe operation in complex environments.

Payload and Delivery Systems

Cargo Drop Mechanism

The UAV is equipped with a cargo drop mechanism for delivering essential supplies such as food, water, and medical kits to isolated survivors. This system is designed to be reliable and precise, ensuring supplies are delivered to the intended location without damage.

Lighting Systems

Integrated lights enhance the UAV’s visibility and operational capability in low-light conditions. Powerful LED lights illuminate the surroundings, aiding operators in identifying obstacles and hazards and signaling survivors and guiding rescue teams.

Loudspeakers

Loudspeakers enable communication with survivors, allowing operators to broadcast messages and instructions, providing crucial information and reassurance. This system is also used to coordinate rescue efforts and direct rescue teams.

Fig 4.1. An illustrative example of a UAV

4.3. Operational Algorithms

The UAV employs sophisticated algorithms to optimize search and rescue operations, enhancing performance, accuracy, and efficiency. Here's a detailed look at the operational algorithms:

Search and Damage Assessment

Upon deployment, the UAV rapidly surveys the area and assesses damage using high-resolution imaging and thermal sensors. Real-time HD video feeds are transmitted to the command center, enabling precise decision-making. The algorithms analyze captured data to identify areas of interest, such as collapsed structures, fire hotspots, and potential survivor locations. The UAV's autonomous flight capabilities allow it to cover large areas efficiently, reducing the time required for initial assessment.

Rapid Mapping

Using advanced software, the UAV generates detailed 2D and 3D maps of the affected area. These maps are more accurate than traditional satellite images, aiding in rescue mission planning and structural damage assessment. Mapping algorithms process captured images to generate high-resolution orthomosaic maps, digital surface models (DSM), and digital terrain models (DTM), providing valuable insights into the terrain and layout of the affected area.

Heat Signature Detection

Thermal cameras scan the landscape for heat signatures indicative of human presence, crucial for night operations and low-visibility conditions. Thermal imaging algorithms detect and highlight heat sources, enabling operators to identify survivors quickly. The UAV can autonomously navigate to areas with detected heat signatures, providing real-time updates to the command center.

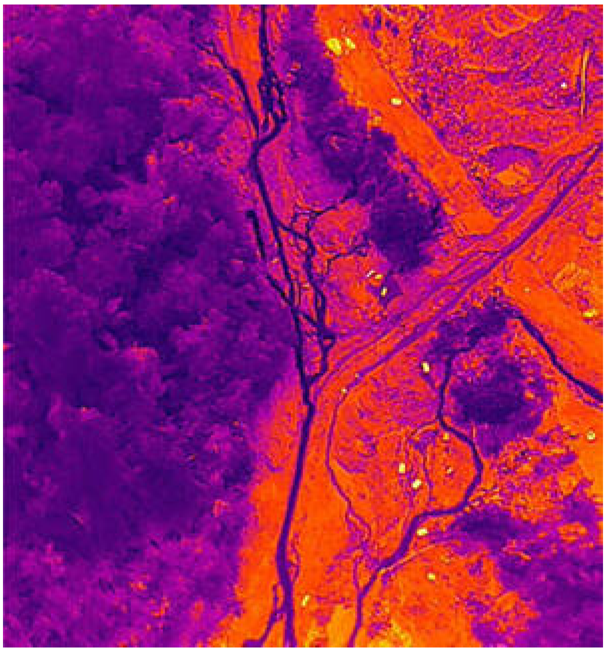

Fig 4.2. Example of thermal imager operation

Obstacle Detection and Avoidance

The UAV's sensors detect and navigate around obstacles such as terrain features and vegetation, ensuring a safe flight path and reducing the risk of collisions. Obstacle detection algorithms use data from lidar, ultrasonic, and optical sensors to create a 3D map of the surroundings, with the flight control system planning and adjusting its path to avoid obstacles.

Data Processing and Analysis

Collected data is processed in real-time, generating actionable insights. The UAV software integrates with Geographic Information System (GIS) platforms to produce comprehensive maps and models. Data processing algorithms analyze captured images and sensor data to identify key features like damaged structures, blocked roads, and survivor locations. The analysis results are used to plan rescue missions, allocate resources, and monitor rescue operations.

4.4 Practical Applications and Advantages

Real-Time Assessment

The UAV provides live video feeds and thermal imaging for quick damage assessment and survivor location. This immediate information flow enhances the efficiency and effectiveness of rescue operations, enabling operators to make informed decisions, prioritize rescue efforts, and allocate resources effectively. The UAV's ability to cover large areas swiftly reduces response times and increases the chances of saving lives.

Detailed Mapping

The UAV creates high-resolution maps of affected areas, crucial for planning and executing search and rescue missions. Detailed maps and 3D models guide rescuers to navigate hazards and optimize routes, providing accurate and up-to-date information on terrain, infrastructure, and obstacles, facilitating efficient planning and execution of rescue operations.

Survivor Communication

Equipped with loudspeakers and lighting, the UAV can communicate with survivors, guiding them to safety and delivering essential supplies. Communication capabilities enable operators to provide instructions and reassurance, reducing panic and improving survival chances. The UAV's ability to deliver supplies ensures that survivors receive necessary aid while waiting for rescue teams.

Environmental Adaptability

The UAV is designed to operate in diverse environmental conditions, from extreme cold to heavy precipitation, ensuring continuous support for rescue missions. The robust design and advanced features enable effective performance in challenging environments, providing reliable support to rescue teams. The UAV's adaptability enhances operational capability and ensures deployment in various disaster scenarios.

4.5. Conclusion

In summary, the UAV system for search and rescue operations is a highly advanced and versatile tool that significantly enhances the efficiency, accuracy, and effectiveness of rescue missions. Integrating cutting-edge technology, robust design, and advanced algorithms, it is an indispensable asset in disaster response and recovery efforts. By providing real-time assessment, detailed mapping, survivor communication, and environmental adaptability, the UAV system greatly improves the chances of saving lives and mitigating the impact of disasters.

CONCLUSIONS

The purpose of this study was to investigate the application of unmanned aerial systems in search operations.

The object of the study was the activity of LLC ATA "KRUNK." During the writing of the diploma thesis, the history and prerequisites for the emergence of the company, its main financial indicators, market activities in aviation services, production activities, as well as information on further development and implementation of new types of work and services, were collected.

LLC ATA "KRUNK" is a small aviation agency, but over the years of its operation, it has established itself as a quality service provider and has achieved many goals, including:

1. Entry into the international market.
2. A wide range of aviation services.
3. Expansion of its own fleet of aircraft.
4. Large customer base and reliable cooperation with them.
5. Establishment of its own training center for flight crews and technical personnel.
6. Establishment of a design bureau.
7. Expansion of certification base.
8. Creation of good infrastructure within the company.

These achievements confirm their effectiveness with stable revenue growth and high competitiveness in obtaining tenders and participating in large-scale international missions.

The subject of the study was the implementation of search and rescue operations using unmanned aerial systems.

Despite the rapid growth in aviation, not enough attention is given to the development of search and rescue work, which significantly affects the efficiency of such operations. Therefore, the network of duty stations is quite weak, which in turn does not allow for search and rescue operations to be carried out quickly and efficiently. In Ukraine, the probability of emergencies is high due to the large number of potentially dangerous enterprises and other objects, accidents at which often lead to emergencies at least at the regional level, as well as natural disasters.

The quality of search and rescue operations directly affects the likelihood of rescuing people, and their lives depend on it. According to the State Emergency Service reports, the number of emergencies increases every year. Therefore, for the effective conduct of search and rescue operations, it is necessary not only to increase funding, expand the rescue teams or equipment fleet but also to expand search and rescue means. This includes creating and financing projects that study the execution of search and rescue operations and develop new tools and methods to optimize and facilitate the search and rescue process.

The study examined the technology of search and rescue operations used in Ukraine, analyzing all aspects, methods, and steps of SAR. The global experience of countries was also collected and analyzed. Their methods and technologies that are effectively used in search and rescue operations were considered. Often, these methods are integrated into UAS, which significantly speeds up the response time and direct search and rescue operations. Some SAR operations are carried out through the joint work of UAS, helicopters, and ground search and rescue teams. In this way, UAS quickly gather information about the incident location, the number of casualties, and their location, transmitting this data to the ground control center, which develops a further rescue plan, forms the necessary number of search and rescue teams, and prepares the required number of helicopters for SAR.

In the project part, several UAS models were analyzed, their main indicators were considered, and the optimal type of aircraft was selected. The choice was made taking into account the specifics of the work and the geographical features of Ukraine.

The work proposed the implementation of a new type of work for LLC ATA "KRUNK" and the selection of an optimal UAS for its implementation. The cost calculation of the flight hour of the Raybird-3 UAS and its comparison with the Mi-171 helicopter was carried out. Analyzing this data, it can be concluded that the use of UAS is more effective since the cost per flight hour is significantly lower, which in turn contributes to competitiveness. With the same amount of work, choosing an economically advantageous type of aircraft will be more prioritized for the customer.

In conclusion, during emergencies, in dangerous or hard-to-reach areas, the use of unmanned aerial systems is a good alternative because they have good maneuverability and much faster preparation for SAR. Although UAS may not always realize their potential due to limited range, they are excellent for initial reconnaissance operations or for delivering medicines, food, and essential equipment, which will help sustain until the arrival of a rescue team. Unmanned aerial systems are undoubtedly the future of aviation, although they are not yet able to fully replace manned aircraft, they can minimize human involvement in dangerous areas and significantly improve the execution of search and rescue operations.

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ADDITION 1. TABLES

Table 1.1

Data on Emergencies

Data on Emergencies	**2018**	**2019**	**% Increase**
Total Emergencies	128	146	14.1
Including:			
Technogenic	48	60	25
Natural	77	81	5.2
Social	3	5	66.7
State Level	2	2	0
Regional Level	6	7	16.7
Fatalities Due to Emergencies	168	199	18.5
People Affected by Emergencies	839	1492	77.8
Material Damage from Emergencies	496, 965	685, 269	37.9

Table 1.2

Sound Wave Length of Signals

Sound Signal	Distance, km
Explosion	12.15
Train noise, siren	7.1
Gunshot	2.3
Tractor rumble	3.4
Car horn, dog barking	2.3
Human scream	1.0-1.5
Tree falling crack	0.8
Sleigh bells, wood sawing	0.5

Table 2.1

Base Locations of State Emergency Service Standby Aircraft

Aircraft Type	Base Location (Airfield)	Readiness for Departure	Range, km
Mi-8	Nizhyn	Day/20 min.	250
		Night/1 hr. 30 min.	
An-32	Nizhyn	Day/20 min.	750
		Night/1 hr. 30 min.	

An-32	Odesa	Day/20 min.	750
		Night/1 hr. 30 min.	
Mi-8	Kharkiv	Day/20 min.	250
		Night/1 hr. 30 min.	

Table 3.1

Technology for Conducting Search and Rescue Operations Using UAVs

1. Receipt of the first information	The PRR System receives information about the occurrence of an emergency situation with a certain object or in a certain area.
2. Initial actions	Preliminary actions, which are carried out with the aim of notifying the management bodies and forces of the PRR System and obtaining additional information.
3. Planning of search works	Development of operational plans for searching the scene of the incident and searching for victims.
4. Operational search measures	Dispatch of the BPS to the scene, assessment of the emergency situation.
5. Transfer of information	Receiving all operational data from the scene of events from the BPS to the ground control center, transmitting information to the rescue team.
6. Planning of rescue operations	Development of operational plans for rescuing victims, providing them with first aid. Their evacuation.
7. Operational rescue measures	Direction of helicopters with a rescue team to the scene. Provision of first aid to victims, their evacuation.

8. Termination	Returning the forces and means of the aviation search and rescue system to the base, where the search and rescue group surveys, refueling, replenishment of supplies and preparation for other operations are carried out.