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Novel passenger VTOL/STOL commuter aircraft

Abstract

We present the design of a novel VTOL/STOL aircraft capable of carrying 40 passengers. Apart from the ability of taking off and landing vertically, it is designed to cruise at an altitude of 28,000 ft. at a cruising speed of 360 knots up to a maximum range of 1000 nautical miles. We provide details of the design geometry, the power plant, gross weight, seating arrangements and other details. The proposed design more than meets the requirements of the US Army Future Long-Range Assault Aircraft (FLRAA).

Keywords: vertical/short take-off, landing aircraft

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Abbreviations: VTOL, vertical take-off and landing; STOL, short take-off and landing; FLRAA, future long-range assault aircraft

Introduction

For over 70 years attempts have been made to design an aircraft able to fly horizontally as well as take off and land vertically. The most prominent among these is the Bell XV-3, an early example of the Tilt Rotor concept. The V-22 Osprey has evolved from this design. Other examples using a tilt-wing design are the CL-84 and XC-142. Hawker-Siddley proposed a VTOL/STOL jet airliner the HS-141using fan lift engines. Of these only the V-22 has achieved production status.

Design attempts can be classified generally under two categories

1) Alter a regular aircraft to emulate a helicopter by endowing it with VTOL capability. The examples mentioned above belong to this category.
2) Alter a helicopter to fly like a regular aircraft. Examples are the Sikorsky X2 and the Eurocopter X[3].

Both approaches result in enormous complexity with limited success. The examples mentioned work, up to a point, but they inherit the weaknesses of either aircraft or helicopters. A new approach would be preferable.

We describe below a novel design of an aircraft that flies like a regular aircraft but also has VTOL/STOL capabilities while losing none of the advantages of helicopters or aircraft.

Material and methods

The distinguishing characteristic of Utterfly® is the two fuselages. Engines/propellers centered between two fuselages is what is innovative about this design. This single feature overcomes many weaknesses of previous design. One thrust axis is preferable over two; wing lift over rotor lift. Passengers/cargo would occupy the two fuselages, with the weights balanced between the two. The aircraft has wings on either side of each fuselage, with struts connecting the two fuselages. Separate struts run between wings.

A pair of engines is mounted on a pyramid structure whose base attaches to the struts. The pyramid structure provides torsional rigidity to the pair of fuselages. The fuselages are designed to locate the center of gravity vertically below the engines. I will discuss later why this makes Utterfly® intrinsically stable.

Two turboprop engines, one above the other, swivel on a shaft. Both engines are connected to a common gearbox. The gearbox drives a pair of coaxial contra-rotating prop/rotors using power from either or both engines. The arrangement is desirable for redundancy.

For horizontal flight the engines/propellers are aligned horizontally. The pair of propellers has opposite pitch; they also spin in opposite directions. Opposite pitch ensures airflow from front to rear. Opposite torques cancel gyroscope effects.

While in this mode Utterfly®, takes off, flies and lands like a conventional aircraft. Its cruising speed is limited by the speed of turbo-prop powered aircraft - about 300 knots. It is in this configuration that it would spend most of its flying time.

A drawing shows the geometry (Figure 1):

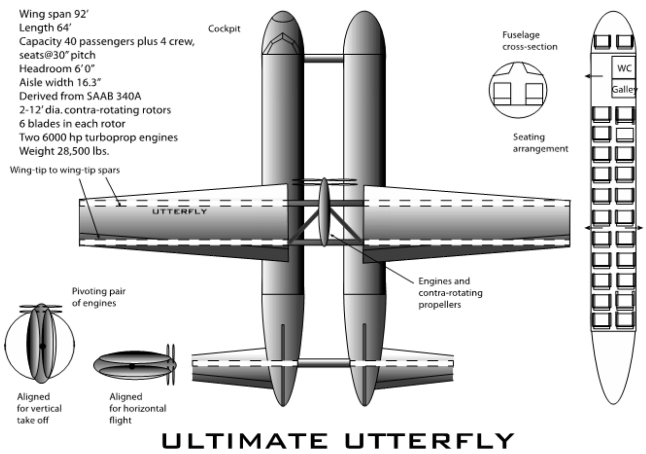

Figure 1 Geometry of ultimate Utterfly®.

For vertical take-off and landing, the engines/propellers swivel to a vertical orientation. The engines rotate about a common shaft.

While in hover mode the propellers act as rotors in a helicopter. Independent swash plates control each rotor. The rotor pitch is controlled as in a helicopter to stabilize the aircraft against roll/pitch/yaw instability and compensate against wind-induced drift. An angle view shows the general layout of the aircraft. The computer rendition below is a 3/4 view showing details of the rotors, engine mount and orientation, one for conventional horizontal flight the other for vertical takeoff and landing. Although the rendition shows 3-bladed rotors, our calculations show the need for 6-bladed rotors (Figure 2–Figure 5).

Figure 2 Twin-fuselage VTOL aircraft configuration.

Figure 3 Central rotor hub and engine mount detail.

Figure 4 Front view of the twin-fuselage VTOL aircraft in hover mode with helicopter-style rotor control.

Figure 5 Three-quarter view showing the aircraft layout, rotor system, and VTOL configuration.

VTOL/STOL mode

Transition from horizontal flight to landing vertically: By swiveling the engines/propellers along the horizontal axis, the speed of Utterfly® decreases while it transforms itself into a VTOL craft. In this mode the propellers point upwards.

A larger payload can be lifted using the short take off mode. When landing in STOL mode, the propeller arrangement facilitates air braking by reversing the pitch of the propellers.

The animation shows Utterfly® executing a vertical takeoff from an urban environment and touching down in a jungle clearing. **https://www.youtube.com/watch?v=7s3roYycN2U**

Results

The following analysis is based on ref.[1] another paper I have found useful is ref.[2] An earlier computation was performed by C. Walker.[3]

The starting parameters specify both upper and lower rotors carry the same load and produce the same thrust (in practice the rotors produce equal but opposite torques), that they are located within 0.2R of each other. The airfoil I am using NACA 0012. The parameters are:

Vehicle: Utterfly®

$\rho_0 = 0.0023769\ lbf\ s^2/ft^4$ (1)

W=2T=28500 lbs. (2)

$a_0 = 1116.5\ fps$ (3)

T=14250 lbf (4)

$M_{tip} = 0.8$ (5)

(Mach number)

$V_{tip} = a_0 M_{tip} = 893.2\ fps$ (6)

$C_{d0} = 0.011$ (7)

(Zero lift drag coefficient)

Two rotors each of diameter 12 ft.

$R = 6\ ft$ (8)

$A = \pi R^2 = 133\ ft^2$ (9)

$N_b = 2 \times 6 = 12$ (10)

Number of blades

$c = 1.75\ ft$ (blade chord) (11)

$\kappa = 1.15$, induced power factor

$\kappa_{int} = 1.16$, induced interference factor

$\sigma = N_b c / \pi R = 1.1191$ (12)

$$P = \kappa_{int}\kappa (2T)^{3/2} / \sqrt{4\rho A} + \rho A V_{tip}^3 (2\sigma C_{d0}/8) = 12315\ hp$$ (13)

Figure of merit=0.725,

Effective induced velocity of the dual rotor system

$(v_i)_e = \sqrt{2T/2\rho A} = 238\ fps\ (162\ mph)$ (14)

Blade loading coefficient is

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$$C_T / \sigma = T / \rho A_b V_{tip}^2 = 0.1191 \quad (15)$$

Where $A_b = N_b cR$; the coefficient has a reasonable value; the angle of attack is 7.75˚, quite far from stall conditions.

The final dimensions are: wing span – 92ft., two turboprop engines each of 6000hp (PW150A), two prop/rotors of diameter 12' and chord 1.75', each with 6 blades and pitch 7.75˚.

Maximum weight - 28,500lbs, accommodation for 40 passengers with a crew of four (captain, first officer and one flight attendant in each fuselage).

Current development

In order to test the design principles I have built a model of Utterfly®. It has a 5' wingspan. This is the second iteration. The first version, Utterfly® I, achieved 40% of design goals. The second iteration, Utterfly® II, has achieved about 90% of the design goal. I have tested its flight characteristics. It takes off and lands vertically. However, I have encountered some problems; the single most important one is that nobody knows how to fly this aircraft. Work continues on a third iteration. The photograph below is of Utterfly II (Figure 6–7).

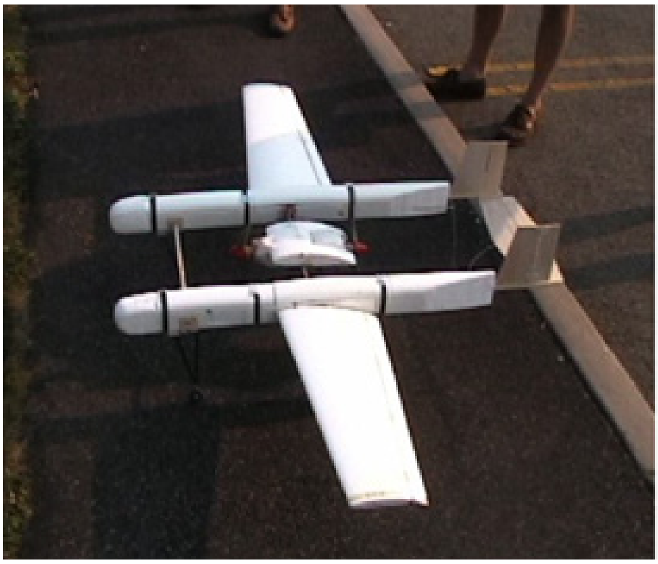

Figure 6 Prototype model of Utterfly® II used to evaluate VTOL flight characteristics and design performance.

Figure 7 Maiden flight of Utterfly®.

Discussion

Possible issues

Aero elastic properties of the fuselage geometry need to be investigated. Because of the prop wash would a T-tail preferable?

Although the twin co-axial geometry is complex, much of the complexity has been solved in the Kamov Ka52 helicopter. The swiveling rotor assembly is also similar to what is used in the V-22 Osprey. Although the complexities mentioned are present in the proposed design, these have been solved in operating rotor craft.

What remains is the twin-engine coupling with the rotors. Although coupling two engines to two coaxial rotors is manageably complex, the arrangement is simplified because the entire assembly swivels around one axis.

The disk loading is estimated to be around 160 *lbs per sq. ft* which will cause a strong downdraft while landing (162 mph). Although the disk loading is relatively high resulting in decreased hover efficiency this drawback is acceptable because the vertical takeoff lifts the aircraft to about 100' in ten seconds, a short interval in a flight that maybe hours long.

Autorotation needs to be investigated. Vortex state instability is another issue. These, and other uncertainties can only be solved by constructing a working model.

Patent application

On Oct 10, 2014 the United States Patent Office issued a patent for this design (#8,857,755 Vertical/Short takeoff and Landing Commuter Aircraft).[4–7]

Conclusion

The design we have proposed has several advantages over existing rotorcraft as well as innovations. In the civilian sector introducing a long-range VTOL/STOL aircraft will facilitate a new class of airlines. Air service will be available in small cities far from airports, because a parking lot, football field or a jungle clearing will substitute for an airport. One result will be to open up small towns to investments in industries, creating employment and prosperity in rural areas.

Settlements in mountainous or forested areas need a small clearing that can be used as a landing ground. Regions in the tropics that are heavily forested, or have tens of thousands of islands (Indonesia and Philippines) can be accessed by VTOL/STOL aircraft.

In larger cities with congested downtown far from airports, a rooftop of an office building can substitute for a runway. It will be possible for an airline, for example, to provide service from a small town in rural New York State, directly to Manhattan, replacing the current option of driving for couple of hours to the nearest airport, flying to JFK, taking public transportation to offices downtown, then retracing the route for the return journey. This is an impediment to investment.

With a range of 1000 nautical miles Utterfly® Aviation can service tens of million customers in heavily populated areas. Utterfly® can be a seed for a novel airline.

Utterfly® has enormous applications in the defense sector. Starting from the announced Future Long Range Assault Aricraft (FLRAA) by the United States Army and Marines with the following specifications; unrefueled combat radius 350 – 520 nautical miles, one-way unrefueled radius of 2440 nautical miles, maximum continuous cruising speed 280 – 330 knots, payload 5200 lbs., passenger 12, it is evident that Utterfly® meets most of these requirements in spades.

Apart from mere transportation the proposed design can be equipped with hard points on wings to carry munitions. When equipped with side-mounted cannons it can serve as a gunship.

The design can be equipped to serve as a field hospital. In the Navy, the proposed design can serve as a tanker for air-to-air refueling with the advantage that it can takeoff from and land on a fuel tanker. It can also be used to transfer munitions from a cargo ship to an aircraft carrier.

Acknowledgments

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Conflicts of interest

The author declares that there are no conflicts of interest.

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