

VTOL aircraft concept, suitable for unmanned applications, with equivalent performance compared to conventional aeroplane

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Abstract—The UAVs business experiences currently a strong growth in particular thanks to the popularisation of its mini class (e.g. DJI Phantom, Parrot Bebop...). Nevertheless, there is still a need for more capable aircraft, mainly in terms of payload and endurance, in both military and civilian markets. This type of aircraft is historically known as the tactical class, which is a compromise between the affordability of the mini class and the capacity of MALE class. It was paradoxically the first class to be developed, long before common drones started to be sold in department stores. Contrary to the mini class drones, which are mostly hand operated, tactical aircraft face the main issue of requiring an airfield for take-off and sometimes for landing, when not using a parachute. Such a problem could be solved by providing the drones with a STOL (Short Take-Off Mass) capacity or even better a VTOL (Vertical Take-Off and Landing Mass) ability. The former is partially proposed by most models present in the market by using most of the time external systems (e.g. Flight deck, catapult, ramp...). However, although there have been several attempts to provide the later, using often a helicopter configuration, resulting aircraft have not achieved the performances of classical aeroplanes. This article introduces a new configuration of VTOL aircraft, particularly well adapted to heavy UAVs. A general sizing is carried out in order to meet typical performances required by the tactical class. Even if only the results of the conceptual design are available for now, the VTOL capacity of the drone seems to be obtained with negligible impacts to its overall performance, which is comparable to fixed-wing drones.

I. INTRODUCTION

Unmanned Aerial Vehicles (UAVs), excluding model aircraft, have long been confined to very specific applications and hence, only a small number of drones were available as such on the market. However, since the beginning of the 21st century, this number has risen extremely quickly and seems to grow up together with the propositions of new attractive applications. The most prolific market is currently and by far the one of the micro UAVs, which takes advantage of the recreational use. However, heavier and therefore more capable UAVs are also actively developed, in particular

UAVs entering the tactical class (TUAVs). This class was in fact the first to be developed and still is of major interest to operators in various fields (e.g. film industry, security, defence, agriculture...).

UAVs are usually categorised by altitude and range. This categorisation seems to be relevant as it is used by the industry for their presentations during events such as ParcAberporth Unmanned Systems forum: "A TUAV has a service ceiling of typically 18,000 ft (5,500 m) with a range of around 160 km" [28]. French government also uses the UAV size and weight in order to describe their needs [7]: "A TUAV is characterised by a span of few meters, and a weight in the range of 100 kg."

TUAVs serve usually within brigades or equivalent and are historically dedicated to Reconnaissance, Surveillance, and Target Acquisition (RSTA) [6].

Despite the fact that TUAVs are by their very nature unoccupied, almost all of them are based on classical manned aircraft configurations, that is to say aeroplanes or helicopters. However the constraints involved by the integration of a pilot or passengers greatly restrain the design freedom for physiological limits reasons. Therefore these configurations, which are very competitive for manned flight though, may be surpassed by more advance configurations when applied to TUAVs. These limitations can be summarized as follows: Aeroplanes have very good speed, payload and autonomy characteristics. However, they require substantial resources on the ground, which can be problematic for a tactical use. In contrast, helicopters require very little resources on the ground, however its autonomy and speed are far from approaching those of aeroplanes, which is detrimental for long observation missions. So far, no exotic configuration has been able to solve entirely the weaknesses of the two classical configurations.

The article exposes a new concept of TUAV aircraft that seems to succeed in this task. That is to say, the proposed aircraft presents a VTOL (Vertical Take-Off and Landing) capacity with performances competing with those of classical aeroplanes.

In section II, the state of the art of the existing configurations is exposed.

In section III page 3, the proposed solution is detailed

In section IV page 5, the "conceptual design" of the proposed solution is carried out for a typical tactical mission in order to compare its expected performances to existing TUAVs.

Eventually, section V page 7 concludes this article

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II. STATE OF THE ART

Most of operational UAVs are based on either aeroplane or helicopter configurations. Both of them present specific advantages that make them more suitable depending on the mission.

A. Aeroplane configuration

1) *Aeroplane performances:* Whatever it is for payload capacity, endurance or speed, the aeroplane configuration remains unmatched since the beginning of aviation. This is so true that its performances have become the reference to evaluate the other configurations.

2) *Cleared area for take-off and landing:* Aeroplane UAVs require, depending on machine capacities, longer or shorter, more or less prepared airfields than conventional aircraft for their take-off and landing but usually longer so as not to create any problems while carrying out tactical operations. That is why most TUAVs based on this configuration are usually equipped with means to provide them with a STOL (Short Take-off and Landing) capacity.

For instance, AAI RQ-7 Shadow, a classical aeroplane TUAV, requires a flat surface of about 95m in length for conventional wheeled landing. Although this landing distance may be particularly reduced, using the air vehicle deployable arresting hook, coupled with ground based arresting cables; the drone requires a minimum open space. Indeed, by analogy with piloted aircraft, the landing distance is not only the runway length but also includes the distance travelled in flight since the aeroplane flies under the 50 ft height limit [2].

If the necessary open area can be further reduced by using a parachute landing, like Sagem Sperwer, it cannot be made too narrow. Even with the latest refinement in terms of GPS-based accuracy recovery system applied to the Sperwer by MMIST manufacturer for the Canadian army, the landing footprint cannot be reduced below 50m of diameter [8] as illustrated in Fig. 1. .

Fig. 1. Take-off / landing footprint

The same problem arises for take-offs. The climb slope is indeed limited for conventional aeroplanes.

3) *Ground equipment:* The equipment necessary for mission operations (e.g. deployment, control...) can be substantial, for instance, in the case of Sagem Sperwer, a classic convoy for outdoor operations consists at least of three specialised vehicles: a launch vehicle, a transport vehicle and a command vehicle as shown in Fig. 2. Moreover, in hostile territory, a security force and its dedicated means of transport must be added to this to support the crew against assaults.

Fig. 2. Ground vehicle

Therefore, an outdoor operation consists in an important exposed convoy, in a cleared area, transporting a priority

target (the TUAV). It is easy to understand why, during the recent conflicts, the tactical UAVs have been operated from inside military bases.

That is why developments of VTOL aircraft are currently being carried out.

This capability has been implemented on existing machines such as SR/C Shadow [30].

However, as for manned aviation, it is the helicopter configuration that has been the most prolific.

B. Helicopter configuration

1) *Helicopter performances:* In addition to its well-known configuration which can be easily implemented, a helicopter UAV can perform a long hover flight which, in addition to makes it of particular interest for aerial missions, enables it to land almost everywhere.

Its design can moreover be easily adapted to be operated from a ship helicopter deck as it has been done for the Northrop Grumman MQ-8 Fire Scout co developed by the U.S. Army and the US Navy. This hence enables a high flexibility of deployment.

2) *Helicopter compensation:* The main limitations which affect helicopters with respect to aeroplanes are:

- A theoretical maximum speed of 200 kts [17]
- A relatively low service ceiling as shown in Fig. 3.

Fig. 3. Comparison of helicopter and aeroplane flight envelopes (courtesy of Bell Helicopter Textron)

- A limited range/endurance ratio. For a TUAV, the range being limited by telecommunications, the crucial defining capability is endurance. For instance, for a same payload mass (90kg), the AAI RQ-7 Shadow, based on an aeroplane configuration, can fly 9 hours whereas the Schiebel Camcopter S-100, its helicopter counterpart, can only fly 5 hours.

C. Hybrid VTOL configuration

Since the start of aviation, there have been, over the years, a lot of VTOL configurations experimented [1]. It may seem opportune to apply one of these configurations to unnamed aircraft [15]. However, they were all designed to some extent for accommodating a pilot and/or passengers. All of these concepts can be classified into three main groups:

- "tilt-thrust" configuration, which consists of tilting the propulsion vertically in order to produce some lift,
- The integration of a separated levitation system,
- "tail-sitter" configuration, which consists of landing nose up, with the aircraft lying on its tail.

1) *"Tilt-thrust" configuration:* The first operational aircraft of this kind is Boeing-Bell V-22 Osprey, which is used by the military. This configuration enables to combine the speed of an aeroplane with the hover capacity of a helicopter. However, its complexity and the restrictions of its design prevent it respectively from being affordable, and from reaching the payload capacity and the endurance of an

aeroplane. This has been proven, for example, by the fact that the Coast Guard cancelled in March 2008 the purchase and use of Bell HV-911 Eagle Eyes, which are also a "Tilt-thrust" configuration UAV. They are likely to be replaced by the more rustic RQ-8A Fire Scout unmanned helicopter with the support of Predator classical aeroplane UAVs. If this configuration is very attractive for manned aircraft because it keeps pilots and passengers in a conventional position, this benefit does not mean a lot any more to UAVs applications.

2) *Separated levitation system configuration:* With respect to the previous concept, this solution is easier to implement. In addition, the design of the levitation system is much less restrictive than before and the latter can be therefore much more efficient at low speed. Nevertheless it is unused or at least poorly used during high speed flight where most of the lift is generated by the additional wings and, therefore, constitutes a useless weight and drag generator. This explains the gyrodynes need for extra power compared to the classical helicopters [5]. This configuration is very well suited when a long hover flight capacity is required, combined with brief high speed travels, which is not really the case for tactical uses.

3) *"Tail-sitter" configuration:* A realistic VTOL arrangement which seems to be the easiest to implement is the "Tail Sitter" configuration. The main advantage of this approach is its simplicity since it is sufficient to make the plane land on its tail to consider it as a VTOL aircraft. Nevertheless, the "Tail-sitter" option creates significant problems when it comes to accommodate a pilot and this is why it has lost interest in the past. However, when it comes to a UAV, this drawback is no longer relevant as placing a pilot is no more of an issue.

Many concepts are proposed and developed, trying to combine aeroplanes and helicopters advantages while trying to avoid their drawbacks. It is obviously a good idea, and this paper proposes a radically different approach in that respect.

III. DESIGN IDEA

A. Efficiency issues

Whatever the propulsion system chosen, using either a propeller or a reaction engine, it would end up being a compromise between the two modes of functioning. On the first hand, it would indeed have to produce a strong force at very slow speed to generate the lift. On the other hand, it would have to generate a small force at much higher speed to create the thrust. According to propulsion theory [11], in order to maximise efficiency, the rotor disk must be as big as possible to generate the lift. Other parameters also have to be taken into account during the sizing of the system, such as the rotor weight, the tip maximum speed and the blades aerofoil drag. Therefore, the optimisation result for a helicopter rotor (large disk surface) is totally different from the one of an aircraft propeller (small disk surface). On a convertible, the optimisation gives an intermediate result that causes problems in both flight modes. In high speed flight, the rotor rotating speed is usually reduced to limit the blade tip speed which makes the transmission

mechanism much more complex. In helicopter mode, the rotors are highly loaded, which precludes any autogiro rescue capability, and are particularly poorly efficient [9]. This leads eventually to a significant drop in performances as shown by the comparison (in table I.) between the Bell Eagle Eye (previously mentioned) and a classical aeroplane or a classical helicopter of equivalent weight.

Name	Bell Eagle Eye	EADS Harfang	Northrop Grumman MQ-8 Fire Scout
Mass	1200kg	1250kg	1430kg
Rotor surface	14.6m ²	2.62m ²	55.5m ²
Payload	95kg	250kg	272kg
Flight time	6H	24H	8H
Propulsion power	641hp	115hp	420hp

TABLE I
SPECIFICATIONS COMPARISON

B. Innovative idea

It has been shown that it may not be so relevant to use the same means for propelling and sustaining the aircraft. This has nonetheless the noteworthy advantage to significantly save drag and weight compared to having a separate levitation system. The idea is therefore to merge the rotor with another system present on the aircraft. The wing seems to be the perfect candidate. It indeed presents a very large span compared to a propeller and is already optimised to maximise the lift to drag ratio. This idea is not new. It has indeed already been investigated and tested on the X-wing, the Y-wing, and more recently on the Boeing X-50 Dragonfly. All these attempts have failed to lead to practical aircraft though. In those configurations, the rotor axis remains vertical during the whole flight and thus, the blade aerofoil has to sustain an airflow in the inverted direction when it is stopped.

The novelty of the proposed aircraft is to tilt the rotor axis in order to keep it more or less parallel to the airflow. This can be achieved using a configuration close to the tail-sitter one described in section II-C.3, page 3. When the rotor is stopped, the aerofoil has thus to sustain an inverted angle of attack, which is not really problematic. In order to keep a wing symmetric around the central vertical plane, a symmetrical airfoil is chosen and the blade is designed so that it does not have any static twist. This does not prevent the rotor from taking advantages of an aero elastic twist though.

C. Deepening the concept

The rotor is located in the nose of the aircraft in order to simplify the rotor mechanism and enhance ground clearance. In helicopter mode, this also improves stability. For aircraft with equivalent MTOW (Maximum Take-Off Mass), the total blade surface area of a helicopter rotor is much smaller than the wing surface area of an aeroplane. For example, the blade surface area of a Bell 212 ($MTOW = 5080kg$) is around

$8.7m^2$ compared to the wing area of the Piaggio P180 Avanti ($MTOW = 5470kg$, which is not designed to minimise the stall speed), which is $16m^2$. This illustrates the crucial need for supplementing the rotor / fore plane in aeroplane mode with an additional fixed wing which can be placed in a tandem configuration as shown in Fig. 4. This is even more true for missions where the cruise speed is very low such as usual surveillance.

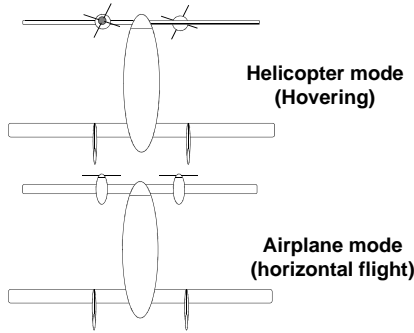


Fig. 4. General overview

Furthermore, the tandem configuration offers an excellent field of vision to the payload as illustrated in Fig. 5. The Scaled Composite Model 281 Proteus takes, for instance, advantage of this fact.

Fig. 5. Tandem configuration

In order to direct rotor thrust regardless of aircraft behaviour and therefore remain controllable throughout the flight, the rotor is based on teetering rotor principle and its design is customised to provide a much greater range of tilt.

The aeroplane propulsion system is directly mounted on the rotor blades. In helicopter mode, its propellers generate the torque required to drive in rotation the main rotor. This eliminates the need for a dedicated powering system for the rotor and reduces the overall complexity of such a component. This configuration also has the advantage of not requiring an anti-torque system. Some prototypes, as the Nagler-Rolz NR 54, have shown the relevance of such a layout [16]. The propulsion technology is not fixed and such a system can comprise either a propeller or a reaction engine depending on the target speed. In the case of a propeller, it should though be contra-rotating in order to balance the gyroscopic forces. The transmission of the power can be done electrically through the rotor shaft by means of a rotary electrical collector, with the power source located in the fuselage. Relying on an electric propulsion system should not be a problem considering recent progress of the technology [13]. The power source can be constituted by a set of thermal power generators and batteries in a serial hybrid power train arrangement. The sizing proposed in this article considers the presence of a heavy fuel piston engine optimised to deliver the cruise power and a turbine APU to generate the boost power required for flights in helicopter mode.

A possible landing gear configuration could be composed of three landing gear legs which could be tilted in order to enable the landing whatever the pitch angle of the aircraft is, from horizontal to vertical, and whatever the slope of the landing field, as shown in Fig. 6.

Fig. 6. Landing gear configuration

This would solve the problem of most tail-sitter that present difficulties to land with wind. It would moreover enable landing in aircraft mode in the case for instance of a mechanical failure preventing any transition.

An ultimate refinement of the design consists of making the system land on its back by positioning the landing gear on the top of the aircraft. This would have the double advantage of preserving the payload integrity from Foreign Object Debris (FOD) when being on the ground and removing the landing gear from the field of vision of the payload when in flight, as shown in Fig. 7.

Fig. 7. Payload location

This design is patented [3].

IV. DESIGN SIZING

In order to assess the performances of such a design, its conceptual design is carried out for a typical tactical mission.

A. Payload

TUAVs have a large sensor capacity. The TUAV baseline sensor is the EO/IR payload. In addition, more and more of them are equipped with a SAR/MTI sensor such as Nano Sar which was placed on AAI RQ-7B Shadow 200 [14]. A third electronic system that is likely to be used on TUAVs is a Communications/Data Relay [6]. Recently, these UAVs are provided with attack capability.

A first estimation of the typical payload required mass $W_{payload}$ can be done accordingly: $W_{payload} = W_{sensorturret} + W_{radar} + W_{pods} + W_{avionic} = 45kg + 10kg + 2 \cdot 15kg + 10kg = 95kg$ Conserving a marge for future implementation: $W_{payload} \approx 100kg$ where $W_{sensorturret}$ [21], W_{radar} [12], W_{pods} and $W_{avionic}$ are respectively the masses of the EO/IR, the SAR/MTI, the optional pods (Communications/Data Relay, ammunition or drop tanks) and the avionic (for UAVs, the avionic mass is included in the payload mass [6]).

B. Mission

It is difficult to set up a design case for a mission since this type of aircraft is relatively new. Nevertheless, a typical mission can be imagined and designed using the method proposed by Roskam [20]. Such a mission is illustrated in Fig. 8 and detailed below.

Fig. 8. Mission

The flight starts by turning on the engines. When they are hot, the take-off is performed in helicopter mode and

followed by the transition. The aircraft then climbs up to its service ceiling and accelerates up to its maximum speed in level flight to reach as fast as possible its field of operation. The field of operation is fixed to 200km/s , which corresponds to the maximum range of the communication equipment. Towards the middle of the mission, the aircraft goes down to its altitude of observation. According to the Concept of Operations (CONOPS) [6], the altitude of operation is around 3000m , which combined to the average Earth altitude (i.e. 840m) provides the loiter altitude. At the end of the mission, the aircraft goes back to where it took off and lands.

According to competitors, the global flight time of a tactical drone increases progressively over the years: It went from 5 hours few years ago to more than 12 hours nowadays (table IV, page 8). Therefore, a flight time of 12 hours has been considered as necessary for the present drone in order to be in line with current alternatives.

C. Mass estimation

Due to the originality of the concept, the mass estimation is very difficult to perform and no conventional methods can be used. The aircraft is supposed to be capable to fly in two distinct modes: as a helicopter and as a fixed wing aeroplane. Therefore, the masses are estimated by first computing, for both modes, the mass of each component using semi-empirical methods and then retaining the heavier result. This could seem irrelevant at first sight. However, in the case of the rotor for instance, which is the component with the mass being the hardest to determine, the main stresses would consist in traction in a helicopter flight, and in bending in aeroplane mode. Both of these constraints are withstood likewise by the sickness of both the upper and lower skins of the blades, which will represent most of the weight.

The aeroplane mass estimations are done based on the formulas provided by Raymer for light aircraft (i.e. unpressurised, small size, slow speed) [18], completed by those provided by Roskam when parameters taken into consideration by the first method are incongruous [20]. The helicopter mass estimations are done using the formulas considered as most relevant by Stepniewski [24].

D. Aerodynamic

The aerodynamic analysis is carried out using the method proposed by Raymer in aeroplane mode [18]. In helicopter mode, the required power of the rotor is estimated using the analysis of W. Z. Stepniewski ([29] for symmetric aerofoil blades. The NACA 0012 is chosen for the rotor blade / fore plane because of the large availability of data. The fuselage is estimated to be of 0.5m of diameter, 3.5m long. It is estimated for extended laminar flow with a maximum cross section fixed at 50% of its length.

E. Stability and manoeuvrability

In order to place the CG (centre of gravity) of the obtained system, a stability study is performed using the method proposed by Raymer [18]. A manoeuvrability study has also

been performed in order to estimate the required dihedral angle of the main wing as well as the surface control areas.

F. Optimisation method

The optimisation problem can be described, as follows:

- **Optimisation settings:** 7 parameters are defined as optimisation settings:
 - The fore plane span
 - The fore plane mean chord
 - The main wing span
 - The main wing mean chord
 - The main engine power
 - The boost engine power
 - The aerofoil type
- **Optimisation constraints:** The only constraint considered is to impose a loiter speed at least 1.1 times superior to the stalling speed.
- **Optimisation criterion:** Contrary to what is generally done, there is no point in minimising the price of the aircraft as it is generally negligible compared to the price of the payload. The aim of the optimisation here is hence to adjust the total mass of the aircraft so that it can perform the tactical operations it is designed for as well as possible.

Because of the nonlinear aspect and complexity of the proposed model, only global optimisation techniques such as stochastic methods can be used to find a good solution. Stochastic methods like heuristic or Meta heuristics have indeed largely proved their effectiveness in finding global optima although the optimality of obtained solutions cannot be guaranteed or theoretically proven. The software used for this study is based on genetic algorithms, differential evolution and non-linear simplex (Nelder Mead algorithm). This hybridisation of global and local techniques makes the convergence of the overall algorithm quicker and also increases the robustness of the tool over a variety of problems [4]. Developed by Cab Innovation, Gencab tool is illustrated in Fig. 9. Consisting of various parameters (i.e. genes) of different types: floating point (the sizes in the present case), integer (the aerofoil type here) or binary, the chromosomes are subjected to random mutations, cross-overs and differential evolutions (i.e. summation of a chromosome gene to the difference between the same genes present in two other chromosomes). After selection, the best elements of the population can be improved at a local level by computing several steps of Simplex.

Fig. 9. Optimisation principal

G. Results

The main dimensions of the aircraft are detailed in Fig. 10.

The main characteristics of the aircraft are summarised in table II.

Empty weight	Fuel	Payload	MTOW	MLW	Power plant
156.8 kg	45 kg	100 kg	301.8 kg	301.8 kg	1 x Gasoline Otto engine, 15.9 kW 1 x Gas turbine, 33.6 kW

TABLE II
MAIN CHARACTERISTICS

Fig. 10. Aircraft 3D model

The main wing aerofoil chosen, in the end, is AH-93-131. The main performances of the aircraft are summarised in table III.

H. Performances comparison

In order to assess the value of the new concept as a TUAV, the expected aircraft characteristics are presented in table IV, page 8 with respect to the ones of current operational TUAVs.

It can be noticed that the Rotor Disc Loading of the aircraft (RDL), i.e. the ratio between the weight and the surface of the rotor, is much lower than for other VTOL UAVs and even lower than for classical helicopters. This is due to the fact that the transition between helicopter and aeroplane flight is done at relatively low speed. Therefore as respect to a classical helicopter, the Mach tip limitation on the advancing blade is much less restrictive, and does not limit as much the rotor diameter. Furthermore, the low disk loading promises excellent auto rotation capacities [11].

V. CONCLUSION

After a quick summary of the characteristics of the tactical UAV class, this article demonstrates the need for designing an aircraft with a VTOL capacity. It nevertheless enhances the fact that such an implementation should be carried out endeavouring to decrease as much as possible the performance loss compared to conventional aeroplane, in term of endurance, speed and payload capacity. This article presents an innovative solution which tries to overcome this issue. It mainly consists in stopping the rotor used to generate the lift during hovering, and converting it into a fixed wing surface that generates lift in aeroplane mode. This process is achieved by tilting gradually the rotor hub from vertical to horizontal, as well as increasing the blades collective pitch angle from almost 0rad to $\frac{\pi}{2}\text{rad}$ while the aircraft is speeding up. A design sizing method has been proposed based on classical aircraft and helicopter methods. According to the obtained conceptual design results, it seems that such a concept would be able to bring a VTOL capacity to the TUAV class at almost no performance cost compared to current existing aeroplanes. Nonetheless, the proposed solution, although it is very promising, is highly challenging in many respects.

A demonstrator, shown in Fig. 11, is thus currently being built in order to test its basic feasibility, assess drone performances during the different flight phases and, above all, verify that the transition from helicopter to plane or vice versa is actually achievable in the air. In order to do so, the

flight dynamics will be investigated and a suitable control law will be brought out for both helicopter and aeroplane modes and for the transition.

Fig. 11. Demonstrator CAO

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Stall speed	Cruising speed	Loiter speed	Range	Endurance	OGE	OGI	Service ceiling
33.9 m/s	95.2 m/s	36.5 m/s	200 km	12.15	2500 m	3027 m	6000 m

TABLE III
MAIN PERFORMANCES

Class	Aeroplane				Helicopter	VTOL	
	Name	Sperwer B	Hermes 450	Falco EVO		Camcopter S-100	Eagle Eye
Manufacturer	AAI	SAGEM	Elbit Systems	Selex ES	Schiebel	Bell Helicopter	?
Introduction	2014	2007	1998	2011	2005	Cancelled	?
Take-off	Classic / Catapult	Catapult	Classic	Classic / Catapult	VTOL	Classic / VTOL	Classic / VTOL
Landing	Classic / Tailhook	Parachute + Airbag	Classic / Tailhook	Classic	VTOL	Classic / VTOL	Classic / VTOL
Length	3.7 m	3.5 m	6.1 m	6.2 m	3.1 m	5.46 m	3.65 m
Wingspan	7.6 m	6.8 m	10.5 m	12.5 m	N/A	4.63 m	6.9 m
Rotor ø	N/A	N/A	N/A	N/A	3.4 m	2.9 m	4.86 m
Height	1 m	1.3 m	?	2.5 m	1.1 m	1.73 m	1.4 m
Empty W	?	275 kg	?	?	97 kg	590 kg	156.8
Gross W	266 kg	350 kg	550 kg	650 kg	200 kg	1200 kg	301.8
Payload	36 kg	100 kg	180 kg	100 kg	50 kg	95 kg	100 kg
Power	47 kW	48 kW	39 kW	49 kW	40 kW	478 kW	15.9 + 33.6 = 49.5 kW
Max speed	220 km/h	240 km/h	176 km/h	216 km/h	222 km/h	370 km/h	342 km/h
Stall speed	?	?	?	130 km/h	0 km/h	0 km/h	0 km/h
Cruise speed	?	?	130 km/h	?	101 km/h	?	131.4 km/h
Range	125 km	200 km	300 km	200 km	180 km	?	200 km
Endurance	16 h	12h	17 h	18 h	6h (25kg)	6 h	12.15 h
Serv ceiling	?	6096 m	5486 m	6000 m	5486 m	6096 m	6000 m
References	[25], [19]	[27]	[26]	[23]	[22]	[10]	N/A

TABLE IV
COMPETITORS SPECIFICATION COMPARISON (“?” WHEN NOT FOUND AND “N/A” WHEN NOT APPLICABLE)

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- [30] Graham Warwick. Flies vtol hybrid. *Aviation Week*, January 2011.