D3.3 – Demonstration of drone deliveries to quarantines on the UAV full mission simulator

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Executive Summary

The Coronavirus Disease (COVID-19) pandemic has disrupted global supply chains, including medical supply chains. Governments worldwide have put several public health and social measures to break the chains of disease transmission. These measures, in turn, impacted the delivery and distribution of medical items and equipment such as vaccines, tests, and personal protective equipment (PPEs) to hospitals and health care facilities. Especially the last mile deliveries to quarantine zones were under scrutiny due to the risk of contagion, and as drivers as well as their vehicles may be quarantined. This called for different approaches for medical deliveries. One such approach is to use unmanned aerial vehicles (UAVs, drones).

The focus here is on **UAVs for long-range flights (LRFs) of at least 1 000 km distance with high payloads (150 kg) that would have the capacity to deliver larger quantities to e.g., health care centres and hospitals,** rather than individual small deliveries. UAVs with such specifications (long range and high payload) are non-existent because of battery power and other technical limitations, therefore, simulation is the only way to test the potentials of using drones for medical and humanitarian aid deliveries. Hence, this HERoS deliverable 3.3 (D3.3) reports on the **demonstration on drone deliveries to quarantines on the UAV full mission simulator.** A simulator for this purpose is built under the HERoS project. The simulator allowed for understanding and testing intricacies of using LRFs of drones for medical and humanitarian aid deliveries. The workflows of such medical deliveries were defined in an earlier HERoS task and can be found in D3.2.

D3.3 is the result of Task 3.3 in the HERoS project. T3.3 implements the workflows for drone deliveries as specified in HERoS D3.2 and demonstrates the use of drones for medical deliveries in and out of quarantines. The purpose of this task is to recognise and define the legal, organisational, and technical conditions to be filled in terms of LRFs in terms of medicine transport. Task 3.3 includes

- The recognition and definition of all legal, organisational, and technical conditions to be fulfilled for a LRF, including
- the update of procedures according to changes in international or local law,
- The technical description of UAV system for LRF,
- The determination of safety precautions and limitations for this flight,
- Connection with SESAR and U-Space,
- The setting up of a full mission simulator incl. ground control station, flying platform for medicine transport,
- communication, air traffic requirements, airworthiness, logistic, and others,
- UAV system tests and crew familiarisation,
- Necessary trainings and courses for personnel incl. medical tests of UAV crew members,
- The conduction of a simulated UAV LRF for medical deliveries,
- The development of recommendations for UAVs for medical deliveries under pandemic conditions, and
- The development of standard operating procedures (SOPs) for this purpose.

Some of the above points were captured earlier in HERoS project milestones (M5: LRF organisation,

M7: LRF simulator, M10: LRF crew, and M12: LRF simulation). Details on these are now provided in various sections of this deliverable.

Works performed under Task 3.3 push the boundary of knowledge to establish a drone-based medical and humanitarian aid delivery It specifies legal, organisational, and technical requirements, provides technical descriptions and SOPs of UAV systems, and notes safety precautions and limitations. The 200-plus hours of simulation done in the project also helped us provide recommendations for medical and humanitarian aid deliveries in pandemics.

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List of acronyms

Abbreviation / acronym	Description
ACC	Airlift Co-ordination Centre
ADSB	Automatic Dependent Surveillance–Broadcast
AFM	Airplane Flight Manual
ATM	Air Traffic Management
BVLOS	Beyond Visible Line of Sight
COVID-19	Novel Coronavirus Disease
EU	European Union
FOB	Forward Operating Base
FMC	Flight Management Centre
GCS	Ground Control Station
GTC	Ground Traffic Co-ordinator
HAN	Hanken School of Economics
HERoS	Health Emergency Response in Interconnected Systems
HOTAS	Hands On Throttle and Sticks
LOS	Line of Sight
LRF	Long-Range Flight
PCPM	Polish Centre for International Aid
PPE	Personal protective equipment
RUPC	Regional UAV Pilot Centre
SESAR	Single European Sky ATM Research
SOP	Standard Operating Procedures
SQU	Squadron
UAV	Unmanned Aerial Vehicle
UTM	Unmanned Traffic Management

1. Introduction

The COVID-19 pandemic has placed governments worldwide under challenging situations by disrupting global supply chains, including medical supply chains (Chamola et al., 2020; Ivanov, 2020; Kovács and Falagara Sigala, 2021; Falagara Sigala *et al.*, 2022). To decrease the new infection rate and to avoid overwhelming healthcare systems, governments worldwide have taken strict controls restricting the movement of people, goods, and services (Guan et al., 2020). Unfortunately, these much-needed social and public measures negatively impacted the delivery of emergency medicines (Kunovjanek and Wankmüller, 2021). This is both due to restrictions of movement by governments and quarantine zones, but also since transport companies feared any deliveries to quarantine and larger outbreak zones. The latter is because such deliveries would risk contagion of the disease to the people (e.g., drivers and delivery personnel), and vehicles or delivery personnel may be put into quarantine (Sperry et al., 2022). This calls for adopting innovative technologies (e.g., drones) for medical deliveries, especially to quarantine zones (Vaishya et al., 2020).

One way to **minimise contagion is by the use of unmanned aerial vehicles (UAVs, drones)** for such deliveries. UAVs have been used for smaller medical deliveries in the past (e.g. for blood, plasma and platelets in Rwanda, Ling and Draghic, 2019; or blood and pathology specimens in Switzerland, Scott and Scott, 2017). Drawing on the specifications of such medical deliveries, HERoS has defined a workflow for medical deliveries with UAVs and reported on that in D3.2. Medical deliveries do have special requirements, after all, both in terms of technical details of e.g., vibration and temperature control, but also with regards to the knowledge, capacity, and licences to handle specific medical items ranging from vaccines to test kits to personal protective equipment (PPE).

Previous medical deliveries by UAVs are for small quantities at any time, and for a limited range. Both the abovementioned cases have made use of large drone fleets and intricated hub-and-spoke systems for their operation. In contrast, **HERoS focuses on long-range flights (LRFs, over 1 000 km distance) and higher payloads (150 kg).** Both are essential to be able to effectively deliver the quantities of items required in outbreak zones, by hospitals, and by health care facilities. The proposed UAVs can handle the package sizes required for hospitals and reach medical professionals rather than individual patients. LRFs are also able to reach remote locations and handle deliveries across country borders. Therefore, the purpose of the task (T3.3) that this deliverable (D3.3) reports on is to recognise and define the legal, organisational, and technical conditions to be filled in terms of LRFs in terms of medicine transport. Task 3.3 includes

- The recognition and definition of all legal, organisational, and technical conditions to be fulfilled for a LRF, including
- the update of procedures according to changes in international or local law,
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- The conduction of a simulated UAV LRF for medical deliveries,
- The development of recommendations for UAVs for medical deliveries under pandemic conditions, and
- The development of standard operating procedures (SOPs) for this purpose.

Some of the above points were captured earlier in HERoS project milestones (M5: LRF organisation, M7: LRF simulator, M10: LRF crew, and M12: LRF simulation). Details on these are now provided in various sections of this deliverable as noted in Table 1 below.

Table 1: HERoS milestones included in D3.3

Milestone	Completion	Section in D3.3
M5 LRF organisation	Jan 31, 2021	Sections 3, 5 and 6
M7 LRF simulator	May 31, 2021	Section 5
M10 LRF crew	Nov 30, 2021	Section 6
M12 LRF simulation	Jan 31, 2022	Section 8

Overall, this deliverable (D3.3) is the result of Task 3.3 in the HERoS project. T3.3 implements the workflows for drone deliveries as specified in HERoS D3.2 and **demonstrates the use of drones for medical deliveries in and out of quarantines.**

The remainder of this deliverable is organised as follows: Section 2 reviews relevant literature to identify legal, organisational, and technical conditions for using UAVs (drones). Section 3 provides the technical specifications of a UAV system consisting of drones and a ground control station for long-range flights (LRFs). Section 4 describes safety precautions, limitations, and connection with SESAR and U-Space. Section 5 presents a full mission simulator. In section 6, necessary training and courses are noted. Section 7 illustrates the simulation of drones for LRFs. Section 8 outlines recommendations for medical deliveries. In section 9, standard operating procedures (SOPs) for drone deliveries are presented. Section 10 concludes the report by noting limitations and challenges faced during the development and operation phases of the simulation.

2. Literature review

A literature review on the use of UAVs for medical deliveries has already been part of HERoS D3.2. The literature review in this deliverable thus serves the function to provide updates from the literature on medical deliveries by UAVs especially in the COVID-19 pandemic and includes elements that are of particular importance to the technical developments of HERoS Task 3.3. These are organised around (b) legal issues that are particularly relevant to the operation of UAVs in long-range flights (LRFs), (c) the organisational conditions of such flights, and (d) their technical conditions. All of these focus on the literature that is particularly relevant for the development of UAVs for LRFs with a high payload.

It is worth noting that the use of drones has been proposed during the COVID-19 pandemic for other than delivery purposes as well, such as monitoring various areas and people's movements, spreading information about curfews and lockdowns, enforcing quarantine zones, or the identification of patients. In contrast, HERoS focuses on the delivery of medical cargo only.

2.1. Medical deliveries by UAVs

Medical deliveries make use of a wide range of transportation modes: road, rail, water, and air transportation. As discovered during the onset of the COVID-19 pandemic, a disproportionate amount of medical deliveries are carried out via air transportation, especially as belly cargo of passenger planes. The grounding of passenger planes in various areas of the world in 2020 has therefore contributed to significant unforeseen supply chain disruptions (see HERoS D3.1; and HERoS publications Kovács and Falagara Sigala, 2021; Falagara Sigala *et al.*, 2022).

Deliveries during disease outbreaks, epidemics and pandemics are hampered by both restrictions of movements such as border crossings or the establishment of quarantine zones, but also by the fear of transportation companies that their personnel or equipment may be quarantined as well. This has happened in both previous epidemics (e.g. Ebola outbreaks), as well as during the COVID-19 pandemic in various areas of the world (Sperry et al., 2022). Disease outbreaks have therefore been considered an interesting application area for the use of UAVs, and one whereby the use of **UAVs would reduce the risk of contagion** to delivery personnel (Vaishya et al., 2020).

The overwhelming majority of literature on UAVs in the COVID-19 pandemic is conceptual in nature. There are though, some notable exceptions. For example, during the COVID-19 pandemic, UAVs have been proposed to be used for the distribution of COVID-19 test kits to people in mountainous areas in Austria (Kunovjanek and Wankmüller, 2021). Similar deliveries of test kits and samples have been in the news in Canada (Farooqui, 2020), China (Jakhar, 2020), and Germany (McNabb, 2020). These are either deliveries to patients only who then report their test results in a specific system, or individual deliveries between patients and laboratories. They require small payloads and relatively short distances. A different approach with a somewhat larger payload is proposed for vaccines to be delivered to remote locations in Indonesia (Adwibowo, 2021). As in the Austrian example, remoteness here is based on terrain but not distance (the solution is proposed for 2 km), and the payload, though somewhat higher, is for a maximum of 10 kg. In general, literature as well as extant pilots of the use of UAVs for medical deliveries in the COVID-19 pandemic has focused on short distances and low payloads. In contrast, HERoS focuses on long-range flights with higher payloads.

2.2. Legal conditions

The legal framework for operating drones medical and humanitarian aid deliveries ~~i~~s a complex matter of policies and regulations varied across countries (Jones, 2017). Overall, currently, there is a lack of a comprehensive legal framework regarding legal obligations, liabilities, roles, and responsibilities of an integrated Unmanned Traffic Management (UTM) system (Ryan *et al.*, 2020). This gap is a substantial barrier to usage of drones for medical and emergency deliveries (Bassi, 2019). Table 2 lists drone regulations approaches by countries.

Table 2: Drone regulations by countries (adapted from Jones, 2017)

Countries	Regulations	Explanations
Argentina, Barbados, and Saudi Arabia	Complete ban on drones	Does not allow drones for any commercial use[1]
Egypt, Nigeria, and Belarus	Partial ban	Have formal processes of licensing drones for different usage conditions
Croatia, Luxemburg, Netherlands, Mexico, and South Korea	Visual line of sight required	Drone can only fly within the visual line of sight

Furthermore, the airspace for drone operations is restricted around sites of national importance such as airports or heavily populated areas (Jones, 2017). Another critical concern for commercial success of drones is flying drones beyond visual line of sight (BVLOS) (Prevot *et al.*, 2016). However, during COVID-19 pandemic, the European Commission regulations permitted drones to be flown BVLOS with approval of Specific Operations Risk Assessment (SORA) (EASA, 2021). BVLOS conditions apply to HERoS since it focuses on LRFs. What has not been solved yet is the requirements for liability insurance across the European Union (EU) (Jones, 2017).

In Europe, the European Aviation Safety Agency (EASA) is the regulatory authority for UAVs or drones (EASA, 2021). National aviation agencies typically follow guidelines provided by EASA but in many countries within Europe these is a drone-specific legal environment (Balasingam, 2017). The standard drone regulations have four elements, including pilot license, aircraft registration, restricted zones, and insurance. The requirements of these four elements vary considerably on the basis of drone mass, drone altitude, drone use, and pilot license level (Jones, 2017). Individual authorities determine basic

[1] "Commercial" drones can be argued to include medical deliveries.

guidelines and measures for technical, safety, security, privacy, and administrative issues (Balasingam, 2017).

EU Regulations such as 2019/947 and 2019/945 set the framework for safely operating drones in European skies (EASA, 2021). EASA adopts a risk-based approach and does not make a distinction between leisure or commercial usage of drones rather it considers the **weight** and specifications of a particular drone as well as the operation a drone intends to undertake (EASA, 2020). The maximum tested payload for drone deliveries is 2 kg (Poljak and Šterbenc, 2020), thus, **regulations for larger drones are lagging behind.** (HERoS payload being 150 kg, the drone itself needs to weigh 500-600 kg.)

The recent EU Regulation 2019/947 (valid since December 30, 2020), caters for most types of drone operation as well as their respective risk levels (EASA, 2021). According to EASA (2021), there are three categories of drone operations, namely, the 'open', 'specific' and 'certified' categories. The open category is for operations that pose a lower risk whereas the specific category addresses riskier drone operations. A certified category covers for operations with high safety risks. In this regard, flying drones for medical deliveries may fall into the certified category and will require a heightened scrutiny by national and EU level authorities.

The use of the HERoS UAV is not restricted to the European Union, however. Rather**, the simulation has been built around the use cases of HERoS end users.** HERoS end users operate globally, e.g., PCPM sends out emergency medical teams (EMTs) to anywhere in the world (see use cases described in HERoS D1.2 and D1.3), Project HOPE is one of the few medical humanitarian NGOs that can also operate in China (and therefore deliver to quarantine zones), and Croce Rossa Italiana is part of the global Red Cross Movement. Thus, HERoS needs to understand and recognise the legal conditions of the particular deliveries it supports, wherever they may be. Thus, the legal conditions that apply to the HERoS simulation were also collected through end users.

Furthermore, medical deliveries are more complex because they also need to follow **regulations for medical cargo** (Skorup and Haaland, 2020). From a regulation perspective, this includes who can handle, send and receive specific types of medical cargo. For example, in the EU, organisations need certificates to operate drones for specific purpose such as medical deliveries (EASA, 2021), but few organisations can provide such certificates to date. The specificities for handling medical cargo have been considered when defining the workflow for HERoS' UAVs (see HERoS D3.2.).

2.3. Organisational conditions

UAV-specific regulations aside, the very notion of these being **unmanned** aerial vehicles means that any flight requires an organisation of a ground control station, (remote) pilots, technicians, and delivery personnel. HERoS focusing on LRFs, BVLOS conditions apply and need to be considered in its **crew composition.**

Furthermore, the focus on medical cargo also places requirements on the delivery itself (see workflow in D3.2). Disruptions such as pandemics can result in the lack of accessibility to specific regions for an extended period of time (Lemmens *et al.*, 2016). Cargo drones emerged as a new solution to address health and humanitarian needs for natural disaster victims and people living in isolated communities (Comes, Bergtora Sandvik and Van de Walle, 2018). Despite the massive potential for using cargo drones for medical and humanitarian aid deliveries, drones are not adopted by hospitals, clinics, and other stakeholders in difficult-to-access regions (Amukele, 2020), probably because, for delivering medical items to remote locations, certain organisational conditions need to be fulfilled (Rejeb *et al.*, 2021). For instance, if vaccines are being delivered using drones, a cold chain for the particular vaccine must be maintained during the entire flight as well as at the location where vaccines would be administered (Comes, Bergtora Sandvik and Van de Walle, 2018). As a result, **health facilities or NGOs receiving drone deliveries in remote regions need to have proper infrastructure.**

Furthermore, a critical organisational challenge for drone operations is managing a large fleet of autonomous drones (Allouch *et al.*, 2021). This can be eased by regulatory measures to some extent. For example, the National Aeronautics and Space Administration (NASA) is collaborating with the US Federal Aviation Administration (FAA) to solve traffic management issues in low-altitude airspace in the US (Federal Aviation Administration, 2019).

The other organisational challenges include a lack of financial resources for integrating drones in emergency operations (Greenwood, Nelson and Gregg Greenough, 2020). Cost is an essential driver for determining the feasibility of drone applications for medical and humanitarian needs (DeBusk, 2010). Consequently, the maintenance and investment of drone-enabled humanitarian aid operations must be affordable for aid organisations to rationalise the implementation and adoption costs (Vizvári *et al.*, 2019). Additionally, many organisations are not developing drone technologies for disaster response (Greenwood, Nelson and Gregg Greenough, 2020). The use of drones for medical and humanitarian aid deliveries is also hindered by negative public perception and technological immaturity (DeBusk, 2010; Vizvári *et al.*, 2019).

2.4. Technical conditions

The general technical conditions for drone deliveries include obstacle detection and avoidance, reliable communication, cyber security, operational reliability, and unmanned traffic management. Drones flying in low-level airspace are a significant threat to manned aircraft such as helicopters and infrastructures such as power lines because of the risk of collusion (Yu and Zhang, 2015). Furthermore, reliable communication among drones operating in shared airspace with manned aircraft systems is required to ensure operational safety and security (Nguyen et al., 2018). Additionally, security threats are a genuine concern for drones nowadays, which impact public acceptance of drones in a highly urbanised environment (Lin et al., 2021). In addition, there are no standards for operational reliability requirements in commercial drones (Schenkelberg, 2016). Such a lack of standards implies that standardisation and maturation of UTM systems are expected to play a significant role in airspace operation.

Further technical conditions must be accounted for when using UAVs for medical deliveries. Medical deliveries are particularly critical because some items, such as for vaccines, a cold chain needs to be maintained (Comes, Bergtora Sandvik and Van de Walle, 2018). Many medical items also require vibration control (Adwibowo, 2021). In order for UAVs to actually reduce the risk of contagion, disinfection procedures need to be applied. Moreover, there are connectivity challenges for LRFs as well as any emergency medical deliveries in remote locations, because of insufficient coverage of terrestrial networks (Hosseini et al., 2019).

The literature suggests that significant efforts have been developed under SESAR JU U-Space innovation projects for the development, testing, and validation of requirements, technologies, and systems for the UTM (SESAR, 2016). However, large-scale integration of drones in the airspace requires dynamic planning of trajectories, airspace situational awareness, and capacity management (Doole, Ellerbroek and Hoekstra, 2018). It will require efforts to develop novel artificial intelligence and machine learning models for aviation and a considerable amount of flight data to train the models to establish performance requirements (SESAR, 2016). In this regard, the HERoS project plays a significant role by gathering 200-plus hours of flight data and identifying necessary conditions for long-range flights in the flight simulator.

3. The HERoS UAV system for LRFs

Every **UAV system** consists of three main components: (i) an airplane, (ii) a ground control station (GCS), and (iii) a communication system between the airplane and ground control station.

The primary role of an **airplane** is to move the payload from location A to location B. In addition, an airplane also performs other tasks such as transporting all devices on board, carrying engines, wings, control surfaces, and antennas. In an airplane, installations such as electrical, fuel, anti-icing, oil, and auto-pilot are also required. In addition to installations, control, navigation, landing aid, power, and camera systems are needed.

For the proper operation of the drone, it is essential to provide the pilot with information about the airplane's position in space. A basic satellite navigation system is needed for that and must be duplicated to ensure operational reliability. The purpose of a second navigation system, also known as an internal navigation system (INS), is to collect data from sensors located on the aircraft. INS also performs as a support system in an emergency, such as GPS signal loss.

The power system consists of two combustion engines with approximately 25 to 50 Horsepower. The structure of an airplane with a high HP is made of metal, and there must be a rear part with an opening ramp that allows to load and unload the plane. A permanent or temporary hull should be considered at the preliminary design level.

The resultant HERoS UAV is proposed to consist of the following components:

- Airplane short take-off and landing (STOL)
- High-wing aircraft with two engines with nacelles on the wings
- Pulling propellers
- The wings reinforced with struts
- Hull with a rectangular cross-section
- Fixed undercarriage
- Three-point chassis with front wheels.
- Butterfly tail or Rudlicki tail
- Landing aid camera in the nose
- Ramp at the rear of the fuselage.
- Fuselage with auxiliary access to the cargo area

The UAV needs to be configured in a way as to allow it to carry a higher payload (150 kg). Table 3 presents a mass table for the above configuration.

Table 3: Mass table for the proposed HERoS aircraft

ITEM	WEIGHT (kg)
Wing left	40
Wing right	40
Engines	60
Fuselage	70
Rudder	20
Autopilot installation	5
Fuel installation	20
Electric installation	10
Wings deicing installation	6
Internal monitoring installation	3
External cameras	4
Nose wheel	10
Main gears	30
ATOL	10
Empty plane mass	**328**
Fuel	100
Plane + fuel mass	**428**
Payload	150
Total Mass	**578**

The **Ground Control Station** is an essential element of a UAV system. It is assumed that a distributed control architecture is better with ground control stations in many places. In this regard, 20 planes would require 20 ground control stations scattered around the world. Such a configuration of ground control stations worldwide would also require a control room.

The **communication system** is the last element of a UAV system and provides the radio connection between the ground and the aircraft. A radio communication system is mandatory to command and control a UAV system. A communication system also ensures a continuous link for emergency operations. A small drone operates in radio frequencies (RF) in the range of 30 MHz to 3 GHz (Giordan *et al.*, 2020).

4. Safety precautions and limitations

This section describes safety precautions and limitations of the HERoS UAV system.

4.1. Safety precautions

This section notes safety precautions for the pilot and the ground control staff. Safety precautions were created based on previous protocols, the knowledge of the aviation personnel involved in the HERoS project, continuous discussions with HERoS end users PCPM and Project HOPE, as well as the experience from simulated flights. The following rules apply throughout:

- Only slight modifications of a task are permitted after a task briefing is completed.
- If two people oversee one task, one person must be designated as a supervisor who should lead the pre-task briefing.
- Any test should be specified in text form and must be followed meticulously.

There are specific safety precautions for pilots vs technicians, and specific checklists to consider.

Safety precautions for the **pilot** to fly the UAV flight safely[2].

- Have checklists at hand for items to check before and during the flight.
- Conduct a thorough pre-flight inspection to ensure everything is in order. Such inspection should be meticulously performed, and any concerns that need to be addressed should be resolved before the flight.
- Conduct a post-flight inspection to understand whether something was damaged during the flight.
- Avoid distraction in the ground control station so the pilot can concentrate on instruments, air traffic control, and navigation.
- Check weather conditions for the entire flight before flying to avoid damaging aircraft due to poor weather conditions.
- Balance weight and fuel, which is critical for the aircraft's performance.
- Study the flight plan before take-off. The flight plan includes checking airspace, traffic patterns, and traffic frequencies. The pilot should also have a backup plan for landing in case of a sudden weather change.
- Practice emergency procedures to be prepared for an emergency that might occur.
- Follow the IMSAFE checklist. IMSAFE stands for illness, medication, stress, alcohol, fatigue, and eating. The checklist allows pilots to check how they are feeling before and during flying to perform optimally.

Safety precautions for **ground technicians:**

- Have checklists at hand for items to check before and after the flight.

[2] Different rules may need to be considered if such a delivery was to take place in a conflict zone.

- Test the aircraft in a position where any unexpected and unintended forward movement would not result in damage or injury.
- Have sound knowledge of the brake and hydraulic systems on UAVs.
- Ensure that before the flight, all equipment and personnel is cleared from the runway.
- Check whether the wheel chocks are placed at the main landing gear.
- Ensure the availability of fire extinguishers in case of a fire.
- Check the attachment of the cargo (payload) in the hull.

Two checklists are used during a simulation, namely before the take-off checklist and the final checklist. These are as follows:

Before take-off checklist

- Altimeter – checked
- Engine – idle
- Flaps – as required (take off)
- Flight controls – checked
- Fuel – checked
- Nose and ramp - closed
- radio – checked and set
- Parking brake – off
- Propeller – exercise

Final checklist

- Action – engine instruments checked
- Camera – on
- Lights – as required
- Flaps – as required
- Airstrip – aligned
- Propeller – high rpm

While going through the above checklists, tasks that require communication with the technician, the pilot must wait for confirmation from the ground technician before moving to the next task in the checklist.

4.2. Limitations

Drones, as flying robots, can fly to places where humans are unwilling or unable to go. For deliveries of medical and humanitarian cargo, drones have the advantage of not having a pilot onboard. However, drones are also vulnerable to weather and restricted by several legal, organisational, and technical constraints. For instance, there is no regulation to date for drones with a capacity of 150 kg load. Additionally, there is no standardised organisation of deliveries using drones. Moreover, there is no certification for flights with high payloads.

A summary of the limitations is below.

- Lack of specific regulations for UAVs delivering medicines.
- Time-consuming authorisation processes.
- Distance coverage and limited flight range.
- Limited payload capacity of extant UAVs.
- Replacement and spare parts of drones.
- Trained staff to launch, monitor, and maintain the UAVs.
- Authorised personnel to receive specific medicines.
- Cold chain and temperature control specifications.
- Social-cultural acceptance in different countries.
- Lack of regulations for light drones.

The above limitations are overcome by using simulation, and an actual ground control station is built. The physical drone system would require satellite connectivity to communicate between drones and ground control stations.

4.3. Connection with SESAR and U-Space

In HERoS, drone traffic management is ensured through the U-space. U-space is a set of specific procedures and services to support secure, safe, and efficient access to airspace for large numbers of drones (SESAR, 2021). The U-space creates the necessary conditions for manned and unmanned aircraft to operate safely in the airspace to prevent collisions among various vehicles. The U-space regulatory framework consists of clear and simple rules that permit safe aircraft operations in all areas and for all types of manned and unmanned operations. The European Commission has a new regulatory framework now for U-space (European Commission, 2021).

U-space services rely on a high level of automation and digitalisation. U-space can be considered an enabling framework to aid routine missions in all airspace classes and environments while ensuring a proper interface with air traffic control and manned aircraft (U-Space, 2022). The SESAR Joint Undertaking drafted the U-space blueprint in 2017 and proposed four sets of services to be implemented, supporting the regulatory framework and the EU aviation strategy for drones. The detailed strategies can be found in SESAR (2017).

Our research suggests that Poland, where the HERoS LRF simulation takes place, has already implemented the U-space system for operational use. The U-space system in unmanned aerial vehicles includes activities supporting the creation in Poland of a friendly environment for the further development of the UAV services market, i.e., the implementation of the U-space concept, assuming the safe and effective integration of manned and unmanned aviation. Many companies in Poland are already doing good things with drone technologies. For instance, The Polish Air Navigation Services Agency (PANSA) developed a digital concept for UAV flight co-ordination entitled “PansaUTM” which is integrated with the most popular drone operator’s Droneradar mobile application.

The SESAR 3 Joint Undertaking is a European partnership between private and public sector partners to accelerate the delivery of the Digital European Sky through research and innovation. It is developed to harness the most cutting-edge technological solutions to manage manned and unmanned aircraft, air taxis, and other vehicles sharing airspace (SESAR, 2022).

Given the above, the structured delivery system developed in the HERoS project fits both SESAR and U-space.

5. Full mission simulator

This section describes a full mission simulator. The HERoS simulator was entirely built as part of the HERoS project. The simulator was built on a simulation engine that represents the environment of the earth. In its simulation environment, the developed cargo plane design was modelled. A physical ground control station was built. The simulation environment allowed for the modelling of the logistics base, avatars of people participating in the cargo mission, vehicles, cargo, terrains, seasons, and weather conditions. This way, a comprehensive UAV cargo simulator with a simulation of the logistics chain in a specific area was created. The simulator consists of two computers - the pilot and the system administrator. A simulator consists of a ground control station, a flying platform, an aircraft, and a landing system described in the following subsections. A drone delivery system was built in a virtual environment. Further subsections include aspects of communication, air traffic requirements, airworthiness, logistics, and specifications of the forward operating base.

The building of the simulation was informed by the use cases of HERoS end users. The HERoS project end user PCPM played a leading role in the final scenario selection process. With their input, the **Uganda scenario with delivery to the Bidi Bidi refugee camp** was chosen. The principal reason for selecting Uganda's Bidi Bidi refugee camp was to apply the knowledge from simulation not only during the pandemic period but also after the pandemic for routine operational works of medical humanitarian organisations. Therefore, in the simulation environment, the airport in Kakira has been modelled. Cargo and mission models (technicians) have been programmed at the airport. At the other end of the map (with actual distance), the Bidi Bidi camp and the UN logistics base have been modelled. Due to the cargo mission, the control station screen has been developed. The screen was selected to avoid the pilot's fatigue during long flights. The screen was placed, so the pilot had a comprehensive overview of the situation. Peripherals such as joystick and thrust are connected to the control station software. Although the plane's control is automatic, the elements have been added to check the feasibility and validity of flights in manual mode.

5.1. Ground control station (GCS)

The Ground Control Station is an essential element of the simulator. A set of principles are proposed to develop a GCS. These principles are presented below:

- Identical appearance and assignment of functions - this ensures one standard of pilot training and the interchangeability of pilots between different geographical spaces.
- Use of commercial flight controllers - this enables low-cost service and availability of a broad range of service parts.
- Vertical ground control station with two screens - this will facilitate the pilot's view of aircraft where on the top screen, the pilot can see airplane status, and on the lower screen aircraft position.

The GCS screens have been refined during simulated flights. The final appearance of the screen was designed based on the opinion of the personnel performing the simulated cargo flights for 8 hours. Figure 1 presents a screen shot of the HERoS GCS.

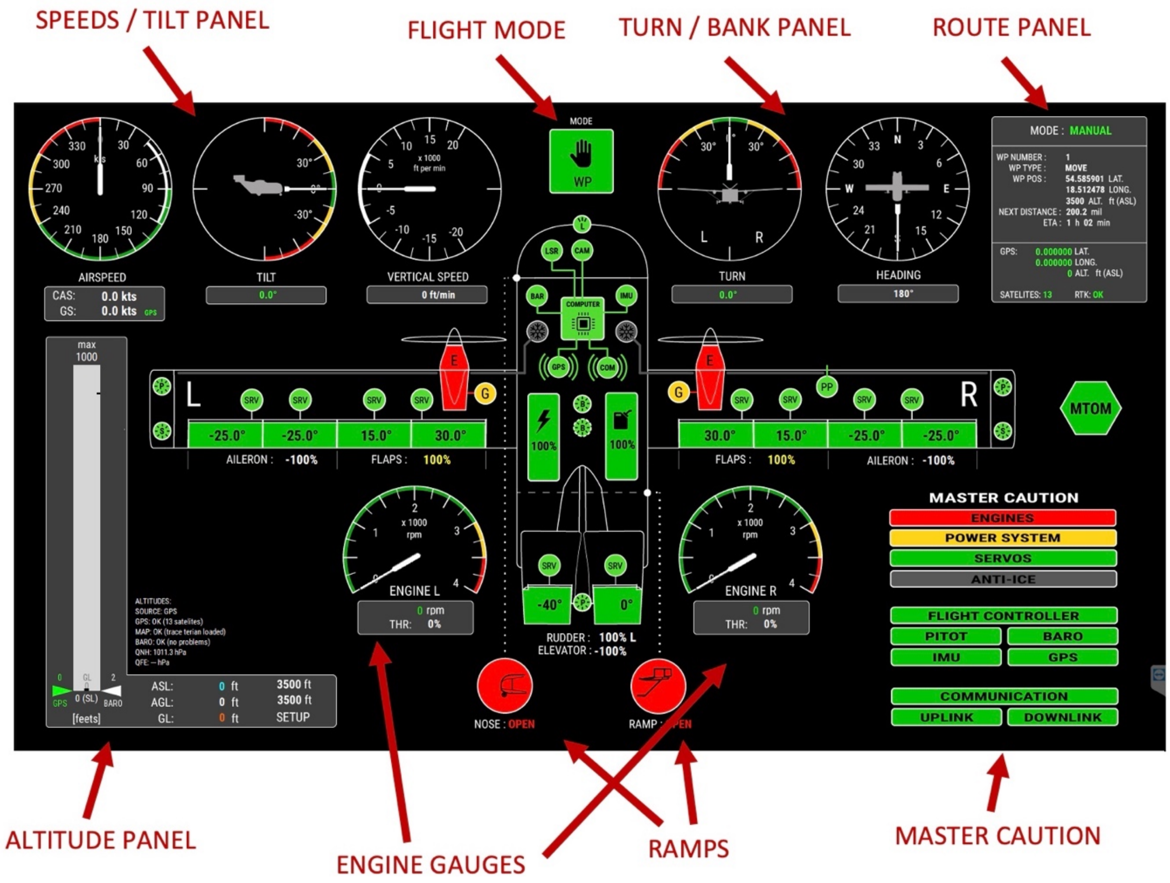


Figure 1: Final system status screen of a ground control station developed under HERoS project

The airplane status screen layout consists of the following panels:

- The information panel displays aircraft speed and inclination.
- The altitude panel displays altitude.
- The engine gauges display the RPMs of the engines.
- The front and rear ramps indicate whether the ramps are open or closed.
- The master caution indicators: display problems in the systems such as servo motors, power systems, and anti-icing systems.
- The flight controller displays a barometer, internal navigation, and GPS.
- The communication panel displays the status of ground-to-air (uplink) and air-to-ground (downlink) communications.
- The maximum take-off weight indicator indicates whether the aircraft exceeds the maximum take-off weight.
- The route panel allows the pilot to track whether the flight is flying the programmed route. It also displays the distance travelled, distance left to travel, and flight time left.

- Turns or bank panel provides information about the aircraft's heading and roll and informs the pilot about the aircraft's behaviour in the event of a turn.
- Flight or control mode indicator displays whether the controls are manual or automatic.
- Flight status panel displays light on aircraft's nose, altitude meter, and camera. It also indicates the onboard computer, barometer, IMU, GPS, and transceiver. It displays the status of fuel and the onboard battery. It also shows the conditions of the engines, anti-icing system, alternators (main and backup), the efficiency of the control plane servos, the degree of deflection of the ailerons and flaps, and the navigation condition and strobe lights.

It is important to note that UAV pilot only receives visual information about the status of the aircraft. As a result, the airplane status information screen must be ergonomic, precise, and provide easy access to crucial information.

Figure 2 depicts the final GCS map screen. The main screen during the LFR flight is the map screen. This screen provides the pilot with real-time information about the aircraft's position (geographical position and altitude) in space. It shows the geographic and spatial orientation of the plane.

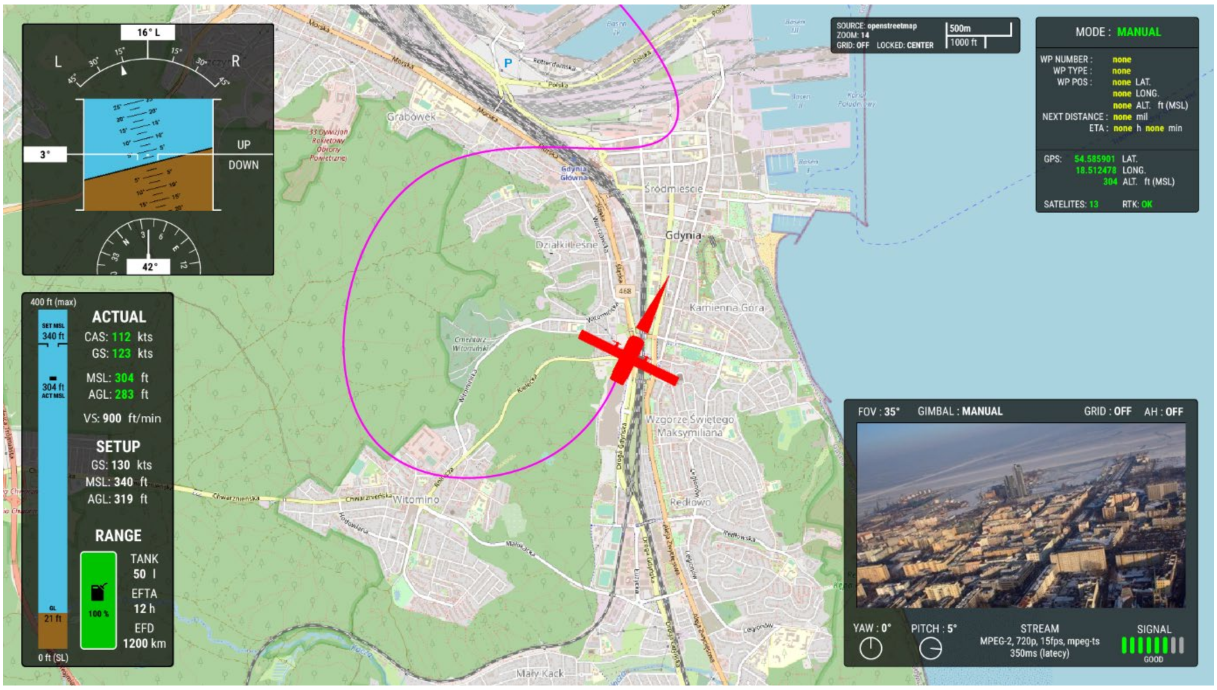


Figure 2: Final GCS map screen developed under the HERoS project

The main screen also displays some small screens:

- In the upper left corner is an artificial horizon screen that provides information about ascent or descent info, left or right bank, and the course. This screen helps the pilot to determine whether the plane is ascending or descending and whether it is tilted. The blue colour on the horizon signifies the sky, and the brown colour represents the ground.

- Below the artificial horizon screen, there is the height control panel. This screen provides information about the aircraft's altitude with respect to the ground and sea levels. The screen also has fuel to distance information.
- In the lower right corner, the camera image in the nose of the aircraft is displayed. The screen in the upper right corner displays information about the airplane route.
- The central part of the screen displays a map with an airplane icon and the flight route. The plane icon shows the direction in which the plane's nose is pointing, and the arrow in front of it shows the direction of flight.

The direction of the plane's nose may not be the actual direction the plane is traveling and is dependent on the wind direction and speed. The wind triangle explains this principle. If the aircraft were flying straight, the wind would deviate it. Therefore, the direction needs to be corrected by turning the plane in the wind direction. Thus, the aircraft has its nose pointing in a direction, but it moves in a slightly different direction.

5.2. The flying platform

This section describes a cargo unmanned aerial vehicle (CUAV) flying platform for transporting medical cargo to areas affected by pandemics or other natural disasters. The CUAV is a twin-engine high-wing airframe, and its design is inspired by the Short C7 Skyvan. Importantly, the Skyvan is a manned plane, while HERoS is adapting its general characteristics for an UAV. In this regard, the CUAV is a prototype with necessary changes for the dimension of the unmanned aerial vehicle. Because the design of the medical cargo under the HERoS project is based on Short C7 Skyvan, the general characteristics and performance measures of Short C7 Skyvan are provided below.

General characteristics of the Short C7 Skyvan:

- Crew: 1-2
- Capacity: 19 passengers
- Length: 12.21 m (40 ft 1 in)
- Wingspan: 19.79 m (64 ft 11 in)
- Height: 4.60 m (15 ft 1 in)
- Wing area: 35.12 m2 (378.0 sq ft)
- Empty weight: 3,331 kg (7,344 lb)
- Max takeoff weight: 5,670 kg (12,500 lb)
- Fuel capacity: 1,109 L (244 imp gal; 293 US gal)
- Powerplant: 2 × Garrett AiResearch TPE-331-2-201A turboprops, 533 kW (715 shp) each Propellers: 3-bladed Hartzell HC-B3TN-5 / T10282H variable-pitch propeller

Performance measures:

- Maximum speed: 324 km / h (201 mph, 175 kn)
- max cruise at 3,050 m (10,010 ft)
- Cruise speed: 278 km / h (173 mph, 150 kn)
- econ cruise at 3,050 m (10,010 ft)

- Stall speed: 111 km / h (69 mph, 60 kn) flaps down, EAS
- Never exceed speed: 402 km / h (250 mph, 217 kn) EAS
- Range: 1,115 km (693 mi, 602 nmi)
- Service ceiling: 6,858 m (22,500 ft)
- Rate of climb: 8.3 m / s (1,640 ft / min)
- Takeoff run to 15 m (50 ft): 482 m (1,581 ft) (STOL)
- Landing run from 15 m (50 ft): 567 m (1,860 ft) (STOL)

The next figures display the conceptual design of the HERoS UAV. Figure 3 displays the first conceptual design of a medical cargo. Figure 4 and Figure 5 are two different visualisations of the first conceptual design.

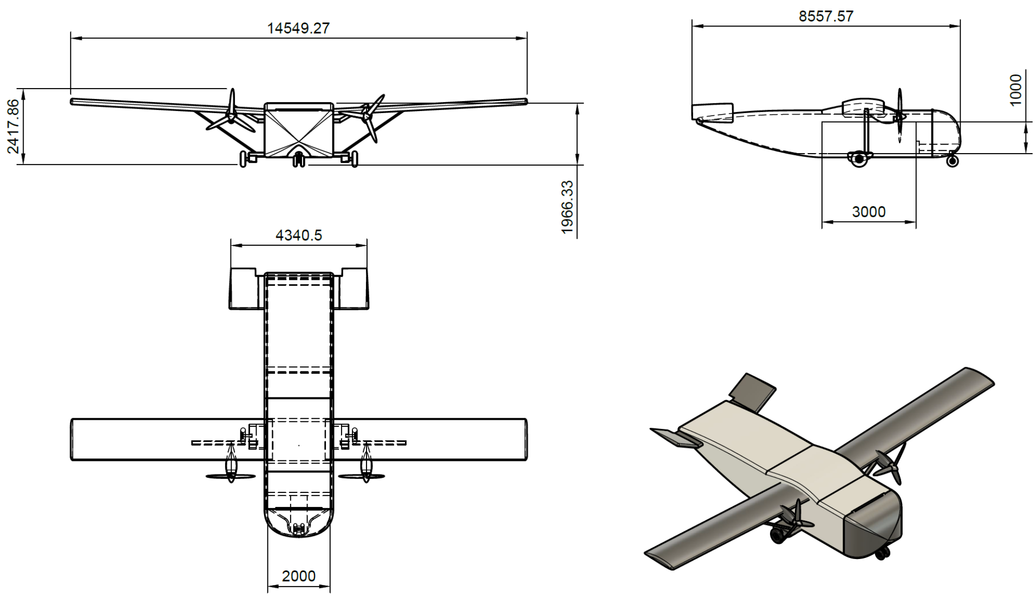


Figure 3: HERoS medical cargo UAV concept 1

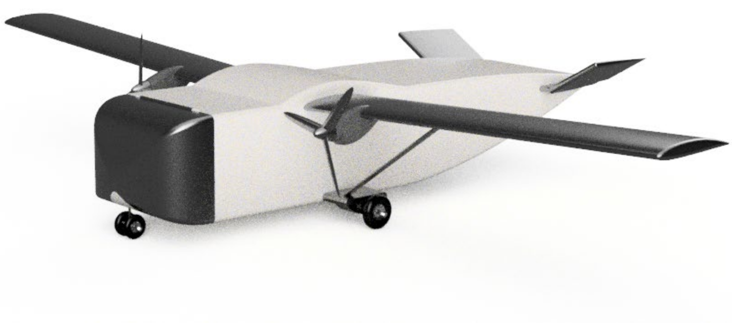


Figure 4: HERoS medical cargo UAV concept 1 visualisation 1

Figure 5: HERoS medical cargo UAV concept 1 visualisation 2

However, this design fell short because the tail was too long. Furthermore, the forklift and rear of the plane weren't aligned. So, the rear was redesigned. In the final configuration, the tail beam shape was changed, and the loading ramp was improved. The upper edge of the loading space was kept at 2 meters in height to improve the loading and unloading. The front fuselage was also raised to ease loading, unloading, and access to the cargo space for service purposes. Figure 6 illustrates medical cargo UAV concept 2 with an open ramp and long tail bar.

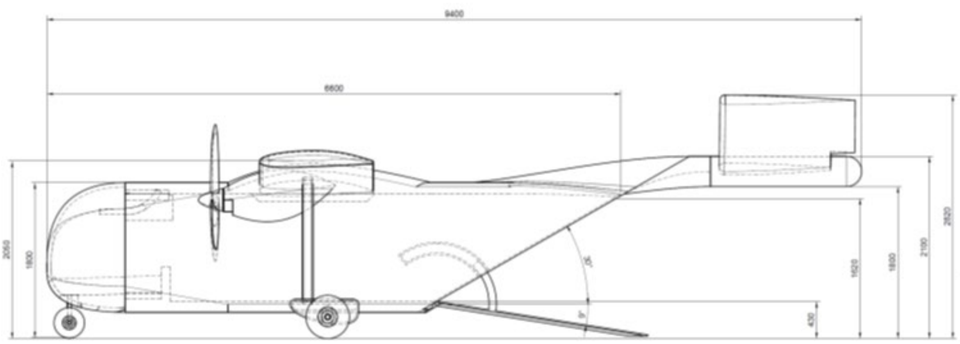


Figure 6: HERoS medical cargo UAV concept 2 with open ramp and long tail bar

After changing the tail shape and adding a drop ramp, the tail was still too long and was still too long and had a negative effect on the balance. To adjust for it, the tail fin was moved to the fuselage, which, in turn, shortened the silhouette and improved loading and unloading possibilities. A butterfly tail (Rudlicki) is used to reduce the weight of this part of the plane. This configuration is modelled in the simulation. Figure 7 to Figure 12 show different views of the final configuration of the HERoS UAV plane. The rear of the aircraft is designed for airdrops. Whether the rear ramp is open or closed can be seen by the system administrator.

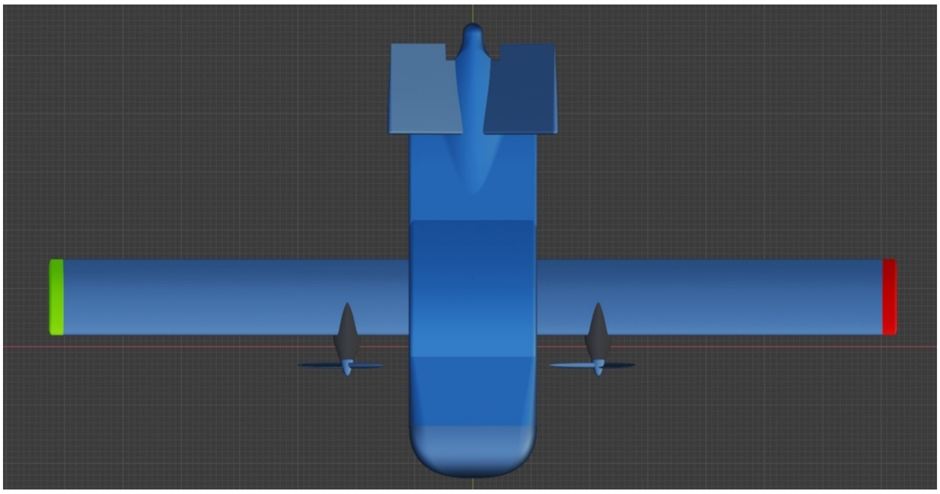


Figure 7: HERoS final plane configuration – top view

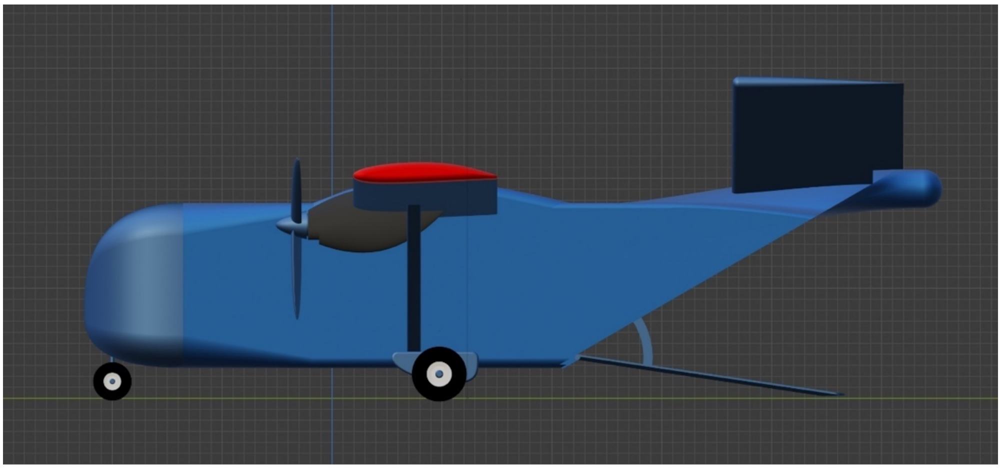


Figure 8: HERoS final plane configuration - side view

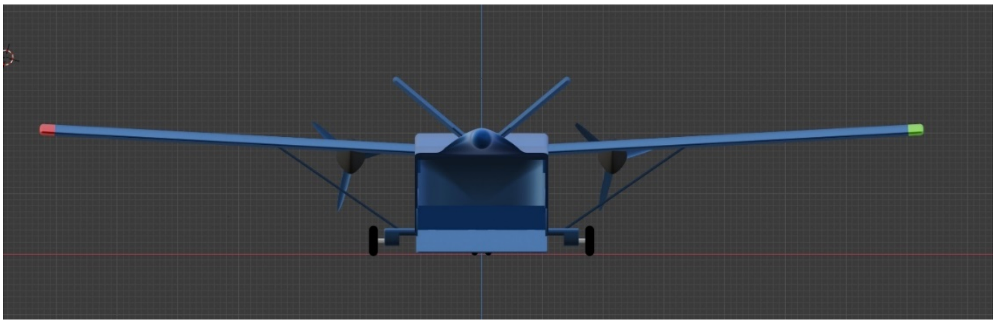


Figure 9: HERoS final plane configuration - rear view

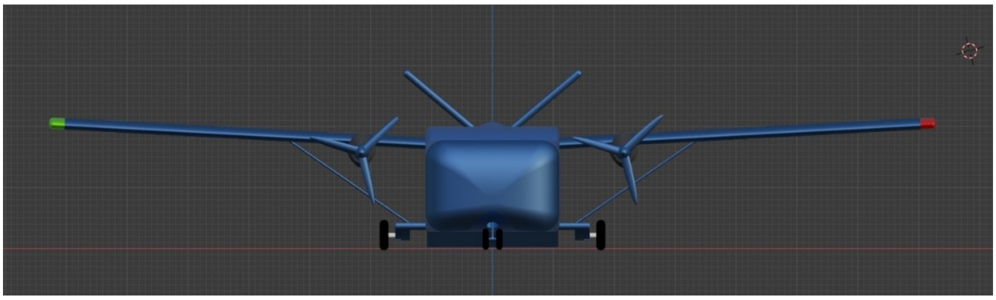


Figure 10: HERoS final plane configuration - front view

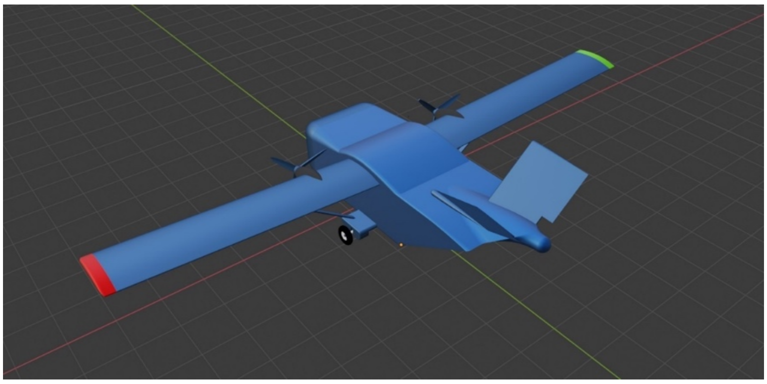


Figure 11: HERoS final plane configuration - top rear view

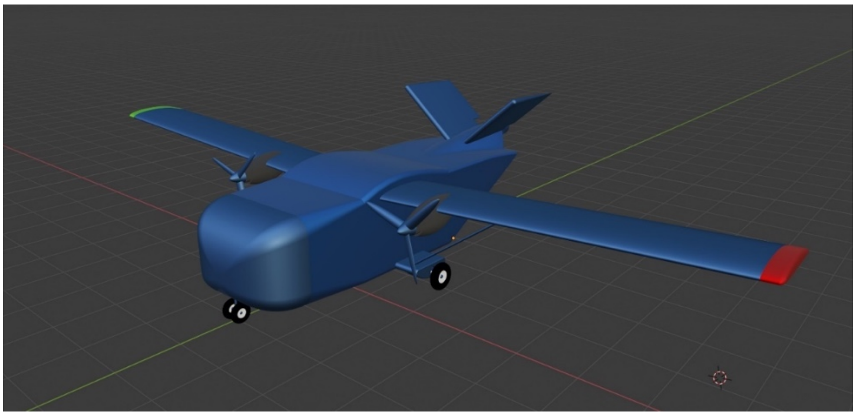


Figure 12: HERoS final plane configuration - top front view

A 3D model of the plane has been programmed into the simulation with features such as shape, mass distribution, moving controls, and a camera in the nose. Then, the lift was programmed to lift the rear ramps and the bow of the plane together. Figure 13 shows the plane flying in the simulated environment. Figure 14 shows the cargo compartment and ramp of the plane, including the medical cargo on it. The nose was designed to be raised for better access to the cargo hold. Figure 15 shows a flight in the simulated environment, including the aircraft making a turn. In the simulation, pilots can set the flight according to waypoints. The aircraft in the simulation performs the flight according to the pre-set waypoints. Figure 16 depicts the start of an airdrop. The rear ramp is open in flight, and the cargo is in it.

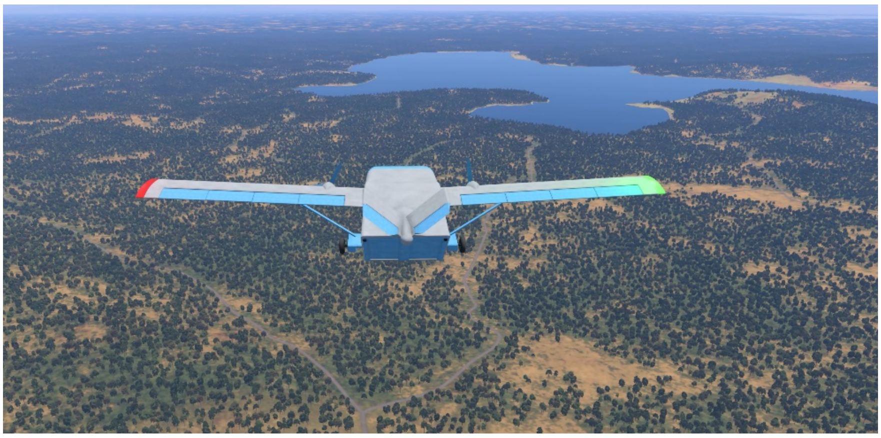


Figure 13: The HERoS plane flying over a region in a simulated environment

Figure 14: Cargo compartment and ramp

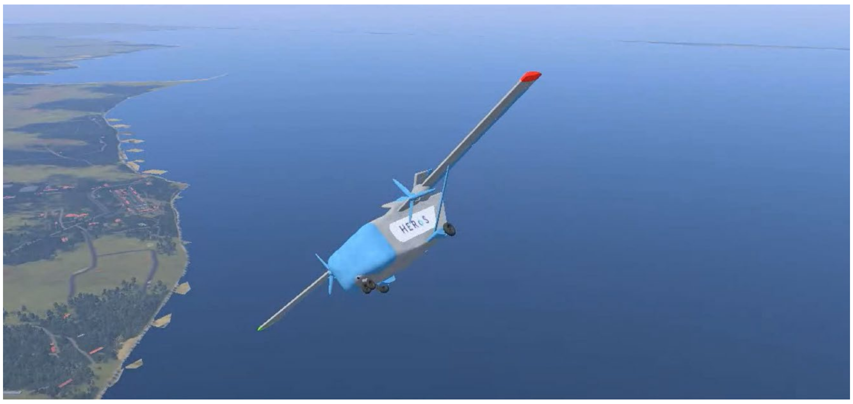


Figure 15: Flight in the HERoS simulated environment

Figure 16: Airdrops in the HERoS simulation

As shown in Figure 14, the load is a medical package. The simulation involved not only UAV flight but also the aspect of this being a medical delivery. As can be seen in Figure 16, the rear ramp is open in flight, and the cargo is in it. UAV medical aid airdrops open a new avenue for aerial airdrops in aid missions.

The ground control station needs cameras to display images on the screen. Cameras are typically placed on the nose of the plane. Two cameras, one with a view of 120 degrees and another with night vision for landing during the night times, are required.

A ground control system would also have an automatic landing system. The aircraft will follow the following sequence:

- Leaving the course into the landing circle
- Descending in a circular motion to an altitude of 1,200 feet and enter landing mode. The optimal number of circles is 3
- Starting the landing sequence
- Entering the landing circle at 45 degrees angle between turns 1 and 2 of the correct traffic circles
- Turning 3
- Exiting to the landing straight
- Lowering the aircraft
- Touching down
- Landing
- Running

5.3. Communication

In the simulation, communication was performed using a 4-channel virtual voice and messenger radio station. Figure 17 shows the panels of the simulated voice communication. It shows the general settings and the advanced settings that allow the entry of critical parameters such as distance range, frequency channels as well as simulated signal degradation depending on terrain, weather conditions, and distance.

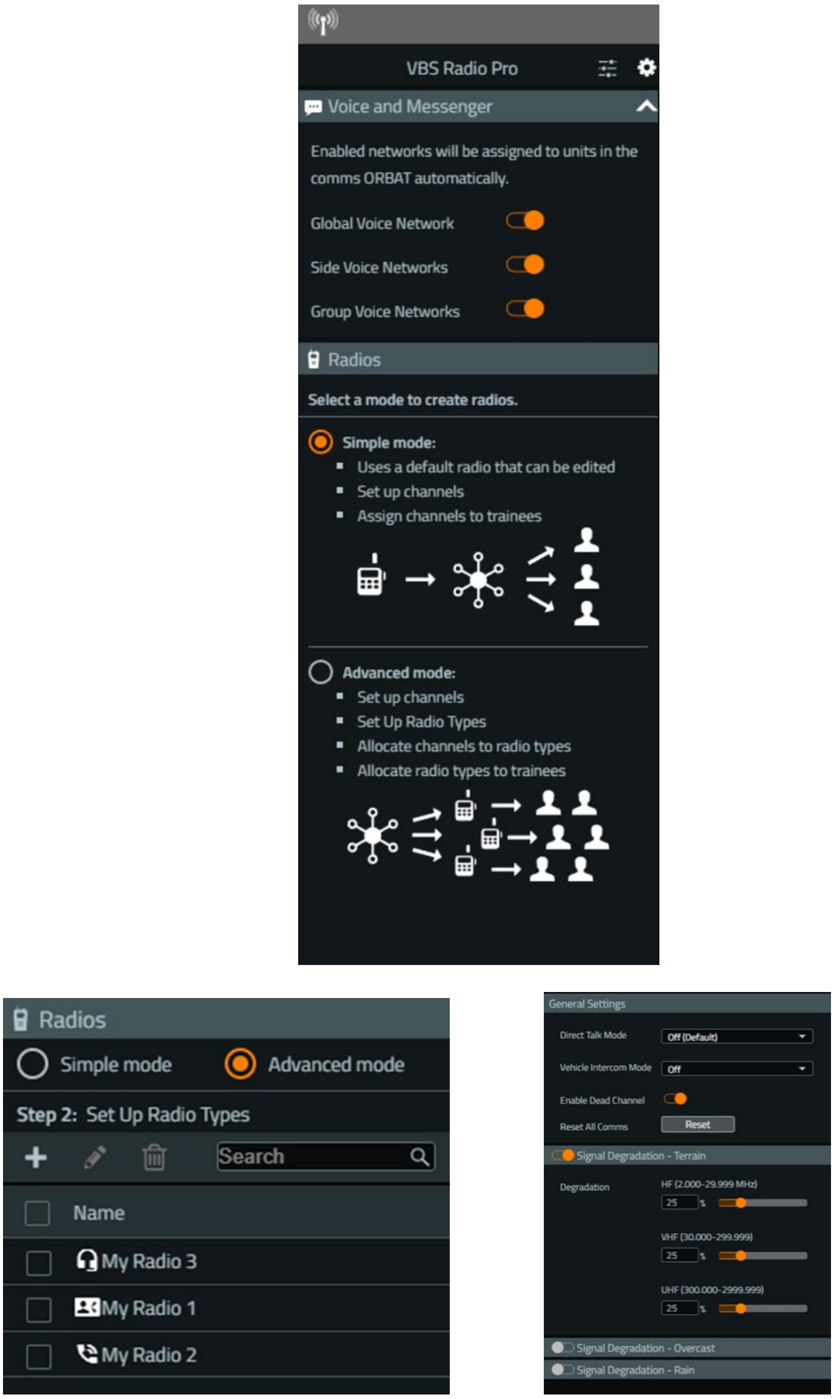


Figure 17: Panels of the simulated voice communication

In actual flight conditions, ground control stations, aircraft, and mission staff would be dispersed across the globe. Consequently, communication should be carried out using the LTE/5G technology to establish voice communication channels between the UAV pilot and the UAV platform and ground personnel. The International Civil Aviation Organization (ICAO) compliant radio communication must be provided to contact the Local Airport traffic control tower. Figure 18 displays the LTE/5G voice communication diagram.

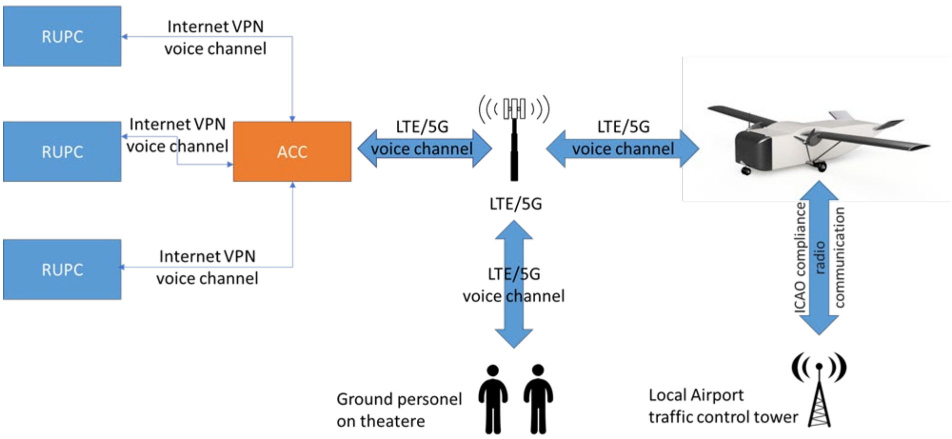


Figure 18: LTE/5G voice communication diagram in HERoS

Next, Figure 19 depicts the Regional UAV Pilot Centre (RUPC) connected to the Airlifts Co-ordination Centre (ACC) with a Virtual Private Network (VPN) and a voice channel. This allows control signals to be reliably transmitted to the ACC and, from there, to the 5G antenna assembly. Through the voice channels, communication with the technicians on the ground control station is performed. Control signals are transmitted to the aerial platform using 5G/LTE technologies. Through the platform, air traffic services are communicated. In the figure, the ACC's key role is apparent as a satellite communications terminal. Satellite connectivity is essential in cases where the reliability of 5G connectivity is problematic for conducting uninterrupted flights.

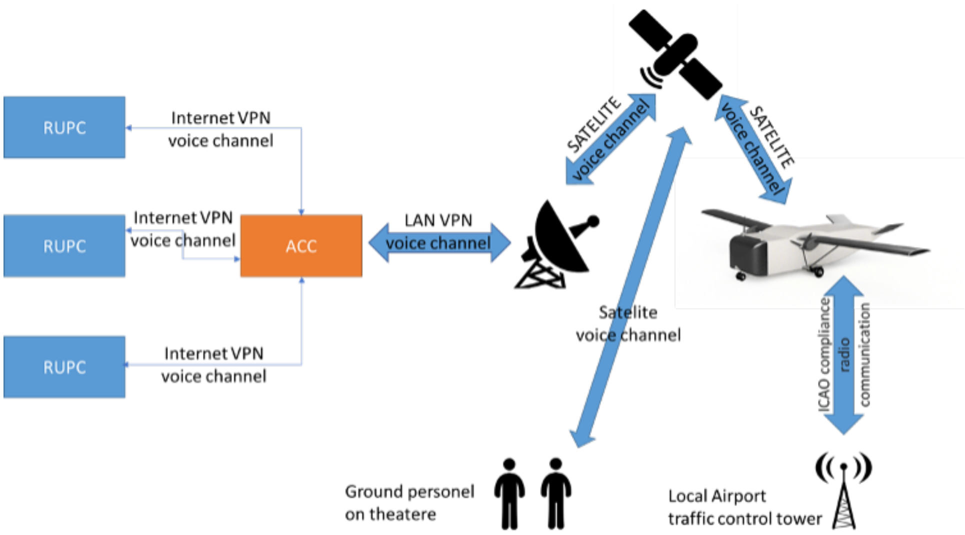


Figure 19: Satellite voice communication diagram in HERoS

5.4. Air traffic requirements

At the beginning of the HERoS project, medical aid scenarios were defined for the simulation. After further analysis during the pandemic, an effort was made to select the scenario that was the most universal and with the broadest possible range of challenges to cater to potential future practical applications. The HERoS project end-user, PCPM, played a leading role in the scenario selection process. With their input, the Uganda scenario with delivery to the Bidi Bidi refugee camp was chosen for the simulation. The principal reason for selecting Uganda’s Bidi Bidi refugee camp was to apply the knowledge from simulation not only during the pandemic period but also after the pandemic for routine operational works of medical humanitarian aid organisations.

Thus, the simulations were conducted considering the air traffic situation in Uganda. After selecting the refugee camp, there was a need to program an operational base chosen to be the Kakira Aiport. Figure 20 displays a part of the aeronautical chart of Uganda. Kakira is located on the outskirts of a major airport jam in Entebbe. And yet it has well-developed road connections.

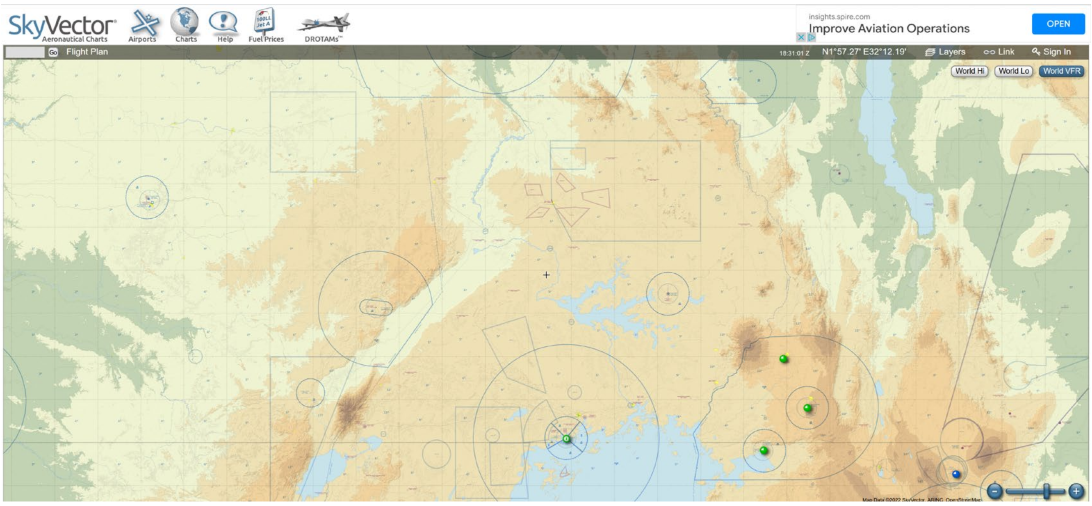


Figure 20: Aeronautical chart of Uganda

Next, Figure 21 shows the aerial situation in the vicinity of the Kakira airstrip. Kakira is at the centre of figure 25. Entebbe airport is in the lower left corner. Entebbe is 66 miles or 106 kilometres away from Kakira. This distance from Entebbe airport ensures that drone flights are not interfering with regular flight operations at the airport.

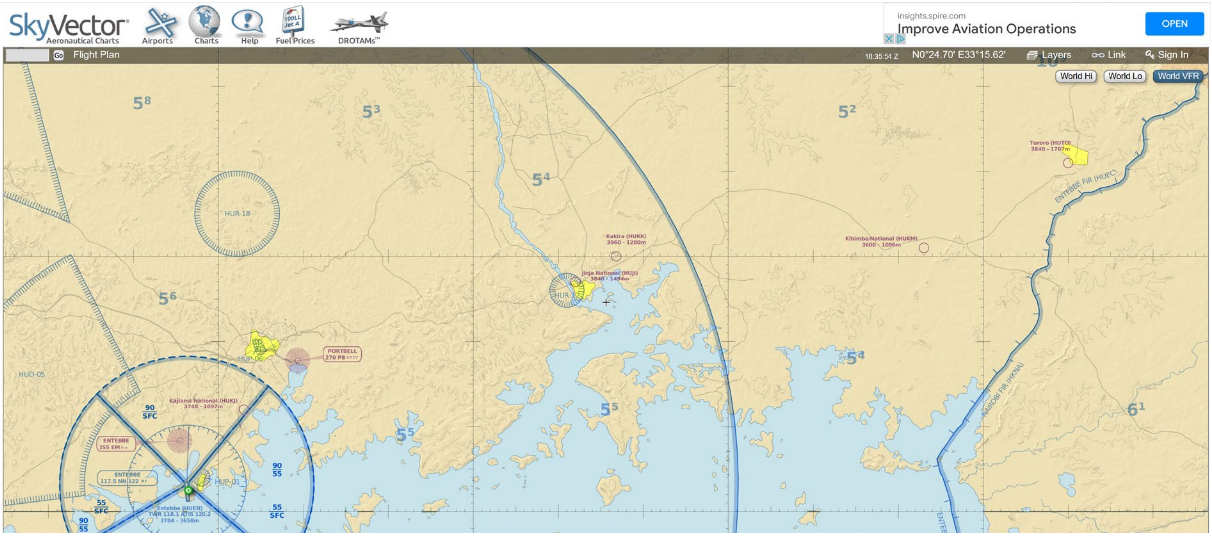


Figure 21: Aerial situation in vicinity of Kakira airstrip

In the simulation, we used flight plans prepared based on the SkyVector website. SkyVector allows you to generate flight plans and, simultaneously, has the DROTAM service. DROTAMs are SkyVector's NOTAMS (Notices to Airman) for drones. During the simulation, the system administrator conducted radio correspondence as an air traffic controller.

5.5. Airworthiness

Maintaining the continuing airworthiness due to the design level as a conceptual design was beyond the scope of this study. However, for example in the EU, according to EU regulations, airworthiness in this class must meet the following general conditions (EASA, 2018). This includes the following points:

- The drone operator and the remote pilot should be aware of the Union and national rules applicable for intended operations, particularly regarding data protection, safety, liability, insurance, security, privacy, and environmental protection. Safety must be ensured for both people on the ground and other users of the airspace. Therefore, the drone operator and the remote pilot must be knowledgeable of the provider's operating instructions, relevant functionalities of drones, environmentally friendly and safe use of drones in the airspace, and the air and ATM procedures applicable for the drone operation.
- A drone must be constructed and designed to fit its intended operation and must be adjusted and maintained so that it does not put any person at risk.
- Drones must have functionalities and features to account for the privacy and protection of personal data by default and by design. Drones should be identifiable and must comply with the applicable prohibitions, limitations, or conditions for the operation in specific geographical zones, at certain altitudes, and beyond certain distances from the pilot.
- Drone companies must provide maintenance information for all operations to the pilot for which the drone is designed. They also should note the limitations and information on the drone's safe operation as well as environmental and operational performance, emergency procedures, and airworthiness limitations. The information should be consistent, unambiguous, and transparent.

5.6. Implementing the workflow for medical deliveries

As defined in D3.2, the workflow for cargo deliveries with UAVs comes with specific challenges. First, because no personnel is on board, activities such as opening the ramp at the delivery place should be fully automatic. Therefore, there is a need to have personnel at the delivery location who can and must ensure that the cargo is properly unloaded. In case there is no designated place for delivery and no personnel present at the delivery location, no one could provide up-to-date information on the condition of the site selected as the landing location for delivering cargo. While it is possible to land at traditional airports with manned traffic, one of the central assumptions in HERoS is that the delivery destinations may be remote and difficult to access by conventional methods of delivering medical aid. Furthermore, there is a risk that drones would be approached by either animals or humans at the delivery location, especially if there is no designated location. Such encounters may disrupt the flight, damage the cargo, and in the worst case, lead to an accident.

Figure 22 shows the UAV delivery flow chart that is implemented in HERoS. According to this, three main stakeholders are involved in the delivery: a warehouse or a sender, a UAV system, and a hospital or a health care facility or any other delivery recipient. The flow depicts a medical delivery from a warehouse to a hospital or healthcare facility.

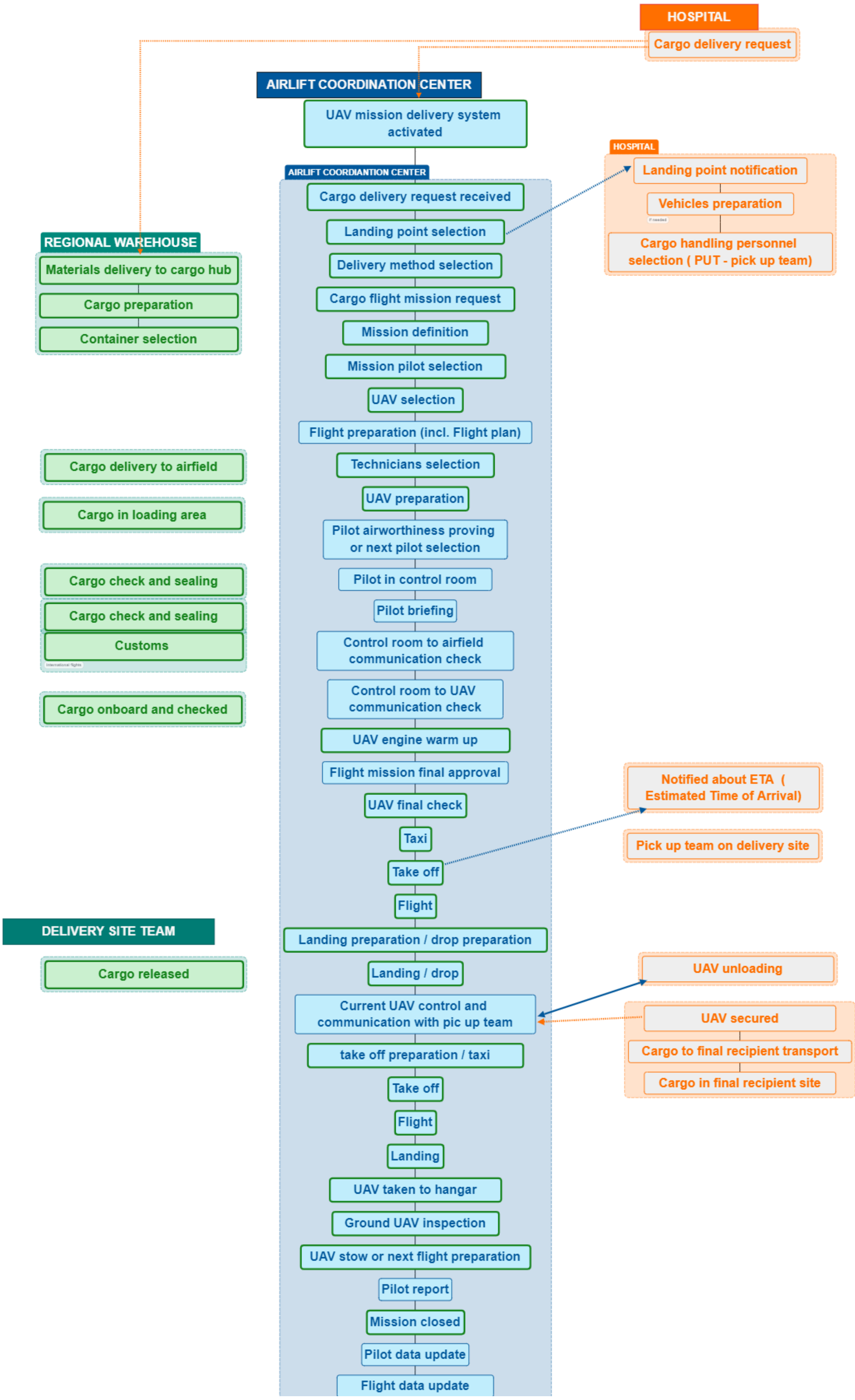


Figure 22: UAV medical cargo delivery flow chart

To operationalise this delivery, the medical facility must raise a delivery request for a particular medical good (e.g., vaccine or tests) which the central warehouse should approve. The UAV system performs only as a delivery mechanism between a warehouse and a healthcare facility, and a proper authorisation mechanism should be in place. In the simulation model, the event initiating the entire process is the issue of a request for medical delivery. Such a request is sent by the entity responsible for its use, such as a hospital, medical centre, humanitarian aid centre, commanders of the refugee camp, etc. The request is sent to the unit responsible for preparing the materials and the material handling line. The material handling line is responsible for the following things:

- Removal from storage
- Packing for land transport
- Delivery to the airport
- Preparation of documentation

The request is simultaneously sent to the UAV flight management centre (FMC, flight line), where the landing site selection process takes place. The landing site should be as close as possible to where the cargo is to be delivered. The choice of the delivery location is one of the components of the delivery method and, consequently, of packing the load into appropriate containers.

After selecting the landing point, the cargo flight is immediately prepared. A new mission is established, and a pilot is assigned to it. The pilot is notified of the task well in advance to be able to prepare for it. At the same time, an air platform is selected for the implementation of the flight. This information is sent to the forward operating base (FOB, see section 5.7), so the technical staff can start preparing the plane for flight. The technical condition is checked and prepared for loading. In the meantime, the flight plan is ready and sent.

In the medical line, personnel is assigned to go to the landing field to collect the cargo. Information about this reaches the flight co-ordination centre. This is the second component of the choice of delivery method. The materials handling line delivers cargo to the airport. The cargo is taken over by the services of the UAV medical supply base, checked according to the manifest, and then repacked into appropriate containers as requested by the FMC. The FMC division of cargo into containers considers the class of supply, the nature of the delivery places, and the presence and level of personnel training concerning the humanitarian mission. The cargo is then closed and sealed. If the aircraft were to cross the border during the flight, it would undergo customs control before the cargo is closed. The shipment is transported to the vicinity of the aircraft (s) and loaded on board.

After loading, the pilot checks the plane's balance, and the aircraft does not exceed the maximum take-off weight. This is done from the GCS level using the MTOM indicator. In the meantime, pilots and ground technicians begin preparing directly for take-off. The pilot connects via satellite communication with the plane to be piloted and with the technicians (a separate voice communication channel). The onboard systems are launched, followed by the engines. After checking the plane, the pilot takes control, starts taxiing, and then takes off.

The pilot shall raise the airplane to cruising altitude and adjust the course according to the flight plan. During the flight, the FMC informs the entity that made the request about the flight and the probable landing time and point. This way, the medical team can prepare the receiving team. While approaching the landing site, the pilot enters the circle. Then it lowers the flight going down to the next levels depending on the situation in the area. Then it flies over the landing field to check the ground's status and determine if any obstacles on the landing field could damage the aircraft.

The pilot communicates with the team that is to receive the cargo. He approaches landing but becomes ready to interrupt the procedure and go around during the ascent if needed. After landing, the cargo receiving team must unload. It is required that the person has been trained and that the plane also has external loudspeakers to transmit voice messages. It is reasonable for the plane to have a self-unloading system, e.g., in the form of chains and catches in containers. After the team unloads and leaves, the pilot begins taxiing. Then it takes off and makes the return flight.

After arriving at the base and landing, the pilot hands over the plane to the ground technical team, closes the mission, completes the documentation, and turns off the GCS. There may be times when it is not possible to land, and the urgent need and the nature of the cargo require a different delivery method. Therefore, the project simulated deliveries using airdrop.

In the following, various **echelon calculations are shown for different distances and cruising speeds** in the simulation (from Figure 23 onwards), with Figure 27 showing the results of the final simulation.

WP3 /delivery simulation/	Flight time (min)	120	02:00	hr:min								
	AIRPLANE SPEED kts	108										
	CRUISE SPEED km/h	200										
	Distance (km)	400										
	Phase of mission	TAXI	TAKE OFF	FLIGHT	LANDING	UNLOADING	TAKE OFF	FLIGHT	LANDING	REVIEW	REFUELING	TOTAL
TIMES	**Echelon in total**	1:40:00	2:10:00	22:10:00	24:40:00	26:20:00	27:10:00	47:10:00	49:40:00	59:40:00	67:10:00	67:10:00
	phase	1:40:00	0:30:00	20:00:00	2:30:00	1:40:00	0:50:00	20:00:00	2:30:00	10:00:00	7:30:00	
	plane	0:10:00	0:13:00	2:13:00	2:28:00	2:38:00	2:43:00	4:43:00	4:58:00	5:58:00	6:43:00	
1-st echelon	**mission time per plane**											
plane 1	06:33:00	00:10:00	00:03:00	02:00:00	00:15:00	00:10:00	00:05:00	02:00:00	00:15:00	01:00:00	00:45:00	
plane 2	6:33:00	00:10:00	00:03:00	02:00:00	00:15:00	00:10:00	00:05:00	02:00:00	00:15:00	01:00:00	00:45:00	
plane 3	6:33:00	00:10:00	00:03:00	02:00:00	00:15:00	00:10:00	00:05:00	02:00:00	00:15:00	01:00:00	00:45:00	
plane 4	6:33:00	00:10:00	00:03:00	02:00:00	00:15:00	00:10:00	00:05:00	02:00:00	00:15:00	01:00:00	00:45:00	
plane 5	6:33:00	00:10:00	00:03:00	02:00:00	00:15:00	00:10:00	00:05:00	02:00:00	00:15:00	01:00:00	00:45:00	
plane 6	6:33:00	00:10:00	00:03:00	02:00:00	00:15:00	00:10:00	00:05:00	02:00:00	00:15:00	01:00:00	00:45:00	
plane 7	6:33:00	00:10:00	00:03:00	02:00:00	00:15:00	00:10:00	00:05:00	02:00:00	00:15:00	01:00:00	00:45:00	
plane 8	6:33:00	00:10:00	00:03:00	02:00:00	00:15:00	00:10:00	00:05:00	02:00:00	00:15:00	01:00:00	00:45:00	
plane 9	6:33:00	00:10:00	00:03:00	02:00:00	00:15:00	00:10:00	00:05:00	02:00:00	00:15:00	01:00:00	00:45:00	
plane 10	6:33:00	00:10:00	00:03:00	02:00:00	00:15:00	00:10:00	00:05:00	02:00:00	00:15:00	01:00:00	00:45:00	

Figure 23: Echelon calculations for 10 planes for 400 km distance and speed 200 km/h

WP3 /delivery simulation/												
	Flight time (min)	240	04:00	hr:min								
	AIRPLANE SPEED kts	54										
	CRUISE SPEED km/h	100										
	Distance (km)	400										
	Phase of mission	TAXI	TAKE OFF	FLIGHT	LANDING	UNLOADING	TAKE OFF	FLIGHT	LANDING	REVIEW	REFUELING	TOTAL
TIMES	**Echelon in total**	1:40:00	2:10:00	42:10:00	44:40:00	46:20:00	47:10:00	87:10:00	89:40:00	99:40:00	107:10:00	107:10:00
	phase	1:40:00	0:30:00	40:00:00	2:30:00	1:40:00	0:50:00	40:00:00	2:30:00	10:00:00	7:30:00	
	plane	0:10:00	0:13:00	4:13:00	4:28:00	4:38:00	4:43:00	8:43:00	8:58:00	9:58:00	10:43:00	
1-st echelon	mission time per plane											
plane 1	10:33:00	00:10:00	00:03:00	04:00:00	00:15:00	00:10:00	00:05:00	04:00:00	00:15:00	01:00:00	00:45:00	
plane 2	10:33:00	00:10:00	00:03:00	04:00:00	00:15:00	00:10:00	00:05:00	04:00:00	00:15:00	01:00:00	00:45:00	
plane 3	10:33:00	00:10:00	00:03:00	04:00:00	00:15:00	00:10:00	00:05:00	04:00:00	00:15:00	01:00:00	00:45:00	
plane 4	10:33:00	00:10:00	00:03:00	04:00:00	00:15:00	00:10:00	00:05:00	04:00:00	00:15:00	01:00:00	00:45:00	
plane 5	10:33:00	00:10:00	00:03:00	04:00:00	00:15:00	00:10:00	00:05:00	04:00:00	00:15:00	01:00:00	00:45:00	
plane 6	10:33:00	00:10:00	00:03:00	04:00:00	00:15:00	00:10:00	00:05:00	04:00:00	00:15:00	01:00:00	00:45:00	
plane 7	10:33:00	00:10:00	00:03:00	04:00:00	00:15:00	00:10:00	00:05:00	04:00:00	00:15:00	01:00:00	00:45:00	
plane 8	10:33:00	00:10:00	00:03:00	04:00:00	00:15:00	00:10:00	00:05:00	04:00:00	00:15:00	01:00:00	00:45:00	
plane 9	10:33:00	00:10:00	00:03:00	04:00:00	00:15:00	00:10:00	00:05:00	04:00:00	00:15:00	01:00:00	00:45:00	
plane 10	10:33:00	00:10:00	00:03:00	04:00:00	00:15:00	00:10:00	00:05:00	04:00:00	00:15:00	01:00:00	00:45:00	

Figure 24: Echelon calculations for 10 planes for 400 km distance and speed of 100 km/h

WP3 /delivery simulation/												
	Flight time (min)	160	03:12	hr:min								
	AIRPLANE SPEED kts	162										
	CRUISE SPEED km/h	300										
	Distance (km)	800										
	Phase of mission	TAXI	TAKE OFF	FLIGHT	LANDING	UNLOADING	TAKE OFF	FLIGHT	LANDING	REVIEW	REFUELING	TOTAL
TIMES	**Echelon in total**	1:40:00	2:10:00	34:10:00	36:40:00	38:20:00	39:10:00	71:10:00	73:40:00	83:40:00	91:10:00	91:10:00
	phase	1:40:00	0:30:00	32:00:00	2:30:00	1:40:00	0:50:00	32:00:00	2:30:00	10:00:00	7:30:00	
	plane	0:10:00	0:13:00	3:25:00	3:40:00	3:50:00	3:55:00	7:07:00	7:22:00	8:22:00	9:07:00	
1-st echelon	mission time per plane											
plane 1	08:57:00	00:10:00	00:03:00	03:12:00	00:15:00	00:10:00	00:05:00	03:12:00	00:15:00	01:00:00	00:45:00	
plane 2	8:57:00	00:10:00	00:03:00	03:12:00	00:15:00	00:10:00	00:05:00	03:12:00	00:15:00	01:00:00	00:45:00	
plane 3	8:57:00	00:10:00	00:03:00	03:12:00	00:15:00	00:10:00	00:05:00	03:12:00	00:15:00	01:00:00	00:45:00	
plane 4	8:57:00	00:10:00	00:03:00	03:12:00	00:15:00	00:10:00	00:05:00	03:12:00	00:15:00	01:00:00	00:45:00	
plane 5	8:57:00	00:10:00	00:03:00	03:12:00	00:15:00	00:10:00	00:05:00	03:12:00	00:15:00	01:00:00	00:45:00	
plane 6	8:57:00	00:10:00	00:03:00	03:12:00	00:15:00	00:10:00	00:05:00	03:12:00	00:15:00	01:00:00	00:45:00	
plane 7	8:57:00	00:10:00	00:03:00	03:12:00	00:15:00	00:10:00	00:05:00	03:12:00	00:15:00	01:00:00	00:45:00	
plane 8	8:57:00	00:10:00	00:03:00	03:12:00	00:15:00	00:10:00	00:05:00	03:12:00	00:15:00	01:00:00	00:45:00	
plane 9	8:57:00	00:10:00	00:03:00	03:12:00	00:15:00	00:10:00	00:05:00	03:12:00	00:15:00	01:00:00	00:45:00	
plane 10	8:57:00	00:10:00	00:03:00	03:12:00	00:15:00	00:10:00	00:05:00	03:12:00	00:15:00	01:00:00	00:45:00	

Figure 25: Echelon calculations for 10 planes for 800 km and speed 250 km/h

WP3 /delivery simulation/												
	Flight time (min)	160	02:40	hr:min								
	AIRPLANE SPEED kts	162										
	CRUISE SPEED km/h	300										
	Distance (km)	800										
	Phase of mission	TAXI	TAKE OFF	FLIGHT	LANDING	UNLOADING	TAKE OFF	FLIGHT	LANDING	REVIEW	REFUELING	TOTAL
TIMES	**Echelon in total**	1:40:00	2:10:00	28:50:00	31:20:00	33:00:00	33:50:00	60:30:00	63:00:00	73:00:00	80:30:00	80:30:00
	phase	1:40:00	0:30:00	26:40:00	2:30:00	1:40:00	0:50:00	26:40:00	2:30:00	10:00:00	7:30:00	
	plane	0:10:00	0:13:00	2:53:00	3:08:00	3:18:00	3:23:00	6:03:00	6:18:00	7:18:00	8:03:00	
1-st echelon	mission time per plane											
plane 1	07:53:00	00:10:00	00:03:00	02:40:00	00:15:00	00:10:00	00:05:00	02:40:00	00:15:00	01:00:00	00:45:00	
plane 2	7:53:00	00:10:00	00:03:00	02:40:00	00:15:00	00:10:00	00:05:00	02:40:00	00:15:00	01:00:00	00:45:00	
plane 3	7:53:00	00:10:00	00:03:00	02:40:00	00:15:00	00:10:00	00:05:00	02:40:00	00:15:00	01:00:00	00:45:00	
plane 4	7:53:00	00:10:00	00:03:00	02:40:00	00:15:00	00:10:00	00:05:00	02:40:00	00:15:00	01:00:00	00:45:00	
plane 5	7:53:00	00:10:00	00:03:00	02:40:00	00:15:00	00:10:00	00:05:00	02:40:00	00:15:00	01:00:00	00:45:00	
plane 6	7:53:00	00:10:00	00:03:00	02:40:00	00:15:00	00:10:00	00:05:00	02:40:00	00:15:00	01:00:00	00:45:00	
plane 7	7:53:00	00:10:00	00:03:00	02:40:00	00:15:00	00:10:00	00:05:00	02:40:00	00:15:00	01:00:00	00:45:00	
plane 8	7:53:00	00:10:00	00:03:00	02:40:00	00:15:00	00:10:00	00:05:00	02:40:00	00:15:00	01:00:00	00:45:00	
plane 9	7:53:00	00:10:00	00:03:00	02:40:00	00:15:00	00:10:00	00:05:00	02:40:00	00:15:00	01:00:00	00:45:00	
plane 10	7:53:00	00:10:00	00:03:00	02:40:00	00:15:00	00:10:00	00:05:00	02:40:00	00:15:00	01:00:00	00:45:00	

Figure 26: Echelon calculations for 10 planes for 800 km and speed 300 km/h

The calculations show that transferring 1.5 tons of cargo would take about 91 hours, i.e., slightly less than four days. Each plane (with the above assumptions) would carry out a mission with a total duration of 7 hours and 22 minutes, which is in line with the time of an eight-hour working day. However, the pilot must attend a briefing before the flight, perform administrative activities related to the flight, and pre-flight checks. The calculation for the 300 km/h shows that, to some extent, savings can be sought by increasing the aircraft's cruising speed. The times to perform pre-flight and post-flight activities are also obtained in the simulation.

In the final simulation, a cruising speed of the aircraft was assumed to be 290 km/h. As a result, the time of one mission from take-off to landing over 400 km distance was 3 hours 44 minutes. Figure 27 shows calculation for the traveling distance of 400 km and a UAV cruise speed of 290 km/h.

WP3 /delivery simulation/	Flight time (min)	83	01:23	hr:min								
	AIRPLANE SPEED kts	157										
	CRUISE SPEED km/h	290										
	Distance (km)	400										
	Phase of mission	TAXI	TAKE OFF	FLIGHT	LANDING	UNLOADING	TAKE OFF	FLIGHT	LANDING	REVIEW	REFUELING	TOTAL
TIMES	**Echelon in total**	1:40:00	2:10:00	16:00:00	18:30:00	20:10:00	21:00:00	34:50:00	37:20:00	47:20:00	54:50:00	54:50:00
	phase	1:40:00	0:30:00	13:50:00	2:30:00	1:40:00	0:50:00	13:50:00	2:30:00	10:00:00	7:30:00	
	plane	0:10:00	0:13:00	1:36:00	1:51:00	2:01:00	2:06:00	3:29:00	3:44:00	4:44:00	5:29:00	
1-st echelon	**mission time per plane**											
plane 1	05:19:00	00:10:00	00:03:00	01:23:00	00:15:00	00:10:00	00:05:00	01:23:00	00:15:00	01:00:00	00:45:00	
plane 2	5:19:00	00:10:00	00:03:00	01:23:00	00:15:00	00:10:00	00:05:00	01:23:00	00:15:00	01:00:00	00:45:00	
plane 3	5:19:00	00:10:00	00:03:00	01:23:00	00:15:00	00:10:00	00:05:00	01:23:00	00:15:00	01:00:00	00:45:00	
plane 4	5:19:00	00:10:00	00:03:00	01:23:00	00:15:00	00:10:00	00:05:00	01:23:00	00:15:00	01:00:00	00:45:00	
plane 5	5:19:00	00:10:00	00:03:00	01:23:00	00:15:00	00:10:00	00:05:00	01:23:00	00:15:00	01:00:00	00:45:00	
plane 6	5:19:00	00:10:00	00:03:00	01:23:00	00:15:00	00:10:00	00:05:00	01:23:00	00:15:00	01:00:00	00:45:00	
plane 7	5:19:00	00:10:00	00:03:00	01:23:00	00:15:00	00:10:00	00:05:00	01:23:00	00:15:00	01:00:00	00:45:00	
plane 8	5:19:00	00:10:00	00:03:00	01:23:00	00:15:00	00:10:00	00:05:00	01:23:00	00:15:00	01:00:00	00:45:00	
plane 9	5:19:00	00:10:00	00:03:00	01:23:00	00:15:00	00:10:00	00:05:00	01:23:00	00:15:00	01:00:00	00:45:00	
plane 10	5:19:00	00:10:00	00:03:00	01:23:00	00:15:00	00:10:00	00:05:00	01:23:00	00:15:00	01:00:00	00:45:00	

Figure 27: Calculation for simulation distance 400 km and UAV cruise speed 290 km/h

Table 4 compares the conceptualised aircraft in the HERoS project with popular aircrafts and their payloads for medical humanitarian cargo. The table compares the times to deliver the equivalent loads of aircraft such as C130, C295, and Mi-17. If the HERoS UAV was to deliver the payload equivalent of the C130 cargo, it would take it about 19 days to do so. For the payload of the Mi-17 cargo, it would require 5 days.

Table 4: Comparison with typical other payloads used in this context

	Aircraft			
	C130	C295	Mi-17	Drone
Payload (kg)	19000	9250	5000	150
Number of flights by the drone to carry the payload	127	62	33	1
Drone time	03:44:00			
Equivalent drone time	472:53:20	230:13:20	124:26:40	3:44

5.7. A forward operating base

A forward operating base (FOB) is a crucial point in the logistic chain. FOB is a place like an airport or a landing strip where drones are deployed. Figure 28 shows a schema of a FOB.

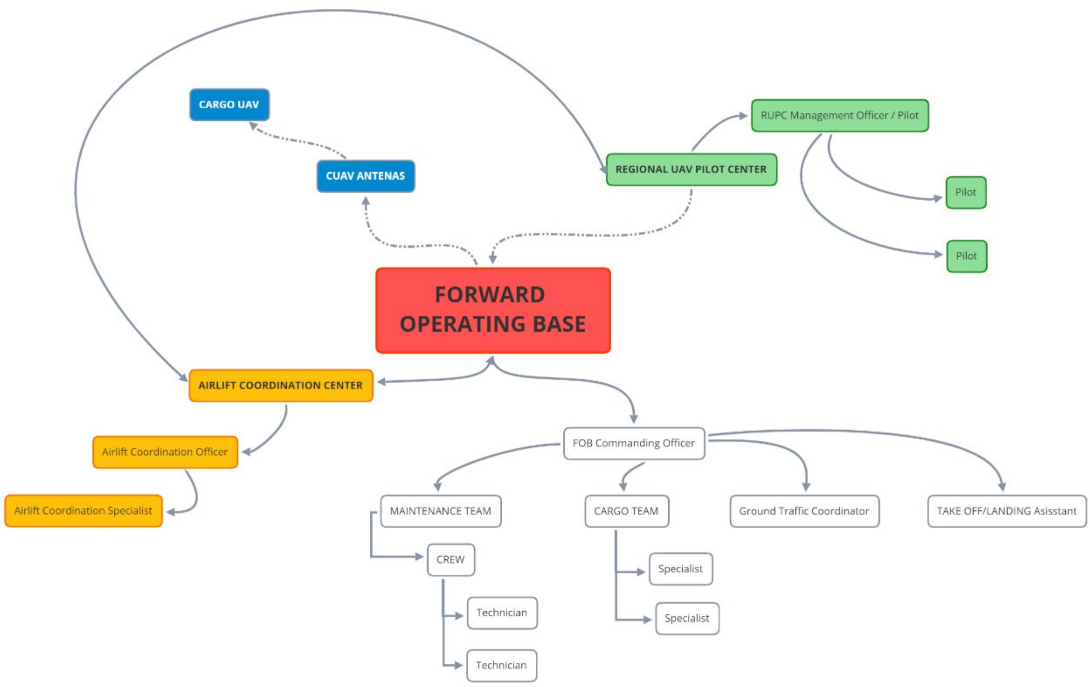


Figure 28: Schema of a forward operating base

The FOB must be equipped with hangars. A commanding officer should be placed in a FOB, who is responsible for:

- The maintenance team;
- The cargo team;
- Ground traffic co-ordinator (GTC);
- Take-off or landing assistants or external pilots.

The maintenance team deals with aircraft maintenance of both running and repairs. The cargo team is responsible for adequately preparing and delivering the cargo to the plane. The GTC is accountable for assigning aircraft to missions and directing them for repairs and maintenance. Take-off or landing assistants and external pilots are responsible for landing those planes without an automatic take-off and landing. The airlifts co-ordination centre (ACC) is crucial in UAV flight management.

The Airlift Co-ordination Centre (ACC) is the flight dispatcher hub and can be considered the brain of the entire system. It contains all the databases used for a flight to ensure uninterrupted deliveries. The ACC must be equipped with the following things:

- An aircraft database containing information on the validity of certificates, air raids, and damages.
- A database of pilots, including the degree of their training, the validity of certificates, personal data, and medical records.
- A database of landing sites with descriptions, photos, comments, information about obstacles, locations, and technicians.
- A statistical database containing flight hours for both pilots and planes.
- A database of UAV flight regulations in different countries
- A set of antennas for ground to air communication i.e., communications with planes

The ACC distributes missions to individual pilots and collects information about their completion. The communications between RUPCs and airplanes are carried out through an ACC. An ACC also manages airplanes by collecting data from the FOB. The ACC must also have a team to check the validity of flight licenses in different countries. The ACC should have a unit investigating aviation incidents or accidents. The ACC must also have a training centre for both pilots and technicians. Training data must be transferred to the database of pilots and technicians.

The FOB commanding officer is also responsible for overall control and communication with ACC and Regional UAV Pilot Centre (RUPC). A FOB is required where medical humanitarian aids need to be delivered. Therefore, FOB must be equipped with landing facilities and material delivery routes. A convenient location for FOB is a material warehouse for humanitarian convoys.

A GCS is located in a Regional UAV Pilot Centre (RUPC). The RUPC can be situated anywhere in the world. The RUPC must have a satellite connection with the ACC from where medical humanitarian cargo were deployed to a FOB. A RUPC must hold the following components:

- GCS
- computer with weather services
- terminal for communication with ACC
- radio for air and ground radio communications (with technicians in FOB)
- device for checking the sobriety of pilots.
- protected access
- links and cables
- sets of transmitting and receiving antennas
- A training centre for pilots

Here it is worth noting the mode of operations for remote control in a RUPC. After receiving the notification from the ACC, the pilot goes to the RUPC. He gets inside with an access card and logs into GCS and opens the mission. He must undergo a sobriety test, the result of which is transmitted to the ACC. After a negative test result, the pilot begins preparing for the flight, i.e., collecting weather information and getting to know the plane assigned to him. It communicates with the technicians in FOB and the aircraft. After successfully checking the plane, the pilot conducts the flight. After landing, he settles the mission, logs out, and locks the room. The room is ready for the next flight.

Between flights, the room is inspected and checked by a team of technicians. RUPCs should be positioned in such a way as to ensure an uninterrupted stream of pilots ready to fly. The longer the flights, the farther the RUPCs must be from each other. Time zone layout should be considered for very long flights. This way, there will always be a handful of pilots in the stock.

Figure 29 presents a conceptual map of the world with an ACC and RUPCs placed in different regions. Figure 30 shows the ACC, RUPCs, the location of the FOB base in Kakira, and the Bidi Bidi refugee camp. In contrast, Figure 31 places ACC and RUPC on the 3D model of the Earth.

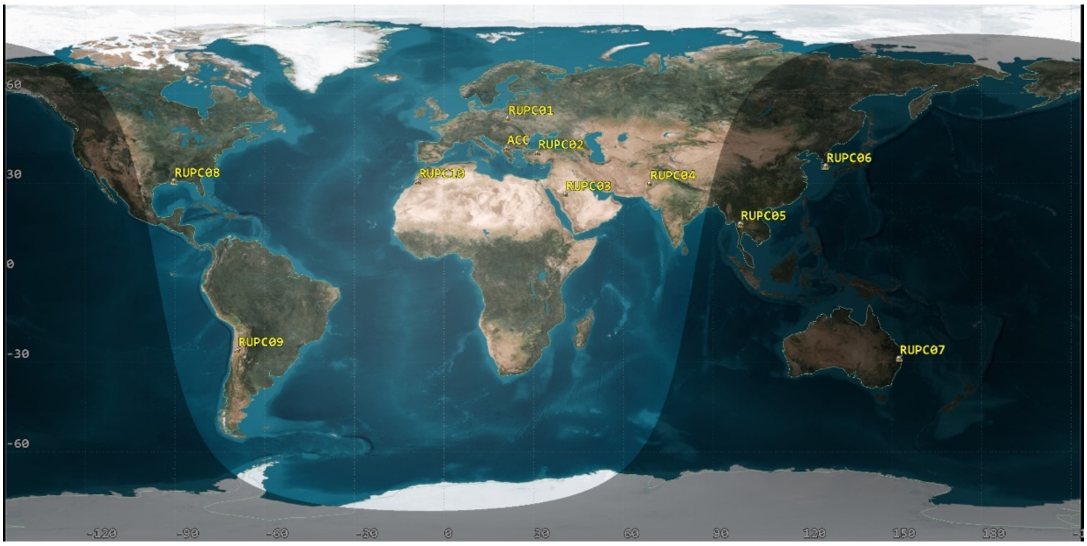


Figure 29: Map of the world with ACC and RUPCs

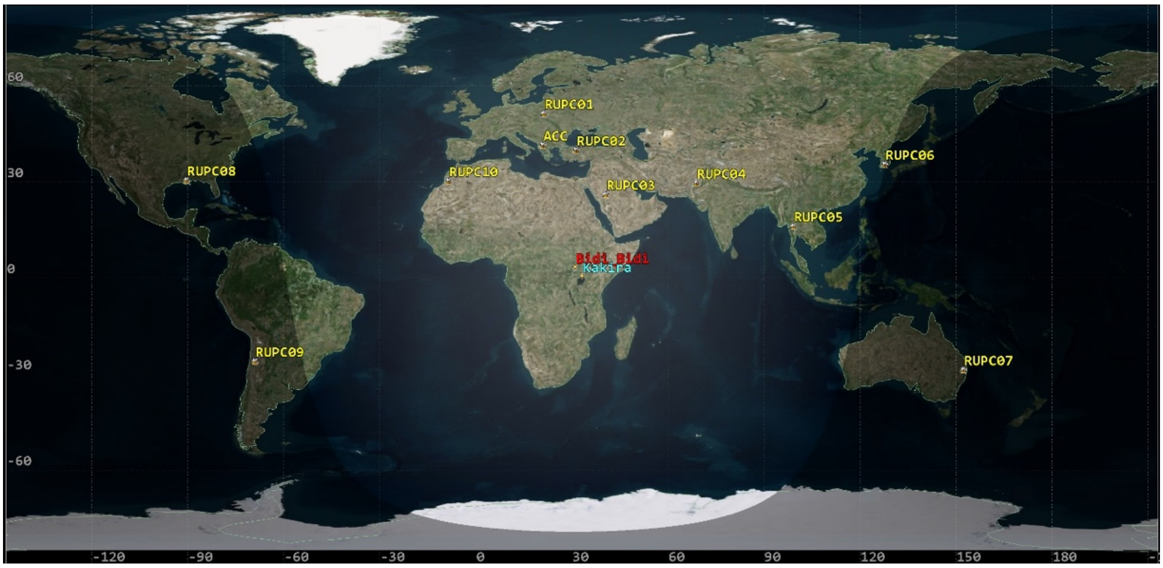


Figure 30: Drone delivery system with all elements placed on world map

Figure 31: Regional UAV Pilot Centres (RUPC) and Airlift Co-ordination Centre (ACC) on the world map

6. Crew familiarisation and UAV system tests

This section reports on crew familiarisation and UAV system tests.

6.1. Crew familiarisation

Crew familiarisation proceeded in two stages. Stage 1 involved the familiarisation of crews with geographic regions. Familiarisation consisted of getting information on the existing climatic conditions of Uganda. The information included temperatures for the year, precipitation, wind directions, and wind strengths. This was followed by familiarising the Bidi Bidi region as a delivery point for future flights. The Bidi Bidi area is the world's largest refugee camp, and for this reason, it was chosen as the destination for deliveries in the simulation. The crew was then informed about the general scheme of Uganda's airspace. They were introduced to the dangerous, restricted, and prohibited zone systems. Attention was given to the restricted zones. Then the crew was familiarised with the take-off airport for the mission, i.e., Kakira airport. Kakira was chosen because it is located away from major airports and thus offers good conditions for unmanned flights.

This was followed by familiarisation with the location of also Entebbe airport and its airport control zone and terminal control area. And this is due to the need to take these elements into account when planning the route. Next, the crew was introduced to the nearest airport, Jinja, located about 10 km from Kakira Airport. The airport was pointed out as the first to land in case of an emergency when a return to the airport could not be made.

The crew was then introduced to other airports located in the vicinity of the planned flight route. i.e., airports Chobe, Pakuba, Lira, Masindi, Arua, and Lira. The crew was also briefed on the situation around Gulu Airport. There are five zones around the city and the airport that would need to be considered because Gulu can also be chosen as a backup airport. Also, Kyoga Lake was identified as a specific type of emergency landing area.

Stage 2 of crew familiarisation involved familiarisation with the UAV system. Familiarisation with the UAV system was combined with a stage of development work on the system. During programming, the crew evaluated the adopted solutions and tested them in successive stages of building the control logic and GCS stations. During the development work (at the test stage), there was a need to change the setup of the control station. This was done based on the ongoing process of refining the system elements to secure 24/7 flight continuity. Since the pilots were familiar with the previous station and the control screen had no significant changes, familiarisation consisted of getting used to the vertical screen setting. After the initial development stage, the crew familiarised themselves with the system in the following sequence of test flights.

6.2. UAV system tests

UAV system tests are related to different flight types, such as basic flights, basic delivery scenario flights, long duration flights, malfunction or crash flights, full mission test flights, and demonstration flights. Basic flights were carried out while the GCS was being programmed and integrated into the model. During these flights, anomalies in the operation of the aircraft control logic and GCS were caught. The in-flight pilot pointed out glitches that occurred during this stage of work. The operation of the on-screen indicators and the position on the map was tested. Automatic flight modes and manual modes (HOTAS) were also tested.

During the basic delivery scenario flights, loading and unloading logic were tested. In the development stage, avatars of people and equipment involved in the delivery action were programmed. The operation of the aircraft loading ramp and the delivery process to the FOB were checked. The take-off was followed by the preparation of the aircraft to land at the place indicated for unloading. In the simulation, various situations, such as the presence of personnel (e.g., medical personnel, UN soldiers, and civilians) and also no personnel at the landing sites were pre-programmed. The unloading was carried out under simulated conditions.

During the long-duration flights, the ergonomics of the control station were tested. In unmanned aviation, the pilot derives knowledge of the aircraft's condition only through visual information displayed on the screens. For this reason, cargo flights can be very monotonous for pilots. Flight monotony causes the pilot to quickly disengage from the flying process. All distractions must then be out of his reach. Therefore, the appearance of the control station, the comfort of the pilot, and his condition, e.g., whether he is rested or not, become particularly important.

Finally, long-duration flights also involved determining the size of the screen indicators and the colour scheme used to indicate correct operation and malfunction. The rearrangement of the screens also took place at this stage. The horizontal setting proved to be more tiring compared to the vertical one. At this stage, it was the ergonomics of the control station that was checked through questions asked by the instructor and the pilot's indication of the position of the indicators on the screen.

During malfunction or crash flights, the pilot's responses to emergency situations were tested. Emergency situations triggered during the tests were as follows.

- Loss of communication
- Loss of thrust in one of the engines
- Failure to open the ramp
- Storm on the flight path

Pilots were expected to perform emergency procedures depending on the situation. The goal of the procedures was to save the aircraft and cargo. In the case of crash tests, pilots were tasked with responding to a situation that did not provide an opportunity to return or make an emergency landing at designated alternate airports. In such a situation, the pilots were taught to find an emergency landing site that would result in the crash of the plane. The pilots had to decide and choose a lonely place to perform the crash.

During the full mission test flights, the pilots' tasks were to combine all related skills and procedures in one flight. Full mission tests were a comprehensive test for previous types of flights. These flights were carried out on a full mission time basis. The pilots were to prepare the flight, receive information about the cargo, obtain permission to take off, take off, take the course, reach the point, land the plane, unload the plane, and then fly back. Flights were from Kakira airport. Flights at this stage lasted precisely the same time and at distances corresponding to distances in real life. During the flights, minor improvements were made to the functioning of the UAV system if they appeared.

The demonstration flights were actual flights for the project. They took place at distances and in time that corresponded to real life. A full cycle of delivery missions took place during the flights. During the flights, the instructor simulated emergency situations to the pilot and expected a reaction. The conclusions from the demonstration flights were used to develop SOPs for the functioning of the FOB and to create delivery matrices using drones.

Apart from tests during flights, other tests were the administrator’s or instructor’s station tests. The administrator station is the central element that controls the simulation. The instructors check the station at all stages of the ground control station and aircraft developments. The administrator station is integrated with the ground control station’s computer. During the test flights, the administrator's station serves as the server of the network scenario.

7. Necessary training and courses

There is no single standard for UAV pilot training in the world. Taking Europe as an example as of now, drones that weigh 600 kg and fly beyond visual sight are not permitted to fly under current EU regulations (EASA, 2021b). In the HERoS project, the range of skills needed for a UAV cargo pilot to fly in international drone flights is also determined.

Since there are no exact regulations regulating the scope of training, a proposal for possible training areas for the pilot is presented here. First, the pilot must undergo theoretical training. The training can include information about the following concepts:

- Aviation Meteorology
- Air navigation
- Aviation regulations
- Human limitations
- Operational procedures
- Technical and operational measures to reduce the risk in the air
- General knowledge of unmanned aerial vehicle systems
- In-flight UAS system performance
- Technical and operational measures to reduce the risk on the ground
- Construction of the plane
- Features of installations and systems
- Aerodynamics

Along with theoretical training, the pilots must also undergo practical training, which should contain the following activities:

- Pre-flight activities
- Preparation of the drone for the flight
- Taking off and landing
- Ground handling
- Activities during the flight
    - change of flight parameters
    - change of speed,
    - change of altitude,
- change of orientation
- Post-flight learnings
- Responding to emergencies

In addition, pilots must obtain authorisation to communicate in aviation radio networks and correspondence in English. For this, there are separate permissions that the pilot must get. Under EU requirements, remote pilots operating UAS in the 'specific' category shall comply with the competency requirements set out in the operational authorisation by the competent authority or in the standard scenario defined in Appendix 1 (EASA, 2022). According to EASA, (2022) the pilot shall have at least the following competencies:

- Ability to apply operational procedures (normal, contingency, and emergency procedures, flight planning, pre-flight and post-flight inspections)
- Ability to manage aeronautical communication
- Manage the unmanned aircraft flight path and automation
- Leadership
- Teamwork and self-management
- Problem solving and decision-making
- Situational awareness
- Workload management
- Co-ordination or handover

The training of ground technicians should be carried out at a level not lower than that provided by PART-66 AML B1.2, which corresponds to the maintenance of aircraft structure, power plant and mechanical and electrical systems, and avionics systems requiring simple tests to prove their serviceability and no troubleshooting (EASA, 2019). The scope includes:

- Flight control system including mechanical rudders, hydraulically powered rudders, rudders electromechanically driven
- Avionics system including both analogue and digital systems
- Structures such a metal, composite, and wood construction

8. Simulation of UAVs for LRFs

In the HERoS project, the simulator (MS7) was first created consisting of a real GCS and a cargo plane model. After building the simulator, the pilots began training in flights over 400 km in the selected geographic region. Mastering flights on the simulator was milestone 10. Next, the virtual environment for medical humanitarian delivery, including refugee camps, UN base airports, equipment sample loads, vehicles people avatars, was programmed. Then a comprehensive simulator of medical humanitarian air missions was created, on which the flights began (milestone 12) to make the delivery of medical humanitarian cargo.

In addition, supporting simulations were performed. It consisted of modelling the UAV mission with the placement of the proposed elements, such as RUPC, ACC, and FOB, on the Earth model. In the next step, the flight route was programmed. An all-around constellation of GPS satellites was placed, and the local operating system was programmed to determine the availability of navigation satellites. Figure 32 shows the simulation of the GPS constellation visible by the UAV during the flight, and Figure 33 the GPS coverage during the flight.

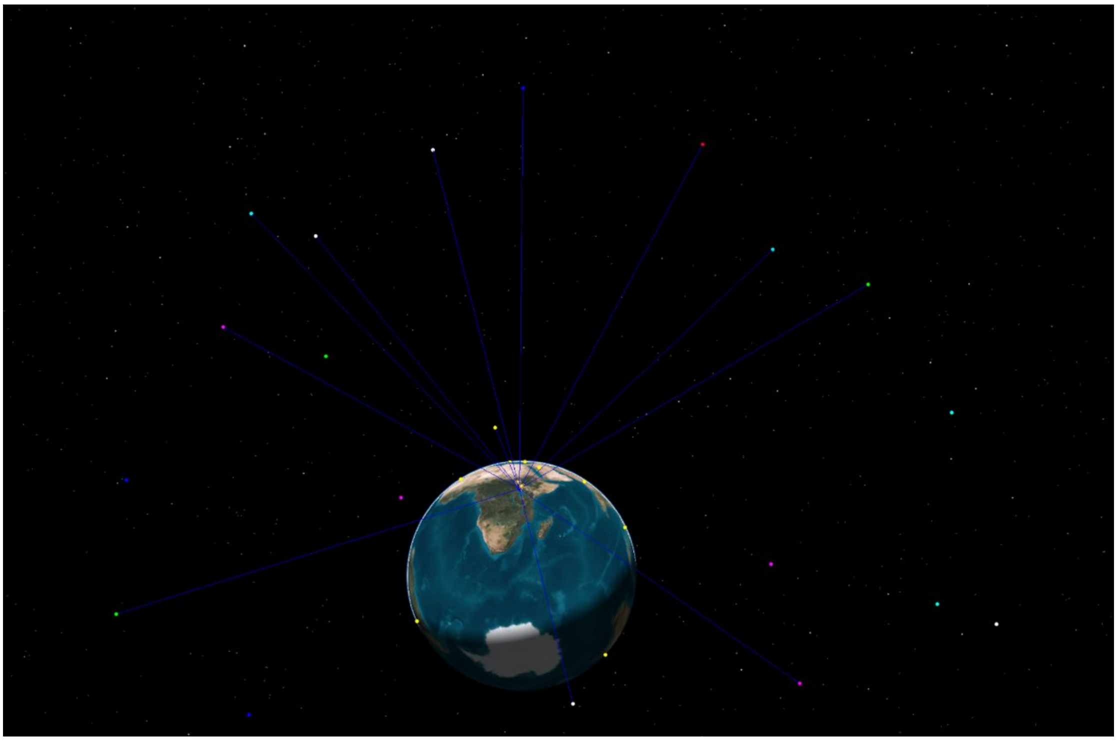


Figure 32: The simulation of the GPS constellation visible by the UAV during the flight

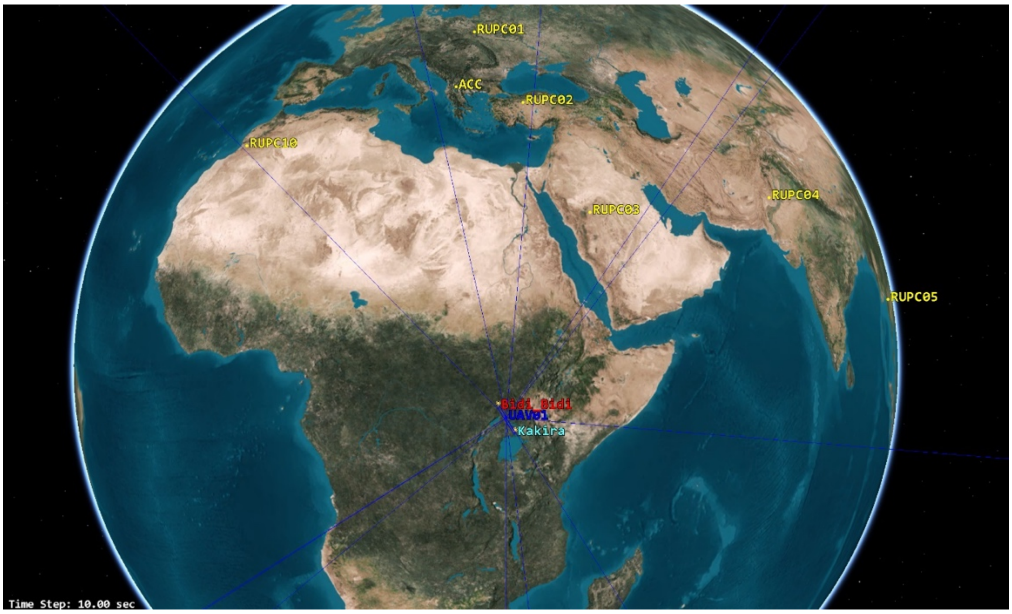


Figure 33: The simulation of the GPS coverage during the time of the UAV flight

Figure 34 displays a 2D view of the **flight path of the LRF simulation**. In the figure, the Kakira airfield is represented by the colour cyan, and the Bidi Bidi refugee camp is designated in red colour. The GPS satellite, in red colour and defined as GPS-27_svn66, is also placed in the figure. The line of sight from airplane to satellite is also visible. The lines of sight to other satellites can also be seen.

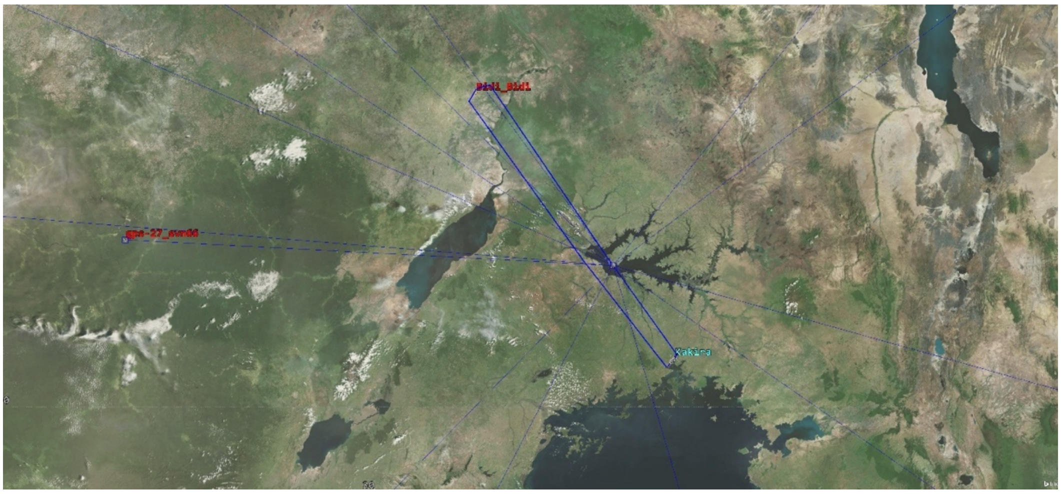


Figure 34: A 2D view of the flight path for a long-range flight simulation

Figure 35 shows the flight path from Bidi Bidi and back in 3D and the GPS position in yellow and designated a gps-18_svn75. The UAV is in the air and its position is described as UAV01. The UAV is in the middle of the figure. The lines running from the UAV are line-of-sight to the GPS satellites.

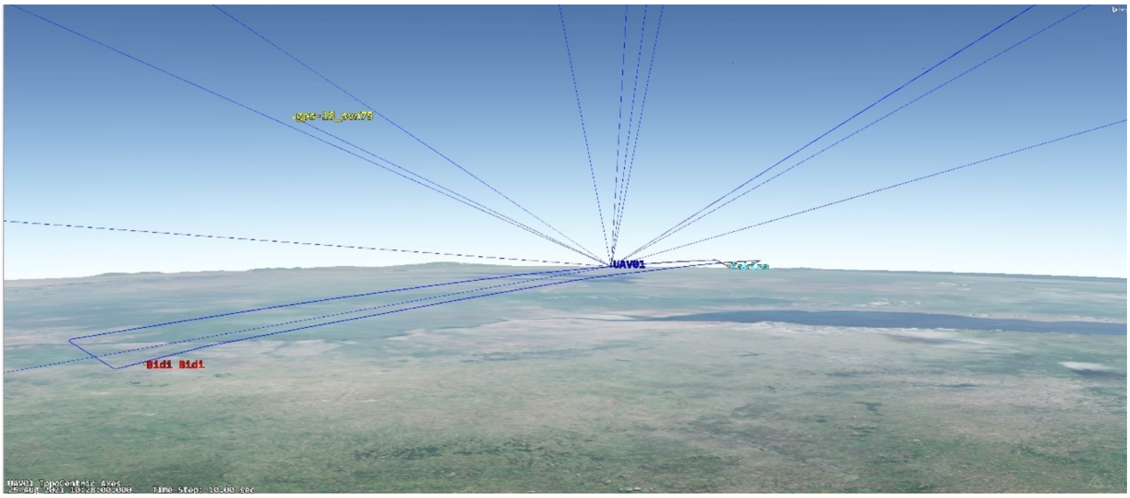


Figure 35: The flight path in 3D

Figure 36 depicts the pilot in front of the first model of **ground control station**. The first version of the simulator was built on three screens arranged side by side and with the central computer unit in the middle. It displayed a map with flight indicators. The map screen also displayed the status of the flight. The right screen showed the image from the onboard camera. On the right-hand side an additional auxiliary computer is placed with an internet connection.

Figure 36: The pilot in front of the first model of ground control station

Figure 37 displays the first version of the simulator, which is designed by following the general principles of ergonomics for computer workstations.

Figure 37: First version of the simulator

Figure 38 depicts virtual reality goggles used by the pilot. However, it did not work out well, as the pilot felt sick afterward.

Figure 38: The first version of the simulator was also attached to virtual reality goggles

After a few flights of three screens side by side, it was discovered that it would be more convenient for the pilot to have the screens above the other. Moreover, a pattern emerged to organise the screens. It was established that the lower screen should be the main screen displaying the map and fundamental parameters for optimum pilot functioning. In contrast, the upper screen must show the airplane status screen with all types of status indicators. Figure 39 shows the final GCS configuration, and Figure 40 the pilot during the final simulation.

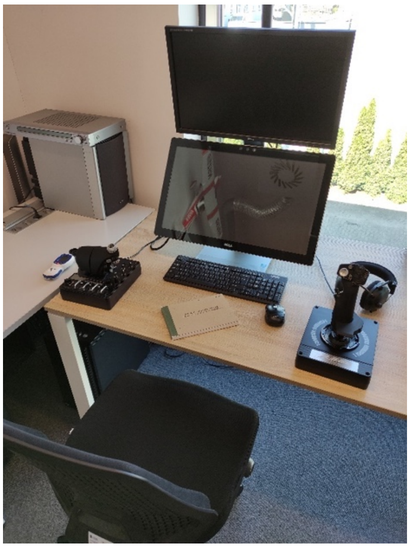


Figure 39: The final GCS configuration

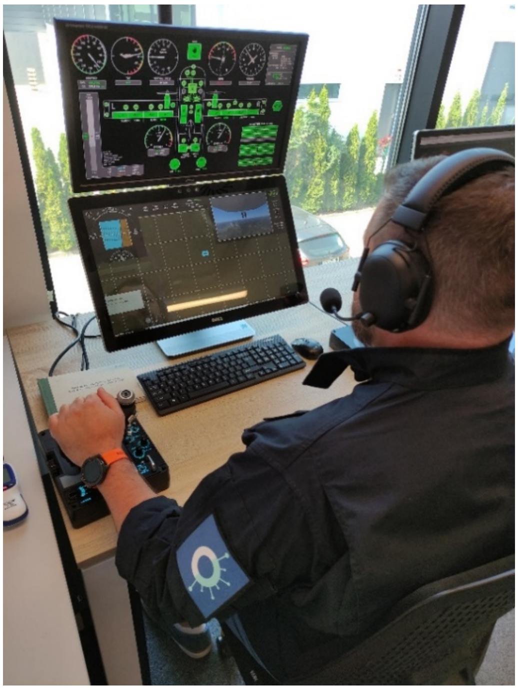


Figure 40: A UAV pilot during the flight simulation

After the aircraft was programmed, the elements of a **medical humanitarian aid mission** were programmed. These elements are:

- Kakira airport
- People avatars (e.g., refugees, UN forces, medics)
- UN base in Bidi Bidi
- Vehicles
- Cargo examples
- Environmental conditions
- Radio

Figure 41 to Figure 43 show various elements of the **simulation area**: Bidi Bidi area, the WFP warehouse with a GPS location in Bidi Bidi, vs. some UN vehicles on the Kakira airfield.

Figure 41: Bidi Bidi area in the simulation

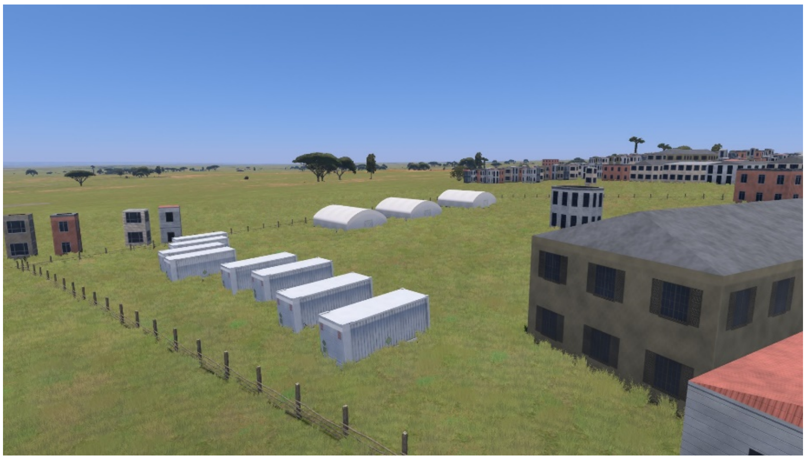


Figure 42: World food program warehouse in Bidi Bidi (3°29'30.0"N 31°24'02.0"E)

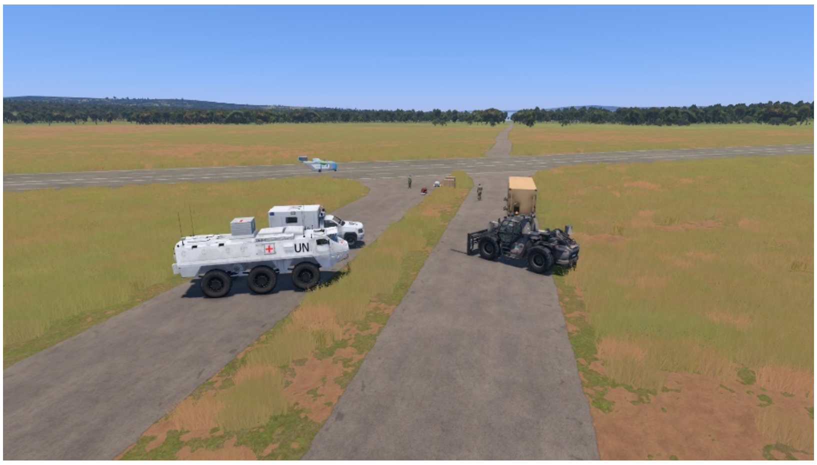


Figure 43: Vehicles on Kakira airfield

A part of the simulation was programming landing strip classes or **delivery points**. Figure 44 shows a screenshot from the simulation displaying an example of an E-E-6 class delivery point. The first letter means knowledge of the landing site, and it is the landing site where the delivery took place the day before. The second letter indicates the presence of staff. In this particular case, E means the presence of doctors. The number indicates the highest class of cargo that can be sent to this point. The number 6 means you can send special medical equipment and drugs. A different example is shown in Figure 45 that depicts delivery point with the code D-C-3/4. The difference between E-E-6 and D-C-3/4 delivery points is that the personnel at the landing site are not medically trained. The numbers 3/4 refer to the fact that class 3 materials and conditionally class 4 cargo can be sent. The FOB commanding officer makes this decision.

Figure 44: Example of E-E-6 delivery point

Figure 45: Example of D-C-3/4 delivery point

A second computer workstation that works as a **system administrator** is necessary for the simulation. This workstation is to turn the simulation on and off and manage it during a flight. Figure 46 shows the workstation of the simulation administrator, and Figure 47 displays a simulation administrator during a flight.

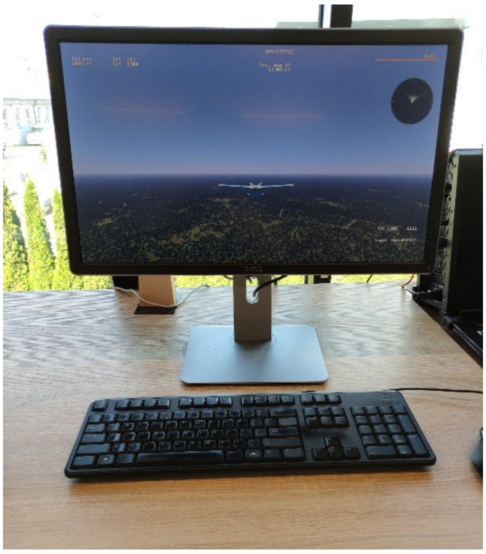


Figure 46: A workstation for simulation administrator

Figure 47: Simulation administrator during simulation

Demonstration flights were divided into stages. In each stage, a particular number of flights hours is planned. The flight hours for each stage were as follows.

- Basic integration flights – 40 h 14 m
- Basic delivery scenario flights 40 h 44 m
- Long duration flights – 40 h 40 m
- Malfunction/crash flights – 41 h 08 m
- Full mission tests flights – 253 h 33 m
- Demonstration flights – 75 h 18 m

During the HERoS project, 128 flights were made, with a total flight time of 491 hours and 37 minutes. Figure 48 shows the cumulative flight hours of the simulation, Figure 49 the percentage distribution of these across stages.

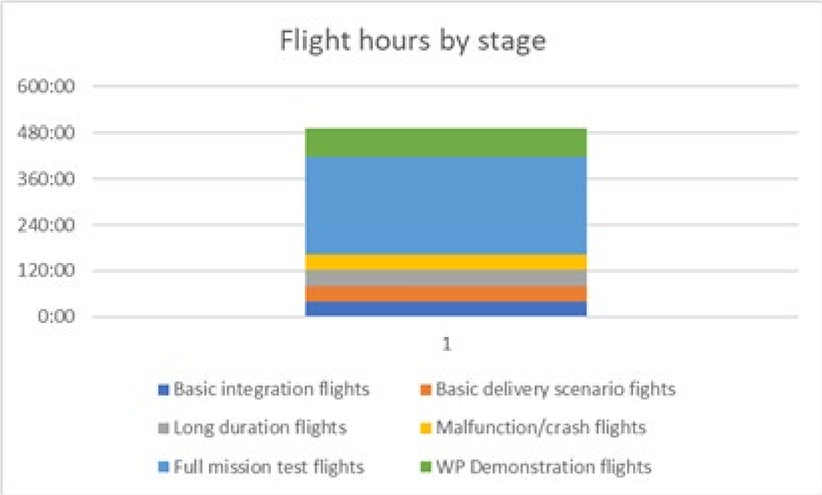


Figure 48: Cumulative flight hours

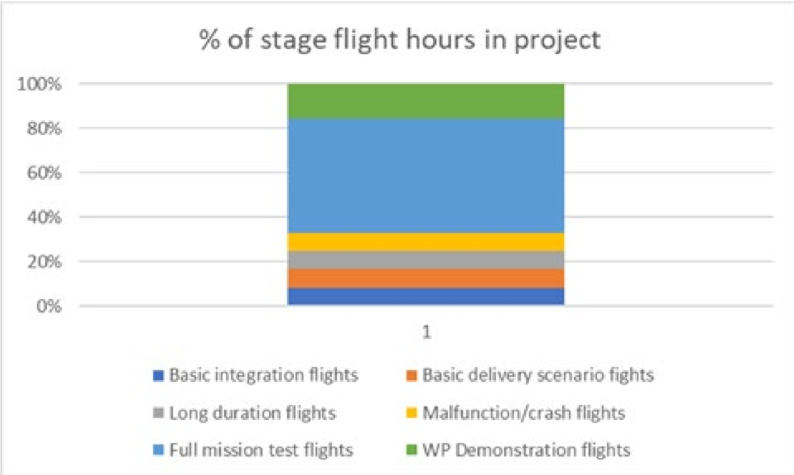


Figure 49: Percentage of flight hours in each stage

The GCS was integrated with the developed aircraft model while flying flights in the simulation to perform the planned stages. The integration allowed for the creation of tools for performing simulated flights. The flights enabled the development of scenarios for medical humanitarian aid delivery. The first key parameter that needed confirmation was the aircraft's cruising speed. During the initial analysis, different speeds were tested. The final speed of the aircraft in the simulation was 280-300 km/h, which is a tourist aircraft's average cruising speed range. The average flight duration for the entire project was 3 hours and 50 minutes.

Figure 50 shows the resultant flight hours per week in the HERoS project. The simulation started in week 69 and ended in week 116 of the project.

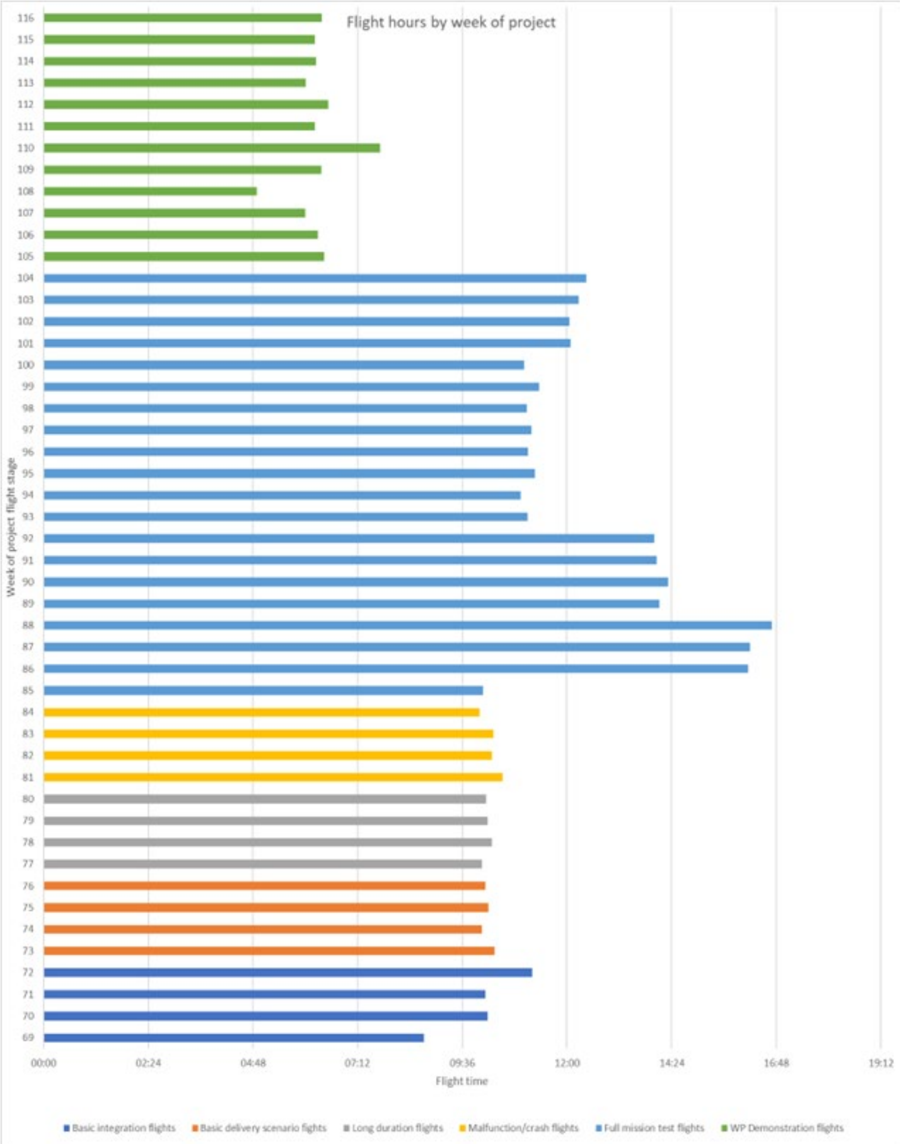


Figure 50: Flight hours per week in the HERoS project

The goals and results of the simulations are as follows:

- To determine the amount of time for deliveries by drone over a given distance. The delivery times assumed at the start of the project for the delivery of the aid were confirmed. For future commercialisation of the UAV system, the cruising speed should be assumed at about 300 km/h.
- To check the working conditions of the pilot during a long-unmanned flight. Despite using principles of ergonomics to design the computer workstations, it was found that the vertical positioning of the screens is less tiring for the pilot. The legitimacy of using commercial solutions in manual drone control is also confirmed.
- To check whether the GCS system would work in a distributed environment. Using off-the-shelf parts confirmed the possibility of working in a distributed environment, where several control rooms (RUPC) must work with each other during flights with many planes distributed globally.
- To define conditions to be met by landing sites to support drone deliveries. Thanks to the use of simulations, many flights were made, which made it possible to determine the landing sites

for future delivery needs. In addition, the range of problems encountered during flights, landing, and discharging led to the development of landing pad codes and the Go-No-Go matrix.

- To identify the possibility of creating drone airbridges for medical humanitarian deliveries. The simulations confirmed the legitimacy of building air bridges using UAVs. However, various problems encountered during the simulation have resulted in solutions such as adding an airlift co-ordination centre for airplane management.

9. Recommendations for medical deliveries

This section notes the recommendations resulting from the simulation of delivery flights using single and airlift drones. First, there is a **need to develop a proposal for international and local UAV delivery rules.** It is also necessary because regional rules may change while delivering medical humanitarian cargo. These rules must include:

- Uniform rules of air traffic connectivity and automatic dependent surveillance-broadcast (ADS-requirements
- Approvals for take-off and landing operations
- A definition of radio (voice) communication
- Standard definitions of the customs duty system
- Specifications of the liability system for aviation
- Specifications of the applicable laws to the flight. This is critical because the pilot while flying a UAV, may fall under two different legal systems. Therefore, the pilot must know which laws to follow.

The above principles can be implemented in the form of an international convention.

Second, there is a **need to have UAV control rooms all over the world**. Ensuring continuity of supply is a critical element of drone relief operations. This requires having many GCS placed in properly prepared places.

Third, two areas need to be addressed if UAV delivery is to become the standard in medical deliveries. At first, **global standards for drone deliveries need to be developed**. Currently, drone deliveries have a maximum payload of 2 kg. In this project, drone delivery is tested for a payload of 150 kg. Therefore, authorities, regions, and countries need to start thinking about developing standards for large cargo drones so that standards can evolve with increasing payload, size, and range. Next, **large drone operations will require access to airports and air traffic control**. For the case of medical humanitarian cargo, it is suggested that FOBs can be placed in airports managed by the UN or UN forces. This may require separate arrangements for UAV operations.

Fourth, it is necessary to **develop a delivery mission description code** because there is no pilot onboard a UAV to visually determine the conditions of the landing site and react to the obstacles. Consequently, there is a need to keep the information on landing sites up to date. Landing sites can be categorised to determine whether they are suitable for landings and take-offs. Therefore, a delivery mission description code must be created to streamline delivery operations. The delivery mission description code is the starting point for assigning a mission to be performed. Each mission can be coded with two letters and a number as depicted in Figure 51. The figure also illustrates the description of the individual codes. The description must include the landing site category, staff attendance, and supply class. Therefore, the code will specify the landing site, the type of personnel present at the site, as well as the type of goods that can be supplied to the site.

LANDING POINT			PERSONEL PRESENCE		CLASS OF SUPPLY	
A	UNKNOWN	no data in database	**A**	no personel	**1**	water
B	LITTLE KNOWN	picture (unknown time) or last delivery more than 6 months earlier	**B**	no cargo handling trained	**2**	bondages, wheat, water
C	POSSIBLE	last delivery no earlier than 6 months or last picture no earlier than 6 months	**C**	cargo handling trained	**3**	food, drinks, medical kits, clothes
D	CONFIRMED	last delivery no earlier than 3 month or last picture no eralier than 3 month or checked on site by ground team (3 months)	**D**	basic medical training	**4**	medicines
E	KNOWN	last delivery no eariler than 1 month or checked on site by ground team (1 month)	**E**	medics	**5**	simple medical equipment (ie. Blood pressure monitor)
F	REGULAR	last delivery no earlier than 1 day	**F**	doctor	**6**	medical special equipment (ie. Respirators) , drugs

Figure 51: Delivery missions code

Figure 52 presents a go-no-go matrix. On the left side, there is a description of the landing site and the associated code letter. On the right are the characteristics of the personnel present at the landing site and the corresponding code letter. At the bottom, there are codes for the supply class. The classes have been divided from 1 to 6, and examples of typical supply items are given. Figure 53 illustrates how to use such a go-no-go matrix.

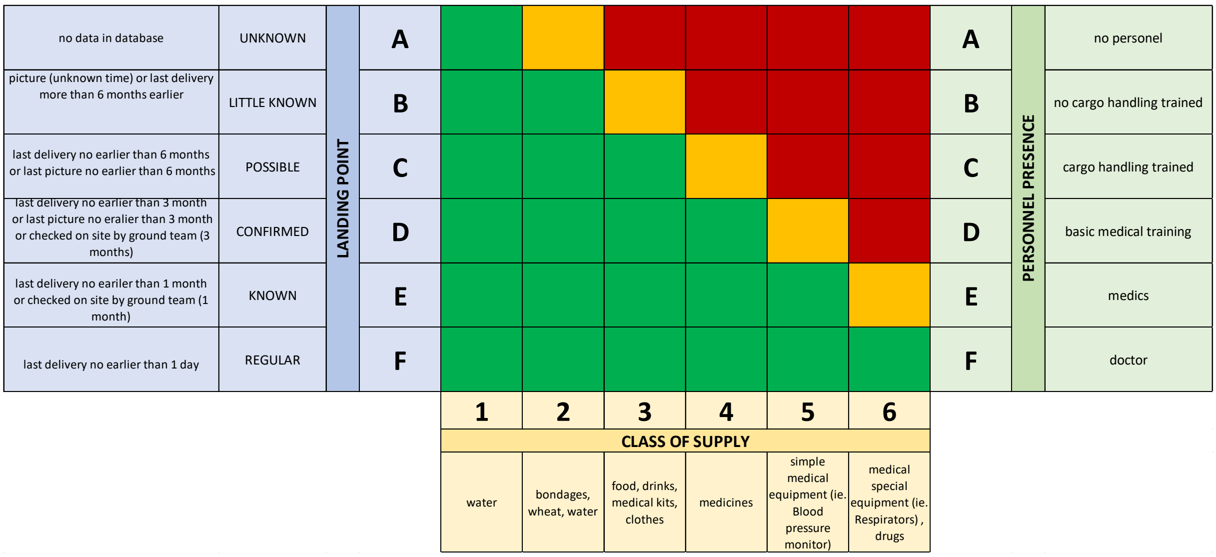


Figure 52: A Go – No-Go matrix

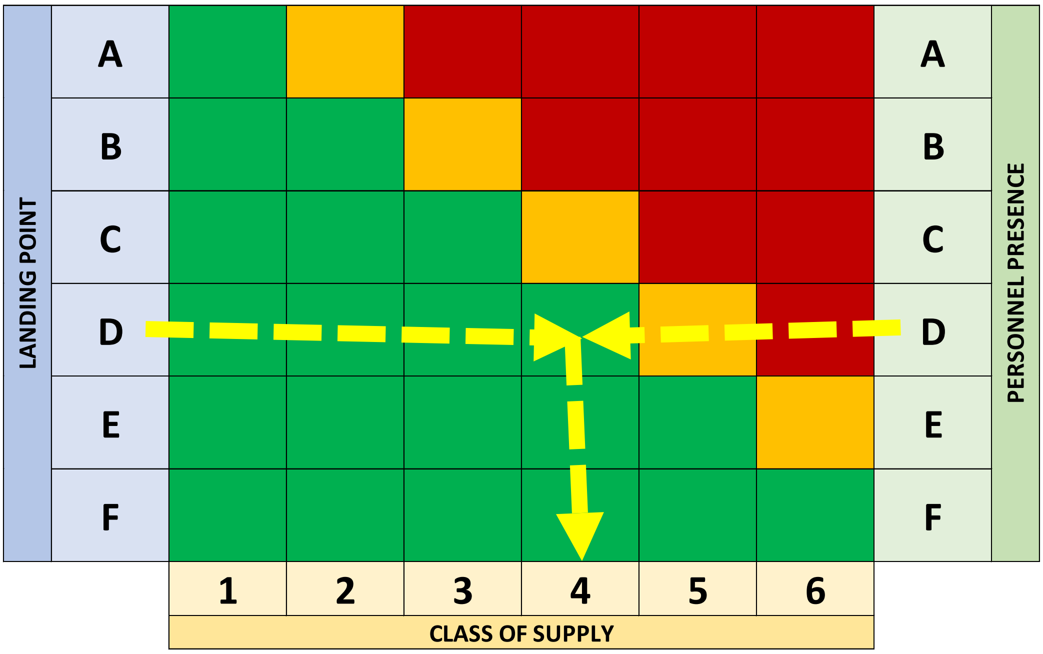


Figure 53: Example 1 of how to use a GO-No-Go matrix

The red colour areas of the go-no-go matrix indicate that due to the absence of humans on board a UAV, it may not be possible to provide a higher supply class of items such as medical equipment because of the personnel level at the landing site. In the example in Figure 54, F-C means that a delivery cannot be made for a supply class higher than 3 or, under special conditions, supply class 4. Such a mission would be coded as F-C-3 or F-C-2.

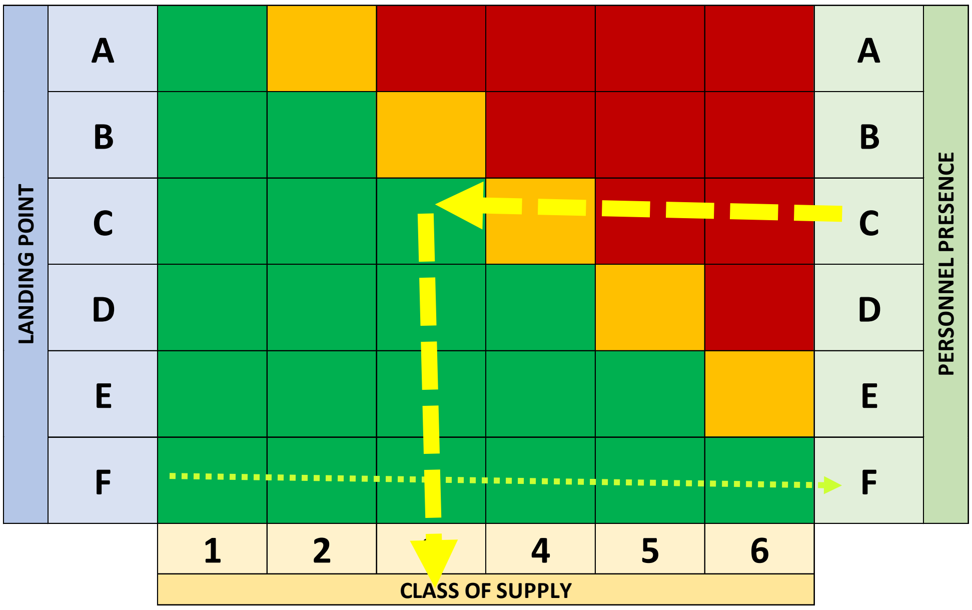


Figure 54: Example 2 Go-No-Go matrix

Finally, as discussed in D3.2, medical deliveries are often restricted to be handled, and thereby received, by medical personnel with specific licences. Which personnel this is (e.g., pharma technician, nurse, or doctor) depends on the actual cargo, as well as the regulations in the country of the delivery. On the other hand, from the perspective of reducing any potential contagion in a pandemic, and also, the risk of anybody tampering with the UAV at the reception site, air drops are also considered. Typically, these would be to pre-determined delivery points where it can be controlled who can access the cargo. Thus, airdropping with parachutes can be a potential solution for delivering emergency supplies. Figure 55 depicts a hypothetical airdrop scenario.

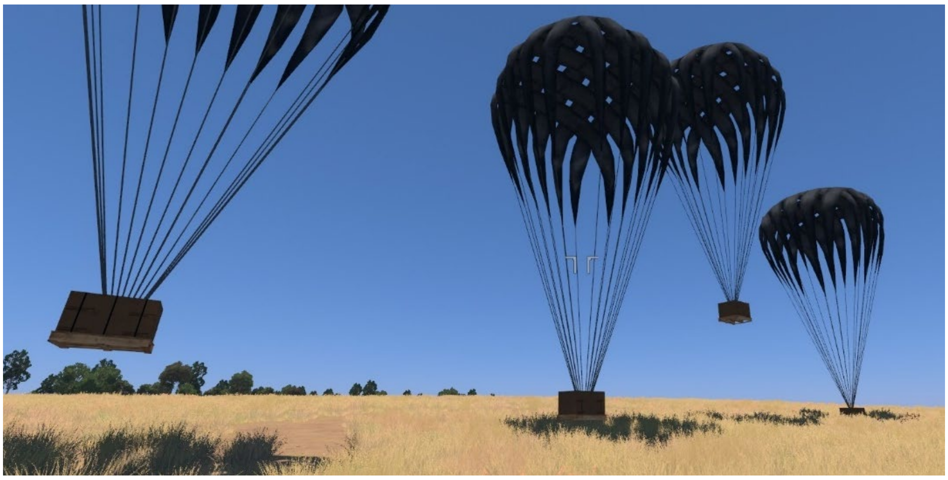


Figure 55: Parachute dropping during simulated cargo flights

From the perspective of flying an UAV, there are several advantages of an airdrop over traditional landing and take-offs. These are as follows:

- Low drop altitude for more accurate delivery.
- Possibility of delivery of equipment and goods such as radio batteries, stretchers, and rations for health care facilities in remote locations.
- Fast rotation of drone deliveries.
- Prevention from unwanted people on board after unloading.
- No danger for personnel on the ground because of the plane's propeller.
- No danger for the plane from people on the ground.
- Avoiding most critical phases of the aerial route (landing and take-off)

Under the HERoS project, supply drops are tested during the simulation. These tests confirm the technical use of this type of cargo delivery. However, the delivery must have a mission code checked against a go-no-go matrix.

10. Standard Operating Procedures

HERoS also developed a set of standard operating procedures (SOPs) for UAVs used for medical cargo. SOPs are essential to unify the rules of cargo flights during medical humanitarian operations. An SOP is a set of step-by-step instructions to help concerned personnel carry out routine procedures efficiently. SOP facilitates achieving efficiency, output quality, and performance uniformity while reducing the chance of miscommunication and non-compliance with industry regulations. Figure 56 provides an overview of the sets of SOPs and their connections to one another. The SOPs are divided behind functional areas. Each of them can be used also separately. However, they complement each other and, as a set, constitute a proposal for the organisation of the supply system.

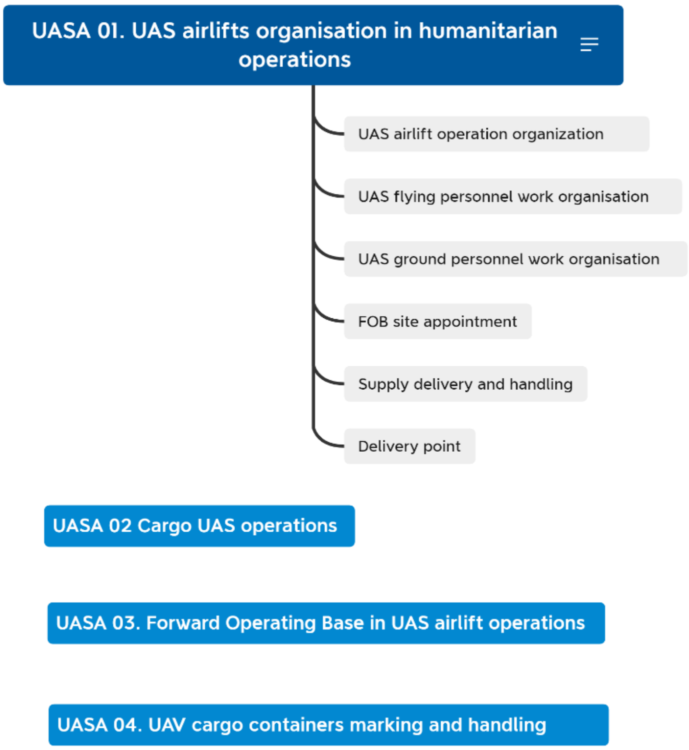


Figure 56: Proposed SOPs

The most crucial document is the procedure UASA-01 (Unmanned Aircraft Systems Airlifts 01) – UAS airlifts organisation for medical deliveries. This is a basic SOP that describes:

- Airlifts operations organisation
- UAV flying personnel work organisation
- Ground personnel work organisation
- FOB site appointment
- Supply delivery and handling
- Delivery point operations

The second SOP needed in operations is Cargo UAS Operations (UASA-02). This SOP gives guidelines for organising cargo flights without arranging airlifts. This is necessary when a few planes are operating, and an airlift organisation is impossible. This SOP describes the organisation of flights and required flight security.

The third proposed SOP is Forward Operating Base in UAS airlift operations (UASA-03). It describes the rules for the implementation of tasks in the FOB. It defines the scope of responsibilities and activities in a FOB.

The fourth and last SOPs is Cargo container marking and handling (UASA-04). For the right medical materials to reach the right places, it is necessary to have landing pad and personnel and properly packed materials and equipment.

The detailed SOPs are provided in the Annex to D3.3.

11. Conclusions

Deliverable 3.3 sets out to report the following:

- All legal, organisational, and technical conditions to be fulfilled for long-range flights, including the update of procedures according to changes in international or local law,
- The technical description of the UAV system for long-range flights,
- Safety precautions and limitations for this flight,
- Connection of UAV system with SESAR and U-Space,
- Descriptions of a full mission simulator include a ground control station, a flying platform for medicine transport, communication, air traffic requirements, airworthiness, logistic, and others.
- UAV system tests and crew familiarisation,
- Necessary training and courses for personnel
- Description of a simulated UAV long-range flights for medical deliveries,
- Recommendations for UAVs for medical deliveries under pandemic conditions, and
- Standard operating procedures (SOPs)

All the above points are covered in this report. As highlighted in the literature review section, a comprehensive legal framework regarding legal obligations, liabilities, roles, and responsibilities of an integrated Unmanned Traffic Management (UTM) system is required (Ryan *et al.*, 2020). Delivering medical items to remote locations remains challenging (Rejeb *et al.*, 2021). This is because health facilities or NGOs receiving drone deliveries in remote regions need to have proper infrastructure as well as trained personnel to handle medical items such as vaccines and test samples. Medical deliveries are particularly critical because some items, such as for vaccines, a cold chain needs to be maintained (Comes, Bergtora Sandvik and Van de Walle, 2018). The technical conditions for drone deliveries include obstacle detection and avoidance, reliable communication, cyber security, operational reliability, and unmanned traffic management.

The conclusions from the experience of developing a full mission simulator are as follows.

- Deliveries to quarantine zones are characterised by problems related to the isolation of people. A drone with a load capacity of 150 kg can theoretically carry a human. Drones delivering cargo to quarantine zones must have a system to restrict people from boarding. Such a person may block the ramp, and the plane may be disconnected from the airlift.
- The delivery system to quarantine zones must also provide for decontamination of the aircraft on return. This will take some time and cause the airlift to stretch over time.
- A draft international agreement specifying rules and regulations for cargo drones for medical and humanitarian aid deliveries should be developed. Such a convention must consider flight matters and the legal system in which flying pilots should operate. Because there are no universal drone navigation rules, there may be a situation where pilots may not be able to fly drones at all.
- There is a need to develop customs duties for drone flights. The issue of customs duties will become relevant when long-distance cargo flights are launched. Also, smuggling may occur during large cargo shipments; therefore, commodity trading procedures must be strictly followed.

- Cargo drones are faster than cargo flights. As a result, in case of emergency deliveries, using cargo drones may be beneficial and may contain low-volume-high-value items.

Conclusions for drone cargo missions and delivery system:

- Flying personnel outside the delivery period must be grouped similarly to airline personnel. The difference is that in airlines, pilots travel around the world, while in the drone delivery system, they live near RUPC. Nevertheless, they should be provided with the appropriate level of training. Additionally, a qualification improvement system with clearly defined experience levels should be developed. This will later lead to the advancement of pilots at all levels, up to the level of instructor at the end of the career. To ensure this, the ACC must also be held responsible for the welfare of pilots and technical staff.
- Personnel qualifications for long-haul cargo flights should be similar to that of truck drivers. The pilot must have good hand-eye co-ordination.
- UAV pilot centres should be created as regional centres where GCS can be placed. The centres should be reliably connected with other elements of the system. The centres should have secured access. After receiving the call from the ACC, the remote control comes to the centre and starts the GCS. It connects with the elements needed to complete the mission. Then the pilot receives an assigned plane to fly. The centres must be accessible to people in wheelchairs.
- ACC must act as a reporting centre. In addition to operational matters, the ACC must contain administrative information, i.e., holidays, sick leaves, etc.
- The landing field should meet the standard requirements for the landing field. It is best if the landing field is a hard surface. Therefore, the role of ACC is to maintain a database of landing sites and road sections on which the plane can land.
- The RUPC room should have the following:
  - GCS deployment space
  - pilot's seat
  - a computer with the Internet and access to weather servers
  - social corner
  - access to a toilet
  - headphones and microphone
  - note-taking tools
  - a device for checking sobriety at any time
  - cameras
  - secure access
  - wheelchair access
- In addition to the GCS, the centre for pilots should have access to social facilities, i.e., toilets, kitchens, etc. It should be assumed that the pilot must use the restroom during the flight. Since in cargo flights, a long autopilot flight is assumed, and at the same time, the pilot is alone during the mission, another issue of the organisational solution is the transfer of control when pilot is not at his seat. The simulations did not give a clear answer to this issue. It has to do with the conceptual level of the aircraft. To determine the above, a design is needed at the executive design level.
- General course of training must be created for pilots at a level not lower than Private Pilot License (PPL). The training system must support the habits of pilots and technicians. Because a drone pilot can be from anywhere in the world, a single standard for maintaining habits is required. This will require a system of certificates and authorisations for pilots and technicians.

Due to the novelty of such a system in unmanned aviation, the habit maintenance system will probably have to be built from scratch. It is also related to the fact that pilots will have habits for specific equipment. Added to this is that unmanned aviation has no single control stud, and each GCS solves the controls differently. Nevertheless, flight and ground personnel will need to receive training to maintain their habits. For pilots, this may be done by periodic checks on the GCS at the RUPC.

Some challenges encountered during the project were as follows:

- An early conceptual model of the aircraft, which did not allow for several analyses related to its operation, measurement of technicians' working time, etc. modelling the plane and introducing the masses that we planned in the conceptual design allowed us to move only in the concept area, which resulted in the simplification of, e.g., engine thrust.
- Budget limitations did not allow to build of a mock-up. During the project, it turned out that it was necessary to make a full-size mock-up to check things live. The matters to be checked in the mock-up would be:
  - charging and discharging (currently based on dimensions)
  - load space comfort
  - drop ropes placed
  - solutions for lowering and raising the ramp
  - availability of points when servicing, e.g., fuel filler
  - chassis spacing
  - placement of cameras
- The last limitation was the lack of an eye-tracking system. In the course of work on the control station screen, we concluded that the screen should be examined with an eyeball tracker.

Bibliography

Adwibowo, A. (2021). Assessments of heavy lift UAV quadcopter drone to support COVID 19 vaccine cold chain delivery for indigenous people in remote areas in South East Asia. *medRxiv pre-print*, at https://www.medrxiv.org/content/10.1101/2021.01.09.21249494v1

Allouch, A., Cheikhrouhou, O., Koubâa, A., Toumi, K., Khalgui, M., & Nguyen Gia, T. (2021). Utm-chain: blockchain-based secure unmanned traffic management for internet of drones. *Sensors*, 21(9), 3049.

Amukele, T. (2020). The economics of medical drones. *The Lancet Global Health*, *8*(1), e22.

Aurambout, J. P., Gkoumas, K., & Ciuffo, B. (2019). Last mile delivery by drones: An estimation of viable market potential and access to citizens across European cities. *European Transport Research Review*, *11*(1), 1-21

Balasingam, M. (2017). Drones in medicine—the rise of the machines. *International journal of clinical practice*, *71*(9), e12989.

Bassi, E. (2019). European drones regulation: Today's legal challenges. In 2019 *International Conference on Unmanned Aircraft Systems* (ICUAS), 443-450.

Chamola, V., Hassija, V., Gupta, V., & Guizani, M. (2020). A Comprehensive Review of the COVID-19 Pandemic and the Role of IoT, Drones, AI, Blockchain, and 5G in Managing its Impact. *IEEE Access*, 8 (*April),* 90225- 90265.

Chen, H., Hu, Z., & Solak, S. (2021). Improved delivery policies for future drone-based delivery systems. *European Journal of Operational Research*, *294*(3), 1181-1201.

Comes, T., Bergtora Sandvik, K. & Van de Walle, B. (2018). Cold chains interrupted: The use of technology and information for decisions that keep humanitarian vaccines cool. *Journal of Humanitarian Logistics and Supply Chain Management*, 8(1), 49-69.

DeBusk, W. (2010). Unmanned aerial vehicle systems for disaster relief: Tornado alley. In *AIAA Infotech@ Aerospace 2010,* 3506.

Doole, M., Ellerbroek, J., & Hoekstra, J. (2018). Drone delivery: Urban airspace traffic density estimation. In *SIDs2018: 8th SESAR Innovation Days*.

EASA (2018). *Easy Access Rules for Airworthiness and Environmental Certification*. Available at: https://www.easa.europa.eu/sites/default/files/dfu/Easy Access Rules for Part-21.pdf%0Ahttps://www.easa.europa.eu/document-library/general-publications/easy-access-rules-initial-airworthiness.

EASA (2019). *Get a Part-66 licence*, *European Union Aviation Safety Agency*.

EASA (2020). *Regulations on UAS (drone) explained*. Available at: https://www.easa.europa.eu/the-agency/faqs/drones-uas.

EASA (2021). *Easy Access Rules for Unmanned Aircraft Systems (Regulation (EU) 2019/947 and Regulation (EU) 2019/945)*. Available at: https://www.easa.europa.eu/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulation-eu.

EASA (2022). *Uas Operations in the 'Open' Category*.

EUCHI, J. (2020). Do drones have a realistic place in a pandemic fight for delivering medical supplies in healthcare systems problems?, *Chinese Journal of Aeronautics*, 34(2), pp. 182–190.

European Commission (2021). Commission Implementing Regulation (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space, Official Journal of the European Union, 161–183. Available at: https://eur-lex.europa.eu/eli/reg_impl/2021/664/oj.

Falagara Sigala, I.; Sirenko, M.; Comes, T. & Kovács, Gyöngyi (2022). Mitigating Personal Protective Equipment (PPE) supply chain disruptions in pandemics – a system dynamics approach, *International Journal of Production and Operations Management,* Vol.42 No.13, pp.128-154, doi: 10.1108/IJOPM-09-2021-0608

Farooqui, S. (2020). Ontario First Nation to receive pandemic supplies through drone shipments, *Toronto Star*, 16 (August). Available at: https://www.thestar.com/news/canada/2020/08/16/ontario-first-nation-to-receive-pandemic-supplies-through-drone-shipments.html.

Federal Aviation Administration (2019). *Unmanned Aircraft System (UAS) Traffic Management (UTM), Enabling Civilian Low-altitude Airspace and Unmanned Aircraft System Operations*.

Giordan, D., Adams, M.S., Aicardi, I., Alicandro, M., Allasia, P., Baldo, M., Berardinis, P. D., Dominici, D., Godone, D., Hobbs, P., Lechner, V., Niedzielski, T., Piras, M., Rotilio, M., Salvini, R., Segor,V., Sotier, B., & Troilo, F. (2020). The use of unmanned aerial vehicles (UAVs) for engineering geology applications', Bulletin of Engineering Geology and the Environment, 79(7), 3437–3481.

Greenwood, F., Nelson, E. L. & Gregg Greenough, P. (2020). Flying into the hurricane: A case study of UAV use in damage assessment during the 2017 hurricanes in Texas and Florida, *PLoS ONE*, 15(2), 1–30.

Guan, D., Wang, D., Hallegatte, S., Davis, S. J., Huo, J., Li, S., Bai, Y., Lei, T., Xue, Q., Coffman, D., Cheng, D., Chen, P., Liang, X., Xu, B., Lu, X., Wang, S., Hubacek, K., & Gong, P. (2020). Global supply-chain effects of COVID-19 control measures, *Nature Human Behaviour*, 4(6), 577–587.

Haidari, L. A., Brown, S. T., Ferguson, Emily, B., Spiker, M., Wilcox, A., Ambikapathi, R., Sampath, V., Connor, D. L., & Lee, B. Y. (2016). The economic and operational value of using drones to transport vaccines, *Vaccine*, *34*(34), 4062–4067.

Hosseini, N., Jamal, H., Haque, J., Magesacher, T., & Matolak, D. W. (2019). UAV Command and Control, Navigation and Surveillance: A Review of Potential 5G and Satellite Systems, *IEEE Aerospace Conference Proceedings*, 1–10.

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case, *Transportation Research Part E: Logistics and Transportation Review*, 136(January).

Jakhar, P. (2020). Coronavirus: China's tech fights back, *BBC News*, 1–12. Available at: https://www.bbc.com/news/technology-51717164.

Jeong, H. Y., Song, B. D. & Lee, S. (2019). Truck-drone hybrid delivery routing: Payload-energy dependency and No-Fly zones, *International Journal of Production Economics*, 214(January), 220–233.

Johnson, A. M., Cunningham, C. J., Arnold, E., Rosamond, W. D., & Zègre-Hemsey, J. K. (2021). Impact of using drones in emergency medicine: What does the future hold?, Open Access Emergency Medicine, 13, 487–498.

Jones, T. (2017). *International commercial drone regulation and drone delivery services* (No. RR-1718/3-RC). Santa Monica, CA, USA: RAND.

Kovács, G. & Falagara Sigala, I. (2021). Lessons learned from humanitarian logistics to manage supply chain disruptions, *Journal of Supply Chain Management,* Vol.57 No.1, pp.41-49, doi: 10.1111/JSCM.12253

Kunovjanek, M. & Wankmüller, C. (2021). Containing the COVID-19 pandemic with drones - Feasibility of a drone enabled back-up transport system, *Transport Policy*, 106, 141–152.

Lemmens, S. Decouttere, C., Vandaele, N., & Bernuzzi, M. (2016). A review of integrated supply chain network design models: Key issues for vaccine supply chains, *Chemical Engineering Research and Design*, 109, 366–384.

Ling, G. & Draghic, N. (2019). Aerial drones for blood delivery', *Transfusion*, 1608–1611.

Mcnabb, M. (2020). Drone Delivery for Coronavirus : Drone Delivers Test Samples to Lab in 7 Minutes, *dronelife*. Available at: https://dronelife.com/2020/06/04/drone-delivery-for-coronavirus-in-germany/.

Nguyen, P. H., Arsalan, M., Koo, J. H., Naqvi, R. A., Truong, N. Q., & Park, K. R. (2018). LightDenseYOLO: A Fast and Accurate Marker Tracker for Autonomous UAV Landing by Visible Light Camera Sensor on Drone, *Sensors*, 18(6), 1703.

Poljak, M. & Šterbenc, A. (2020). Use of drones in clinical microbiology and infectious diseases: current status, challenges and barriers, *Clinical Microbiology and Infection*, 26(4), 425–430.

Prevot, T., Rios, J., Kopardekar, P., Robinson III, J. E., Johnson, M., & Jung, J. (2016). UAS Traffic Management (UTM) Concept of Operations to Safely Enable Low Altitude Flight Operations, in *16th AIAA Aviation Technology, Integration, and Operations Conference AIAA*, 1–16.

Rejeb, A., Rejeb, K., Zailani, S., Treiblmaier, H., & Hand, K. J. (2021). Humanitarian Drones: A Review and Research Agenda', *Internet of Things (Netherlands)*, 16(May), 100434.

Roca-Riu, M. & Menendez, M. (2019). Logistic deliveries with drones State of the art of practice and research', in *19th Swiss Transport Research Conference*.

Ryan, R., Al-Rubaye, S., Braithwaite, G., & Panagiotakopoulos, D. (2020). The Legal Framework of UTM for UAS', in *AIAA/IEEE Digital Avionics Systems*, 10–14.

Schenkelberg, F. (2016). How reliable does a delivery drone have to be?, *Proceedings - Annual Reliability and Maintainability Symposium*, 2016 (April).

Scott, J. E. & Scott, C. H. (2017). Drone delivery models for healthcare, *Proceedings of the Annual Hawaii International Conference on System Sciences*, 2017(January), 3297–3304.

SESAR (2016). *European Drones Outlook Study*, *Single European Sky ATM Research*. Available at: http://www.sesarju.eu/sites/default/files/documents/reports/European_Drones_Outlook_Study_2016.pdf.

SESAR (2017). *U-space Blueprint*, *SESAR Joint Undertaking*. doi: 10.2829/614891. Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.sesarju.eu/sites/default/files/documents/reports/U-space%20Blueprint%20brochure%20final.PDF

SESAR (2021). *Delivering drone solutions for smart and sustainable air mobility and innovation in a nutshell*. Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.sesarju.eu/sites/default/files/documents/reports/U-space RandI portfolio.pdf.

SESAR (2022). *Delivering the digital future*, *SESAR Joint Undertaking*. Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.sesarju.eu/sites/default/files/documents/reports/SESAR%203%20launch%20brochure.pdf

Skorup, B. & Haaland, C. (2020). How Drones Can Help Fight the Coronavirus, *SSRN Electronic Journal*.

Slabinac, M. (2015). Innovative solutions for a last-mile delivery, *International Scientific Conference Business Logistics in Modern Management*, 111–129.

Sperry, D., Schuster, A. M., Cotten, S. R., Agrawal, S., Mack, E., Britt, N., & Liberman, J. (2022). Trucking in the Era of COVID-19. *American Behavioral Scientist*, 00027642211066039.

Tan, L. K. L., Lim, B. C., Park, G., Low, K. H., & Yeo, V. C. S. (2021). Public acceptance of drone applications in a highly urbanized environment, Technology in Society, 64(December 2020), 101462.

U-Space (2022) *Rolling Plan ICT Standardisation (For Rolling plan for ICT standardisation*, *U-Space*. Available at: https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/u-space-0.

Vaishya, R., Haleem, A., Vaish, A., & Javaid, M. (2020). Emerging Technologies to Combat the COVID-19 Pandemic, *Journal of Clinical and Experimental Hepatology*, 10(4), 409–411.

Vizvári, B., Golabi, M., Nedjati, A., Gümüşbuğa, F., & Izbirak, G. (2019). Top-down approach to design the relief system in a metropolitan city using UAV technology, part I: the first 48 h', *Natural Hazards*, 99(1), 571–597.

Yu, X. and Zhang, Y. (2015). Sense and avoid technologies with applications to unmanned aircraft systems: Review and prospects', *Progress in Aerospace Sciences*, 74, 152–166.

PURPOSE

The purpose of this SOP is to establish airlifts using UAS to deliver humanitarian and medical aid in regions hit by natural disasters. The legitimacy of this SOP can be used to organize airlifts to all regions where the delivery of medical and humanitarian aid by traditional methods is difficult or impossible. The SOP also provides guidance on the organization of the airspace in case of the necessity of deliveries using UAS

SCOPE

This SOP covers:

- rules for the organization of air deliveries using UAS
- principles of organization of work of flying personnel
- rules of organization of work of technical personnel
- principles for Forward Operating Base (FOB)
- rules for delivering materials to FOB and handling them until loading to UAS
- rules of operation at the place of unloading / dropping

This SOP does not covers:

- Cargo UAS flights and aerials operations (see: UASA 02)
- Detailed organization and operation of FOB (see: UASA 03)
- UAV cargo containers marking system and handling (see: UASA 04)

RESPONSIBILITIES

A summary of the roles listed in the procedure and the responsibilities of each role holder for the procedures detailed in the SOP.

The details of the responsibilities should be a brief list of the key tasks performed. This section should not be a complete summary of the SOP.

INTERNAL REFERENCES

Insert relevant references as required, sufficient for the user to find the source document.

EXTERNAL REFERENCES

Insert relevant references as required, sufficient for the user to find the source document. Web references should be included were possible.

GENERAL

1. AIRLIFT OPERATION ORGANIZATION

Airlifts are the most complicated way to use UAS in humanitarian operations. They require high-quality work from every team member participating in airlifts. The involved personnel must demonstrate the accuracy and timeliness of the tasks performed.

Pay attention to adhere to the times and themes. Time is a key element of the whole project. Airlifts are a series of successive events, one of which results from the other. Therefore, any delay affects the sequence of events that follows. Accumulation of delays and errors may lead to emergencies or accidents.

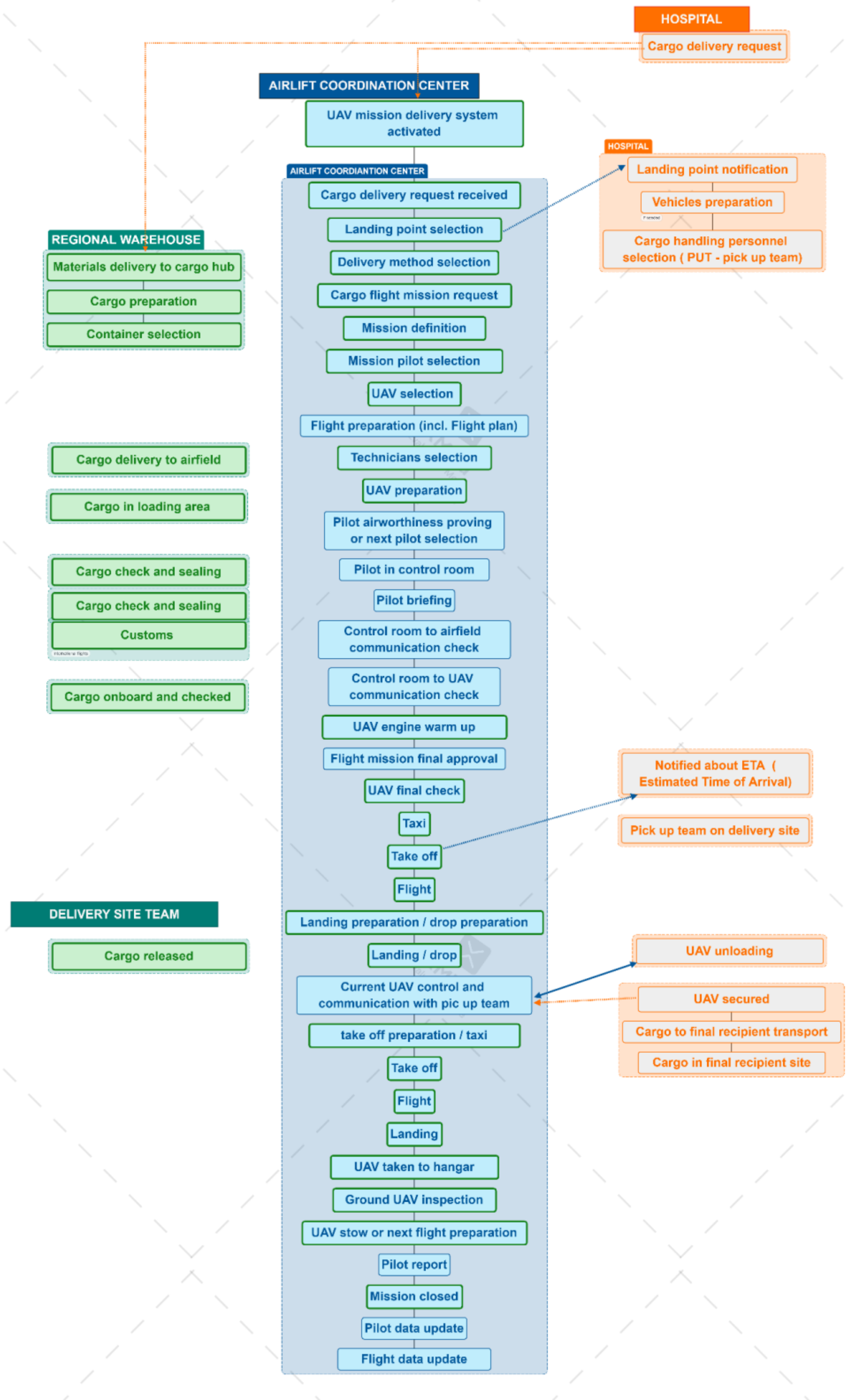
The course of the delivery mission by the UAV is shown in the diagram.

Operation of the airlift ACC:

- obtain a cargo delivery request,
- choose a landing point,
- choose a delivery method,
- issue a cargo mission request,
- select pilots and RUPCs,
- choose planes,
- confirm aircraft availability,
- order preparation (select technicians),
- establish separations between airplanes,
- activate RUPC,
- Prepare flight plans (or data for flight plans for pilots)
- hand over the direction of airplanes to the appropriate RUPCs control
- the sequence of take-offs and landings control the entire airlift,
- check the completion of missions by pilots
- make the wrong assignment of pilots to airplanes,
- make current cargo settlements
- perform an ongoing control of fuel consumption by the airlift
- regularly check the wear of spare parts
- apply for deliveries,

Separations between planes should be selected depending on the situation, in such a way as to allow people who are there to unload the plane at delivery point.

It is better to aim for uninterrupted deliveries rather than delivering everything as quickly as possible.



HOSPITAL
Cargo delivery request
AIRLIFT COORDINATION CENTER
UAV mission delivery system activated
AIRLIFT COORDIANTION CENTER
Cargo delivery request received
Landing point selection
Delivery method selection
Cargo flight mission request
Mission definition
Mission pilot selection
UAV selection
Flight preparation (incl. Flight plan)
Technicians selection
UAV preparation
Pilot airworthiness proving or next pilot selection
Pilot in control room
Pilot briefing
Control room to airfield communication check
Control room to UAV communication check
UAV engine warm up
Flight mission final approval
UAV final check
Taxi
Take off
Flight
Landing preparation / drop preparation
Landing / drop
Current UAV control and communication with pic up team
take off preparation / taxi
Take off
Flight
Landing
UAV taken to hangar
Ground UAV inspection
UAV stow or next flight preparation
Pilot report
Mission closed
Pilot data update
Flight data update
HOSPITAL
Landing point notification
Vehicles preparation
Cargo handling personnel selection (PUT - pick up team)
REGIONAL WAREHOUSE
Materials delivery to cargo hub
Cargo preparation
Container selection
Cargo delivery to airfield
Cargo in loading area
Cargo check and sealing
Cargo check and sealing
Customs
Cargo onboard and checked
Notified about ETA (Estimated Time of Arrival)
Pick up team on delivery site
DELIVERY SITE TEAM
Cargo released
UAV unloading
UAV secured
Cargo to final recipient transport
Cargo in final recipient site

2. AIRLIFTS COORDINATION CENTER – ACC

The Airlift Coordination Center (ACC) ACC is the flight dispatcher's hub and the brain of the entire system.

2.1. ACC is responsible for:

- maintaining an up-to-date database of pilots,
- maintaining an up-to-date database of technicians,
- maintaining an up-to-date database of landing sites,
- maintaining an up-to-date database of UAV systems (planes and GCSs),
- maintaining an up-to-date database of completed missions,
- maintaining an up-to-date database of international and local aviation regulations,
- organizing staff training
- preparation of an aviation mission,
- approval of the pilot for a given mission
- transmission of control signals to the satellite
- personnel Management,
- making arrangements,
- choosing an aircraft for the mission,
- checking the aircraft for availability,

2.2. ACC is equipped with:

- aircraft database containing information on the validity of certificates, air raid, damage, etc.
- database of pilots including the degree of their training, validity of certificates, personal data, medical track, etc.
- database of landing sites with descriptions, photos, comments, information about obstacles, location technician
- database a statistical database containing flight hours for both pilots and planes.
- database of UAV flight regulations in different countries
- Set of antennas for ground-air communication (with planes)
- Communication devices

2.3. ACC work organization

The work of ACC is managed by the chief of ACC, The ACC chief is responsible for the overall responsibility work of the ACC.

The work of ACC is organized into shifts on duty, which are responsible for the course of current operations.

2.4. A shift of ACC consist of:

2.4.1. Shift commander operators

Shift commander is responsible for:

- organization of the shift on duty,
- decision-making
- issuing permits for flights
- approval of air mission requests
- ongoing communication with the FOB
- organizing deputy personnel
- control airlift according to operational situation

2.4.2. Operator

The operator is responsible for:

- work in your position
- liaising with the pilots of the missions under his care
- sending requests and requests on time
- completing databases
- admission of pilots to flight

3. REGIONAL UAV PILOT CENTER – RUPC

The RUPC is the UAV pilot's work room. RUPCs are deployed outside the theater of operations and connected to the ACC by a communication system that allows the control of the UAV. In some situations, the RUPC may be connected directly to the aircraft control, e.g. if the mission is in a RUPC country / region. A key element in making a decision in this regard is the safety of the aerial platform.

3.1. RUPC EQUIPMENT

- GCS
- computer with weather services
- terminal for communication with ACC
- radio for air and ground radio communications (with technicians in FOB)
- device for checking the sobriety of pilots.
- protected access
- links and cables
- sets of transmitting and receiving antennas

3.2. PILOT PRINCIPLES OF WORK

3.2.1. READINESS

In the case of an airlift, there is a need for an uninterrupted flow of pilots to fly.

Pilots receive their preparedness categories from the ACC.

There are 3 categories of readiness: I, II or III

3.2.1.1. Readiness I:

- Pilot in RUPC ready for take-off,
- Connectivity checked Engines not warmed up
- Delivery pint may be indicated after startup
- The remote control can remain in this standby for 2 hours

3.2.1.2. Readiness II

- Pilot within 2 hours to RUPC
- The remote control can stay in this standby for 24 hours.

3.2.1.3. Readiness III

- Pilot 8 hours from RUPC
- The remote control can remain in this standby for 72 hours

3.2.2. GENERAL FLIGHT FLOWCHART

The procedure of the pilot's work from receiving the task to mission preparation:

- receive mission request,
- check the mission ability checklist,
- confirm acceptance of the mission,
- check the nearest RUPCs, go to RUPC,
- open RUPC protect RUPCs from others during the flight Flight preparation enable GCS,
- check the correctness of GCS operation, connect to ACC,
- check aviation radio,
- check the terrestrial radio,
- check whether the mission is up to date, take the plane number,
- check the weather,
- send the forecast to the ACC,
- open an air mission, enter your name and surname,
- check sobriety, obtain confirmation of taking a sobriety test,
- Confirm the flight plan,
- report readiness to fly,

- get connected to the plane,
- report to a technician,
- order the electrical circuit to be turned on,
- check the control connectivity, check the pressure,
- calibrate the barometer,
- receive a report that the plane is ready,
- check that the ramp is closed (if there is cargo on board),
- check the closing of the nose,
- turn on the circuits,
- turn on the fuel pump,
- check fuel flow to engines,
- check the navigation lights
- check the landing light
- check with anti-collision lights
- check the camera
- check that it is clean around the propeller
- give the command to start the motors
- receive confirmation that the engines are safely
- switched on start the engines
- check the tachometer indications,
- increase the revolutions to those indicated for warming up the engines,
- check engine temperatures,
- check that the ramp is closed (if the cargo is loaded after warming up the engines)
- check the ailerons
- check the flaps
- check the tail obtain approval for commissioning,
- start the engines
- Obtain permission to taxi,
- make a taxi,
- obtain permission to occupy the lane,
- take the belt,
- get permission to start, take the start make a flight,

Landing

- climb to the landing
- preparation
- ceiling
- lower to the specified height
- make contact with personnel at the helipad
- make a circle over the airport
- check compliance of personnel presence
- check the landing field,
- start the approach

- control parameters in accordance with the aircraft manual
- land
- open the ramp
- receive a discharge report
- make a taxi,

After the flight

- complete the mission in GCS and in the on-board computer,
- Turn off the GCS,
- turn off other devices
- report leaving RUPC to ACC
- secure RUPC and check protection

4. FORWARD OPERATING BASE PRINCIPLES

FOB is a place in the theater of operations where drones are deployed. It will be an airport or a landing strip.

Personnel FOB is a Commanding Officer who is responsible for:

- maintenance team
- cargo team
- Ground traffic coordinator (GTC)
- Take-off / landing assistant / s (external pilot / s)

Maintenance team deals with aircraft maintenance. Both running and repairs.

The cargo team is responsible for the proper preparation of the cargo and its delivery to the plane.

The GTC is responsible for assigning aircraft to missions, directing them for repairs and maintenance, tip.

TO / L assistant is an outdoor pilot for landing planes (if without Automatic Take-off and landing

4.1. FOB APPOINTMENT

Choosing a place for an FOB must meet the following conditions.

- airport or air base,
- the existing runway,
- preferably paved,

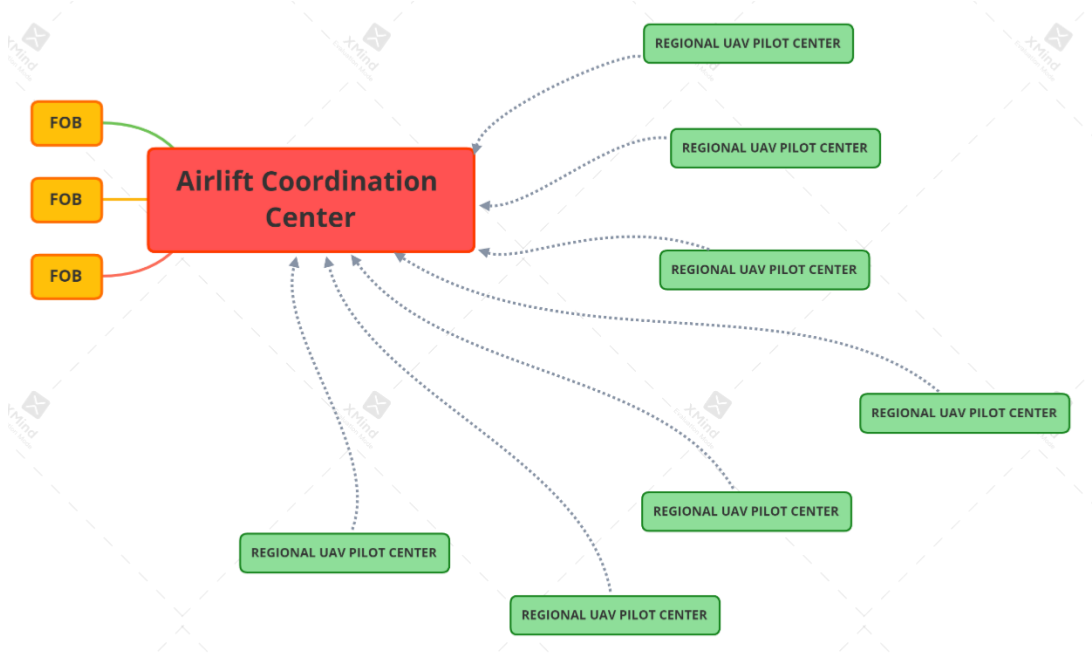
- hangars or places to erect them rest rooms for staff or places to put up containers a place for the arrangement of staff working rooms,
- a place for a canteen, toilets or a place for them,
- access roads,
- fence,
- place for the FOB protection,
- place of access control

4.2. FOB COMMANDING OFFICER

FOB Commanding Officer manages the work of the entire FOB and cooperates with ACC and local structures.

FOBCO is responsible for:

- managing the work of FOB,
- managing the heads of subordinate teams,
- contacts with the airport operator,
- constant refueling of airplanes and vehicles,
- safety of installations,
- aggregates and fuel tanks,
- FOB protection,
- FOB logistics use of the runway
- ensuring cargo storage on the FOB
- train compilation of cargo for airplanes container
- FOB material management
- adherence to local rules



5. SUPPLY DELIVERY AND HANDLING

Supply delivery and handling are a part of cargo and airlift missions.

5.1. SUPPLY DELIVERY

5.1.1. Booking & Planning Shipments

- Receive shippers' requests and check the security status
- Receive shipper freight information
- Plan the routing-direct or consolidation
- Request capacity against forwarder or carrier inventories
- Confirm capacity
- Arrange pick up of freight
- Picked up from the shipper

5.1.2. Receive Shipments into Carrier Domain

- Electronic air waybill information
- Electronic house waybill information for consolidated shipments
- Truck number and type (if available)
- Estimated arrival time (if available)
- Security screening needs (if known/available)

5.1.3. Accept Shipments as Ready for Carriage

- Carrier requirements

- Local export rules and regulations
- Rules and regulations of the transit airport(s) and air spaces (if any)
- Import regulations of the destination country

5.1.4. Prepare Cargo for Flight

5.1.5. Send Shipments to Flight

5.2. HANDLING

- Container doors put on the roof shall be secured against falling down.
- A container shall be exclusively filled with baggage, cargo or mail.
- Mixing of loads must be avoided.
- Heavy items should be loaded on the bottom of a container.
- Containers with heavy loading must be handled with extreme care in order to avoid damage to the container.
- The outer loading limit in the door area is indicated by the metal edge of the base.
- After loading has been finished, the container doors shall be closed and locked.
- In case of flexible reinforced doors, each strut must be checked for proper fitting in the lock.
- A fire extinguisher must always be at hand Before closing the ramp, make sure that there are no animals or people.

6. DELIVERY POINT

The delivery point is the place where the cargo is delivered by UAV and from which it is picked up by the recipient

6.1. DELIVERY PONT DESCRIPTION

Delivery point consists of:

- Runway
- airplane parking places after landing
- cargo unloading places
- parking of the receiving team's vehicles
- personnel area during landing and take-off

6.2. DELIVERY POINT APPOINTMENT

When choosing a delivery point, you should take into account the following conditions

- a rectangle with dimensions of 300x100
- no tall trees on the narrow sides

- flat area
- wetland – no
- no tall grass (over 1 m)
- Access roads
- a place to park cars
- place to deposit cargo before packing place the cargo before packing for vehicles
- place for waiting staff

6.3. DELIVERY POINT MANAGER

The delivery point manager is responsible for the safety of starting and landing operations and the security of the ground personnel at the delivery point.

The manager receives information from the ACC about the location of the delivery point and the direction of the plane's approach to landing.

Upon arrival at delivery point, the manager appoints:

- location of the airplane after landing
- cargo unloading places
- parking of the receiving team's vehicles
- personnel area during landing and take-of

6.4. DROPPING

- Cargo from the UAV may be dropped.
- Dropping should be used when landing is not possible and the type of cargo allows it to be dropped.
- Airdrops can be used for supply classes 2 to 5 inclusive.
- In addition to the class, the type of cargo is also important, so if you need to drop it, you must obtain a separate consent.
- The approval may be given before take-off or during the flight.
- The height of the drop depends on the characteristics of the parachute.
- Before the drop, the pilot must make sure that there are personnel who can collect the drop in the drop zone.

6.5. DROP ACTIONS

During the drop, the pilot:

- circle over drop zone to make sure staff are present

- positions the plane parallel to the drop zone and starts the approach to the drop
- introduces a correction to the wind direction (the table depends on the type of parachute)
- when on course he opens the ramp
- Releases the load
- closes the ramp
- ensure that all cargo has left the deck
- makes sure that the cargo has landed
- supports the ground team in finding the cargo (if visible from the air)

6.6. GROUND PERSONNEL WORK

- Ground personnel is organized in working shifts in accordance with the FOBCO decision.
- No fewer than two technicians should be assigned to each airplane.
- Each technician is assigned planes for which he is the primary responsible.
- Working in tandem, technicians change roles.
- One is primary and the other is secondary.
- When working on an airplane, technicians double-check.
- The working hours of technicians may not exceed 8 hours a day and an average of 40 hours a week

7. AIRSPACE ORGANIZATION

In order to organize the airspace for the delivery of UAVs, it is necessary to:

check local UAV flight regulations with the indicated MTOM,

Obtain approvals from local aviation authorities,

- Agree with local authorities on flight routes with humanitarian aid,
- In the case of cross-border flights,
- organize a state border crossing system,
- including agreeing on the reporting of border crossing by planes,
- Agree an altitude range for unmanned cargo flights,
- Separate an airport for the needs of FOB,
- Check the compliance of the voice communication frequency for UAV cargo flights,
- Grant approvals for alternate airports,
- Agree the rules of forced landing in a territory other than the airport,
- Agree on the rules for the use of locators
- Agree on the rules of using ADS-B devices Confirm the squawk codes: 7700, 7600.
- Agree the legal order in which the pilot operates and provide information to the pilots
- Separate TFR zones from the airspace between FOB and delivery sites,
- Issue NOTAMs for local aviation,

Title: **CARGO UAS OPERATIONS**	Version Number: <1>	Abbreviation: **UASA-02**	Page 1 of 6

PURPOSE

The purpose of this SOP is to establish cargo UAS operations to deliver humanitarian and medical aid in regions hit by natural disasters.

SCOPE

This SOP covers:

- principles of organization of work of flying personnel
- rules of organization of work of technical personnel

RESPONSIBILITIES

A summary of the roles listed in the procedure and the responsibilities of each role holder for the procedures detailed in the SOP.

The details of the responsibilities should be a brief list of the key tasks performed. This section should not be a complete summary of the SOP.

INTERNAL REFERENCES

Insert relevant references as required, sufficient for the user to find the source document.

EXTERNAL REFERENCES

Insert relevant references as required, sufficient for the user to find the source document. Web references should be included were possible.

GENERAL

Flying and ground personnel have roles in the UAS cargo operations process.

1. PILOTS ORGANIZATION OF WORK

1.1. READINESS

In the case of an airlift, there is a need for an uninterrupted flow of pilots to fly.

Pilots receive their preparedness categories from the ACC.

There are 3 categories of readiness: I, II or III

1.1.1. Readiness I:

- Pilot in RUPC ready for take-off,
- Connectivity checked Engines not warmed up
- Delivery pint may be indicated after startup
- The remote control can remain in this standby for 2 hours

1.1.2. Readiness II

- Pilot within 2 hours to RUPC
- The remote control can stay in this standby for 24 hours.

1.1.3. Readiness III

- Pilot 8 hours from RUPC
- The remote control can remain in this standby for 72 hours

1.2. FLIGHT FLOWCHART

The procedure of the pilot's work from receiving the task to mission preparation:

- receive mission request,
- check the mission ability checklist,
- confirm acceptance of the mission,
- check the nearest RUPCs, go to RUPC,
- open RUPC protect RUPCs from others during the flight Flight preparation enable GCS,
- check the correctness of GCS operation, connect to ACC,
- check aviation radio,
- check the terrestrial radio,
- check whether the mission is up to date, take the plane number,
- check the weather,

- send the forecast to the ACC,
- open an air mission, enter your name and surname,
- check sobriety, obtain confirmation of taking a sobriety test,
- Confirm the flight plan,
- report readiness to fly,
- get connected to the plane,
- report to a technician,
- order the electrical circuit to be turned on,
- check the control connectivity, check the pressure,
- calibrate the barometer,
- receive a report that the plane is ready,
- check that the ramp is closed (if there is cargo on board),
- check the closing of the nose,
- turn on the circuits,
- turn on the fuel pump,
- check fuel flow to engines,
- check the navigation lights
- check the landing light
- check with anti-collision lights
- check the camera
- check that it is clean around the propeller
- give the command to start the motors
- receive confirmation that the engines are safely
- switched on start the engines
- check the tachometer indications,
- increase the revolutions to those indicated for warming up the engines,
- check engine temperatures,
- check that the ramp is closed (if the cargo is loaded after warming up the engines)
- check the ailerons
- check the flaps
- check the tail obtain approval for commissioning,
- start the engines
- Obtain permission to taxi,
- make a taxi,
- obtain permission to occupy the lane,
- take the belt,
- get permission to start, take the start make a flight,

Landing

- climb to the landing
- preparation
- ceiling
- lower to the specified height

- make contact with personnel at the helipad
- make a circle over the airport
- check compliance of personnel presence
- check the landing field,
- start the approach
- control parameters in accordance with the aircraft manual
- land
- open the ramp
- receive a discharge report
- make a taxi,

After the flight

- complete the mission in GCS and in the on-board computer,
- Turn off the GCS,
- turn off other devices
- report leaving RUPC to ACC
- secure RUPC and check protection

2. DELIVERY POINT

The delivery point is the place where the cargo is delivered by UAV and from which it is picked up by the recipient

2.1. DELIVERY PONT DESCRIPTION

Delivery point consists of:

- Runway
- airplane parking places after landing
- cargo unloading places
- parking of the receiving team's vehicles
- personnel area during landing and take-off

2.2. DELIVERY POINT APPOINTMENT

When choosing a delivery point, you should take into account the following conditions

- a rectangle with dimensions of 300x100
- no tall trees on the narrow sides
- flat area
- wetland – no
- no tall grass (over 1 m)

- Access roads
- a place to park cars
- place to deposit cargo before packing place the cargo before packing for vehicles
- place for waiting staff

2.3. DROPPING

- Cargo from the UAV may be dropped.
- Dropping should be used when landing is not possible and the type of cargo allows it to be dropped.
- Airdrops can be used for supply classes 2 to 5 inclusive.
- In addition to the class, the type of cargo is also important, so if you need to drop it, you must obtain a separate consent.
- The approval may be given before take-off or during the flight.
- The height of the drop depends on the characteristics of the parachute.
- Before the drop, the pilot must make sure that there are personnel who can collect the drop in the drop zone.

2.4. DROP ACTIONS

During the drop, the pilot:

- circle over drop zone to make sure staff are present
- positions the plane parallel to the drop zone and starts the approach to the drop
- introduces a correction to the wind direction (the table depends on the type of parachute)
- when on course he opens the ramp
- Releases the load
- closes the ramp
- ensure that all cargo has left the deck
- makes sure that the cargo has landed
- supports the ground team in finding the cargo (if visible from the air)

3. GROUND PERSONNEL WORK

- Ground personnel is organized in working shifts in accordance with the FOB Commanding Officer decision.
- No fewer than two technicians should be assigned to each airplane.
- Each technician is assigned planes for which he is the primary responsible.
- Working in tandem, technicians change roles.
- One is primary and the other is secondary.
- When working on an airplane, technicians double-check.
- The working hours of technicians may not exceed 8 hours a day and an average of 40 hours a week

Title: **FORWARD OPERATING BASE IN UAS AIRLIFTS OPERATIONS**	Version Number: <1>	Abbreviation: **UASA-03**	Page 1 of 5

PURPOSE

The purpose of this SOP is to establish FOB organization in terms of UAS airlifts operations to deliver humanitarian and medical aid in regions hit by natural disasters. The legitimacy of this SOP can be used to organize FOB for ailifts to all regions where the delivery of medical and humanitarian aid by traditional methods is difficult or impossible.

SCOPE

This SOP covers:

- FOB
- principles of organization of work of flying personnel
- rules of organization of work of technical personnel
- principles for Forward Operating Base (FOB)
- rules for delivering materials to FOB and handling them until loading to UAS
- rules of operation at the place of unloading / dropping

This SOP does not covers:

- Cargo UAS flights and aerials operations (see: UASA 02)
- Detailed organization and operation of FOB (see: UASA 03)
- UAV cargo containers marking system and handling (see: UASA 04)

RESPONSIBILITIES

A summary of the roles listed in the procedure and the responsibilities of each role holder for the procedures detailed in the SOP.

The details of the responsibilities should be a brief list of the key tasks performed. This section should not be a complete summary of the SOP.

INTERNAL REFERENCES

Insert relevant references as required, sufficient for the user to find the source document.

EXTERNAL REFERENCES

Insert relevant references as required, sufficient for the user to find the source document. Web references should be included were possible.

GENERAL

1. AIRLIFT OPERATION ORGANIZATION

Airlifts are the most complicated way to use UAS in humanitarian operations. They require high-quality work from every team member participating in airlifts. The involved personnel must demonstrate the accuracy and timeliness of the tasks performed.

Pay attention to adhere to the times and themes. Time is a key element of the whole project. Airlifts are a series of successive events, one of which results from the other. Therefore, any delay affects the sequence of events that follows. Accumulation of delays and errors may lead to emergencies or accidents.

The course of the delivery mission by the UAV is shown in the diagram.

2. FORWARD OPERATING BASE PRINCIPLES

FOB is a place in the theater of operations where drones are deployed. It will be an airport or a landing strip.

Personnel FOB is a Commanding Officer who is responsible for:

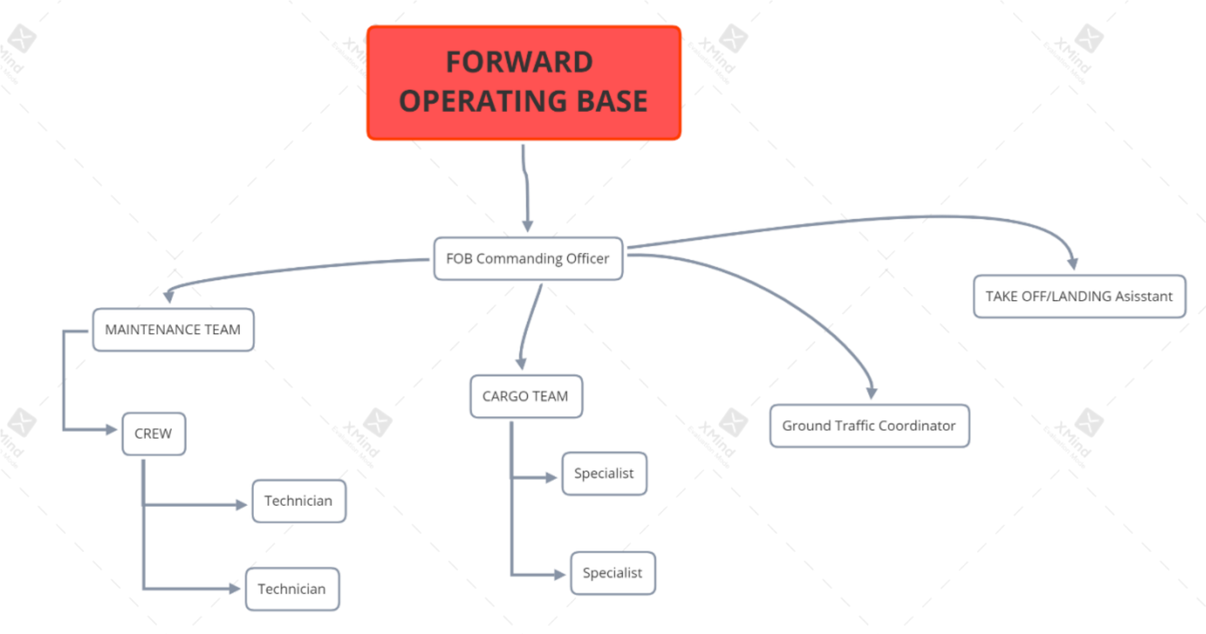
- maintenance team
- cargo team
- Ground traffic coordinator (GTC)
- Take-off / landing assistant / s (external pilot / s)

Maintenance team deals with aircraft maintenance. Both running and repairs.

The cargo team is responsible for the proper preparation of the cargo and its delivery to the plane.

The GTC is responsible for assigning aircraft to missions, directing them for repairs and maintenance, tip.

TO / L assistant is an outdoor pilot for landing planes (if without Automatic Take-off and landing



2.1. FOB APPOINTMENT

Choosing a place for an FOB must meet the following conditions.

- airport or air base,
- the existing runway,
- preferably paved,
- hangars or places to erect them rest rooms for staff or places to put up containers a place for the arrangement of staff working rooms,
- a place for a canteen, toilets or a place for them,
- access roads,
- fence,
- place for the FOB protection,
- place of access control

2.2. FOB COMMANDING OFFICER (FOBCO)

FOB Commanding Officer manages the work of the entire FOB and cooperates with ACC and local structures.

FOBCO is responsible for:

- managing the work of FOB,
- managing the heads of subordinate teams,
- contacts with the airport operator,
- constant refueling of airplanes and vehicles,

- safety of installations,
- aggregates and fuel tanks,
- FOB protection,
- FOB logistics use of the runway
- ensuring cargo storage on the FOB
- train compilation of cargo for airplanes container
- FOB material management
- adherence to local rules

2.3. MAINTENANCE TEAM

Maintenance Team is responsible for:

- maintaining the airworthiness of aircraft,
- repairs
- keeping damage statistics
- preparing reports on damage
- making scheduled inspections
- spare parts management
- ground tests and checks
- preparing the plane for flight
- extruding on the plane preparing for take-off safe stowage in the hangar (s)

2.4. CARGO TEAM

Cargo team is responsible for:

- maintaining the operability of the containers
- receipt of materials
- separation into containers according to the class of supply
- closing and sealing
- preparation of containers for flight
- assistance during customs
- clearance delivery of containers to the appropriate aircraft
- storage of empty containers
- requesting the return of containers from FOBs
- preparation of documentation billing of materials sent

2.5. GROUND TRAFFIC COORDINATOR (GTC)

GTC is a main point of decision regarding planes ground traffic in the FOB.

GTC is not Ground controller

GTC is responsible for:

- choosing a plane to fly
- setting airplanes at the airport
- management of the movement of aircraft for loading
- management of the movement of loaded aircraft
- post-mission aircraft traffic management
- making decisions to move the plane to the area of establishing communication with the pilot
- deciding on cargo exchange

2.6. TAKE-OFF/LANDING ASSISTANT (TOLA)

TOLA is an external pilot.

TOLA is designated when airplanes without ATOL participate in the operations.

TOLA must be licensed to take off and land in a specific type of airplane.

TOLA is responsible for:

- tracking parameters during preparation for take-off and warm-up of engines
- take off
- transfer of control to the correct pilot/RUPC
- taking over the landing plane
- landing
- taxiing to a designated place

3. SUPPLY DELIVERY AND HANDLING

See SOP UASA-04.

Title: **UAS CARGO CONTAINER MARKING AND HANDLING**	Version Number: <1>	Abbreviation: **UASA-04**	Page 1 of 14

PURPOSE

SOP describes the method of marking and handling containers intended for the transport of materials with the use of UAVs.

Scope

This SOP covers:

- supply classes
- container markings,
- selection of the supply class in relation to the landing site,
- handling of loaded containers,
- handling of empty containers,

If there are any areas in which this SOP specifically does NOT apply, these should also be mentioned.

Responsibilities

A summary of the roles listed in the procedure and the responsibilities of each role holder for the procedures detailed in the SOP.

The details of the responsibilities should be a brief list of the key tasks performed. This section should not be a complete summary of the SOP.

The use of flow diagrams may be useful, especially in complex procedures.

Internal References

Insert relevant references as required, sufficient for the user to find the source document.

External References

Insert relevant references as required, sufficient for the user to find the source document. Web references should be included were possible.

GENERAL

Airlifts are the most complicated way to use UAS in humanitarian operations. They require high-quality work from every team member participating in airlifts. The involved personnel must demonstrate the accuracy and timeliness of the tasks performed.

Pay attention to adhere to the times and themes. Time is a key element of the whole project. Airlifts are a series of successive events, one of which results from the other. Therefore, any delay affects the sequence of events that follows. Accumulation of delays and errors may lead to emergencies or accidents.

The ability to read the markings on the containers and the correct selection of the supply classes allows you to waste time, which may turn out to be critical.

1. SUPPLY CLASSES

Six classes of cargo supply that can be transported by UAVs have been defined.

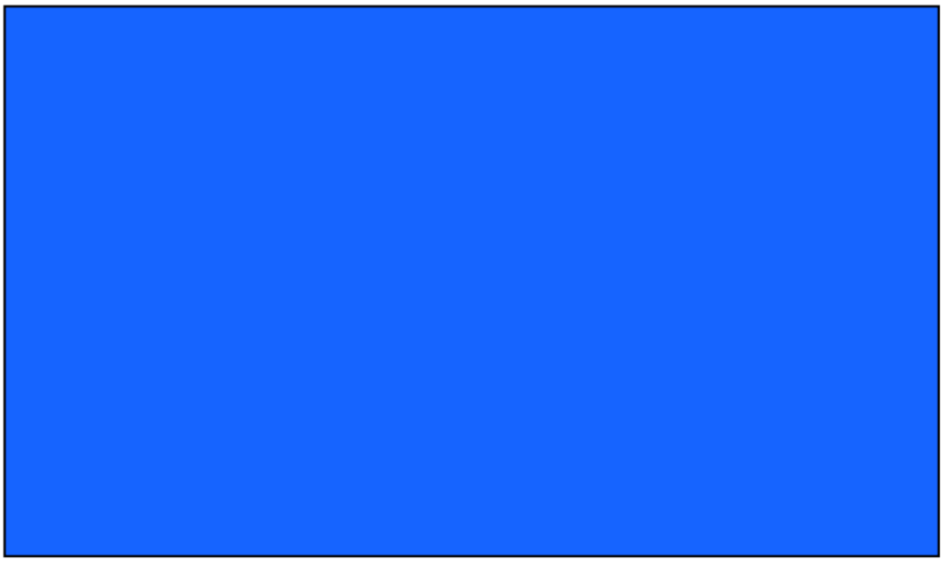
Classes of supply:

1. Water
2. medical dressings without expiry date, grain, tools, administrative and housekeeping supplies and equipment, cereals
3. rations, liquids, food, medical kits, clothing
4. medicines,
5. simple medical equipment ie. blood pressure monitor
6. special medical equipment ie. respirator,

2. CONTAINER MARKINGS

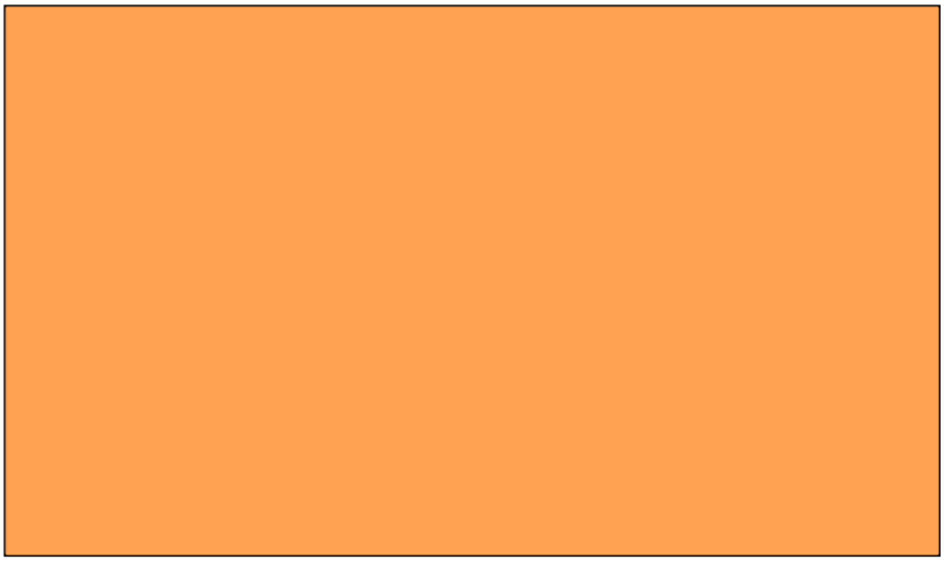
Below are the container markings for each class. Additionally, the marking of refrigerated, sealed, heated and dangerous containers.

2.1. CLASS 1 - blue

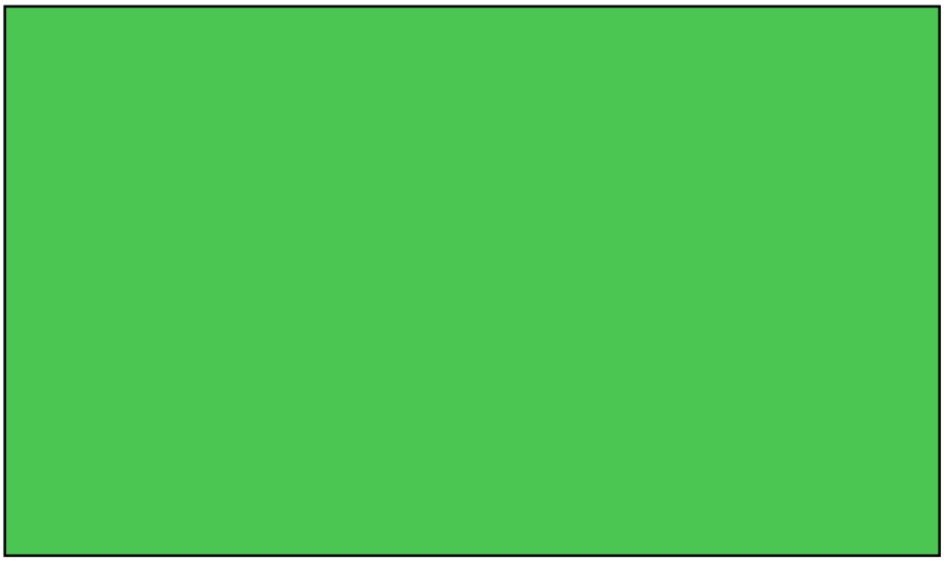


2.2. CLASS 2 - white

2.3. CLASS 3 - orange



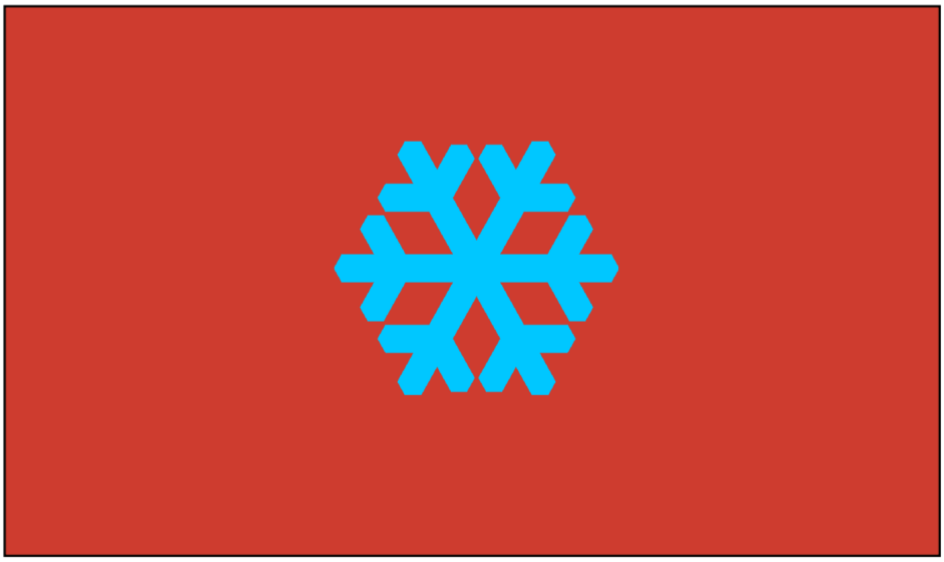
2.4. CLASS 4 - green



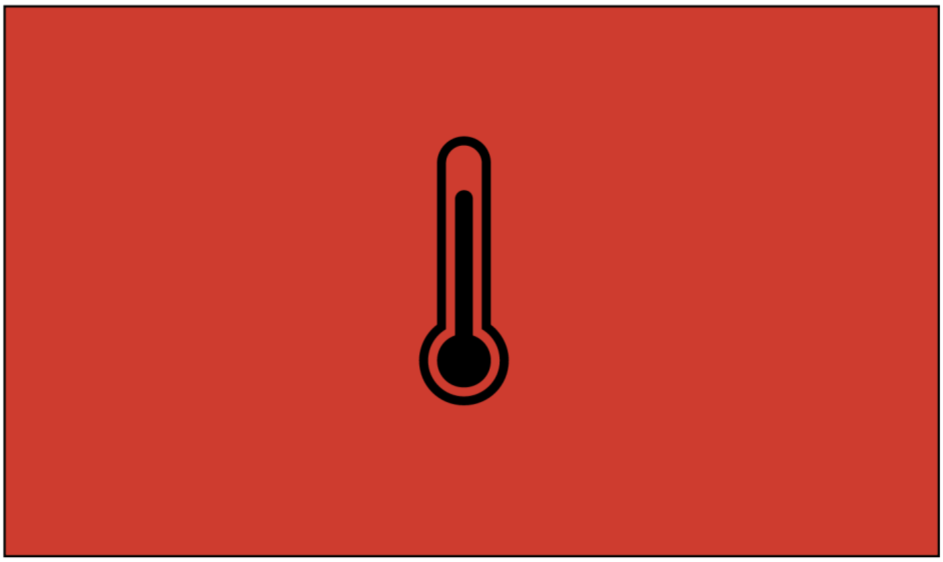
2.5. CLASS 5 - red

2.6. CLASS 6 - black

2.7. Refrigerator



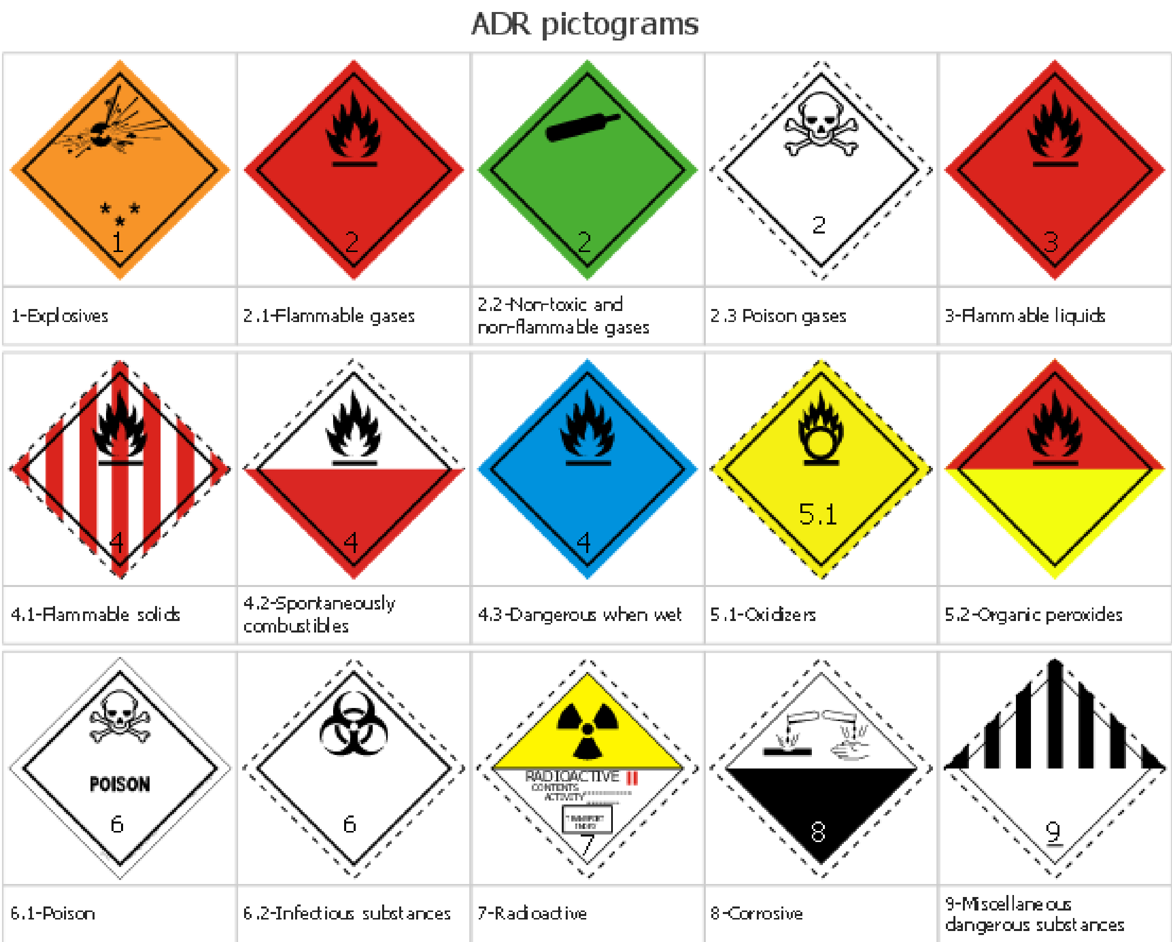
2.8. Heater



2.9. Hermetic

2.10. ADR – Dangerous cargo

Dangerous goods are labeled in accordance with the international dangerous goods labeling system

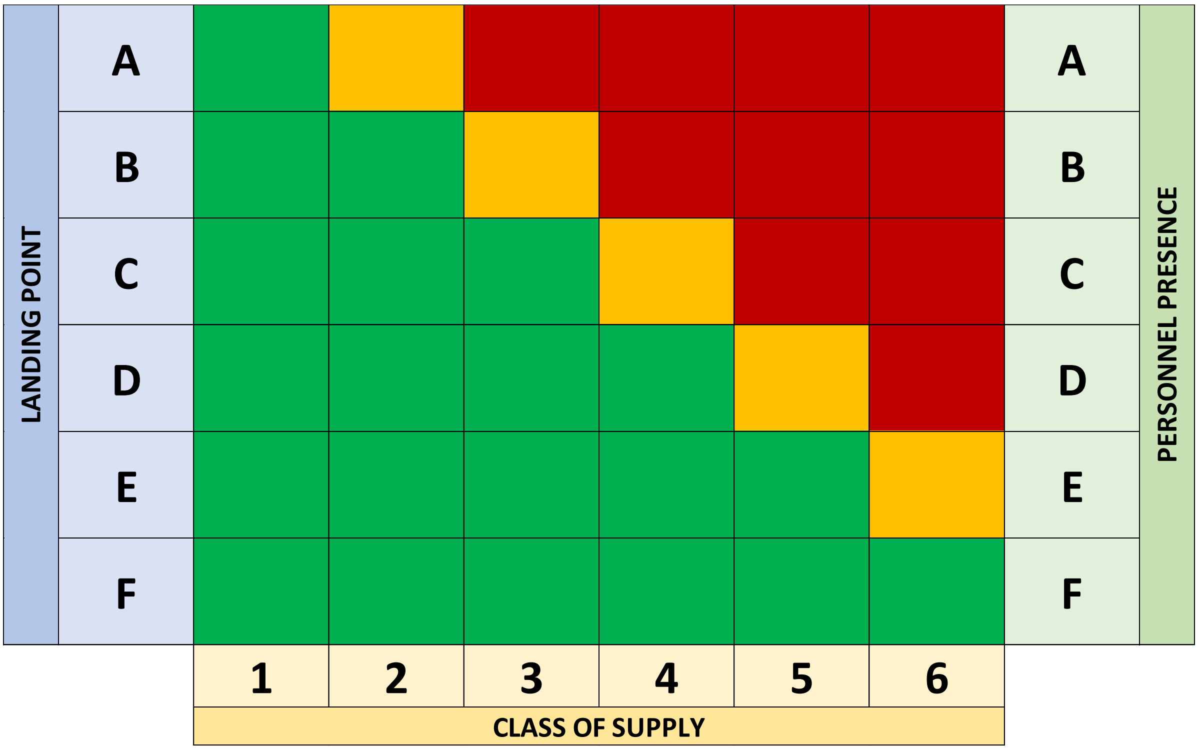


3. SELECTION OF THE SUPPLY CLASS IN RELATION TO THE LANDING SITE

In order to determine which supply class can be delivered to specific delivery point match landing point code and class supply.

Example. Class 3 can be delivered to landing point class C,D,E or F.

In special situations, it can be delivered to landing site class B.



4. HANDLING OF LOADED CONTAINERS

Handling of loaded containers:

move carefully,

do not throw,

do not hang around,

check the weight before loading onto the plane,

do not remove stickers,

Conduct a safety risk assessment,

Establish control measures to mitigate any associated risks,

Determine accurate weight and balance parameters according to the type of cargo and storage location,

Ensure that storing configuration does not hinder the use of emergency equipment,

Doublecheck the availability of operational and personal protective gear,

Strength supervision of loading and unloading sequences to guarantee freight is properly stocked,

When handling hazardous materials, crew members and ground staff must be aware of safety precautions,

The access to the cargo deck should be restricted to authorized qualified personnel,

Set an action plan for potential undeclared dangerous goods that are hidden within the consignment,

Instruct personnel on what are the approved cargo locations,

After loading, close and check the ramp.

5. HANDLING OF EMPTY CONTAINERS

Empty containers should be returned to FOB on a regular basis by the most reliable means of transport.

Containers may be replaced from full to empty ones to UAVs. The condition is that this is done by personnel trained in loading and securing the containers.

REMEMBER. By keeping empty containers in the base, you prevent the supply of important medical equipment.