

**AN AIRCRAFT CONFIGURED FOR AT LEAST A VTOL OR STOL MODE AND A
FORWARD FLIGHT MODE**

5 FIELD OF INVENTION

The invention relates to an aircraft configured for at least a VTOL or STOL mode and a forward flight mode.

10 BACKGROUND

An example objective of aircraft design may be to obtain the shortest take off and landing distance. In modern times this has become even more significant due to the cost of the associated infrastructure including runways and airports. In Military applications such infrastructure is often even more costly for example in the case of aircraft carriers.

Prior art approaches at solving this problem include such aircraft as Vertical Take-Off and Landing (VTOL) aircraft; Short Take-Off and Landing (STOL) aircraft, Airships or Lighter Than Air (LTA) aircraft. Examples of VTOL aircraft include helicopters, tilt-rotor aircraft like the Osprey and the Harrier jet. Examples of LTA aircraft include blimps, semi-rigid airships, rigid airships and balloons. A common problem with such prior art approaches is that they can only be optimised for one mode of flight; either vertical or forward.

Another example objective of aircraft design, for example Unmanned Aerial Vehicles (UAV) design, may be to reduce the cost of associated infrastructure as well as the cost of the aircraft. Generally UAVs may be used for surveillance or monitoring in remote or demanding locations. It may therefore be desirable to provide a UAV with VTOL or STOL capabilities.

SUMMARY

In accordance with an aspect of the present invention, there is provided an aircraft configured for at least a Vertical Take-Off and Landing (VTOL) or Short Take-Off and Landing (STOL) mode and a forward flight mode comprising:

a fuselage providing static lift, including at least a portion filled with a gas at a
5 preselected pressure,

at least two fixed wings providing aerodynamic lift during forward flight mode, attached to or integrated with said fuselage, and

at least one propulsion unit(s) propelling said fuselage and including a controlled thrust vectoring system configured to provide a substantially vertical thrust vector during
10 VTOL or STOL mode and a substantially horizontal thrust vector during forward flight mode,

wherein said gas and said preselected pressure being selected, such that said gas at said preselected pressure within said fuselage has a density less than that of air at standard sea level atmospheric conditions,

15 wherein said aircraft is capable of being configured as an Unmanned Aerial Vehicle (UAV).

Said wings may include at least a portion filled with said gas.

20 Said fuselage and said wings may be formed by a flexible outer skin in use pressurised with said gas.

The aircraft may further comprise a rigid body section, to which said fuselage and said propulsion unit(s) are attached.

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Said rigid body section may be releasable from said flexible outer skin and said flexible outer skin is deflatable, to form a disassembled state.

Said propulsion unit(s) may comprise a pair of propulsion units rotatably or
30 pivotably mounted to either side of said rigid body section,

The controlled thrust vectoring system may comprise

a pair of actuators attached to said rigid body section, each configured to rotate or pivot a respective said propulsion unit according to a control signal, and

control means providing said control signals to said actuators according to pre-programmed instructions to provide said controlled thrust vectoring.

5 The aircraft may further comprise reinforcing members attached over the wings to support the bending load from the dynamic lift during forward flight mode.

Said fuselage and/or said wings may comprise a number of sealable compartments.

10 The aircraft may further comprise a plurality of load attachments housed within receptacles within said rigid body section.

Said propulsion unit(s) may comprise a covered and/or ducted fan(s) driven by an electric motor(s).

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The aircraft may further comprise a plurality of sensors providing said control means sensor data including location, altitude and attitude.

20 The aircraft further comprises a data communications link to a base station, wherein said base station receives sensor data, and selectively uploads instructions to said control means.

25 Said controlled thrust vectoring system may be configured to provide a transitional thrust vector during a transition mode between said VTOL or STOL mode and said forward flight mode.

Said wings may be located substantially centrally of said fuselage

Said wings may be located at a longitudinal point of balance.

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BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Figure 1 is a side view of an aircraft according to an example embodiment.

5 Figure 2 is a plan view of an aircraft according to an example embodiment.

Figure 3 is a hidden detail side view of the aircraft according to an example embodiment.

Figure 4 is an internal view showing the spars according to an example embodiment.

10 Figure 5 is a hidden detail plan view of the aircraft according to an example embodiment.

Figure 6 is a view of the system bay and load attachment according to an example embodiment.

15 Figure 7 is a side view of the aircraft during difficult landing conditions according to an example embodiment.

Figure 8 is a front view of the aircraft according to an example embodiment.

Figure 9 is a block diagram of the Flight Control Computer according to an example embodiment.

20 Figure 10 is a flow diagram of the Flight Control Computer software according to an example embodiment.

Figure 11 is a side view of the aircraft hovering according to an example embodiment.

Figure 12 is a side view of the aircraft moving forward and backward while hovering according to an example embodiment.

25 Figure 13 is a side view of the aircraft yawing according to an example embodiment.

Figure 14 is a side view of the aircraft in transition from VTOL to forward flight according to an example embodiment.

30 Figure 15 is a side view of the aircraft pitching according to an example embodiment.

Figure 16 is a side view of the aircraft rolling according to an example embodiment.

Figure 17 is a side view of the aircraft taking off according to an example embodiment.

Figure 18 is a side view of the aircraft landing according to an example embodiment.

Figure 19 is a schematic view of assembly of the aircraft according to an example embodiment.

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DETAILED DESCRIPTION

In an example embodiment, principles of LTA technology are combined with conventional fixed wing or Heavier Than Air (HTA) technology, to provide a hybrid LTA fixed wing aircraft. Such a combination exploits the advantages of "free lift" from LTA to reduce the Maximum Take-Off Weight (MTOW) to achieve practical VTOL capability. Thrust vectoring together with the fixed wings allows effective forward flight characteristics, not found in the prior art. One example application for such an embodiment is a UAV.

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Aircraft Structure

Referring to Figure 1 an example embodiment consists generally of two main sections, a flexible section 100 and a rigid body section 102. Flexible section 100 may consist of a fuselage 104 and wings 106. Rigid body section 102 may consist of a system bay 108 that carries all avionics (not shown), a propulsion system 110, and tail fins 112. The rigid body section 102 may be releasably attached to the flexible section 100, for example, by Velcro fastening straps through slots in both the body and flexible section.

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The flexible section 100 once assembled is filled with a gas at a predetermined pressure such that the gas has a density less than that of air at standard sea level atmospheric conditions (101.325 kPa, 15°C). An example is helium, which in addition to its low density is relatively safe (compared to the flammability of e.g. hydrogen). The gas volume will be sealed and enclosed by the outer skin 200 and will completely fill the fuselage 104 and wings 106. The gas may be provided at a high pressure, for example 400kPa, so as to hold the shape of the aircraft during forward flight. External wing load bearing structure 202 may also be provided to improve rigidity and transfer loads from

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the wings to the fuselage. The flexible section 100 is sized in volume to accommodate the unladen weight with neutral buoyancy. In general 1m^3 of helium provides about 1kg of lift, so for example where the unladen aircraft weighs 3kg the helium volume might be approximately 3 m^3 .

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The Fuselage (104 in Figure 1) will now be described in more detail with respect to Figures 2 and 3. The fuselage may be generally rounded at the front section 204 and generally flat or angled at the rear section 206. The mid section 208 is generally straight, forming the majority of the volume for the helium. The flexible outer skin 200 of the flexible section 100 may for example be formed from flexible poly-vinyl-chloride (PVC) material. This may be formed in the complete shape, may be formed in sections and the sections permanently sealed together, or stored as separate sections and releasably attached and sealed during assembly. The skin may be selected according to weight, the designed pressure of the helium and maximum speed.

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Referring to Figure 3 the fuselage 104 may be compartmentalised to ensure that in case of a puncture, deflation will be minimised. Each compartment 300 may vary in size, for example areas of high structural importance may have higher density of smaller compartments. Each compartment may be formed of internal walls 302, and inflated via a one-way valve in the internal walls 302. In this fashion each compartment 300 can be inflated via a central connection for the pressurised helium supply, but in case of puncture of one compartment only that compartment will deflate.

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The wings (106 in Figure 1) will now be described in more detail with respect to Figures 4 and 5. The wings may be designed with a suitable airfoil section and sized according to the requirements of the forward flight mode. The wing section attaches to the fuselage and is filled with helium forming the complete flexible section 100. The wings include a reinforcing spar to take bending loads from the lift generated. Other reinforcing may be required although for example dynamic pressure at 40 knots is not expected to cause any deformations on the shape of the wing inflated with the pressure of the helium. The wings may be located and sized according to conventional HTA design. For example they may be located at the longitudinal balance point, such that the plane is balanced during steady state flight.

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The external wing load bearing structure (202 in Figure 2) will now be described with more detail with reference to Figure 4. For example the structure may include a left wing section 410, a fuselage section 412 and a right wing section 414. Each section may be detachable from the other, and may be attached for example by locking pins 402
5 into matching receptacle 408. Each section in turn may include laterally extending spar members 400, longitudinally extending rib members 406 and cross bracing members 404. For example each section may be manufactured from carbon composite for high rigidity and strength and low weight. The spars may be attached in a releaseable fashion to the wings and/or fuselage. For example two hook and loop fastened straps may be
10 around the middle of each of the wings.

Referring to Figure 5 the wings 106 may also be compartmentalised to ensure that in case of a puncture, deflation will be minimised. Each compartment 500 may vary in size, for example areas of high structural importance may have higher density of
15 smaller compartments. Each compartment may be formed of internal walls 502, and inflated via a one-way valve in the internal walls 502.

Referring to Figure 6, the rigid body section 102 provides mounting for the various load attachments and propulsion units. The rigid body section may be
20 manufactured from rigid but lightweight high-density foam, for example polyurethane. The rigid body section 102 may be generally rectangular in plan view of approximately the same width as and extend the majority of the length of the fuselage 104.

The system bay (108 in Figure 1) will now be described in more detail with reference to Figure 6. An example system bay is shown including provision for load
25 attachments. Receptacles in the foam are made for installation of the various load attachments. The receptacles are of the same depth as the attachment so that the outer surface is flush for good aerodynamics. Example load attachments for a surveillance platform configuration include a flight control computer 600, surveillance camera 602, datalink 604, fuel or battery 606, propulsion unit servo 608 and slots for fastening to
30 flexible section 610. Each attachment may be secured by friction fit, glue or a mechanical clamping arrangement. Cabling or wiring can be accommodated through tracks in the foam.

In Figure 7 a recovery line system 700 is provided for recovery in difficult landing conditions, for example strong wind or rough sea conditions. A line 702 may be released from system bay 108 over a landing site; and the line 702 may then be recovered and attached to a winch 704 on the ground 706. The winch 704 is then operated to reel in the aircraft 708 while in VTOL mode.

For some load attachments requiring line of sight, eg camera, a non flush mounting may be required. For example a pan-tilt camera may require a dome shape window to protrude from the surface for the moving parts, with the main body of the camera is encased in the foam.

Referring to Figure 8 the propulsion system (110 in Figure 1) will now be described in more detail. The propulsion system may be used to provide controlled thrust vectoring. In an example embodiment two propulsion units are provided, one propulsion unit 808 mounted on the left side of rigid body section 102 and one propulsion unit 806 mounted on the right side of rigid body section 102. Each propulsion unit may for example include a casing 802, a fan or propeller 800 within the casing 802, a prime mover driving the fan and ducting directing the flow from the fan 800. Control fins 804 are provided on the outer side of each casing 802. Alternatively variable ducting or other controlled thrust vectoring may be used.

The prime mover may for example include a combustion engine, a jet or turbine based engine or an electric motor. Fuel or an energy source for the prime mover may for example be stored in or attached to rigid body section 102 or to each unit. Each unit may be mounted to the rigid body section 102, in a rotatable or pivotable configuration. For example a rotating bearing with an axle connected through a gearing to a servo. The capacity of each propulsion unit will be according to the MTOW in VTOL mode. For example for a MTOW of 6kg the propulsion units would be capable of at least 60 N of maximum thrust.

Control system

The method and system of the example embodiment can be implemented in a avionics system shown schematically in Figure 9. The piloting of the aircraft will be automatically operated by a Flight Control Computer (FCC) 900. A number of sensors for sensing flight parameters eg. airspeed, heading, altitude etc provide the necessary
 5 feedback for the FCC to pilot. The FCC provides control signals to position servos 902 and throttle controller 906 to control the magnitude and direction of the thrust vectors. The battery 908 is connected to each module for power.

The FCC may include a memory storing a preprogrammed flight/mission plan. A
 10 wireless datalink 904 provides two way communications between the ground station and the aircraft. Sensor data like airspeed and GPS co-ordinates can be transmitted to the ground station. The ground station with its ground controller can upload new flight/mission plans in real-time for any mid flight mission changes.

15 An example embodiment of flight/mission plan processing will now be described in more detail with reference to the flow diagram in Figure 10. The FCC includes a processor 1000 that receives longitude, latitude, airspeed and heading data from onboard GPS sensor 1002. Other sensors including attitude 1004, pitch 1006, roll 1008 and yaw 1010 allow the processor 1000 to sense the aircraft's altitude and attitude. The
 20 processor then analyses the data to determine thrust vectors for take off and landing and to navigate to target locations. The thrust vectors for VTOL mode 1012 include yaw 1014, pitch 1016 and transition to forward flight mode 1018. The thrust vectors for forward flight mode 1020 include roll 1022, pitch 1024 and transition to VTOL mode 1026. The direction of each of the thrust vectors are then supplied to the position servos
 25 to rotate each propulsion unit and the magnitude supplied to the throttle controllers.

Operation

The example embodiment can fly with conventional wings providing aerodynamic
 30 lift with additional static lift from the helium. In this fashion the example embodiment is able to achieve the VTOL capability while still enjoying relatively conventional forward flying characteristics similar to an HTA aircraft. For example efficient turning and altitude

control may be achieved by banking and pitching up and down respectively, which is generally not available with conventional LTA aircraft.

5 According to an example embodiment there are two basic modes of flight: VTOL and forward flight. During both modes, and the transition between those modes, control may be achieved by thrust vectoring of the propulsion units (110 in Figure 1).

10 In Figure 11 the thrust of the propulsion units is vectored upward 1100 to provide vertical lift for hovering. In Figure 12a to move forwards while still hovering in VTOL mode the propulsion units are rotated forward 1200 simultaneously in the same direction. In Figure 12b to move backwards while still hovering in VTOL mode the propulsion units are rotated back 1202 simultaneously in the same direction. In Figure 13a to yaw left during hovering in VTOL mode the propulsion units are both rotated 1300 asymmetrically, with the left unit backward and the right unit forward. In Figure 13b to
15 yaw right during hovering in VTOL mode the propulsion units are both rotated 1302 asymmetrically, with the left unit forward and the right unit backward.

In Figure 14b during the transition mode from VTOL to forward flight mode the propulsion units are rotated 1400 to vector the thrust from vertical to the direction of
20 flight. In Figure 14a the transition is complete in forward flight mode the propulsion units are fully rotated 1402 to vector the thrust in the direction of flight. In Figure 15a in forward flight the propulsion units are rotated symmetrically and simultaneously down 1500 to pitch down. In Figure 15b in forward flight the propulsion units are rotated symmetrically and simultaneously up 1502 to pitch up. In Figure 16a a left roll is
25 achieved by rotating the propulsion units 1600 asymmetrically, with the left unit downward and the right unit upward. In Figure 16b a right roll is achieved by rotating the fans 1602 asymmetrically, with the left unit upward and the right unit downward.

Referring now to Figure 17 during take off the propulsion units may be operated
30 to full power setting in VTOL mode 1700, with the thrust vectored upwards. The combined lift from the helium and thrust from the fan will effect lift-off vertically to a hover 1702. Once off the ground, for example about 5 meters, the propulsion units will transition 1704 from VTOL to forward flight mode by rotating the propulsion units forward and full forward flight mode 1706 is activated once a threshold speed is reached.

During forward flight mode an example embodiment may operate between a minimum speed, for example 20 knots, and a maximum speed, for example 50 knots. The operating altitude during forward flight mode may be between a floor altitude, for example 1500 feet, and a ceiling altitude, for example 2000 feet. Example operational limitations include ambient temperature, although this may be improved by adjusting or optimising the pressure of the helium gas during operation.

Referring now to Figure 18 during landing, the propulsion units will be operated to decelerate 1800 while approach the landing site. Then once a threshold speed is reached the propulsion units are transitioned 1802 back into VTOL mode to achieve a hover 1804, for example at about 5 meters off ground level. Power to the propulsion units is then slowly reduced until touch down.

In military applications, for example, it may be advantageous to allow assembly and dismantling, so as to store the sections in a reduced volume. An example embodiment may be disassembled into a kit-set and deflated form.

Referring to Figure 19 assembly may be achieved in four steps. In Figure 19a the left wing section 410, the fuselage section 412 and right wing section 414 are installed over the wings 106 and fuselage 104 respectively. In Figure 19b the flexible section 100 is inflated from a pressurised helium source 1900, via a valve 1902 in an outer wall of the flexible section 100, to a designated pressure, for example 400kpa. In Figure 19c the tail fins 112 are attached, for example by locking pins 1904 into matching receptacles 1906 to the rigid body section 102. In Figure 19d the flexible section 100 is attached to the rigid body section 102 with hook and loop fastened straps (not shown). Dismantling may follow the same steps in the reverse sequence.

Applications of an example embodiment

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As a Naval Surveillance UAV, an example embodiment can be deployed from a ship with a Heli-pad. Dismantling and deflation will allow stowage in small package. In rough sea conditions landing can either be achieved by the winch system previously

described. Ditching into the sea if landing is too high risk is also possible with retrieval possible as the flexible section may be designed to float or achieve at least neutral buoyancy in water. Also a minimal metallic structure in the example embodiment reduces corrosion maintenance requirements.

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As a Land Base Surveillance UAV an example embodiment can be portable in a disassembled state and with lightweight components can be transported in a backpack. Simple assembly and dismantling together with a rugged airframe can ensure easy and reliable operation. Any puncture can be temporarily repaired in the field with simple patching of the puncture.

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Advantages of example embodiment

The structural weight can be lower compared to an equivalent size aircraft of a conventional fixed wing design, allowing more payload or endurance capacity. 1 cubic meter of helium provides about 1.1kg of lift at the example pressure of 400kPa and 15°C. The 'free lift' provided by the helium can also help in lowering the thrust required for vertical take-off, enabling a smaller engine to be used to power an equivalent size aircraft. The 'free lift' allows lighter flight therefore consuming less power increasing the endurance. Thrust vectoring allows both an effective VTOL mode as well as an efficient forward flight mode.

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The compressible flexible section may "absorb" forces during crashes, and punctures may easily be repaired by tape. Also, because the flexible and rigid body sections can be separated as independent items in case of damage, they may be easily interchangeable between aircraft. The manufacture can be relatively inexpensive allowing a relatively low unit cost.

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Operation, assembly and dismantling can be quick and easy. There is no requirement for long runway for take-off and landing. General handling and operation can be relatively safe with no exposed rotor blades or propellers. Once disassembled a small and lightweight package can be achieved for either storage or transport.

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It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in example embodiments without departing from the spirit or scope of the invention as broadly described. The example embodiments are, therefore, to be considered in all respects to
5 be illustrative and not restrictive.

CLAIMS

1. An aircraft configured for at least a Vertical Take-Off and Landing (VTOL) or Short Take-Off and Landing (STOL) mode and a forward flight mode comprising:

a fuselage providing static lift, including at least a portion filled with a gas at a preselected

pressure,

at least two fixed wings providing aerodynamic lift during forward flight mode, attached to or integrated with said fuselage, and

at least one propulsion unit(s) propelling said fuselage and including a controlled thrust vectoring system configured to provide a substantially vertical thrust vector during VTOL or STOL mode and a substantially horizontal thrust vector during forward flight mode,

wherein said gas and said preselected pressure being selected, such that said gas at said preselected pressure within said fuselage has a density less than that of air at standard sea level atmospheric conditions,

wherein said aircraft is capable of being configured as an Unmanned Aerial Vehicle (UAV).

2. An aircraft as claimed in claim 1 wherein said wings including at least a portion filled with said gas.

3. An aircraft as claimed in any one of the proceeding claims wherein said fuselage and said wings are formed by a flexible outer skin in use pressurised with said gas.

4. An aircraft as claimed in claim 3 further comprising a rigid body section, to which said fuselage and said propulsion unit(s) are attached.

5. An aircraft as claimed in claim 4 wherein said rigid body section is releasable from said flexible outer skin and said flexible outer skin is deflatable, to form a disassembled state.

6. An aircraft as claimed in claims 4 or 5 wherein said propulsion unit(s) comprises a pair of propulsion units rotatably or pivotably mounted to either side of said rigid body section.

7. An aircraft as claimed in claim 6 wherein said controlled thrust vectoring system comprising a pair of actuators attached to said rigid body section, each configured to rotate or pivot a respective said propulsion unit according to a control signal, and control means providing said control signals to said actuators according to pre-programmed instructions to provide said controlled thrust vectoring.

5 8. An aircraft according to any of the preceding claims further comprising reinforcing members attached over the wings to support the bending load from the dynamic lift during forward flight mode.

9. An aircraft according to any of the preceding claims wherein said fuselage and/or said wings comprise a number of sealable compartments.

10. An aircraft according to any claims 4 to 8 further comprising a plurality of load attachments
10 housed within receptacles within said rigid body section.

11. An aircraft according to any of the preceding claims wherein said propulsion unit(s) comprise a covered and/or ducted fan(s) driven by an electric motor(s).

12. An aircraft according to claim 7 further comprising a plurality of sensors providing said control means sensor data including location, altitude and attitude.

15 13. An aircraft according to claim 12 further comprising a data communications link to a base station, wherein said base station receives sensor data, and selectively uploads instructions to said control means.

14. An aircraft according to any of the preceding claims wherein said controlled thrust vectoring system is configured to provide a transitional thrust vector during a transition mode between said
20 VTOL or STOL mode and said forward flight mode.

15. An aircraft according to any of the preceding claims wherein said wings are located substantially centrally of said fuselage.

16. An aircraft according to claim 15 wherein said wings are located at a longitudinal point of balance.