(12) UK Patent Application (19) GB (11) 2 419 122 (13) A

(43) Date of A Publication 19.04.2006

(21) Application No: 0520284.1

(22) Date of Filing: 05.10.2005

(30) Priority Data:
(31) 0422095 (32) 05.10.2004 (33) GB

(71) Applicant(s):
Alexander Stuart Hardy
1 Crawford Road, Camberwell, LONDON,
SE5 9NF, United Kingdom

(72) Inventor(s):
Alexander Stuart Hardy

(74) Agent and/or Address for Service:
Mathys & Squire
120 Holborn, LONDON, EC1N 2SQ,
United Kingdom

(51) INT CL:
B64C 29/00 (2006.01) B64C 27/08 (2006.01)
B64C 27/26 (2006.01) B64C 27/52 (2006.01)

(52) UK CL (Edition X):
B7W WBCB WHRC WPF W102 W104 W107 W108 W109 W601
B7G GCHC

(56) Documents Cited:
DE 004302791 A1 DE 002628274 A1
FR 002667568 A1 US 6719244 A
US 4703906 A US 3393882 A
US 3366347 A US 3106369 A
GB 17653/10

(58) Field of Search:
UK CL (Edition X) B7G, B7W
INT CL B64C
Other: ONLINE:EPODOC,WPI,OPTICS

(54) Abstract Title: **Vertical take-off and landing aircraft**

(57) The aircraft comprises an airframe portion comprising means for supporting a pilot and defining a central axis, and a rotor-head comprising at least two rotors arranged to rotate about respective axes displaced from the central axis of the aircraft. Several different types of aircraft are disclosed and several different aspects are independently claimed. In one aspect, the rotor head is able to pivot about an axis 1216 perpendicular to the central axis of the aircraft. In another aspect, the rotors are in respective planes that are inclined to define a non-zero dihedral angle. In a further aspect an explosively-deployed parachute, rotor brake, and means for signalling an emergency are provided. In still further aspect, a lift-providing aerofoil portion (eg. 2712) is provided which may be variable in angle of attack. Single-passenger aircraft in which the pilot is either standing or seated are disclosed, as well as multi-passenger aircraft. The aircraft may comprise ducted rotors, or open rotors having variable pitch blades. Mechanical or fly-by-wire control systems may be used.

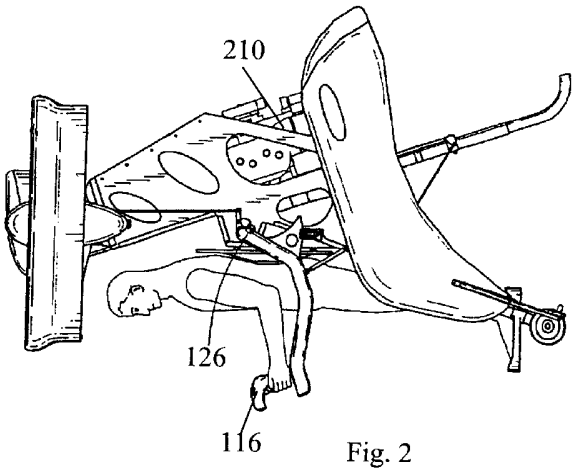


Fig. 2

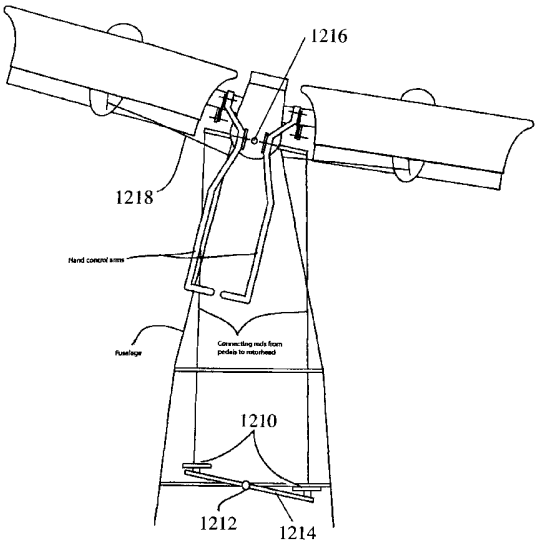


Fig. 12

GB 2 419 122 A

Original Printed on Recycled Paper

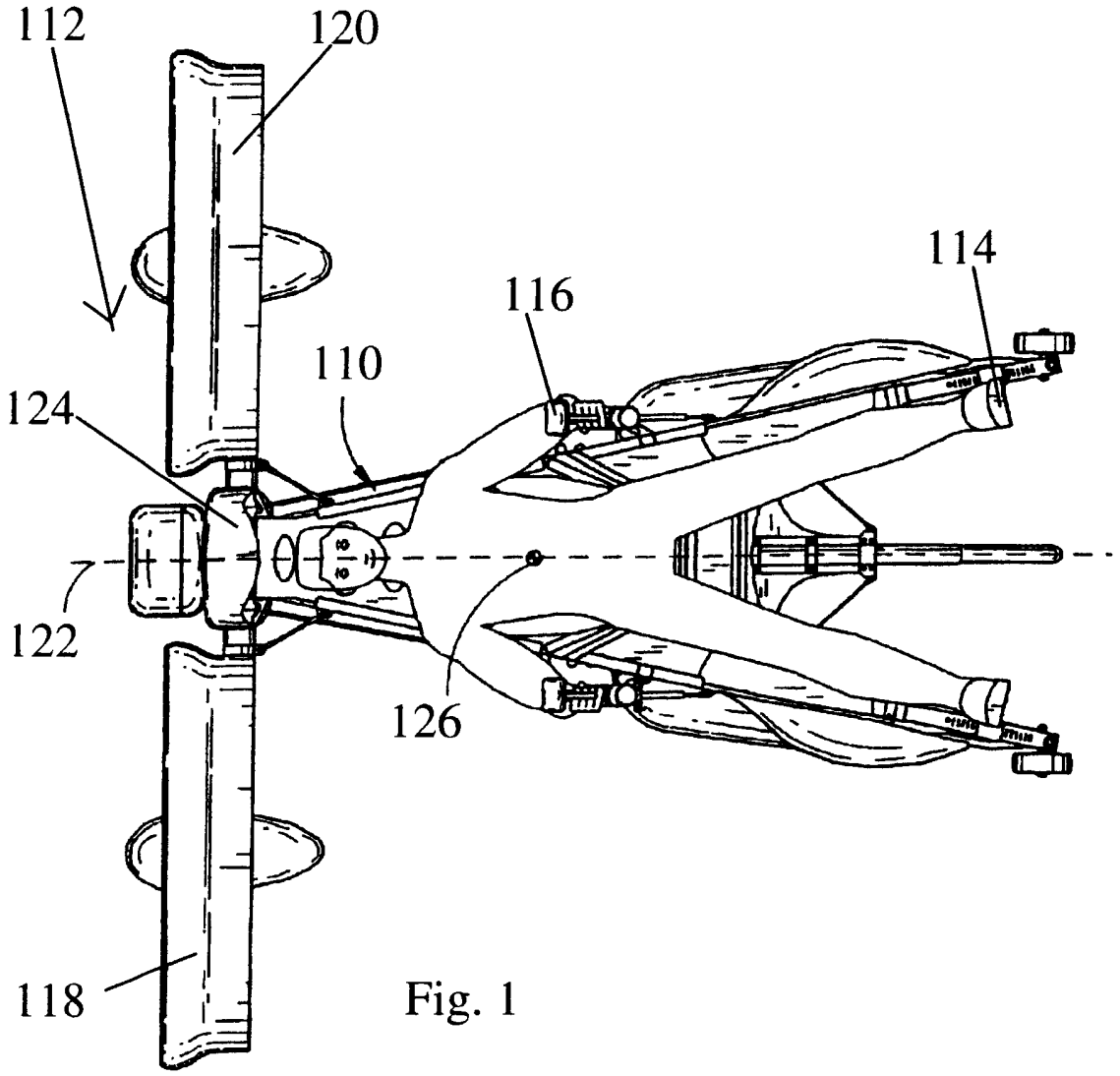


Fig. 1

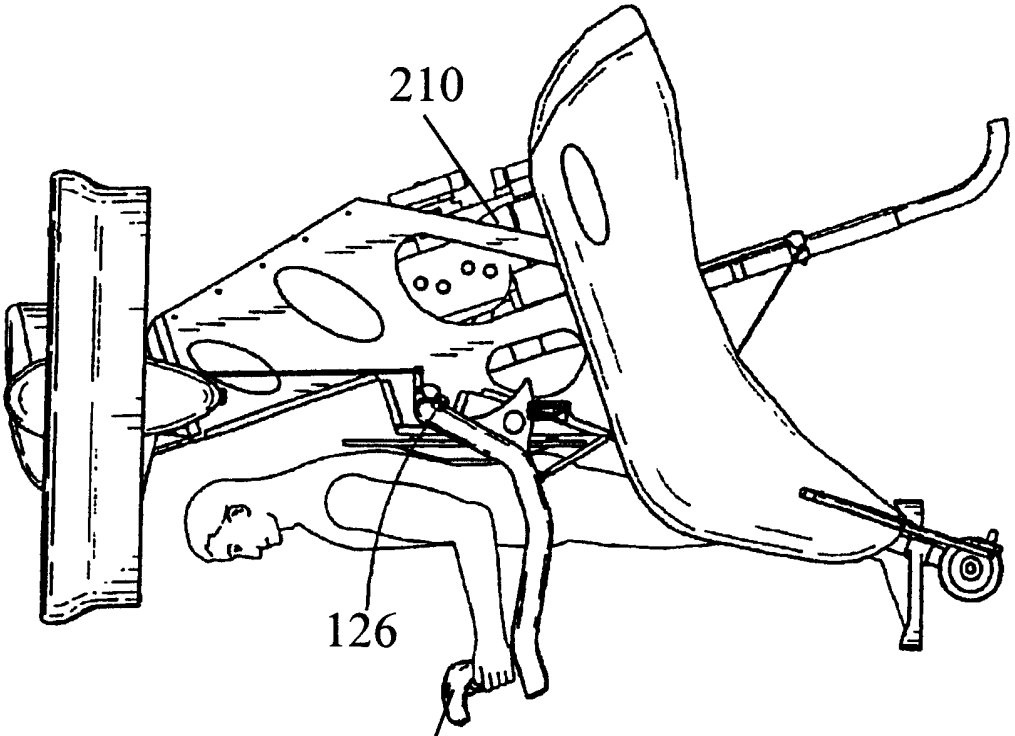


Fig. 2

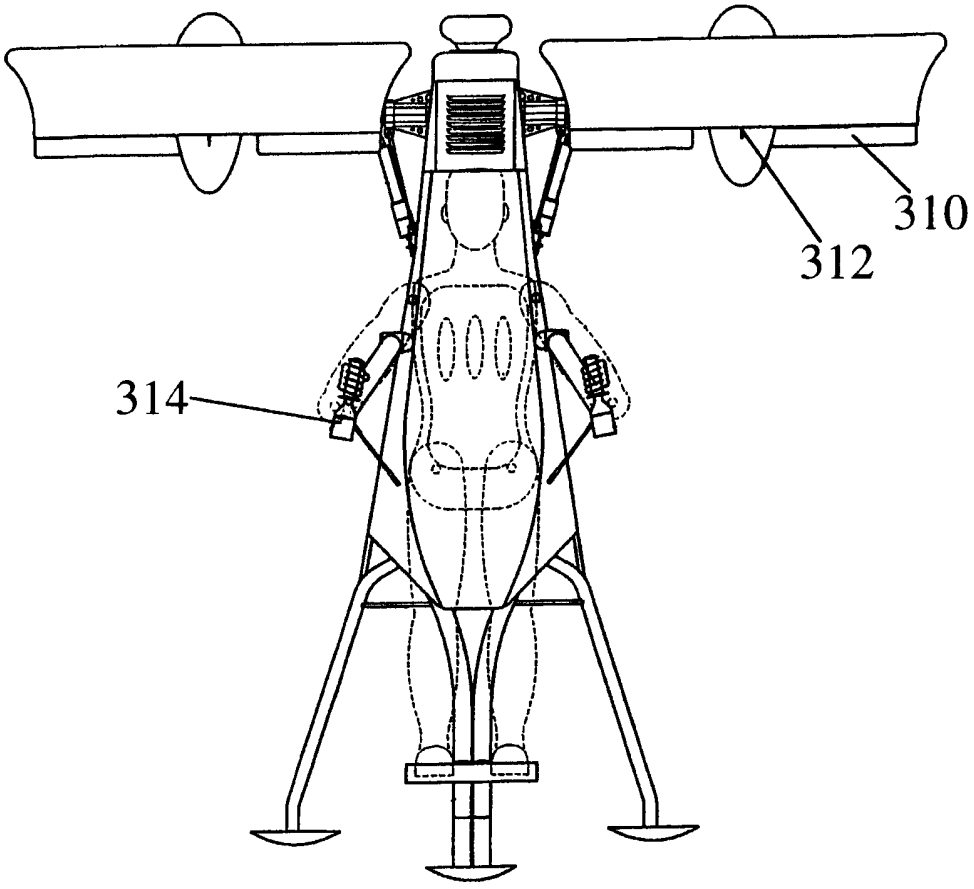


Fig. 3

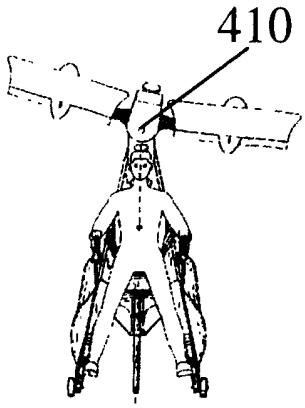


Fig. 4

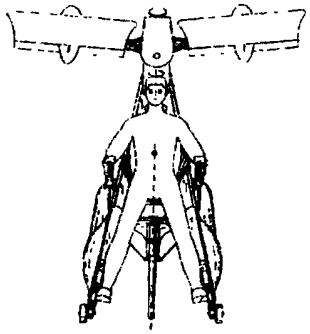


Fig. 5

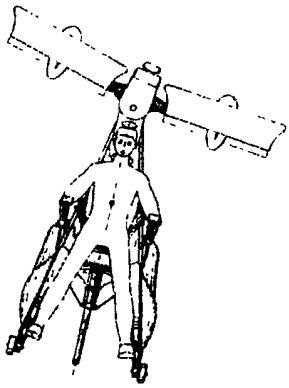


Fig. 6

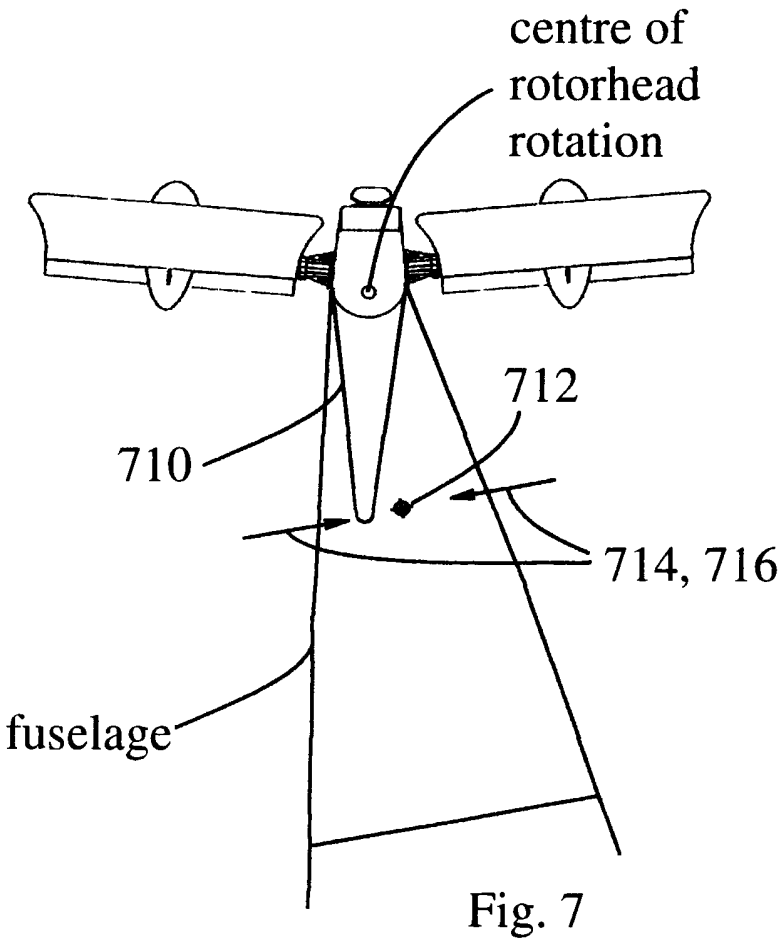


Fig. 7

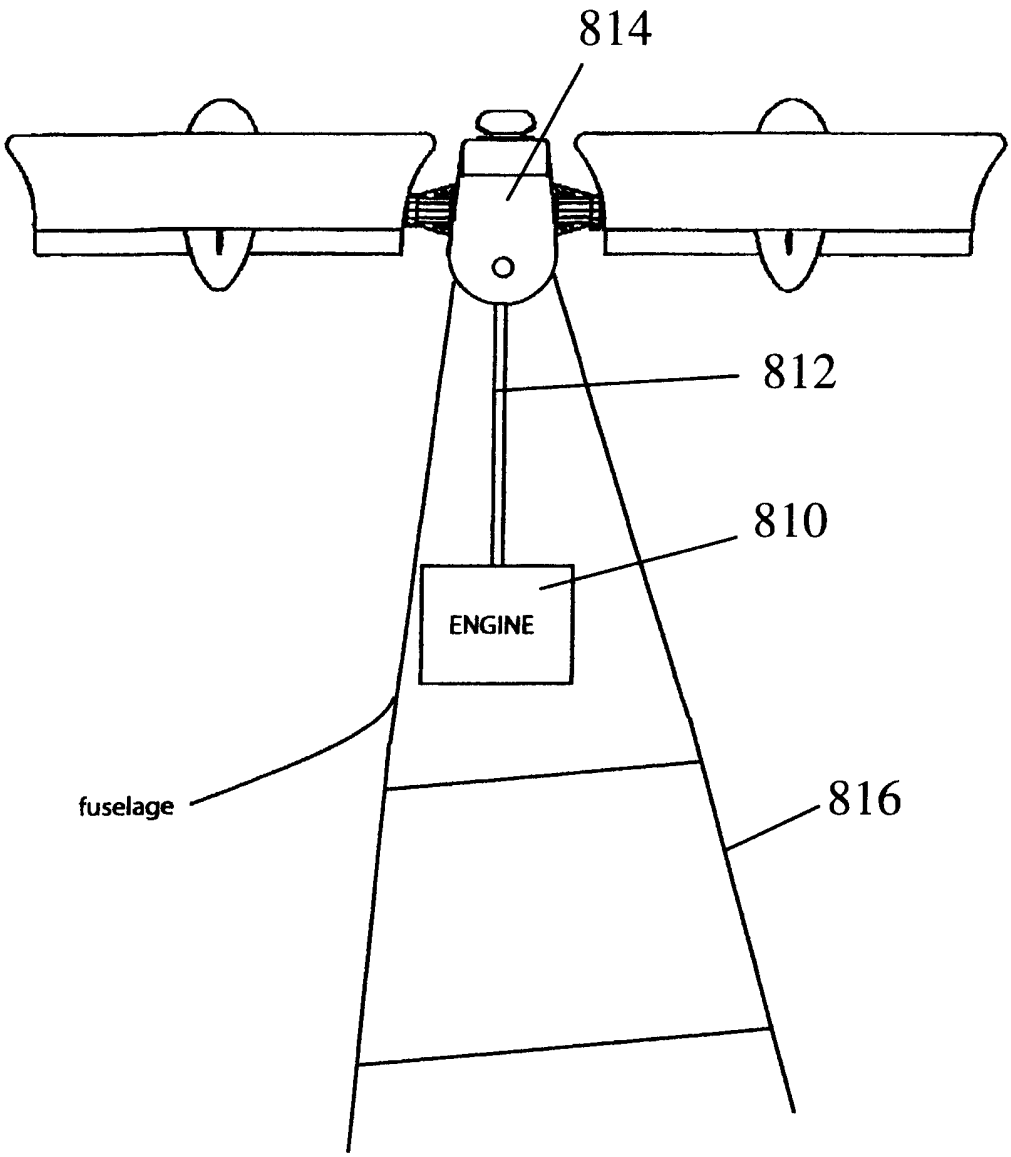


Fig. 8

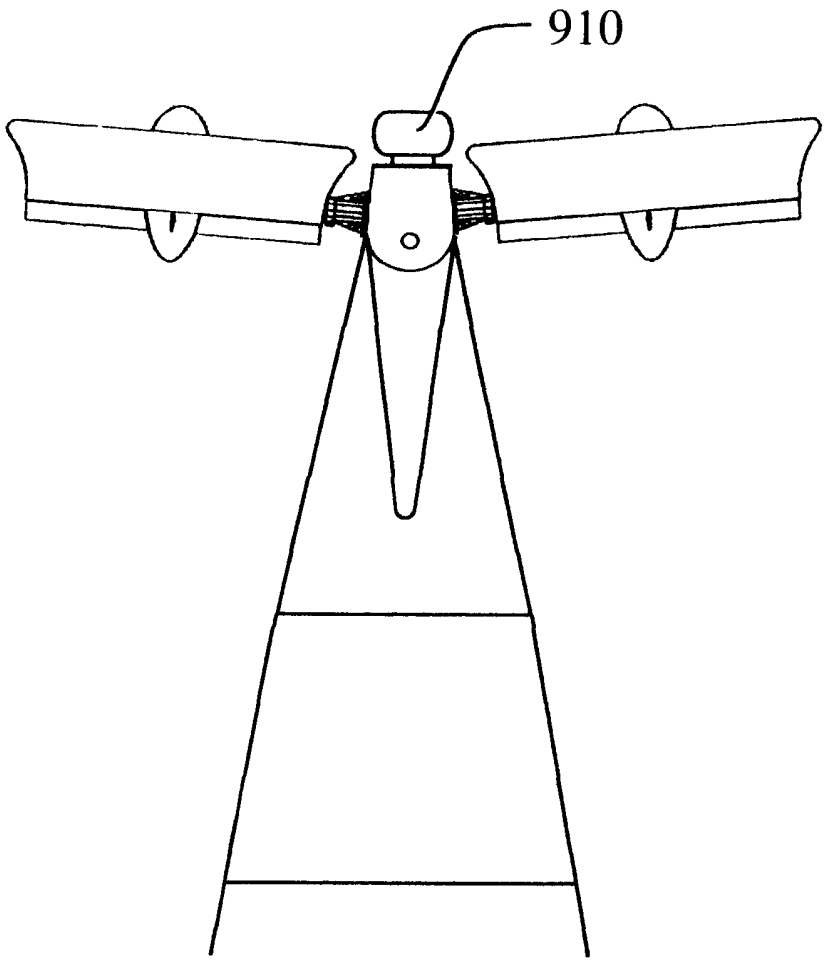


Fig. 9

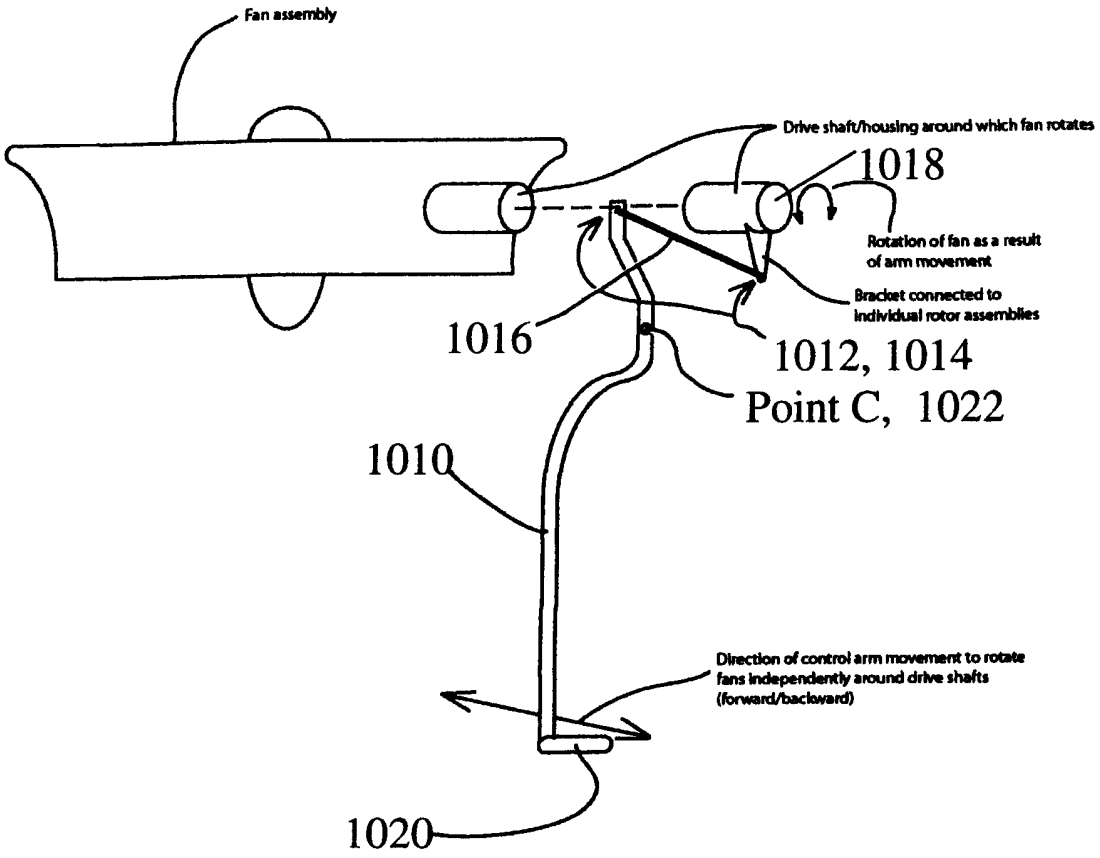

Fan assembly
Drive shaft/housing around which fan rotates
1018
Rotation of fan as a result of arm movement
Bracket connected to individual rotor assemblies
1016
1012, 1014
Point C, 1022
1010
Direction of control arm movement to rotate fans independently around drive shafts (forward/backward)
1020

Fig. 10

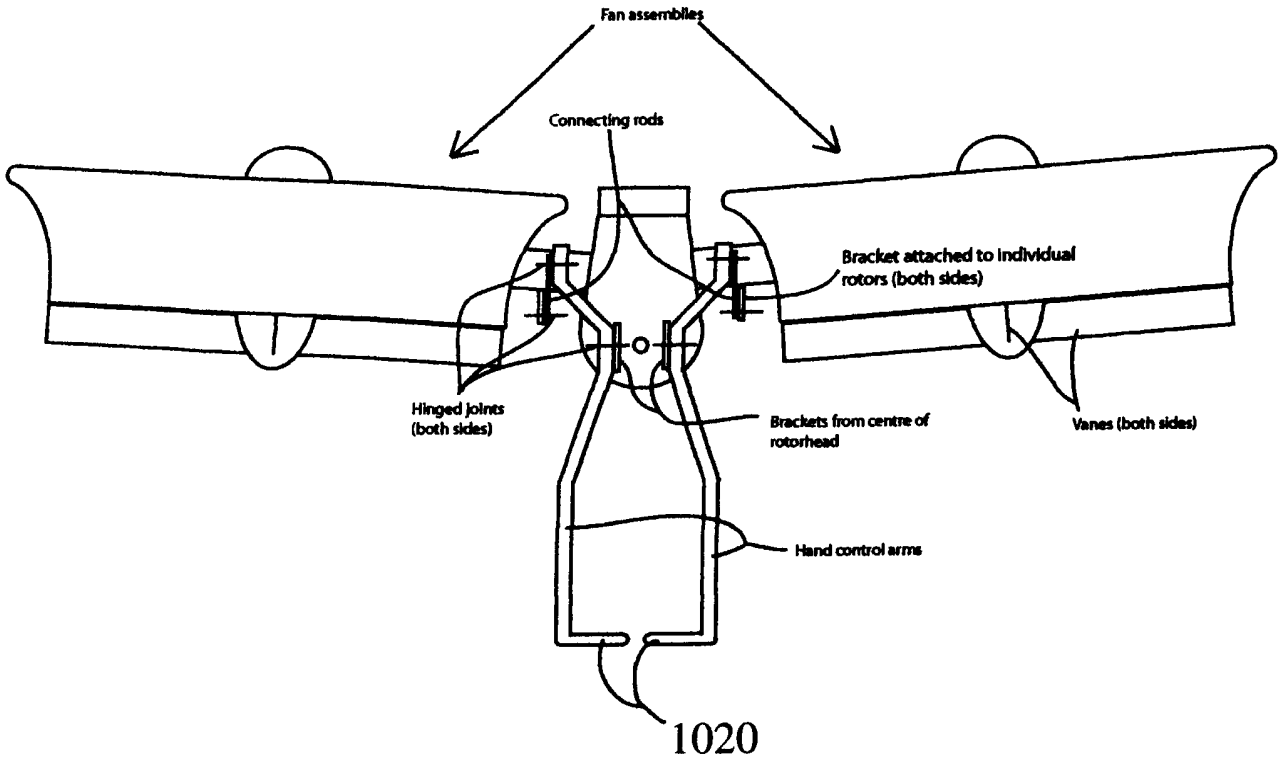

Fan assemblies
Connecting rods
Bracket attached to individual rotors (both sides)
Hinged joints (both sides)
Brackets from centre of rotorhead
Vanes (both sides)
Hand control arms
1020

Fig. 11

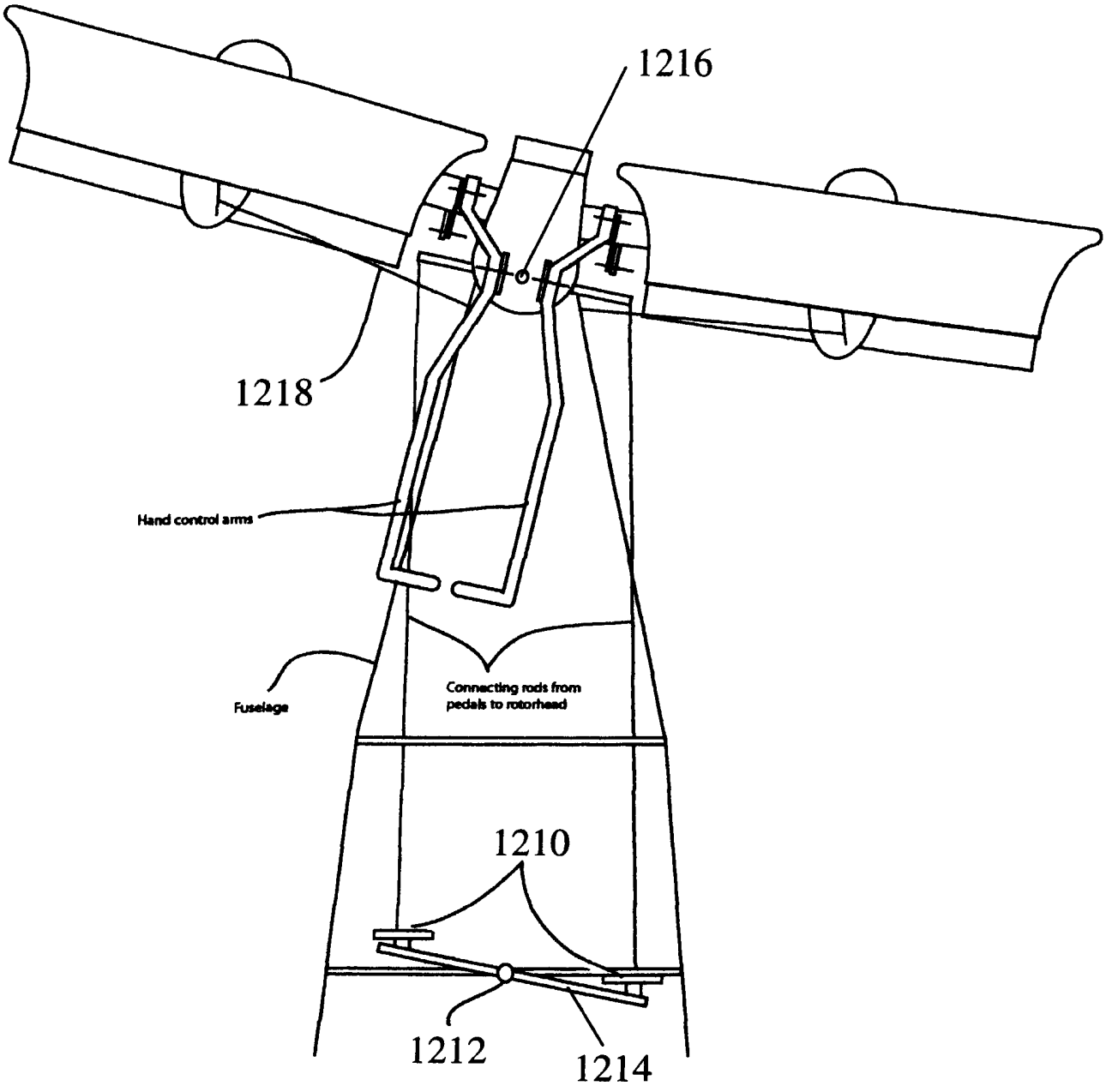

1216
1218
Hand control arms
Fuselage
Connecting rods from pedals to rotorhead
1210
1212
1214

Fig. 12

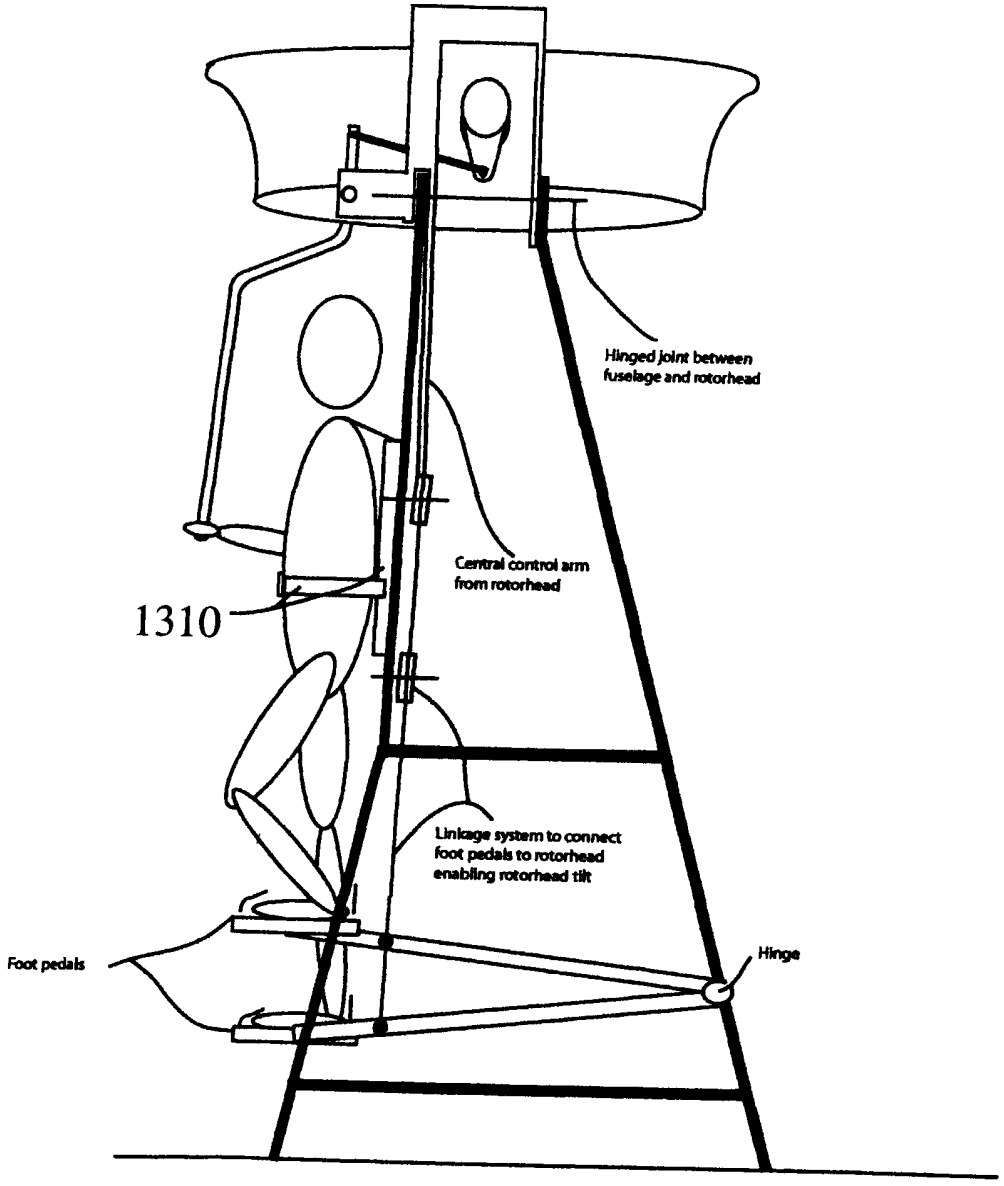

Hinged joint between fuselage and rotorhead
Central control arm from rotorhead
1310
Linkage system to connect foot pedals to rotorhead enabling rotorhead tilt
Foot pedals
Hinge

Fig. 13

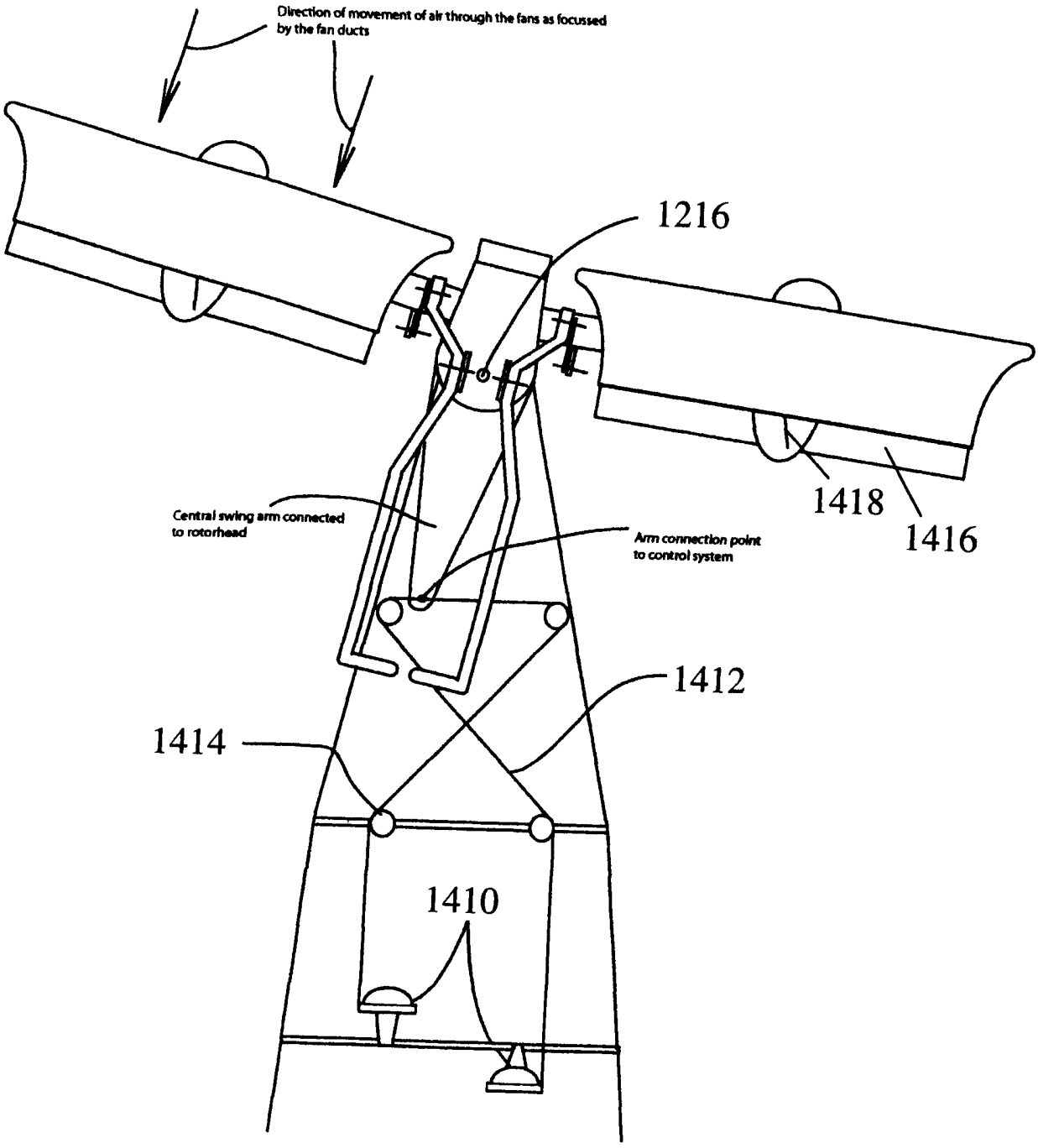

Direction of movement of air through the fans as focussed by the fan ducts
1216
Central swing arm connected to rotorhead
Arm connection point to control system
1418
1416
1412
1414
1410

Fig. 14

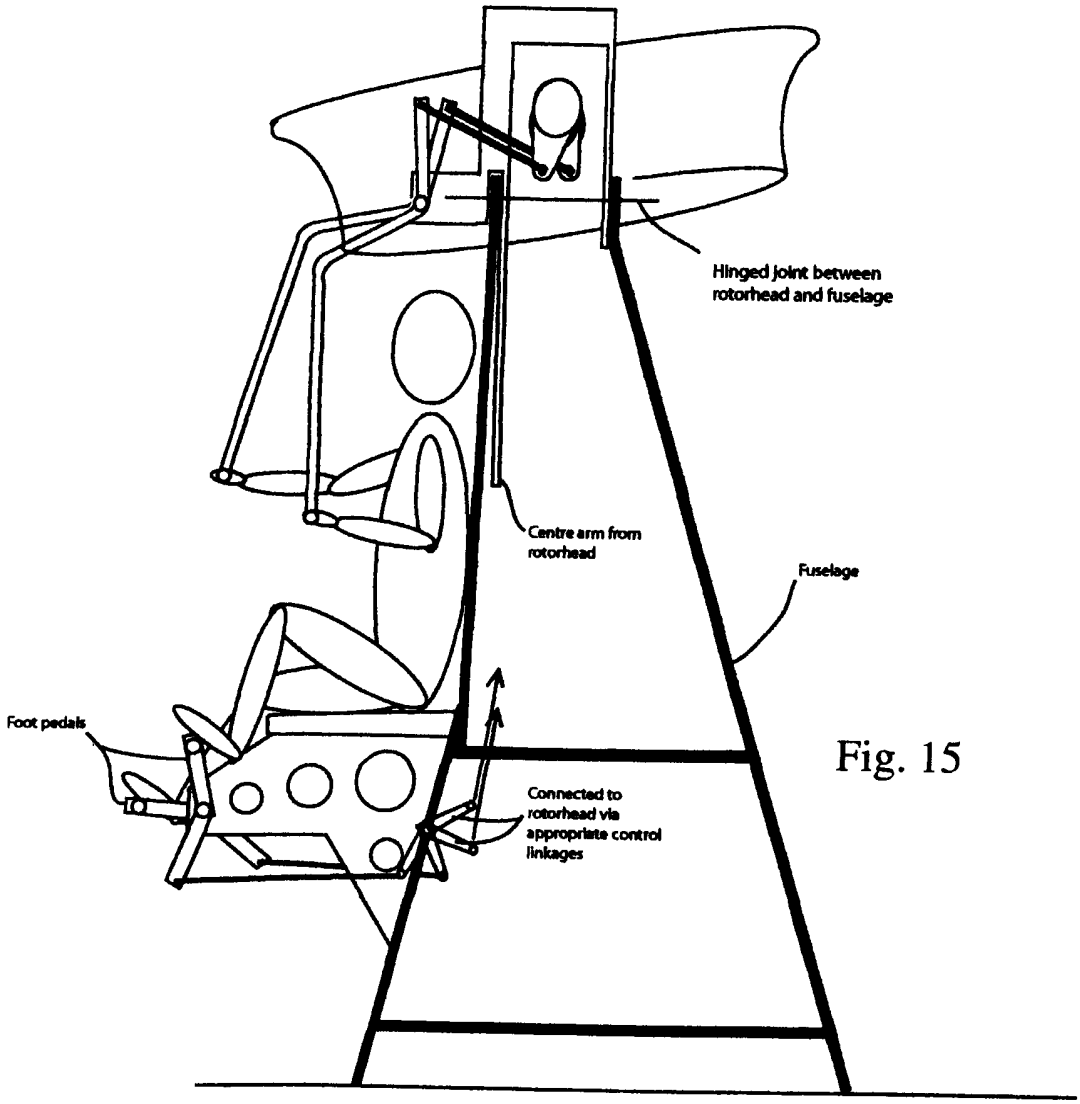

Hinged joint between rotorhead and fuselage
Centre arm from rotorhead
Fuselage
Foot pedals
Connected to rotorhead via appropriate control linkages

Fig. 15

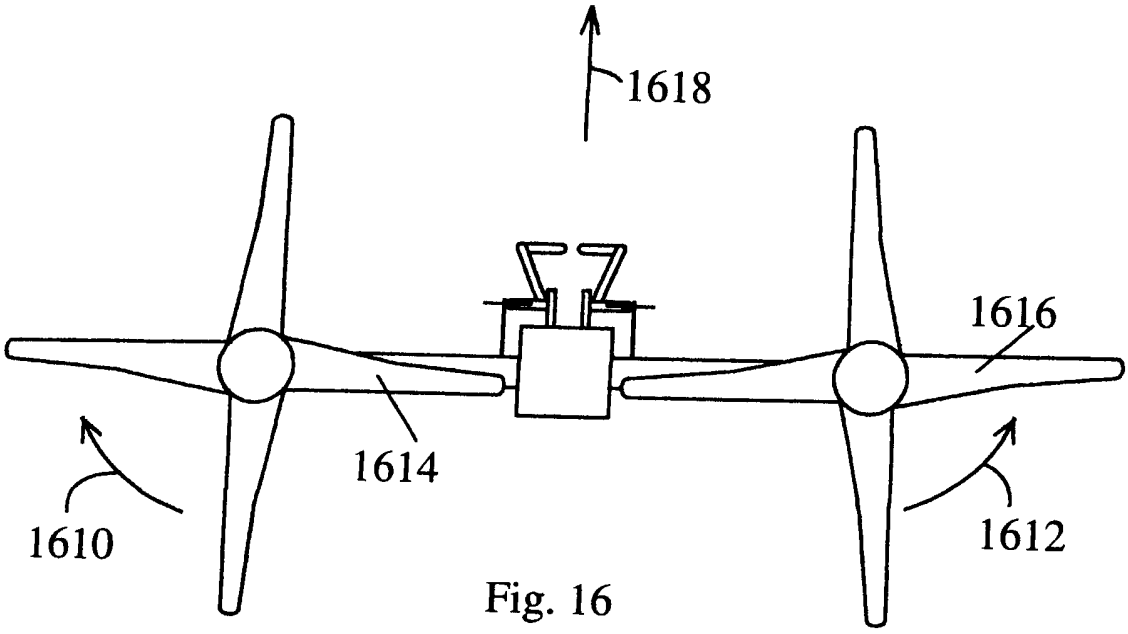


Fig. 16

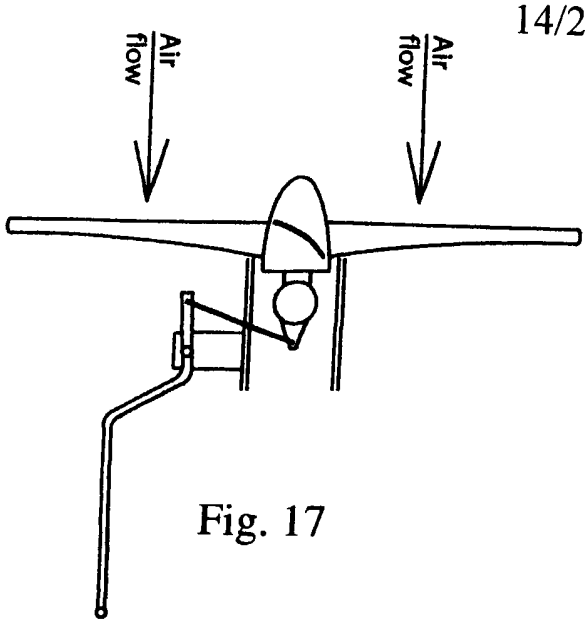


Fig. 17

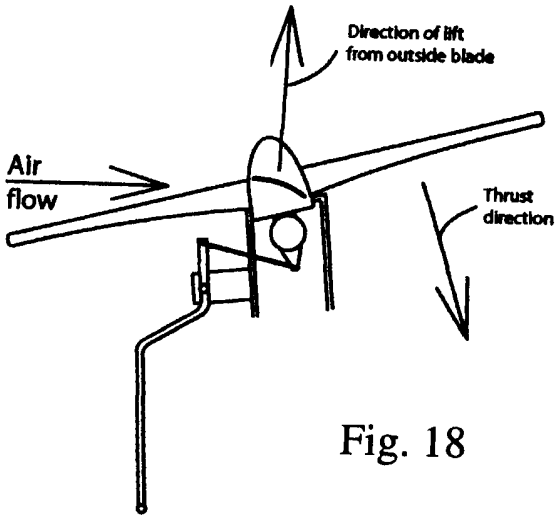


Fig. 18

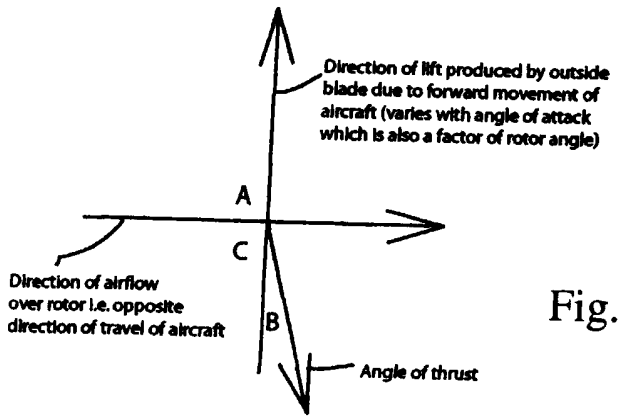


Fig. 19

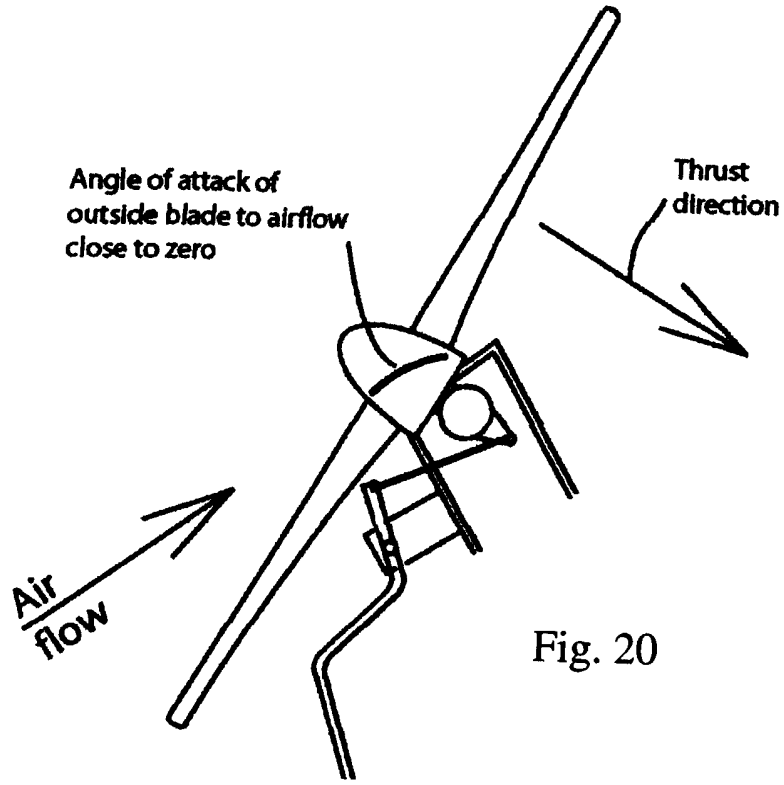

Angle of attack of
outside blade to airflow
close to zero
Thrust
direction
Air
flow

Fig. 20

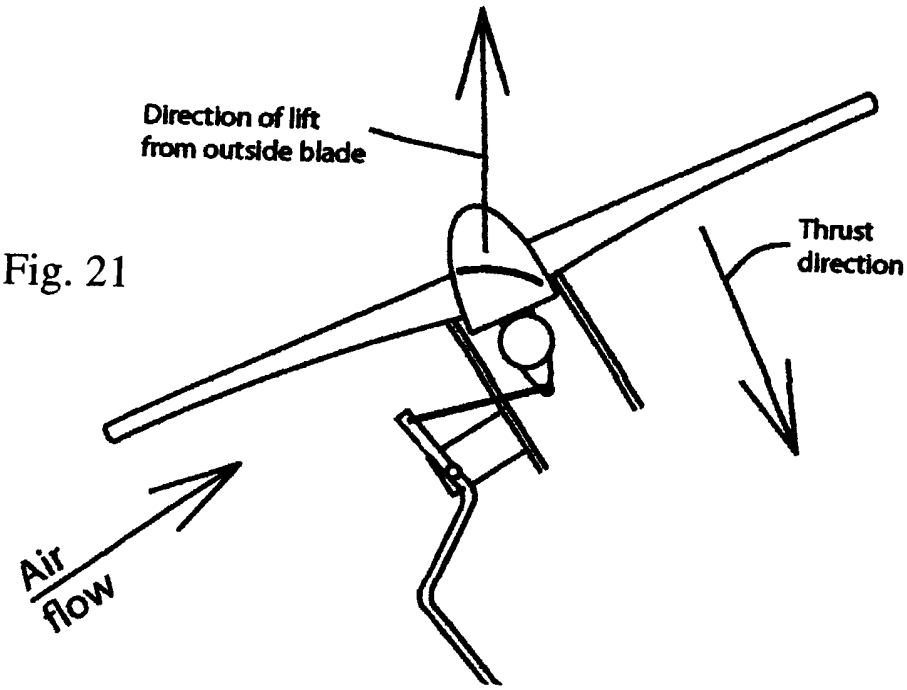

Direction of lift
from outside blade
Thrust
direction
Air
flow

Fig. 21

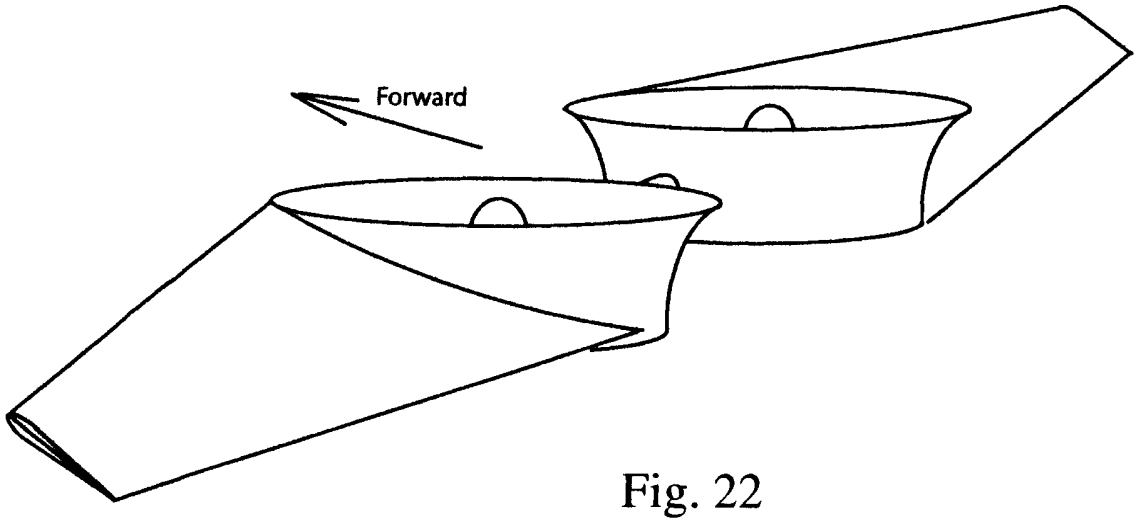


Fig. 22

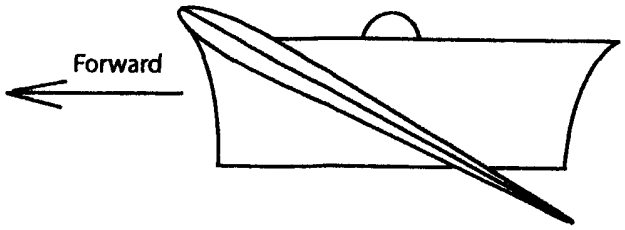


Fig. 23a

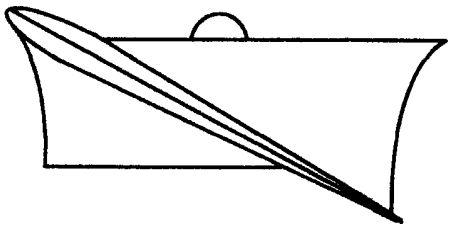


Fig. 23b

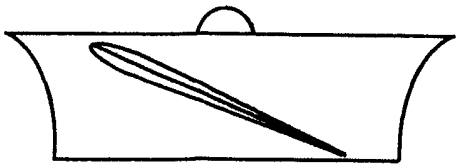


Fig. 23c

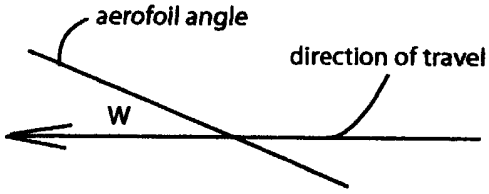


Fig. 23d

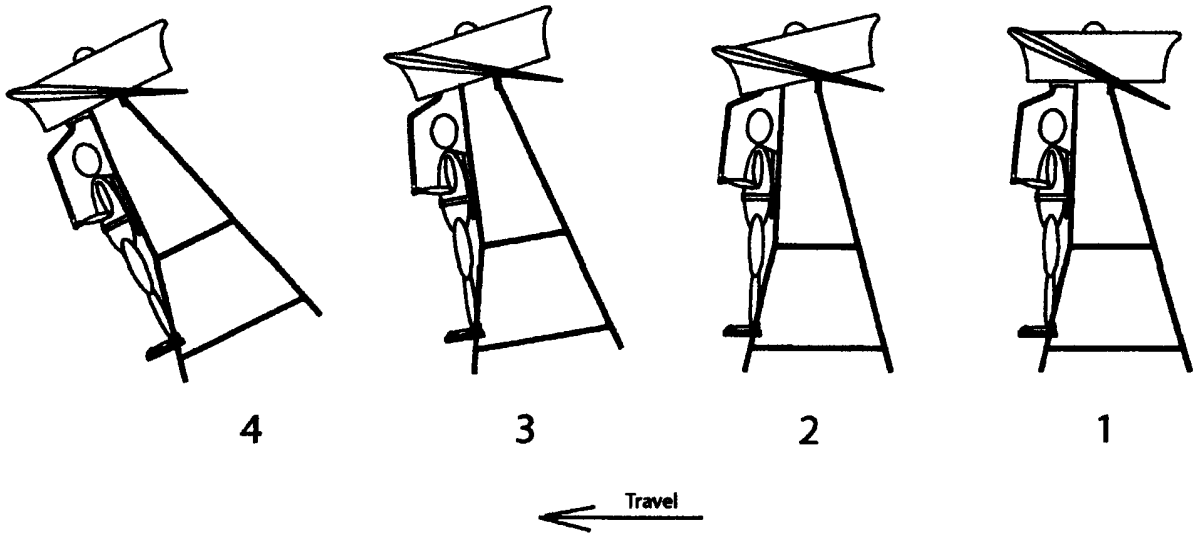


Fig. 24

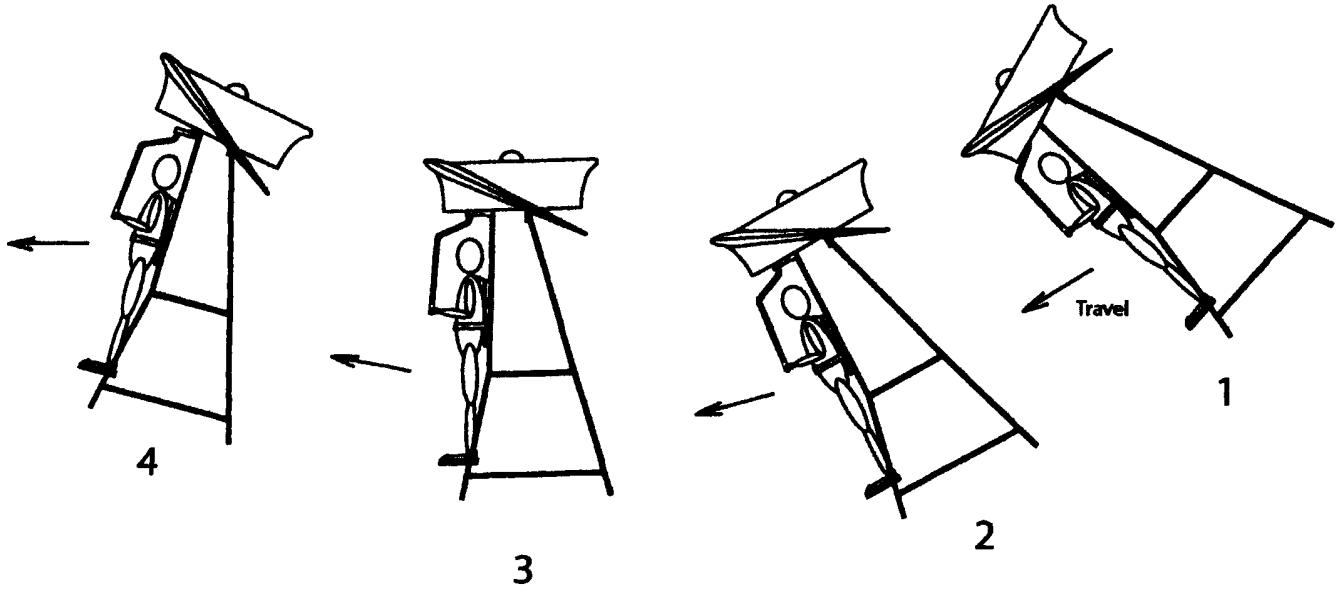


Fig. 25

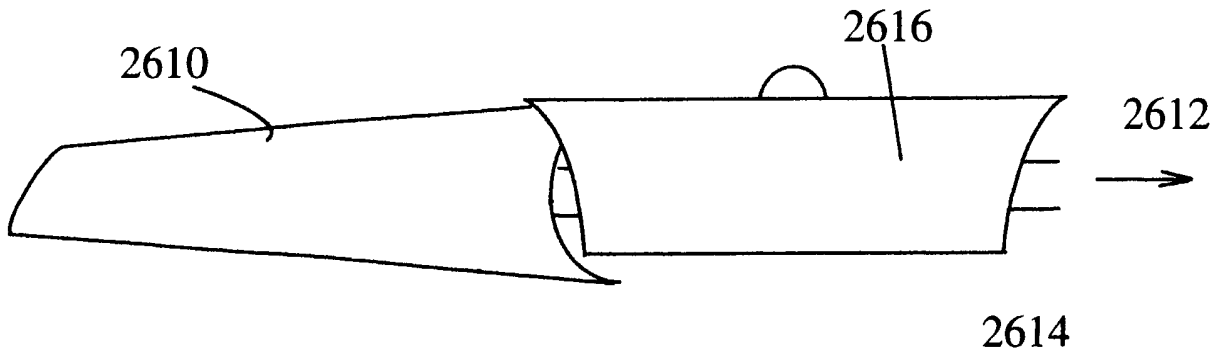


Fig. 26

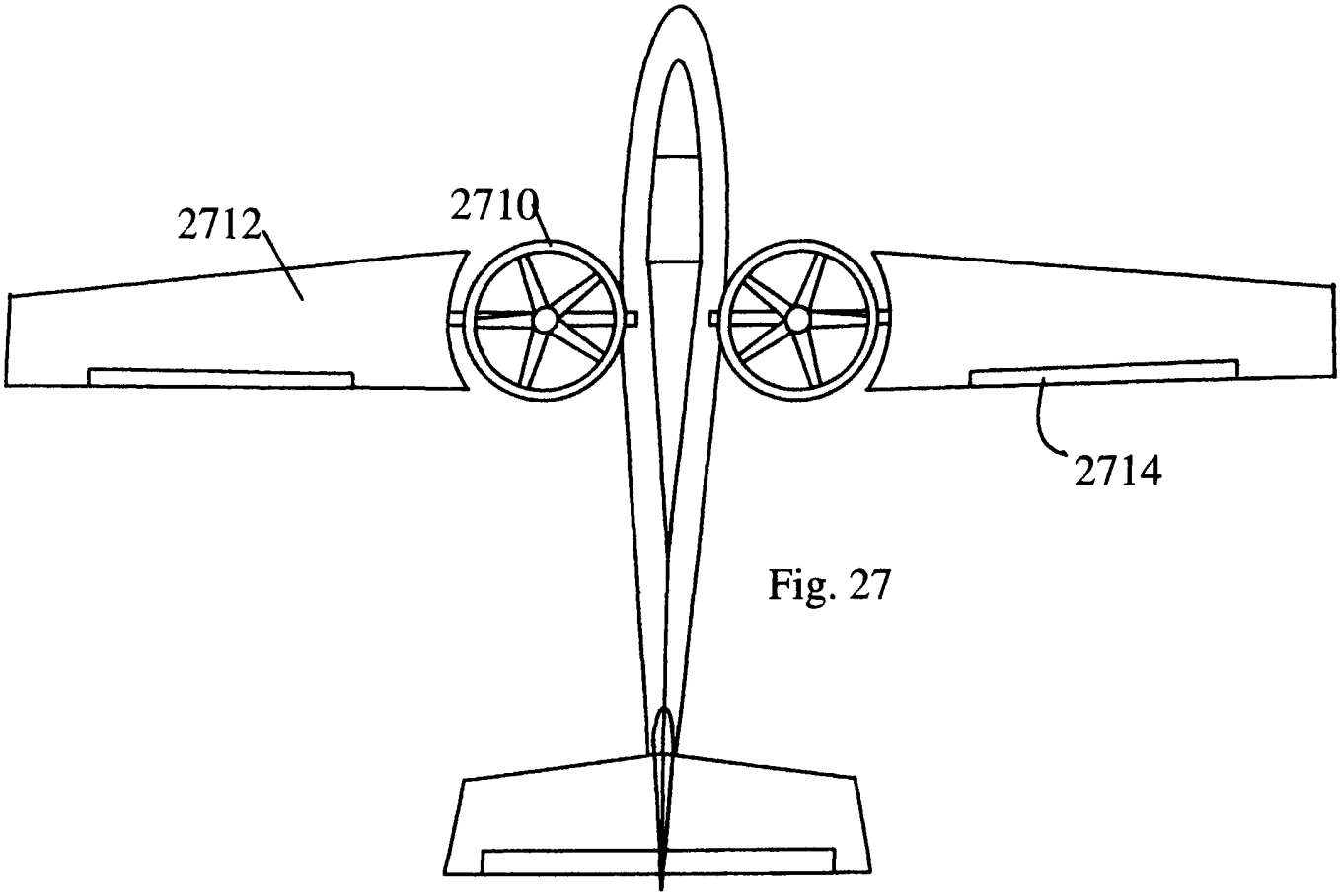


Fig. 27

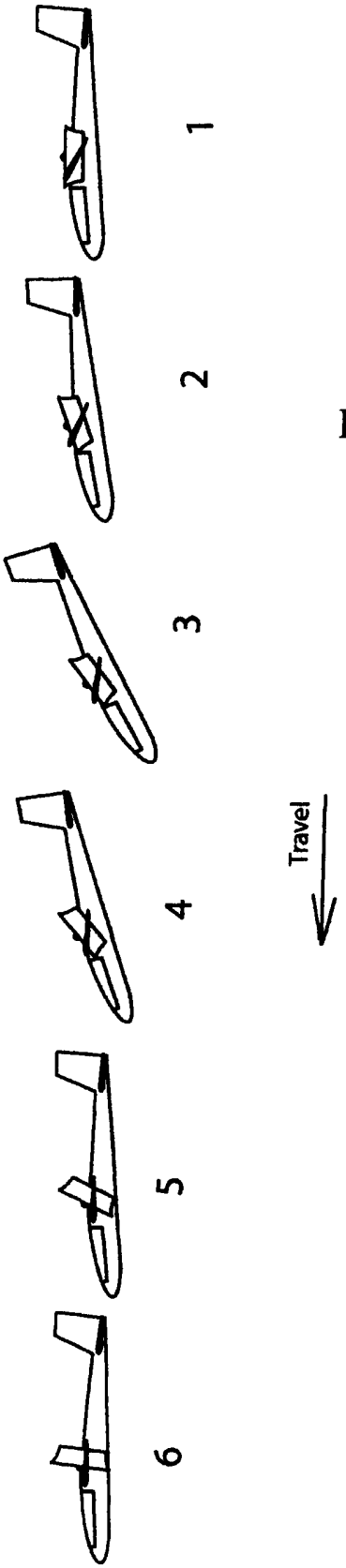


Fig. 28

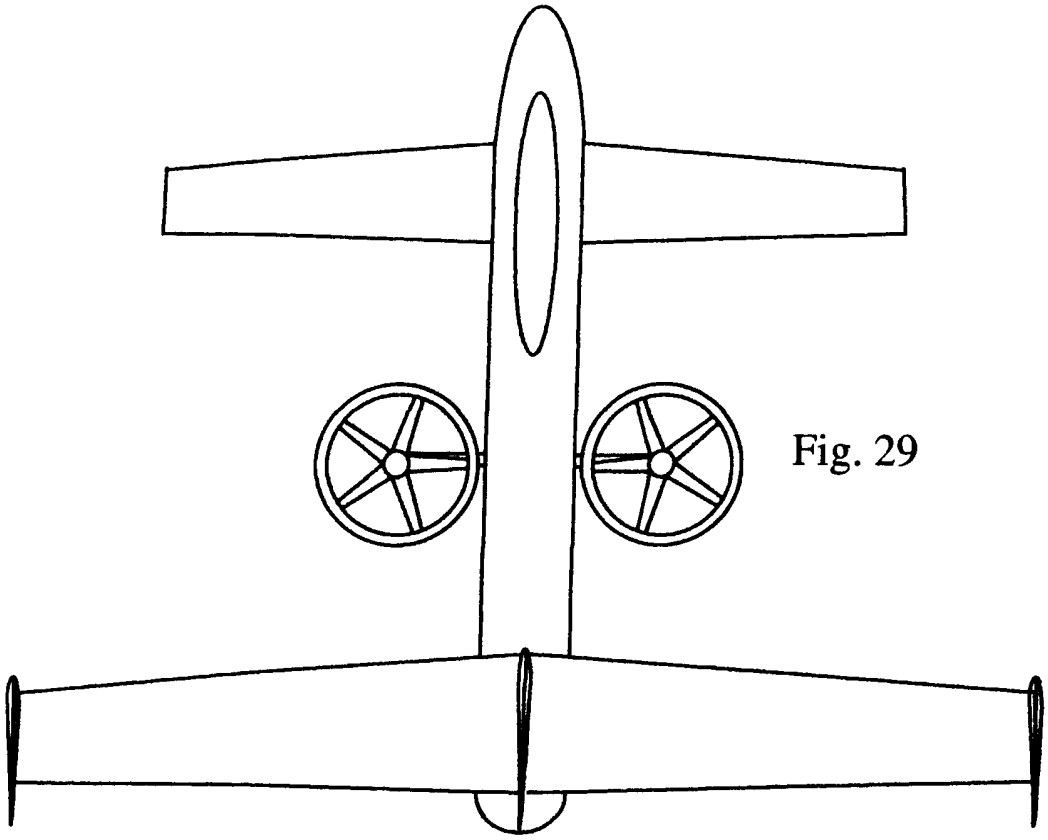


Fig. 29

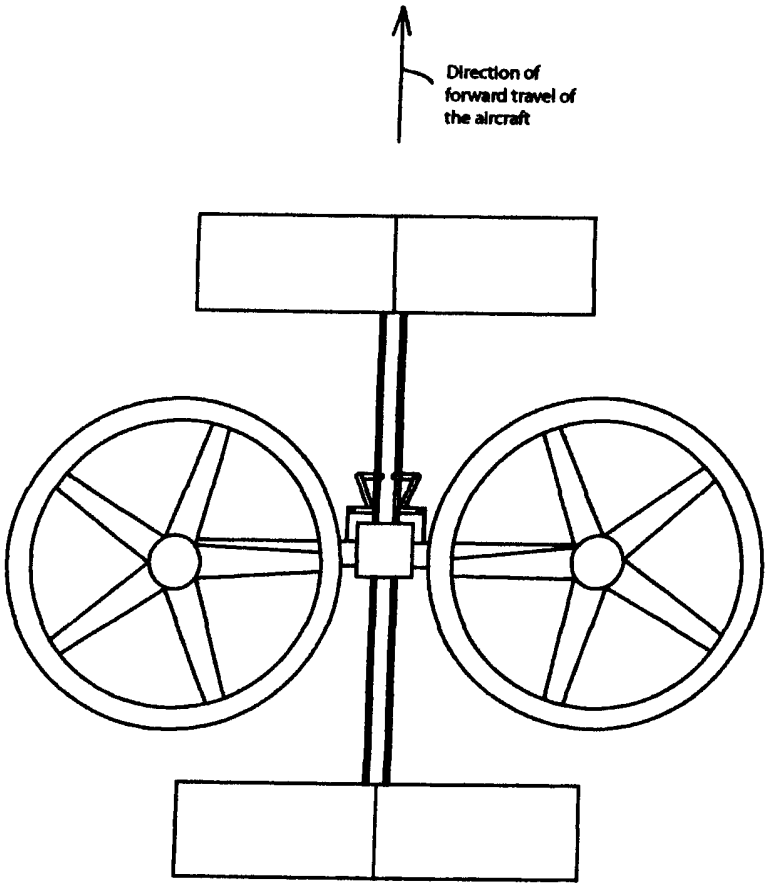


Fig. 30

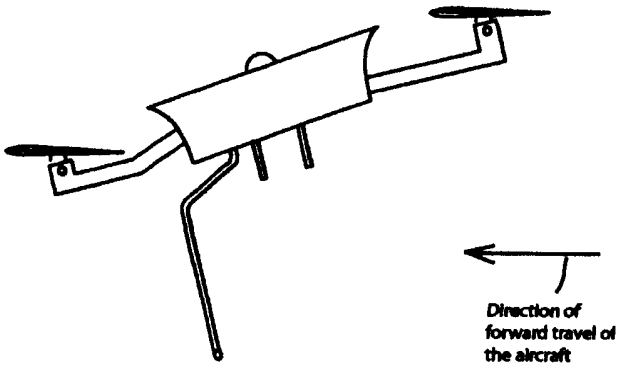


Fig. 31a

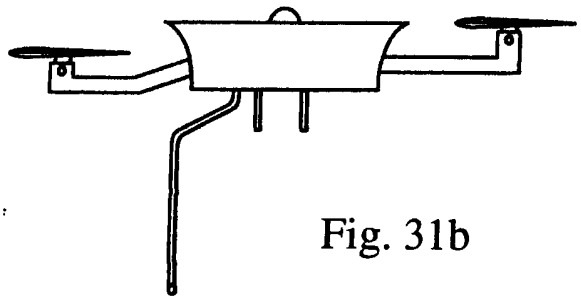


Fig. 31b

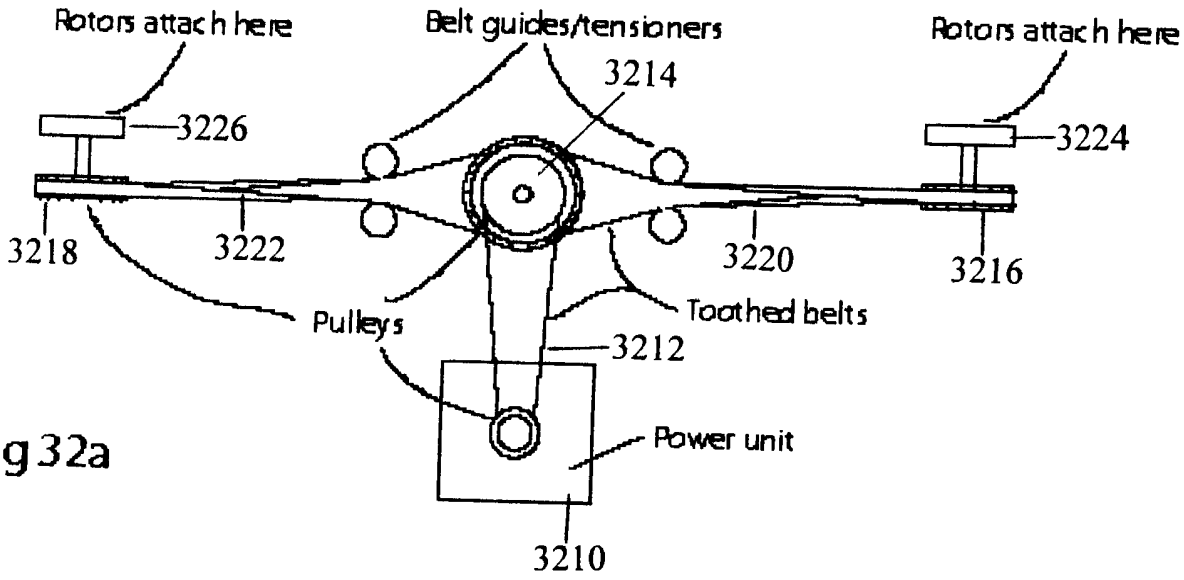


Fig 32a

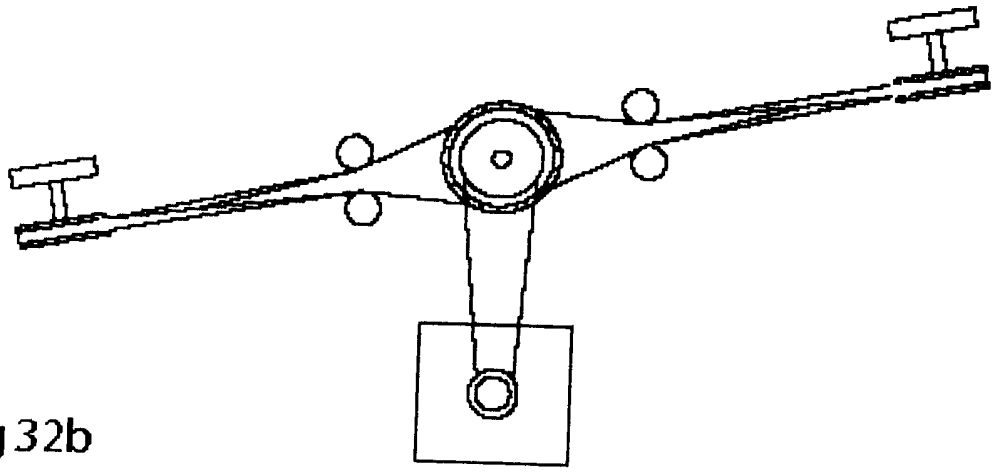


Fig 32b

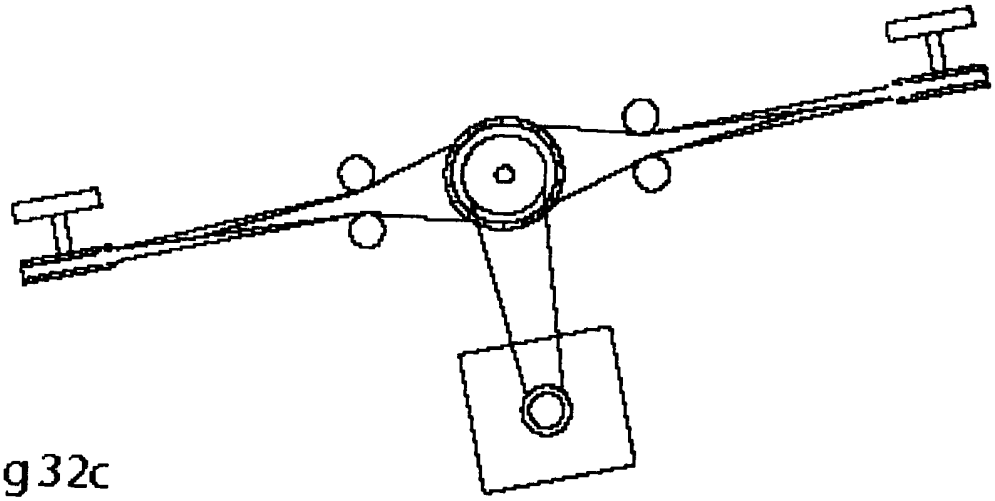


Fig 32c

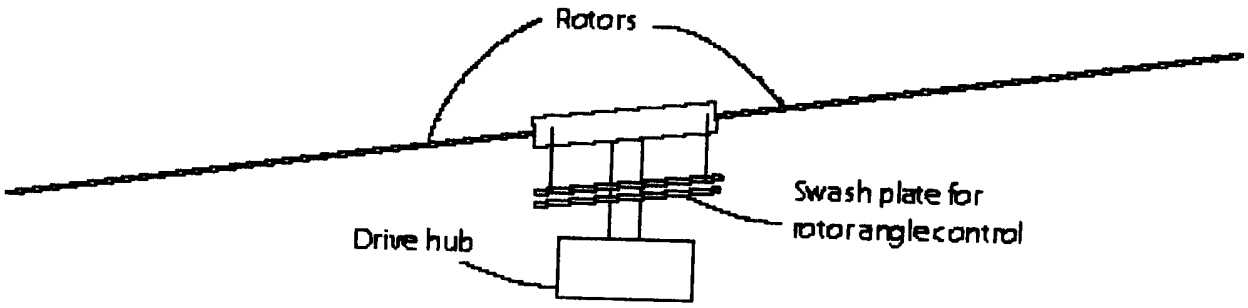

Rotors
Swash plate for
rotor angle control
Drive hub

Fig 33


Direction of travel

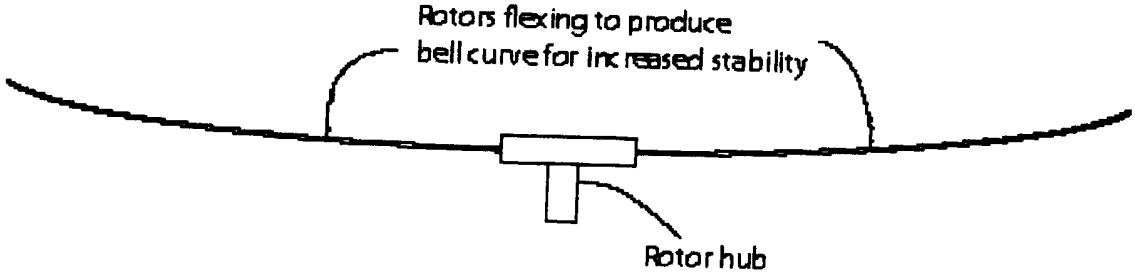

Rotors flexing to produce
bell curve for increased stability
Rotor hub

Fig 34

Aircraft

The present invention relates to aircraft and particularly, but not exclusively, small aircraft capable of vertical take-off, particularly adapted for personal transportation.

There have been a number of proposals for small vertical take-off aircraft, particularly rotorcraft. Whilst there have been a large number of proposals over the years, commercial success has been extremely limited due to a number of problems. Firstly, there is a requirement for a compact power unit with a high power-to-weight ratio and a sufficient energy store to sustain the required power for a useful time. Secondly, and most importantly most vertical take-off proposals and most rotorcraft designs suffer from instability, particularly dynamic instability and controllability issues. A third issue is safety.

In recent years, internal combustion and more recently electric measured power units have become available which can, with reasonable reliability, provide the requisite power in an appropriate size and weight. Gas turbines are also available, albeit at generally far greater cost. The instability and controllability issue is often a far more serious problem. Whilst recent advances in computer control technology have made "fly-by-wire" systems feasible, which damp instabilities or otherwise render essentially unstable systems controllable, there are still problems in producing a basic system that is sufficiently stable. The third issue, safety, arises in part from the first two issues, namely there are none of the requirements for a compact power plant operating at high output levels and a sophisticated control system to render the system stable and a small degradation of the performance of either the power system or the control system, or a perturbation or mechanical or electrical malfunction rapidly render a system uncontrollable. Unlike a conventional aircraft or helicopter there is generally no capability to glide or auto-rotate and so, in the event of failure, this is likely to be catastrophic.

WO-A-02/47978 and US-6488,232, the entire disclosures of which I incorporate herein by reference for all purposes, disclose a single passenger aircraft in which a

person is suspended by means of two ducted fans. A set of vanes deflects the thrust under the control of a fly-by-wire system.

A single-passenger vertical take-off and landing aircraft comprising:

an airframe portion, comprising means for supporting a pilot and aircraft control means for controlling the operation of the aircraft, wherein the airframe portion defines a central axis for the aircraft;

a rotorhead portion comprising at least two rotors coupled to the top of the airframe portion and arranged to rotate in respective planes about respective axes displaced from the central axis of the aircraft;

a motive power unit drivingly coupled to the rotors via a drive shaft;

characterised in that:

the rotorhead portion is coupled to the airframe portion via a pivot to enable the rotorhead portion to pivot relative to the airframe portion in the plane of the aircraft and about an axis perpendicular to the central axis for the aircraft.

The axis about which the rotorhead portion can pivot may be substantially parallel to the preferred direction of motion of the aircraft.

Enabling the rotorhead portion to pivot relative to the airframe portion provides greater manoeuvrability when compared to the prior art systems, particularly during forward flight of the aircraft. In particular, the pivoting may enable the aircraft to perform banked turns as described in more detail below. The pivoting arrangement may further increase the stability of the aircraft during hovering and turning and may also allow the aircraft to maintain its position in less than ideal conditions, for example during a cross wind.

Preferably, the rotorhead portion pivots to tilt the rotors on rotation of the aircraft about the central axis of the aircraft

In one embodiment, the motive power unit is coupled to the airframe portion and wherein the drive shaft comprises a pivot to enable the rotorhead portion to pivot relative to the airframe portion.

In an alternative embodiment, the motive power unit and the drive shaft remain stationary relative to the rotorhead portion and move relative to the airframe portion as the rotorhead portion pivots relative to the airframe portion.

Preferably, the rotorhead portion is coupled to the airframe portion via at least one actuator, wherein the actuator is arranged to rotate the rotorhead portion relative to the airframe portion on rotation of the aircraft about the central axis of the aircraft.

In one embodiment, the actuator may be arranged to rotate the rotorhead portion relative to the airframe portion in response to control means to effect a turning and/or banking of the aircraft.

In a preferable embodiment, the rotors may be arranged so that the planes of the rotors define a non-zero dihedral angle.

A single-passenger vertical take-off and landing aircraft comprising:
an airframe portion, comprising a motive power unit, means for supporting a pilot and aircraft control means for controlling the operation of the aircraft, wherein the airframe portion defines a central axis for the aircraft;
a rotorhead portion comprising at least two rotors coupled to the top of the airframe portion and arranged to rotate in respective planes about respective axes displaced from the central axis of the aircraft, wherein the rotors are coupled to the motive power unit via a drive shaft;
characterised in that:
the planes of the rotors define a non-zero dihedral angle.

Arranging the rotors so that the planes of the rotors define a non-zero dihedral angle diverts the thrust produced by the rotors away from the central axis of the aircraft. Hence, the thrust force produces a larger "footprint" of thrust for the aircraft on the ground or on the underlying air mass. This increases the stability of the aircraft and enables the aircraft to operate in more turbulent conditions.

In a preferred embodiment, the dihedral angle is greater than around 2 degrees, preferably greater than around 5 degrees.

Preferably, the dihedral angle is less than around 20 degrees, preferably less than around 15 degrees.

In a preferred embodiment, the dihedral angle is around 8 degrees.

In one embodiment, the dihedral angle may be varied before or during flight.

The dihedral angle may be varied automatically in response to environmental conditions.

In a preferred embodiment, the hub may further comprise an explosively-deployed parachute, the rotorhead portion may comprise a rotor brake arranged to substantially prevent the rotation of the rotors; and the aircraft may further comprise means for signalling an emergency condition and means for deploying the rotor brake and the parachute in response to signalling of the emergency condition.

A single-passenger vertical take-off and landing aircraft comprising:
an airframe portion, comprising a motive power unit, means for supporting a pilot and aircraft control means for controlling the operation of the aircraft, wherein the airframe portion defines a central axis for the aircraft;
a rotorhead portion comprising at least two rotors coupled to the top of the airframe portion at a hub and arranged to rotate in respective planes about respective axes displaced from the central axis of the aircraft, wherein the rotors are coupled to the motive power unit via a drive shaft;
characterised in that:
the hub comprises an explosively-deployed parachute;
the aircraft further comprises a rotor brake arranged to substantially prevent the rotation of the rotors; and
the aircraft further comprises:
means for signalling an emergency condition; and

means for deploying the rotor brake and the parachute in response to signalling of the emergency condition.

Providing a parachute and a rotor brake for the aircraft may increase the safety of the pilot in an emergency situation. Advantageously, the rotor brake is deployed prior to deployment of the parachute to inhibit the down draft from the rotors interfering with the deployment of the parachute.

The signal may comprise an alert signal generated by the aircraft. For example, a motive power unit failure may cause an alert signal to be generated or motion or altitude detectors may generate an alert signal if the aircraft is out of control, for example if the aircraft is rolling uncontrollably or if the altitude is decreasing at a fast rate. Alternatively or additionally, an alert signal may be generated by the pilot, for example via an emergency button on the aircraft.

In a preferred embodiment, the aircraft further comprises at least one aerofoil portion displaced from the rotors and positioned to provide lift on forward motion of the aircraft.

A single-passenger vertical take-off and landing aircraft comprising:
an airframe portion, comprising a motive power unit, means for supporting a pilot and aircraft control means for controlling the operation of the aircraft, wherein the airframe portion defines a central axis for the aircraft;
a rotorhead portion comprising at least two rotors coupled to the top of the airframe portion at a hub and arranged to rotate in respective planes about respective axes displaced from the central axis of the aircraft, wherein the rotors are coupled to the motive power unit via a drive shaft; and
at least one aerofoil portion displaced from the rotors and positioned to provide lift on forward motion of the aircraft.

Providing at least one aerofoil portion in addition to the rotors may reduce the thrust force required to be produced by the rotors for lift purposes when the aircraft is

airborne since, when the aircraft is travelling forwards, the shape of the aerofoil will provide lift for the aircraft in addition to that produced by the rotors.

In a preferred embodiment, the angle of attack of the or each aerofoil may be varied.

Preferably, the angle of attack of the or each aerofoil may be varied by the pilot.

Alternatively or additionally, the angle of attack of the or each aerofoil may be varied automatically depending on the configuration of other elements of the aircraft and / or on environmental conditions.

In one embodiment, the rotors may comprise ducted fans.

In one embodiment, the aerofoil portion is coupled to the outside of the ducted fans.

Preferably, the aerofoil comprises two or more aerofoil portions wherein at least one aerofoil portion is coupled to each side of the aircraft.

Preferably, the at least one aerofoil portion is substantially symmetrically arranged around the aircraft. This may enable the aerofoil to produce the same amount of lift for a given air speed and direction on each side of the aircraft.

In an alternative embodiment, the rotors comprise open rotors.

Preferably, the axes of the rotors are symmetrically disposed about the central axis of the aircraft.

Alternatively, the rotors may be asymmetrically disposed about the central axis of the aircraft, for example to compensate if the weight of the aircraft itself is not evenly balanced about the central axis of the aircraft.

In one embodiment, the engine may comprise a combustion engine.

In an alternative embodiment, the engine may comprise a motor powered by a battery.

In one embodiment, at least one direction of the aircraft may be varied by tilting the rotors. The control means are preferably arranged to enable the pilot to tilt the rotors as a single unit or independently of each other. For example, the rotors may be tilted to point their respective axes backwards or forwards to induce forward or backward pitching moments on the aircraft.

In one embodiment, vanes may be provided in the air stream produced by the rotors. This may increase the stability of the aircraft and all the direction of the aircraft to be controlled.

Preferably, the direction of the vanes may be varied to change the direction of the thrust produced by the rotors. This may produce a rotational or translational force on the aircraft.

Preferably, the control means may enable control the direction of each vane or of groups of vanes independently.

In one embodiment, the pilot may be supported in a standing position. This may allow the pilot to use their body weight to apply pressure to any foot controls provided.

Alternatively, the pilot may be supported in a seated position. This may be advantageous in an aircraft intended for long distance use.

In one embodiment, the aircraft control means controls the operation of the aircraft via a fly-by-wire system.

In an alternative embodiment, the aircraft control means controls the operation of the aircraft via a mechanical system.

Preferably, the control means comprises hand-operated controls and / or foot-operated controls.

In some embodiments, some aspects of the operation of the aircraft may be controlled via a fly-by-wire system and other aspects of its operation may be controlled via a mechanical system. For example, the thrust power of the aircraft may be controlled via a fly-by-wire system and the direction of the aircraft may be controlled via a mechanical system.

Embodiments of the invention will now be described with particular reference to the drawings in which:

Fig. 1 is a front view of a prior art aircraft;

Fig. 2 is a side view of a prior art aircraft;

Fig. 3 is a front view of a further embodiment of a prior art aircraft;

Fig. 4 is a schematic diagram of a front view of an aircraft according to one embodiment;

Fig. 5 is a schematic diagram of a further front view of an aircraft according to one embodiment;

Fig. 6 is a schematic diagram of a further front view of an aircraft according to one embodiment;

Fig. 7 is a schematic diagram of part of an aircraft according to a further embodiment;

Fig. 8 is a schematic diagram of part of an aircraft according to a further embodiment;

Fig. 9 is a schematic diagram of part of an aircraft incorporating a safety system;

Fig. 10 is a schematic diagram of a portion of an aircraft having a mechanical control arm according to one embodiment;

Fig. 11 is a schematic diagram of a portion of an aircraft including mechanical hand controls according to one embodiment;

Fig. 12 is a schematic diagram of one embodiment of part of an aircraft having mechanical hand and foot controls;

Fig. 13 illustrates a pilot operating one embodiment of an aircraft having mechanical controls;

Fig. 14 is a schematic diagram of a further embodiment of part of an aircraft having mechanical hand and foot controls;

Fig. 15 illustrates a pilot operating a further embodiment of an aircraft having mechanical controls;

Fig. 16 is a schematic diagram of one embodiment of part of an aircraft having open rotors;

Fig. 17 is a schematic diagram of a side view of part of a hovering aircraft according to one embodiment;

Fig. 18 is a schematic diagram of a side view of the portion of the aircraft shown in Fig. 17 during forward flight;

Fig. 19 illustrates the respective directions of the airflow and lift of a rotor and the resultant thrust force;

Fig. 20 is a schematic diagram of the portion of the aircraft illustrated in Fig. 17 during a steep forward dive;

Fig. 21 is a schematic diagram of the portion of the aircraft illustrated in Fig. 17 pulling out of a steep forward dive;

Fig. 22 is a schematic diagram of ducted fans incorporating aerofoil portions according to one embodiment;

Fig. 23a is a schematic diagram of a further embodiment of a ducted fan incorporating an aerofoil portion;

Fig. 23b is a schematic diagram of a further embodiment of a ducted fan incorporating an aerofoil portion;

Fig. 23c is a schematic diagram of a further embodiment of a ducted fan incorporating an aerofoil portion;

Fig. 23d illustrates the angle of attack of one embodiment of an aerofoil;

Fig. 24 illustrates schematically the transition from hover to forward flight of an aircraft including an aerofoil according to one embodiment;

Fig. 25 illustrates schematically an embodiment of an aircraft including an aerofoil performing a power dive manoeuvre;

Fig. 26 is a schematic diagram illustrating the attachment of an aerofoil to an aircraft having a ducted fan according to one embodiment;

Fig. 27 illustrates a plan view of an aircraft according to one embodiment;

Fig. 28 illustrates a process of transition from hover to forward flight for an aircraft according to one embodiment;

Fig. 29 illustrates a plan view of a further embodiment of an aircraft;

Fig. 30 illustrates a plan view of a further embodiment of an aircraft;

Fig. 31a is a schematic diagram illustrating the process of forward flight in an aircraft according to Fig. 30;

Fig. 31b is a schematic diagram illustrating the aircraft according to Fig. 30 in a hovering position.

Figs. 32a-c illustrate a belt-drive system.

Fig. 33 illustrates a swash plate for rotor angle control.

Fig. 34 illustrates flexing of rotor blades.

A prior art single-passenger aircraft will now be described in more detail with reference to Fig. 1. Further details of a prior art aircraft are discussed in International Patent Publication No. WO-A3-02/047978 and United States Patent No. 6,488,232, to which the reader is referred, the contents of which are incorporated herein by reference in their entirety.

With reference to Fig. 1, the prior art aircraft includes an aircraft body portion 110 and a propulsion system or rotorhead portion 112, positioned above the aircraft body. The aircraft body portion 110 includes means for supporting the pilot 114, in this case a pair of foot rests on which the pilot can stand to operate the aircraft, and control elements 116 for enabling the pilot to interact with the control system of the aircraft to control the operation of the aircraft. As illustrated in Fig. 2, the aircraft body further includes a motive power unit 210, preferably supported behind the pilot.

The rotorhead portion 112 of the prior art aircraft comprises two ducted fans 118, 120 attached above the aircraft body portion. The fans are symmetrically disposed about a central axis 122 defined generally by the aircraft body portion and are attached to a central hub 124. The fans are arranged within ducts and are driven by the motive power unit via a drive shaft, which passes up the aircraft body portion to a gear box or gear assembly at the hub 124, which drives the fans. The fans are preferably arranged to rotate in opposite directions during operation of the aircraft to ensure that there is a zero net torque on the aircraft produced by the rotation of the fans.

The aircraft is arranged so that the approximate centre of gravity of the aircraft 126, including the pilot, lies in the central axis of the aircraft, preferably between the pilot and the motive power unit.

Lift is provided to the aircraft by the thrust force caused by the rotation of the fan elements. The direction and speed of travel of the aircraft can be controlled by the pilot using the control elements 116 via a fly-by-wire or mechanical system. For example, in the embodiment illustrated in WO02/047978, the control mechanism to the left of the pilot may be used to control the speed of rotation of the fans, and hence the thrust or lifting force produced by the fans. The control mechanism to the right of the pilot may be used to control the direction of the thrust force, and hence the direction of motion of the aircraft.

The direction of the thrust force produced by the fans may be controlled in a number of different ways. US 6,488,232 discloses a system in which forward and backward translational control of the aircraft is effected by tilting the fan assemblies in forward and backward directions. Aircraft roll or lateral translation is achieved by the pilot shifting his body weight to move the centre of gravity of the aircraft.

As illustrated in Fig. 3, in the aircraft disclosed in WO02/47978, the direction of the thrust force produced by the fans is controlled by vanes 310, 312 with moveable flaps arranged below the fans. In the embodiment disclosed, two sets of mutually perpendicular vanes 310, 312 are arranged directly below the fans in the airstream produced by the rotation of the fans. One set of vanes comprise pitch vanes 310, which are arranged in the plane of the aircraft and perpendicular to the direction of forward motion of the aircraft, and which are operable to induce forward or backward pitching moments on the aircraft. A second set of vanes comprise roll vanes 312, which are arranged perpendicular to the pitch vanes and are operable to produce rolling moments on the aircraft to the left or right.

The flaps of the vanes are controlled by the pilot using the control mechanism 314 via a fly-by-wire system to control the direction of travel of the aircraft. For example, as discussed in Paragraphs 63 to 66, the contents of which are incorporated herein by

reference, tilting the flaps of the pitch vanes away from the direction of normal travel (rearwards), will direct the thrust force from the fans rearwards along the vane and will produce a forward pitching moment on the aircraft. Similarly, tilting the flaps of the roll vanes to the left will produce a rolling moment to the right on the aircraft and vice versa.

According to one method, to produce a yaw moment, one of the pitch vanes is tilted to the rear and the other pitch vane is tilted forward to produce a yaw moment to the left or the right on the aircraft.

A combination of the systems for controlling the aircraft may be provided. For example, as disclosed in WO02/47978 Paragraphs 76 and 77, the fans may be tilted to provide a constant forward motion for the aircraft and vanes may further be provided to enable manoeuvring of the aircraft in addition to the forward motion.

The control mechanisms described in WO02/047978 Paragraphs 56 to 62 and US6,488,232 Column 16 Line 62 to Column 20 Line 8, which are incorporated herein by reference comprise joysticks and buttons which may be moved to produce motion of the aircraft. The movement of the joystick by the pilot is mirrored in the movement produced by the aircraft control system, for example moving the joystick to the right causes the aircraft to move to the right and moving the joystick backwards causes the aircraft to lift. The control mechanism may be operably connected to the aircraft via a mechanical system, as described in US 6,488,232 Columns 17 to 19, the contents of which are incorporated herein by reference, or via a fly-by-wire system, as disclosed in WO02/047978 Paragraphs 53-55, the contents of which are incorporated herein by reference.

An embodiment of an aircraft according to an aspect of the present invention will now be described with reference to Figs. 4 to 8.

As illustrated in Fig. 4, the rotorhead of the aircraft according to the embodiment illustrated is able to rotate, as a unit, around a point 410 just below the central rotorhead gearbox. In the present embodiment, rotation is permitted in the lateral

plane only and is facilitated by a universal joint in the main drive upshaft around which the rotorhead rotates. Fig. 4 illustrates a situation in which 12 degrees of left rotation and 8 degrees of dihedral are provided.

As described above, lateral control of the aircraft in prior art systems is only achieved by the shifting of the pilot's bodyweight or by the movement of flaps attached to vanes below the fans. Shifting the pilot's bodyweight, however, only allows small variations in the position of the centre of gravity of the aircraft, which would be enough only to compensate for the smallest instability, and does not provide a system viable for controllable flight. It would also always remain beyond the influence of any automated / 'fly by wire' control system. Whilst the addition of vanes under the fans and 'fly by wire' contributes some hover stability and basic lateral balance, to be truly flyable, substantially more control is required.

The pivoting rotorhead of the present embodiment allows for much more radical manoeuvrability during forward flight than in the prior art system, including enabling the aircraft to perform bank turns, as well as increasing stability during hovering and enabling the aircraft to maintain its position even in less than ideal conditions, such as in a cross wind. It may provide flight characteristics for the aircraft similar to that of ailerons during forward flight and cyclic rotor control when hovering.

Rotation of the rotorhead may be effected once rotation of the aircraft has been initiated by a movement in the centre of gravity, movement of control vanes, or another similar system. Alternatively, the rotorhead may be tilted relative to the aircraft body, for example using actuators, in order to bank the aircraft.

The rotation of the rotorhead around a fixed point in the lateral plane, allowing tilting of rotorhead relative to the aircraft body or fuselage, can be achieved in several ways, using either powered actuators through a variety of linkage options or mechanical force applied physically by the pilot. The aircraft described herein has a 'fly by wire' system in which the aircraft controls are electronically coupled to the flight control system, but aspects of the system described herein may be applied to other aircraft, for

example aircraft in which the control system is mechanically coupled to the flight control system.

As illustrated in Fig. 7, in one implementation of the system described above, for the sake of weight, strength and aerodynamics, a rigid arm 710 may be extended directly from the rotorhead down inside the fuselage behind the pilot. The arm of the embodiment illustrated 710 reaches to, or preferably beyond, the centre of gravity of the fuselage 712 in order to maximise leverage, minimising the necessary force applied by the actuators to achieve required movement (this does of course increase the physical range of the actuator movement and ideal dimensions will depend on the choice of the actuator mechanism). Actuators 714, 716 are mounted on the fuselage and apply force to the arm in direction shown in Fig. 7, allowing accurate and controlled changes to the relative angle between the fuselage and the rotorhead. As this angle change is applied, the movement of the centre of gravity of the aircraft away from the centre of thrust will bring about a banking effect and allow lateral control and movement during hover similar to that of a helicopter. During forward flight a bank turn will be achieved.

As turning begins, an apparent centrifugal force (based on the required acceleration) will pull the fuselage outwards, increasing the effectiveness of the bank (also like a helicopter) as illustrated in Fig. 6 in which a 12 degree bank turn is being performed. In implementing the system, consideration should be given to the different performance characteristics during forward flight of an open rotor system as opposed to those of a ducted fan (which are described in more detail below). The force required by the actuators must be calculated based on the fuselage mass as opposed to that of the rotorhead as, during flight, the rotorhead becomes the 'fixed point' under which the fuselage 'hangs'.

An additional feature of the present embodiment, illustrated in Fig. 5, is the application of some dihedral to the rotorhead. In the embodiment illustrated in Fig. 5, approximately 8 degrees of dihedral have been applied to the rotors, but any appropriate dihedral angle may be selected.

The addition of dihedral to the rotors may increase the overall area over which the thrust force produced by the rotors acts. This may increase the overall stability of the aircraft. The wider thrust 'footprint' may further provide more subtle control and stability during lateral manoeuvres and may further help to prevent excessive side slip during bank turns.

The addition of dihedral can be achieved using universal joints in the half shafts or by a realignment of the central gearbox. The addition of universal joints to the half shafts may also advantageously allow the rotors to be folded flat against the side of the aircraft for more efficient storage and transportability.

Fig. 8 illustrates a further embodiment of the system described above in which the motive power unit 810 and drive shaft 812 are fixed relative to the rotorhead 814 and the fuselage 816 or aircraft body pivots relative to the rotorhead and motive power unit combination. This may be advantageous since it is not necessary to incorporate a pivot point into the drive shaft joining the motive power unit to the rotorhead. Although it is not illustrated in Fig. 8, it will be clear to one skilled in the art that a dihedral may also be added between the rotors in this embodiment.

Fig. 9 illustrates a further embodiment of the aircraft incorporating a safety system. The prior art aircraft described above have no glide capability or autorotation facility, meaning that in case of catastrophic failure of any vital part of the aircraft, a crash is inevitable. A 'panic' system may be provided as part of the aircraft so that, in an emergency situation, the pilot may initiate a safety system. On receipt of a panic signal, the system of the present embodiment is arranged to cut instantly the ignition or the power to the motive power unit and to apply an emergency brake to the rotors. In the embodiment described, this is quickly followed by an explosively deployed parachute 910 being fired from a structure on top and in the centre of the rotorhead, the rotorhead hub, or high on the back of the aircraft body (well above the centre of gravity). The rotor brake may reduce the likelihood of suction or tangling occurring between the parachute and the rotors. A prior art explosively deployed parachute may be used in this embodiment. The parachute must be capable of carrying the weight of both the aircraft and the pilot. One advantage of explosively deployed parachutes is

that the deployment of the parachute is fast enough to be effective even at low levels. The rotor brake and parachute safety system aims to increase the likelihood that the pilot, the aircraft and those on the ground will sustain only minimal injury and damage during an emergency situation.

As discussed above, the systems and features described herein may be implemented in conjunction with a fly-by-wire system or a mechanical system. One embodiment of a mechanical or manual control system will now be described with reference to Figs. 10 to 16.

A manual or mechanical system may typically be described as a system wherein control input from the pilot is translated directly into the relevant movement of the physical controls of the aircraft without interpretation or autonomous decision making by an automated or active system such as a gyro, computer based flight system or any active fly-by-wire system.

Some kinds of active system cannot be effective unless they have influence over all available aircraft control apparatus, thus making the active systems irrelevant to a mechanical/manual control system. For such systems, exception could be made for specific circumstances, such as a "hands-free" hover system, which would have to be manually initiated by the pilot, possibly using vanes only and specifically turned off after use (as described in more detail below). It should be noted that a manual control system does not necessarily require a mechanical link between pilot controls and aircraft control mechanisms, but that manual systems are generally literal and non interpretive, giving the pilot the final say in how the aircraft control apparatus behaves.

The advantages of a mechanical control system, particularly one using physical linkages are many, most obviously cheapness and ease of manufacture and maintenance. As long as the motive power unit, the drive train and the blades are in working condition, the rest of the craft is preferably maintainable by a competent mechanic with a basic tool kit. Control rods, cables, wires, chains, levers and hydraulics are well within the ability of a car mechanic and a rotary motive power

unit, which may be used in conjunction with the systems described herein, can easily be maintained. The drive train may be manufactured in quantity, thus reducing cost, and the rest of the aircraft may also be manufactured relatively cheaply.

Movement of bodily-operated controls by the pilot could be translated into movement of the aircraft's control apparatus in a number of ways. Rods, levers, wires, chains, hydraulics, pneumatics or any number of different electromechanical actuators, or various combinations of these, could be used to make the mechanical links between body and machine. Figs. 10 to 16 illustrate schematically a few of many possible linkage options.

The basic control movements of the embodiments illustrated, for example which part of the body moves which piece of control apparatus, will now be described in more detail.

The hand controls of the embodiment illustrated are in two parts. As illustrated in Fig. 10, they include two control arms 1010 coming down in front of the pilot and directly connected via a hinged joint 1012 on the rotorhead centre to a connecting rod 1016, which is in turn connected 1014 to the relevant rotor assembly 1018. The arms are connected at Point C 1022 via a hinge to a bracket from the central rotorhead hub. These arms 1010 can be moved independently in a forwards/backwards direction by each hand using a hand grip 1020 at the end of each arm. The movement forward/backward of each arm results in the rotation of the associated fan around its drive shaft (right hand, right fan, left hand, left fan) and thus a change in the direction of thrust from that fan according to the direction of movement of the arm. The arm twists the fan around its drive shaft, moving the direction of thrust of that fan in a forward/reverse direction as illustrated in Fig. 10, i.e. if the pilot moves the arm forward, the thrust is directed backward, moving the aircraft forward and vice versa.

The control arms of the present embodiment 1010, are free to move independently in a forward/backward plane, but can only move in unison in a left/right plane in order to enable and control the tilt of the rotorhead as a whole, as illustrated in Figs. 12 and 14. This movement may be assisted by foot controls as described in more detail below.

The second part of the hand controls to consider, are the hand grips 1020, which will be described with reference to Fig. 11. Movement of the control arms illustrated in Fig. 11 forward and backward allows independent tilting of fans around drive shafts. One hand, in this embodiment the right hand, has control of the throttle and if applicable, rotor pitch angle thus controlling climb and descent (these two controls may be linked). This may take the form of a twist grip and/or a finger or thumb lever or a combination of these movements. The left hand control may include controls for a navigation system, communications, fire control, but preferably includes the trim and/or vane control, described in more detail below.

The function of the foot controls of the present embodiment are simple, but the implementation can be achieved in many ways. One embodiment of the implementation will now be described with reference to Fig. 12 in which two foot pedals 1210 are provided, which are joined by a rigid bar 1214 hinged at a central point 1212. Essentially, in this embodiment, the two foot controls 1210 are linked 1214 and counterbalanced, so if one goes down, the other goes up. They are mechanically connected in this way and cannot move otherwise. The foot pedals rotating across the front of the fuselage are connected directly to the rotorhead enabling tilt by shifting of pilot's weight between left and right foot. Additional force to control the rotorhead is applied through sideways movement of the hand controls, hence the load is shared between the upper and lower body of the pilot.

Fig. 14 illustrates a further embodiment of the foot controls in which the foot pedals 1410 are linked via a wire, a cable or a chain connection via a plurality of rollers 1414, which ensures that the foot controls of the embodiment illustrated in Fig. 14 are also linked and counterbalanced. Again, the load and control is shared between the hand and foot controls.

When one foot is pressed down, this brings about a corresponding movement in the rotorhead which tilts around point A 1216, i.e. if the left foot is pressed down, the rotorhead tilts towards the left and a left bank is initiated, and vice versa.

Some possible methods of achieving this are shown in Figs. 12 to 15. It should be noted that the essence of the idea is 'left foot down, left bank, right foot down, right bank'. As there are many possible ways of achieving this, any combination of systems comprising rods, levers, wires, cables, chains, hydraulics, pneumatics, electromechanical actuators, or any other appropriate systems may be provided.

It should be further noted that, in the embodiments illustrated, tilting of the rotorhead is achieved by a combination of foot control and lateral movement of the hand control arms, so spreading required mechanical force and overall control between upper and lower body, avoiding excessive physical strength requirements for the pilot, and allowing more controlled and instinctive input from the pilot to the control system.

The pilot may be standing or sitting as illustrated in Figs. 13 and 15. The advantages of the pilot standing is that their bodyweight acts for them in operation of the controls. To bank left, the pilot pushes the control arms to the right and instinctively presses with the left foot to brace, naturally leaning into the corner allowing the pilot to utilise their body weight to aid the turn so creating an instinctively balanced bank turn.

The aircraft is preferably provided with a body harness 1310 as shown in Fig. 13, which preferably enables the pilot to make the necessary movements to control and move the aircraft as described above. In the embodiment illustrated in Fig. 13, the rear hinged foot controls are linked to the rotorhead by appropriate means to achieve rotorhead tilt. In Fig. 13, the foot position illustrated is for a right bank manoeuvre.

In some embodiments, the pilot may be seated as illustrated in Fig. 15. In this case the advantages of the pilot's weight acting on the controls are lost, however a more controlled and less balance-orientated control input may be achieved. This may allow a more considered approach to flying the aircraft, as well as removing some of the physical stress from piloting over long periods. In Fig. 15, forward thrust is being given on the right fan and reverse thrust on the left fan (not shown) to produce a yaw moment. The foot position represents a right bank.

Embodiments of the aircraft may be arranged to carry at least one passenger. In a preferred embodiment, the pilot and passenger may be aligned back-to-back on the front (pilot) and rear (passenger) of the frame of the aircraft in a standing or seated position. This would mean the passenger would be facing backwards during flight. This arrangement would provide all-round visibility, which would be advantageous in for example, military, search and rescue and camera platform applications. Changes to aircraft balance could be compensated for by trim adjustment and a two-person aircraft can preferably be adjusted to be used by only one person.

Vanes 1416, 1418 may further be provided on the aircraft as illustrated in Fig. 14 and may provide some advantages even to a mechanical control system. For example, they may provide increased stability and help prevent excessive side-slip. They may further increase direct lift on the aircraft by moving against the turn through a simple mechanical linkage for example via connecting rods 1218 provided between the fuselage and the vanes as illustrated on Fig. 12. Vanes 1416, 1418 could also provide an additional predetermined assistance to manoeuvring, for example via electro-mechanical actuators utilised by a control on the left hand (such as thumb joystick, sliders or something similar on a radio controlled aircraft control system). An overall trim control may be provided by the vanes to compensate for example for weight/balance variations due to payload, fuel use or even weather conditions. They could also provide an overall adjustment to general flight characteristics, which could help compensate for unpredictable operational circumstances or aircraft setup. In some embodiments, it may also be possible to provide a hands free (but legs active) hover mode where a fly-by-wire system takes over vane control only for the specific task of maintaining a hover, allowing the pilot to temporarily do something other than fly the machine with his hands.

Embodiments of the aircraft may be provided with ducted fans or ducted rotors, as illustrated in Figs. 1 to 15 or may be provided with open rotors. Open rotor systems will now be described in more detail with reference to Figs. 16 to 21.

It has been shown that a ducted fan has greater thrust creating efficiency in a specific direction than an open rotor due to the 'focusing' of the airflow through the rotors and

the 'wing effect' (i.e. increase in airflow speed over a curved surface) created by the shape of the duct. Although this means increased thrust efficiency in a hover situation, the duct creates disadvantages to forward flight. Forward movement while balanced on thrust created from a ducted fan can be compared to walking on stilts. That is, you can proceed as long as you keep your balance but it is easy to trip and, if you start to fall, it is difficult to recover. An open rotor system, however, during forward movement gains the benefits of the 'helicopter effect', that is increased lift due to increased movement of air over the rotor blades is brought about by the forward movement of the aircraft. This makes the helicopter or open rotor system difficult to hover on the spot, but very easy to manoeuvre when travelling from one place to another (e.g. during forward flight).

Problems may be caused by the duct of the ducted fan system. The duct is aerodynamically inefficient when moving sideways through the air (i.e. during forward movement of the aircraft) and is designed to create a very specific and unchanging set of circumstances under which the blades perform (i.e. vertical movement of air through the duct), as in Fig. 12. Open rotors, however, have been shown to work very well during forward flight as is shown by the helicopter, which behaves with many similarities to a fixed wing aircraft under these circumstances. Further advantages of applying an open rotor system to the aircrafts described herein will now be discussed in more detail.

On one embodiment of the aircraft described herein, as illustrated in Fig. 16, an open rotor system may comprise two rotors 1614, 1616 turning in opposite directions 1610, 1612 with the outside blades moving towards the front of the aircraft and direction of normal travel 1618. The number of blades may vary and the blade pitch may be fixed or variable. Counter rotation of the rotors offsets the torque effects produced by each rotor.

In one embodiment, independently variable blade pitch may be provided on each rotor. This feature may be particularly useful if open rotors are provided, as described below. Providing independently variable blade pitch may allow more efficient use of available power for altitude adjustment. It may also assist with banking by allowing

one rotor to have a greater pitch than the other, so tilting or side-slipping the aircraft. This feature may be particularly advantageous when combined with the tilting rotorhead system described herein and may also allow the possibility of emergency autorotation.

Each rotor may also be provided with a swash plate system, as illustrated in Fig. 33, for altering the direction of thrust on each rotor independently. In one embodiment, the system may be designed to work only in a forward/reverse direction so removing the need to rotate each rotor around its drive axis.

As the rotors are tilted forwards to initiate forward flight (by moving thrust angle in a reverse direction), air begins to flow over the rotors from the direction of travel, the faster the forward movement, the more air flows into the rotors from the front, as illustrated in Fig. 18. When this happens the blades moving forwards in the direction of travel of the aircraft (outside blades) move faster through the air than those moving backward (inside blades) so increasing lift produced by those blades, resulting in a shift in lift force outward away from the centre of the aircraft, making the primary lift blade the one moving in the direction of travel (the outside blade). As forward speed increases, so does the amount of mechanical lift (that induced by forward motion) and therefore stability and manoeuvrability. Most importantly, however, the outside blade which is producing its extra lift due to the airflow from the front provides lift in a different direction from the angle of thrust, as illustrated in Fig. 18. Angle B, highlighted in Fig. 19, represents this differential and is a factor of the angle of attack of the forward moving blade. Angle A, highlighted in Fig.19, represents the difference in angle between lift produced by the forward moving blade and the direction of airflow creating that lift. This is also a factor of the angle of attack of the blade and the direction of aircraft movement (and thus airflow direction). The rotor will generate mechanical lift as long as the angle of attack of the blade to the airflow remains positive and therefore mechanical lift is induced effectively by forward motion in the same way as a helicopter.

Even during extreme manoeuvring such as a steep dive, as illustrated in Fig. 20, when Angle A could be temporarily decreased below 90 degrees (causing the angle of

attack of the outside blade to become effectively zero or even negative), pull out can be achieved by simply returning angle A to 90 degrees or more (i.e. a positive angle of attack). This would be achieved by simply tilting the rotor back, as illustrated in Fig. 21, making this a highly manoeuvrable aircraft.

If a ducted fan based aircraft was in this situation, thrust would have to get directly under the aircraft to compensate for the dive as no mechanical lift through motion would be created. With open rotors, the increased angle of attack of the outside blade as the rotor tilts back, gives the aircraft the necessary lift to pull out of its dive with much less fan tilt than a ducted fan and while maintaining controlled forward thrust. In fact no matter how steep the dive this will still hold true as, the steeper the dive, the steeper the angle of airflow over the outside primary lifting blade. In addition, the increased airspeed would add to the mechanical lift produced by that blade. In Fig. 21, the offset of the lift angle to the thrust angle (Angle B in Fig 19) will also tilt the aircraft backwards around a horizontal plane (effectively 'pulling up the nose') and will continue to do so until controls are reset and equilibrium is achieved.

The use of open rotors may allow an increase in rotor diameter, which allows greater lift for the aircraft at a lower rate of revolutions per minute (rpm). In turn, this may reduce drive train stress and increase stability of the aircraft, decreasing the "rate to double" for the aircraft, or the rate at which a problem, for example in the balance of the aircraft, will double in magnitude.

A further advantage of using open rotors is that the aircraft may be provided with autorotation capabilities, which may allow the aircraft to land safely and in a controlled manner even if power from the engine(s) is lost. The autorotation feature allows the rotor blades to continue turning under their own momentum even without being driven from the engine. In situations of engine failure, the autorotation functionality may disengage the rotor from the engine allow the blade to continue to rotate without causing the engine to be driven backwards by the rotors.

As set out above, the aircraft described herein may be implemented with either a ducted fan or an open rotor system. In some embodiments with a plurality of rotors, both open rotors and ducted fans may be used.

As illustrated in Fig. 34, embodiments of the aircraft may be provided with flexible rotor blades, preferably as open rotors, but optionally within a duct. The rotors are preferably flexible enough to produce a bell curve shape in cross-section. The flexible rotors may increase the stability of the aircraft.

Embodiments of the aircraft described herein may further comprise one or more aerofoils and this feature is described in more detail below with reference to Figs. 22 to 31. The aerofoils may advantageously provide some or all of the lift required to keep the aircraft in the air during forward flight, as well as act as control surfaces during manoeuvring.

In one embodiment, as illustrated in Fig. 22, wing sections may be attached to the fans themselves. As the fans are tilted to produce forward motion, so the angle of attack of the aerofoils change. The angle of attack may be defined as the difference in angle between the wing section or aerofoil and the direction of the airflow over it, which is in turn a factor of direction of travel rather than the fan angle (indicated as Angle W in Fig. 23d). As forward speed increases, a decreasing angle of attack increases aerofoil efficiency. This would also allow greater forward speed for the aircraft as more of the thrust can be used for forward motion as opposed to lift, and greater manoeuvrability of the aircraft, since the aerofoils can be used as traditional control surfaces.

Figs. 23a, b and c show how the aerofoils dimensions could vary in different embodiments, as could the difference in angle between the thrust and the wing section (thus affecting the angle of attack). Different aerofoil dimensions may prove more effective for different aircraft functions and flight characteristics. Fig. 23a provides an aerofoil with a greater angle of attack and wing depth. Fig. 23b illustrates an embodiment wherein the fan duct extends to follow the trailing edge of the aerofoil. Fig. 23c illustrates an embodiment with a smaller wing section.

Fig. 24 illustrates schematically how the aerofoil may be brought into play during the change from hover to forward movement.

1> the aircraft is in a hover position

2> the fans of the aircraft tilt forwards to induce a forward movement

3> the forward speed increases, tilting the aircraft forward. The angle of attack decreases as the greater speed leads to a greater lift from the aerofoil so allowing the fans to maintain greater tilt angle as they have to produce less of the lift necessary to keep the aircraft in the air. This in turn enables greater forward speed so increasing aerofoil efficiency etc.

4> illustrates the situation in which fan and aerofoil lift balance have been achieved as the aircraft reaches maximum speed. If more speed is attempted by tilting the rotors further, a negative angle of attack is produced and the aircraft will dive. In order to maximise efficiency of the aircraft, the correct compromise between relative angle of fan and aerofoil must be achieved. This angle is also a factor of the aerofoil dimensions as that will affect the performance of the wing section at different speeds.

Fig 25 illustrates schematically how the wing section of the present embodiment aids in one aspect of aircraft manoeuvring: a power dive and recovery.

1> the rotors are tilted forward producing a power dive. This is brought about by creating a negative angle attack on the aerofoils by tilting the rotors forward and thus, at the same time, tilting the fans in such a way as to produce more forward thrust and less lift.

2> the rotor is tilted back towards a neutral position (relative to the fuselage) giving the aerofoil a positive angle of attack and thus increased lift. The fans are also putting more effort into lift while still producing some forward thrust.

3> the increased lift and the drag at the rotorhead swings the aircraft towards the upright, allowing fan induced lift to compensate for reduced aerofoil lift brought about by decreasing speed and increased drag. If continued forward flight is required at this point, reintroducing some forward rotor tilt between point 2 and 3 would facilitate this by maintaining a neutral angle of attack and negating 'stall out' (position 4).

4> Induced 'stall out'. If the manoeuvre is continued as illustrated in Fig. 25, in position 4 the aerofoil has been stalled out so it no longer produces lift but acts as an

air brake. Fan thrust is now holding the aircraft up and is also tilted against the direction of travel until forward movement is dissipated and hover is achieved.

It should be noted that the fans are preferably arranged to be able to move independently, whereas Figs. 24 and 25 show a two dimensional model where fans/aerofoils are moved in tandem. During forward flight, if the aerofoils/fans are moved independently, the effect will be similar to that of a control surface. An increase in angle of attack of one aerofoil (relative to the other) will induce an increase in lift on that side and therefore a banking effect. This is aided by the fan also temporarily thrusting in a slightly more downward (as opposed to forward) direction.

In some embodiments, the aerofoil addition may provide a possible alternative to the open rotor system discussed earlier due to the increased flyability it offers the aircraft.

In some embodiments, as mentioned above, the aerofoils and fans may be able to alter their angle independently of each other. Although there are many ways an aerofoil could be attached to the aircraft, Fig. 26 schematically illustrates a situation where the aerofoil 2610 is connected directly to the rotorhead centre or fuselage 2612 along the line of the drive shaft housing 2614, allowing the angle of attack to be fixed relative to the fuselage or otherwise altered independently of the fan 2616 rotational position.

If the aerofoil is placed elsewhere, care should be taken to ensure that, at certain fan angles, the airflow from the fan should not affect the performance of the aerofoil (or vice versa). Although flight principles are similar to those previously discussed, this system implies some possible advantages to flight characteristics but increases complications in the control system and therefore may prove more suited to a 'fly by wire' system, although mechanical control is also possible.

In some embodiments, the aerofoils are large enough to provide all the necessary lift under forward flight conditions so allowing all thrust produced by the fans to be used to create forward motion while the aerofoils provide the lift. Although this idea can be applied to the 'single passenger aircraft', it also offers possibilities for a more conventionally styled aircraft to use aspects and features of the system described

herein, as illustrated in Fig. 27. In the embodiment illustrated in Fig. 27, the fans 2710 and aerofoils 2712, which may be provided with ailerons 2714, are able to rotate around the line of the drive shaft independently. The aerofoil 2712 area may be increased, preferably to supply the total amount of necessary lift at the appropriate forward speed.

Fig. 28 illustrates how an aircraft such as that illustrated in Fig. 27 could move from hover to forward flight. Each position from 1 to 6 represents an increase in forward speed from 1 (hover) to 6 (forward flight with full lift from aerofoils and fans only producing forward thrust). It is noted that the angle of attack changes differently to the fan angle. Banking could be achieved by independently changing the aerofoil angle of attack as discussed earlier, or by changing the fan angle or by conventional ailerons as disclosed in Fig. 27, or any combination thereof. A swinging rotorhead as described above could provide hover or slow speed banking, for example where the forward speed is insufficient to allow the aerofoils to behave as control surfaces, as could vanes or, depending on rotorhead configuration, any combination thereof.

It will be appreciated by one skilled in the art that a wide variety of embodiments of aircraft may be implemented within the scope of the present invention and Figs. 29 and 30 schematically illustrate further embodiments or aircraft incorporating both fans and aerofoils. In the embodiments shown, the front and rear aerofoils could have independently adjustable angles of attack or conventional control surfaces. Similarly, the aerofoils could be split down the middle and the angle of attack of the left and right aerofoils could be independently controllable. The aerofoils may add additional balance to the aircraft.

Figs. 31a and 31b illustrate the relative orientations of the fan and aerofoils of the aircraft of Fig. 30 during forward flight and hover respectively. As for all of the embodiments described above, the adjustment of the aerofoil angle can be synchronised to the fan angle or may be independently controlled. Preferably, the rear aerofoil is positioned higher to enable cleaner airflow during forward flight. The attitude of the aircraft may be altered or trimmed by changing the relative angle of attack between the front and the rear aerofoils.

A further embodiment of an aircraft is illustrated in Figs. 32a-32c, which illustrates an aircraft with a belt drive system. The belts may comprise toothed belts of any suitable material. As illustrated in Fig. 32a, the power source 3210 (e.g. the engine) is aligned horizontally allowing drive in the vertical plane with a belt 3212, chain or other appropriate linkage connection to a drive pulley 3214 at the centre of the rotorhead. This allows the rotorhead to swing independently of the engine and frame (if required), as illustrated in Fig. 32b, and removes the need for a drive shaft with a universal joint, which may add complexity to the system. The main drive shaft is connected, for example on the same shaft, to a pulley 3216, 3218 for each rotor drive belt 3220, 3222. The rotor belts 3220, 3222 twist through 90° with respect to the drive belt 3212 to convert the drive from vertical to the horizontal drive plane used by the rotors 3224, 3226. The belt twist angle may vary as the rotors move to provide forward or reverse thrust.

Advantageously, the belt drive system may be substantially simpler, cheaper and lighter than the shaft and gearbox drive option with no loss of reliability and the possibility of an increase in performance as the power consumption of the drive system itself may be reduced.

Embodiments of the system described herein may further include a stabiliser bar or fly bar to increase the stability of the helicopter.

It will be appreciated that the systems described above may be arranged to carry a load rather than a passenger and that the controls for the aircraft may be operated remotely, for example via a radio link. Further, embodiments of the system may be implemented as model aircraft, which may be controlled by a remote control device, for example via a radio link. This may be useful, for example to transport equipment, such as weather monitoring equipment or video recording equipment to an altitude.

Aspects of the systems described above may be provided independently or in any combination and modifications to the systems described may be provided and will be clear to one skilled in the art.

Claims:

1. A single-passenger vertical take-off and landing aircraft comprising:
an airframe portion, comprising means for supporting a pilot and aircraft control means for controlling the operation of the aircraft, wherein the airframe portion defines a central axis for the aircraft;
a rotorhead portion comprising at least two rotors coupled to the top of the airframe portion and arranged to rotate in respective planes about respective axes displaced from the central axis of the aircraft;
a motive power unit drivingly coupled to the rotors via a drive shaft;
characterised in that:
the rotorhead portion is coupled to the airframe portion via a pivot to enable the rotorhead portion to pivot relative to the airframe portion in the plane of the aircraft and about an axis perpendicular to the central axis for the aircraft.

2. An aircraft according to Claim 1 wherein the axis about which the rotorhead portion can pivot is substantially parallel to the preferred direction of motion of the aircraft.

3. An aircraft according to Claim 1 or 2 wherein the rotorhead portion pivots to tilt the rotors on rotation of the aircraft about the central axis of the aircraft.

4. An aircraft according to any preceding claim wherein the motive power unit is coupled to the airframe portion and wherein the drive shaft comprises a pivot to enable the rotorhead portion to pivot relative to the airframe portion.

5. An aircraft according to any of Claims 1 to 3 wherein the motive power unit and the drive shaft remain stationary relative to the rotorhead portion and move relative to the airframe portion as the rotorhead portion pivots relative to the airframe portion.

6. An aircraft according to any preceding claim wherein the rotorhead portion is coupled to the airframe portion via at least one actuator and wherein the

actuator is arranged to rotate the rotorhead portion relative to the airframe portion on rotation of the aircraft about the central axis of the aircraft.

7. An aircraft according to Claim 6 wherein the actuator may be arranged to rotate the rotorhead portion relative to the airframe portion in response to control means to effect a turning and/or banking of the aircraft.

8. An aircraft according to any preceding claim or any of Claims 20 to 53 wherein the rotors are arranged so that the planes of the rotors define a non-zero dihedral angle.

9. A single-passenger vertical take-off and landing aircraft comprising:
an airframe portion, comprising a motive power unit, means for supporting a pilot and aircraft control means for controlling the operation of the aircraft, wherein the airframe portion defines a central axis for the aircraft;
a rotorhead portion comprising at least two rotors coupled to the top of the airframe portion and arranged to rotate in respective planes about respective axes displaced from the central axis of the aircraft, wherein the rotors are coupled to the motive power unit via a drive shaft;
characterised in that:
the planes of the rotors define a non-zero dihedral angle.

10. An aircraft according to Claim 8 or 9 wherein the dihedral angle is greater than around 2 degrees.

11. An aircraft according to any of Claims 8 to 10 wherein the dihedral angle is greater than around 5 degrees.

12. An aircraft according to any of Claims 8 to 11 wherein the dihedral angle is less than around 20 degrees.

13. An aircraft according to any of Claims 8 to 12 wherein the dihedral angle is less than around 15 degrees.

14. An aircraft according to any of Claims 8 to 13 wherein the dihedral angle is around 8 degrees.

15. An aircraft according to any of Claims 8 to 14 wherein the dihedral angle may be varied before or during flight.

16. An aircraft according to Claim 15 wherein the dihedral angle is varied automatically in response to environmental conditions.

17. An aircraft according to any preceding claim wherein the rotors comprise a flexible material.

18. An aircraft according to any preceding claim wherein the rotors have a curved profile.

19. An aircraft according to any preceding claim or any of Claims 25 to 53 wherein the hub further comprises an explosively-deployed parachute, the rotorhead portion comprises a rotor brake arranged to substantially prevent the rotation of the rotors and the aircraft further comprises:
means for signalling an emergency condition; and
means for deploying the rotor brake and the parachute in response to signalling of the emergency condition.

20. A single-passenger vertical take-off and landing aircraft comprising:
an airframe portion, comprising a motive power unit, means for supporting a pilot and aircraft control means for controlling the operation of the aircraft, wherein the airframe portion defines a central axis for the aircraft;
a rotorhead portion comprising at least two rotors coupled to the top of the airframe portion at a hub and arranged to rotate in respective planes about respective axes displaced from the central axis of the aircraft, wherein the rotors are coupled to the motive power unit via a drive shaft;
characterised in that:

the hub comprises an explosively-deployed parachute;

the aircraft further comprises a rotor brake arranged to substantially prevent the rotation of the rotors; and

the aircraft further comprises:

means for signalling an emergency condition; and

means for deploying the rotor brake and the parachute in response to signalling of the emergency condition.

21. An aircraft according to Claim 19 or 20 wherein the rotor brake is deployed prior to deployment of the parachute.

22. An aircraft according to any of Claims 19 to 21 wherein the signal comprises an alert signal generated by the aircraft.

23. An aircraft according to any of Claims 19 to 22 wherein the alert signal generated by the pilot, for example via an emergency button on the aircraft.

24. An aircraft according to any preceding claim, Claim 29 or any of Claims 33 to 45 wherein the aircraft further comprises at least one aerofoil portion displaced from the rotors and positioned to provide lift on forward motion of the aircraft.

25. A single-passenger vertical take-off and landing aircraft comprising:

an airframe portion, comprising a motive power unit, means for supporting a pilot and aircraft control means for controlling the operation of the aircraft, wherein the airframe portion defines a central axis for the aircraft;

a rotorhead portion comprising at least two rotors coupled to the top of the airframe portion at a hub and arranged to rotate in respective planes about respective axes displaced from the central axis of the aircraft, wherein the rotors are coupled to the motive power unit via a drive shaft; and

at least one aerofoil portion displaced from the rotors and positioned to provide lift on forward motion of the aircraft.

26. An aircraft according to Claim 24 or 25 wherein the angle of attack of the or each aerofoil may be varied.

27. An aircraft according to Claim 26 wherein the angle of attack of the or each aerofoil may be varied by the pilot.

28. An aircraft according to Claim 26 or 27 wherein the angle of attack of the or each aerofoil is varied automatically depending on the configuration of other elements of the aircraft and / or on environmental conditions.

29. An aircraft according to any preceding claim wherein the rotors comprise ducted fans.

30. An aircraft according to Claim 29 as dependent on any of Claims 24 to 28 wherein the aerofoil portion is coupled to the outside of the ducted fans.

31. An aircraft according to any of Claims 24 to 30 wherein the aerofoil comprises two or more aerofoil portions and wherein at least one aerofoil portion is coupled to each side of the aircraft.

32. An aircraft according to any of Claims 24 to 31 wherein the at least one aerofoil portion is substantially symmetrically arranged around the aircraft.

33. An aircraft according to any preceding claim wherein at least one rotor comprises an open rotor.

34. An aircraft according to any preceding claim wherein the axes of the rotors are symmetrically disposed about the central axis of the aircraft.

35. An aircraft according to any of Claims 1 to 33 wherein the rotors are asymmetrically disposed about the central axis of the aircraft.

36. An aircraft according to any preceding claim wherein the engine comprises a combustion engine.

37. An aircraft according to any of Claims 1 to 35 wherein the engine comprises a motor powered by a battery.

38. An aircraft according to any preceding claim wherein power from the engine is transmitted to the rotors via a belt drive system.

39. An aircraft according to any preceding claim wherein at least one direction of the aircraft may be varied by tilting the rotors.

40. An aircraft according to any preceding claim wherein the rotors may be tilted independently of each other.

41. An aircraft according to any preceding claim wherein the blade pitch may be varied.

42. An aircraft according to Claim 41 wherein the blade pitch may be varied independently for each rotor.

43. An aircraft according to any preceding claim wherein at least one rotor is provided with a swash plate system.

44. An aircraft according to Claim 43 wherein the swash plate system is arranged to operate only in an forward and reverse direction.

45. An aircraft according to any preceding claim wherein vanes are provided in the air stream produced by the rotors.

46. An aircraft according to Claim 45 wherein the direction of the vanes is varied to change the direction of the thrust produced by the rotors.

47. An aircraft according to Claim 45 or 46 wherein the direction of each vane or of groups of vanes may be controlled independently.

48. An aircraft according to any preceding claim wherein the pilot is supported in a standing position.

49. An aircraft according to any of Claims 1 to 47 wherein the pilot is supported in a seated position.

50. An aircraft according to any preceding claim further comprising means for supporting a passenger.

51. An aircraft according to any preceding claim wherein the aircraft control means controls the operation of the aircraft via a fly-by-wire system.

52. An aircraft according to any preceding claim wherein the aircraft control means controls the operation of the aircraft via a mechanical system.

53. An aircraft according to any preceding claim wherein the control means comprises hand-operated controls and / or foot-operated controls.

54. An aircraft substantially as described herein with reference to any of Figs. 4 to 34.

PATENTS • DESIGNS • COPYRIGHT • TRADE MARKS
The Patent Office
INVESTOR IN PEOPLE

-36-

Application No: GB0520284.1 **Examiner:** Chris Vosper

Claims searched: 1-8 **Date of search:** 9 February 2006

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,Y	1,6	US 4703906 A EIKMANN (figs. 9,10; lines 35-52)
X,Y	X:1,4 Y:8	US 3106369 A CURTISS-WRIGHT (figs. 2,3; col. 4, line 58 to col.5, line 8)
X,Y	X:1,5 Y:8	US 3366347 A SOCIETE NATIONALE- (figs. 1 and 3; col. 4, lines 15-26)
X,Y	X:1,5 Y:8	US 3393882 A NORD (fig. 1; col.4, lines 3-18
X,Y	X:1 Y:8	DE 2628274 A1 SCHMEIZER (figs. 1,2 and 4; WPI Abstract, Accession No. AN1978-A4619A [37])
Y	8	US 6719244 A GRESS (fig. 2)
Y	8	GB 17653/10 1910 British Patent Specification, SMITH, see figure X.
A	-	FR 2667568 A1 VINTILA (drawings - particularly figs. 7 and 8)
A	-	DE 4302791 A1 SCHUSTER (fig. 1)

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

B7G; B7W

Worldwide search of patent documents classified in the following areas of the IPC

B64C

The following online and other databases have been used in the preparation of this search report

ONLINE:EPODOC,WPI,OPTICS