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Research Paper

# MediDrone: First Aid Delivery Drone for Remote Areas

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***Abstract*— In steep communities, forest settlements, and areas where ground access is delayed, especially in disaster-stricken areas, it is hard to provide first aid reliably. In this study, the design of the MediDrone is demonstrated. MediDrone is a GPS-guided quadcopter that is used to transfer a small first-aid package from a ground station controlled by an operator to a remote location. Four brushless motors and electronic speed controllers, a Pixhawk/APM class flight controller, GPS with compass, a LiPo supply and a telemetry and RC link, and a camera and a cargo lock actuated by servos are recommended. The sequence of operations include waypoint entry, pre-arm checks, autonomous flight, landing confirmation, controlled release of first aid and RTL. The mission logic is supplemented with battery-reserve and communication-link failsafes. Thrust margin, expected endurance, travel time and successful delivery rate are estimated theoretically, to enable field testing later. The views of the interface-level mission, telemetry and release are offered as a review of the software design. No physical flight measurements are claimed. The architecture offers a logical foundation for low-cost emergency logistics around areas lacking in road access.***

***"Keywords*— Unmanned aerial vehicle, emergency first aid, GPS navigation, quadcopter, autonomous mission, servo gripper, return-to-home, telemetry, flight safety**."

## I. INTRODUCTION

### *A) Background and Motivation*

Road access to rural settlements, hill slopes and forest areas can be obstructed by distance, geographical location, rains or disaster debris. Delayed response may lead to not being able to get bandages and other first aid supplies to the victim in time. An aerial route may be feasible and a safe landing site available, and then a small UAV can be used to transport. Medical logistics services have demonstrated that they can save time in selected applications, like blood supply and AED dispatch [1]–[4].

MediDrone is aimed at delivering a small first aid kit not diagnostic or medical therapy. The operator chooses a destination and the flight controller performs a pre-programmed GPS mission, the vehicle lands, and drops the payload. The mission then moves back to the take-off location, where a behaviour is already programmed for an emergency in the event of low battery, loss of radio control and/or loss of telemetry [11]–[17].

### *B) Research Objectives and Contributions*

The main technical contributions comprise an integrated quadcopter hardware architecture; an autonomous route and controlled payload-release state machine; quantitative mission-feasibility equations; and an operator-facing monitoring interface. The verification protocol addresses controller readiness, landing-site safety, release authorization, battery reserve and return-to-home behavior before supervised deployment.

## II. RELATED WORK

### *A) Emergency Medical Drone Logistics*

Nisingizwe et al. studied drone delivery of blood products in Rwanda, which resulted in faster delivery time than estimated road delivery times [1]. Schierbeck et al. experimented with defibrillators delivered by drones in an actual emergency and Kremer et al. explained the potential reach of autonomous flying logistics to underserved populations [2] and [3]. The feasibility study for remote diagnostics-sample delivery and AED also illustrates the need for payload handling, dispatch coordination and local operating conditions.The feasibility study on remote diagnostic-sample delivery and AED also underscores the importance of payload handling, dispatch coordination and local operating conditions [4]–[9]. These studies are not measured findings for MediDrone, but instead are operational systems.

### *B) Autonomous Flight and Safety Control*

ArduPilot AUTO missions consist of a series of waypoint commands that are stored along with non-navigation operations. RTL offers a return to a home point that is defined [11],[12]. Servo-gripper actions can be programd via autopilot outputs and carried out as mission directives [13]. The failsafes for the battery, radio and ground station need to be specifically programmed and checked [14]–[17]. QGroundControl provides mission planning, vehicle

telemetry and flight controls. The mission upload, command acknowledgement and heartbeat exchanges [18]–[24] are described by MAVLink. The proposed first-aid mission combines these elements of flight management into the delivery sequence.

## III. MATERIALS AND METHODS

### *A) System Hardware and Integration*

The UAV is constructed using a quadcopter configuration of propellers, 4 BLDC Motors & 4 appropriate ESCs, flight controller, GPS/compass, LiPo battery, receiver, telemetry transmitter & receiver, camera, servo actuated release bracket and securely mounted First Aid box. Navigation and stabilisation are provided by the controller; motor drive control is provided by the ESCs; and a mechanically restrained cargo latch is released by the servo only after a certified safe landing condition. The mission coordinates and ground station status are shown on the ground station.

"TABLE I. COMPONENTS AND FUNCTIONAL ROLES"

| Component | Primary function |
|---|---|
| Quad frame / 4 propellers | Lift and mechanical support |
| BLDC motors / 4 ESCs | Thrust and motor-speed control |
| Pixhawk/APM flight controller | Stabilization and mission execution |
| GPS with compass | Position and heading estimates |
| LiPo battery | Power and energy reserve |
| RC receiver + telemetry | Pilot override and data link |
| Servo release + first-aid kit | Restrained payload and delivery |
| Camera + ground software | Visual review and mission monitoring |

### *B) Integrated System Architecture*

Figure 1 shows that the information path and the route for actuation are both shown. The GPS and operator mission controls are processed in the controller and all the other propulsion and payload latch and camera are coordinated from the controller. Telemetry provides the operator with position, state and battery data. First aid kit is only released if landing state has been verified. RTL and emergency transitions are controlled from the same controller.




"Fig. 1. Horizontal MediDrone communication, control, power and payload architecture."

### *C) Mission Planning and Control Sequence*

The process of a mission's initiation is to input the destination and the operator confirming local airspace and obstacle clearance; launch site suitability and reception conditions. Before arming, the flight controller monitors GPS lock, compass calibration, battery reserve and motor status [17]. The path includes takeoff, safe cruise waypoints, approach and return to home element of the landing zone. The communications between the mission and the aircraft are handled by mission commands sent to the aircraft via an acknowledged protocol [22] and [23].

Payload is secured during launch and travel. The operator or approved controller condition checks stationary state and safe propulsion status prior to enabling the servo when landing. If the car is OK to be re-launched, the RTL is done at the end of the delivery. Otherwise the mission could remain on the ground awaiting recovery. This relieves the need to state the ground-landing release's compatibility with automatic departure in all configurations.

### *D) Mission Feasibility Equations*

The TWR is the static rotor thrust available as a function of the takeoff weight. A margin of safety is required but not sufficient for safe manoeuvring:

$$\text{“}TWR = \frac{4\,Tmotor}{mtakeoff\ g}\text{”} \quad (1)$$

The approximate usable airborne duration (in minutes) is calculated from the battery capacity and the average electrical current, the useable capacity is related to the reserve capacity by η:

$$\text{“}tusable = \frac{60\,CAh\,\eta}{Iavg}\text{”} \quad (2)$$

A planning level route time includes the return and delivery legs, and due to wind and detours, route distances and airspeeds are adjusted:

$$\text{“}tmission = \frac{dout}{vout} + \frac{dreturn}{vreturn} + tdelivery\text{”} \quad (3)$$

The percentage of delivery and recovery completed flights, at mission level, is the dependability of the delivery.

$$\text{“}Success\ rate = \frac{Ncompleted}{Nlaunched} \times 100\%\text{”} \quad (4)$$

### *E) Electrical and Mechanical Design Constraints*

The loaded take-off mass is the sum of the mass of frame, motors, ESCs, flight controller, battery, telemetry, camera, landing gear and payload. The prop diameter and the clearance between the prop and the frame should be adjusted to the motors used. The servo linkage must be mechanically locked securely and cannot be accidentally released on reset, loss of power or signal. Monitoring battery voltage during thrust demand. Avoid blocking the GPS receiver or rotating propellers.




"Fig. 2. Principal airframe, navigation, communication and payload components."

### *F) Safety State Machine*

The controller has a number of states: IDLE, PREARM, TAKEOFF, CRUISE, APPROACH, LAND, RELEASE, RTL and COMPLETE. FAILSAFE is a safeguarded transition. Loss of telemetry shall not per se result in uncontrolled deployment of the payload. When the system is depleted of energy, it will suspend the delivery plan and try to return or land safely, depending on the accuracy of the system in determining its location and battery level [14]–[16]. Geofencing, return altitude, landing-site checks, and pilot takeover must be done to get the plane operational.

*G) Navigation Accuracy and Route Generation*

Mission coordinates are geographic positions, but flight control requires a continual assessment of position, velocity, attitude and heading. The autopilot navigates between accepted way points with a combination of GPS and compass information as well as internal inertial readings. Place waypoints with sufficient distance from trees, power lines, protected airspace and undulating terrain. A straight line between two GPS coordinates doesn't necessarily indicate a collision free path and the path must also be vetted for local obstacles prior to takeoff. Therefore, it is not sufficient to have a valid map marker. Pre-arm tests, placement quality [11, 12, 17] are also important for reliable flying.

The landing site is more constrained than en-route navigation since it must be a surface that allows the UAV to land with the first-aid kit. To enter the destination, a safe landing zone and a recovery option must be provided in case the landing zone is not available. The operator should not rely on video alone for the depth and height of ground clearance, however, camera visibility provides the operator with supporting situational information. The recorded GPS data can then be compared to the desired path to measure lateral waypoint error and how far off it the landing point was.

*H) Servo-Gripper Release and Package Retention*

The servo mechanism is a load bearing subsystem, and needs its own verification apart from navigation. A held latch should be able to withstand vibration and acceleration when manoeuvring the lock while still being able to open the lock on the supply voltage set. It shall reset to the locked state when powered on, and in an unknown command state. An authorised release may only be allowed once the controller has entered the delivery state and the operator or independent interlock has confirmed that the conditions are safe. ArduPilot has a programmable gripper function, and a gripper command on mission level, but successful physical release requires shape of the mechanism, the torque of the servos and the electrical wiring [13].

Locate the first aid box so that it cannot be blown about, is protected from the rain, wind, and accidental contact with the rotors. A phased test sequence involves a series of tests that take place, with unloaded servo cycling followed by loaded release with propellers removed, vibration exposure, landing-contact verification, and then finally supervised flight trials. Securement of a connection is to be verified after every change of payload mass and center of gravity. Stability and flight duration will differ when the motor controller settings are the same but the payload is different.

*I) Telemetry, RC Override and Link Supervision*

Complementary links are RC control, mission telemetry. The radio receiver enables pilot interaction and the telemetry interface sends real-time position and system status, flight mode and command acknowledgements to the ground station. The MAVLink heartbeat monitor will show if a connected component is still visible, but a lack of heartbeat does not provide any information on the reason for the failure [18, 23, 24]. Losses of telemetry and loss of GPS have different safety implications and the operator interface should distinguish between the two.

Various programmed actions may be necessary depending on the loss of radio link or ground station link or reliable position estimate. The safest reaction varies depending on the elevation, the location and if the vehicle is able to drive home. Hence, in all failures, an RTL instruction is not recoverable by guarantyd. Important design considerations are redundant monitoring, a conservative launch reserve and an unobstructed recovery site. Failure mode behaviour should be validated using the actual configuration of the controller and not taken from the software interface [14]–[17].

*J) Flight-Electronics Wiring and Power Budget*

Every motor has its own ESC and receives the power from the LiPo main power distribution network. The flight controller produces the control signals to drive the motors and requires a steady regulated voltage for all of its sensors and telemetry items. Don't rely on battery capacity alone (AH) to determine mission range. The average amperage draw is affected by total mass, propeller efficiency, wind and acceleration and hover time. So, Equation (2) is a rough planning estimate, and should not replace power logging. Bench verification should include checking controller supply integrity, checking wiring retention and common reference ground.

When appropriate, the camera and payload servo can produce transient demands for current that should be separated from sensitive supplies for the navigation and receiver. The motor output for each ESC should be checked in a controlled bench run for correct output. The direction of a propeller should be verified when none of the blades are attached. Actuator cycling should have no effect on telemetry. Once these checks have been completed, a loaded thrust test should only be carried out in a protected space, with the proper physical precautions.

## IV. EXPERIMENTAL RESULTS

*A) Evaluation Scope and Acceptance Criteria*

The technical evaluation is based on the subsystem configuration, operator interface behaviour, and functional acceptability requirements. To assess the endurance quantitatively, payload release reliability and delivery performance must be realized and instrumented flight trials and traceable telemetry recording is required. Quantitative performance claims can only be made after bench, simulator and flight tests give the necessary values to verify flight range, release reliability and energy consumption. Software in the loop and ground verification are provided by PX4 and ArduPilot tools [25]–[27].

TABLE II. FUNCTIONAL VERIFICATION MATRIX

| Condition | Expected controller response |
|---|---|
| GPS fix unavailable | Reject autonomous arming / mission |
| Battery below launch reserve | Reject takeoff; request recharge |
| Radio / telemetry lost | Enter configured fail-safe state |
| Landing not verified | Keep payload servo locked |
| Delivery confirmed | Record release event and RTL plan |
| Landing zone unsafe | Abort approach or choose safe recovery |

*B) Mission-Planning Interface Output*

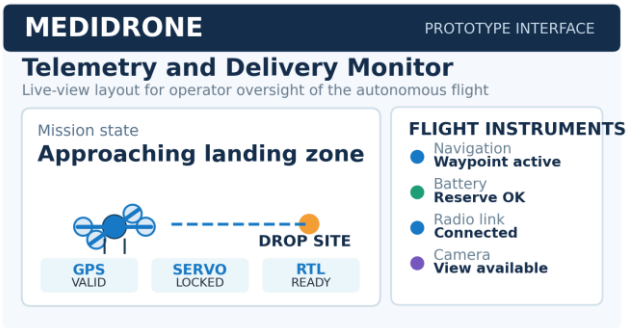
The operator interface for an aerial destination entry, confirmation of home point and waypoints, and confirmation of delivery conditions (as desired) is shown in Fig. 3. The mission-planning interface displays the created waypoint mission and the mission's configuration parameters. The goal is to offer visibility of the flight navigation order, payload selection and safety criteria prior to flight.




"Fig. 3. Mission-planning interface with GPS waypoints and flight-condition fields."

*C) Telemetry and Landing Visualization*

Figure 4 shows the operator telemetry-monitoring interface. Progress of the mission, GPS validity, servo-lock status, RTL availability and camera status are separated, allowing a flight operator to find contradictory situations. For an added layer of verification, a video feed could provide the visual confirmation, but it is not a substitute for height, ground-contact or propulsion-state verification.




"Fig. 4. Telemetry monitoring interface for waypoint and payload status."

*D) Delivery Completion and Return Workflow*

Figure 5 shows the payload handling control states; landing verification, authorised servo actuation and subsequently RTL or ground recovery. The control sequence sets up the conditions to safely discard the payload and to recover the aircraft. The release mechanism will be subjected to repeated latches, payload stability and unintended motion testing. The autonomous take-off has to be validated independently prior to the return sequence being enabled on the landing at the remote site.




"Fig. 5. Payload-release and return-state interface design."

*E) Verification Strategy and Performance Measures*

The test should be carried out in the sequence of software mission replay, to motor-off actuator checks, to tethered propulsion assessment, to low risk supervised flights. Takeoff mass, thrust margin, average current, GPS error, waypoint deviation, release confirmation, time to complete the route, return energy reserve. Variability requires a controlled batch of repeated testing per configuration and no numerical success rate can be inferred from an interface screen alone.

"TABLE III. PLANNED EVALUATION MEASURES"

| Measure | Data required / reporting unit |
|---|---|
| Position error | GPS track vs surveyed target (m) |
| Delivery time | Arm command to payload handoff (s) |
| Endurance | Airborne time with payload (min) |
| Payload release | Confirmed release / attempts (%) |
| RTL reserve | Remaining battery at return (%) |
| Mission completion | Successful deliveries / launched missions (%) |

Environmental limitations include wind gusts, precipitation, electromagnetic interference, inappropriate landing surfaces and radio shadowing. First-aid supplies must be packaged so they will not be accidentally opened, and so sterile material will not be damaged by weather and vibration. Operational approval and trained oversight and local aviation standards [28]–[30] must be confirmed prior to outdoor flights.

*F) Mission-Planning Acceptance Tests*

If the operator can enter, view, and edit destination coordinates, have a choice of launch point, can distinguish between outbound and return waypoints, and can ensure that the payload is set, then the mission-planning interface is appropriate. Bad latitude/longitude, missing landing-zone and conflicting return instructions should be rejected by negative tests. Before the operator arms the motors, the task that is uploaded to the controller should be read back from the controller. The telemetry can be saved with the mission identity and revision time, and subsequently viewed flight can then be matched with the correct route.

Launch checklist includes: Motor and propeller inspection, GPS lock, compass condition, battery reserve condition, RC override condition, weather conditions, and a clear plan for first-aid handoff. If used, the checklist is a record of operations, but does not replace competent flight operation or permission in the area. The following points should be configured to prevent the normal mission from becoming armable: each one of the checklist failure points [17, 19, 21] should be so configured.

*G) Controlled Landing and Payload Test Protocol*

The repeatability of the release command with different payload masses and battery conditions should be verified by servo testing. Test operator notes time of command, servo response, movement of the latch, separation of the payload and any other unexpected movements. Check landing independent of latch operation: The drone must be stable, prevent contact with the propellers of the first-aid box and safeguard people around. The release interlock is expected to prevent an anticipated premature command in a constrained ground test. The mission then determines whether a successful delivery would lead to an acknowledged event, before determining which return state to use.

If delivery fails, it should not be silently logged as a successful delivery, but should be recovered manually. Likewise, if a wrong release is made while in flight, this is a safety failure regardless of whether or not the destination is reached. Navigation completion, landing safety, correct payload separation and successful home recovery are therefore evaluated separately in the evaluation, Equation (4) only accounts for a mission to be completed when all of the required outcomes have been achieved.

*H) Battery, Wind and Return-Reserve Evaluation*

For each test, record energy at takeoff, arrival, release and landing, duration of flight and peaks of motor current.Record energy at takeoff, arrival and release and landing, as well as duration of flight and peaks of motor current for each test, including minimum planned payload, and maximum authorised payload and wind. If the forecasted consumption is unable to provide an adequate return reserve, then the mission must be denied. The route time calculated in Equation (3) shall encompass descent, landing, servo actuation, relaunch (if permitted) and any specified holding time. Because of the wind, it may be necessary to slow down the return leg and one should not assume the same length of time for outbound and inbound trips.

Low battery events are not combined with flight-controller resets, motor anomalies and lost telemetry. The operator needs to decide whether the vehicle entered the RTL, if the vehicle landed with the correct configuration, if it was disarmed while in the site and if the first-aid cargo remained inside the vehicle. This is crucial because in the event of an emergency, the objective is to get the aircraft and passengers safely recovered, rather than meet the schedule of a delivery.

*I) Operational Constraints and Future Validation*

For use in communities and disaster areas practicalities are needed beyond an aircraft's ability to fly. The system needs to provide a safe storage site for the first-aid kit, have an approved ground operator, designated drop points and a suitable clear line of sight and a person at the drop point to receive the contents. Camera-based observation can support the coordination of the local context but cannot support obstacle avoidance without the use of dedicated perception and control algorithms. So MediDrone won't automatically identify survivors or even navigate through the thick jungles.

The length of the route, the amount of the load, the wind, the height, the error of landing, latency of the commands, the percentage of successful deliveries and return energy should be recorded in a field evaluation. If a comparison to ground transport were to be made, this would need to be done in practice on the same route and in similar conditions. The desired required range of operation should be examined for regulatory compliance, particularly for longer-range and beyond-visual-line-of-sight applications [28]–[30]. These measurements will determine if the proposed architecture delivers reliable value-added beyond software interface.

*J) Operational Scenario Analysis*

The suggested conditions of operation are hilly communities, areas in forests and disaster areas. For each one, the restrictions are different: poor radio communications, limited landing area, poor GPS reception and unknown ground clearance. Therefore, the route planning is based on authorized waypoints, confirmed landing zones and energy for the return leg. If it is not possible to establish the safe approach, the ground operator shall discontinue delivery.

The first aid box is used to give temporary basic first aid until the expert responders arrive. "Site readiness and acceptance procedures must be checked by a designated addressee before launch. The UAV is not intended to autonomously diagnose medical conditions or administer medication.

*K) Reliability and Failure-Mode Assessment*

The failure mode analysis methodology decomposes the power loss, position estimation error, communication failure, actuator issues, and mechanical instability. A low voltage can cause a decrease in available thrust prior to an emergency condition, an incorrect magnetometer calibration can destroy way point tracking and a servo brownout will prevent payload delivery even if the landing is safe. Every defect has its own detection signal and respond. But it's not enough to just watch the final dashboard state. Failure to latch or delayed telemetering may be hidden behind a green mission status.

High impact actions should be continued to be positively recognised along the command pathway. One delivery command is sent and is acknowledged by the controller and connected with a local or remote release indicator. If an order is given more than once, it will not be given a second uncontrolled order. Once a connection is down, it is necessary for the system to check the actual controller mode status, and then send out a mission-resume request. Thus, Command Type, Transmission Time, Acknowledgement, Control Mode, Outcome Observed [22]–[24] should be present in the operator facing event log.

*L) Reproducible Test Records and Acceptance Reporting*

A mission record is a record that can be reproduced, which contains mission ID, aircraft configuration, cargo mass, battery ID, programd waypoints, flight-controller settings, wind conditions, distance of the mission, timestamps, telemetry lost, and failsafe events. The logging of the firmware version, propeller type and servo calibration allows to compare trials regularly. The results of navigation, landing, delivery and return shall be recorded individually.

The navigation, energy and release indicators measured should include information about the conditions under which they were obtained, such as a laboratory experiment,

hardware-in-the-loop experiment or an outdoor flight experiment. Comparisons should be made in the same cargo classes, distances, and pre-arm and landing procedures.

*M) Field-Test Sequencing and Ground Procedures*

Verification will vary from the inspection of unpowered wiring and checks of the servos with the propeller removed, to checks of restrained propulsion and supervised flights outside. If manual control recovery, short waypoint navigation, landing-site appropriateness and payload retention and RTL performance are successful, the entire delivery mission should be conducted. The acceptance criteria need to be clear when moving from stage to stage.

The operator shall put in place a delivery protocol with the recipient to include landing site preparedness, confirmation of arrival, handoff of first aid and contingency protocols. Note that mission is not complete until the aircraft physically arrives at or recovers the kit at the destination GPS point, not when it arrives at the GPS point.

*N) Energy Budget and Payload Trade-Off*

Flying time is dependent on battery size, takeoff weight, wind exposure and the amount of propulsion required. The more energy in the pack, the more weight! The payload enclosure may cause a shift in the center of gravity and an increase in drag. Thus, the feasibility of the route should be determined with a fully loaded airframe and the return reserve should be checked.

Electrical demand and possible voltage transients are created by the servo, camera and telemetry link. Bench measurements should be taken with regulated supply voltage during motor acceleration, radio gearbox and latch actuation. The warning values for battery voltage should be different from the remaining energy.

## V. CONCLUSION

MediDrone is a first-aid UAV system based on a quadcopter platform, autonomous waypoint control, servo actuated medical payload, camera assisted control, telemetry and protection for return-to-home. It is a GPS guided system designed to deliver first-aid supplies in terrain constrained environments. The architecture isolates motor control, navigation, payload actuation and ground monitoring. The evaluation equations provide reproducible definitions of thrust margin, energy-limited flying time, route duration and delivery success. The prototype interfaces imply the desired operating sequence, but are not validated mission outcome for the field. Additional measures required for implementation include integrated hardware testing, safe payload-release testing, GPS and failsafe testing, endurance testing under various weather conditions, aviation authorisation, and comparing the performance to existing ground-delivery methods.

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