# Development of a Novel Platform for Greater Situational Awareness in the Urban Military Terrain

Stephen D. Prior[1], Siu-Tsen Shen[2], Anthony S. White[3], Siddharth Odedra[1], Mehmet Karamanoglu[1], Mehmet Ali Erbil[1], Tom Foran[1]

[1] Department of Product Design and Engineering,
School of Engineering and Information Sciences, Middlesex University,
London N14 4YZ, United Kingdom

[2] Department of Multimedia Design, National Formosa University,
64 Wen-Hua Rd, Hu-Wei 63208, Taiwan

[3] Department of Computing and Multimedia Technology,
School of Engineering and Information Sciences, Middlesex University,
London NW4 4BT, United Kingdom

Corresponding Email: s.prior@mdx.ac.uk

**Abstract.** The conflicts in Afghanistan and Iraq and the more recent war in the Gaza Strip have emphasized the need for novel platforms which provide for greater situational awareness in the urban terrain. Without intelligent systems, which can accurately provide real-time information, collateral damage to property will result, together with unnecessary civilian deaths. This situation is exacerbated by the fact that within the next decade 75% of the world's population will be living in urban areas. This paper outlines the current state of unmanned aerial vehicles throughout the world and presents a novel design of a multiple rotary wing platform which has great potential for both military and civilian application areas.

**Keywords:** unmanned aerial vehicles, situational awareness, military operations, urban terrain.

## 1. Introduction

It has been reported that within the next decade 75% of the world's population will be living in urban areas [1, 2]. We can therefore extrapolate that future military operations will predominantly be fought out in these difficult combat zones. This has to some extent already been borne out by the conflicts in Iraq and Afghanistan, where the US and UK military have paid a high price for restoring freedom (see Table 1). The recent one-sided war in the Gaza Strip has further emphasized the need to prevent collateral damage and unnecessary loss of civilian life.

**Table 1.** US, UK and Civilian Casualties in Iraq and Afghanistan [3].

| Country | Theatre | Dead | Wounded |
|---|---|---|---|
| US | Iraq | 4,201 | 43,993 |
| | Afghanistan | 627 | 4,400† |
| | **Total** | **4,828** | **48,393†** |
| UK | Iraq | 176 | 3,294* |
| | Afghanistan | 125 | 1,970* |
| | **Total** | **301** | **5,264*** |
| Civilian | Iraq | **97,094** | **N/A** |
| | Afghanistan | **10-30,000§** | **N/A** |
| | **Total** | **107-127,000** | **N/A** |

† *Estimated data based on known US casualty rates in Iraq.*

** OP Telic and Herrick Casualty and Fatality Tables up to 15 Nov 2008 – MoD Factsheets.*

*§ Estimates of civilian deaths range from 10,000 to 30,000 for the period 2001 to 2008.*

Medical intervention in the combat zone during the so-called ‘golden hour’ has improved over time such that 9 out of 10 soldiers injured now survive. Any loss of life is regrettable and the more that technology can do to remove personnel from the battlefield the better.

Conducting Military Operations in the Urban Terrain (MOUT) is clearly more dangerous than operating in open terrain, and therefore requires greater situational awareness if casualties are to be reduced.

## 2. The World of Unmanned Autonomous Systems

Autonomous Systems now come in all shapes and sizes, and can be categorized into the following five main segments in relation to the vertical space plane:

- Space (Unmanned Space Vehicles, USVs)
- Aerial (Unmanned Aerial Vehicles, UAVs)
- Ground (Unmanned Ground Vehicles, UGVs)
- Surface (Unmanned Surface Vehicles, USVs) – typically sea going vessels.
- Sub-surface (Unmanned Undersea Vehicles, UUVs)

In this paper we will focus mainly on the design and selection of small UAVs due to their inherent suitability for MOUT.

The growth in UAVs over the last ten years has been impressive, driven in large part by the conflicts in Iraq and Afghanistan and the ongoing ‘War on Terror’. According to estimates by Frost and Sullivan, the aggregate military UAV expenditure (2003-2012) for the US and Europe is expected to be £20bn [4], with the US DoD alone forecasting a FY09 UAS procurement spend of US$2bn [5].

Probably the most reliable and up-to-date source of information relating to international UAV usage originates from the Unmanned Vehicle Systems Website and Yearbook which lists UAV activity across the international spectrum [6].

The latest data for 2008-09 lists 974 Unmanned Aircraft Systems (UAS) being developed in 49 countries throughout the world. This has increased by 104% in the last four year period.

Of these 974 systems, 578 (60%) are classed as military, 115 (12%) are civil/commercial and 242 (25%) are dual purpose. Other categories are Developmental and Research. In terms of the 49 UAS producing countries, the US is in the lead with 341 (35%) systems, followed a long way behind by Israel 72 (7%), France 65 (7%), Russian Federation 53 (5%), UK 51 (5%) and Germany 36 (4%).

The most common type of UAV remains the Fixed Wing system (71%), followed by Rotary Wing (18%), Shrouded Rotary Wing (Ducted Fan) (3%), Lighter-than-Air (3%), and then a series of other systems which include motorized parafoils, tilt rotors, flapping wings, etc. AeroVironment Inc, in the US, is at the forefront of this technology with their Wasp III fixed wing UAV system (See Fig 1 below).


**Fig. 1.** The WASP III Unmanned Aerial Vehicle (AeroVironment Inc., USA).

## 3. The Middlesex Co-Axial Tri-Rotor (HALO™)

In light of a greater understanding of the problems associated with the dismounted soldier, such as the mass of any system, its endurance and performance a Preliminary Design Specification (PDS) was constructed, the key points of which are given below:

Design requirements (in no particular order):

- MTOW of 5kg or less
- System shall be capable of being backpack able (0.35 x 0.45 x 0.3 m = 47 lt)
- Linear Speed (0-3 m/s)
- Ability to hover and perch
- Endurance of 30-60 minutes
- Rate of climb in hover of 3.5 m/s
- Manoeuvrable in at least 4 DOF (X, Y , Z, and RZ)
- Ability to carry a payload of up to 2 kg (to include fuel/power source)
- Less than £5,000 (excluding the sensor payload)
- Quiet in operation (< 60 dB(A) @ 3m)
- GPS waypoint autonomous control
- Autonomous vertical take-off and landing (VTOL)
- Set-up in less than 5 minutes
- Turnaround in less than 10 minutes
- Safe operation at all times
- Ability to detect, identify, locate and report the four main target types: IED's, Snipers, Technicals (4x4 armed vehicles) and Armed Combatants

Having reviewed all the alternatives, we focussed on both quadrotor and tilt rotor designs due to their innovative principles and VTOL capability. Finally, we concluded that a multiple rotary winged Co-Axial Tri-Rotor UAV with a VTOL capability could be a novel solution to MOUT. We named our UAV 'HALO™' due to its force protection operational role.

Our proposed UAV system consists of a unique Co-Axial Tri-Rotor design (UK Patent Application No. 08 108 86.2; Design Registration 4008525) which incorporates six AXI 2217/20 brushless out-runner motors, each capable of producing approx 5.6 N (570 g) of thrust at 7 Amps (6,200 RPM), connected to six GWS 1060, 3-bladed props (See Fig 2).

The mass of this UAV is 3.25 kg, which consists of a main system mass of 3.05 kg and an interchangeable payload of 0.2 kg. The system has the capability to increase this payload up to 2 kg if necessary depending on the required sensor package. The UAV is powered by 2 x 8,000 mAh, 14.8v Lithium-Polymer (Li-Po) batteries from MaxAmps™ in the US, which will draw a nominal current of 7 A per motor, making a total current draw per battery of 21 A. This will give a predicted minimum endurance of 23 minutes, dependent on payload and environmental conditions.

The gross dimensions of this UAV are ∅0.7 m (tip to tip) x 0.3 m. The system is capable of hover and perch (it can land and still rotate its camera sensors).

**Fig. 2.** The Middlesex University Co-Axial Tri-Rotor Unmanned Aerial Vehicle.

### 3.1 The Co-Axial Drive Principle

Fundamental to the success of our chosen design is the co-axial drive unit, this consists of two props one mounted above the other rotating about the same axis in opposite directions and powered by separate motors. This arrangement allows the torque output of both units to be balanced thus negating the yaw moment, whilst providing considerable thrust for a small package size (See Fig 3).

Co-axial props have been used on a number of commercial aircraft including the British Supermarine Spitfire and the Russian Tupolev Tu-95 with great success.

An excellent book describing the benefits of the co-axial arrangement, together with the momentum theory analysis is given by J. Gordon Leishman [7].

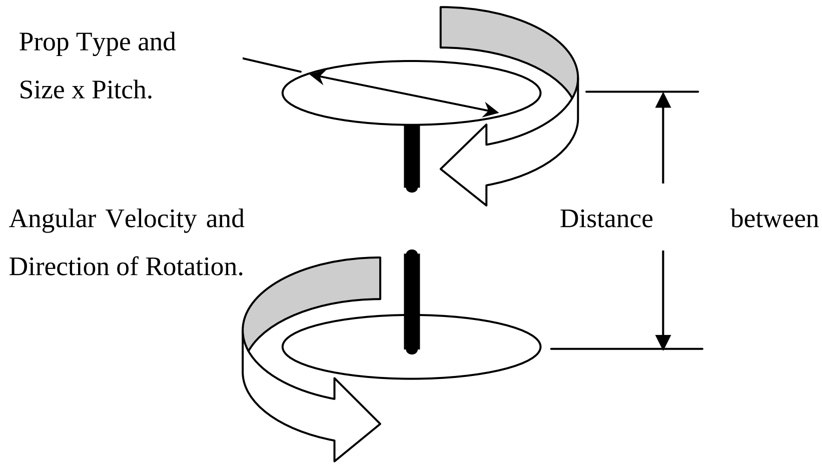


**Fig. 3.** The Co-Axial Drive Configuration.

After extensive testing with many different motor and propeller combinations, it was found that each co-axial unit could produce a maximum Thrust of 19.6 N (2 kg) at 18 Amps (which is the Current capacity of the AXI motor).

Momentum Theory states that the Thrust, T of the propeller is proportional to the Rotational Speed, $n^2$ and the Diameter, $D^4$ of the propeller:

$$T = \quad \rho \,.\, n^2 \,.\, D^4 \,.\, C_T \qquad (1)$$

Also the Power, P of the propeller is proportional to the Rotational Speed, $n^3$ and the Diameter, $D^5$ of the propeller:

$$P = \rho \, . \, n^3 \, . \, D^5 \, . \, C_P \tag{2}$$

*Where $\rho$ = Density of Air 1.225 $kg/m^3$; $C_T$ = Thrust Coefficient and Cp = Power Coefficient for a given propeller.*

## 4. Conclusion

The wars in Iraq and Afghanistan have been costly in both human and monetary terms; personnel and machines are wearing out and the political fallout from injuries and deaths of civilians and military servicemen and women cannot be underestimated. Unmanned Aircraft Systems typically cost 1% of manned systems and can provide ISTAR in places where manned systems cannot go.

There is a requirement for small, lightweight and agile VTOL UAVs to be developed for use in the section or company sized unit within MOUT situations which at the present time remains unfulfilled.

Apart from the obvious benefits in the military context, it is the author’s belief that within the next decade we will begin to see more and more applications in the civilian field of small unmanned aerial systems which will operate semi-autonomously and eventually fully autonomously in areas such as energy conservation and monitoring, agriculture, farming and emergency service operations.

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