Hermes
Executive Summary

RMIT University Undergraduate Team
38th Vertical Flight Society, Student Design Competition
Document.2
Table of Contents

• Introduction
• Mission Requirements
• Aircraft RFP Requirements
• Design Approach
• Calculations and Methodology
• Configuration
Introduction

The world is undergoing rapid change in the face of new challenges that occurs everyday. One of those challenges is effective logistical supply in areas that deem regular aircrafts inoperable or inefficient.

Hermes UAV platform, named after the Greek God of Speed and the emissary of God is a fitting name for a platform that goes above and beyond in delivering goods with precision, speed and for a variety of terrains.

The aircraft is a Quadrotor Compound System Hybrid Electric VTOL aircraft capable of achieving cruise speeds of 230 km/h and carrying a payload of 55 kgs. It has a total endurance of 90 minutes at cruise speeds.
## Mission Requirements

<table>
<thead>
<tr>
<th>Mission</th>
<th>Profile Description</th>
<th>Profile Schematic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Delivery Mission</td>
<td>• Vertical Take off&lt;br&gt;• Cruise 13 minutes&lt;br&gt;• Vertical Landing, Deliver Package&lt;br&gt;• Vertical Take off from Delivery Site&lt;br&gt;• Cruise 13 minutes&lt;br&gt;• Land Back at Airbase</td>
<td><img src="image" alt="Local Delivery Mission Schematic" /></td>
</tr>
<tr>
<td>Logistics Mission</td>
<td>• Vertical Take off&lt;br&gt;• 70 minute cruise Limit&lt;br&gt;• Vertical Land at Logistics Base&lt;br&gt;• Reserve 20 minutes</td>
<td><img src="image" alt="Logistics Mission Schematic" /></td>
</tr>
</tbody>
</table>
## Aircraft RFP Requirements

<table>
<thead>
<tr>
<th>RFP Requirement</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continued safe flight in the event of a failure</td>
<td>Fail Safe design practices adopted</td>
</tr>
<tr>
<td>Multi-Mission capability without reconfiguration</td>
<td>Compound multirotor configuration sized to satisfy Logistics and Local delivery mission</td>
</tr>
<tr>
<td>VTOL operation</td>
<td></td>
</tr>
<tr>
<td>Vehicle no larger than 6.1m x 6.1m</td>
<td></td>
</tr>
<tr>
<td>Operation over populous areas</td>
<td>'Path to certification' under CASA part 101</td>
</tr>
<tr>
<td>Autonomous operation</td>
<td>Autopilot System paired with LIDAR and a high-quality camera gives Hermes the ability to fly safely without a pilot, day or night.</td>
</tr>
<tr>
<td>Operation in day and night VFR conditions</td>
<td></td>
</tr>
<tr>
<td>Delivery to precise location</td>
<td></td>
</tr>
<tr>
<td>Obstacle Detection</td>
<td></td>
</tr>
</tbody>
</table>
Design Approach

Configurations evaluated on:
1. Safety
2. Cost
3. Payload handling
4. Technology readiness

Trade study on mission accomplishment

Powerplant configuration:
1. Electric
2. Internal combustion engine
3. Hybrid

Design specifications:
1. Blade aerodynamics
2. Wing and tail sizing
3. Landing gear

Certifications based on:
1. Civil Aviation Safety Authority
2. Federal Aviation Administration
3. Society for Automotive Engineers
Aircraft Configuration

4 VTOL vehicle configurations were considered for analysis. The configurations were Conventional, Coaxial, Multirotor and Compound.

To determine the most appropriate of the 4 options an analytical hierarchy process was performed using the top design parameters in accordance with the RFP. The parameters considered were safety, cost, payload handling and Technology readiness.

From these parameters the most suitable configuration was a quadrotor compound for the advantages it provides in both the VTOL stages and cruise stages of the missions.

This configuration was further optimized to fulfil the RFP requirements to create the VTOL UAV for payload delivery Hermes.
Mission Analysis Take off and Landing

Aircraft on ground VTOL rotors start

VTOL rotors
Climb mode
2.5m/s

Aircraft 150 m AGL
VTOL rotors hover mode
Pusher propellor in operation

Forward speed for lift attained at 136 km/h
VTOL rotors stop running, Cruise mode is engaged

Airspeed reduced
Zero thrust Pusher Prop
VTOL rotors enter hover mode

Vertical Landing
Engines Shut
Design Methodology

Initial Inputs
- Mission Requirements
  - Payload (50kg)
  - Range
  - Hover & Cruise Time
- Design Selection
  - Disk Loading
  - Tip Speed
  - Wing and Rotor Aspect Ratio
  - Number of Blades
- Initial Data
  - Efficiencies
  - Figure of Merit
  - Specific Fuel Consumption

Iteration Loop
- Rotorcraft Sizing
  - Estimate Initial Takeoff Weight
  - Fuel Estimation
  - Useful Weight's
  - Vertical Drag
  - Rotor Sizing Calculations
  - Forward Flight Drag
  - Transition Power Required
  - AUW 1 - Rotorcraft
- Fixed Wing Sizing
  - Empty-Weight Estimation
  - Wing Loading & L/D
  - Wing Configuration & Characteristics
  - Airfoil Selection
  - Wing Sizing Calculations
  - Forward Flight Power Required
  - AUW 2 - Fixed Wing

Decision:
- AUW 1 & 2 - Iterated and Optimised
  - NO
  - YES
- Sizing Optimised
Power Required- Phases of Flight

- The power consumption of the aircraft through the delivery mission is shown below.
- Overall we notice that there is a higher demand of energy from the local delivery mission for VTOL operations.

![Power required Local Delivery](chart.png)
Power Required- Phases of Flight

• The power required for Logistical Delivery is shown.

• Overall, the power required by the cruise segment is higher.

• Thus, taking both the cases into account the aircraft was designed for both the cases so that it can complete the mission without any reconfiguration.
Conceptual Design

For conceptual design the system selection process was crucial as it determined the final performance of the aircraft.

For the purpose of the RFP off the shelf parts were selected based on the requirements they satisfied. Effective trade studies were also done on all the possible systems. The design choices for the layout, powertrain, payload handling operations and Aircraft electronics/Avionics have been shown below.
**Structural Design**

- **Wing integrated Battery**
  - Battery present in wing
  - For added structural stiffness

- **Twin Boom configuration**
  - Added to aid high wing loading in design
  - Will integrate motor cooling capability

- **Carbon Fibre Fuselage**
  - For weight optimisation of airframe along with shock absorption for package protection

- **Skids Landing gear**
  - Non-retractable skids
  - For landing and take off from unprepared surfaces
  - Aid in fuselage strengthening at cargo bay

- **Navigation Lights**
  - Aid in visual identification during night operations
Payload Handling

- High wing for ease of access during payload loading
- Side door for loading cargo using payload dolly cart to transport payload
- Bottom hatch for payload delivery: opens after landing, package has shock absorptive padding
- Skids for ease of landing on unprepared surfaces
Powerplant

VTOL Rotors
- 2m diameter
- 85% VTOL efficiency
- Quadrotor configuration
- For effective Distributed Electric Propulsion and high Area Efficiency

Phillips Li-ion battery
- 245 Wh/kg Li-ion battery
- For VTOL operations
- 20% minimum SOC,
- 45 Kgs battery Pack

Rotax 912
- 60 KW
- Internal combustion Piston engine
- 230 km/h cruise flight
- 18.5 L/h fuel consumption

REX 30
- Brushless DC motor
- 17KW power
- 2X motors per rotor for Safety considerations

Airmaster WWR68W
- Propeller designed to be Used with Rotax 912

For VTOL operations
- 20% minimum SOC,
- 45 Kgs battery Pack
Aircraft Systems

The AP 10.1 Automatic Controller System, is used as the primary navigation and autopilot system.
- Multiple CPU access
- Online sensor failure tolerances
- Integrated GPS

CM142-ISR & Target Acquisition
- High resolution
- Day and night vision using a thermal camera
- Obstacle detection

Ouster OS2 LIDAR sensor
- Obstacle Detection
- 11.25°-33.75° Field of view
- 240m range
- Accuracy of 5.5cm-10.5cm

POLAR-500
- Inertial Navigation
- Incorporated GNSS system
- Precise attitude estimation

ODROID-XU4
- Onboard computer
- Backup system for SLAM algorithm

MXR Mode S Interrogator
- Traffic and collision avoidance system
- Omni-directional surveillance

Trimble R12i
- Access to multiple satellite constellations
- Real time data transmission

Hovermap HF1
- LIDAR obstacle detection
- Simultaneous Location Mapping
- Backup to GPS & Primary LIDAR sensor

These integrated systems provide current sense and avoid technology. They also aid in emergency landing and system redundancy.

Accurate navigation of the vehicle can be accomplished with these systems. For precise payload delivery.

Enables autonomous flight overpopulated areas hence fulfilling the mission requirement of autonomous cruise and VTOL.
Navigation, Obstacle Detection & Avoidance

Traffic and Collision Avoidance System used to prevent collisions between aircraft.

LIDAR and thermal camera used to detect objects such as people and buildings. Also, in conjunction with SLAM algorithm for safe emergency landing.

Automatic controller system used to fulfill autonomous vertical takeoff and cruise flight.

Delivery to precise location is fulfilled with integrated navigation systems.

Landing Zone
15.25 m x 15.25 m
(50’ x 50’)

Automatic controller system used to fulfill autonomous vertical takeoff and cruise flight.
Path to Certification

The path adopted for certification of the aircraft considers the following regulations:

• Australia’s Civil Aviation Safety Regulations (1998) Part 101
• Federal Aviation Administration (FAA) Advisory Circular AC 25.1309
• Society for Automotive Engineers (SAE) ARP4761

An initial Functional Hazard Assessment (FHA) was conducted to identify and classify all failure conditions associated with aircraft functions.

FHA - Key safety features identified:
- Two redundant motors driving each rotor
- Redundant and proven autonomous flight control system
- Backup obstacle detection and navigation sensors