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A drone service to support the Isle of Wight NHS in the UK

Andy Oakey[1*] (a.oakey@soton.ac.uk), Tom Cherrett[1] (t.j.cherrett@soton.ac.uk)

1. Transportation Research Group, University of Southampton, UK

Abstract

With interest in drone delivery growing throughout the world, this study explores the challenges associated with developing a medical drone logistics service to support the National Health Service on the Isle of Wight in the UK. Two separate trials were undertaken to investigate the potential for drone delivery in this area, carrying medical goods and aseptic cancer medicines. The first trial took place using a fixed-wing drone during COVID-19 lockdown restrictions, whilst the second used hybrid fixed-wing vertical take-off and landing (VTOL) drone. Key findings suggested that electric VTOL drones present significant advantages in terms of point-to-point direct servicing, emissions, and time-savings, though range and payload limitations introduce further challenges. Legislation, airspace management, and technology findings were also made, with legacy regulations causing barriers to carriage of medical goods by drone. Future work seeks to understand the costs and benefits of a more sustained service in a medical setting.

Keywords: drone; logistics; island; medicine; covid-19; proof of concept;

Introduction

Interest in using uncrewed aerial vehicles (UAVs, or drones) in logistics has been growing in recent years, with innovations in their construction and operation offering potential opportunities for experimentation across a range of application areas [1]. Several major logistics companies have been exploring services in many countries around the world, including Amazon and UPS in the United States [2], [3], and DHL in Europe [4]. Many new operators have also developed their own systems and trials in a variety of settings, with the majority focussing on moving medical products [5].

Medical drone deliveries are typically investigated due to the short lifespan of critical healthcare products and the potential patient benefits which can result from faster delivery [1]. This time saving is often greatest in areas where existing logistics methods are unreliable or geography and infrastructure makes surface transport inefficient [6]. Further benefits are often seen with regards to energy and emissions impacts [7]; a key factor when the environmental impact of healthcare in developed nations has been identified as a problem to be addressed [8], [9].

In the developed nations, many experimental trials have already taken place, though, to the best of the authors' knowledge, none have reached the point of sustained commercial operation, with advances in technology and regulation being highlighted as key barriers to achieving this milestone [2], [5], [10]. It is understood that the only example of commercial drone operation is seen in Africa, where medical

products are routinely delivered without legacy regulation or congested airspace being an issue [11].
The majority of drone flights in which the aircraft is flown beyond visual line of sight (BVLOS) are completed in segregated airspace to reduce the risk of collision with crewed aircraft [12]–[15]. In the UK, this typically takes the form of a temporary danger area (TDA), in which a section of airspace is isolated for use; though this is not practical for long-term operation due to the limitations it imposes on other airspace users [16].
Progress is being made towards this goal in the UK with Skyports completing extended proof-of-concept flights to remote areas of Scotland [17], though they are now working with the Civil Aviation Authority (CAA) to develop areas of regulation to make flights more accessible [18]. Despite these efforts, current regulations create a significant barrier to developing drone services in developed nations where no management system exists to oversee the safe integration of UAVs and crewed aircraft in shared airspace [16].
In the Isle of Wight (IOW) area of the Solent (UK) studied in this paper (Figure 1), a flight crossing has previously been attempted by a smaller drone platform [19]. Strong winds and technical issues meant that contact with the drone was lost, and the platform never retrieved, highlighting that the technology needs to be fit for the environment in which it is used.
Through the development of two drone logistics trials to support the National Health Service (NHS) on the IOW, this paper presents the methods used and key initial findings around the core research questions: (i) what are the most suitable NHS cargoes for UAV logistics which can have a tangible impact on patient care?; (ii) what implications does legislation present in terms of the carriage of goods and wider operation of drones going forward?; and (iii) what challenges are faced in delivering proof-of-concept trials in developed nations?

Method

In two separate trials as part of the UK government funded Solent Future Transport Zone project [20], investigations were made to develop a drone delivery service to the IOW in the UK (Figure 1).

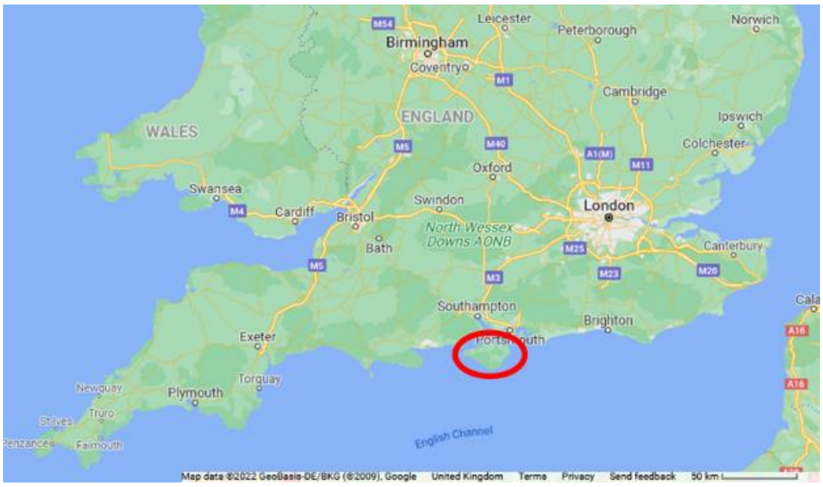

Figure 1. Case Study Area: Isle of Wight, in UK context [21]

Trial 1 – COVID-19 Supply Support

The first trial was planned to support the NHS on the island with supplies during the first COVID-19 pandemic lockdown (May 2020) [22], during which time the ferry service linking the UK mainland was operating a significantly reduced timetable [23]. Flights operated from Lee-On-Solent Airport on the mainland to Binsted Farm Airstrip on the island, with a TDA isolating the airspace used for safe BVLOS passage (Figure 2). A fixed-wing UAV, known as ULTRA TD-1 (Figure 3), built by the University of Southampton for Windracers Ltd. was used in this trial. Powered by two, four stroke engines, connected directly to two bladed wooden propellers, with a wingspan of 10-metres, it is designed to carry 100 kg over 1000 km, with the payload secured into the loading bay using cargo netting and straps. A key feature of this UAV is that is has been designed to eliminate single points of failure with a unique 'masterless control' autopilot system developed by Distributed Avionics [24]. Due to being flown between airfields, onward transportation of goods by road became a necessity.

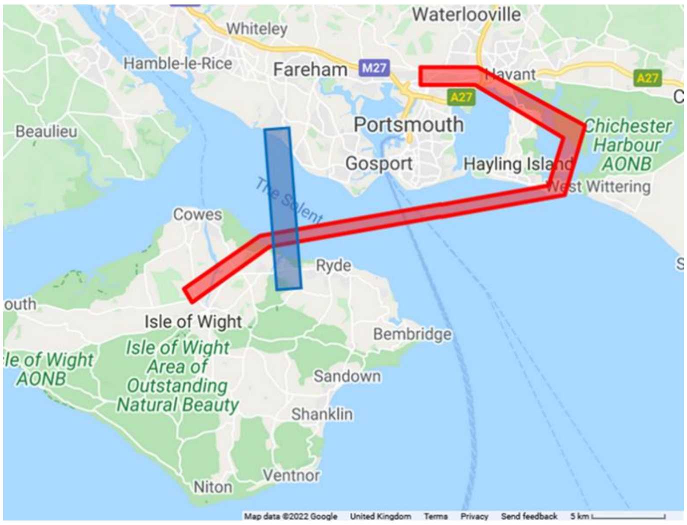

Figure 2. Trial 1 TDA (blue area): Lee-On-Solent Airport, Mainland UK (north of map) to Binsted Airstrip, IOW (south of map) [25]. Trial 2 TDA (red area): QA Hospital, Portsmouth, Mainland UK to St. Mary's Hospital, IOW [26]

Figure 3. ULTRA TD-1 fixed-wing drone used in Trial 1

The second trial, supported by Apian Ltd., identified a need to support the island's hospital with aseptic medicines to improve supply reliability and flexibility to the pharmacy since its own manufacturing unit was closed in 2020 [27]. A VTOL-Fixed-Wing Hybrid UAV was used to enable point-to-point delivery and minimise travel times. The platform used was a Skylift Mugin V50 fully electric UAV with a 5-metre wingspan and 75cm propellors (Figure 4). Payloads (max. limit of 20kg) fitted into a small, closed cargo bay which prevented lateral and vertical movement. To ensure safe passage of BVLOS flights, a segmented TDA was set up between Queen Alexandra Hospital (QA), Portsmouth, and St. Mary's Hospital, IOW, allowing select parts of the danger area to be activated as needed so that wider aviation in the area was less affected (Figure 2). To reduce the risk of overflight in a dense urban area, the route travelled east, via Thorney Island military base, before continuing towards the island. Ground transportation from the pharmacy manufacturing unit (PMU) was required during the trials (~3mi/5km), though a closure of the QA helipad for maintenance meant that flights started at Thorney Island. Ground transport connections were still required, but the greater distance (~9mi/14.5km) meant that timings and modal choice were less favourable.

Figure 4. Skylift Mugin V50 VTOL-fixed-wing drone used in Trial 2

During the investigation, dialogue with the NHS was started to begin to identify which commodities would benefit most from drone delivery. In the first trial, a benign shipment of medical specimen carriers was completed, with an approximate total weight of 10kg (Figure 5). These are commonly used by the NHS for the routine transfer of patient diagnostic samples between collection centres and diagnostics labs. The second trial focussed on the movement of aseptic medicines (used in the treatment of some cancers) using a medical carrier of 46 cm × 26 cm × 31 cm and loaded weight of ~5kg (Figure 6).

Figure 5. Empty medical carriers carried in Trial 1. Approx. dimensions of the medium (middle) carrier = 46 cm × 26 cm × 31 cm. Total loaded weight ~10kg.

Figure 6. Aseptic medicine carrier loaded into the drone. Same dimensions as the medium carrier (left). Loaded weight ~5kg.

Part of this trial sought to quantify whether the vibrations encountered during flight adversely affected the quality and efficacy of the medicines carried; a key requirement of the PMU in granting permissions for further live trials for patients. The return flights are planned to carry UN3373 diagnostic specimens in the same carrier after further testing.

Findings and Discussion

Considerable insight was gained during the trials into the realities of integrating UAVs into current NHS logistics systems alongside the challenges of operating such platforms in mixed-air traffic settings.

Trial Preparations – Auditing NHS Practices

During preparations for the trials, investigations into products which could best support St. Mary's Hospital on the island were carried out. This included an audit of goods shipped in both directions, particularly where transit time and reliability were challenges [28]. Several possible use cases were identified, including specialist diagnostic specimens which required analysis on the mainland, typically with a short shelf-life, and a preference to minimise the duration during which environmental conditions (temperature, vibration) are not maintained [29]. These goods would be subject to dangerous goods regulations, under the classification of 'Infectious Substances', and UN number UN3373 [30]. It has since been identified that legislation for carriage by drone do not exist, with regulations being focused on crewed aircraft [31]. The UK Civil Aviation Authority (CAA) and European Aviation Safety Agency (EASA) have acknowledged this [32], [33], though progress to create standard operating procedures is limited.

Another identified use case was blood stock for transfusion. The island does not currently use any emergency blood stocks (only routine and ad-hoc), suggesting there may be scope to offer such a service with potential benefits to patient care [34]. Blood stocks are not defined as dangerous goods [30], though there may be challenges relating to the sensitivity of products in relation to the vibration profile of drones [35].

One final area of opportunity was identified in the carriage of short-life pharmacy products, such as aseptic cancer medicines. These treatments are currently carried from a pharmacy manufacturing unit to the IOW hospital by a hovercraft and taxis, giving potential to improve service reliability, flexibility, and environmental improvements. The goods were not classed as dangerous due to the volumes being carried, though are still sensitive, like blood products, meaning they may be vulnerable to vibrations imposed by drones.

The first trial explored the viability of an airbridge to support the island with benign cargoes, whilst the second developed this further to carry more time-critical and sensitive products identified in the investigations described above.

Trial 1 – COVID-19 Supply Support

During trial 1, multiple test flights of lower risk (smaller, lower mass) platforms were carried out, followed by one return flight of ULTRA TD-1 from the mainland to the IOW on 9th May 2020, carrying three empty medical carriers. Onward delivery from Binsted to St. Mary's Hospital was made by road transport after unloading from the UAV. The loaded flight took 13 minutes 5 seconds, whilst the onward road connection took around 15 minutes [36].

The additional time required to reach the final destination highlighted that drone platforms with no VTOL capabilities are perhaps less suited to small or shorter-range deliveries. The fastest ferry-based alternative from Southampton (mainland) would have taken 25 minutes, with an onward connection of around 15 minutes, though during the pandemic lockdown, a reduced frequency during the lockdown restricted flexibility [23]. This presented an opportunity to provide a standby/on-demand service for goods delivery if required, though during business-as-usual service (BAU), a ferry and road link would be more effective.

Following the first successful flight, the UK government announced an easing of the COVID-19 lockdown restrictions which allowed non-essential general aviation (GA) flights to resume [37], causing a large growth in aero club, private, and business flights (typical GA flyers) (Figure 7) [38]. At Lee-On-Solent Airport, GA represents a large user base [39]–[41], meaning that the sudden growth in traffic made it unsafe to be testing experimental aircraft. Furthermore, without alternatives to a TDA, it would not have been practical to continue trials due to the TDA obstructing a significant section of busy airspace. These changes meant that further flights to the island were not carried out in this trial, though they did highlight the need for rigorous testing in quieter airspace, and an update to regulations relating to BVLOS flights. Further research into other larger scale deliveries using ULTRA TD-1, and integrated airspace for crewed and uncrewed craft has since commenced [16], [42].

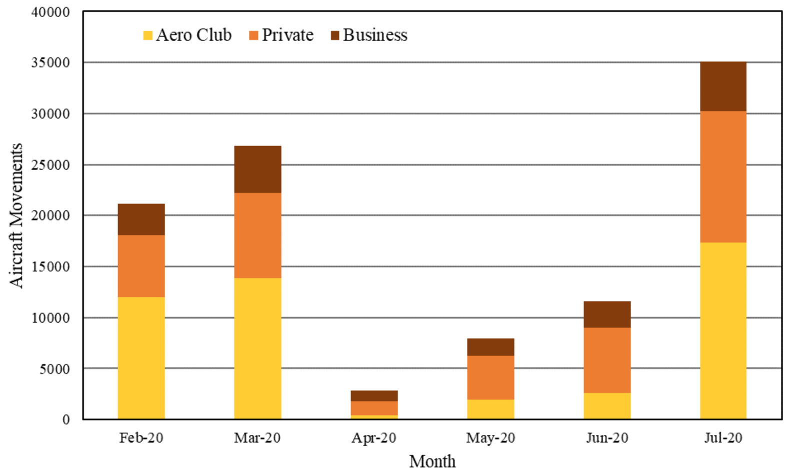

Figure 7. Change in non-essential flights at major UK airports through the COVID-19 UK lockdown [38]

Trial 2 – Chemotherapy/Diagnostic Specimens Medicine Supply

Building on the findings of the first trial, the second trial sought to deliver more time critical goods to draw on a key benefit of drone transport. The chemotherapy medicines were selected as the commodity to focus on due to the challenges faced after the in-house aseptic medicine unit was closed in 2020 [27]. Learning from the airspace and runway limitations of the first trial, an electric VTOL-fixed-wing hybrid drone was used to enable (i) point-to-point service for maximum time benefit and minimal onward transfer requirements; (ii) the ability to take-off from less congested airspace; (iii) longer range than a solely VTOL aircraft; and (iv) a reduction in tailpipe emissions.

Following discussions with NHS staff, it became apparent that validating the environment in which the cargo is carried was critical to gain the necessary approvals from a medicine quality assurance perspective. This included proving that drone flight does not cause standard industry packaging to fall outside of given temperature ranges (e.g., 2-8°C), and that the vibration profile of the drone used does not cause adverse effects on the quality of the products carried. The former had already been demonstrated by multiple studies [43], [44], but the requirement to use industry standard approved packaging somewhat limited the choice of drone, meaning a larger craft had to be used. With respect to the vibration investigation, a need was identified to be determine the effects for the specific drone platform on the products carried [45].

Two investigation flights were made to assess the effects of vibration, on 28/10/2021 and 23/11/2021, respectively. The flights were completed within line-of-sight, locally to Thorney Island military base to limit risks whilst the UAV was undergoing development to be ready for the journey to the IOW. Accelerometers were used to monitor vibrations, whilst redundant (past expiry date) medicines were used to validate the effects on a chemical structure basis.

Vibration profiles were notably different than the BAU methods (taxi-hovercraft-taxi), with higher frequency vibrations being much larger in amplitude than lower frequencies, particularly during the transition to fixed-wing flight (Figure 8). Despite these differences, it was found that no significant chemical changes (such as aggregation or fragmentation of the structures [46]) had occurred in the products themselves to affect their safety or efficacy, resulting in approval for flights of live products to be given [47].

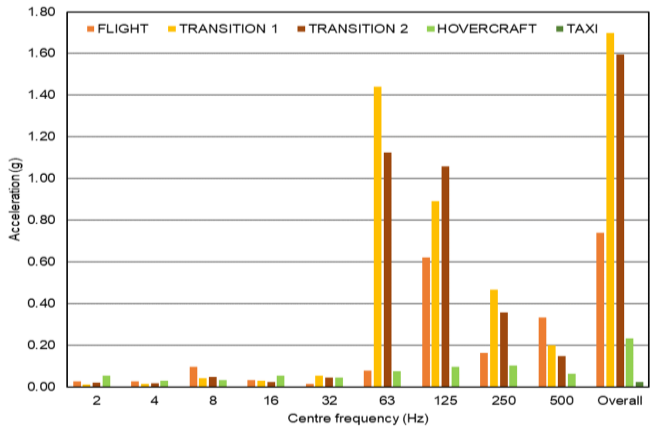

Figure 8. Cargo vibration comparison: flown redundant medicines (yellow/red/orange) vs. BAU (greens)

Further flights were due to take place during the initial TDA, in November 2021, however, technical difficulties and adverse weather limited activity during this period.

Permissions have been given to extend the TDA, enabling BVLOS flight trials to continue, with a view to completing multiple journeys to St. Mary's Hospital in early 2022 [26]. The proposed activity will use a 3rd party logistics carrier to move the medicines from the PMU to Thorney Island military base before onward delivery by drone, direct to the helipad at the IOW hospital. On the return journey, it is planned that UN3373 diagnostic specimens will be carried, reducing empty running of the aircraft; a factor which is widely known to increase delivery costs in logistics [48].

Conclusions

Two trials to support the island population of the Isle of Wight in the UK have been undertaken, exploring a range of use cases. The first of which delivered benign goods during a time of transport shortage, allowing a standby service to be available. A second trial built on the first by exploring a near point-to-point journey carrying short-life aseptic medicines. The following key findings were made:

- Legislation
  - Airspace management can be contentious and limiting the development of long-term operation. Alternatives, with supporting technology, need to be implemented.
  - Dangerous goods and medical regulations need to be updated to cover UAV transport.
- Cargoes
  - UAV transport of time sensitive cargoes is likely to give greater benefits over benign goods.
  - Dangerous goods legislation and the vibration differences of drones may affect the carriage of sensitive products by UAV.
- Technology
  - Many platforms are still experimental, and rigorous testing prior to trials should be undertaken to guarantee service reliability. Weather and other external limitations may still restrict activities for safety reasons.
  - Electric VTOL configurations maximise time benefits, whilst reducing tailpipe emissions and the need for onward-logistics, though can impact on range and payload.

Work to validate the transport method's safety and effectiveness in terms of the cargo moved has been completed, and further work to investigate the challenges of a more sustained operation are ongoing, with results likely to quantify any cost, reliability, time, and flexibility benefits.

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